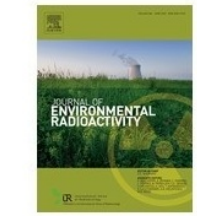
# 8th International Conference on Environmental Radioactivity
# Krakow, Poland
# September 14 – 19

## ABSTRACT BOOK



The ENVIRA 2025 conference continues the tradition of bringing together experts, early-career researchers, and students working in the field of environmental radioactivity and related disciplines. As environmental challenges and radiological concerns continue to evolve, this conference provides a unique forum for discussing current advances in analytical techniques, radioecological modeling, radiation protection, and nuclear forensics.

The scientific program will encompass a wide range of topics including natural and anthropogenic radioactivity in the environment, radiochemical methods, tracer applications, radioecology, low-level detection, environmental monitoring, and risk assessment. Emphasis will be placed on interdisciplinary approaches that integrate radioanalytical chemistry, environmental science, nuclear physics, and health physics.

ENVIRA 2025 aims to foster collaboration between academic researchers, regulatory agencies, and industry professionals. A special focus will be given to innovative techniques and emerging applications of radiotracers in environmental studies, as well as challenges related to nuclear decommissioning and waste management.

**Join us in Kraków for a week of scientific exchange, networking, and collaboration at the forefront of environmental radioactivity research.**

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# Influence of the “Galerna” meteorological phenomenon on the emission of radiological "false alarms" in real time

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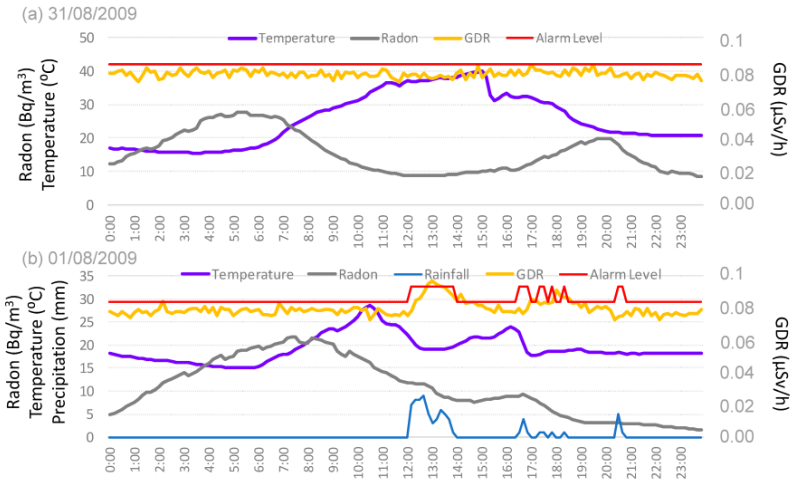
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The Gamma Dose Rate (GDR) is a crucial parameter in radiation protection, as highly penetrating gamma radiation poses significant health risks, including an increased risk of cancer after exposure. prolonged. Therefore, monitoring and understanding GDR is essential for public health and safety, environmental surveillance, and regulatory compliance.
Meteorological conditions play a critical role in measuring both radon and GDR concentrations.
In this work, the GDR from 2009 to 2018 measured in Bilbao (northern Spain) has been analyzed for:

- characterize GDR concentrations.
- determine the impact of precipitation on GDR concentrations.
- analyze the impact of the occurrence of "Galerna", which is a local meteorological event in this area, which can develop both with and without precipitation.
- establish correlations and dependencies between the variations in GDR and 222Rn levels under Galerna events, with precipitation and without precipitation

The daily mean concentration of GDR is 0.07624 ± 0.00004 µSv/h, where the uncertainty is given as the standard error of the mean.
The average over the entire 2009-2018 period of daily and P95 GDR concentrations are higher under precipitation (0.07655 ± 0.00001 µSv/h and 0.0811 ± 0.0002 µSv/h, respectively) than without precipitation (0 .0759 ± 0.0008 µSv/h and 0.07955 ± 0.0008 µSv/h, respectively).
The relationship between GDR and radon concentration during precipitation days and non-precipitation days can be explained by several environmental factors.
The Galerna produces an increase in the GDR even if there is no precipitation, as shown in the figure.



The analysis has shown increases in GDR under precipitation accompanied by reductions in radon concentrations when the Galerna develops. These GDR concentrations should be recognized as natural radiological events, requiring the classification of such GDR peaks as false alarms in the radiological surveillance network. Understanding these interactions improves the ability to accurately interpret radiological data and improve public safety measures.

# Study of Radioactivity in the reservoirs that supply water to Great Bilbao

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Water has always been essential for life and plays a fundamental role in all areas of society. Today, water is of greater importance due to the challenges that must be faced, such as climate change, population growth, possible contamination, etc. herefore, in the event of radioactive contamination, it would have repercussions from immediate to long-term consequences, with human health facing considerable risks.

To achieve this purpose, a study has been carried out of the parameters to control indicated by Royal Decree 3/2023, in addition to analyzing the different parameters controlled by various surveillance networks in Spain, as well as the laboratories that make up the ALMERA network (Analytical Laboratories for the Measurement of Environmental Radioactivity) for better control of water. Likewise, companies in the sector that have equipment to be able to carry out continuous measurements have been sought.

The optimal locations for the installation of this type of devices at strategic points on the main water supply line for the population of Bizkaia and the equipment that should be installed there have been obtained, calculating the cost per station.

In this work, the cost of hypothetical situations has been analyzed: partial or total contamination of the water of Greater Bilbao and the recovery period thereof, with or without the need for supply.

Despite the high cost that the implementation of continuous surveillance equipment would entail, only at strategic points on the main water supply line for the population of Bizkaia, the population would be protected in the event of contamination due to an episode. nuclear contamination, etc.

# Development of a Deep Learning-Based Model for Radionuclide Identification

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In the event of a radiological release due to a nuclear power plant accident, rapid and accurate determination of radionuclide concentrations is essential to assess environmental contamination and radiation dose rates. Such assessments serve as critical data for evacuation planning and decontamination efforts, particularly during the early stages of an incident, where effective response can minimize casualties.

Traditionally, radionuclide identification relies on gamma-ray spectrum analysis, which is time-intensive and often inaccurate for complex spectra involving multiple radionuclides with similar energy peaks. To address these challenges, this study introduces a deep learning-based radionuclide identification model using a Convolutional Neural Network (CNN). By analyzing gamma-ray spectra, the model effectively distinguishes radionuclides with overlapping energy peaks, outperforming conventional methods in speed and accuracy.

Key radionuclides, including Cs-134, Cs-136, Cs-137, I-131, and others identified in the Fukushima Daiichi nuclear disaster, were used for training. Synthetic gamma-ray spectra, incorporating noise and background radiation, were generated to simulate real accident conditions. The CNN model, designed with a 1D architecture, includes convolutional, max pooling, batch normalization, and dense layers to extract key features and minimize overfitting.

Performance evaluation using metrics such as Jaccard Score, Hamming Loss, and Classification Report demonstrated the model's high accuracy in multi-label classification. The model achieved a Jaccard Score of 0.742 and an AUC of 0.8968, indicating robust radionuclide identification capability. These results confirm the effectiveness of the proposed deep learning approach for rapid and precise radionuclide identification in nuclear emergency scenarios.

# Determination of natural radioactivity and the associated radiation hazards in decorated vitrified tiles collected from Tamil Nadu, India

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Gamma ray spectrometry with NaI(Tl) detector was employed to determine the activity concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K in vitrified tiles which has been used as modern building materials in Tamil Nadu. It is found that, 68 ± 5 Bq kg$^{-1}$is a mean value for $^{226}$Ra, 116 ± 8 Bq kg$^{-1}$ for $^{232}$Th, 540 ± 40 Bq kg$^{-1}$for $^{40}$K and these mean values are greater than the world average value of 50, 50, 500 respectively as suggested by UNSCEAR 1993. This leads the average indoor gamma absorbed dose rate (84 nGyh$^{-1}$) and excess lifetime cancer risk (2.13×10$^{-3}$ mSv y$^{-1}$) slightly greater than the world average value proposed by UNSCEAR 2000. This implied that, regular attention is necessary to use as building materials. In order to assess the distribution pattern of radionuclides in tiles, multivariate statical analysis was performed and it reveals no health hazards due to presence of $^{40}$K.

**Keywords:** Vitrified tiles, Gamma ray spectrometry, radiological hazards, statistical analysis.

# Analyzing low levels of naturally occurring radionuclides in foods – Insights from the first German total diet study

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The presence of natural radionuclides in foods is well-known, yet detailed information on their levels remains limited. The presented investigation seeks to bridge this gap by systematically examining the diet-related activity concentrations of naturally occurring radionuclides, including lead-210 (Pb-210), uranium-234 (U-234), uranium-238 (U-238), radium-226 (Ra-226), and radium-228 (Ra-228). Conducted by the Federal Office for Radiation Protection (BfS) in collaboration with the Federal Institute for Risk Assessment (BfR), over 200 different foods were sampled and analyzed from 2016 to 2019 (Hofmann et al., 2024) as part of the first German total diet study (BfR MEAL Study) (Sarvan et al., 2017).

Homogenized and pooled samples, averaging 2 kg in fresh weight, were delivered from the BfR to the BfS. The samples underwent drying at 105 °C and dry-ashing at 400 °C, resulting in ash yields between 5 g and 119 g. Before starting with the radiochemical separation techniques, between 2 g to 10 g ash material were dissolved by microwave digestion for each radionuclide analysis. Pb-210 was quantified via co-precipitation with iron hydroxide, followed by extraction chromatography, and liquid scintillation counting, achieving an average chemical yield of 74% and a detection limit of 16 mBq/kg fresh weight. U-234 and U-238 were determined through sequential extraction and alpha spectrometry, offering a robust detection limit of 0.91 mBq/kg fresh weight, albeit with a slightly lower yield of 63%. Ra-228 and Ra-226 determinations were combined for efficiency, using progeny Ac-228 for Ra-228 measurement and the Rn-222-emanation technique for Ra-226. The detection limits were 20 mBq/kg for Ra-228 and 5 mBq/kg for Ra-226, with a chemical yield of 90%.

The study revealed generally low radionuclide activity concentrations compared to international data, though Ra-228 and Ra-226 frequently dominated the activity levels (Hofmann et al., 2025). Between 1% and 19% of Ra-226, Ra-228, and Pb-210 results exceeded the International Atomic Energy Agency (IAEA) guidance levels of 0.1 Bq/kg or 1 Bq/kg, while U-234 and U-238 remained below the IAEA's suggested threshold of 10 Bq/kg. Intriguingly, the average Ra-226/Ra-228 ratio in food items was significantly lower than that found in soils, indicating an isotope-dependent transfer of these radionuclides from soil to plants and subsequently to the food chain. These results provide a foundational basis for further dose assessments and risk evaluations, thus enhances our understanding of public exposure to natural radionuclides through food consumption.

References

Hofmann, P. et al. (2024): The first German total diet study: Analytical techniques to identify natural radionuclides in food samples. J. Radioanal. Nucl. Chem. 333 (5), 2449-2460.

Hofmann, P. et al. (2025): Levels of naturally occurring radionuclides in foods from the first German total diet study. Science of The Total Environment. 965, 178653.

Sarvan, I. et al. (2017): Expositionsschätzung von Stoffen in Lebensmitteln. Bundesgesundheitsbl. 60 (7), 689-696.

# Estimation of Radon ($^{222}$Ra) activity concentration levels and associated effective dose in bottled drinking water from South Africa

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The naturally occurring radioactive gas Radon-222 ($^{222}$Rn), poses potential health risks due to its inhalation and ingestion, especially through drinking water. This paper presents the investigation of the activity concentration levels of $^{222}$Rn in 21 brands of bottled water samples collected from the open market in South Africa. The samples were analysed using a highly sensitive system consisting of the Ionization Chamber AlphaGUARD (PQ 2000), an AquaKIT set, and an AlphaPUMP, ensuring precise measurement of radon activity. The results revealed significant variations in radon concentrations across different brands, with values ranging from 0.062 ± 0.046 Bq/m³ to 0.198 ± 0.286 Bq/m³, with a mean of 0.118 ± 0.034 Bq/m³. These measurements were then used to estimate the annual effective ingestion dose of radiation for consumers across various age groups, based on the guidelines provided by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The mean effective doses were found to be $4.057 \times 10^{-4} \pm 1.188 \times 10^{-4}$ mSv/y for infants (1–2 years), $2.428 \times 10^{-4} \pm 7.111 \times 10^{-5}$ mSv/y for children (7–12 years), and $2.058 \times 10^{-4} \pm 6.026 \times 10^{-5}$ mSv/y for adults, all of which are below the recommended international safety limits and are comparable to other published studies. These findings suggest that the bottled drinking water in South Africa is safe for consumption and does not pose a significant health hazard from $^{222}$Rn radiation. The study underscores the importance of monitoring radon levels in bottled water to assess the associated radiological health risks, particularly in South Africa, where access to safe drinking water is essential. This research provides baseline data for future regulatory frameworks and policy development and can serve as a valuable reference for bottled water producers. Furthermore, it highlights the need for continued investigation into the regulation and mitigation of radon exposure in drinking water sources throughout the country.

**Keywords:** Radon-222, activity concentration levels, annual effective ingestion dose, bottled drinking water, South Africa

# Distribution coefficient in soils with natural enrichment of long-lived natural radionuclides ($^{238}$U and $^{226}$Ra)

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A systematic study has been performed to clarify some hypothesis and assumptions in the use of the distribution coefficient of natural radionuclides (238U and 226Ra) in soils. For that, soils with natural enrichment of these radionuclides were used. The processes involved in the equilibria between solid and liquid fractions of the soils are expected to be different from those corresponding to recently spiked soils.

The soil solution was extracted by centrifugation method. In this sense, a device was designed to maintain a permanent pool of water, which assured zero matric suction at the most external layer of the soil core. In such a way that the centrifugation speed can be related with the effective suction applied to the sample and therefore with the different origins of the soil water with respect to its association with the solid phase.

One of the main factors affecting the soil Kd values is the soil texture. Therefore, the study was performed in three soils with different textural characteristics. However, to eliminate the influence of other soil parameters, the three soils were constructed from a single soil by sieving. The Kd ranges obtained for 226Ra were: loamy coarse sand from 0.86 to 116 L kg-1, loamy fine sand from 0.37 to 42.0 L·kg-1and loam from 5.2 to 182 L kg-1. In the case of 238U were: loamy coarse sand from 0.595 to 3.270 L kg-1, loamy fine sand from 4.020 to 413 L·kg-1and loam from 4.93 to 73 L kg-1.

Firstly, the influence of the parameters used in the method to obtain the soil solution on the Kd value was studied. In this study were included the amount of water added to the soil during the incubation period, the incubation time, and the centrifugation speed. The results pointed out that (in general) the incubation time has not significant influence on the desorption of 238U and 226Ra, in such way that the lower assayed time (24h) is sufficient to achieve the equilibrium between the solid and liquid soil fractions. Only the loamy coarse sand soils showed slower equilibrium process for 238U, requiring times up 7d. The most important factor in the desorption process of uranium was the amount of water added during the incubation period, especially in the soils with coarser grain size. On the other hand, statistically significant influence of centrifugation speed on the radium concentration in solution was observed for soils with smaller grain size.

As a second aim, possible correlations between Kd and chemicals present in soil solution were searched by multivariate regression analyses. Due to the soil samples being constructed from a single soil, the variations observed in the chemicals concentration in the soil solution were small. But even so, the pH showed a clear influence in the sorption-desorption process for both studied radionuclides. Other significant variables were the dissolved organic matter (DOM) and the conductivity (the latter only in the case of radium).

**Observed Atmospheric $^{133}$Xe Concentrations in the Arctic and North Atlantic Oscillation (NAO)**

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It is well known that the background radiation of radioactive xenon in the global air mainly comes from radiopharmaceutical production facilities. At present, the $^{133}$Xe emissions from some major $^{99}$Mo and other medical isotope production plants are an order of magnitude higher than the emissions from about 450 nuclear power reactors in the world. These production facilities are located in limited areas of the world, such as Canada (MDS Nordion, which stopped producing $^{99}$Mo on March 31, 2018), the Netherlands (Tyco healthcare), Belgium (IRE), South Africa (NTP) and other regions. They account for 38%, 26%, 16%, 16% and 4% of the total global $^{99}$Mo production, respectively (Zahringer et al., 2009).

The global radioxenon background is not negligible and continues to interfere with the IMS's radioxenon monitoring in the CTBT's verification regime. In order to understand the radioxenon background, three radioxenon monitoring stations were selected in the Arctic, an area believed to be free of local radioxenon contamination. Two of them are located in the North American Arctic region, namely Yellowknife (62.5°N), Resolute (74.7°N), and the other is located in Spitsbergen Norway (78°N)

The daily activity concentration of $^{133}$Xe observed at these stations from 2013 to 2020 show strong seasonal variation characteristics, that is, most of the observed $^{133}$Xe appear in the winter and spring season from October to April of the following year, and are 30 to 50 times higher in winter than in summer; the $^{133}$Xe activity concentration observed in Spitsbergen is about 10 times that observed in Yellowknife and Resolute Island, and there is a certain time lag between the $^{133}$Xe observed at the North American station and the $^{133}$Xe observed in Norway (Zhang et al. 2022).

Many studies have recognized that various pollutants, including sulfur, nitrogen compounds, persistent organic pollutants, can be transported from the lower latitude Eurasian industrial zone to the Arctic during winter and spring (Arnold et al. 2016). These patterns are mainly controlled by the North Atlantic Oscillation (NAO) with obvious seasonal variation.

Therefore, these $^{133}$Xe observations can also be interpreted as the result of long-range transport by air masses. In this study, we investigated how NOA controls the transport of

radioactive xenon to the Arctic, especially during winter and spring. The results show that the monthly mean $^{133}$Xe concentrations are positively correlated with the NAO index.

More interestingly, as a noble gas, $^{133}$Xe is not affected by air chemistry and deposition processes, and can be used as a tracer with a half-life of 5.24 days. Its surface concentrations during the Arctic winter and spring are estimated to increase by more than several hundred percent compared to concentrations occasionally observed during summer.

This study is the first international report on $^{133}$Xe observed at three Arctic monitoring stations Yellowknife, Resolute, and Spitsbergen. It is believed that the $^{133}$Xe observed at these stations is correlated and comes from the same source. A deeper analysis of these monitoring data will strengthen our understanding of the dispersal atmospheric transport models.

**References**

M. Zahringer, A. Becker, M. Nikkinen, P. Saey, G. Wotawa, CTBT radioxenon monitoring for verification: today's challenges, J Radioanal Nucl Chem (2009) 282:737–742, DOI 10.1007/s10967-009-0207-3.

Weihua Zhang, Jussi Paatero, Ari-Pekka Leppanen, Bredo Møller, Louise Kiel Jensen, Kjartan Gudnason, Mikhail Sofiev, Pål Anderson, Morten Sickel, Agnieszka Burakowska, Marek Kubicki, Amanda Anderson, Evaluation of $^{137}$Cs, $^{133}$Xe and $^{3}$H activity concentrations monitored in the Arctic atmosphere (2022) Journal of Environmental Radioactivity Volumes 253–254, 107013.

Arnold, S. R., K. S. Law, C. A. Brock, J. L. Thomas, S. M. Starkweather, K. von Salzen, A. Stohl, S. Sharma, M. T. Lund, M. G. Flanner, T. Petaja, H. Tanimoto, J. Gamble, J. E. Dibb, M. Melamed, N. Johnson, M. Fidel, V. –P. Tynkkynen, A. Baklanov, S. Eckhardt, S. A. Monks, J. Browse, and H. Bozem (2016), Arctic air pollution: Challenges and opportunities for the next decade, Elementa: Science of the Anthropocene, 4:000104, https://dx.doi.org/10.12952/journal.elementa.000104

# Dose Assessment of Natural Radionuclides in Food Consumed in Germany

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From 2016 to 2021, Germany undertook its first comprehensive total diet study (BfR MEAL study), to evaluate the extent and variety of a large array of substances, for example contaminants or nutrients to which individuals are exposed through their dietary consumption (Sarvan et al., 2017). As part of the MEAL study, a detailed sampling and analytical methodology was employed to measure natural radionuclide concentrations of lead-210, uranium-234, uranium-238, radium-226 and radium-228 across a range of food categories, including vegetables, fruits, cereals, meat, fish and dairy products (Hofmann et al., 2024). These findings revealed that, although natural radionuclides are inherently present in food due to their ubiquity in the environment, the concentrations measured are within safe limits as established by international guidelines (Hofmann et al., 2025).

Here, we provide now the first dose assessments caused by these natural radionuclides in food products commonly consumed in Germany (Hofmann et al., 2025). Polonium-210 was additionally included in the dose calculations based on conservative estimates, since it is known to be an important contributor to the public annual effective dose through food consumption (UNSCEAR, 2000). Consumption rates were sourced from the Radiation Protection Ordinance (StrlSchV, 2018). This ordinance specifies assumed consumption rates for various age groups and food categories, encompassing six age groups as well as ten food groups. In this study we related 134 specific activity values of individual foods to the food groups “milk and dairy products”, “fish”, “meat, sausage, eggs”, “cereals and cereal products”, “local fresh fruit, fruit products, juices”, “potatoes, root vegetables, juices”, “leafy vegetables” and “vegetables, vegetable products, juices”. The calculated annual effective dose received by different demographic groups, such as infants, children, and adults, indicates that the dose level from natural radionuclides in food remains significantly below the recommended public exposure limit of 1 mSv/a. This analysis highlights the importance of continuous monitoring and assessment to ensure food safety and protect public health from radiological risks.

References

Hofmann, P., Achatz, M., Behrend, K., Berg, T., Busse, C., Guttmann, A., Hummrich, H., Lindtner, O., Lucks, C., Manteufel, L., Rast, M., Sarvan, I., Schmidt, B., Schmidt, K., Scholtysik, C., Walther, D., 2024. The first German total diet study: Analytical techniques to identify natural radionuclides in food samples. Journal of Radioanalytical and Nuclear Chemistry 333, 2449-2460.

Hofmann, P., Achatz, M., Fohlmeister, J., Schmidt, K., Berg, T., Sarvan, I., 2025. Levels of naturally occurring radionuclides in foods from the first German total diet study. Science of The Total Environment 965, 178653.

Sarvan, I., Bürgelt, M., Lindtner, O., Greiner, M., 2017. Expositionsschätzung von Stoffen in Lebensmitteln. Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz 60, 689-696.

StrlSchV, 2018. Strahlenschutzverordnung (StrlSchV), Bundesgesetzblatt Jahrgang 2018 Teil I Nr. 39, Bonn, 4 October 2018, pp. 1570-1663., pp. 2024, 2036.
UNSCEAR, 2000. United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and Effects of Ionizing Radiation. UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes. Volume I: Sources. UNSCEAR, New York.

# Natural Radioactivity in the Pilanesberg Alkaline Ring Complex

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The Pilanesberg Alkaline Complex in South Africa is one of the world's largest alkaline and partially peralkaline geological complexes, having distinctive lithological and mineralogical features which can be associated with natural radioactivity. The spatial distribution and geochemical behaviour of naturally occurring radionuclides (potassium-40, uranium-238, and thorium-232) within the complex are investigated by means of in situ gamma measurements. The investigation revealed that radionuclide concentrations vary significantly between rock types, owing to processes such as magmatic differentiation, hydrothermal alteration, and accessory mineral crystallization. The high quantities of uranium and thorium in red syenite in the complex are due to accessory minerals like zircon, titanite and apatite, which integrate these elements under reducing conditions during late-stage magmatic crystallization. In contrast, potassium enrichment is concentrated in foyaites, indicating advanced peralkaline magmatic evolution. Hydrothermal fluid interactions have also mobilized uranium, notably in the complex's faulted and fractured zones, resulting in varying uranium concentrations in volcanic and intrusive rocks. These findings underline the complex geochemical evolution of the Pilanesberg Alkaline Complex and its potential as a model for understanding radionuclide distribution in alkaline systems. The study adds to the overall understanding of uranium, thorium, and potassium geochemistry by providing insights on natural radioactivity in peralkaline environments.

# FRN application and conventional methods for soil redistribution analysis in the la Zanguenga micro-basin (Panama Canal)

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Soil erosion is a key process in the degradation of terrestrial ecosystems, affecting agricultural productivity and environmental sustainability. This study evaluates soil redistribution in the La Zanguenga Creek micro-basin (a high pineapple production area). This micro-basin is part of the Panama Canal's hydrographic basin, which feeds the Gatun Lake, an artificial reservoir essential for the canal's operation. For its analysis, three methods were applied: Fallout Radionuclides (FRN), erosion pins, and the Universal Soil Loss Equation (USLE) model. The FRN method allows for the analysis of soil dynamics at different spatial and temporal scales, making it an effective tool for quantifying erosion and sedimentation rates. Erosion pins provide direct measurements, though they may present a degree of subjectivity depending on the accuracy of the reader. In contrast, mathematical models, while useful, have limitations due to specific parameters and require a considerable number of additional readings.

The integration of multiple methods enables a more comprehensive assessment of soil redistribution in the La Zanguenga Creek micro-basin. In this region, soil losses due to erosion reach 200,08 t/ha in bare soils and 13,72 t/ha under conventional planting, exceeding the soil loss tolerance threshold of 11 t/ha/year (Mejia, 2018). These figures are largely attributed to human activities and the rainfall patterns characteristics of the area, which are further altered by the effects of climate change, leading to more frequent heavy rains. The impact of runoff varies depending on its speed and the vegetation cover present during rainfall events. In the case of the La Zanguenga micro-basin, the extensive pineapple cultivation areas lack sufficiently dense foliage to reduce aggressive soil displacement. However, different production systems are employed in the region, which may either increase or decrease soil erosion.

This study aims to identify which of these methodologies is most suitable for local farmers, helping them understand soil redistribution processes through these techniques and providing tools to optimize agricultural practices and mitigate erosion effects.

Mejia, J. (2018). *EVALUACIÓN DE LA PÉRDIDA DE SUELO Y NUTRIENTES POR EROSIÓN*.

# Radionuclide Assessment of Oil Palm Plantation Soils in Ondo and Ekiti State, Nigeria.

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**Abstract**

This research investigated the natural radionuclide elements in soils from oil palm plantation farmlands within Ondo and Ekiti states with the associated risk factors because these states are known for massive production of palm oil which forms a component part of human daily foods. Forty (40) soil samples were collected determine the concentrations of the naturally occurring radionuclides elements using Gamma Ray Spectrometer comprising a 7.6 cm x 7.6 cm Nal(TI) detector coupled to a multichannel analyser for spectral analysis. The results showed that the average concentration levels of K-40, Th-232 and U-238 in Ondo state are: 126.40 $\pm$ 2.74 Bq/kg, 29.20 $\pm$ 1.19 Bq/kg and 18.64 $\pm$ 0.97 Bq/kg respectively and that of Ekiti state are: 110.95 $\pm$ 2.88 Bq/kg, 23.05 $\pm$ 1.15 Bq/kg and 17.31 $\pm$ 0.93 Bq/kg respectively. Further analysis showed that the average values of radium equivalent ($Ra_{eq}$), external hazard index ($H_{ex}$), internal hazard index ($H_{in}$), absorbed dose rate (D) and annual effective dose equivalent (AEDE) were 70.12 Bq/kg, 0.19, 0.24, 24.13 nGy/h and 38.70 µSv/y for Ondo state respectively and that of Ekiti state was recorded as: 58.80 Bq/kg, 0.16, 0.21, 26.58 nGy/h and 32.60 µSv/y respectively. These values lower than the average range of worldwide specification and were concluded to be less hazardous. However, further and constant monitoring of these soils was recommended, particularly that of Ondo state which has bitumen deposit.

**Keywords:** Ekiti state, Gamma ray spectrometer, Oil palm, Ondo state, Plantation, Radionuclides, Soil, Spectrometric.

# Analysis of Radioactive Concentrations in Metal Samples Irradiated by Neutron

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This study presents radioactive concentrations for Metal samples irradiated by neutron from reactor vessel in Kori nuclear power plant (Unit 1). The metal samples taken from a baffle-former bolt were dissolved in concentrated $HNO_3$ 1mL and concentrated HCl 3mL (aqua regia) on hot plate. The solution was evaporated to dryness and dissolved with small quantity of 3M $HNO_3$. The stock solution was made from dissolved samples with distilled water weighing accurately the mass with a scale with 4 decimal places. A small amount of the sample taken from the stock solution was put in 20mL plastic vial.

The sample in plastic vial was put on plastic holder at 10cm distance between sample and detector, and, then, measured the gamma radioactive concentration by a HPGe gamma spectrometer. Pu and Am isotopes were measured by alpha spectrometer after radiochemical separation with anion exchange resin and TRU resin. Fe-55 and Ni-63/Ni-59 isotopes were measured by liquid scintillation counter after radiochemical separation with anion exchange resin and Ni resin. Tc-99 and Sr-90 isotopes were measured by liquid scintillation counter after radiochemical separation with TEVA resin and Sr resin.

The measured radioactive concentrations in metal samples irradiated by neutron were validated with measured by Pace Lab. in USA.

Keywords: Radioactive Concentration, Metal Samples Irradiated by Neutron, HPGe Gamma Spectrometer, Alpha Spectrometer, Liquid Scintillation Counter

## ACKNOWLEDGMENTS

This work was supported by KOREA HYDRO & NUCLEAR POWER CO., LTD (No. 2023-Tech-08)

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy(MOTIE) of the Republic of Korea (No. 2023-00270244).

# A comparative study between $^{7}$Be detected in TSP and $PM_{10}$

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In the present study, $^{7}$Be collected with different systems is compared, one of them uses a $PM_{10}$ head and the other captures total suspended particles (TSP), examining whether there are significant differences in their quantification.

Airborne dust samples were periodically collected from February 2024 until January 2025 over 1-week periods using: 1) $PM_{10}$: a high-volume MCV sampler at a flow rate of 30 $m^3h^{-1}$ using glass micro-fiber filters (150 mm in diameter, type GF20, MCV) and 2) TSP: a high-volume sampler PTI (air-flow rate 90,000 L $min^{-1}$) fitted with square polypropylene filters (440 mm side).

The sampling point of the aerosol samples discussed here is located at the University of Málaga (4° 28' 4" W; 36° 43' 40" N), at a height of 10 m above the ground and approximately at 5 km from the coastline. This is one of the environmental radioactivity monitoring network stations operated by the Spanish Nuclear Security Council (CSN).

Activity concentrations of $^{7}$Be were determined by low level gamma spectrometry using a coaxial-type germanium detector (Canberra Nuclear: Genie 2000). Gamma line of 477.7 keV was used. The counting intervals ranged from 172,800 to 216,000 s. The concentrations were corrected for decay to the mid-collection period.

The activities of $^{7}$Be measured in the two collectors yield a correlation coefficient of 0.87, suggesting that they are providing consistent results. Although there are no significant differences in the measured activities, that high correlation is a good indicator that both methods are reliable. The activities measured in $PM_{10}$ are, almost always, higher than those in the TSP samples, with differences ranging from 4% to 44%, being the correlation coefficients r=0.86. The only points at which the activities of $^{7}$Be measured in TSP exceeds the measurements in PM10 are in weeks where the highest concentrations of dust are detected in both filters, suggesting that extreme conditions can influence the measurements. Besides, in those weeks $^{137}$Cs is detected and the analysis of back-trajectories shows the African origin of the air masses. To study these differences, some meteorological data has been collected: average temperature, precipitation, wind speed and direction, and a VARIMAX analysis has been conducted. The conclusion drawn from this VARIMAX analysis is that the meteorological variables and measured activities can be effectively summarized into two principal components, which together account for 71% of the total variance: First Component associates the concentrations of $^{7}$Be in both $PM_{10}$ and TSP with temperature and wind direction. This suggests that these factors are likely influencing the behavior or distribution of $^{7}$Be in the atmosphere. Second Component links dust concentration (measured in both filters) with wind speed, indicating that wind plays a significant role in the dispersion or accumulation of dust particles.

Overall, the analysis highlights that: (1) $^{7}$Be is more concentrated in smaller particles, (2) measurements further support the consistency between these two sampling methods, (3) $PM_{10}$ and TSP collectors are reliable for measuring $^{7}$Be activities, with $PM_{10}$ typically showing higher values except under specific conditions of high dust concentration.

# Proficiency testing for Cs-137 and Cs-134 determination in soil

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**Introdution.** Official laboratories are subject to regular comparative tests conducted by the National Reference Laboratory in the scope of applied research methods. Organizing periodic proficiency tests (PT) is one of the most important tasks of reference laboratories. The Department of Chemical Research of Food and Feed, National Veterinary Research Institute acts as the National Reference Laboratory in the scope of radioactive contamination and is responsible for conducting these tests for official laboratories operating within the national system of control tests of radioactive contamination of food and feed.

**Material and methods.** The certified reference material IAEA-478 "Radionuclides in soil" was used for the study. The reference values of radioactive concentrations (established on the basis of measurement results of expert laboratories) were: $^{137}$Cs - 65.0 ± 0.9 Bq/kg, $^{134}$Cs - 112.2 ± 1.4 Bq/kg. The material was placed in a Marinelli type measuring container (450 cm$^3$). A sequential proficiency testing program was used. The object was sent between successive proficiency testing participants. The geometry of the measuring container was consistent with the geometry of the calibration source used to calibrate the detectors. The detection method was gamma spectrometry using a semiconductor detector (pure germanium HPGe detector) and a scintillation detector (NaI(TI) crystal).

**Results.** Nine official laboratories participated in the proficiency test The methodology used by the International Atomic Energy Agency (IAEA) was applied to evaluate the results. In this approach, criteria (correctness, precision) are adopted that take into account the uncertainty of measurements estimated by the participants. The obtained $^{137}$Cs and $^{134}$Cs results reported by the laboratories were within the reference value +/- uncertainty range for these radioisotopes.

**Conclusions.** The radionuclide $^{137}$Cs is still present in the natural environment, and is still occurs in measurable concentrations in food of animal origin. It is the mainstay of radiometric measurements and is most often used for assessment in PT proficiency testing. $^{134}$Cs does not currently occur in the natural environment. Due to its short half-life (2.1 years), it is a short half-lived isotope. Based on the obtained proficiency testing results, it can be stated that official laboratories perform reliable determinations of $^{137}$Cs and $^{134}$Cs radioactive concentrations.

**References**

1. PN-EN ISO/IEC 17043:2011. Conformity Assessment - General Requirements for Proficiency Testing.
2. Shakhashiro A., Fajgelj A., Sansone U.: Comparison of different approaches to evaluate proficiency test data. In: Combining and Reporting Analytical Results. RSC Publishing, Cambridge 2006, pp. 220–228.
3. Shakhashiro A., Trinkl A., Sansone U.: the IAEA's 'ALMERA Network' proficiency test on the determination of gamma-emitting radionuclides: A test of results comparability. Applied Radiation and Isotopes, 2006, 66, 1722–1725.

# Contamination of wild animal bones with the radioactive isotope $^{90}Sr$

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**Introdution.** Strontium-90, an artificial isotope and beta emitter, plays an important role in the toxicity of radioactive contamination. As a result of recorded nuclear accidents and other radiation events, $^{90}Sr$ can contaminate natural areas inhabited by wild animals. Due to its long half-life (T1/2=28.5 years) and chemical properties similar to calcium, $^{90}Sr$ is very easy to penetrate and accumulate in the bone tissue of living organisms. This creates a real possibility of the occurrence of cancer diseases such as leukemia or bone cancer as a result of harmful ionizing radiation. Examination of bone samples from wild animals is an important parameter for estimating the level of exposure of these animals and the level of contamination of the natural environment.

**Objective.** The aim of the study was to estimate the concentration of $^{90}Sr$ in the bones of wild animals.

**Material and methods.** In order to assess the contamination of bones of wild animals, research material was collected from four groups of animals (wild boars, roe deer, red deer, fallow deer). After grinding and homogenization of the prepared bone tissue material, the samples were ashed and then analyzed using the liquid scintillation counting method (LSC) using the Quantulus 1220™ detector. In the event of the appearance of interferents, an additional step of sample purification was applied using a special Dowex 1x8 ion exchanger.

**Results.** Measurable concentrations of $^{90}Sr$ were detected in the majority of the tested animal bone samples. The average concentration in deer bones was 7.14 Bq/kg, in roe deer bones it was 5.34 Bq/kg, in fallow deer bones it was 3.98 Bq/kg and 3.74 Bq/kg in wild boar bones. The highest concentration of $^{90}Sr$ was found in deer bones, which was 17.1 ± 2.23 Bq/kg. The obtained results confirm the migration of $^{90}Sr$ from environmental areas to the organisms of wild animals and its characteristic accumulation in bone tissue.

**Conclusions.** As a result of radiation incidents and then radioactive fallout, $^{90}Sr$ can get into the environment. The absorption and accumulation of $^{90}Sr$ in the bones is mainly caused by the type of food consumed by wild animals and their stay in contaminated areas. Analysis of radioactive contamination of $^{90}Sr$ bones of wild animals allows for estimating the degree of environmental contamination. This research also confirms that the problem of environmental contamination in Poland following the nuclear reactor accident in Chernobyl is still relevant.

**Keywords:** $^{90}Sr$, bones, contamination, wild animals.

# Fukushima-derived radiocesium in the western North Pacific Ocean a decade after the accident

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Introduction The accident of Fukushima Dai-ichi Nuclear Power Plant (FNPP1) occurred on March 11, 2011, and resulted in the release of 30-40 PBq radiocesium ($^{134}$Cs + $^{137}$Cs) into the environment. It has been estimated that 70-80% of the FNPP1-derived radiocesium was deposited and discharged in the North Pacific Ocean. The radiocesium deposited and discharged in the coastal area of Japan had been transported eastward to the international date line by the summer of 2012, the North American Continent by 2015, and then the Bering Sea through the Gulf of Alaska by 2017 along with the anti-clockwise subarctic surface current. Simultaneously, the FNPP1-derived radiocesium was also transported southward through the subsurface layer, about 200-400 m depth due to the subduction of the subtropical mode water (STMW) and central mode water (CMW) in the northwestern North Pacific Ocean just after the FNPP1 accident. Previous studies found that the FNPP1-derived radiocesium is a good tracer for the transport of the mode waters, which has not been revealed well. However, because observations of the vertical profile are limited, the temporal change in the FNPP1-derived radiocesium in the subsurface layers in the western North Pacific Ocean is unclear. We measured vertical profiles of radiocesium there in 2020-2022 and discussed its temporal change a decade after the FNPP1 accident.

Methods We collected seawater samples during the R/V "MIRAI" cruises of MR20-05C in October 2020 and MR21-06 in November 2021 and the R/V “HAKUHO-MARU” cruise of KH-22-7 in July-August 2022. 40 L of seawater was collected from the surface (10 m) to 800 m depth at 12 stations from 25 to 47°N and from 150 to 170°E. Radiocesium in the seawater sample was concentrated using ammonium phosphomolybdate or KNiFC-PAN resin (Triskem International). The recovery rate of Cs from the seawater sample was about 95%. Activity concentrations of $^{134}$Cs and $^{137}$Cs were measured using gamma-ray spectrometers at Kanazawa University. The uncertainties of the $^{134}$Cs and $^{137}$Cs measurements were about 15–20% and 3–5%, respectively. The detection limits of the decay-corrected $^{134}$Cs and $^{137}$Cs concentrations were about 0.9 and 0.01 Bq m$^{-3}$, respectively.

Results and Discussion The FNPP1-derived $^{134}$Cs was still observed at all the stations a decade after the accident. The vertical profile of $^{134}$Cs activity concentration decay-corrected to the FNPP1 accident date was different between the subarctic and subtropical regions. The two regions are divided by the Kuroshio Front around 35°N. In the subarctic region, $^{134}$Cs was observed in the surface layer shallower than 300 m depth, corresponding to the maximum depth of the winter vertical mixing. The highest concentration (2.1 Bq m$^{-3}$) was observed at 200 m depth, which could not be explained by the vertical mixing but by lateral mixing. We conclude that this highest concentration was derived from the return of the FNPP1-derived $^{134}$Cs along with the anti-clockwise subarctic current (Kumamoto et al., 2020) because that was higher than those in the subtropical region. In the subtropical region, $^{134}$Cs was detected from the surface to 600 m depth and the maximum concentration was observed around 400 m depth (the highest concentration was 2.0 Bq m$^{-3}$). The subsurface maximum in the subtropical region was observed about 10 months after the accident, which was derived from the subduction of STMW (Kumamoto et al., 2014). Our results indicate that the FNPP1-derived $^{134}$Cs in STMW subducted in March 2011 still remained in the subtropical region of the western North Pacific a decade after the accident, suggesting that STMW has circulated with in the subtropical region of the

western North Pacific.

# An Overview of the Feasibility of Leveraging Deep Learning for Environmental Radioactivity: Opportunities, Challenges, and Interdisciplinary Solutions

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Developments in science and specifically in the environmental radioactivity research have been solved lots of problems and limitations, however, it also created new challenges from detection to quantification and from distinguishing data to interpretation of radioactive contaminants in complex environmental matrices. One of these issues is about the prevailing methods, while effective in themselves, have limitations in terms of speed, accuracy, scalability, and sensitivity in the context of huge datasets that is used for continuous monitoring and comprehensive radiological surveys. The application of using artificial intelligent machines as the state of art of solution, relevantly deep learning models, could became a potential tool to help solving this problem in a revolutionary way. The deep learning techniques with such endless capability in patterning recognition, anomaly detection, and predictive modeling, might help us to enable an accurate and cheap option for monitoring and analyzing environmental radioactivity. In this paper we tried to emphasis the possibility and the potential of utilization of deep learning machines for improving accuracy of data gathering, expedite analysis of data, and enable better decision-making. Reviewing prominent methodological advancements by presenting the successful relevant cases of using artificial intelligent as well as outlines new research directions to capitalize on the full potential of deep learning techniques in the field of environmental radioactivity research. It is aimed to highlight the getting benefits from interdisciplinary research to application of it in solving for new challenges. Additionally, the possibility of using the AI in environmental sustainability, specially regarding the challenges related to environmental radioactivity has been discussed for it limitations and opportunities.

**Keywords:** Environmental Radioactivity; Deep Learning; Sustainability;

# Possibility of F1NPS-derived radio-caesium in fish of Eastern China Sea as bio-indicator for ocean tracer

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The radio-caesium in environment around Japan after the Fukushima-Dai-ichi Nuclear Power Station (F1NPS) accident, were reported, and was demonstrated to be depurated enough as below the seafood safety regulatory level. Although data was accumulated around Japan main land, it was not enough data from the Eastern China Sea (ECS), where the F1NPS-derived radio-caesium was suggested to be transported to mid layer water by the Subtropical Mode Water (STMW), Central Mode Water (CMW) and to surface water by North Equatorial Current (NEC) (Kumamoto et al., 2018; Aoyama et al., 2019; Takata et al., 2018; Huang et al., 2021) for the ECS. In this study, the necessary issues is extracted by data evaluation and pre-examination of radio-caesium levels in biota and seawater in the ECS waters, to check the feasibility of bio-indicator application as tracer for ocean circulation, from the viewpoint from global distribution and temporal level records collected from ECS for further understanding (Inomata and Aoyama, 2023). As a result, the released radio-caesium to Pacific Ocean by the F1NPS accident was confirmed to be brought to the ECS followed by go around to Sea of Japan (SOJ)(Inoue et al., 2020). On the other hand, F1NPS-derived $^{137}$Cs radioactivity concentration in surface water off Okinawa was estimated to be 0.3 mB $l^{-1}$ in 2020. The measured $^{137}$Cs radioactivity concentration in fish muscle collected off Ishigaki, Okinawa was approximately <0.31-0.88 Bq kg-ww$^{-1}$ in 2024, being greater than expected radioactivity levels extrapolated from the exponential decrease before 2010. Therefore, depuration delay might be contribution from F1NPS-derived $^{137}$Cs, whereas, it was not clear the supply source to be STMW or ECS. The $^{137}$Cs radioactivity concentrations in open water surface fish reported around Taiwan, demonstrated the similar depuration delay, and suggested remaining issue to be source identification of global fallout or NEC brought radio-caesium. Possible way to verify supply source to ECS waters could be data of $^{134}$Cs, however, the radioactivity levels in seawater decreased below the detection limit due to radioactivity decay during 14 years. Since fish muscle has concentration ratio (CR) of 100 for piscivorous fish, which may enable detection of $^{134}$Cs in 2025.

**Reference**

Kumamoto et al., 2018, Time evolution of Fukushima-derived radiocesium in the western subtropical gyre of the North Pacific Ocean by 2017. J. Radioanal. Nuclear Chem., 318, 2181–2187

Aoyama et al., 2019, Fukushima radionuclides in the marine environment from coastal region of Japan to the Pacific Ocean through the end of 2016. Progress Nuclear Sci. Technol., 6, 1-7

Takata et al., 2018, Appearances of Fukushima Daiichi Nuclear Power Plant-Derived $^{137}$Cs in Coastal Waters around Japan: Results from Marine Monitoring off Nuclear Power Plants and Facilities, 1983−2016. Environ. Sci. Technol., 52, 2629−2637

Huaong et al., 2021, Radiocesium in the Taiwan Strait and the Kuroshio east of Taiwan from 2018 to 2019. Sci Report, 11, 22467

Inomata and Aoyama, 2023, Evaluating the transport of surface seawater from 1956 to 2021 using $^{137}$Cs deposited in the global ocean as a chemical tracer. Earth Syst. Sci. Data, 15, 1969–2007

Inoue et al., 2020, Circulation paths of $^{134}$Cs in seswater southwest of Japan in 2018 and 2019. J. Environ. Radioactivity, 106382

# Air Sampling at Barakah NPP – Challenges with environmental conditions on system performance and enhancements made to instruments and monitoring protocols.

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The Barakah Nuclear Power Plant (BNPP) in the United Arab Emirates was envisioned in 2008 with the Emirates Nuclear Energy Corporation (ENEC) beginning construction of the first unit in 2010. The location of this project is in the Western Region of Abu Dhabi in the Arabian Peninsula and is located on the Arabian Gulf. As part of the operational requirements, ENEC has a Radiological Environmental Monitoring Program (REMP) which is implemented by the Environmental Radiochemistry Laboratory (ERL). This program is responsible for monitoring the environment around the BNPP site to ensure that no unmonitored radiological release pathways exist through the sampling of air, water, sediment, and biota on a regular basis. Air sampling is a key component of this program and is monitored 24/7.

The pre-operational monitoring phase for air sampling, to establish baseline variations in the environment around BNPP, began in August of 2014. The operational phase of the REMP began in March 2020 when the first fuel was loaded into Unit 1. During this time, the ERL has encountered challenges due to the harsh environmental conditions present around the BNPP site. These conditions include high temperature (>45 °C), high humidity (> 90% RH), high dust content, and corrosive conditions due to salinity of the Arabian gulf and shallow ground water surface soils which are categorized as Aquisalids. These conditions have impacted the operational performance of the physical samplers through corrosion of electronic components, premature failure due to thermal stress of materials and components, and unpredictable plugging of particulate filters due to dust loading and water saturation from the high humidity.

The ERL has worked with F&J Specialty Products Inc to develop an air sampler system better capable of working in conditions encountered around BNPP in addition to providing telemetry information to aid in maintaining operational knowledge on the status of the system to plan for filter loading issues. This presentation will discuss the issues which were encountered, the design and testing of the modified system, and the current performance status of the new air sampler systems

# Transport of Fukushima-derived $^{137}$Cs into the South China Sea via Subtropical Mode Water intrusion through the Luzon Strait

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The Luzon Strait is an essential channel connecting the North Pacific Ocean and the South China Sea (SCS). Despite numerous studies on regional ocean circulation, the intrusion pathways and transport mechanisms of Subtropical Mode Water (STMW) into the SCS remain insufficiently understood. The Fukushima Daiichi Nuclear Power Plant accident in March 2011 released radiocesium ($^{137}$Cs) into the ocean, providing a unique opportunity to trace the STMW's transit from the Kuroshio Extension region to the SCS. Using a three-dimensional numerical ocean model (ROMS), this study investigates the pathway and transport timescale of $^{137}$Cs associated with STMW intrusion into the SCS via the Luzon Strait. To clearly identify STMW-driven transport, atmospheric deposition of $^{137}$Cs was excluded by utilizing a scenario with only oceanic discharge. Model simulations indicate an increase in $^{137}$Cs concentrations within the STMW layer at the Luzon Strait approximately seven years after the Fukushima accident. Transport of $^{137}$Cs through the STMW layer precedes surface circulation-derived transport into the Luzon Strait. The net flux of $^{137}$Cs into the SCS exhibits a notable seasonal variation, with elevated fluxes during winter and reduced levels in summer, modulated primarily by horizontal transport and variations in the Kuroshio intrusion pattern. In particular, the leaking path of Kuroshio intrusion increases the net inflow of $^{137}$Cs compared to the looping or leaping paths. Considering the role of SCS as a gateway to downstream marginal seas such as the East China Sea, Yellow Sea, and Japan/East Sea, understanding these transport mechanisms is critical for evaluating the path of $^{137}$Cs and other tracers in the region.

# In-situ gamma radiation assessment of coastal and hinterland regions of Kanyakumari high background natural radiation area, India

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Assessing radiological risks to ecosystems, agricultural systems, and public health relies on the absorbed dose rate in air ($D_{air}$). Since it may not always be possible to measure and rely solely on point data, combining point data with other methods provides a more comprehensive assessment. Alternatively, the car-borne survey technique allows direct measurement of $D_{air}$, providing a thorough assessment of background radiation levels. This study presents the natural gamma radiation survey conducted using a vehicle-mounted NaI(Tl) scintillation spectrometer in the coastal and hinterland regions of Kanyakumari, a high background natural radiation area (HBNRA) in India (Fig. 1). The comprehensive study allowed the authors to distinguish the background radiation levels between the coastal and hinterland regions. Most of the coastal regions exhibited high background natural radiation levels (ranging between 39.11 – 1796 nGy $h^{-1}$, with a geometric mean of 150.2 ± 211.4 nGy $h^{-1}$), while a few of the hinterland regions exhibited elevated background radiation levels (ranging between 44.28 – 456.4 nGy $h^{-1}$, with a geometric mean of 118.6 ± 53.11 nGy $h^{-1}$). The z-score for the $D_{air}$ in the coastal area, with 1262 points, suggested 28 extreme outliers and 53 mild outliers, whereas the z-score for the $D_{air}$ of the hinterland region, with 882 points, suggested 19 extreme and 36 mild outliers. The dose distribution map, created using the 2144 data points, clearly displayed these outliers as hotspots (Fig. 2). The frequency distribution of $D_{air}$ was right skewed, with the tail extending asymmetrically towards more positive values. The resulting p-value from the t-test was less than 0.05, indicated a statistically significant difference between the dose rates of the coastal and hinterland regions.




**Fig. 1** Study area map

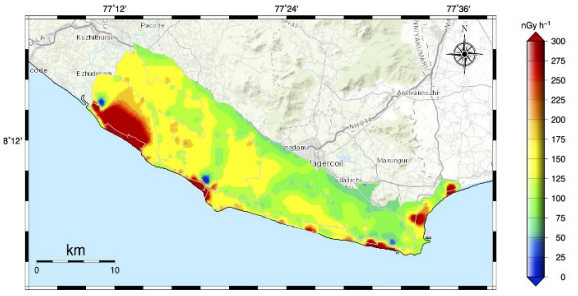



**Fig. 2** Absorbed dose rate spatial distribution map

# Ultra-sensitive radionuclide detection with Ion-Laser InterAction Mass Spectrometry

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Interferences from isobars typically restrict the applicability of Accelerator Mass Spectrometry (AMS) to only a select group of long-lived radionuclides. The novel Ion-Laser InterAction Mass Spectrometry (ILIAMS) technique at the Vienna Environmental Research Accelerator (VERA) can overcome this limitation in many cases by highly-efficient isobar removal at eV-energies [1]. This opens exciting possibilities in environmental radioactivity ($^{90}$Sr, $^{99}$Tc, $^{135,137}$Cs), astrophysics ($^{44}$Ti, $^{53}$Mn, $^{182}$Hf), Earth science and cosmochemistry ($^{26}$Al, $^{36}$Cl, $^{41}$Ca) research.
For example, ILIAMS-assisted AMS allows the detection of $^{26}$Al and $^{41}$Ca directly from crushed stony meteorites containing intrinsic ~1% Al and Ca, respectively, for fast provenance checks for extraterrestrial origin [2,3]. The measurement of $^{41}$Ca in chemically untreated concrete from nuclear decommissioning and in coral sand samples emphasizes the huge potential of this technique for nuclear clearance. The presence of isobars originating from the natively abundant elements ($^{26}$Mg, $^{41}$K) does not cause any analysis problems making radiochemical separation redundant.
For $^{90}$Sr, ILIAMS enables a detection limit of <0.016 mBq in a sample of mg of stable Sr – at least a factor 100 better than other techniques. Recently, we have successfully determined the $^{90}$Sr/Sr ratio in less than 0.5 g contemporary coral aragonite and seawater samples of less than 500 ml, and analyzed the $^{90}$Sr concentration in small samples of soils, snails, antlers and reactor concrete after adding Sr carrier.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008324 (ChETEC-INFRA) and European Union's Horizon Europe call HORIZON-INFRA-2021-SERV-01 under grant agreement number 101058414 (ReMade@ARI). (Extra-)terrestrial samples were kindly provided by A. Bischoff (U Muenster), M. Knebel (JEN mbH), B. Bookhagen (U Potsdam), K. Schniebs (Senckenberg Dresden), Forst- und Landwirtschaftsbetrieb der Stadt Wien, E. Strub and M. Schiffer (U Cologne).

References: [1] Martschini et al., Radiocarbon 64 (3) (2022) 555.
[2] Bischoff et al., Meteorit. Planet. Sci. 59 (2024) 2321.
[3] Bischoff et al., Meteorit. Planet. Sci. 59 (2024) 2660.

# Data Base of Radioecological Parameters for Arid Environments

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Nuclear technology has a wide range of uses in agriculture, food preservation, water management, health, aeronautics, and energy production.

Any country that utilizes nuclear technology must be prepared for the rapid elimination of malfunctions and must have a plan for assessing the impact of any releases on the population and environment, mitigating their consequences, and rehabilitating contaminated areas.

This involves creating a Decision Support System (DSS), combining temporal and spatial data on the transfer of radioactive material in the environment, particularly in food chains. Unfortunately, some countries with intensive nuclear use and development have yet to establish a DSS. This is especially hard in arid climates, where the necessary information is often sparse or entirely absent.

The creation of a DSS requires the identification of many parameters including statistical information on the local population, industrial production, and food products. A significant factor is radionuclide transfer from contaminated soil into plants directly consumed by humans or used as animal feed. The driving processes might differ significantly in arid climates from those in well-studied temperate or humid regions. We support these efforts by consulting and guidance in this field, as well as by developing and providing a database of transfer factors.

Our large database contains relevant radionuclide concentration ratios from soils to crops in arid conditions. These coefficients can be used for calculating food contamination to assess radiation doses and identify the most sensitive products in arid regions. This continuously updated database is available online.

This paper presents instructions for preparing abstracts for the 8th International Conference on Environmental Radioactivity, which will held from September 14 to 19, 2025, in Kraków, Poland.
The authors are encouraged to submit an abstract (A4-size with 25 mm margins on all sides) in a pdf format by **April 30th, 2025**. The title should be placed at the top, followed by the author(s) name(s), affiliation(s) and address(es), and email address of the contact person if available. Use "Calibri" font. If you have to utilize other fonts, all the fonts must be embedded in the file. The font size should be 14 point for the title, and 11 point for the main text. The font size in figure and table (including captions) should be at least 10.5 point. The abstract must not exceed one page and may include figures, tables, and references, if necessary.
All abstracts must be submitted via Indico for which you will need to create an account. Abstracts are submitted online through the Indico submission system:
https://indico.ifj.edu.pl/event/1258/abstracts/
Abstracts submitted via email or other means will not be considered. Filenames should follow the style of '*surname_forename*_ENVIRA2025_*contribution*.pdf'. Names should be written with standard Latin characters, while contribution indicates the preferred presentation format: oral or poster. The example of a correct file name is 'Lem_Stanislaw_ENVIRA2025_oral.pdf".By submitting an abstract, you agree to its publication in the official program of the Conference. All accepted and published abstracts must have registered presenting authors. Authors will be notified of acceptance of their abstract by email no later than the **15th of May 2025**.
For any questions or further information on abstract submission, please contact envira2025@ifj.edu.pl.

# Accelerator Mass Spectrometry: Techniques for Measurement of Long-Lived Radionuclides and Applications

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Accelerator mass spectrometry enables the measurement of rare radionuclides, such as $^{10}$Be, $^{14}$C, $^{26}$Al, $^{36}$Cl, $^{41}$Ca, and $^{129}$I. Most of these radionuclides can be produced by cosmic-ray interactions with both extra-terrestrial and terrestrial materials. Some are also produced by nucleogenic processes. The measurements of these radionuclides yield information about the exposure conditions and durations. Measurements of terrestrial cosmic-ray produced (cosmogenic) nuclides provide information on glacial chronologies, erosion rates, burial ages, even hominid evolution. Measurements of cosmogenic nuclides Measurements of cosmogenic nuclides in extra-terrestrial materials provide meteorite exposure ages and information about lunar and asteroidal surface processes.

Be-10 and $^{26}$Al have been measured from core samples taken from underneath the Greenland Ice Sheet (GIS) GIS near the dome of the ice sheet and from sediments collected underneath the ice at Camp Century. These measurements can be used to develop scenarios for the extent of the ice sheet during the later Pleistocene and indicate that the GIS is a dynamic feature that has undergone considerable change during the Pleistocene, and is likely to continue changing, perhaps having profound influence on coastal regions.

While measurements of radionuclides from terrestrial samples provide important information on the connections between climate and Earth's evolving landscape, measurements in extra-terrestrial materials provide information about the nature of Earth's solar system environment. Recent measurements of lunar and asteroidal samples evince dynamic processes on their surfaces.

# Uranium and thorium preconcentration from liquid samples via the use of a polymeric complexing membrane

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The present work summarizes the already implemented research and the subsequent progress in uranium and thorium preconcentration from liquid samples, via the use of a polymeric complexing membrane which consists of a PVC matrix, DBP plasticizer, Aliquat-336, and calcon carboxylic acid complexant. It is produced in liquid form after dissolving the aforementioned ingredients in THF. The technique relies on membrane stabilization within glassware following the dryness of THF. The liquid samples are added above, and the complexation is carried out under continuous stirring. After complexation, the membranes are digested with c. $HNO_3$, and c. HCl, and are finally dry-ashed. The leftovers are utilized for the separation of radionuclides, either through anion exchange or extraction chromatography. The measurements are performed by alpha spectrometry after electroplating of radionuclides on stainless steel plates.

This technique has already been applied in uranium analysis of water samples, achieving recoveries of the order of 96±5 % for tap water and 93±6 % for seawater [Kallithrakas et al., 2018]. They have also been used in uranium analysis in urine samples with a final recovery of 78±6 % [Xarchoulakos et al., 2022]. The great advantages of the technique are the speed of complexation and that the analysis was very efficient even in seawater.

Currently, the above membrane is applied in thorium analysis in water samples. After membrane digestion and ashing, the residue is dissolved in 8M $HNO_3$, separated via anion exchange, and eluted in 10M HCl solution [Lee et al., 2005]. The first experiments resulted in thorium recovery of the order of 45% for a 0.25 L sample and a contact time of 4 hours. A flowchart of the thorium analysis is depicted in Figure 1. To optimize thorium recovery, the following factors must be studied:

The equilibration time, the composition of the membrane, the sample's volume, and the complexation temperature. A back-extraction process will also be applied to reduce the time of sample preparation.

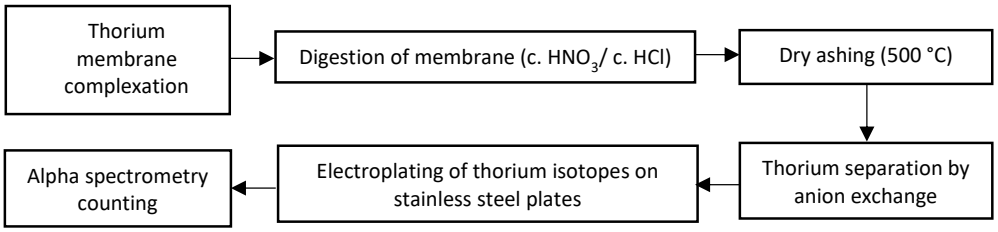



**Figure 1.** Thorium analysis after preconcentration by membrane complexation.

## References

1. Kallithrakas-Kontos, N.G., Xarchoulakos, D.C., Boultadaki, P., Potiriadis, C., Kehagia, K., 2018. Selective Membrane Complexation and Uranium Isotopes Analysis in Tap Water and Seawater Samples. Anal. Chem. 90, 4611−4615.
2. Xarchoulakos, D.C., Kallithrakas-Kontos, N.G., 2022. Uranium analysis in urine after membrane complexation and alpha spectrometry counting. J. Radioanal. Nucl. Chem. 331, 283–288.
3. Lee, S.H., La Rosa, J., Gastaud, J., Povinec, P.P., 2005. The development of sequential separation methods for the analysis of actinides in sediments and biological materials using anion-exchange resins and extraction chromatography. J. Radioanal. Nucl. Chem. 263, 419- 425.

# Assessment of averted doses for the verification of seafood distribution/consumption restrictions imposed after the FDNPP accident

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Radionuclides released due to the Fukushima Daiichi Nuclear Power Plant accident in March 2011 were deposited from the atmosphere onto land and into the sea, contaminating agricultural and marine products in the areas affected by the accident. To reduce internal exposure from consuming contaminated food, the Government of Japan imposed restrictions of distribution and/or consumption of food. The standard limit for radiocesium concentration in general food for the imposition of restrictions was 500 Bq/kg from the accident to March 2012, and has been 100 Bq/kg from April 2012 to the present. The current standard was determined based on assumptions that the annual committed effective dose to a consumer group with the highest food intake is less than 1 mSv. This standard was introduced as a measure to ensure safety and security during the high social anxiety after the accident, and it was exceptionally strict in comparison with the standards in other countries and regions. This strict restriction may have contributed to overcome a great disruption at the time of the accident.

More than 14 years after the accident, radionuclide concentrations in food have decreased significantly, and fewer types of food exceed the standard. At the same time, a large number of costs are still required to maintain the restrictions and food monitoring, and to provide financial support to farmers and fishermen. As well as ensuring that radiation exposures are reduced by the restrictions, we should also pay attention to economic and social impacts caused by prolonged restrictions. Considering these facts, it is necessary to review whether the current standard set shortly after the accident was reasonable in terms of the radiation protection and of economic and social impacts. Therefore, this study aims to conduct assessments of current restrictions by the following three steps:

1. Assessments of averted doses due to the imposition of restrictions.
2. Evaluations of costs for the imposition of restrictions.
3. Assessment of the reasonableness of restrictions based on the above.

This presentation focuses on step 1. Previous studies of post-accident ingestion doses have revealed that even with conservative assumptions, the ingestion dose does not exceed the target annual additional dose of 1 mSv. This study assesses how much ingestion dose was reduced by the restrictions. It requires more realistic assessments that accurately reproduce the restrictions actually applied.

This study first focused on seafood, which has been most affected by restrictions in terms of the domestic distribution volume. The 95$^{th}$ percentile values of the annual committed effective doses to general Japanese adults were 19 μSv in the first year after the accident and 12 μSv in 1–3 years after the accident, respectively. In contrast, when assuming that restrictions were not imposed, 95$^{th}$ percentile doses were 25 μSv and 15 μSv, respectively, and averted doses by the imposition of restrictions were 5.5 μSv and 3.2 μSv, respectively.

We will focus on steps 2 and 3 as future work. This study will provide important information for optimizing radiological protection measures for ingestion doses.

# THE DISTRIBUTION OF BERYLLIUM-7 CONCENTRATION IN RAINWATER IN TWO SEASONS

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**Abstract**

There has been no study of the distribution of Beryllium-7, $^{7}$Be concentrations in rainwater in Peninsular Malaysia that has been fully conducted by researchers to date. Therefore, the main objective of this study is to obtain and collect data from three different sampling stations in Peninsular Malaysia based on the amount of rainfall received throughout the year. This study involved collecting individual rainwater samples using rainwater collection funnels for both seasons over a six month study period. All rainwater samples were taken to the Radiochemistry and Environment Group (RAS), Nuclear Malaysia for preparation and analysis. All rainwater samples were analyzed using various procedures involving chemicals used and filtered using Whatman qualitative filter paper. Calculation of the activity of dry filter paper containing $^{7}$Be concentration in rainwater that has been analyzed with a Gamma Spectrometry for 24 hours counting with a detection efficiency of 20% and the uncertainty used to calculate the gamma detector error, $\gamma$ is the 95% confidence level, which is within ± 10%. The overall study results provided a range of $^{7}$Be concentrations that did not differ significantly between the dry and wet seasons for both seasons from all study stations, , 0.21 to 3.59 Bq/L and 0.24 to 3.14 Bq/L each respectively. Meanwhile, the $^{7}$Be concentration values from this study are not significantly different from several results reported by other researchers. In conclusion, both seasons did not have a statistically significant effect on the concentration of $^{7}$Be in rainwater in this study from all three sampling stations ($p$ value > 0.05). However, further studies need to be conducted so that more data can be collected to be used as reference data for the concentration of $^{7}$Be in Peninsular Malaysia.

**Keywords:** Distribution, Beryllium-7, Rainwater, Gamma Spectrometry, Reference Data

# ENRICHMENT FACTOR AND GEOACCUMULATION INDEX OF HEAVY METALS IN THE SURFACE SEDIMENTS IN THE SEMBRONG CATCHMENT

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**Abstract**

Sembrong catchment is one of the important ecosystems in Peninsular Malaysia and it has evolved from a natural ecosystem to a human dominated ecosystem. Sembrong catchment is located in Kluang, Johor and the morphology provides important information about the physical characteristics with a freshwater reservoir of 7.7547 $km^2$. The catchment area is approximately 130 $km^2$ with land use having changed significantly with increased agricultural activities covering 8% (1984) to 82% (2010). Therefore, this study focuses on heavy metals (Na, P, Cu, Zn, Al, Ni, Cr, Mn) and subsequently determines the degree of sediment contamination using the enrichment factor and geoaccumulation index. Surface sediment sampling involved twelve stations using plastic scopes for two different seasons and all samples were taken to the Radiochemistry and Environment Group (RAS), Nuclear Malaysia for preparation and analysis. All samples were analyzed using EDXRF (Energy Dispersive X-ray Fluorescence) spectrometry at the Materials Technology Group (MTeG), Nuclear Malaysia. Hence, with these two values of sediment contamination from activities in the surrounding area can be controlled from entering the Sembrong catchment area for the short and long term.

**Keywords**: Catchment, Ecosystem, Agricultural, Sediment, Surrounding

# SHORT-TERM SOIL EROSION RATE IN DIFFERENT LAND USE AREAS IN THE SEMBRONG CATCHMENT

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**Abstract**

Soil erosion is one of the environmental problems that often becomes an obstacle in a development process especially in the opening of land for agricultural activities and new settlements. The use of Beryllium-7 as a tracer has been proven through several studies that tested the potential of this fallout radionuclide as a very efficient and significant tracer in estimating soil erosion rates in the short term. This study was conducted in the Sembrong catchment area, Kluang for both seasons by taking soil samples using a metal corer to within 5 cm of the soil surface in different land use areas . The sample was sliced into 2mm and then dried using an oven at 45 – 60 ˚C until the weight became constant. All the samples were sieved and then put into a 6ml vial tube before being counted using a Gamma Spectrometry overnight. The results of the analysis from this study found that there were varying results for both seasons throughout the study. The dry season has given higher soil erosion rates compared to the wet season, 0.62 t $ha^{-1}$ $yr^{-1}$ to 27.11 t $ha^{-1}$ $yr^{-1}$ and 0.44 t $ha^{-1}$ $yr^{-1}$ to 20.04 t $ha^{-1}$ $yr^{-1}$ each respectively. Mixed crop at Station 15 and UK's Farm at Station 13 gave the highest values for soil erosion rates in both seasons, 27.11 t $ha^{-1}$ $yr^{-1}$ and 20.04 t $ha^{-1}$ $yr^{-1}$. However, there was no statistically significant difference in soil erosion rate between the two seasons across all land uses. In conclusion, the use of Beryllium-7 as a tracer to identify soil erosion rates in different land use areas in the study for both seasons was successful.

**Keywords**: Environmental, Beryllium-7, Fallout Radionuclide, Varying, Soil erosion

# Radiological characterization, car-borne survey and radioecological risk assessment of soils from Ghazaouet, Western Algeria

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**Keywords: Gamma radiation, Soils, risk assessment, ERICA tool, Western Algeria**

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**Abstract:**

Human exposure to ionizing radiation, both indoors and outdoors, primarily arises from natural background radiation. This radiation is emitted by terrestrial radionuclides found in the Earth's crust along with their decay products, as well as by cosmic radionuclides.

Human beings can be exposed to artificial radioactivity, such as Cesium-137 ($^{137}$Cs), primarily generated through nuclear fission, and understanding the exposure pathways is essential for evaluating health risks.

The main objectives of this research are to assess the levels of natural background gamma radiation, to analyse both natural and man-made radionuclide concentrations in surface and core soils, and to conduct a risk assessment using the ERICA tool.

Natural background gamma radiation was measured along roads in the vicinity of Ghazaouet (western Algeria) using a car-borne spectrometer system (FHT 1376 Mobysis).

A total of 20411 data of the background gamma dose rate were collected during December 2021.

A total of seventeen (17) surface soil samples and one core soil sample were collected from the western region in March 2023. The detailed methodology applied for the treatment and analysis by HPGe gamma spectrometry was described in Taieb Errahmani et al.,(2020)**[1]**.

The ERICA tool was used to assess the radiological risk of the region. This was based on the activity concentrations of radionuclides detected in the soils.

The measured dose rate was found to be in the range of 8.6-62.1 nSv.h$^{-1}$ with a mean value of 35.35 nSv.h$^{-1}$. The background gamma dose rate was mapped using Map Info software.

The radionuclides that were analyzed in soil by gamma spectrometry were $^{238}$U daughters ($^{210}$Pb , $^{234}$Th, $^{226}$Ra, $^{214}$Pb and $^{214}$Bi), $^{232}$Th daughters ($^{212}$Pb, $^{208}$Tl and $^{228}$Ac), $^{137}$Cs and $^{40}$K.

The spectrometric analysis indicated that the surface soils contained $^{137}$Cs with an average activity concentration of 11.73 ± 0.58 Bq/kg. In contrast, the soil core samples showed a decreasing presence of $^{137}$Cs down to a depth of 25 cm, where it had an average activity concentration of 2.41 ±0.13 Bq/kg, which is very low compared to $^{137}$Cs detected in soils from a high altitude site **[2]**.

Activity concentrations (Bq·kg$^{-1}$ d.w.) in soil core were found to be in the range of 153.55±6.96–387.18±15.63 ($^{40}$K), 13.68 ±4.26–50.26±15.65 ($^{210}$Pb), 9.05±0.48–18.88±1.23 ($^{214}$Bi),13.01±1.23–28.88±2.74 ($^{228}$Ac).

The total dose rates for lichens and bryophytes assessed using the ERICA tool were found to be significantly elevated compared to other environmental matrices, measured at **16 µGy h$^{-1}$**, which does not pose a radiological health risk.

**References:**

[1] **Taieb Errahmani, D.,** Noureddine, A., Abril Hernandez,J.M., Boulahdid, M., 2020. Environmental radioactivity in a sediment core from Algiers Bay: radioecological assessment, radiometric dating and pollution records. *Quaternary Geochronology , 56.*

[2] **Taieb Errahmani D**., Noureddine A., Abril J.M., 2022. Depth-distributions and migration of fallout radionuclides in mountain soils from Chréa National Park (Algeria): The role of rhizospheres. *Journal of Environmental Radioactivity*,Vol.242, 106799.

# Environmental radiological risk assessment of algae from Algiers coastline

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***Keywords:*** *Risk assessment, algae, gamma spectrometry, ERICA tool, Algiers coastline*

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**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[1]. 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].

**References:**

**(1)** Tejera A., Perez –Sanchez L, Guerra G., Arriola Velasquez A.C, Alonso H., Arnedo M.A., Rubiano G., Martel P., 2018. Science of the Total Environement , Vol. 658, Pages 122-131.

**(2)** UNSCEAR, 2008. United Nations Publications, New York, vol. 1

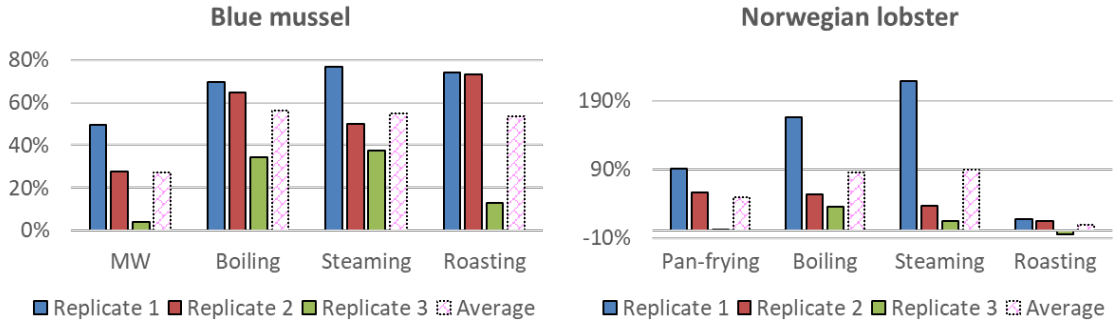
# Can cooking practices affect dietary exposure to $^{210}$Po in seafood?

**Francisco Piñero-García*, Timmy Nordqvist, Rimon Thomas, Eva Forssell-Aronsson and Mats Isaksson**

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The internal exposure, due to ingestion, typically range between 200 – 800 μSv/y, depending on food habits (UNSCEAR, 2000). One of the radionuclides of major concern is $^{210}$Po due to its high radiotoxicity. Moreover, it has been demonstrated to be the main contributor to internal dose by food consumption (IAEA, 2017). To carry out a realistic dose assessment, food preparation and cooking effect must be considered since activity concentration of the radionuclides could change due to different process such as thermal influence, dehydration, or interaction with other substances. However, the impact of food preparation and cooking could be different for each radionuclide since it depends on the physical and chemical properties of the element (Komperød et al., 2020). Therefore, the current study investigated **the impact of cooking techniques on $^{210}$Po in seafood**, in particular blue mussel (*Mytilus edulis*) and Norwegian lobster (*Nephrops norvegicus*). The figure shows the increase or reduction in the content of $^{210}$Po in blue mussels and Norwegian lobster after cooking practice, compared to the reference group.




The results show high variability in the influence of cooking practices on the levels of $^{210}$Po. This could be related to the difficulties to have a representative control group, since we are assuming a homogeneous levels of $^{210}$Po and water contents in the samples. In general, the results of the study highlight an increase of $^{210}$Po levels after cooking. For blue mussel, boiling, steaming and roasting experiments increased, on average, the levels around 50%. However, when MW was used for cooking them, the impact on $^{210}$Po levels was lower. For Norwegian lobster, considering the average values of the replicates, boiling and steaming increased the level of $^{210}$Po approximately 90%, in the case of pan-frying the increase on average was around 50%, while in the case of roasting the lowest increase was found, < 10% on average.

**References:**

IAEA. (2017). *The environmental behaviour of Polonium* (Technical Reports Series, Issue. IAEA.

Komperød, M., Piñero-García, F., Guðnason, K., Kiel Jensen, L., Kämäräinen, M., Roos, P., & Kristin Skjerdal, H. (2020). *Natural Radioactivity in Nordic Fish and Shellfish – Final report*. NKS Nordic nuclear safety research.

UNSCEAR. (2000). *Sources and effects of ionizing radiation* (UNSCEAR 2000 Report to the General Assembly,with Scientific Annexes, Issue. United Nations. http://www.unscear.org/docs/publications/2000/UNSCEAR_2000_Report_Vol.I.pdf

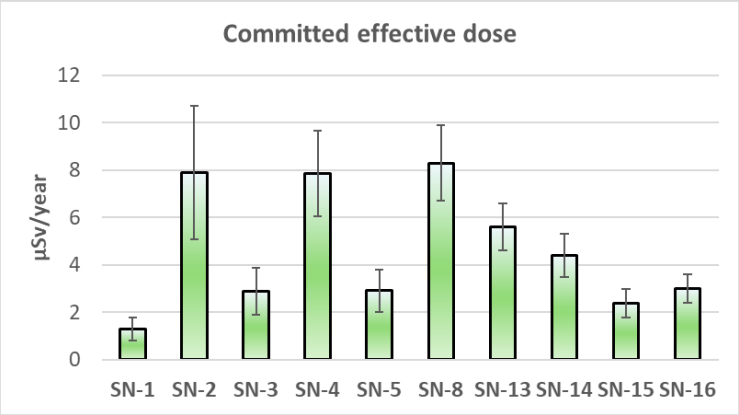
# What is the potential bioaccessibility of naturally occurring radionuclides in snus when consumed?

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In Sweden, snus is the most common product of tobacco used, more than cigarettes[1]. Snus consumptions rate increases year by year, above all in adolescents and young adults, due to the perception of being less harmful[2]. Swedish snus contains carcinogenic ingredients such as tobacco-specific nitrosamines, high radiotoxicity naturally occurring radionuclides (e.g.$^{210}$Po), among others[2,3]. This study aimed to investigate the presence of naturally occurring radionuclides in snus, their bioaccessibility during consumption, and the associated radiological risks to consumers. A total of 16 samples were purchased from Swedish stores to reflect the national market. A radiological characterization of the samples was conducted through digestion, radiochemical processing, and alpha spectrometry analysis, focusing on $^{210}$Po, $^{232}$Th, $^{234}$U, and $^{238}$U. The activity concentrations of these radionuclides in the snus were calculated. A bioaccessibility study analysed the same radionuclides, simulating real-life snus use to estimate the fraction extracted by saliva.




The radiometric characterization revealed that $^{210}$Po ranged from 2.4–3.0 mBq/g in loose snus and 1.2–5.1 mBq/pouch in pouched snus. For $^{232}$Th, levels varied between 0.22–0.42 mBq/g in loose snus and 0.1–0.66 mBq/pouch in pouched snus. $^{234}$U ranged from 0.22–0.27 mBq/g in loose snus and 0.07–0.21 mBq/pouch in pouched snus, while $^{238}$U was between <0.04–0.23 mBq/g in loose snus and 0.08–0.26 mBq/pouch in pouched snus. Minimal or no activity was detected in tobacco-free snus (SN-9 – SN-12). The bioaccessibility study demonstrated that all samples transferred $^{210}$Po into saliva, with leaching values ranging from 9 ± 3% to 34 ± 7%. Only a limited number of samples showed leaching of other radionuclides, and just one sample appeared to have transferred all radionuclides into saliva. The committed effective dose from one year of snus consumption attributed to $^{210}$Po ranged between 1.3 - 8.3 µSv, averaging at 4.55 µSv.

**References:**

1 Folkhalsomyndigheten. *Use of tobacco and nicotine products*, <https://www.folkhalsomyndigheten.se/the-public-health-agency-of-sweden/living-conditions-and-lifestyle/andtg/tobacco/use-of-tobacco-and-nicotine-products/> (2024).

2 López-Cervantes, J. P. *et al.* Use of oral moist tobacco (snus) in puberty and its association with asthma in the population-based RHINESSA study. *BMJ Open Respir Res* **11** (2024). https://doi.org/10.1136/bmjresp-2024-002401

3 McAdam, K. *et al.* Comprehensive survey of radionuclides in contemporary smokeless tobacco products. *Chemistry Central Journal* **11**, 131 (2017). https://doi.org/10.1186/s13065-017-0359-0

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

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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.

## Competing risk model; a new integrated approach to assessing contextual impacts of ionising radiation

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Global heating is now accepted with heatwaves and forest fires seriously impacting air quality and resulting in massive areas being subjected to air pollution. Nuclear energy is therefore increasingly being identified as a "green" alternative to provide for our energy needs. However there is much public resistance due to fear of radiation effects. Radiation protection approaches do little to ease this fear as they are grounded in the idea that any dose has a potential to harm. This approach ignores other risks associated with other forms of energy production focusing solely on determining the risk from radiation alone. The model we are proposing here is an attempt to set radiation risk in context – to balance the risks of action to limit or optimise factors impacting climate change with those of inaction – for example excluding a nuclear action without proper analysis. Existing attempts to approach this problem include adverse outcome pathway analysis (AOP) which proposes to evaluate causal relationships. It links in a linear way existing knowledge along one or more causally connected key events between two points – a molecular initiating event caused by the stressor of interest, and an adverse outcome. However the commonality of response pathways between radiation and other stressors such as heat, drought, flood, food scarcity, air pollution, or environmental degradation plays into a competing cause model for the same endpoint outcome rather than a single agent risk model. The aggregate exposure pathway analysis (AEP) is a more quantitative approach known as STOP (source to outcome pathway) which tries to look at multiple stressors. Here only the most relevant pathway and stressor is considered using logical inference from available data. This is different from competing risk analysis (CRA) which is a special type of survival analysis that aims to estimate correctly, the marginal probability of an event in the presence of competing events. In a CRA all risks can be compared by using a Baysian inference to identify the most relevant risks to the system under consideration. Crucially for CRA it is not necessary to know the exact pathway involved in determining the outcome. This concept has been developed here to try to examine the important possibilities and threats to, for example, the ecosystem. If nuclear energy is to be a part of the solution to the energy and climate crisis a CRA would point to environmental benefits such as habitat preservation. Habitat degradation is a human and environmental health risk; nuclear power generation could demonstrably mitigate against this by making new builds such as small modular reactors eco-friendly – setting aside land to offset environmental harm from the build. A CRA approach would also involve attributing a societal value to biodiversity, carbon storage properties of trees and bogs etc. In conclusion the advantages of a CRA approach are that a basket of stressors can be assessed to predict different outcomes not all of which need be adverse.

# Monte Carlo-Based Cancer Risk Assessment of Radon Contamination in Groundwater of Artisanal Mining Areas of Southwest Nigeria

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*Radon contamination in groundwater poses a significant environmental and public health concern, particularly in regions with intensive artisanal mining activities that disturb the natural geological formations. This study investigates the levels of radon ($^{222}Rn$) in groundwater sources within the artisanal gold and gemstone mining communities in Southwest Nigeria and assesses the associated lifetime cancer risks using a Monte Carlo probabilistic approach. The activity concentration of $^{222}Rn$ was determined in groundwater samples using a potable RAD7 electronic radon detector. The measured activity concentration of $^{222}Rn$ ranged from 0.44 – 117 Bq/L with an overall mean value of 13.8 Bq/L. The mean radon value is higher than the international safety standard of 11.1 Bq/L set by the United State Environmental Protection Agency. Cancer risk assessment performed based on the United States Environmental Protection Agency (USEPA) model for ingestion and inhalation pathways indicate a non-negligible radiological health risk to local populations relying on the untreated groundwater for drinking and domestic use. This study will serve as a valuable baseline data for Nigeria's radiological safety efforts and will also support the global discourse on groundwater protection in mining-impacted areas.*

# The spatial-temporal variation and transport of artificial radionuclides ($^{137}$Cs and $^{239,240}$Pu) around Korea Seas (East Sea, Yellow Sea, Southern coastal of Korea)

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We analyzed spatiotemporal variation in the artificial radionuclides $^{137}$Cs and $^{239,240}$Pu in seawater around Korea Seas (East Sea, Yellow Sea and Southern coastal of Korea) from 2018 to 2024. The $^{137}$Cs activity in surface water of the East Sea range of 0.88 - 1.97 mBq kg$^{-1}$ (average: 1.33 ± 0.29 mBq kg$^{-1}$, n=21). Vertically, the highest activities of $^{137}$Cs were sub-to surface later (0 - 100 m) and decreased with depths. The $^{239,240}$Pu activities range of 1.70 - 5.18 μBq kg$^{-1}$ (average: 3.83 ± 1.43 μBq kg$^{-1}$, n=11) in the surface layer. $^{239,240}$Pu activities were lower in the surface layer and also decreased with depths. This trend appears to be result from the adsorption onto particle and resultant sedimentation of Pu in the water column. The surface layer $^{137}$Cs activities in the Yellow sea and Southern coastal of Korea ranged from 0.56 - 1.96 mBq kg$^{-1}$ (average: 1.42 ± 0.39 mBq kg$^{-1}$, n= 10), 0.92 to 2.43 mBq kg$^{-1}$ (average: 1.65 ± 0.33 mBq kg$^{-1}$, n=29), respectively. In these regions, the spatial and vertical distributions of $^{137}$Cs and $^{239,240}$Pu were almost consistent. However, a substantial increase in $^{137}$Cs was observed at some stations in the southernmost part of South Sea, which seems to be due to the fluvial input of surround region. Overall, the distribution of $^{137}$Cs and $^{239,240}$Pu seems to be primarily influenced by local boundary inputs, such as freshwater from river, atmospheric deposition, sediment resuspension, and others from the surrounding Far East Asian continents. We quantified the interlinked budget balance of $^{137}$Cs between the East Sea, Yellow Sea and Southern coastal of Korea. This study suggests that advection from the open ocean is the dominant source of $^{137}$Cs in the Korean Seas and the major sinks for $^{137}$Cs in these regions are natural decay and removal via sinking flux.

# A new experimental setup for the on-line measurement of radionuclides at the Jungfraujoch high altitude research station

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The Swiss Federal Office of Public Health's environmental radioactivity monitoring network aims at measuring the trends in environmental radioactivity in the region and warns the public of any abnormal occurrence such as an influx in artificial radioactivity.

As part of a recent modernization of this monitoring network a new measurement device was installed at the Jungfraujoch high altitude research station at 3'450 meters asl. This largely self-developed prototype samples about 80'000 cubic meters of ambient air per week through a chlorinated polyvinylchloride filter paper that retains the aerosol particles. An integrated high-purity germanium detector (HPGe) mounted just below the filter paper continuously acquires high-resolution gamma-ray spectra during the sampling period. The spectra are automatically stored and analyzed every 5 minutes which provides (a) an on-line measurement with high temporal resolution and (b) a means to measure any short-lived particle-bound radionuclides such as the Radon daughters Lead-214 or Bismuth-214. Activity concentrations of the detected radionuclides are derived from the peaks in the spectra corresponding to the gamma ray emissions of the radionuclides. The detection of an artificial radionuclide triggers an alarm that requires verification by qualified staff before being transmitted to the civil protection authorities.

After the sampling period of one week, the filter paper is sent to the laboratory. The large volume of sampled air allows for the identification and quantification of tiny amounts of radionuclides in the ambient air. The detection limit of the weekly mean value of Cesium-137 is as low as 1 micro-Bq per cubic meter of air or less and can be compared with the results from the on-line measurement with the integrated HPGe detector.

This poster describes the experimental setup and provides an overview of the instrumental challenges involving the sampling of ambient air under challenging meteorological conditions with a cloud frequency of almost 40 percent, mainly formed by lifting of air masses. The difficulties associated with the sampling of aerosol particles are outlined as well as the influence of cosmic radiation on the gamma ray spectra, primarily via secondary reactions with the material of the HPGe detector itself or its housing.

The instrument is the first of its kind at this altitude and gives insight into the influence of the frequent stratospheric intrusions and the background variations in the free troposphere. Future work will focus on improving the temporal resolution and analyzing the trends in the cosmogenic Beryllium-7 activity concentration.

# Distribution of $^{137}$Cs in the East Sea and coastal water off southern Korea Peninsula

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This study investigates the vertical and horizontal distribution of the artificial radionuclide, cesium-137 ($^{137}$Cs, half-life: 30.17 year), in seawater of the Korean seas (the East Sea and the coastal water off southern part of Korean Peninsula) immediately after the Fukushima wastewater release in 2024. In the East Sea surface, $^{137}$Cs activities ranged from 0.88 - 1.55 mBq kg$^{-1}$ (average: 1.19±0.27 mBq kg$^{-1}$, n=8). The activity was highest at the surface and decreased with depth, reaching value with minimum detectable activity (MDA), < 0.27 mBq kg$^{-1}$ at depths >2,000m. $^{137}$Cs activities in the surface off southern Korean sea, ranged from 1.38 - 2.24 mBq kg$^{-1}$ (average: 1.68±0.34 mBq kg$^{-1}$, n=5), with slightly higher activities in the surface compared to those in deeper water. The temporal variation of $^{137}$Cs activities in both regions showed an overall exponential decrease of $^{137}$Cs since the 2000s, except for the few years after the Fukushima accident (in March, 2011). Based on this trend, effective environmental residence time ($\tau_{EF}$) of $^{137}$Cs in the mixed layer depth of the East Sea was estimated to be 21.1±8.3 years. The oceanic residence time ($\tau_{OC}$) was calculated to be 69.8±1.2 years. According to the $^{137}$Cs mass balance in the East Sea (based on the balance between atmospheric input and vertical mixing), the downward flux of $^{137}$Cs from mixed layer to the deep-water (1,350 - 2,000 m) were calculated to be 1.87 -1.89 Bq m$^{-2}$ yr$^{-1}$ with oceanic residence time of 50.0 - 50.6 yrs.

# Annual distribution and deposition of atmospheric $^{210}$Pb in Busan, the largest port city in Korea

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This study investigated the annual and seasonal variations of $^{210}$Pb in aerosols in Busan, a major harbor city with extensive port infrastructure and dense industrial activities. Aerosol samples were collected using a high-volume air sampler from April 2019 to February 2021, and classified into total suspended particles (TSP, 2019 - 2020), particulate matter with an aerodynamic diameter ≤10 μm ($PM_{10}$), and ≤ 2.5 μm ($PM_{2.5}$, 2020–2021). The 210Pb concentrations ranged from 0.10 to 1.98 mBq $m^{-3}$ (n = 92) for TSP, 0.09 to 1.97 mBq $m^{-3}$ (n = 99) for $PM_{10}$, and 0.02 to 2.07 mBq $m^{-3}$ (n = 89) for $PM_{2.5}$. Across all particle sizes, $^{210}$Pb concentrations exhibited clear seasonal patterns, with maxima in autumn and winter (October - February) and minima in summer (July - September), with differences reaching up to a factor of two between seasonal extremes. These seasonal increases in $^{210}$Pb concentrations are attributed to the combined effects of anthropogenic emissions from the vast port and industrial facilities in the vicinity of Busan Port, seasonal changes in prevailing winds, decreased precipitation, and enhanced atmospheric stability. The dry deposition fluxes of $^{210}$Pb in Busan were found to be comparable to or slightly higher than those observed in other major port and coastal cities worldwide. Particle-size and multi-tracer analyses revealed that fine particles ($PM_{2.5}$, $PM_{10}$) are more strongly influenced by mixed natural and anthropogenic sources compared to TSP, as also indicated by seasonal and particle-size-dependent variations in the $^{210}$Pb/Pb ratio. Overall, this study demonstrates that $^{210}$Pb in aerosols serves as an effective environmental tracer for assessing the combined impact of emission sources and meteorological factors in port areas. The findings underscore the importance of considering particle size and source characteristics when evaluating the environmental and health implications of airborne radioactivity in harbor cities

# Measurements of Radioactivity Equilibrium and Disequilibrium in Oil Scale

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Radioactivity equilibrium and disequilibrium in NORM and TENORM are common phenomena that have been studied for many years both from scientific and radioecology points of view. The study of radioactive waste in the oil and gas exploration field has been very well known for many decades with many published papers. However, little research has been undertaken to study equilibrium and disequilibrium. Since oil scale has the significance presence of high Z elements such as Ba and Sr, along with Fe, gamma ray self-attenuation can seriously underestimate radioactivity measurements especially for low energy photon below 100 keV. The usual gamma ray counting techniques to determine U and Th are very difficult in oil scale. We present results for the complete decay chain of U-238 and Th-232 for those radioisotopes that decay via gamma-rays. We also show results for the determination of U and Th via neutron activation analysis.

# Modelling the relationship between naturally occurring radionuclides and grain size of sediment from the Karoo Supergroup

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**Abstract:** Sediments play a fundamental role in understanding environmental processes within aquatic systems, with naturally occurring radionuclides serving as valuable tracers for sediment transport, deposition, and erosion. This study investigates the relationship between sediment grain size and the concentrations of the naturally occurring radionuclides, potassium ($K^{40}$), uranium ($U^{238}$) and thorium ($Th^{232}$). Sediment samples were collected from various locations within the Mkomazi River Basin, South Africa and analysed by means of gamma spectroscopy to extract radionuclide concentrations. The results revealed a distinct relationship between radionuclide activity and sediment grain size, characterized by an initial exponential decline in nuclide concentrations followed by a linear increase as grain size increased. The concentrations of the three naturally occurring radionuclides were combined to derive an arbitrary activity, which was found to have a strong correlation with the average grain size of the samples. A mathematical model was devised to estimate the average sediment grain size by using this arbitrary activity, and a mean estimation error of 17.2% was achieved. Findings suggest that $U^{238}$ concentrations are the most significant predictor of sediment grain size, while $Th^{232}$ has minimal influence. This study highlights the potential for in situ radionuclide measurements to estimate sediment grain size in aquatic environments, offering a novel approach for sediment transport studies.

# BACKGROUND LEVELS OF NATURAL AND ARTIFICIAL RADIONUCLIDES IN SOILS OF THE LOCAL AREA OF THE EURASIAN STEPPE ZONE: CONTRIBUTION TO GLOBAL ENVIRONMENTAL MONITORING

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This study presents the findings on background content of natural ($^{238}$U, $^{235}$U, $^{232}$Th, $^{226}$Ra, $^{210}$Pb, $^{212}$Pb, $^{214}$Pb, $^{40}$K) and artificial ($^{137}$Cs, $^{90}$Sr, $^{241}$Am, $^{239+240}$Pu) radionuclides in soils of the local zone of the Eurasian Steppe located within the territory of the Republic of Kazakhstan. The study area is located within 49-55°N and 65-75°E and covers steppe and forest-steppe landscapes. The area geographically belongs to the mean latitudes zone of the Northern Hemisphere, which is characterized by an increased density of global precipitation of artificial radionuclides. The data obtained make it possible to assess the current radiation status of the area, determine the spatial distribution of radionuclides, and form a base of initial values for subsequent radiation monitoring. The studies are important both for the regional analysis of the state of the environment and for the generation of global reference data used in environmental monitoring and assessment of interest areas for siting of radiation-hazardous objects. In the study area, 3 research profiles along the meridians 65°, 70° and 75° E were laid. The length of the profiles was about 440-540 km and was limited to latitudes from 49° to 55° N. In each profile, a spot sampling of 15 topsoil samples was accomplished from a depth of 0-5 cm. After the samples were prepared for the laboratory analysis (drying, removal of stones and plant inclusions, sieving, grinding, homogenization), the activity concentrations of natural and artificial radionuclides were determined. The activity concentrations of $^{137}$Cs, $^{241}$Am, $^{238}$U, $^{235}$U, $^{232}$Th, $^{226}$Ra, $^{210}$Pb, $^{212}$Pb, $^{214}$Pb, $^{40}$K– were determined by direct gamma-ray spectrometric measurement, $^{90}$Sr and $^{239+240}$Pu by β- and α-spectrometric methods, respectively preceded by radiochemical preparation.

Mean values were determined as a result of studies using statistical data processing methods (arithmetic mean for natural radionuclides, geometric mean for artificial radionuclides) of the activity concentrations of radionuclides in the soil cover with a 95% confidence level: $^{238}$U – 24-26 Bq/kg, $^{235}$U – 1.1-1.4 Bq/kg, $^{232}$Th – 32-37 Bq/kg, $^{226}$Ra – 30-35 Bq/kg, $^{210}$Pb – 65-74 Bq/kg, $^{212}$Pb – 32-37 Bq/kg, $^{214}$Pb – 20-23 Bq/kg, $^{40}$K – 513-600 Bq/kg and $^{137}$Cs – 8-14 Bq/kg, for $^{241}$Am – 0.14-0.24 Bq/kg, for $^{90}$Sr – 1.6-3.1 Bq/kg and for $^{239+240}$Pu – 0.35-0.53 Bq/kg. The data obtained can serve as reference values for long-term radiation monitoring and detection of changes in the radiation background as a result of human impact.

Studies of the vertical distribution of radionuclides in the soil profile and in fractions of soil microaggregates of various dispersity have also been conducted to identify the features of their migration and redistribution in various soil components.

# Environmental distribution and migration of cesium-bearing microparticles emitted from the Fukushima accident

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Radionuclides including radioactive Cs were released into the environment due to the Fukushima Daiichi Nuclear Power Plant accident in 2011. Two years after the accident, glassy water-resistant particles incorporating radioactive Cs were first reported. Such glassy particles are called cesium-bearing microparticles (CsMPs). 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 humans and other organisms.

Several types of CsMPs have been reported, which is assumed to reflect the difference in the accidental progress of each unit. Type-A particles emitted from Unit 2 were dispersed to wide area of eastern Japan including Kanto region due to their small size (~0.1–10 μm). Type-A particles were also isolated from the river, estuary, and ocean, which suggested that Type-A particles were transported from land to ocean through river systems. In addition, Type-A particles apparently increased the Kd and CF values in the river and ocean. In the ocean, Type-A particles are not likely to be found in coastal sediments because they would be transported farther offshore. Type-B particles emitted from Unit 1 were deposited within 20 km north-northwest of the FDNPP due to their large size (10–500 μm). Type-C particles emitted from Unit 3 were probably deposited directly on the ocean surface, which also affects the Kd and CF values in the ocean. Type-C particles are not likely to be transported farther offshore due to their large size (10–500 μm), which suggested that they are found only in coastal sediments. The result of dissolution experiment for Type-C particles in seawater will also be presented. These deposition areas depending on each type of CsMPs were consistent with the direction of atmospheric plumes observed in each emission event of the corresponding unit. These results will contribute to the prediction of the migration of radioactive Cs and assessment of radioactive Cs uptake by organisms.

# Monitoring of $^{226}$Ra and uranium isotopes concentrations in underground water samples released from a phosphogypsum disposal area

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Radionuclides of natural origin of the uranium and thorium series are present in most materials. These materials are commonly referred to as Naturally Occurring Radioactive Materials (NORMs). In Greece, industrial activities involving NORMs are relatively limited. Among them are three fertilizer industries, of which only one remains operational. This particular facility, located in northern Greece, has been in continuous operation since 1965.

Phosphogypsum, a by-product of the fertilizer production process, which contains elevated levels of radionuclides such as $^{226}$Ra and uranium isotopes, is deposited continuously near the industry, by the sea side, in an open land disposal area of about 500000 m$^2$. The total estimated mass of deposited phosphogypsum is around 13 million tons.

Groundwater quality monitoring is critical in this context due to the potential leaching of radionuclides from the phosphogypsum into the subsurface environment. To evaluate this risk, water samples are collected systematically from a network of 20 boreholes strategically positioned around the disposal area. Concentrations of $^{226}$Ra and uranium isotopes in these samples are determined through alpha spectrometry, a sensitive and accurate method suitable for low-level radioactivity measurements.

Following the implementation of a drainage channel around the perimeter of the disposal site, recommended by the Greek Atomic Energy Commission, the monitoring programme also includes an evaluation of this intervention's effectiveness in mitigating radionuclide migration.

The aim of this work is to present the monitoring programme implemented since 2003 by the Environmental Radioactivity Department of the Greek Atomic Energy Commission (EEAE), which is the national competent authority for the control, regulation and supervision in the fields of nuclear energy, nuclear technology, radiological and nuclear safety and radiation protection.

# The ability of calcium oxalates to incorporate Eu(III) and Cm(III)

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Plant cells and plants produce calcium oxalate (CaOx) and store it for instance in vacuoles. There are several functions of CaOx in plants discussed including calcium regulation and detoxification (e.g., heavy metals) [1]. Klotzsche et al. showed for the first time that in the presence of Eu(III), *Nicotiana tabacum* BY-2 cells formed a biomineral composed of Eu(III) and oxalate [2]. This biomineralization could be part of a detoxification strategy for Eu(III) used by BY-2 cells. CaOx can incorporate different cations (e.g. Eu(III) [3]), as well as proteins [4]. To better understand the uptake and behavior of trivalent lanthanides (Ln(III)) and actinides (An(III)) in plants, we first conducted abiotic experiments with Eu(III) and Cm(III) across a concentration range from trace levels to the millimolar scale. Our study aimed to elucidate the speciation of Eu(III) and Cm(III) after incorporation in CaOx using powder X-ray diffraction (PXRD), inductively coupled plasma mass spectrometry (ICP-MS), luminescence spectroscopy, scanning electron microscopy (SEM) coupled with spectrum imaging analysis based on energy-dispersive X-ray spectroscopy (EDXS), and chemical microscopy.

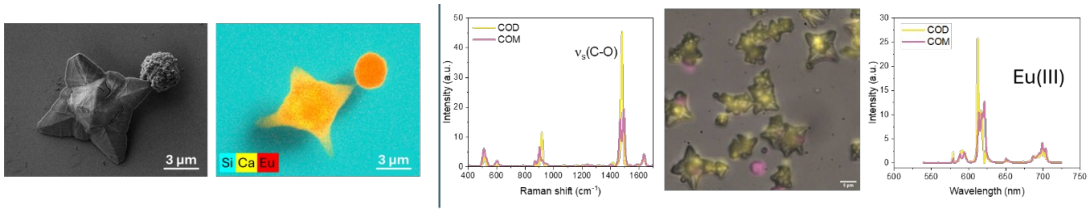



Figure 1. CaOx in the presence of 50 µM Eu(III). Left: SEM image and corresponding element distribution. Right: Results of chemical microscopy (COM/COD: CaOx monohydrate/CaOx dihydrate).

We could show that CaOx has the potential to incorporate large amounts of Eu(III) and Cm(III). More than 90% of the respective heavy metal was incorporated. Eu(III)- or Cm(III)-containing CaOx monohydrate (COM) was formed in the concentration range 0.05 to 5 µM. In the case of Cm(III), an increase in the distance between the interplanar spacing d in Å was observed, the so-called uniform strain effect. At 50 µM Eu(III), both phases, COM and COD were formed and contained Eu(III) (see Figure 1). The luminescence results obtained by using Cm(III) and Eu(III) as molecular probes will be compared and discussed. The obtained results contribute to the overall understanding of the An(III) /Ln(III) uptake by plants.

The authors are indebted to the U.S. Department of Energy for the use of $^{248}$Cm via the transplutonium element production facilities at Oak Ridge National Laboratory; $^{248}$Cm was made available as part of a collaboration between HZDR and the Lawrence Berkeley National Laboratory (LBNL).

[1] Franceschi VR, Nakata PA. (2005) Annu. Rev. Plant Biol. doi: 10.1146/annurev.arplant.56.032604.144106. [2] Klotzsche, M. et al. (2023) Analyst, DOI: 10.1039/d3an00741c. [3] Lochhead, MJ et al. (1999) J. Phys. Chem. B. 103, 3411. [4] Touryan, LA et al.

(2001) J. Cryst. Growth 233, 380.

# The impact of uranium and malic acid on soil microbial communities and a *Mesorhizobium* isolate

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Radionuclides (RNs) that are released into the environment, for example, from contaminated sites or due to accidental events, can migrate via the groundwater into the surface soils. There they may interact with indigenous microorganisms and plants, potentially entering the food chain and posing health risks to humans. Accurate modeling of the RN uptake by plants requires a thorough understanding of the mechanisms governing their transport and accumulation, including the role of soil microorganisms. Both soil microbes and plant root exudates can alter the speciation of RNs in the soil, affecting their mobility and bioavailability [1, 2]. Microorganisms exhibit different mechanisms to interact with RNs, which enable them, for instance, to increase their survival rates in unfavorable environments. The main microbe-heavy metal interaction processes, which also apply to RNs, are biosorption, bioaccumulation, biotransformation, and biomineralization [3].

In this study, we investigate the impact of uranium (U) and malic acid (MA), as an example of a common plant root exudate, on the composition of the microbial community in a reference soil (Refesol 01-A, Fraunhofer IME) based on 16S rRNA gene analysis as well as the interaction of U with a selected soil microorganism. The soil community comprised three main phyla: Firmicutes, Actinobacteriota, and Proteobacteria. However, after 28 days of exposure with 1.8 or 7.1 mg U/kg soil and 20 mg MA/kg soil, no apparent changes in the abundance of these three phyla in the soil were observed. *Mesorhizobium* sp. DNB0012 was isolated from the U exposed soil and is used to study its interaction with U and MA. *Mesorhizobium* spp. are mainly found in association with legume rhizosphere systems [4]. The bioassociation of 100 µM U to *Mesorhizobium* sp. DNB0012 was studied by batch experiments as a function of the exposure time. *Mesorhizobium* sp. DNB0012 showed a rapid biosorption of U reaching an equilibrium after only 2 hours with about 38% of the initial U adsorbed to the biomass. The results of a viability assay with live/dead staining exhibited a significant toxicity of U to the cells compared to control cells without U. Time-resolved laser-induced fluorescence spectroscopy (TRLFS) is used to determine the U(VI) speciation in the presence of *Mesorhizobium* sp. DNB0012. First TRLFS results confirmed the presence of one U(VI) species in the cell pellet indicating the bioassociation of U. Further studies on the impact of *Mesorhizobium* sp. DNB0012 and MA on the U speciation are in progress.

This study assess the interaction between U, MA and soil microorganisms on a molecular level and its impact on the bioavailability of U. Knowledge about the interaction of U with a plant-associated microorganism will be provided. The results can help to improve radioecological models for the assessment of the RN transport and transfer in the environment to the food chain.

This study is funded by the German Ministry of Education and Research under contract No. 15S9437C.

References:
[1] Gupta (2017), *Rev. Environ. Contam. Toxicol. 241*, 139-160.
[2] Banala (2021), *Environ. Technol. 21*, 101254.
[3] Lloyd (2003), *FEMS Microbiol. Rev. 27*, 411-25.

[4] Laranjo (2014), *Microbiol. Res. 169*, 2-17.

# Environmental Assessment of Natural and Artificial Radionuclides in Beira Interior, Portugal: Insights for NORM Management

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In the Beira region of Central Portugal, soils are particularly enriched in lithogenic radionuclides and their progeny. Former mining activities, combined with natural rock weathering processes, contribute to concerns regarding the dispersion of radioactivity and the potential for increased population exposure. Airborne transport mechanisms facilitate both short and long-range dissemination of radioactive pollutants via atmospheric pathways. Consequently, the assessment of radionuclides in bioindicator samples is essential for understanding these transfer processes, with mosses being especially suitable due to their capacity to accumulate airborne elements. Understanding the behavior and transfer mechanisms of these radionuclides, particularly via atmospheric deposition pathways, is essential for risk assessment

This study evaluates both natural and anthropogenic radionuclides in moss samples collected across multiple sites in the Beira region. Moreover, additional sampling is planned or underway in soil, surface waters (including both spring and flowing waters), and aerosols. We collected samples in the Serra da Estrela and Beira Interior regions in Portugal, encompassing altitudes from 400 to 1500 meters. The radionuclides under investigation include $^{137}$Cs, $^{7}$Be, and lithogenic isotopes such as $^{226}$Ra, $^{228}$Ra and $^{40}$K quantified using gamma and alpha spectrometry.

All sampling sites were georeferenced to enable GIS analyses. Spatial distribution maps of radioactivity levels were produced and examined for potential correlations with geological parameters, such as uranium content in the bedrock, as well as geomorphological characteristics. In addition, inter-radionuclide correlations were explored to infer mechanisms of distribution and deposition.

Preliminary findings indicate that artificial and local radionuclides exhibit distinct spatial patterns, suggesting they follow different environmental transfer pathways. These results support the hypothesis that lithogenic radionuclides are incorporated in mosses in proportion to their abundance in underlying soils. In contrast, radiocesium uptake appears to be primarily governed by atmospheric and meteorological conditions. These findings underscore the importance of integrating biomonitoring, geospatial analysis, and radiometric techniques to support radioprotection strategies and improve NORM management in geologically complex regions.

# Model simulation and cost-benefit assessment of countermeasures to reduce the $^{137}$Cs load from un-decontaminated dam lakes in Fukushima, Japan

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The lakes in the area affected by the Fukushima Daiichi Nuclear Power Plant accident have not been decontaminated even 14 years after the nuclear accident in 2011, and there are concerns that the desorption of radiocesium ($^{137}$Cs) from the lake sediment will prolong the radioactive contamination of the benefit area of the dam. In this study, we considered two scenarios (1. dredging, 2. aeration of the lakebed) as countermeasures to reduce the $^{137}$Cs desorption, and simulated the effect of each scenario to decrease the discharge load of $^{137}$Cs using a mathematical model that reproduces the $^{137}$Cs dynamics in dam lakes. We also assessed the cost-benefit by the entire dredging the dam lakebed.

The numerical model used in this study consists of two modules: lake water part and sediment part. The study site is a dam lake located about 20 km from the Fukushima Daiichi Nuclear Power Plant. The input parameters of the model were the monthly observed data of $^{137}$Cs concentrations and water quality in inflow/outflow water observed since 2014 (Tsuji et al., under review), $^{137}$Cs and water quality in lake water observed data of observed each quarter of the year in 2014-2017 (Tsuji et al., 2020), $^{137}$Cs profile in the lake sediment (Funaki et al., 2022), and the parameters of $^{137}$Cs desorption obtained from the sediment incubation experiment (Tsuji et al., 2022). In addition, hydrological data provided by the dam management office, meteorological data recorded by the local meteorological weather station, and the parameters related to the diffusion and generation of $^{137}$Cs and its relevant components in the literatures were input. The simulated period was 2014-2023. Two countermeasure scenarios were assumed, 1) dredging scenario: the $^{137}$Cs concentration in the sediment at the start of the simulation was set to one-thousandth of the observed value. 2) aeration scenario, the concentration of dissolved oxygen in the lake bottom was fixed at the saturation value, to avoid the retention of $NH_4^+$ which can promote $^{137}$Cs desorption from sediment. In each scenario, decontamination of $^{137}$Cs in the catchment area of the dam lake was not assumed, and the inflow load of $^{137}$Cs into the dam lake was unified among the three simulations. The cost of dredging was estimated based on the actual cost of decontamination work of small-scale reservoirs by a construction company. The benefit per year was estimated as the maximum value supposing that the net profit of agriculture and fishing in the dam beneficiary area completely recovered to that before the nuclear disaster.

As a result, the numerical simulation predicted that the dredging scenario would reduce the discharge load of dissolved $^{137}$Cs by up to 23% per year, and the aeration scenario would reduce the discharge load of dissolved $^{137}$Cs by up to 15% per year. Both scenarios decreased only the concentration of $^{137}$Cs in the lake bottom water, so the effect of the decrease in $^{137}$Cs in discharge water emerged during the lake circulation period (in winter season). However, because the particles which contain $^{137}$Cs continuously carried from the catchment area and deposited on the lake bed, the effect of reducing the $^{137}$Cs load was estimated to be limited unless conducting the decontamination of the hinterland forest area.

The cost of full-scale dredging of the dam lake was estimated to be approximately 260 million dollars, and the maximum benefit was estimated to be 4 million dollars per year. Considering that decontamination of the forest would also be necessary to completely eliminate the risk of contamination by $^{137}$Cs, it would take as long as several hundred years to generate benefits that match the cost of decontamination work.

References

Tsuji, H. et al. Env. Pollut. under review; Funaki, H. et al. (2022) Sci. Total Environ., 812, 152534; Tsuji, H. et al. (2022) Applied Geochem., 140, 105303. Tsuji, H. et al. (2020) Global Environ. Res., 24, 115-127.

# Review of the marine radioecology of tritium in Japanesse coastal waters

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For better uderstanding for the behaviour of tritium in marine ecosystem, the published of the waters around Japan were examined and evaluated radio-ecologically. After 1960, tritium radioactivity, originated to the atmospheric nuclear bomb tests, was monitored in the marine environment around Japan. Special and vertical distribution of tritium was clarified in seswaterof the Pacific Ocean (Miyake et al., 1968; 1969; 1970; 1971; Shimada et al., 1972; 1973; 1975). After the last Chinese atmospheric nuclear bomb test in 1981, the tritium radioactivity concentration in seawater decreased, due to the radioactivity decay (Miyamoto, 2022). After 1990, Tritium radioactivity levels appeared to be stable, being approximately 1.0 Bq $l^{-1}$ in surface water in Japanese coasts, whereas showing variation of the level which was caused by nuclear facility operation and terrestrial freshwater (or underground water) contribution. Since the European nuclear fuel reprocessing plant operation was known as substantial supply source to adjacent waters (Masson et al., 2005; Hunt 2010; Fiévet et al., 2021), tritium measurement were intensively deployed, especially of seawater and biota in front water off Rokkasho Aomori, where the nuclear fuel reprocessing plant was constructed. As a result, tritium radioactivity in seawater and fish increased during the active test operation of March 2006 – October 2008 (MERI, 2019). Concentration ratio (CR) of Tissue Free Water Tritium (TFWT) for fish increased several times greater than the usual CR 1.1 of the back ground value. The CR of Organically Bound Tritium (OBT) increased slightely. The ratio of the OBT to total tritium (THWT+OBT) was considered to be 0.25 by radioactivity observed as maximum cases. With regard to off Fukushima waters, the tritium radioactivity increased to several tens of Bq $l^{-1}$ after the accident of the Fukushima Dai-ichi Nuclear Power Station (F1NPS). Due to the management of aftermath of the accident and the dilution to oceanic water, the tritium radioactivity decreased after 2018, not only in surface water but also in fish (MERI, 2019). After 2023, due to the public concern about the release of the water treated by the multi-nuclide removal equipment of Advanced Liquid Processing System (ALPS), the measurement of radioactivity levels of tritium in marine algae, additionally to seawater and fish, were deployed around coastal water of F1NPS by Tokyo Electric Power Company Holdings (TEPCO). The TEPCO also carried out aquarium experiment of rearing marine algae, invertebrate and fish using the ALPS treated water (Shibata et al., 2022; 2024). In suumary, the overall accumulated data from 1960s-2020s was explainable by the experiment derived transfer parameters of tritium between seawater and biota, and was compatible to the scientific understanding of previous studies (Fiévet et al., 2021; Tani et al., 2023).

Reference

Fiévet , B., Bailly du Bois, P., Voiseux, C., 2021. Concentration factors and biological half-lives for the dynamic modelling of radionuclide transfers to marine biota in the English Channel. Sci. Total Environ. 791, 148193

Shibata, T., Ishikawa, Y., 2022, Deuterium transfer analysis including food chain from seawater into abalone. Radiation Protection Dosimetry, 198, 1125-1130.

Shibata, T., Omizu, Y., Furuta, T., Ishizawa, N., Irino, T., Yamanaka, K., 2024, Tritium transfer from seawater into marine organisms TFWT. Radiation Protection Dosimetry, 200. 1824-1828.

Tani, T., Ishikawa, Y., 2023, A deuterium tracer experiment for simulating accumulation and elimination of organically bound tritium in an edible flatfish, olive flounder. Sci. Total Environ. 903,

166792.

# $^{134}$Cs, $^{137}$Cs and $^{239+240}$Pu concentrations in surface air at Chiba City, Japan during 2016 to 2023: factors controlling their seasonal and interannual variations

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To elucidate current levels of $^{134}$Cs, $^{137}$Cs and $^{239+240}$Pu in surface air at Chiba City, we carried out radiometric analysis of their radionuclides during the period from March 2016 to December 2023. Interannual variation revealed that $^{137}$Cs and $^{134}$Cs activity concentrations in surface air exhibited decrease trends, although the $^{134}$Cs have not detected in dust samples after March 2021. On the other hand, Interannual variation of $^{239+240}$Pu in surface air exhibited no clear trend. The $^{137}$Cs and $^{239+240}$Pu in surface air indicated seasonal variations; $^{137}$Cs occurred maximum in winter and minimum in summer (as shown in Fig. 1), whereas maximum $^{239+240}$Pu appeared in spring (as shown in Fig. 2). The maximum $^{137}$Cs in winter is attributable to resuspension of $^{137}$Cs-bearing soil particles, contaminated by Fukushima Daiichi Nuclear Power Station (FDNPS) accident, due to low humidity and low rainfall in winter, and transport of air mass including airborne dust dispersed from the area affected by the FDNPS following northerly wind in winter. Spring maximum of $^{239+240}$Pu is due to the arrival of yellow dust (Kosa), where originates in East Asian continental deserts, at Chiba City because of the similar seasonal change between atmospheric dust density (and/or Kosa events) and $^{239+240}$Pu in surface air. Moreover, the relationship between dust density and $^{239+240}$Pu in surface air revealed that massive $^{239+240}$Pu activity concentrations in spring were divided into two groups: high and low concentration groups. This finding suggests that Kosa events occurred different areas with high $^{239+240}$Pu density and low one in the East Asian arid and deserts. We apply $^{137}$Cs/$^{239+240}$Pu activity ratio as a new indicator because $^{137}$Cs was affected by the local effects of FDNPS accident, whereas most of $^{239+240}$Pu is global fallout origin. The results revealed that the $^{137}$Cs/$^{239+240}$Pu ratios showed minimum in spring, which suggests that the enhancement of the global fallout radionuclides due to the arrival of yellow dust occurred in spring, which caused marked increase of the $^{239+240}$Pu, and then the ratios were lower than that in other seasons. This survey is the result of "environmental radioactivity level survey" which is commissioned project by Japan Nuclear Regulation Agency.

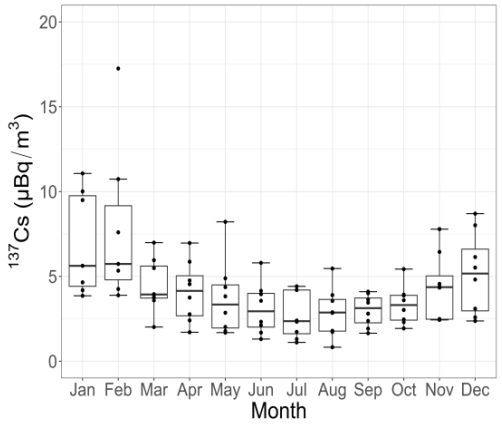



Fig. 1 The seasonal variability of $^{137}$Cs activity concentrations in each month during the period from March 2016 to December 2023.

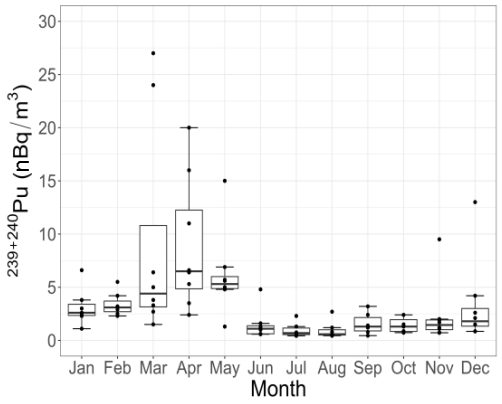



Fig. 2 The seasonal variability of $^{239+240}$Pu activity concentrations in each month from March 2016 to December 2023.

# Partitioning of plutonium between bottom waters and sediments in the Far Eastern Seas

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Plutonium in marine environments has predominantly been injected to ocean surface by global fallout owing to atmospheric thermonuclear testing in the early 1960s, and close-in fallout in the early 1950s to the North Pacific. As a result, the seabed sediment in the world ocean has been contaminated by plutonium isotopes. It is an important issue whether deep ocean sediment is one of the final sinks of plutonium or not. There is little knowledge about the transport processes of plutonium isotopes from water columns to sediment in the deep ocean. As possible mechanisms, partitioning between bottom water and surface sediment, direct input of sinking particles, and deep-ward transport of resuspended shallow sediment particles have been speculated. To elucidate the behaviors of plutonium in the sediment of deep oceans, it is important to clarify the temporal change of plutonium in the sediments, as does plutonium in bottom water. However, there is little information on the temporal variability of plutonium in deep ocean sediment. After the report of the Russian radioactivity dumping in the Far Eastern Seas (the Sea of Japan and Okhotsk Sea) in 1993, the monitoring of radionuclides in the water column and sediment has been conducted by the Hydrographic Department of Japan Coastal Guard (JCG). To better understand the biogeochemical behavior of $^{239,240}$Pu in the Far Eastern Seas, we examined the temporal changes of $^{239,240}$Pu activity concentrations in bottom waters and sediments of the Far Eastern Seas (Sea of Japan: SOJ, and Okhotsk Sea: OS) during the period of 1994 to 2021. The $^{239,240}$Pu activity concentrations in bottom waters ranged from 5 to 83 mBq m$^{-3}$, in which $^{239,240}$Pu in each site did not show clear trends during 1994 -2021, except shallow sites, in contrast to those of $^{137}$Cs in the Far Eastern Seas. The $^{239,240}$Pu activity concentrations in the sediments, ranging from 0.003 to 2.25 Bq kg$^{-1}$dry, showed high variability. The $^{239,240}$Pu activity in sediments at each site did not show clear trends during the corresponding period, except St. 3 and 8, where high variability was observed. If temporal changes of the $^{239,240}$Pu activity concentration in the bottom water and sediments are governed by exponential processes, we calculated the change rates of $^{239,240}$Pu in the bottom water and sediments. Change rates of $^{239,240}$Pu in the bottom water of the SOJ were nearly zero, except shallow SOJ and OS. Change rates of $^{239,240}$Pu in the sediments were nearly zero, except for two sites, although showing large uncertainties. To elucidate the transfer processes of $^{239,240}$Pu from seawater to sediment, we introduced practical partition coefficients ($K_d$) of $^{239,240}$Pu between bottom water and surface sediment. The $K_d$ values, ranging from 1.1 ×10$^2$ to 2.8 ×10$^5$ L kg$^{-1}$, showed large variability. However, the $K_d$ values of $^{239,240}$Pu in each site did not show trend, except St. 3 and 8. The $K_d$ values of $^{239,240}$Pu decreased with increasing depth, in contrast to $^{137}$Cs. These findings suggest that chemical processes may be important as factors controlling the movement of $^{239,240}$Pu between seawater and sediment in deep waters.

# Long-term observations of Beryllium-7 and Sodium-22 in ground-level air

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Beryllium-7 ($^{7}$Be) and Sodium-22 ($^{22}$Na), two relatively long-lived cosmogenic radionuclides, are useful tracers for tropospheric circulation and stratosphere–troposphere exchange (STE). This presentation synthesises multi-decadal variability, seasonal patterns, and recent trends in atmospheric $^{7}$Be and $^{22}$Na concentrations, based on a dataset of surface observations from Switzerland.

The dataset comprises weekly measurements of high-volume air filters (approximately 100,000 m³/week) at six monitoring sites, with time series extending up to 30 years. The primary objective of this monitoring network is to detect anomalous increases in artificial gamma-emitting isotopes, such as $^{137}$Cs, $^{134}$Cs, $^{131}$I, $^{106}$Ru and others. Concurrent measurements of the natural radionuclides provide valuable insight into the origin and characteristics of the observed air masses.

As expected, the long-term variations in $^{7}$Be and $^{22}$Na concentrations reflect the dependence of their production rates on the solar cycle. The monitoring stations are situated at mid-latitudes near a major mountain range (the Alps), a geographic setting that gives rise to a distinct annual cycle. Notably, $^{7}$Be and $^{22}$Na concentrations are approximately twice as high during summer months compared to winter. Evidence of enhanced STE in spring and early summer is provided by elevated concentrations $^{22}$Na and the $^{7}$Be/$^{22}$Na ratio. Superimposed on the annual cycle are short-term fluctuations, typically lasting two to four weeks. We explore the relationship between these variations and prevailing synoptic-scale weather patterns.

Recent observations suggest that atmospheric $^{7}$Be and $^{22}$Na concentrations confirm a more vigorous vertical mixing of the troposphere due to global warming. However, a significant challenge in interpreting the $^{7}$Be and $^{22}$Na signals is the correct accounting of washout during rain events, which itself will be influenced by climate change. This last point will be illustrated by daily measurements of radionuclides as well as weather variables at one station.

# Transport of the Cs-137 water in the North Pacific subtropical mode water at the end of March 2011 to the East China Sea and Sea of Japan

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The Fukushima Dai-ichi Nuclear Power Plant (FNPP1) accident in 2011 released radiocaesium ($^{137}$Cs and $^{134}$ Cs) into the North Pacific Ocean (NPO) primarily in late March and early April 2011. Subsequent to the incident, the $^{137}$Cs activity concentrations were measured in the NPO. The $^{137}$Cs activities measured enable the study the movement and circulation of the NPO ocean waters, including the mode water in NPO, by using them as a tracer. The study involves the transport of subtropical mode water (STMW) by focusing on the $^{137}$Cs activity in the water which has the same density as STMW. STMW has been identified as a thermostad, characterized by its low potential vorticity, with a density of approximately 25.2 $\sigma_\Theta$ within or near the top of the thermocline in the northwestern North Pacific subtropical gyre. The STMW is formed in a wintertime or early springtime mixed layer (ML), the thickness of which is approximately a few hundred meters in the North Pacific subtropical gyre. Inomata et al. (2018) reported that radioactive cesium ($^{137}$Cs) into the North Pacific Ocean due to the Fukushima Daiichi Nuclear Power Plant accident was transported to the East China Sea (ECS) and Japan Sea (JS). The density $\sigma_\Theta$ at which$^{137}$Cs activities were detected in the ECS and JS was approximately 25.2 kg m$^{-3}$, which indicates that $^{137}$Cs contaminated into the STMW after the accident reached to the East China Sea and Japan Sea. In this study, the advection and diffusion of 137Cs in the STMW were examined using a numerically approach with the North Pacific Region Model (ROMS). Since the formation area of the STMW covers a wide area of the North Pacific Kuroshio Current or the Kuroshio Extension, we divided the formation area into multiple rectangles and set tracers (dye01, 02 ,...) uniformly at 10 Bq m$^{-3}$ in the depth of $\sigma_\Theta$ from 25.0 to 25.4 kg m$^{-3}$ in the rectangles at 0:00 on April 1. After simulating the diffusions for tracers in the NPO, we examined the time series of the total amount of the tracers in the ECS and the JS. The number of tracer simulation ensembles is four, because the start date of the simulation for a tracer is January 1 of four consecutive years. First, we set the tracers, dye-01, dye-02, dye-03, and dye-04 0.33±0.03 PBq, 0.36±0.02 PBq, 0.04±0.01 PBq, and 0.23±0.05 PBq corresponding to the rectangles which range 28-35°N and 130-140°E, 28-35°N and 140-150°E°N, 35-42°N and 140- 150°E, and 28-42°N and 150- 160°E respectively and simulated the advection-diffusion of each tracer. The inventory of these tracers showed the following results: (1) The 80% of dye-04 were transported east of 160°E in one year after the initial simulation; (2) Approximately half of dye-01 and 02 were east of 160°E two years after the start; (3) In the ECS, the inventories of dye-01 and 02 had peaks around 1 year and 2 to 3 years after the start, respectively; (4) At the time of the peak, approximately 1.5% of the total amount, initially set, for dye-01 and 02 is present in the ECS; (5) In the JS, the inventories of dyes-01 and 02 began to increase around 1.5 years after the start and gradually increased (to about 0.2 and 0.3% of the initially set total amount in 5 years). Secondly, the area for the tracer dye-02 was divided into eastern and western segments, and tracer dye-06 and dye-07, which were set in the area, were simulated. The tracer dye-06 and 07 exhibited comparable time series of the inventories in the ECS and the JS.

**Assessing uranium contamination in groundwater of North-East Punjab: Spatial and vertical distribution and extraction using $NdFeO_3$**

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**Abstract**

High prevalence of uranium in groundwater and corresponded potential health hazards to human population of north-east Punjab, India is presently a matter of great concern, as the groundwater is a major source of drinking water for human consumption as well as irrigation. So, the current integrated study was carried out to understand the spatial and vertical distribution of uranium and its remediation using $NdFeO_3$. In this study, in comparison to the samples from deeper aquifers, high prevalence (surpassing WHO limit 30 µg/L in drinking water) of uranium was observed in groundwater samples collected from shallow depth (< 200 ft) and mean uranium concentration has been observed is 33.98 µg/L. Approximately 13% of groundwater samples had uranium concentrations above the WHO (2011) recommendation of 30 µg/L. For the remediation of U(VI), $NdFeO_3$ was synthesized using sol gel method and shown optimal performance under the following adsorption parameters: pH (7), adsorbent dosage (0.4 g/L), and contact period (30 min). The maximum Langmuir adsorption capacity of $NdFeO_3$ was 56.68 mg/g observed and primarily accomplished through monolayer chemisorption and electrostatic interactions. The potential of $NdFeO_3$ as a key filling component in columns used in water filtration systems was

explored for practical application and successfully utilized for treatment of high prevalent groundwater samples from north-east Punjab, India.

# Monitoring Terrestrial Gamma Radiation to Characterize Mud Volcanic Activity: Evidence from the Piparo Mud Volcano, Trinidad and Tobago

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The Piparo Mud Volcano is a significant natural hazard in Trinidad and Tobago, highlighted by its violent 1997 eruption that devastated everything within a one-mile radius, displaced 31 families, killed livestock, and destroyed critical infrastructure. Such destructive events are driven by overpressurized subsurface conditions, causing mud volcanoes to act as natural vents, releasing fluidized mud and gas to the Earth's surface or seafloor. These emissions may occur gradually or in more abrupt bursts, as demonstrated during heightened activity in 2019 and 2024. These recent events underscore the urgent need for enhanced monitoring and a deeper understanding of the mud volcano's structure. Yet, despite the ongoing and severe risks posed by sporadic eruptions, current monitoring frameworks are predominantly surface-based and event-driven, offering limited insight into the deeper structural and geophysical precursors that may signal impending activity. To address this gap, this research advances the foundational work of previous investigators, who studied gamma radiation changes at the Piparo Mud Volcano, following volcanic events between 2018 and 2019. Our dataset, however, spans a broader timeframe, capturing radiation fluctuations both before and after an eruption event. This approach transforms natural radioactivity from a passive background signal to a potential predictive indicator of volcanic activity. This study pioneers a novel framework that utilizes gamma radiation monitoring to capture the precursory subsurface dynamics of the Piparo Mud Volcano. Specifically, this study aims to: (1) explore the correlation between spatial gamma radiation patterns and geomorphological features, (2) examine temporal variations in gamma radiation and correlate them with eruption events, and (3) evaluate the use of gamma radiation to predict volcanic activity. To achieve these objectives, gamma radiation data were collected at 40 locations over a 23-month period using a Geiger-Muller counter. The measurements were taken at five intervals (0, 4, 11, 17, and 23 months), both 1 meter above and 0.5 meters below ground level (GL). The results indicate that the highest gamma radiation levels above GL occur in the southern and eastern areas of the main crater, while the northern and western sections show the highest gamma radiation levels below GL. This spatial pattern aligns with the presence of syngenetic fractures and smaller subsidiary craters, which are more common in the active northern and western areas. Gamma radiation also fluctuates with time, with levels above GL rising steadily from month 0, then peaking at month 11, before declining through months 17 to 23. In contrast, radiation levels below GL follow the opposite trend. Notably, these shifts coincide with an eruption between months 11 and 17, suggesting a link between radiation fluctuations and volcanic activity. This study demonstrates that gamma radiation offers a promising method for monitoring mud volcanic activity. By correlating radiation shifts with eruption timing, this technique could enable early detection, enhancing volcano monitoring systems and risk management strategies.

# Assessment of metal distribution in algae used as bioindicators for the environmental monitoring of Swedish nuclear power plants

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Marine macroalgae are an essential part of the environmental monitoring program of nuclear power plants (NPPs) thanks to their ability to efficiently absorb waterborne pollutants, such as radionuclides and heavy metals. *Fucus serratus* (toothed wrack) and *F. vesiculosus* (bladderwrack), are two brown algae species that grow on the Swedish coast, permanently attached to rocks and stones. Both species are commonly used as bioindicators, to monitor the levels of radionuclides in sea water around Swedish NPPs. *Fucus* spp. are particularly reflective over long period of environmental conditions such as the salinity, the water temperature and the concentration of metal in water. These environmental conditions and the growth cycle of the plant influence the algae uptake, turnover and retention of radionuclides and heavy metals released by NPPs. These mechanisms are not fully understood and can affect the results of radiological monitoring based on algae bioindicators. The concentration of radionuclides in *Fucus* spp. is usually assessed by gamma-ray spectroscopy using representative samples of dried and ground algae as part of the regular environmental monitoring at NPPs. In order to access the concentration of stable elements, other techniques like inductively coupled plasma mass spectrometry (ICP-MS) or X-ray fluorescence (XRF) have to be used. However, since elements are not homogeneously distributed in the plant tissues, these two conventional approaches are sensitive to the sampling collection method.

In this work, *Fucus* spp. samples were collected at different times and at various distances from the discharge point of the cooling water of the Ringhals NPP (Sweden). Gamma spectroscopy, XRF and ICP-MS measurements were performed on segmented algae samples to determine the differences in radionuclide and heavy-metal concentrations, between the blade (leaf equivalent) and the stipe (stem equivalent). These conventional methods were then complemented with elemental mapping techniques, to fully assess the distribution of elements at the tissue- and cell-scale. Maps of the metal distributions in *Fucus* spp. were obtained by micro-XRF, laser ablation ICP-MS and micro particle-induced X-ray emission (micro-PIXE). Results confirm the heterogeneous distribution of heavy metals in the plants and highlight the influence of the dilution of the source term on the elemental distribution.

# Radionuclide resuspension: driving force of the persistence of anthropogenic radionuclides at trace level in the atmosphere

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Resuspension is a generic term encompassing several processes either induced by environmental conditions or by human activities. Resuspension can lead to the long-term persistence of formerly deposited substances, among them long-lived radionuclides, especially when they are located at the interface between the Earth's compartment and the atmosphere or more simply in the biomass.

Resuspension is rather permanent, ubiquitous and can operate at small and large scales. Various examples of radionuclide resuspension will be provided showing the wide range of resuspension conditions and the associated processes. In the early stage after a massive radionuclide deposition and when the plume has spread away, resuspension is the almost unique process that can contribute to the persistence of a tail of activity levels int the atmosphere. Conversely, long after a radiological pulse such as a nuclear accident release and deposition or after a long period of regular releases as it was the case during the nuclear weapons testing era, resuspension can explain most of the variability of the anthropogenic radionuclide background.

A rather simple method can allow to distinguish the respective contribution of local and remote resuspension. Due to climate change, resuspension from soil surface is exacerbated. This can be seen through the increased variability of the airborne $^{137}Cs$ background level.

Due to more and more coercive regulations, routine releases from the nuclear industry are historically low. In such context, resuspension from soil can compete with the contribution from stack release. Some examples from France will be provided.

Resuspension is usually expressed through a coefficient corresponding the ration between the airborne activity and soil surface activity. The time variation of such coefficient is characterized by an exponential relationship. However, there is a rather large uncertainty of the value to be chosen.



Visualization of dust resuspension due to ploughing

# Transport of radiocaesium in the North Pacific Ocean related with climate change

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Radionuclides have been released into the environment as a result of large-scale nuclear testing between the 1950s and 1960s, the Chernobyl Nuclear Power Plant (NPP) accident in 1986, the Fukushima NPP accident in 2011, direct releases from reprocessing NPPs, and dumping of nuclear materials. In the marine environment, radionuclides with long half-lives are considered to be useful tracers for the study of marine transport processes. With the recent acceleration of global warming, the marine environment is experiencing major changes in the global meridional circulation, biogeochemical processes, and surface ocean acidification. These changes associated with climate change are expected to affect the temporal variability and spatial distribution of radionuclides in the marine environment, including long-lived radionuclides such as $^{137}$Cs, $^{90}$Sr, $^{3}$H, $^{14}$C, $^{129}$I, $^{236}$U, $^{237}$Np and Pu isotopes. They are useful tracers for detecting changes in marine processes in the marine environment.

This study focuses on the spatial and temporal distribution of $^{137}$Cs in the North Pacific Ocean. Radiocesium has historically been one of the most widely measured and monitored nuclides in the world's oceans. In particular, the number of $^{137}$Cs data observed in the North Pacific Ocean is the largest in the world. The main sources of $^{137}$Cs in the North Pacific Ocean are global fallout (GF-$^{137}$Cs), which occurred in the 1950s and 1960s, and $^{137}$Cs released from the 2011 Fukushima Daiichi nuclear power plant accident (F1NP-$^{137}$Cs). The GF-$^{137}$Cs were released by precipitation associated with stratospheric-tropospheric air mass exchange in the region 30-50°N, 140-160°E; GF-$^{137}$Cs were transported eastwards and reached their maximum in the late 1960s off California. These GF-$^{137}$Cs migrated southwards while sinking into the subsurface. The subducting GF-$^{137}$Cs were transported westwards through the sub-surface and entered the Indian Ocean by Indonesian through-flows.

On the other hand, the F1NP-$^{137}$Cs) were deposited in the area between 30-50°N and 140-160°E by precipitation during March and April 2011. Radiocaesium released directly around the Fukushima NPP was the largest point source in the North Pacific; some of the F1NP-$^{137}$Cs was deposited in the subtropical mode water (STMW) forming region and transported in the subsurface layer, and transported into the Sea of Japan. The North Pacific STMW is an important water mass characterized by its homogeneous nature within the main pycnocline; the STMW is mainly formed in the Kuroshio extension region, where active mesoscale eddies strongly interact with the atmosphere. This interaction increases the release of oceanic latent heat due to increased wind speeds in the forming region, which facilitates the formation of STMWs. This plays an important role in ocean oxygen utilization, carbon sequestration and climate regulation. Another part of the F1NP-$^{137}$Cs reached offshore Canada and was transported northwards into the Bering Sea, eventually entering the Arctic Ocean.

Measurements of $^{137}$Cs in the North Pacific Ocean are very limited, but these GF-$^{137}$Cs and F1NPS-$^{137}$Cs were transported via different pathways. Ocean current in the North Pacific is sensitive to changes in the global meridional circulation. These changes may be reflected in changes in the apparent half-life residence time of $^{137}$Cs. Long-term measurements of $^{137}$Cs and other radionuclides analyses may be important for detecting changes in atmospheric and oceanic circulation and other related processes.

# Development of Shrimp Reference Material for Radioactivity Measurement and Its Application in Proficiency Test

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Environmental radioactivity monitoring, particularly the measurement of Caesium isotopes ($^{137}$Cs and $^{134}$Cs), plays a critical role in assessing the safety of the environment and public health, especially in the aftermath of nuclear incidents like the Fukushima Daiichi disaster. To ensure the accuracy and reliability of radioactivity measurements, the use of **Certified Reference Materials (CRMs)** or **Reference Materials (RMs)** is essential for **quality assurance (QA)** and **quality control (QC)**. These materials provide known massic concentrations of radionuclides and serve as benchmarks for calibrating instruments and validating analytical methods.

Proficiency test is crucial for verifying laboratory competence and ensuring consistent, accurate results across different laboratories. It allows for the detection and correction of systematic errors, the optimization of measurement techniques, and compliance with international safety standards. Furthermore, the use of RMs in proficiency tests ensures that data on environmental radioactivity, such as that in seafood like shrimp, meets regulatory requirements and supports public health protection. As part of this research, KRISS has recently developed a shrimp RM.

In this presentation, we will discuss the importance of using CRMs and RMs, particularly in proficiency testing, for environmental radioactivity monitoring. We aim to highlight how these materials enhance the reliability of data and contribute to long-term monitoring efforts, ensuring the safety of ecosystems and seafood products after events like the Fukushima accident.

# Long-Term Distribution of $^{137}$Cs in Seawater around the Korean Peninsula: Assessing the Impact of the Fukushima Nuclear Accident

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The Fukushima Daiichi nuclear disaster in March 2011 resulted in the release of significant amounts of radioactive substances, including Cesium-137 ($^{137}$Cs), into the environment. This event marked a major environmental concern, particularly in the Pacific Ocean, as radioactive materials spread across vast distances through ocean currents. One of the regions potentially affected by this contamination is the seawater surrounding the Korean Peninsula, which is influenced by major ocean currents, such as the Kuroshio Current and the Tsushima Current. Given the proximity of the Peninsula to the site of the accident and the dynamic marine environment, understanding the behavior of $^{137}$Cs in this region is crucial for assessing its long-term environmental and ecological impacts.

The primary objective of this study is to explore the distribution characteristics of $^{137}$Cs in the seawater around the Korean Peninsula over a decade since the Fukushima disaster. The study focuses on both surface seawater and depth profiles to understand the spatial and temporal variability in concentrations of this radioactive isotope. By evaluating the movement, dilution, and potential accumulation of $^{137}$Cs within different water masses, this research aims to contribute valuable insights into the environmental consequences of the Fukushima accident on the marine ecosystem in the Korean coastal waters.

The distribution of $^{137}$Cs in the seawater is influenced by various factors, including ocean currents, mixing processes, sedimentation, and biological activity. Moreover, understanding the time-series behavior of $^{137}$Cs in these seawaters is important not only for environmental monitoring but also for assessing potential risks to marine life and the fishing industry, which are integral to the local economy. While global studies on the fate of Fukushima-derived radionuclides have been conducted, there remains a need for detailed, region-specific studies to provide accurate assessments of the situation.

The results of this investigation will enhance the understanding of the long-term behavior of Fukushima-derived radionuclides in the region and provide a foundation for future environmental monitoring efforts. Through collaboration with international bodies and the continuous monitoring of radioactivity levels in the marine environment, the findings of this study will support ongoing efforts to ensure the safety of marine ecosystems and the health of coastal communities.

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# Age dating of sediment cores in Sorsogon Bay, Philippines using $^{210}$Pb method: A revisit

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The $^{210}$Pb age dating method is a well-established technique for the retrospective assessment of sediment transport in aquatic environments. Previously, this method was applied to characterize sedimentation processes in Sorsogon Bay, Philippines, using the Constant Initial Concentration (CIC) age-dating model to determine sedimentation rates (SR). This study revisits and validates the reported SRs to ensure more accurate age profiles and enhance historical interpretation. Sediment cores SO-01 (CAS), SO-03 (CAD), and SO-07 (SOR) from Madrid et al. (2011) were reanalyzed, assessing all possible combinations of regression lines for $^{210}$Pb activity profiles. The sediment age profiles were validated using high-resolution dry bulk density (DBD) and mass accumulation rate (MAR) data, correlating observed peaks with historical events such as Mt. Bulusan eruptions and major typhoons. In core CAD, peaks in DBD and MAR profiles corresponded to Mt. Bulusan eruptions (1933, 1978–1983, 1988, 2006) and typhoons (1947/Jean, 1979/Yayang, 1981/Anding, 1983/Warling, 1988/Unsang, 2006/Reming and Milenyo). CAS and SAM cores, located farther from Mt. Bulusan, did not record volcanic signals but showed sedimentary changes associated with typhoons and anthropogenic influences. SAM exhibited an abrupt sedimentation increase in the 1980s, attributed to intensified urbanization. CAS registered six distinct peaks linked to typhoon events in 1947 (Jean), 1952 (Trix), 1967 (Welming), 1970 (Sening), 1983 (Warling), and 1995 (Rosing).

The findings highlight the importance of constructing reliable sediment age models for understanding sediment provenance as well as environmental changes driven by nature (e.g. extreme weather events, climate change) and human activities (e.g. land use change). Such models are essential tools for advancing climate change research and developing effective coastal management strategies. Integrating DBD and MAR profiles with historical event records proved to be a robust approach for validating age profiles and reconstructing sedimentation history.

# Optimization of a liquid scintillation counting methodology for the determination of tritium in water using the Hidex 300 SL spectrometer

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Tritium ($^3$H) is a cosmogenic radionuclide produced naturally in the Earth's upper atmosphere. Additionally, significant amounts of anthropogenic tritium have been introduced into the environment as a result of nuclear weapons testing and operations of nuclear facilities, including nuclear power plants. Monitoring tritium levels in the environment is crucial for assessing the impact of nuclear energy production, ensuring environmental safety, and managing radioactive waste.

This study presents the development and optimization of an analytical method for the low-level determination of tritium in aqueous samples, using a Hidex 300 SL liquid scintillation counter equipped with an Active Guard system. Specific calibration and optimization steps were performed to achieve the lowest possible detection limits. Deep glacial groundwater from Krakow was employed as dead water for background evaluation. The analytical procedure included an initial distillation step to remove potential contaminants affecting measurement accuracy. Optimization focused on selecting suitable parameters such as the type of vials (PTFE, polyethylene or glass vials), the sample volume, the scintillation cocktail (e.g., Hidex AquaLight+ ULL for ultra-low level tritium counting or AquaLight Beta), and the counting time. Data acquisition and analysis were performed using MicroWin software. The resulting protocol achieved a minimum detectable activity (MDA) of 2.9 Bq/kg, enabling high-sensitivity tritium determinations and contributing to improved environmental monitoring in the context of nuclear energy activities.

This work was supported by the AGH University of Krakow research subsidy no. 16.16.210.476

# Different models for calculation of $^{222}$Rn flux and validation with experimental data in Bratislava, Slovakia

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Radon ($^{222}$Rn) is a naturally occurring radioactive gas widely used as a tracer in environmental studies as an indicator of various geophysical, hydrological, and meteorological processes. It is used for monitoring atmospheric stability, for investigating groundwater-surface water interactions, assessing air quality, and detecting geological anomalies linked to seismic activity or uranium deposits. Moreover, radon flux is nowadays recognized as a perspective tracer for understanding carbon dioxide emissions from the soil i.e., radon tracer and radon calibrated methods.

Various theoretical models are applied to determine radon exhalation, including both analytical and numerical approaches based on the soil's properties (soil moisture, soil dry bulk density, porosity etc.) and uranium contents. In this contribution, we focused on the determination of radon flux using various theoretical models. In order to determine radon diffusion coefficient, several semi-empirical formulas were used.

These modelled results were compared and validated through field measurements performed continuously in Bratislava for four years (2021 – 2024). Further, the modelled and measured radon flux at our locality were compared with the European radon flux map.

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).

# Radon flux maps for the Slovak Republic based on several approaches and their experimental verification

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Worldwide interest in the naturally occurring radioactive gas $^{222}$Rn (radon) is primarily related to the possibility of its accumulation in enclosed spaces, which can pose a potential health hazard. Since one of the main sources of indoor radon is the soil, mapping the radon exhalation rate from the soil is of critical importance.

In this study, radon flux maps with a spatial resolution of 0.5 km × 0.5 km covering the territory of the Slovak Republic were created based on several approaches combining both theoretical and empirical models. The required input parameters include the measured concentrations of the radioactive elements $^{238}$U, $^{232}$Th and $^{40}$K in the soil and $^{222}$Rn in the soil air, obtained from the Slovak geological map server. Another set of input parameters includes soil parameters such as soil porosity, radon emanation coefficient, dry bulk density of the soil and soil volumetric moisture, the representative values of which were determined from the granulometric fractions of sand, silt and clay in soil samples. The effective diffusion coefficient of radon, which is an important variable in determining the radon flux, was calculated using several semi-empirical relationships. This parameter is significantly affected by soil moisture, which is subject to high temporal and spatial variability. Soil moisture data were obtained from two online databases, the ERA-I/L and the GLDAS-Noah.

The created radon flux maps for the Slovak Republic were compared against radon fluxes determined experimentaly at several locations and also with existing European radon flux maps, for which different sets of input parameters were used.

This study was supported by the Slovak Research and Development Agency (project No. APVV-21-0356), the Scientific Grant Agency of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences (VEGA projects: No. 1/0019/22 and No. 1/0086/22).

# Historical Deposition and Distribution of Microplastics in Marine Sediments at the Mouth of the Kocasu River, Southern Marmara Sea, Türkiye

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Plastic pollution currently poses a significant threat to marine ecosystems, with microplastics disrupting biogeochemical cycles by impacting aquatic environments. In this study, microplastic pollution was investigated in core sediment collected from the mouth of the Kocasu River at a depth of -32 meters, in the southern Marmara Sea.

Radiocarbon dating, grain size analysis, total organic carbon (TOC) measurements, and microscopic examinations were conducted. Microplastics were classified according to their color, shape, and size. Under a stereomicroscope, microplastic abundance ranged from 800 to 6,600 items per kilogram, while fluorescent microscopy revealed a range of 400 to 17,800 items per kilogram. The average microplastic abundance was 5,400 items per kilogram, with a marked decline in microplastic content occurring below a core depth of approximately 45 cm, dated to 484 ± 21 BP. The majority of microplastics were concentrated in the upper 0–45 cm of the sediment core. Microplastics within the size range of 200–50 µm were predominant, with black being the most frequently observed color. Fragments constituted the dominant shape category, accounting for 69% of the total microplastics identified. Radiocarbon dating further indicated a significant decrease in microplastic abundance below approximately 75 cm, dated to 1422 ± 21 BP.

The spatial distribution of microplastics showed higher concentrations near river mouths, where younger deposits were located. This indicates that land-based pollution is responsible for microplastic accumulation on the seabed. This study provides the first data on microplastic pollution in the region, highlighting the role of the Kocasu River as a carrier of microplastics. The findings are important for understanding the impacts on marine ecosystems and for developing environmental management strategies. This study funded by İstanbul University with project number FBA-2023-40344.

# Phytoremediation of radionuclide-contaminated soil - long-term trial in sunflower cultivation

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## 1 Introduction

The last nuclear power plant in Germany was shut down on 15 April 2023. In addition to contaminated construction waste, significant quantities of contaminated soil must also be disposed of during decommissioning. In order to avoid expensive disposal of these soils in deep geological repositories, concepts for volume reduction and decontamination are being investigated. One of these is phytoremediation, a technique we are focusing on in this paper. In particular, we investigate the potential of sunflowers for radionuclide uptake from contaminated soil in order to optimize efficiency and time.

## 2 Material and methods

The soil originates from the site of the former Dresden Rossendorf reactor operated from 1957 to 1991 [1]. Due to the extended time period since decommissioning, the radionuclides reached a chemical equilibrium state. This state is difficult to reproduce on short time scales by spiking uncontaminated soils. Therefore, plants are grown in soils from the contaminated sites. Before planting, the soil is sieved to 2 mm to remove concrete particles. The experiment is carried out in plant pots (Ø x H: 18 cm x 17 cm) in a climate chamber with optimized growth conditions. Small sunflowers, Helianthus annuus, are planted. These have delivered promising results in inactive preliminary trials. In order to support the growth of the plants, Hoagland solution was used for irrigation [2]. The growth of the sunflowers are analyzed every month. Three pots are harvested per month and the plants are divided into their stem, leaf and flower components. The specific gamma activity of each of these samples is measured by using an HPGe detector. Soil to plant transfer factors are finally calculated using the previously measured specific activity of the soil.

## 3 Results and discussion

The experiments indicate that the transfer factor for both Cs-137 and Co-60 in the stems and leaves is already at its maximum after the second month and that the largest proportion of radionuclide uptake therefore occurs in the second month. The development of the transfer factor for Cs-137 is shown in Figure 1. It is related to the growth phases of the sunflower: between the first and second month, the plants grow in length [3]. This ends in the third month. The transfer factors for the nuclides become smaller again in the third month. This work shows that the uptake of Cs-137 and Co-60 depends on the growth phases of the sunflowers.

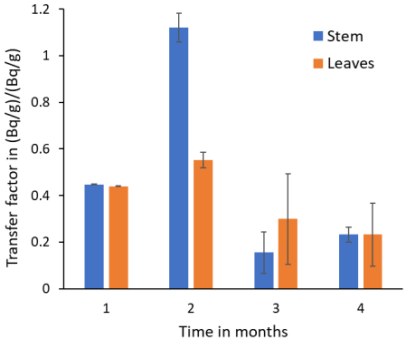



Fig. 1: The diagram shows the temporal development of the transfer factor for Cs-137 in stems and leaves of sunflowers in the first few months.

[1] Knappik, R., Geyer, K., Jansen, S., Graetz, C. (2019). Stilllegung und Rückbau des Rossendorfer Forschungsreaktors RFR. International Journal of nuclear power. **64**

[2] Smith, G. S., Johnston, C. M., Cornforth, I. S. (1983). Comparison of nutrient solutions for growth of plants in sand culture. The New Phytologist. **94** (4): 537–548. doi:10.1111/j.1469-8137.1983.tb04863.x

[3] Meier, U. (2018). Growth stages of mono- and dicotyledonous plants: BBCH Monograph. Open Agrar Repositorium, pp. 42-45. https://doi.org/10.5073/20180906-074619

# Estimation of Doses from Ingestion of Contaminated Food in the Event of a Nuclear Detonation

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The project PREDICT (Improvements in atmospheric dispersion modelling and protective action strategies in case of nuclear detonations) is a collaboration between 13 northern European institutes from 7 countries. PREDICT's aim is to enable the existing decision support systems such as ARGOS and JRODOS to simulate and predict consequences due to the fallout of a nuclear detonation. This objective is pursued by improving and adapting nationally used atmospheric dispersion and transport codes as well as foodchain transfer models to capture the peculiarities of nuclear detonation.

The main focus of the initial activities of PREDICT has been on determining the characteristics of the radioactive cloud following a nuclear detonation and in ranking radionuclides that are radiologically important, in terms of their dose contribution from different pathways (ground-shine, inhalation and ingestion). With regards to the estimation of ingestion dose, our focus has been on foodstuffs that were likely to (a) form substantial parts of the diet and (b) be important in terms of potential radionuclide transfer at specific timepoints (1 day, 7 days, 30 days, 6 months and 1 year). Based on these considerations, 7 food groups have been identified: Cereals, Leafy vegetables, Root vegetables, Potatoes, Fruits and berries, Dairy products and Meat. In addition, we anticipated that we would also need to consider transfer to grass as a feedstuff for grazing (dairy and meat) cattle.

In the present work, a brief overview of the contributions from the Norwegian partners in the PREDICT project will be given along with a more elaborated account of the work conducted related to the adaptation of FDMT (Terrestrial Food chain and Dose Module). FDMT is the radionuclide transfer foodchain module of ARGOS which is used by Norway in order to estimate contamination levels in food and feed products, as well as to predict doses to the public in case of a nuclear or radiological accident.

## Behavior and distribution of $^{210}$Po in brackish aquatic ecosystem of Uruguay

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The study of the presence, distribution, and transfer of natural radionuclides in the environment is becoming increasingly important. Specifically, the uranium-238 ($^{238}$U), uranium-235 ($^{235}$U), and thorium-232 ($^{232}$Th) decay chains provide a set of radionuclides with a wide range of half-lives, whose evolution in different natural compartments provides information about the behavior of an ecosystem.

Polonium-210 ($^{210}$Po) is a natural radionuclide belonging to the $^{238}$U series, characterized by its high radiotoxicity and its ability to bioaccumulate in certain tissues, transferring through the food chain and contributing to the dose received by both marine biota and humans through the consumption of marine products. Various studies conducted in the marine environment show that $^{210}$Po concentrations in organisms vary widely among different phylogenetic groups as well as among different tissues of the same species. However, freshwater and brackish aquatic systems have been poorly evaluated.

To partially address this deficiency, a study of $^{210}$Po was conducted in Castillos Lagoon, a brackish lagoon on the eastern coast of the Rocha department with intermittent connection to the ocean, to determine $^{210}$Po activity concentrations in different compartments and understand activity flows between them. Seasonal sampling was conducted at 5 selected points in the lagoon, where $^{210}$Po activity concentrations were determined in water, sediment, different species of fish, freshwater razor clam, blue crab, shrimp, phytoplankton, and zooplankton. $^{210}$Po was determined using alpha spectrometry, with radiochemical separation and self-deposition on silver disk.

In this study, the average values of $^{210}$Po concentration in water and sediments for the various seasonal samplings conducted will be presented, along with the ranges of the calculated distribution coefficients, Kd (L/kg), between sediment and water. Transfer coefficients between biota and water or sediment were also calculated, ranging from $10^2$ to $10^5$ depending on the aquatic organism and the tissue considered.

The results show that $^{210}$Po present in water is concentrated by phytoplankton and transferred to the next trophic level along marine food chains, with the main absorption route through ingested food, while the absorption of dissolved forms of $^{210}$Po in water provides only a minor contribution. The great variability of the results obtained in different species may correlate with the feeding habits of the organisms analyzed. Species that feed on phytoplankton and zooplankton tend to have high $^{210}$Po activity concentrations. However, species located at higher levels of the food web, such as top predators (piscivores), tend to have lower activity concentrations of this radionuclide.

# Corrected $^{210}$Pb based estimations of sediment accumulation rates in a marine area contaminated by legacy oil derived NORM discharges

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In recent years, the lead-210 ($^{210}$Pb) geochronological tool has been extensively applied to help determine the accumulation and burial rates of Blue Carbon in various marine environments via the radiometric analysis of sediment cores. Numerous physical disturbances, originating from both anthropogenic and natural sources, can influence the results obtained using this tool.

Additionally, the presence of NORM derived $^{210}$Pb and radium-226 ($^{226}$Ra) can present another challenge if sediment cores are collected in areas that have been or are affected by NORM industrial activities. More worryingly, heavy metals associated with NORM discharges can severely impact the direct measurement of $^{210}$Pb via gamma spectrometry, subsequently affecting $^{210}$Pb-based estimations of sediment accumulation rates (SARs).

In this study, several sediment cores were collected in proximity to a decommissioned oil and gas platform located offshore in the UK North Sea (North West Hutton (NWH), 61.11N, 1.31E). Elemental and radioelemental signatures from legacy NORM discharges were observed in the sediment cores collected within 200 m North and South of the former NWH platform and were thoroughly characterised using ICP-MS and gamma spectrometry, respectively. This enabled the forensic differentiation of the NORM-derived $^{226}$Ra fraction from the natural background and the generation of relative factors based on bulk elemental composition analysis to correct $^{210}$Pb results obtained from initial gamma spectrometric analysis. This corrective approach was validated by measuring polonium-210, a decay product of $^{210}$Pb, via alpha spectrometry, and allowed the estimation for the first time of Blue carbon accumulation and burial rates in sediment cores using different modelling $^{210}$Pb modelling approaches (CIC, CFCS, CRS, and rplum).

# Increasing iodine-129 concentrations in the West Philippine Sea

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Iodine-129 ($^{129}$I) is a radioactive isotope with a long half-life, introduced into the environment due to human nuclear activities, such as nuclear weapons testing, nuclear fuel reprocessing, and nuclear accidents. It serves as a useful indicator of nuclear activity impacts, an environmental tracer, and a marker of the Anthropocene epoch. Earlier research involving corals suggested heightened levels of $^{129}$I in the West Philippine Sea (WPS) and the broader East and South China Sea regions, but the origin of this radioisotope remained unclear. This study presents $^{129}$I concentration measurements taken from 119 surface seawater samples across various Philippine seas and compares them with existing data from the Yellow, East, and South China Sea to identify the possible source of the increasing $^{129}$I concentrations in the WPS. Results show that $^{129}$I concentrations in the WPS, averaging 10.8 x $10^{6}$ atoms/kg of seawater and ranging from 6.54 to 14.8, are significantly higher, particularly 1.5 to 1.7 times greater ($P < 0.0001$) than in other areas of the country. The primary source of this increasing $^{129}$I concentration appears to be located around the Bohai and Yellow Seas. One possibility is that $^{129}$I from European nuclear fuel reprocessing facilities and historical nuclear weapons testing at Lop Nor and Semipalatinsk is deposited on soils in northeastern China. Rivers then carry these radioactive materials, drain into the Bohai and Yellow seas, and are eventually transported to the WPS through prevailing ocean currents (Fig. 1). Moreover, analysis of a new coral core from the WPS indicates a continuous upward trend in $^{129}$I/$^{127}$I ratios of about 1 x $10^{-12}$ per year from 1971 to 2020, indicating that $^{129}$I input into the WPS continues to the present. This study underscores the importance of developing policies to tackle transboundary radioactive contamination and highlights the valuable application of $^{129}$I as a tracer for understanding the complex ocean circulation patterns in the South China Sea region.

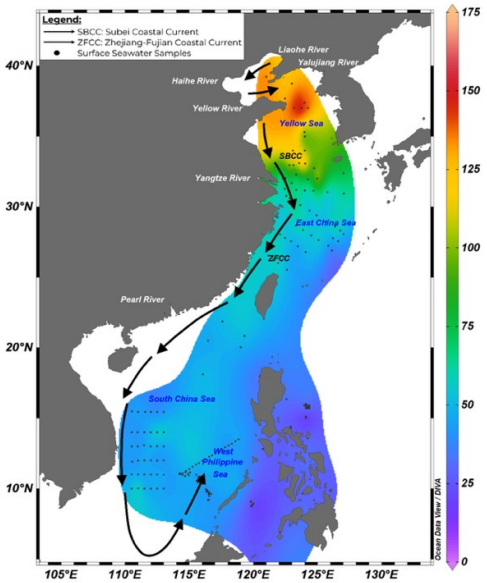



**Figure 1**. Map of $^{129}$I/$^{127}$I (x $10^{-12}$) ratios of surface seawater with major ocean currents (Subei Coastal Current or SBCC and Zhejiang-Fujian Coastal Current or ZFCC) possibly transporting seawater with high $^{129}$I/$^{127}$I ratios to the WPS and the across the region[This study, 1–4].

**References**

1. Wang, Y. et al. *Environ Sci Technol* **58**, 12633–12642 (2024).
2. Zhang, M. et al. *Environ Sci Technol* **56**, 12298–12306 (2022).
3. Burr, G. S. et al. *Elementa* **8**, (2020).
4. Liu, D., Hou, X., Du, J., Zhang, L. & Zhou, W. *Sci Rep* **6**, (2016).

# The distribution of Sr in the calcium-rich soils in the Arabian Peninsula

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The subtropical environment presents new challenges for radioecology research. The mineral soils are formed of silicate, calcite and gypsum. The specific characteristics are high salinity and high concentration of strontium. Typical local soils are poor in organic matter. Due to the high contents of Ca and Mg, it is interesting to investigate their relationship to Sr behavior in soil. The solubility of Ca/Mg minerals, high salinity, and high concentration of stable Sr, which overwhelmed the potential contamination by radiostrontium, are key parameters for modeling $^{90}$Sr migration.

To reveal the Sr behavior in this complex system, we employed the column experiments and Tessier's sequential extraction (SE). The results of the SE are in Figure 1. Sr showed a similar distribution among soil fractions as Ca. However, there are some differences in the detailed analyses. The availability of elements decreases from the water fraction to the organic matter. The most available Sr is present in Sandstone, followed by Gypsum. Sr in Calcareous Sand is mainly associated with carbonates. Carbonates could still be considered as a relatively available fraction. The least available Sr is in Limestone. Noteworthy, Mg has the most similar distribution to Sr in Limestone. The highest quantity of Sr was released from 1 g of Gypsum, i.e. 0.26 mg, followed by Sand 0.096 mg, Limestone 0.042 mg and Sandstone 0.023 mg. The mass ratio of Sr and Ca in the Sand (0.0096) approaches the most to the stable ratio in the sea water (0.02).

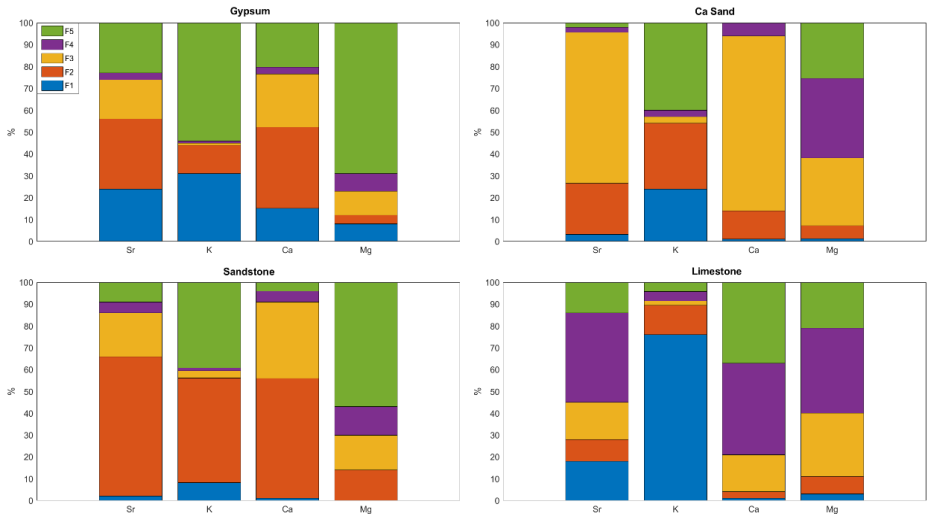



*Figure 1: Tessier's sequential extraction. F1 – water-soluble fraction, F2 – ion-exchange fraction, F3 – carbonate fraction, F4 – Fe/Mn oxides, F5 – organic matter.*

Conclusion: To understand the Sr behavior in specific soils, it is necessary to reveal it is distribution in soil fractions. Especially when the soil matrix is formed by relatively soluble calcium minerals, potential contamination of $^{90}$Sr will remain highly mobile in the local soils.

# Interaction of *Phaseolus vulgaris* plants with U(VI): Release of root exudates and their impact on the U(VI) speciation

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The safety assessment of radioactive contaminated sites and potential repositories for high-level radioactive waste necessitates the consideration of the release of radionuclides (RNs) into the groundwater and their subsequent transport into the soil, where they can be taken up by plants. Consequently, RNs may enter the human food chain, which poses a significant risk to human health. In the context of plant biology, RNs are non-essential elements that have the capacity to induce changes in various physiological processes, developmental stages, and metabolic pathways. In order to protect themselves from stress, plants release root exudates into the rhizosphere. Furthermore, root exudates have been demonstrated to play a pivotal role in shaping bacterial communities and facilitating nutrient uptake. It is vital to consider the role of root exudates in modulating the bioavailability of RNs by altering their speciation.

The present study investigates the effects of uranium (U) on the crop plant *Phaseolus vulgaris* (bush bean) cultivated in hydroponic solution. The time-dependent bioassociation of U(VI) with the plants is studied as a function of the U concentration using inductively coupled plasma mass spectrometry, whilst the U(VI) speciation in hydroponic solution is studied by time-resolved laser-induced fluorescence spectroscopy (TRLFS). Furthermore, the release of root exudates by *P. vulgaris* plants is studied to understand their impact on the U speciation. In order to achieve this objective, root exudates that are released into the hydroponic solution in the presence and absence of U are isolated, enriched by solid phase extraction and analyzed by high performance liquid chromatography or non-target screening analysis in cooperation with AFIN-TS GmbH.

*P. vulgaris* plants were exposed for 72 h to 20 or 200 µM U(VI) in phosphate-reduced, half-concentrated Hoagland medium. The bioassociation of U to *P. vulgaris* plants is time- and concentration-dependent. The majority of U was accumulated in the roots, resulting in phenotypic adaptations in both roots and leaves. Thermodynamic calculations of the U(VI) speciation in the medium demonstrated that a range of U(VI) species (including U(VI) sulfate, hydroxo and carbonate complexes) can be anticipated within the studied pH range of 5 to 7. Following a 72-hour exposure of the plants to 20 or 200 µM, three U(VI) species were detected in the medium by TRLFS. One of these species was assigned to the $(UO_2)_2(CO_3)_3^{4-}$ complex, while another was found to be a $(UO_2)_x(OH)_y^{2x-y}$ complex. The third species, whose proportion increased with increasing exposure time, is hypothesized to be a U(VI) complex with a root exudate. However, further research is required to elucidate the identity of this complex and its potential influence on the migration behavior of U and its bioavailability. In the presence of U(VI), *P. vulgaris* roots excreted a greater number of metabolites than in its absence. Indications have been found that the roots of these plants release glutamate as well as organic acids, e.g., citric, malic, succinic, and formic acids.

This work contributes to the process understanding of the interaction of U with plants, which is important for the improvement of radioecological models for the assessment of the RN behavior in the environment.

This study is part of the project TRAVARIS, which is funded by the German Federal Ministry of Education and Research under the contract number 15S9437C.

# Radial Distribution of $^{137}$Cs in Japanese cedar and Its Implications for Sustainable Forest Management in Fukushima.

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Radiocesium ($^{137}$Cs), with a half-life of 30.04 years, remains the dominant long-term contaminant in Fukushima Prefecture and surrounding regions following the nuclear accident. Forests, covering about 70 % of the affected areas, are of critical concern due to their vital ecosystem services (timber, food, recreation, etc.). The potential resumption of commercial forestry, particularly in high-contamination zones, depends on adherence to national radiocesium standards for wood products. Japanese cedar, the dominant coniferous species and a key timber resource, presents an unusual radiocesium distribution pattern, with higher concentrations in heartwood than sapwood—a deviation from typical trends in other tree species. This anomaly demands rigorous investigation into the underlying biochemical and environmental mechanisms governing $^{137}$Cs uptake, translocation, and retention. This study examines the driving factors behind these patterns, identifies key knowledge gaps, and proposes future research directions to enhance risk assessment and sustainable forest management. cedar.

Keywords: radiocesium, forest ecosystems, Japanese cedar, Fukushima

# How past and actual releases from a U-conversion facility impact the aquatic environment?

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A U-conversion facility located in the south of France, is designed to purify uranium from the "yellow cake" (i.e. uranium ores concentrate) and to convert U into $UF_4$. Since the beginning of the conversion activity in the early 1960s, the conversion process has produced amounts of nitrate liquid effluents stored in ponds surrounding conversion workshops. Currently, the storage ponds contain 350,000 $m^3$ of nitrate-bearing liquid effluents. The main radionuclides stored in these ponds are uranium isotopes, $^{230}$Th, $^{234}$Th, $^{226}$Ra, $^{90}$Sr, $^{99}$Tc, $^{239}$Pu, $^{241}$Pu and $^{241}$Am. The presence of artificial radionuclides is due to the conversion of irradiated uranium from spent nuclear fuels, between 1960-1982.

Previous studies underline the role of wind in disseminating radioactive droplets and particles in the terrestrial environment located around the site. This process could also be involved in the delivery of radionuclides into the aquatic environment. For more than 15 years current site discharges into the canal no longer include industrial effluents but consist mainly of rainwater collected on the whole site which still contains substantial uranium activity. Thereafter, the canal flows down into the Bages lagoon wich is connected with the Mediterranean Sea.

In 2023-2024, ASNR conducted a specific study around this U-conversion facility to assess the radiological status of the aquatic environment in addition to other studies carried out in the atmospheric and terrestrial environments. Various types of environmental indicators were sampled in channels and in the Bages lagoon: surface waters, sediments, aquatic plants, fishes and mollusks. Measured radionuclides included those involved in the conversion of the "yellow cake" such as natural uranium and main $^{238}$U decay products. In addition, the legacy of the conversion of irradiated uranium namely the artificial radionuclides cited above were also measured. The aim of this communication is to assess both the impact of current discharges downstream in the canal, and the persistence of the past discharges into the lagoon.

# Gamma radiation and Radon exhalation in Uruguayan building materials

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Natural radiation accounts for approximately 80% of global average exposure, with radon inhalation being the largest contributor. $^{222}$Rn is classified as the second leading cause of lung cancer. While international agencies have set guidelines to limit annual exposure to below 1 mSv from building materials, Uruguay lacks specific national regulations, aside from recently introduced recommendations for indoor radon concentrations.

Samples from five categories of building materials—cements and cementitious mixtures, granites, bricks and concrete blocks, ceramic and porcelain tiles, and gypsum—were collected from local suppliers, representing both domestic and imported products. After drying and milling, the samples were tested using gamma spectrometry and radon exhalation techniques. The activity concentrations of $^{226}$Ra, $^{232}$Th, and $^{40}$K were measured with a high-purity germanium detector, while the exhalation of $^{222}$Rn was assessed using the sealed can technique and CR-39 solid-state nuclear track detectors.

Radiological risks were evaluated using the activity concentration index (I) and the alpha index (I$\alpha$). Additionally, dose simulations for granite were performed using the RESRAD-BUILD model developed by Argonne National Laboratory, which accounted for external exposure, radon inhalation, dust inhalation, and ingestion under various occupancy scenarios.

Granites showed the highest concentrations of all three radionuclides (mean values: $^{226}$Ra = 79.4 Bq/kg, $^{232}$Th = 123.9 Bq/kg, and $^{40}$K = 1058 Bq/kg), while gypsum and fiber cement showed the lowest. Despite these variations, all values remained below the clearance levels recommended by the IAEA and the European Commission (1 Bq/g for uranium and thorium series, 10 Bq/g for $^{40}$K).

The activity concentration index (I) exceeded 1 only in granite samples, which is permissible for surface materials such as countertops under international standards. All other materials had indices well below the recommended limits.

Radon exposure rates and exhalation values were highly variable. Granite once again exhibited the highest mean radon emission (590 kBq·h/m$^3$), while most other samples fell below detection thresholds. One granite sample marginally exceeded the national recommended radon concentration for indoor air (300 Bq/m$^3$). This sample was further analyzed through dose simulations for four scenarios - one-room residence, part-time occupancy (0.6), One-room residence, full-time occupancy (1.0) – One-room workspace (0.33) and standard residence (0.67)-. In all scenarios, the simulated annual doses remained well below the 1 mSv/year threshold established by international safety recommendations.

This work concludes that the studied building materials available in Uruguay are radiologically safe for use in both residential and public construction. All measured radionuclide concentrations were below the established clearance limits, and dose simulations confirmed that exposure levels—even in worst-case scenarios—do not pose significant health risks.

The research provides a scientific basis for the safe use of commonly marketed construction materials in Uruguay and underscores the need for further studies on indoor radon levels to support public health policy and regulation.

This work was supported by the Agencia Nacional de Investigación e Innovación [grants ANII FCE_1_2021_1_167264 and ANII POS_FCE_2021_1_1010820].

# Distribution and origin of naturally occurring radioactive materials (NORMs) in mylonitic rocks of north Abu Rusheid, Eastern Desert, Egypt

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Abstract

Mylonitic rocks in north Abu Rusheid, Eastern Desert of Egypt, are rich with naturally occurring radioactive materials (NORMs). Uranium (U) and thorium (Th) decay series are widely considered as NORMs, with more abundance in the Earth's crust. NORMs may become concentrated through industrial processes such as niobium (Nb) and tantalum (Ta) extraction, zircon and zirconia, metal production, and mining of uranium ore. This study investigated the distribution and mineralogical hosts of NORMs in mylonitic rocks from North Abu Rusheid, located in Egypt's mineral-rich Arabian-Nubian Shield. Thirty samples were collected from three trenches (TA, TB, and TC) to measure trace element concentrations using inductively coupled plasma mass spectrometry (ICP-MS). Mineralogical studies were conducted using heavy liquid separation and environmental scanning electron microscopy (ESEM) with EDX to identify minerals. Results indicated significantly elevated concentrations of refractory elements such as Nb (up to 1322 μg $g^{-1}$), Ta (up to 252 μg $g^{-1}$), Zr (up to 1901 μg $g^{-1}$), U (up to 171 μg $g^{-1}$), and Th (up to 454 μg $g^{-1}$) were higher than upper continental crust values. Metal concentrations such as Sn were (up to 136 μg $g^{-1}$), Zn (up to 574 μg $g^{-1}$), and Pb (up to 771 μg $g^{-1}$). The minerals identified in this study include columbite (host to Nb, Ta, and U), zircon (Zr-rich), cassiterite (Sn-rich), and uranothorite (a radioactive mineral containing both U and Th). The spatial distribution and mineralogical associations suggest a common origin for U and Th, with notable implications for radiological protection in potential mining activities. This research highlights the need for risk assessment and management strategies for radiation exposure in future resource exploitation in the North Abu Rusheid area. These findings will support safe practices in mineral extraction industries.

# Simulation-Based Assessment and Validation of Radiological Environmental Impacts from the Oceanic Discharge of ALPS Treated Water

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The water treated by the Advanced Liquid Processing System (ALPS treated water) has been released into the ocean since August 2023, as part of the decommissioning process of the Fukushima Daiichi Nuclear Power Station (1F) by Tokyo Electric Power Company Holdings, Inc. (TEPCO HD). Radioactive nuclides, including tritium ($^{3}$H), are routinely discharged into the ocean from nuclear facilities worldwide. However, ocean discharge from an accident-affected nuclear power plant is unprecedented. Moreover, concerns were raised domestically and internationally, as long-lived radionuclides such as carbon-14 ($^{14}$C) and iodine-129 ($^{129}$I) cannot be completely removed. Therefore, TEPCO HD prepared a "Radiological Environmental Impact Assessment Report," which was reviewed and deemed appropriate by the International Atomic Energy Agency (IAEA). In the report, a Regional Ocean Modeling System (ROMS) was applied to the coastal waters off Fukushima to evaluate the dispersion of ALPS-treated water. The model incorporated results from the Japan Meteorological Agency's short-term weather forecasting system and ocean reanalysis data (JCOPE2M), considering the effects of wind stress, the Kuroshio Current, and mesoscale eddies. The model's reproducibility was validated through the simulation of cesium-137 ($^{137}$Cs) dispersion following the Fukushima accident, showing good agreement with observed annual average concentrations. It was also demonstrated that the annual variability in average concentration distributions was small, suggesting that future annual average concentrations could be predicted if discharge rates are known. The discharge rate for ALPS-treated water was set to ensure that annual tritium releases would not exceed 22 TBq. Discharge rates for 29 other nuclides were also determined based on the composition of the treated water. Model simulations indicated that areas where tritium concentrations exceed the pre-accident background level (70 Bq/m$^{3}$) would be limited to offshore Fukushima. Based on IAEA and International Commission on Radiological Protection (ICRP) guidelines, average marine concentrations of 30 major nuclides were estimated proportionally, and both external and internal exposure doses were evaluated. The results showed that the additional dose would be on the order of $10^{-5}$ mSv/year, which is negligible compared to natural background radiation levels (1–2 mSv/year). Although the dose was extremely low, carbon-14 and iodine-129 contributed relatively more than tritium. From August 2023 to August 2024, approximately 4.5 TBq of tritium was discharged, equivalent to about one-fifth of the annual limit. Validation of the evaluation model using monitoring data is essential. Although monitoring of tritium concentrations in the surrounding marine area has been conducted, large temporal and spatial variations have made it difficult to capture detailed concentration distributions. Furthermore, the locations of maximum concentrations have not always been precisely monitored. Minor residual leakage from the 1F site and its vicinity has contributed to background concentrations remaining higher than pre-accident levels, although the impacts have been localized and limited. Nevertheless, detectable impacts on background concentrations have been limited to the vicinity of the discharge outlet, which is consistent with model predictions. These findings are critical for verifying the safety of the discharge. Going forward, it will be important to continue ensuring safety by accumulating monitoring data, conducting detailed verification of the model, and updating the simulation as necessary to reflect new observations.

# Aging of the atmosphere and radiocarbon dating

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The natural variability of atmospheric $^{14}C$ has been significantly altered by anthropogenic activities linked to technological advancements and energy consumption over the past two and a half centuries. The Suess effect, a consequence of the combustion of old carbon (fossil fuels) since the mid-18th century and the bomb peak from the thermonuclear tests of the mid-20th century, have obscured the natural $^{14}C$ signal in the atmosphere. The bomb peak i.e., the excess of $^{14}C$ carbon was produced in the atmosphere in the years between 1952 to 1963. The higher-than-natural levels of $^{14}C$ in the atmosphere were detectable between 1954 and 2021. Measurements of $^{14}C$ in the air and in the leaves or tree rings allow reconstruction of the changes that are results of the Suess effect. The fading of the bomb peak and future scenarios of the atmospheric $^{14}C$ levels are of concern for the future applications of the dating method. This paper presents an overview of $^{14}C$ applications which rely on the bomb peak and the consequences of a 'dark atmosphere'.

**Effects of Low-Dose Ionizing Radiation on Cataractogenesis and Lens Protein Expression in Voles (*Myodes glareolus*) from the Chornobyl Exclusion Zone**

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Radiation-induced cataracts were historically believed to have high dose thresholds for formation. However, recent evidence from the atomic bomb survivors has prompted a reassessment of these limits, with the International Commission on Radiological Protection (ICRP) lowering the threshold for acute exposures to the eye to 0.5 Gy in 2012. Despite epidemiological data suggesting that even low-dose radiation can contribute to cataractogenesis, the mechanisms underlying this process remain poorly understood. The objective of this study was to investigate cataract formation in the lenses of voles collected from the Chornobyl Exclusion Zone (CEZ). Animals were collected in 2018 along trap lines from several areas in the CEZ as part of a major investigation of the environmental effects of radiation in the CEZ. Extensive data concerning ambient and internal dose to the animals is available as well as gross pathology, blood work and other health indicators. This part of the project is aimed at assessing the effects of low-dose ionizing radiation on lens morphology and lens protein distribution to enhance understanding of radiation-induced ocular changes. Eyes of voles from CEZ were fixed in formalin, processed and embedded in paraffin and sectioned. The ocular sections were stained with hematoxylin and eosin (H&E) to assess lens morphology. Immunohistochemistry was performed to evaluate the expression of alpha A (αA) and alpha B (αB) crystallin. Fluorescence intensity and lens measurements were analyzed to investigate the relationship between radiation dose and lens protein expression. Our very preliminary data based on a limited number of samples suggests that compared to control animals collected from background dose areas, animals collected from low-dose radiation areas had internal doses in the range 5.5-7.5 μGy/h and was associated with morphological changes, including a reduction in lens diameter and an increased width of the germinative zone, along with more densely distributed αA-crystallin staining. Animals collected from high-dose radiation areas had internal doses ranging from 363.8-370.9 μGy/h. This resulted in further morphological changes and greater alterations in crystallin staining patterns, including asymmetric distribution of αA-crystallin, disorganized fiber cells, and increased αB-crystallin expression. These initial findings if confirmed with analysis of further samples and robust statistical analysis could support the suggestion that cataract formation may not strictly adhere to a dose-threshold model, as even low levels of radiation may be initiating molecular and structural alterations associated with the development of cataracts.

# Pathways and Distribution Characteristics of Radioactive Material Dumped in the East/Japan Sea

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Long-term behavior of radioactive material dumped in the northern East/Japan Sea was analyzed using Lagrangian particle tracking over 30 years. The analysis focused on the pathways and distribution characteristics of the radioactive material in the surface and subsurface layers. The locations and amounts of the most significant dumping event in the northern Japan Basin in 1986 were used as initial conditions. Multi-decadal simulations were performed over the entire East/Japan Sea using ocean model data with vertical velocity, which reproduced intermediate water critical for the sinking of radioactive material by strong winds. The results showed that particles released from the surface dispersed across the entire East/Japan Sea within 2 years, with concentrations in the south decreasing after 3 years. Subsurface material was transported to the southwest East/Japan Sea via vertical diffusion and intermediate water circulation. Long-term concentrations decreased due to decay and broad diffusion, comparable to the observed variability. This research provides a new perspective on East/Japan Sea circulation characteristics by utilizing long-term radionuclide tracking based on a dumping event.

# Spatial variations in radioactive Cs of soil and crop within a field in Fukushima, Japan

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A large amount of radioactive cesium ($^{134}$Cs and $^{137}$Cs, RCs) was released into the atmosphere and deposited widely onto the eastern Japan due to the accident at the Tokyo Electric Power Company's Fukushima Dai-ichi Nuclear Power Plant in March 2011. The monitoring of RCs activity concentration in soil and food has been conducted since the accident. In monitoring for agricultural fields, samples are taken from the same fields each year, but the activity concentrations can fluctuate due to factors other than the physical decay. One factor is inhomogeneous distribution of RCs in soil and crop within a field. Accordingly, sampling errors caused by the spatial variations must be considered to determine how much the monitoring values fluctuate. We investigated the spatial variations in the RCs activity concentrations in soil and broccoli (*Brassica oleracea* var. *italica*) within a field in Fukushima, Japan.

The field is plowed every year. The area was 1,350 m$^2$. Broccoli and soil samples (n = 37) were taken at 10 m intervals in November 2024. The coordinates of the sampling points were recorded using an RTK-GNSS system. Soils were collected from both sides for broccoli samples to a depth of approximately 15 cm and composited into one sample. The soil samples were air-dried and sieved through a 2 mm sieve. The buds of broccoli were cut, dried for 48 h at 80 °C, and ground using a blender. $^{137}$Cs activity concentrations were determined using a germanium semiconductor detector. Transfer factors (TF) of $^{137}$Cs from air-dried soil to dried buds were calculated. Semi-variogram was analyzed with the GS+ software, and the spatial distribution map was created using ordinary kriging or inverse distance weighting with the ArcGIS software.

The max values of $^{137}$Cs activity concentrations in soil and broccoli bud were 923 and 32.8 Bq/ kg dry weight, respectively (Table 1). Coefficient of variation (CV) for the activity concentration in soil was approximately 20 %. The CVs of broccoli bud and TF were greater than 20 % and larger than the soil CV. The semi-variogram analysis presented that the activity concentrations in soil and broccoli bud were randomly distributed, whereas TF showed a spatial correlation with a range of 11.7 m. Soil $^{137}$Cs distribution might be related to the cropping direction because only one ridge showed high activity concentrations although the reason was unclear. There was no correlation between the activity concentrations in soil and in broccoli bud, suggesting that other factors affected the transfer of $^{137}$Cs, such as phytoavailable potassium content. We estimated how much the mean could fluctuate due to the spatial variations in the envelope sampling (5 points sampling), a widely applied method. The results showed that there were 24 % and 36 % variations in the activity concentrations of soil and broccoli bud, respectively, and 31 % variation in TF. These results indicate that the means in 5 points sampling can fluctuate several times due to the spatial variations even in a cultivated field.

Table 1. Descriptive statistics of $^{137}$Cs in soil and broccoli buds.

| | $^{137}$Cs in soil (Bq/kg dry soil) | $^{137}$Cs in broccoli bud (Bq/kg dry weight) | Transfer factor |
|---|---|---|---|
| Min | 496 | 8.55 | 0.0152 |
| Max | 923 | 32.8 | 0.0426 |
| Mean | 681 | 16.4 | 0.0243 |
| Coefficient of variation (%) | 19.4 | 28.8 | 24.8 |

# Application of isotopic approach to assess the quasi-equilibrium levels of $^{137}$Cs in Fukushima forests

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Radionuclides from atmospheric fallout are intercepted by aboveground forest biomass and then transported to the forest floor with litterfall, throughfall, and stemflow, which leads to a decrease in radionuclide inventories in biomass during an early stage after deposition. Accordingly, a well-studied dominant trend in Fukushima forests during that period was the fast decrease in radiocesium inventories in the aboveground tree biomass. After the early stage, depending on the local conditions and form of fallout, radionuclide inventories and concentrations in tree biomass may show different trends, including both increase and decrease, until reaching a quasi-equilibrium level.

In this study, we applied an isotopic approach to assess the quasi-equilibrium of Fukushima-derived radiocesium ($^{137}$Cs) in a typical mature Japanese cedar forest. The concentrations of radiocesium in the aboveground biomass compartments as of 2020 correlated well with the equilibrium concentrations of the naturally occurring stable isotope of cesium ($^{133}$Cs) entering the aboveground biomass from the soil, indicating that the quasi-equilibrium distribution of radiocesium had been achieved after a period of removal of the initially intercepted radiocesium from the biomass compartments. The isotope concentration ratio $^{137}$Cs/$^{133}$Cs in the biomass as of 2020 is estimated as $3.6 \cdot 10^{-5}$ ($\mu g\ kg^{-1}$) ($\mu g\ kg^{-1}$)$^{-1}$ (95% CI: $1.6 \cdot 10^{-5}$ - $5.6 \cdot 10^{-5}$). The isotope inventory ratio $^{137}$Cs/$^{133}$Cs in the 5-cm topsoil was slightly lower, $(2.52 \pm 2.39) \cdot 10^{-5}$ ($\mu g\ kg^{-1}$) ($\mu g\ kg^{-1}$)$^{-1}$, indicating the presence of some amounts of radiocesium intercepted from the atmospheric fallout in March 2011 in the biomass compartments. The total radiocesium inventory in aboveground biomass stabilized between 2017 and 2020 at the level of (3.1+1.7) % of its total inventory in the ecosystem.

# Linking prey composition to variability of radiocesium contamination in masu salmon: Insights from DNA metabarcoding in a forested river system

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After the 2011 accident at the Fukushima Daiichi Nuclear Power Plant (FDNPP), radiocesium ($^{137}$Cs) contamination levels in masu salmon (*Oncorhynchus masou*) have remained high. In forested headwater streams, masu salmon primarily acquire radiocesium by ingesting terrestrial and aquatic insects., contamination originating from forest ecosystems strongly influences radiocesium levels in terrestrial and aquatic insects, and subsequently in masu salmon. As a result of persistent cycling of contamination within forests, the decline in radiocesium concentrations in masu salmon has been remarkably slow. Given that individual masu salmon show considerable variation in radiocesium concentrations, examining the relationship between dietary composition and individual radiocesium levels provides a valuable approach for identifying major sources of forest-derived radiocesium in fish inhabiting headwater ecosystems.

This study focused on masu salmon populations from the Ota River, a forested river system located approximately 20 km north of the FDNPP. The Ota River watershed includes upstream areas within the Difficult-to-Return Zone, where high levels of radiocesium contamination persist. We collected masu salmon along with their potential prey, terrestrial and aquatic insects across spring, summer, autumn, and winter during 2018–2019, and measured radiocesium concentrations in these organisms. In addition, we conducted dietary metabarcoding analyses on 114 masu salmon. DNA was extracted from stomach contents, and PCR amplification was performed using universal primers targeting arthropod DNA, followed by high-throughput sequencing. Whereas previous studies of fish feeding ecology have predominantly relied on morphological identification of stomach contents, DNA metabarcoding enables more detailed and accurate taxonomic classification, as well as the detection of prey items that are easily digested and otherwise difficult to identify.

Analysis of prey composition revealed that prey assemblages varied significantly with season, body size, and sampling site, and were also associated with individual radiocesium concentrations in fish. Regarding seasonal and size-related effects on prey composition, our findings were consistent with previous studies, indicating a higher proportion of terrestrial insects in diets during summer and autumn, and a tendency for larger individuals to consume more terrestrial insects. Radiocesium concentrations in terrestrial insects exhibited substantial variability, which was strongly influenced by their functional feeding groups. Our results suggest that variability in diet composition and radiocesium level of prey items contributed to the wide range of radiocesium concentrations observed among individual masu salmon.

# Feasibility Study on Simulation-Based Efficiency Calibration for Environmental Gamma Spectrometry

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High-purity germanium (HPGe) gamma spectrometers are widely utilized for environmental radiation monitoring due to their superior energy resolution and efficiency. In current operational practice, efficiency calibration of HPGe gamma spectrometers is performed twice a year using certified gamma standard sources to maintain the accuracy of the measurements. However, this process requires substantial costs, manpower, operational downtime, and waste disposal procedures.

In our laboratory, long-term calibration data collected over the past nine years (2016-2024) indicate that the detection efficiency performance of gamma spectrometers has been consistently maintained at a stable level. Moreover, the intrinsic performance of HPGe detectors should not change dynamically once certified, suggesting a growing need for alternative methods that can reduce the reliance on frequent physical calibrations.

In this study, we aim to evaluate the feasibility of using simulation-based efficiency values calculated by tRAYcy, a Monte Carlo-based modeling tool developed by ORTEC for simulating the interaction of gamma radiation with matter. Experimental efficiency data were accumulated over the past nine years in our laboratory by measuring an HPGe spectrometer (GEM30P4-83, ORTEC) using a mixed gamma standard source containing nine radionuclides. Based on this detector, we constructed a corresponding model using tRAYcy, and efficiency values were calculated. As shown in Figure 1, the experimental efficiencies (blue) represent the averaged values from our measurements with a 1-liter Marinelli beaker geometry, while the tRAYcy-calculated efficiencies (red) show good agreement, with relative errors indicated at each energy point, remaining within 5%. Both efficiency curves were fitted using fifth-degree polynomials.

Future work will focus on refining our detector modeling in tRAYcy by incorporating additional factors such as time coincidence correction (TCC) and improving the detailed structure modeling. In addition, we plan to extend the approach to other HPGe spectrometers currently operated in our laboratory. Through these efforts, we seek to assess whether simulation-driven calibration could serve as a practical and reliable alternative to efficiency calibration procedures for gamma spectrometers used in environmental radiation monitoring.

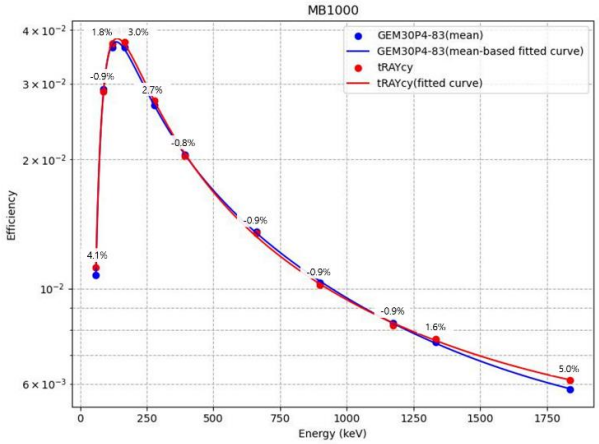



Figure 1. Comparison of experimental efficiency curves (blue) and simulation-based efficiency curves (red) for an HPGe gamma spectrometer.

# Extensive study on vertical migration of $^{137}$Cs in undisturbed soil after the Fukushima Dai-ichi Nuclear Power Plant accident.

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The depth distribution of $^{137}$Cs is important not only for radiation protection, but also for radioecology and geoscience. Most of the deposited $^{137}$Cs is adsorbed on surface soil particles and then migrates downward over time by various processes. Previous studies on depth distribution of $^{137}$Cs have focused on short-term or localized areas and lacked temporal and spatial comprehensiveness. This study aims to grasp the depth distribution of $^{137}$Cs in undisturbed areas over a wide area affected by the Fukushima Dai-ichi Nuclear Power Plant accident and its change with time. Additionally, uncertainties in the relaxation mass depth ($\beta$, g cm$^{-2}$), a parameter representing the depth distribution, and differences from the findings after the Chernobyl Nuclear Power Plant accidents and the Weapons test were evaluated.

Soil samples were collected at 84-91 locations, mainly within 80 km of 1F, during a total of 17 campaigns between December 2011 and September 2024. Soil was collected with a scraper plate, 8-9 layers to a depth of 0-10 cm. Air dose rates at 1 m above the ground were also measured at the same location using NaI scintillator. The $^{137}$Cs-activity in the samples was analyzed by germanium detector (GC3020-7500SL, Canberra, Meriden, USA). The Cs depth distribution in the soil was evaluated by the depth at which 90% of deposition occurs ($L_{90}$) and $\beta$. To obtain $\beta$, the exponential function and the hyperbolic scant function were fitted. Samples for which both functions could not be fitted were excluded from the analysis. For samples with hyperbolic scant distribution, the deposition was further determined by a fitted function, and then an exponential approximation was assumed to calculate an effective $\beta$ ($\beta_{eff}$) that satisfied both deposition and air dose rate.

The geometric mean of $L_{90}$ increased from 2.0 cm 9 months after the accident to 5.6 cm 13.5 years after the accident. Changes in $\beta$ and $\beta_{eff}$ with time are shown in Figure 1. Both $\beta$ and $\beta_{eff}$ increased with time and was well represented by a power function (Root Mean Squared Error = 0.71 g cm$^{-2}$). The International Commission on Radiation Units and Measurements recommends $\beta$ values depending on years after the deposition based on the findings after the Chernobyl Nuclear Power Plant accident and the Weapons test, and the $\beta$ values in this study are generally lower than the recommended values.

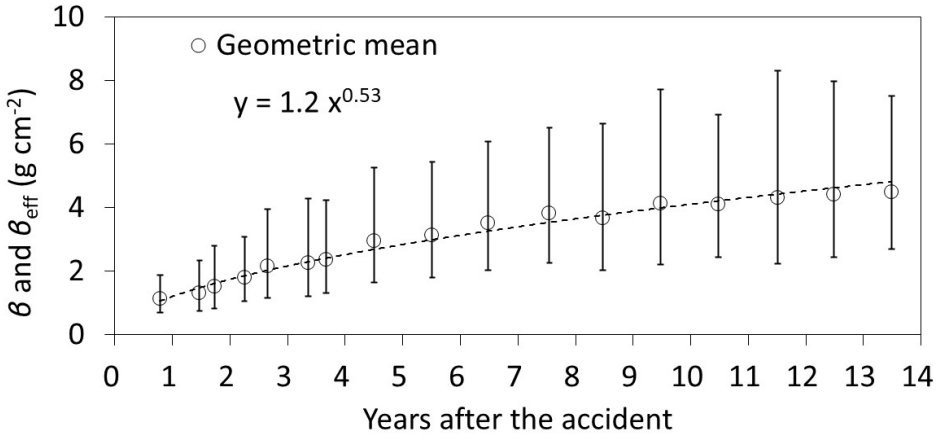



Figure 1. Increase in $\beta$ and $\beta_{eff}$ with time after the Fukushima Dai-ichi Nuclear Power Plant accident.

# Determination of background concentrations of tritium in the freshwater of Fukushima and in the seas around Japan.

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Tritium is a naturally occurring radioactive nuclide of hydrogen, produced routinely by a nuclear reaction in which cosmic ray-derived neutrons destroy nitrogen and oxygen in the atmosphere. The tritium reaches terrestrial waters through rainfall and flows into the marine environment through rivers. Tritium is also produced artificially by nuclear facilities and released into the marine environment either directly or via the atmosphere and rivers. In Japan in 2011, the Tokyo Electric Power Company Holdings, Inc. nuclear power plant accident occurred and the contaminated water with high concentrations of radioactive nuclides was produced. They removed various nuclides other than tritium from the contaminated water to safe levels to produce the Advanced Liquid Processing System (ALPS) treated water. The ALPS treated water is diluted with a large amount of seawater and then discharged into the sea. As the treated water is diluted by the surrounding seawater after discharge, the concentration of tritium in the seawater is the same as before discharge. It is important to determine the background concentration of tritium in Japan, as the discharge will continue for a long time into the future. In this study, the background concentrations of tritium collected from the Northern Pacific coast of Japan, the Sea of Japan, and the freshwater area of Fukushima Prefecture have been determined.

Seawater and some marine fishes were collected from off Fukushima and the Japan sea by the R/V Soyo-maru, while other fishes and marine algae were obtained through the fisheries cooperatives. Fresh water samples and freshwater fishes, white-spotted char (*Salvelinus leucomaenis*), were taken from the Takigawa Dam reservoir on the Tomioka river basin in Fukushima Prefecture. Tritium in samples were determined according to the method published by the MEXT of Japan (2002). As the concentrations of tritium were low in samples collected in the marine environment, the seawater and water samples in marine organisms were concentrated using a solid polyelectrolyte membrane electrolysis technology. Tritium in samples were then measured by a low background liquid scintillation system.

In Figure 1, tritium concentrations in the marine environment around Japan have been shown to be low in all cases, lower in marine than in freshwater. The tritium concentrations in water of the Takigawa Dam were <0.26−0.41±0.86, and the TFWT concentrations in white-spotted char were 0.23±0.052−0.35± 0.052. These tritium concentrations were similar to that, 0.50±0.21 Bq/L, in the river water around Japan reported by Sugihara (2009).

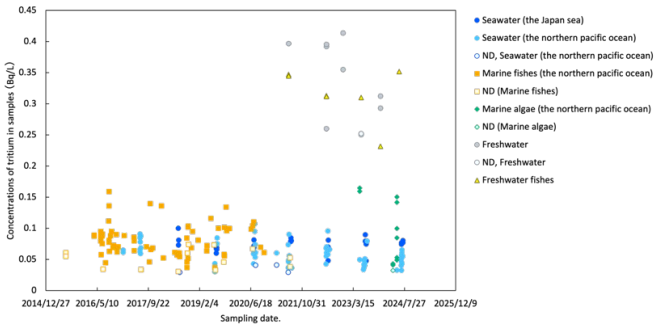


Figure 1. Tritium concentrations in the freshwater and marine environment in Japan.

MEXT of Japan (2002) version 2.0, Official methods of analysis of tritium. Chiba, Japan Chemical Analysis Center, 127pp (in Japanese).; Sugihara, S. (2009) Distribution of Tritium in River Water. J. Plasma Fusion

Res., 85, 429-430 (in Japanese).

# Airborne $^{210}$Pb and trace elements as tracers for atmospheric pollution in Helsinki metropolitan area

**Eleftheria Ioannidou,[1] Stefanos Papagiannis[2], Manousos Ioannis Manousakas[2], Mika Vestenius[3], Konstantinos Eleftheriadis[2], Jussi Paatero[3], Alexandra Ioannidou,[1,*]**

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Over a 44-year period (1962–2005), 16,070 daily and 608 weekly air filters from metropolitan area of Helsinki, Finland, were analyzed to assess long-term atmospheric pollution trends. Daily filters were used to measure the radioactive isotope $^{210}$Pb, while weekly filters assessed concentrations of 17 different trace elements (Na, Al, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Br, Pb). The determination of the concentrations of the radioactive isotope was completed with the appropriate automatic alpha and beta radiation analyzer. In addition, the weekly filters were properly prepared and measured using the Epsilon 5 high-resolution X-ray spectrophotometer. Most elements showed significant decrease in concentration, with Pb declining by 95%, followed by large reductions in Al (86%), Si (88%), S (82%), and Ca (89%), and smaller reductions in Cu (37%), Br (32%), and Cl (22%); $^{210}$Pb decreased by 51.6%. Source analysis based on Positive Matrix Factorization Analysis, using SoFi software, identified four main pollutant origins: road dust (linked to leaded fuel), heavy oil/secondary sulfate combustion, traffic emissions, and natural dust (soil). For the total of 44 years studied, significant decreases in concentrations were observed for all elements, most of which were over 50%: Na(-74%), Al(-86%), Si(-88%) , S(- 82%), K(-82%), Ca(-89%), Ti(-80%), V(-89%), Cr(-82%), Mn(-77%), Fe(-77 %), Ni(-61%), Zn(-72%) and Pb(-95%).

To understand the spatial origin and potential sources of pollutants, Potential Source Contribution Function (PSCF) analysis was applied, which calculates the probability for each potential pollutant source area, based on the frequency of high concentrations. From the trajectory analysis, it emerged that Finland is an area directly affected by transboundary pollution, mainly from air masses coming from its eastern border (air masses coming from Russia), but also from areas of Northern Europe. In these source areas there are intense industrial activity and energy production facilities, with the result that the air masses coming from there are enriched with several gaseous pollutants, containing both trace elements and radioactive isotopes.

# Airborne $^{210}$Pb and trace elements as tracers for atmospheric pollution in Helsinki metropolitan area

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Over a 44-year period (1962–2005), 16,070 daily and 608 weekly air filters from metropolitan area of Helsinki, Finland, were analyzed to assess long-term atmospheric pollution trends. Daily filters were used to measure the radioactive isotope $^{210}$Pb, while weekly filters assessed concentrations of 17 different trace elements (Na, Al, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Br, Pb). The determination of the concentrations of the radioactive isotope was completed with the appropriate automatic alpha and beta radiation analyzer. In addition, the weekly filters were properly prepared and measured using the Epsilon 5 high-resolution X-ray spectrophotometer. Most elements showed significant decrease in concentration, with Pb declining by 95%, followed by large reductions in Al (86%), Si (88%), S (82%), and Ca (89%), and smaller reductions in Cu (37%), Br (32%), and Cl (22%); $^{210}$Pb decreased by 51.6%. Source analysis based on Positive Matrix Factorization Analysis, using SoFi software, identified four main pollutant origins: road dust (linked to leaded fuel), heavy oil/secondary sulfate combustion, traffic emissions, and natural dust (soil). For the total of 44 years studied, significant decreases in concentrations were observed for all elements, most of which were over 50%: Na(-74%), Al(-86%), Si(-88%) , S(- 82%), K(-82%), Ca(-89%), Ti(-80%), V(-89%), Cr(-82%), Mn(-77%), Fe(-77 %), Ni(-61%), Zn(-72%) and Pb(-95%).

To understand the spatial origin and potential sources of pollutants, Potential Source Contribution Function (PSCF) analysis was applied, which calculates the probability for each potential pollutant source area, based on the frequency of high concentrations. From the trajectory analysis, it emerged that Finland is an area directly affected by transboundary pollution, mainly from air masses coming from its eastern border (air masses coming from Russia), but also from areas of Northern Europe. In these source areas there are intense industrial activity and energy production facilities, with the result that the air masses coming from there are enriched with several gaseous pollutants, containing both trace elements and radioactive isotopes.

# An Efficient Separation Method of $^{90}$Sr for Various Environment Samples Using Cation Exchange Resin

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Colum separation method using cation exchange resin (Chromalite® CGC100X8, 100-200 mesh, $H^+$ form, CEX) is a safer, faster and more convenient alternative to the traditional fuming nitric acid method for radiochemical analysis of $^{90}$Sr in environmental samples. This method has been applied for several years to analyze $^{90}$Sr in seawater as part of marine environmental monitoring efforts around the Korean Peninsula.

This study aims to expand the application of the CEX separation method to other types of environmental samples such as soil, sea sediment, and pretreated ash sample from biological materials including fish, seaweed, shellfish, and milk. Acid extracts from soil and sea sediment are diluted to 0.2M HCl using NaOH and deionized water, then loaded onto CEX (8 x 26 cm) without additional chemical pretreatment. Strontium (Sr) is selectively recovered using 4M HCl solution following a calcium (Ca) removing step. The 4M HCl eluate is either diluted for a 2$^{nd}$ CEX (8 x 22 cm) separation or processed through carbonate precipitate to recover Sr. For sea sediment samples with extremely high Ca content (~30%), a large CEX (8 x 33 cm) is required to minimize Sr loss during the loading step due to Ca interference. Unlike inorganic samples, ash samples are completely digested using a fusion digestion system. The dissolved ash is converted into a weakly acid solution and loaded onto a CEX (5 x 26 cm). Most bio-ash samples achieve sufficiently purification and high chemical recovery over 80% in a single column separation. However, samples with high Ca content, such as milk and fish, require a 2$^{nd}$ column separation using smaller CES (3 x 26 cm).

Chemical recoveries of Sr in soil and sea sediment were over 80% and 60%, respectively, in sequential column separation with or without the carbonate precipitation step. Most bio-ash samples yielded over 80% recovery. The chemically purified $^{90}$Sr was stored for 2 weeks to allow secular equilibrium, after which $^{90}$Y was quantified via Cerenkov radiation counting using a low-background LSC.

This method is cost-effective due to the reusability of CEX, which regeneration through a simple process. It is also efficient, minimizing the need for extensive chemical separation and allowing simultaneous separation of multiple samples. Furthermore, the column work is automized via a programmed solution injection system.

This separation method was successfully applied to both terrestrial and marine environmental samples in 2024.

# Analysis of $^{210}$Po, $^{234}$U and $^{238}$U in the components of the post-mining environment in the Sudetes

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The paper presents the results of the analysis of uranium ($^{238}$U, $^{234}$U) and polonium ($^{210}$Po) content in plant and soil samples collected from the area of the former uranium mine in Kowary (Sudety, Poland). The post-mining areas in Kowary are a place with an increased potential for contamination with natural radionuclides, due to the intensive exploitation of uranium ores carried out there in the past. Although several decades have passed since the end of mining activities, phenomena such as the movement of radionuclides, their accumulation in plants and the potential impact on local biocenoses remain a current subject of research. Analysis of the radionuclide content in environmental components is crucial for assessing the state of contamination, identifying potential ecological threats and planning remediation activities and radiological monitoring. The aim of the study was to assess the degree of environmental pollution and to determine the possibility of bioaccumulation of radionuclides by selected plant species occurring in the immediate vicinity of historical excavations.

Plant and soil samples were collected in selected locations located at various distances from former mining excavations. Before analysis, appropriate sample preparation was carried out, including drying, mineralization and radiochemical separation of the tested isotopes. The determinations were made using alpha spectrometry. Based on the obtained spectra, isotope concentrations were calculated and the highest and lowest concentrations of $^{210}$Po, $^{234}$U and $^{238}$U in the samples were determined, and annual effective doses for adults were calculated.

Literatura:

1. Prusińska, Maria, et al. "Optimization of $^{210}$Po determination in soil." *Nukleonika* 66.2 (2021): 75-79.
2. Skwarzec, Bogdan, et al. "Polonium, uranium and plutonium radionuclides in aquatic and land ecosystem of Poland." *Journal of Environmental Science and Health, Part A* 47.3 (2012): 479-496.
3. International Workshop on Environmental Contamination from Uranium Production Facilities and Their Remediation, & International Atomic Energy Agency. (2005). *Environmental contamination from uranium production facilities and their remediation: proceedings of an International Workshop on Environmental Contamination from Uranium Production Facilities and Their Remediation; held in Lisbon, 11-13 February 2004*. Internat. Atomic Energy Agency.

# Photon dose rate monitoring station with source-specific detection

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There is an early warning network (EWN) in operation in Europe comprising over 4500 stations performing real-time measurements of gamma dose rate. As there hasn't been any accidental atmospheric release of radioactivity, which would activate the alarm of EWN, the functionality of EWN monitoring stations in conditions of ground contamination hasn't proved yet. Accidental scenario under which they would be paralyzed is quite likely, e.g. ground deposition of atmospheric contamination, monitoring results would bring only vague data and their interpretation can be misleading than.

An innovative concept of a gamma dose rate monitoring unit was developed with the ambition of coping with this issue. The information which is going to be gained is not only gamma dose rate in the reference point, but due to ability of radioactive contamination distribution determination also values of the parameters particularly important for needs of crisis management. These parameters are e.g. total dose rate; dose rate from the deposit; activity concentration of I-131 and Cs-137 in air, surface activity concentration of I-131 and Cs-137.

The measurement setup uses two NaI(Tl) detectors, collimated and separated by lead shielding, to distinguish between soil and airborne contamination. However, despite this distinction, there are challenges associated with the deposition of airborne contamination on the surface of the probe. To address this, a supplementary detection unit consisting of set of GM detectors has been introduced. The measurement response enables differentiation of photon dose rate contributions originating from airborne contamination, surface deposition, and contamination of the device itself. Functionality of the supplementary detection unit was experimentally proved. Within a realistic accidental scenario simulating gamma ground contamination levels in the Czech Republic following the Chornobyl accident (≈5000 Bq/m$^2$), in the reference height 1m the system is capable of distinguishing an airborne dose rate of approximately 0.2 μGy/h from background contribution.

An assumption that aerosol deposition on the device surfaces happens homogeneously is a condition for functionality of the supplementary detection unit. A set of radioactivity dissipation experiments was performed to confirm this assumption. Technetium-99m and ultrasonic generators of aerosol particles were employed for this purpose, experiments were performed in a controlled environment.

The conference contribution describes a dose rate monitor of a novel structure, its detection capabilities and characterises the conditions under which it can bring reliable results.

The study was supported by the institutional funding of the Czech Ministry of the Interior of the Czech Republic (project VK01020090).

# Records of plutonium isotopes in different sedimentary environments in China

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Plutonium isotopes are promising tools for studying the modern sedimentary processes because of their long half-lives, high particle affanity and increasingly sensitive measurement technologies. In this study, records of plutonium isotopes in sediment cores collected from different sedimentary environments in China, such as shallow lakes, peat, and shrub dunes, were systematically investigated and comapred. Results showed that plutonium isotopes recorded in most sedimentary environments in China are mainly sourced from the global fallout of the Nuclear Weapon Tests (NWT) conducted during the 1940~1980s. It was found that the original deposition record of plutonium isotopes in shallow lake sediments and peat sediments were not fully preserved due to the post-deposition process such as sediment resistribution within water cloumns or sediment migration in deep layers. In comparison, nebkha (a unique type of aeolian dune formed by the interception of wind-blown sediments by vegetation, are widely distributed in arid and semi-arid regions) sediments are less affected by post-deposition processes, and the rapid accumulation of both distant and proximal plutonium-bearing sediments transported by wind resulted in the high preservation efficiency of Pu isotopes in arid environments. The findings not only underscore the widespread nature of plutonium contamination on a global scale—even in remote deserts—but also demonstrates the potential of plutonium isotopes as chronostratigraphic markers for interpreting aeolian sedimentary processes in desert environments.

# National propositions for post-accidental management in case of nuclear releases in the marine environment.

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The French Steering Committee for Post-Accidental management (CODIRPA) was established in 2005 to advice the government on post-accident management following a nuclear accident. These reflections led in 2012 then 2022 to the publication of post-accident management recommendations, which propose that public protection actions be based on a geographic zoning strategy for contaminated areas. In 2022, a "Marine Environment Management" working group was created with the mission of examining the relevance of these recommendations in the event of accidental contamination of the marine environment. The WG included more than 50 stakeholders issued from governmental institutions, nuclear operators and civil society. Obviously, the discussions considered feedback from the management of the consequences of the Fukushima accident in 2011. This conference will present the main issues and proposal arising from this work.

The dispersion of radionuclides at sea and their transfer to biological organisms is subject to environmental specificities. Dispersion kinetics differ from those in the atmospheric environment, with ocean currents being the vectors for transporting contamination. Dispersion and dilution at sea can take weeks, during which contaminated areas fluctuate. Establishing a fixed map of environmental contamination (as proposed in the terrestrial recommendations) from which to draw zoning would prove impossible. Sediments also play a major role through their ability to accumulate certain radionuclides which can be remobilized, especially on coastal areas, or constitute a secondary source of contamination for benthic organisms in a medium to long-term post-accident phase.

The primary issue in case of marine release is obviously related to fishing, but several other issues have been highlighted: shellfish farming, maritime traffic, tourism, ecological heritage... They were discussed to characterize them and identify the key points to be considered in the recommendations.

The risks of exposure to the population were studied based on a fictitious accident scenario with a major direct liquid release into the sea. Calculations of marine dispersion and transfers to seafood were carried out using ASNR numerical models. Dose calculations were done for different exposure scenarios (fisherman, tourist and local resident) and considering the various external and internal exposures pathways. The results show a very low risk of exceeding the effective dose limit of 20 mSv during the first-year post-emergency by external exposure, corresponding to the criterion to define the terrestrial exclusion zone. The main concerns would then relate to the measures and controls necessary to define and manage areas prohibiting or restricting the consumption of marine products before their sale, as well as those restricting access to beaches and associated activities.

The recommendations of the WG are thus focused on these topics, with an emphasis on the treatment of fishing and shellfish farming. It appears that the main principles of post-accident management defined in France for an accident involving contamination of the terrestrial environment could be applied to the marine environment. However, the mobility of radionuclides in this environment makes it difficult to define post-accident zoning a priori. This operational difficulty could be overcome by a strategy based on the results of environmental radioactivity monitoring, including citizen measurements, which should be carried out over a long period of time and over potentially large areas.

# Steps towards the determination of $^{237}Np/^{239}Pu$ atom ratios on air filters from Vienna, Austria

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In the early 1960s air filters were collected at the meteorological observatory Hohe Warte 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 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).

Now we concentrate on the determination of the $^{237}Np/^{239}Pu$ atom ratios of the collected aerosols (mainly from 1964-66), which represent pure nuclear weapons fallout nearly undisturbed by mixing or dilution processes. As there is still no Np tracer for AMS available, the challenge is to develop a chemical procedure where $^{237}Np$ is separated simultaneously with the Pu isotopes (including also $^{242}Pu$ or $^{236}Pu$ as a yield tracer). After carefully adjusting the oxidation states of Np and Pu (Maxwell et al. 2011), we used UTEVA to separate them from matrix elements and other radionuclides. When using $^{242}Pu$ as a tracer not only for Pu isotopes, but also for $^{237}Np$ (i.e. as a so-called non-isotopic tracer), it is essential that the ratio of the respective Np and Pu yields is well known. This ratio, however, is likely to change between different sample batches if they are processed after longer intermittence. Therefore, a certified reference material (e.g. IAEA-385 Sediment from Irish Sea) should always be co-processed together with the samples of interest as an internal standard for yield shift corrections.

Schönfeld T, Liebscher K, Karl F, Friedmann C, 1960, Nature 185, 192-193
Irlweck K, Friedmann Ch, Schönfeld T, 1981, Mitteilungen d. österr. Sanitätsverwaltung 82 (5), 81-84
Wallner G, Uguz H, Kern M, Jirsa F, Hain K, 2022, JENVRAD 255, 107030
Maxwell SL, Culligan BA, Jones VD, Nichols ST, Noyes GW, 2011, J Radioanal Nucl Chem 287, 223-230

# Correlation analysis between the in-situ measured and estimated annual gamma-dose values

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Some of the natural background radiation is from cosmic sources, and the majority comes from radionuclides on Earth. Among the terrestrial radionuclides, gamma-emitting isotopes are responsible for external exposure, while alpha and beta emitting isotopes are the most important for internal exposure. The most significant gamma-emitting natural radioisotopes in soil are Ra-226, Th-232, U-238 and K-40. The radiation exposure they cause can be measured by dose rate meters or can be estimated using different formulae.

In this study, gamma dose rate values were determined for 900 points in the Transdanubian region, Hungary. At the measurement locations soil samples were collected. The soil samples were dried, pulverized and homogenized, and then analyzed by gamma spectrometry to determine the main gamma emitting radioisotopes. Based on the activity concentrations of gamma-emitting radionuclides, the annual dose to the environment has been calculated

The aim of this study is to investigate the correlation between the measured and estimated annual gamma dose values and to determine the dependence of the estimation accuracy on different parameters (for example soil type, soil physical parameters).

# Modelling of radionuclides sorption in sediments of the Chornobyl exclusion zone based on smart-$K_d$ approach

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The current safety assessments of the specially equipped engineered near-surface disposal facility (ENSDF) for radioactive waste (RW) located in Chornobyl exclusion zone (ChEZ) are based on constant (conservative) distribution coefficients ($K_d$) reflecting sorption as the one of the predominant processes in the hydrogeological environment but not taking into account changing geochemical conditions strongly influencing the sorption behavior of radionuclides (RN). The mechanistic smart-$K_d$ approach [1] implemented in this study allows to consider variable geochemistry more realistically.

A global model of RN migration from ENSDF with groundwater was constructed and parameterized with two categories of data: site-specific (geophysical characteristics of sediments, relevant minerals of sediments (sorbents), geochemical conditions (groundwater), dose relevant RN: $^{137}Cs$, $^{90}Sr$, $^{239\text{-}240}Pu$, $^{241}Am$ and $^{237}Np$ (sorptives)) and invariant (thermodynamic) data for aqueous speciation, mineral solubility and surface species for relevant element/mineral pairs.

Mechanistic sorption models comprise of surface complexation model (SCM) and ion exchange for representative minerals of ChEZ sediments (quartz, orthoclase, kaolinite, montmorillonite, illite) for all above-mentioned RNs. As SCM data for some element/mineral pairs were missing, chemical and mineralogical analogies were applied (e.g. U(VI) used as chemical analogue for Np(VI) and Pu (VI)).

Calculated smart-$K_d$ values (in $m^3/kg$) for all relevant elements were determined as a function of pH, Eh, ionic strength, [DIC], [$SO_4^{2-}$] (Figure 1). They served as input data to calculate limits of specific activities of the RN with respect to RW acceptance criteria, applying an inverse modelling approach. Varying the smart-$K_d$ values and the site-specific parameters, global sensitivity analysis will be performed.

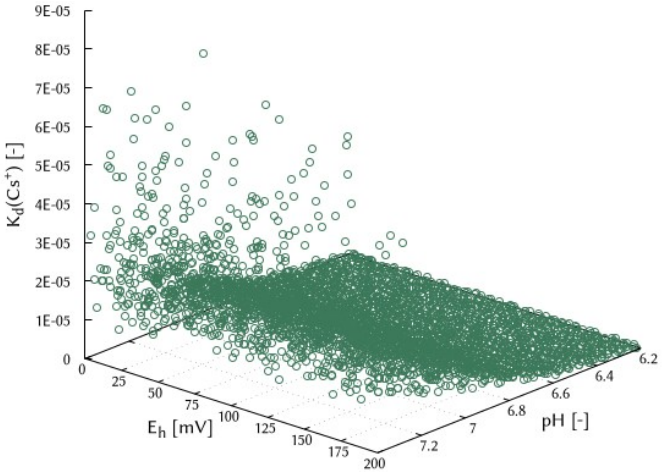



Figure 1. 3D scatter plot of smart-$K_d$ values for $Cs^+$ as function of pH and Eh

The authors gratefully acknowledge the funding provided by the Siebold Sasse Foundation (Leibniz University Hannover, Germany).

1. Stockmann, M., Schikora, J., Becker, D.-A., Flügge, J., Noseck, U., Brendler, V. (2017) Smart $K_d$-values, their uncertainties and sensitivities – Applying a new approach for realistic distribution

coefficients in geochemical modeling of complex systems, Chemosphere 187, pp. 277–285.

# Estimate the Po-210 content of consumables

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In addition to basic consumer goods, a significant part of the population consumes a variety of pleasure goods, such as tea, coffee, chocolate and tobacco products. Products of plant origin may also contain naturally occurring radionuclides, of which some have been shown to contain elevated levels. The main radioisotopes taken up and assimilated by plants come from the soil and atmospheric fallout. Several parameters influence the transport processes within plants, which determine in which part of the plant the given radionuclide accumulates. Large differences in radionuclide concentrations can be expected for the same plant species of different origin/soil. According to previous studies, radioisotopes such as Po-210 and Pb-210 mainly fall from the atmosphere onto the surface of plants, where they may remain for a shorter or longer period, depending on the surface quality of the leaves, or may even be assimilated into the given plant. Increased levels have typically been found in tobacco samples and mushrooms. In our work, we determined the main gamma-emitting radionuclide content and the activity concentration of the Po-210 isotope in extra-food products marketed in Hungary, whether we find elevated radionuclide concentrations in different consumer products.

The main gamma-emitting radionuclide content of the samples was determined using a high-purity HPGe semi-conductor gamma spectrometer. For the determination of the polonium content of the samples, the samples were first dissolved by a complete combined acid procedure and after the alpha-source was prepared with spontaneous deposition. The Po-210 activity concentration of the samples was determined by alpha spectrometry using semiconductor (PIPS) detector. Taking into account the consumption patterns of the products, we estimated the radiation exposure of the population through their consumption.

# Application of a sensitive LSC measurement procedure to the determination of $^3$H in drinking water and rainwater in the city of Seville

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The determination of tritium in environmental matrices is an important tool for carrying out environmental research such as hydrological studies when water samples are analysed and biological studies in the case of organically bound tritium. In both situations, as tritium produced during nuclear weapon tests has mostly decayed nowadays, more sensitive methods for the determination of this radionuclide are needed. Simultaneously, this reduction of the total tritium activity in the environment allows to perform a wider variety of environmental studies using this radionuclide as a tracer.

In this work, we present recent applications of an experimental procedure published recently (García-León et al., 2024), where the Liquid Scintillation Counting (LSC) equipment available at the University of Seville was optimized to obtain a Minimum Detectable Activity (MDA) as low as 74mBq/L, or 0.627 Tritium Units (TU) per litre of sample starting from 250ml of a water sample that was subject to electrolytic enrichment and counted by LSC for 10h.

This optimization was achieved by performing a careful selection of an NPE-free scintillation cocktail and counting conditions of the newer Quantulus GCT 6220, which provided a low background due to the use of Guard Compensation Technology (GCT). In the present contribution, the results of participation in Spanish and international proficiency tests are shown, allowing to conclude that the newer procedure is accurate in addition to being precise and more sensitive. Additionally, some insight into the medium-term performance of the system is given, as stability concerns regarding newer, more software-reliant spectrometers such as the Quantulus GCT 6220 have been raised by other authors.

Once the validation of the method had been performed, its application to two sets of rainwater and tap water samples, collected in Seville, (N37.359196 W5.98679), has allowed to obtain two respective time series of tritium activity concentration. Consequently, a decreasing trend in the activity concentration of $^3$H in drinking water has been observed, with a minimum of $(130 \pm 40)\mathrm{mBq/L}$. Additionally, the results in rainwater show interesting variations, being the minimum value obtained $(180 \pm 50)\mathrm{mBq/L}$. As expected, this improved procedure allowed us to obtain values above the MDA in almost all cases, allowing to continue with environmental monitoring even though the levels of tritium are the lowest observed in the time series in our monitoring station.

References

García-León, J. L., García-León, M., Manjón, G., & Rivera-Silva, J. (2024). Optimization of a new liquid scintillation spectrometer for the measurement of environmental levels of 3H in water samples. *Journal of Environmental Radioactivity*, *277*. https://doi.org/10.1016/j.jenvrad.2024.107465

Acknowledgements

This work has been funded partially by the government of Spain through PID2022-140680NB-I00 of MCIN/AEI/10.13039/501100011033 and the Consejo de Seguridad Nuclear (CSN).

# Pu and U isotopic signatures in sediment samples from Lake Bo Langvlei, South Africa

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We present the radiochemical method for the determination of major and minor uranium and plutonium radionuclides in sediment samples using ICP-MS techniques (sector field and multi-collector). The sediment core was obtained from Lake Bo Langvlei in South Africa. The main objective of this study is to provide comprehensive U and Pu datasets ratios (e.g., $^{236}U/^{239}Pu$, $^{236}U/^{233}U$, $^{240}Pu/^{239}Pu$, $^{241}Pu/^{239}Pu$), in order to identify sources of radioactive fallout contamination.

The Pu isotope ratios show large variations with three major phases: (i) an initial phase dominated by the nuclear weapon testing in the Pacific Proving Grounds ($^{240}Pu/^{239}Pu > 0.20$, sediment depth 7.5 - 10.5 cm), followed by (ii) a period of maximum Pu activity marked by fallout from the nuclear tests in French Polynesia ($^{240}Pu/^{239}Pu$ ~0.15, sediment depth 4.5 - 7.5 cm), and finally (iii) a phase with a Pu isotope signature consistent with global fallout ($^{240}Pu/^{239}Pu > 0.18$, sediment depth 2.0 - 4.5 cm). We observed $^{233}U/^{236}U$ isotope ratios varying between 0.010 and 0.023, with large uncertainties.

## Direct Plutonium Transfer from soils to animal biota in Palomares

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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 refuelling 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.

The Palomares radioactive particles disseminated in the soils have a micrometre size, are formed by a mixture of weapon Pu and enriched U, and particularly are found in a quite refractory form as we have proved by performing controlled leaching experiments treating isolated particles from the area to different leaching agents (water, HCl 2M, rumen cow fluid). This refractory behaviour limits enormously the transfer of the Pu and U to water and plants, appearing as the most important transfer route the direct one from soils to specific animal biota (snails, rabbits).

In this presentation we will show initially a compendium of the experiments performed in our laboratories by a) isolating and characterizing Palomares radioactive particles using non conventional, no radiometric techniques, and b) performing control laboratory leaching experiments to analyse its behaviour. Afterwards we will concentrate our presentation in showing the experimental work performed to demonstrate and evaluate the direct transfer of radioactive particles from soils to snails and rabbits, and its relation of these transfers with the feeding habits of these animals.

# Estimation of air dose in forest considering slope directional movement of Cs in forest soil

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Forests contaminated by radionuclides released in the Fukushima Daiichi nuclear accident have yet to be decontaminated except for an area about 20 meters from the forest edge and there are areas of high air dose rates scattered throughout the forest. Because forests make up about 70% of Fukushima Prefecture, decontamination of forests more than 20 meters from the forest edge is necessary to reduce the air dose rate in the forests and restore life and industry surrounding the forests. But it is impossible to decontaminate the entire forest. Therefore, it is necessary to consider appropriate scop and methods for forest decontamination. In this study, we attempted to develop a model to quantitatively evaluate air dose in response to forest and soil condition to examine decontamination methods that would enable rapid reductions in air dose rates in forests.

First, we developed a model to evaluate the air dose rate in forests using the point-kernel integration method. This method is a method for calculating the air dose rate by dividing a volume source into minute regions, treating each region as a point source, and adding up the contribution of the dose rate from each point source at the evaluation point. . The forest evaluated was a 1,064.2m x 1,032m forest slope in Kawauchi Village, Fukushima, Japan. The evaluation area was classified into forest and non-forest. This forest slope was modeled by stacking rectangular prisms consisting of air layer, homogeneous air and tree trunk layer, litter layer, O layer, and soil layer as shown. Next, we developed a model to evaluate the dynamics of radioactive Cs in forest soil. This model is a compartment model consisting of multiple soil layers and evaluates the balance of Cs-137 abundance in each compartment as a function of time. In parallel, we analyzed the distribution of radioactive Cs concentration in soil on forested slopes and developed a model for estimating slope movement of Cs in forest. This model divides the slope into multiple compartments and calculates the Cs concentration in each compartment at the end of rainfall.

By combining these three models, we developed a model that can calculate air dose rates with higher accuracy by taking into account both the slope movement of Cs in forest soil and the dynamics of radioactive Cs within the forest. Using this integrated model, we set up decontamination scenarios for one forest area of Kawauchi Village, Fukushima and predicted future changes in the air dose rate for each scenario. Although there are issues remaining regarding the parameter settings of our model, it can quantitatively evaluate the effect of reducing the air dose rate when decontamination is carried out in forests and therefore can provide useful knowledge for formulating forest decontamination policies in local government of Fukushima.

This work was supported by JSPS KAKENHI Grant Numbers 19H01164, 24H00776.

# Polyelectrolyte complexes of chitosan and sodium alginate for the sorption of selected radionuclides from aqueous solutions

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The worldwide production of radioactive waste is projected to rise in the coming years as more countries turn to nuclear energy to lessen their dependence on fossil fuels. As a result, it is crucial to explore and develop remediation methods capable of removing radionuclides from radioactive waste, including those released into the environment [1,2]. Radioactive waste wasters that contain radioactive metal ions, e.g. Cs(I), Sr(II), Co(II) and Am(III) are dangerous for people and for the environment. There are several methods to removal them from aqueous samples, water streams and wastes. Alternative method of eliminating the radioactive metals from waste water is sorption by low cast natural materials of the biological origin. Among its major advantages over conventional treatment are: low cast, easy regeneration of biosorbent and possibility of metal recovery [3].
This work focuses on the synthesis of hydrogel sorbents based on a polyelectrolyte complex (PEC) of chitosan and sodium alginate and the examination of the sorption process of the radionuclide $^{137}$Cs(I) $^{85}$Sr(II), $^{60}$Co(II) and $^{241}$Am(III). The sorption process was investigated in relation to the pH of the initial solution and the contact time between the solution and the sorbent. These parameters were measured using γ-ray spectrometry with high-purity germanium. The equilibrium data were analyzed using the Langmuir, Freundlich, and Dubinin–Radushkevich sorption isotherms. The PEC was characterized by SEM, SLMK and TGA/DTG. The sorption capacity of the PEC was determined based on the removal efficiency and distribution coefficients.

**Acknowledgments**
This work was financed by Military University of Technology under research UGB 22-027.

**References**
[1] Liu H, Tong L, Su M, Chen D, Song G, Zhou Y (2023) The latest research trends in the removal of cesium from radioactive wastewater: a review based on data-driven and visual analysis, Sci. Total Environ., 869, 161664.
[2] Ma Z, Ranjith PG, Rathnaweera TG, Kong L (2019) Review of application of molecular 28 simulations in geological high-level radioactive waste disposal, Appl. Clay Sci., 168, 29 436–449.
[3] Ahmad WA, Jaapar J, Mior Ahmad KMZ (2004) Removal of heavy metals from wastewater. In: Pandey A (ed): Concise encyclopedia of bioresource technology, The Haworth Press Inc., New York, pp 152-157.

# Radon concentrations, causes, and exposure in South African tourist caves

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Radon is a naturally occurring radioactive gas resulting from the decay of uranium, which is present in varying amounts in all rocks and soil. In caves, radon concentrations can be particularly high due to the confined nature and limited ventilation of these environments. The concentration of radon in caves is influenced by several factors, including the lithology of the cave, the uranium content of the surrounding geology, the rate of radon emanation, and the cave's ventilation dynamics. Limestone caves, for example, can exhibit significantly different radon levels compared to caves formed in other rock types, due to differences in permeability and uranium content.

High radon levels pose significant health risks to humans, particularly to cave explorers, guides, and researchers who may spend extended periods in these environments. Radon is a known carcinogen, and prolonged exposure to high concentrations can lead to lung cancer. Therefore, monitoring and mitigating radon levels in caves is essential for the safety of frequent visitors and workers in these natural formations. Furthermore, understanding radon behavior in caves provides valuable insights into geological and environmental processes, making it a critical area of study in both environmental science and public health.

This study presents measurements of radon concentrations in various tourist caves in South Africa, aiming to assess radon exposure and risk to guides, tourists, and researchers. Additionally, it investigates the relationship between radon concentrations and cave dynamics, along with the environmental processes influencing its accumulation. Measurements were conducted using electret ion chambers (EICs) and the radon concentrations determined in different parts of the caves. These results were mapped and analyzed with geographic information systems (GIS) software and areas with elevated radon levels were identified. These areas were then correlated with occupation by tour guides and tourists to determine their exposure. Finally, the cave geometry, dynamics and geology are then used to determine the possible causes of elevated radon concentrations and explain its accumulation.

# Modeling Rainfall-Induced Soil Moisture Effects on Ambient Dose Rates in Fukushima Forests

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The Fukushima Daiichi Nuclear Power Plant accident, triggered by the Great East Japan Earthquake in March 2011, caused widespread contamination of forested areas with radioactive materials. Among the released radionuclides, cesium-137 (Cs-137), with its long half-life, has remained a primary contributor to elevated ambient dose rates in forests over the long term. Recent studies (e.g., Nakanishi et al., 2023) have shown that rainfall increases soil moisture, which attenuates gamma rays emitted from Cs-137 in the soil, leading to a temporary decrease in dose rates. This variation poses challenges in accurately analyzing long-term trends in ambient radiation levels.

The objective of this study is to model the effect of rainfall-induced soil moisture fluctuations on ambient dose rates in forests and to clarify the mechanisms behind these changes. Continuous monitoring of meteorological parameters, soil moisture, and ambient dose rates has been conducted since April 2024 at two sites—Iitoi and Fuyuzumi—located approximately 40 km northwest of the Fukushima Daiichi NPP. These sites were selected for their contrasting forest structures due to thinning treatments, providing an opportunity to evaluate the impact of forest density on rainfall infiltration and soil water dynamics.

Results showed that, following rainfall, soil moisture in the thinned plots increased from 33.1% to 35.0%, and ambient dose rates decreased significantly from 0.90 µSv/h to 0.75 µSv/h. In contrast, the control plots exhibited a decrease in soil moisture from 28.6% to 25.5%, with dose rates remaining around 0.85 µSv/h. These findings indicate that forest density affects both rainfall interception and soil evaporation, which in turn influence temporal variations in ambient dose rates.

Additionally, a simplified version of the model was applied to data from ten other monitoring sites with periodic observations. This enabled the estimation of long-term trends in ambient dose rates after correcting for the effects of rainfall. The outcomes of this study provide a valuable tool for assessing long-term radiation exposure due to Cs-137 and offer critical insights for future forest management and resident return policies.

**Reference**

Nakanishi, M., Onda, Y., Takahashi, J., Kato, H., Iida, H., Takada, M. (2023) Changes in air dose rates due to soil moisture content in the Fukushima prefecture forests, *Environmental Pollution*, 334, 122147,DOI:10.1016/j.envpol.2023.122147

# Preliminary results in: Simultanious determination of $^{210}$Bi, $^{210}$Po, $^{226}$Ra and $^{228}$Ra with spontaneus deposition on various surfaces by liquid scintillation counting

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**Abstract**

The accurate determination of naturally occurring radionuclides, such as $^{226}$Ra, and its decay products - $^{210}$Pb, $^{210}$Bi, and $^{210}$Po - is essential in environmental, geological, and radiological research, including $^{228}$Ra, which plays a crucial role in assessing groundwater dynamics and long-term radiological exposure. These isotopes act as important tracers and dating tools: $^{210}$Pb is used for recent sediment and soil dating, $^{210}$Bi and $^{210}$Po help study short-term aerosol and environmental processes. The measurement of $^{210}$Po is also important on its own, as it is highly carcinogenic. $^{226, 228}$Ra indicate natural radioactivity and long-term exposure risks. Their precise measurement supports radioprotection, environmental monitoring, and the understanding of both natural and artificial processes.

The determination of $^{226,228}$Ra is most commonly performed using gamma or alpha spectrometry. Gamma spectrometry offers the advantage of minimal chemical preparation; however, it is limited by relatively high detection limits. In contrast, alpha spectrometry provides significantly lower detection limits, but requires labor-intensive and time-consuming radiochemical separation procedures. A similar situation applies to $^{210}$Pb, which is typically measured by gamma spectrometry despite its low gamma yield or by liquid scintillation counting in oxalate form. Given that $^{210}$Pb reaches secular equilibrium with its decay products, $^{210}$Po and $^{210}$Bi, within approximately two years, it can be indirectly quantified through the measurement of these daughter isotopes. Overall, these conventional methods often involve considerable delays and may not always yield precise or efficient results.

To overcome these challenges, we developed an improved methodology based on LSC coupled with spontaneous ion deposition techniques. This approach allows for the rapid and sensitive determination of $^{210}$Po, $^{210}$Bi, with minimal sample preparation. The method adapts the classical $^{210}$Po disk deposition technique by using **wires** (made of different shapes and materials) instead of a disk, enabling direct immersion in the scintillation cocktail. This innovation enhances counting geometry in the LSC spectrometer, reduces quenching, and eliminates shadowing effects.

In parallel, $^{226}$Ra and $^{228}$Ra from water samples were measured by spontaneous deposition onto manganese dioxide-coated polyamide forms, which were directly introduced into the LSC cocktail. This adaptation enabled efficient and reproducible $^{226}$Ra detection without extensive chemical processing.

Deposition was tested on copper wire and subsequently on **silver-coated** copper and **nickel** wire, as these materials exhibit different properties influencing radionuclide deposition behavior. Additionally, wires were shaped into **spirals** to assess potential improvements in deposition efficiency. Testing with copper wires of various diameters (0.75mm - 3mm) revealed that the highest efficiency (65.85 ± 5.17%) was achieved using a 3 mm wire. The efficiency of the nickel wire was significantly lower compared to the others (42.21 ± 5,36%). Silver coating further increased the efficiency (72.93 ± 6.07%), while the spiral form offered no additional gain (64.29 ± 2.99%). Time-resolved measurements confirmed the co-deposition of $^{210}$Bi and $^{210}$Po, with $^{210}$Po depositing more efficiently on silver. Their equilibrium in natural systems allows simultaneous deposition to lower detection limits to 7–12 mBq.

To demonstrate applicability, the method was tested on peat moss from Crveni Potok (Tara National Park, Serbia), yielding 78.28% efficiency (±7.09%). With ~13% overall uncertainty, it is well-suited for low-level, multi-isotope environmental analyses.

# Modeling the Fate of Cs-137 in the Ocean: Toward Detection of Climate Variability

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Cesium-137 ($^{137}$Cs) is a long-lived, soluble anthropogenic radionuclide introduced into the world's oceans since 1945. A significant pulse of $^{137}$Cs was supplied by atmospheric nuclear weapons testing in the early 1960s, followed by a steady decline. Additional localized increases in $^{137}$Cs concentrations resulted from reprocessing plant discharges starting in the 1970s and from the Fukushima Daiichi Nuclear Power Plant accident in 2011. By 2025, except in limited areas such as parts of the Arctic Ocean and coastal regions near Fukushima, the impacts of these inputs have largely diminished. Due to its conservative behavior in seawater and long half-life, $^{137}$Cs serves as an effective tracer for studying ocean circulation processes. In this study, we simulated the spatial and vertical distribution of $^{137}$Cs from 1945 to 2030 using a global ocean general circulation model (OGCM) driven by Ocean Model Intercomparison Project (OMIP) Normal Year Forcing (NYF), and compared it to results using OMIP Global Interannual Atmospheric Forcing (GIAF) from 1958 to 2007. Model outputs were validated against an extensive observational database containing more than 19,000 $^{137}$Cs measurements. Simulated distributions showed good agreement with observations, particularly at basin scales in the North Pacific and North Atlantic. In the North Pacific, subduction was identified as the dominant mechanism transporting $^{137}$Cs into the intermediate layers, whereas deep convection controlled its distribution in the North Atlantic deep ocean. The model developed in this study enables derivation of key diagnostic metrics that characterize tracer transport properties, such as the apparent half-life (Tap) and the first-moment depth of cesium-137 ($^{137}$Cs). These metrics are highly sensitive to the strength of ocean circulation and vertical mixing, suggesting comparisons with observational datasets could facilitate detection of changes associated with climate variability. Through the application of these tracer diagnostics, it may be possible to detect phenomena such as the Pacific Decadal Oscillation (PDO) in the North Pacific, variability of the Atlantic Meridional Overturning Circulation (AMOC) in the North Atlantic, and the formation of Subantarctic Mode Water (SAMW) and Antarctic Intermediate Water (AAIW) in the Southern Ocean. In the comparison between the Global Interannual Atmospheric Forcing (GIAF) and Normal Year Forcing (NYF) cases, the tracer diagnostics did not clearly detect the PDO signal, possibly due to relatively weak tracer response to decadal-scale variability or limitations in model resolution and temporal sampling. However, in the North Atlantic and Southern Ocean, the first-moment depths were found to be deeper in the GIAF case than in the NYF case, suggesting enhanced subduction under interannual variability. Although no vertical profiles of $^{137}$Cs have been observed in these key regions since the 1970s, future observations could reveal changes in tracer-based indicators critical for understanding climate variability. Therefore, integration of long-term $^{137}$Cs observational data with climate-sensitive modeling frameworks will be essential for improving detection and attribution of ocean circulation changes under global warming scenarios. In addition, from the perspective of preparing for future uncertainties, maintaining long-term $^{137}$Cs monitoring is crucial to establish a baseline for detecting potential future releases associated with severe nuclear accidents.

# The Influence of Ionizing Radiation for the Stability of $^{137}Cs$ Natural Sorbent Based on Dioctahedral Vermiculite

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Radioactivity is an intrinsic component of the environment. However, environmental threats arise when radionuclides are released into the environment in an uncontrolled manner. Consequently, all ecosystems and their constituents become susceptible to contamination. One significant environmental threat and radioecological challenge is posed by the long-lived radionuclide $^{137}Cs$. This isotope's environmental presence is linked to nuclear failures and accidents, such as those at Chernobyl or Fukushima. Elements of the environment that have become contaminated undergo various decontamination procedures to mitigate contamination.

The focal point of this study is the exploration of the potential applications of dioctahedral clay minerals. These minerals are inherently present in the environment. They possess the capability to sorb radioactive $^{137}Cs$. Nonetheless, the challenge lies in determining whether this sorption is enduring and non-destructive. Consequently, the objective of the research was to examine the influence of ionizing radiation on the structure of dioctahedral vermiculite. Natural vermiculite was saturated with stable Cs, encapsulated in a membrane, and the entire material was immersed in water and exposed to external radiation. A Cs-137, ZCs-10 source (IBJ, Świerk, $A_0$ = 155.59 MBq) was employed for this purpose.

Periodically, the composition of the solution containing the mineral was assessed by quantifying Cs, Al, and Na using the ICP-MS method. The analyses enable the determination of these elements' presence within the solution. A this moment, we can observe that there is an amount of the ions in solution, but, subsequent mineralogical analyses upon the conclusion of the experiment will provide insights into whether and how the mineral's interlayer structure has been disrupted or destroyed. This research is of significant importance and plays a pivotal role in the advancement of environmental decontamination methods.

Acknowledgements

The work was created as a result of research project no. 2021/43/B/ST10/00632 financed by the National Science Centre.

# Spatiotemporal variations of K-40 in atmospheric fallout caused by volcanic eruptions: A case study for Kyushu Island, Japan

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In the previous study, we evaluated the atmospheric impact of the eruptive activity of Sakurajima volcano, one of Japan's most active volcanoes located in southern Kyushu Island, on the atmospheric environment of Kagoshima City next to the volcano (around 10 km west), based on the amount of K-40 in atmospheric fallout measured in environmental radiation monitoring [1]. In Kagoshima City, there is a good correlation between volcanic ash fallout caused by Sakurajima volcano eruptions and K-40 fallout in atmospheric fallout, demonstrating that K-40 is an effective tracer for understanding the dynamics of erupted volcanic ash in the air.

In this study, we focused on atmospheric fallout monitoring data from various locations in Kyushu Island, where many active volcanoes, including Sakurajima Volcano, are concentrated, and evaluated and verified the relationship between K-40 fallout levels and volcanic activity of active volcanoes in the region (Fig. 1). The monitoring data were referred to the Environmental Radiation Database [2] in the same way as the previous study.

In Miyazaki City, located approximately 80 km east-northeast of Sakurajima Volcano, K-40 fallout tends to increase during active periods of Sakurajima Volcano, indicating that the volcanic ash from Sakurajima Volcano affects the atmospheric environment at Miyazaki City. Additionally, abnormally high K-40 fallout was observed in February and April 2011, which could be attributed to the large eruption of Shinmoedake volcano, located approximately 50 km west of Miyazaki City.

Furthermore, abnormal K-40 fallout amounts were confirmed at various locations, likely related to significant Aso volcano and Unzen volcano eruptions. At observation points east of erupted volcanoes, an increase in K-40 amount in atmospheric fallout could be attributed to incoming volcanic ash.

The K-40 fallout in atmospheric fallout measured through environmental radiation monitoring can serve as supplementary data for evaluating the ashfall area and deposition amount of volcanic ash and thus constitute valuable information for assessing the scale and ashfall-related environmental impacts of explosive volcanic eruptions.

[1] Kikawada and Hirose (2024) *J. Environ. Radioactiv.*, **278**, 107471.
[2] Nuclear Regulation Authority,
"Environmental Radioactivity and Radiation in Japan"
https://www.kankyo-hoshano.go.jp/data/database/




**Fig. 1** Map of Kyushu Island.
The location of active volcanoes and monitoring points for environmental radiation monitoring are shown with closed triangles and closed circles, respectively.

# Atmospheric Dispersion Modelling and Radiological Environmental Impact Assessment for the Potential Reopening of the Bataan Nuclear Power Plant, Philippines

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To address the growing demand in energy, the Philippine government set out a target to integrate nuclear energy in the country's energy mix and reduce its dependence on fossil fuels by 2032. One consideration is the revival of the inactive Bataan Nuclear Power Plant (BNPP), a Westinghouse Pressurized Reactor that can generate 621 MWe of electricity. As the unit was constructed in the 1980s, this work presents an updated radiological and environmental impact assessment (REIA) for the atmospheric releases during normal operation according to recent local weather conditions.

The Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) tool is used to simulate the air concentration and deposition of radioactive releases for $^{131}$I and $^{137}$Cs for the two pronounced seasons in the Bulacan-Pampanga-Bataan airshed in the months of February (dry season) and August (wet season) 2023. Meteorological data from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) at Cubi Point Weather Station, Zambales confirms the dominant ENE wind direction during the dry season for the months of November to April and a SW direction in the months of May to October reflected in the Global Data Assimilation System (GDAS) used in the dispersion simulations.

Ground level air concentration at a critical residence 1.5 km ENE from the plant was calculated to be $4.02 \times 10^{-6}$ Bq/m$^3$ for $^{137}$Cs and $1.08 \times 10^{-5}$ Bq/m$^3$ for $^{131}$I. Results also show that topographic effects play a significant role in the dispersion of radionuclides during the wet season. Dispersion simulations show that the Cordillera Range in the north-central part of the Luzon Island act as physical obstruction and reduce the overall horizontal dispersion of the radionuclides in the immediate downwind direction. During the dry season, the prevailing wind direction carries the radionuclides toward the West Philippine Sea, resulting to minimal exposure of the public. This study also demonstrates the use of HYSPLIT as an assessment tool for atmospheric releases at potential sites of nuclear power plants and its implications for REIA.

**References**

Climate and Agrometeorological Data Section (CADS), Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)

Draxler, R., Stunder, B., Rolph, G., Stein, A., Taylor, A., Zinn, S., Loughner, C., Crawford, A. 2023. HYSPLIT 5.3 User Guide. NOAA Air Resources Laboratory, Silver Spring, Maryland, USA

Final Safety Analysis Report: Philippine Nuclear Power Plant Unit 1. National Power Corporation

List of Airsheds in the Philippines. Environmental Management Bureau. https://air.emb.gov.ph/list-of-airsheds-in-the-philippines/

# The negative effects of environmental radioactivity on microbial communities inhabiting the surface of glaciers

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Environmental radioactivity have two sources, natural and anthropogenic. Studies testing the direct influence of natural radioactivity were mainly conducted in areas with elevated background radioactivity, such as the Ramsar area (Iran). While, the effects of anthropogenic radioactivity on biota are strongly limited to nuclear power plant accidents and former nuclear weapons test sites. The last decades of research have revealed that biotic sediment on the surface of glaciers worldwide, called cryoconite, effectively accumulates natural and anthropogenic radioisotopes originated from the atmospheric deposition. Due to simple trophic networks and truncated trophic structure, low temperatures, and elevated radioactivity, glaciers are good systems for testing radioisotopes-organisms interactions, both in terms of accumulation and negative effects of ionizing radiation (IR) on organisms.

Our study was conducted on the glaciers in the Alps. The first step assessed the factors on a glacial and interglacial scale that affect the accumulation of the main natural ($^{210}$Pb), and anthropogenic radioisotopes ($^{137}$Cs, $^{239+240}$Pu, $^{241}$Am) and their potential fate. This allowed us to understand the relationship between organisms and radioisotopes, primary microbial communities, which are crucial for glaciers and glacier-adjacent ecosystems functioning. The second part of the study tested the negative effect of natural and anthropogenic radioactivity on the biodiversity of bacterial and micro-eukaryotic assemblages, and the abundance of genes annotated to pathways related to DNA-repairing systems. Finally, to understand the cause-and-effect of the former relationship, we conducted a laboratory experiment testing the effect of elevated IR on oxidative and DNA-repairing systems activity based on differential gene expression using RNA-seq.

Analysis based on 20 glaciers sampled across the Alps revealed a high variation in mean activity concentrations of both natural and anthropogenic radioisotopes, ranging 36 Bq kg$^{-1}$ to 5785 Bq kg$^{-1}$ for $^{137}$Cs and from 1013 Bq kg$^{-1}$ to 10 711 Bq kg$^{-1}$ for $^{210}$Pb. This strong variation was also observed between samples on the same glacier. This intra-glacial variation is related to the organic matter content and chlorophyll concentration of the sediment. The inter-glacial variation is primarily related to the organic matter content of the sediment, with no effect of past precipitation. The richness of bacterial strains was negatively related to the total measured activity concentration between glaciers, with no effect of the $^{210}$Pb/$^{137}$Cs ratio. The negative effects of IR on the biodiversity of micro-eukaryotes were stronger when the total share of $^{210}$Pb was higher. This difference was explained by the differential accumulation of these radionuclides in cryoconite: $^{210}$Pb is more strongly bound to developing communities, while $^{137}$Cs is mainly bound to minerals. Moreover, glaciers with higher activity concentrations of $^{137}$Cs and $^{210}$Pb are inhabited by bacterial strains with a higher abundance of genes related to DNA-repairing systems, as a potential adaptation for living in an environment with elevated radioactivity. As these organisms are often endemic species, global

warming along with elevated radioactivity could threaten glacial biodiversity.

# Association of heavy metals and radionuclides to wastes from non-operating metallic mining sites in Extremadura (Spain)

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During the 2nd half of the 19th century and the first decades of the 20th century, there was a huge boom of mining sites in Extremadura (located at the western part of Spain) devoted to the extraction of heavy metals, such as Cu, Ni, Zn, Pb, Ag, Fe, Sn, and W, among others. However, due to various reasons theses activities ceased, and there are many abandoned metallic mining sites, many of them in ruins, with waste dumps left on site. Three former mining sites were selected, in which Pb-V-Zn-Ag, Pb-Ag, and Pb-Zn were exploited. The assessment of their environmental radiological impact was carried out in a previous work. In this study, samples from unaltered soil and waste dumps were considered in order to assess whether there is any difference in the association of Ag, Al, Ba, Ca, Cs, Fe, K, Mg, Mn, Na, Pb, Sr, Th, U, V, Zn. This assessment was carried out by the application of a sequential extraction procedure based on Tessier method, which gives information about: water soluble, exchangeable, carbonate, easily reducible, moderately reducible, organic-sulphidric, acid and residual fractions. Due to the low level of activity concentration in bulk samples, these elements were determined by ICP-MS. Comparing the results from unaltered soil and waste dumps, it can be observed that U association to water soluble and exchangeable fractions was about 10 % for both sample types, although differences in less mobile fractions can be observed.

Acknowledgements
This study was funded by the Consejería de Economía, Ciencia y Agenda Digital of the Junta de Extremadura, through the project “Evaluación del impacto radiológico ambiental de la minería metálica en Extremadura” (Ref. IB20060).

# Development of scenarios to assess the transfer of radionuclides to groundwater from liquid discharges in NORM industries

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By-products and wastes from NORM (Naturally Occurring Radioactive Material) industries present usually enhanced concentration of naturally occurring radionuclides. Some of them are liquid, such as waters from acid drainage sites, uranium mine tailings, or phosphogypsum ponds. There is a huge variability in the types of locations, size of water bodies, radionuclide concentration, type of water, hydrogeochemical characteristics of the site that can have a significant influence on the transfer of naturally occurring radionuclides to groundwater. Then, their occurrence in groundwater can pose a radiological hazard, since it can be used for irrigation, watering animals or drinking water. In this study, we developed two different scenarios in which most of these parameters are fixed after consulting the corresponding literature. The first scenario is based on a pond with high radionuclide concentration that leaks/percolates into a groundwater aquifer; whereas in the second scenario the source term is a leaking pipe in the ground above the aquifer. The purpose of these scenarios is to fixed the variable that can influence the transfer in order to later being able to compare the predictions made by several modelling software (PC-CREAM08, RESRAD offsite, Normalysa, AFRY, etc.)

Acknowledgements
This study is funded by the Consejo de Seguridad Nuclear through the project “Metodología simplificada para la estimación de la contaminación radiactiva de aguas subterráneas por efluentes líquidos”.

# Uranium mineralization in Camarines Norte, Philippines I. In-situ gamma spectrometry, geochemistry, and mineralogy

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Several localities with elevated radioactivity have been reported in the Camarines Norte mineral district, including the only verified uranium mineralization in the Philippines. To date, studies in this area are limited to reflected microscopy, exploration geochemistry, and preliminary resource estimates reported during the 1960/1970s. With renewed interest in nuclear energy and recognizing the importance of assessing the Philippines' natural uranium resources, we present the result of regional and local ground radiometrics surveys in the Camarines Norte mineral district designed to vector towards nuclear material-bearing localities. There is a prominent lithologic control on the measured K, eU, and eTh abundances with boxplot-defined high background and anomalous values located within the Eocene Tumbaga Formation and in the margins of Miocene intrusives. Background equivalent uranium (eU) values defined by the current dataset (n=161) range from 1 to 3 ppm. Dose rate of up to 5000 nSv/hr was measured at Nakalaya, with an eU value up to ~700 ppm. In Bessemer, the measured dose rate reaches up to 360 nSv/hr, with corresponding eU of 31.5 ppm. Dose rates measured in survey mode show an order of magnitude increase towards known uranium mineralized localities (e.g., Bessemer). Uranium mineralized zones delineated in Bessemer and Nakalaya have widths of less than 1 meter and are characterized negative Th/U anomaly in gamma transects. Bulk uranium concentrations determined by He mode ICP-MS/MS (n=27) indicate 10-100 times uranium enrichment in the Camarines Norte localities relative to Philippine crustal abundances. Likewise, we report the mineralogical characterization of uraninite from its principal Philippine locale with scanning electron microscopy, X-ray diffraction, and electron microprobe techniques. Larap uraninite is octahedral in form and measures ~80-250 microns along the c-axis. Powdered uraninite separates yield 2θ peaks at 28.15° (*1 1 1*), 32.73° (*2 0 0*), and 46.90°(*2 2 0).* Larap uraninite polyhedra consists of $U^{4+}$ cations coordinated with eight O atoms in cubic arrangement with each O atom bonded to four $U^{4+}$ cations, with a lattice constant value of 5.4905 Å. EPMA-WDS spectra confirm the presence of Th, Y, Ca, P, and Pb suggesting potential cation substitution. Assuming that the total Pb present is radiogenic, the timing of uranium mineralization in Larap can be constrained at 18-16 Ma.

# Radon Progeny Monitoring Outdoors Using Multiple NaI Detectors

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Monitoring of radon progeny concentration in atmospheric aerosol offers valuable insight into various environmental processes such as air masses transfer, aerosol residence times and seismic activity. However, measuring the atmospheric concentration of radon progeny in real time may prove challenging, mainly due to their relatively short half-lives. A gamma-spectroscopy technique utilizing a 3x3 NaI(Tl) detector measuring radon progeny collected on an air-filter during air sampling has been developed and is being applied at the Nuclear Engineering Laboratory of the National Technical University of Athens [1]. In this work, the measuring technique is upgraded by introducing another 2x2 NaI(Tl) detector for the monitoring of short-lived radon progeny in the surroundings of the measurement site. Radon progeny attached to sampled aerosol are measured with the NaI 3x3 detector, considered as the primary detector, while the gamma background near the primary detector, which is substantially higher during precipitation events, is measured with the NaI 2x2 detector. The combination of the signals from the two detectors improves the monitoring of radon progeny variations in atmospheric aerosol, filtering the rain-induced signals and yielding more reliable measurements which will hopefully contribute to a better understanding of radon progeny fluctuations in the lower tropospheric air.

[1] Kanoutos, K., Petropoulos, N.P., & Anagnostakis, M.J. (2024). *Continuous Measurement of Radon Progeny in Atmospheric Aerosol Using a NaI(Tl) Detector and a High Volume Air Sampler*. Poster presented at: Applied Nuclear Physics Conference (ANP 2024), 23-27 September 2024, Thessaloniki, Greece.

# Determination of $^{210}$Po in seafood using large-area grid ionization chamber alpha Spectrometry

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Polonium-210 ($^{210}$Po), a naturally occurring radionuclide in the $^{238}$U decay series, exists at trace concentrations in the environment. As a pure alpha emitter, $^{210}$Po ranks among the most radiotoxic nuclides known. With wide dispersion in the environment, $^{210}$Po enters human body via food chains, thus being a serious threat to human health. $^{210}$Po was known as one of the most important sources of internal dose received by humans from foods[1]. The maximum permissible human body-burden of ingested $^{210}$Po was $1.1 \times 10^3$ Bq[2]. Consequently, rapid analysis capability for diverse sample matrices is essential for risk assessment and post-incident decision-making. The purse of this study is to develop a rapid and reliable method for determination of $^{210}$Po using large-area grid ionization chamber α spectrometry.

In the experiment, the soft tissues of clam sample were taken out, dried at 105 ℃, and grinded into powder. 0.1-0.5 g of power was digested with $HNO_3$-$H_2O_2$ in microwave system, $^{209}$Po standard solution was added as the tracer. Followed eliminating acid, adding ultrapure water to disperse sample solution under ultrasonic. Then the sample solution was transferred directly into dish (ϕ25cm ), and the sample dish were then put in the vacuum oven, evaporated to dryness. The counting source prepared in this way can be put in large-area grid ionization chamber directly. The sample source were counted using large-area grid ionization chamber. The chamber filled with commercially available mixed gas of 90% Ar and 10% $CH_4$ to about 48.26 kPa[3]. Standard source ($^{237}$Np-$^{239}$Pu-$^{241}$Am mixed source, ϕ25cm) was used for energy calibration and efficiency determination.

The ϕ25cm blank dish was counted for 24 h, while mixed standard source for 30 min, to obtain detection efficiency 33% of the large-area grid ionization chamber α spectrometry. The minimum detectable activity (MDA) was $1.0 \times 10^{-3}$ Bq. $^{209}$Po standard solution was spiked in calm powder and the present method was used to prepare source. The recovery was 98.5%. The dry clam samples were analyzed using two methods. The result of 0.057 Bg/g activity in clam samples is good agreement with the commonly used method that the spontaneous deposition source (ϕ2cm) measured using multichannel α spectrometer. The method developed for measurement of seafood could achieve higher recovery (above 98%) and lower MDA, using small quantity of sample (0.1 - 0.5 g of dry sample).

Compared with the traditional method, the developed method can avoid separation process, using less quantity of sample and simplify the measurement process. The method is useful for measurement of other biological or environmental sample.

## REFERENCES

1. P. Planinšek, L. Benedik, et al. Comparison of various dissolution techniques for determination of 210Po in biological sample. Appl Radiat Isot, 81(11): 53-56 (2013).
2. H. Lee, J.Wang, et al. Annual dose of Taiwanese from the ingestion of $^{210}$Po in oysters. Appl Radiat Isot, 73: 9-11 (2013).
3. H.H ötzl, R.Winlkler, et al. Experiences with large-area Frisch grid chambers in low-levelα spectrometry. Nuel Instrum Methods Phys Res, 223(84): 290-294 (1984).

# A Computer Code for the Calculation of Efficiency Correction Factors due to Self-attenuation in γ-Spectroscopic Analysis of NORM

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Measurement of natural radioactivity with γ-spectroscopy remains a complex procedure, mainly due to the various parameters affecting detection efficiency. Self-attenuation inside the samples poses a major challenge, which is particularly intense for Naturally Occurring Radioactive Materials (NORM). For the accurate analysis of NORM, efficiency corrections need to be performed, especially for the low energy photons. The development of a MATLAB® code as a standalone application [1], focusing on the calculation of correction factors for self-attenuation, has been the goal of this on-going work. The Efficiency Correction Factors (ECF) are calculated with the "Integral Method" [2], for different materials, densities, source-to-detector configurations and photon energies. Several parameters affecting calculations were studied, namely material matrix, density and effective interaction depth inside the detector. The initial code results were compared with efficiency calculations from Monte Carlo simulations and proved promising, while also indicating that self-attenuation corrections should not only be limited to low energy photons (e.g. below 200 keV) as they may be important for much higher photon energies as well.

[1] Alafogiannis, I., Tugnoli, F., Mitsios, I., & Anagnostakis, M. (2022). Development of a Computer Code for the Calculation of Self-absorption Correction Factors in γ-Spectrometry Applications. *HNPS Advances in Nuclear Physics*, 28, 98–103. https://doi.org/10.12681/hnps.3607

[2] Debertin K., & Helmer R.G. (1988). *Gamma and X-ray Spectrometry with Semiconductor Detectors*. Amsterdam: Elsevier Science Publisher B.V.

# Radiochemical separation of $^{227}$Ac in environmental samples using solid-phase extraction with ion-imprinted polymer resin

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## Introduction

Radiochemical separation of naturally occurring actinides in water often requires several steps. Accurate quantification of actinium (Ac) necessitates the use of an internal standard. However, the scarcity of long-lived Ac tracers poses a challenge for a wide application of $^{227}$Ac as an environmental tracer. Radioactive $^{227}$Ac (actinium-227, $t_{1/2}$ = 22 years) arises from the radioactive decay chain of $^{235}$U (uranium-235, $t_{1/2}$ = $7.04 \cdot 10^8$ years, 0.7 % of the total U), is one of the rarest naturally occurring radioisotopes and is expected to be found at secular equilibrium with $^{235}$U. The direct predecessor of $^{227}$Ac in the $^{235}$U chain is $^{231}$Pa (protactinium-231, $t_{1/2}$ = $3.276 \cdot 10^4$ years) which has a high affinity to particles and sediments, unlike the $^{227}$Ac which is predominantly partitioned within the water column of lake and marine systems. This phenomenon enables to exploit $^{227}$Ac as a promising tracer for upwelling velocity and for providing information on water column stratification changes useful on 100-year scale.[1] Herein we propose a method for the radiochemical separation of $^{227}$Ac in water, employing a polymer resin imprinted with yttrium (III).[2]

## Materials and Methods

To test the extraction of $^{227}$Ac in the scope of use as a geological tracer, water sampled from the Lake Geneva was spiked with $^{227}$Ac and $^{243}$Am tracers. The actinides were pre-concentrated in two steps by co-precipitation with iron hydroxide and calcium oxalates which were then wet-ashed by microwave-assisted acid digestion under pressure. The extraction of $^{227}$Ac and $^{243}$Am was achieved from samples at pH 3 on 5 mL columns containing 2 g of $Y^{3+}$-imprinted polymer resin.[3] $^{227}$Ac and $^{243}$Am were released from column with 2 M HCl, electrodeposited on stainless steel discs and stored for 120 days to enable an ingrowth of alpha-emitting progenies of $^{227}$Ac prior to alpha spectrometry counting.

## Results

The experiments with water from Lake Geneva spiked with $^{227}$Ac and $^{243}$Am yielded a radiochemical recovery of $^{243}$Am in the range of 70-80 % using Y-imprinted resin. Initial counting shortly after the electrodeposition identified traces of $^{227}$Ac progenies (Figure 1, green trace). The samples were recounted after 120 days at equilibrium between $^{227}$Ac and its progenies and showed an ingrowth as expected (Figure 1, red trace). To quantify the $^{227}$Ac, $^{215}$Po peak free from isotopic interferences was used. Naturally occurring $^{238}$U and $^{234}$U were also partly (30 % of total U in water) retained by Y-imprinted resin, requiring a further development of a radiochemical separation method.

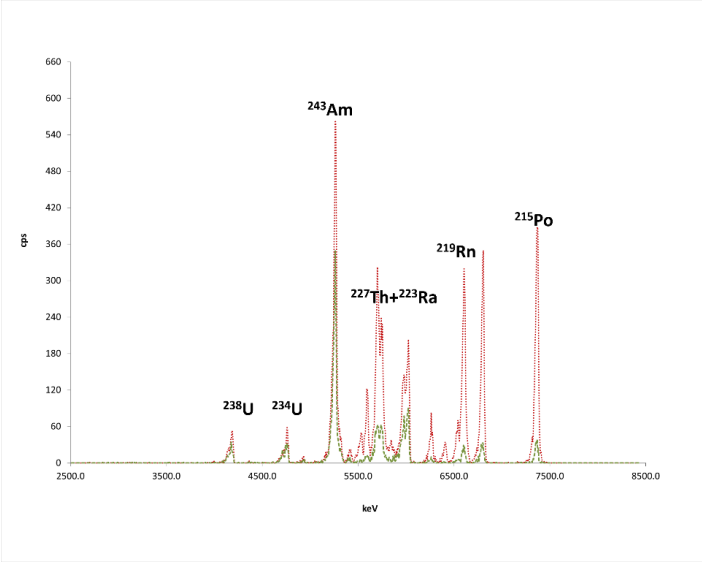



**Figure 1.** Alpha-spectrum of $^{227}$Ac progenies in Lake Geneva water extracted by Y-imprinted resin in the presence of $^{243}$Am tracer shortly after the radiochemical separation (green trace) and after 120 days of ingrowth (red trace).

## Conclusion

Tracer experiments with lake water showed that Y-imprinted resin can be applied for the determination of naturally occurring $^{227}$Ac. Combined with a very sensitive detection technique, *e.g.* accelerator mass spectrometry, it can pave the way to a broader adoption of $^{227}$Ac as an oceanographic tracer in environmental sciences.

## References

[1] Actinium-227 as a deep-sea tracer: sources, distribution and applications. W. Geibert *et al.* EPSL 198 (2002) 147-165
[2] Chauvin *et al.*, *Chem. Eur. J.* 12 (2006) 6852-6864
[3] Solid-phase extraction of Ac-225 using ion-imprinted resin and Am-243 as a radioactive tracer for internal dosimetry and incorporation measurements. Cusnir *et al*. *Anal. Chim. Ac.* 1194 (2022) 339421

# Determination of the depth distribution of Cs-137 in forest soil profile in Austria

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The Cs-137 concentration in Austrian soil results from its deposition during the Chernobyl accident in 1986 and to a minor part from its deposition during the nuclear weapon tests between 50's and 60's. Since this time the Cs-137 migrated into deeper soil depths. The Cs-137 concentration in the first 30 cm of Austrian soil was determined in the past in various projects. Nevertheless, just a few soils from forest environment have been analysed.

In 2022 a project started, in which soil layers of the forest environment down to 30 cm depth were analysed. It was financed by the federal ministry of Agriculture and Forestry, Climate and Environmental Protection, Regions and Water Management. Therefore, sampling sites were chosen regarding the interactive map of the soil contamination with Cs-137 [1] of Austria. This map is based on several hundred measurements taken after 1986, which were compiled. In the regions where no measurements were conducted the contamination was calculated by interpolation.

During the Chernobyl accident the contamination depended on the amount of rain at the specific location. Hence, some parts of Austria like Upper Austria still show higher contamination than other parts. The chosen sampling sites are located in the higher contaminated regions of Austria. In some cases, a high variability of the Cs-137 content has been observed in the first soil layer, even though the sampling was performed in close locations.

The results of the soil profiles show the migration of Cs-137 in the soil. Most of the Cs-137 is still located in the first 10 cm in forest soils. The results are presented in Bq/kgTr and Bq/cm². The values can be used to check if the data provided by the interactive map of soil contamination still fits reality. Additionally, they can be used to correct the data provided if necessary. This can happen when it was generated by an interpolation step between the measurement locations. Besides, this data can also be used to calculate transfer factors to plants, especially mushrooms, which are collected near these sampling sites.

[1] https://secure.umweltbundesamt.at/caesium/

# Radon exhalation from polymetallic nodules collected for research from the Clarion–Clipperton zone of the Pacific Ocean

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For several decades, polymetallic nodules lying on the ocean floor have been the subject of intensive global research, regarded as a potential future source of strategic metals. Recently, the issue of ionizing radiation exposure affecting personnel involved in the extraction, transport, storage, and processing of these nodules has become a topic of increasing scientific debate (Volz et al., 2023; Kunze et al., 2024; Dołhańczuk-Śródka et al., 2024). This concern arises from the fact that, in addition to valuable metals, these nodules also contain naturally occurring radioactive elements.

The aim of the present study was to assess the potential radiological hazards associated with polymetallic nodules. Samples used for radon exhalation analysis were obtained from the Interoceanmetal Joint Organization repository. These nodules were originally collected from the Clarion–Clipperton Zone in the Pacific Ocean.

Radon-222 exhalation was measured using an AlphaGUARD radon monitor in flow mode, employing a sealed exhalation chamber. The nodules were selected randomly, with each sample originating from a different collection site. Nodules from geologically diverse environments may differ not only in their mineralogical composition and origin but also in their radionuclide content, which directly influences their radon-emitting potential. Consequently, even under identical measurement conditions, nodules from different locations exhibited significantly varied radon exhalation coefficients.

The highest recorded surface exhalation rate was $2.45 \times 10^{-2}$ Bq·m$^{-2}$·s$^{-1}$. Such elevated emission could be attributed to localized enrichment in Ra-226, a highly porous structure, or the presence of fissures and channels that facilitate radon transport to the surface. This particular sample stood out both in absolute terms and in the variability of its readings.

The remaining samples showed exhalation coefficients ranging from approximately $3.3 \times 10^{-3}$ to $1.5 \times 10^{-2}$ Bq·m$^{-2}$·s$^{-1}$, reflecting considerable variability in the emission properties of the nodules studied. These results provide a valuable basis for assessing potential exposure risks associated with contact with this material during storage and transport.

References

Kunze Ch., Hummrich H., Lüttke T., Flesch K., Arndt R., Krzikalla A., Lucks Ch., Kuhn T., Vink A., Rühlemann C.: Full radionuclide analysis of polymetallic nodules from the Clarion-Clipperton-Fracture Zone in the NE Pacific. Applied Geochemistry, 2024, 175, 106165. https://doi.org/10.1016/j.apgeochem.2024.106165

Volz J. B., Geibert W., Köhler D., Rutgers van der Loef M. M., Kasten S., 2023, Alpha radiation from polymetallic nodules and potential health risks from deep-sea mining, Scientifc Reports,13:7985, doi.org/10.1038/s41598-023-33971-w.

Dołhańczuk-Śródka A., Kłos A., Janecki D., Ziembik Z., Skowronek A., Strzelecka A., Mianowicz K., Abramowski T.: Assessment of natural radioactivity levels in polymetallic nodules and potential health risks from deep-sea mining, Journal of Hazardous Materials, Volume 480, 5 December 2024, 136494, https://doi.org/10.1016/j.jhazmat.2024.136494.

# Evaluating impacts of the Fukushima Daiichi Nuclear Power Plant accident on tritium tracer applications in Fukushima Prefecture waters, Japan

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The anthropogenic tritium (H-3) with a half-life of 12.32 ± 0.02 years was released during the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident prompting tritium radionuclide measurements and complicating tritium-tracer interpretation in terrestrial waters of Fukushima Prefecture, Japan. In Fukushima Prefecture, the long-term tritium monitoring of rivers, dams, lakes and the ocean waters started from May 2011 to present, accounting for 96 monitoring sites sampled twice a year in summer and autumn-winter periods [1]. For the Fukushima coastal area, the highest tritium concentration of 12.71 TU was recorded on June 25, 2013, in the Maeda River site, which is located 5 km north of the FDNPP site boundary. Also, a few coastal river sites located from 20 km north of the FDNPPS site had measured tritium values up to 8 TU in 2011, indicating the anthropogenic influence. To establish tritium data in Fukushima precipitation, tritium in precipitation values from a general circulation model simulation of the FDNPP atmospheric release were matched to available tritium measurements in daily and monthly precipitation across Japan, leading to a tritium peak of 582 TU [2]. These modeled tritium values were combined with the tritium time-series scaled from the Tokyo to Fukushima coastal area allowing the estimation of mean transit times (MTTs) for tritium measurements in river, spring and artesian well between 2011 and 2014 [2]. The results show that tritium measurements in river and springs required the FDNPP tritium input while the artesian well tritium measurements were only affected by the thermonuclear testing input and not by the FDNPP accident [2]. Comparing these short-term measurements with long-term tritium monitoring data of the Fukushima Prefecture allows us to confirm that the FDNPP tritium pulse had negligible impact on the tritium levels [3]. It is also important to note that tritium in monthly precipitation had the highest value of 12.5 TU on June 2023 [3], whereas the release of water treated by an Advanced Liquid Processing System from the FDNPP site to the Pacific Ocean started on August 2023 below the established international safety standards [4]. In summary, the primary tritium source is precipitation containing natural tritium formed by cosmic rays in the upper atmosphere and tritium remains a useful tracer to estimate Fukushima waters circulation considering both natural and anthropogenic inputs.

References:

[1] Fukushima Revitalization Portal Site (2025). https://www.pref.fukushima.lg.jp/site/portal/

[2] Cauquoin, A., Gusyev, M., et al. (2025) Modeling tritium release to the atmosphere during the Fukushima Daiichi Nuclear Power Plant accident and application to estimating post-accident water system transit times, Japan, Environmental Science and Pollution Research, https://doi.org/10.1007/s11356-025-35919-1

[3] Gusyev, M., Cauquoin, A., Hirao, S., and Akata, N.: A review of tritium radioisotope in Fukushima waters, Japan, EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025, EGU25-20793, https://doi.org/10.5194/egusphere-egu25-20793, 2025.

[4] Cauquoin, A., Gusyev, M., Komuro, Y., Ono, J., and Yoshimura, K.: Simulation of anthropogenic tritium discharge into the ocean from the Fukushima Daiichi Nuclear Power Plant, EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025, EGU25-11395, https://doi.org/10.5194/egusphere-egu25-11395, 2025.

# Recovery of Rare Earth Elements and Carbon Sequestration of Phosphogypsum: Implications for Climate Action Resource Utilization

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Phosphogypsum, a major by-product of phosphoric acid production, is generated globally at 300 million metric tons annually and poses environmental challenges due to its radionuclide and heavy metal content. Philippines alone, millions of metric tons PG have accumulated highlighting the need for processing and recycling solutions to mitigate environmental hazards and recover critical minerals. PG contains rare earth elements essential for electronic and clean energy technologies. Additionally, its calcium-rich matrix makes it a possible candidate for carbon sequestration via mineral carbonation, presenting a dual opportunity for strategic material recovery and contribution to climate action. This study presents part 1 systematically evaluating radioactivity and REE concentrations in PG and explore optimized recovery pathways. Multi-technique characterization including HPGE Gamma Spectrometry, XRD, FE-SEM-EDS, and ICP-AES was employed to assess radioactivity, elemental composition and REE distribution. REE leaching experiments were made via Response Surface Methodology using Central Composite Design of Experiment optimizing for four factors five levels—concentration, temperature, leaching time, and solid-to-liquid ratio. HPGE gamma spectrometry revealed Ra-226 as the primary radionuclide in Philippine PG with in-situ radiometric survey shows average radiological profile of PG as TENORM having K (0.10%), eU (77.98 ppm) and eTh (1.15 ppm) and with average dose rate of 1.82 mSv/yr above the 1mSv/yr regulatory limit. Physical fractionation showed that REEs were evenly distributed throughout size fractions, indicating no significant enrichment in any size range to support recovery. FE-SEM EDS examination revealed their composition and microstructure. Due to REE sulfates and fluorides interrupting homogeneous crystallization, agglomerated PG structures have greater REE contents than crystalline forms. EDS showed fluorites were high REE-bearing minerals in PG. Uranium and radium were found homogeneously incorporated in gypsum matrix. PG samples showed calcium sulfate dihydrate and quartz as the main crystalline phases by XRD. REE-bearing minerals were not found, suggesting they are amorphous or below the instrument's detection limit. Second-order canonical models were generated, sulfuric acid leaching showed a maximum REE recovery of 46.32% under optimized conditions, pending experimental validations. Comparative modeling with hydrochloric and nitric acids revealed lower predicted efficiencies 32% and 56%, respectively, faux maximum efficiencies due to the presence of saddle points visualized in the models. Carbon sequestration efforts are currently under development. These findings highlight integrated strategies for TENORMs PG resource utilization for both economic and climate action.

# Exploring plant-fungal symbioses for bioremediation of radioactively contaminated soils from nuclear sites in Germany

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Over the past decades, significant quantities of solid radioactive waste have accumulated during the operation and decommissioning of nuclear facilities in Germany. In particular, this is related to radioactively contaminated soil at the Helmholtz-Zentrum Dresden-Rossendorf nuclear research reactor site and the Rheinsberg NPP site in Brandenburg. These soils, containing typical radionuclide vectors of nuclear installations operation, are categorized as low to intermediate-level radioactive waste. Their removal and treatment for the intermediate or final disposal entails high costs and significant efforts. Bioremediation represents a promising alternative for reducing the radioactive waste volume, particularly through biogenic processes aimed at radionuclide uptake or immobilization. Of special interest are plant-fungal symbioses, particularly involving arbuscular mycorrhizal (AM) fungi, which can significantly alter the chemical behavior and mobility of radionuclides in the rhizosphere, and enhance radionuclide availability for plant uptake.

This study investigates how specific plant-fungal associations could facilitate the removal of radionuclides from contaminated soils, potentially lowering their concentrations below regulatory limits. The plants selected for this experiment – *Medicago sativa* (lucerne) and *Helianthus annuus* (sunflower) – are known accumulators of soil radionuclides.

The three batches of plant seedlings were inoculated correspondingly with the commercial AM fungal mixture "Tyroler Glückspilze Mykorrhiza Granulat", a saprotrophic basidiomycete *Schizophyllum commune* with proven radionuclide bioaccumulation capacity and activated charcoal (1.5 $g \cdot kg^{-1}$) known to enhance cation exchange capacity and nutrient retention, thereby potentially promoting radionuclide uptake.

The experiment was conducted in growth chambers, using 3 kg soil from Rossendorf site per pot, over three months. The growth conditions included 20 °C temperature, a 16/8 h light/dark cycle, 55% relative humidity, and periodic watering with Hoagland nutrient solution. After cultivation, plant shoots and roots were harvested separately, dried at 105 °C, ashed at 400 °C for 24 hours, digested in 8M $HNO_3$, and analyzed using HP-Ge gamma spectrometry.

The initial results demonstrated that AM inoculation of *M. sativa* grown on soil from Rossendorf site led to a moderate increase in $^{60}Co$ and $^{137}Cs$ activity concentration in aboveground biomass. Charcoal addition significantly boosted $^{60}Co$ uptake by plant shoots (~ 80%) but had minimal impact on $^{137}Cs$ accumulation in plants. In turn, the presence of *S.commune* caused 60 % increase of $^{137}Cs$ activity concentration in plant shoots.

For *H.annuus*, the colonization both with AM fungi and *S.commune* resulted in up to 40-50 % increase in $^{137}Cs$ and $^{60}Co$ activity concentrations in their shoots, although plant biomass was slightly reduced compared to control plants. Charcoal-treated sunflowers showed only a slight increase in $^{137}Cs$ activity concentration in root and shoot tissues.

Overall, $^{137}Cs$ and $^{60}Co$ were mainly retained in the root system of the studied plants, and their root-shoot translocation was limited. *S.commune* had the strongest positive impact on the radionuclide accumulation by both plant species, while AM fungi demonstrated a moderate impact. Ongoing experiments with plant cultivation on highly radioactive soil from Rheinsberg NPP site will provide a more comprehensive understanding of the uptake patterns for gamma-emitting radionuclides and help assess whether plant-fungal remediation can reduce soil contamination to levels below the threshold for radioactive waste classification and allow clearance of the material.

# MetroPOEM – Metrology for the harmonisation of measurements of environmental pollutants in Europe

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**Abstract:** For its ultimate success, the zero-pollution ambition of the European Green Deal requires highly sensitive and state-of-the-art detection techniques to determine ultra-low amounts of pollutants in the environment. Mass spectrometry has become a key method for the determination of non-radioactive polluting elements, and is also of increasing importance for the detection long-lived radionuclides. This project will bridge the gap between the radiometric techniques and mass spectrometry by comparing and linking both techniques, thus significantly improving measurement uncertainties and detection limits. As an important part of achieving this aim, this project will develop reference materials, resulting in SI-traceable measurement procedures tracking the sources of pollution by commonly available mass spectrometers.

The MetroPOEM Project Consortium has 23 Partners in 14 countries. HZDR's Department of Accelerator Mass Spectrometry and Isotope Research contributes to the project with its expertise in the detection of rare radionuclides in the environment using the supreme isotopic abundance sensitivity of IBC's DREAMS facility and the soon to be commissioned new accelerator mass spectrometry (AMS) system HAMSTER. As part of the project we will work to push the isotopic abundance detection limits for $^{236}$U, $^{237}$Np, $^{239}$Pu, $^{240}$Pu, $^{241}$Am, and $^{90}$Sr to new limits.

# Enhancing Uranium Recovery from Coal Ash Using Semipermeable Membranes and Radiochemical Methods: A Novel Approach

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Today's energy transition requires not only the development of renewable energy sources, but also the efficient use of available strategic resources. Uranium, as a nuclear fuel, plays a key role in providing stable, low-carbon electricity. Although its main sources are natural deposits exploited by mining, alternative ways to obtain them, including secondary raw materials, are gaining attention. One of these is the ash from coal combustion, a material in which uranium can reach higher concentrations than in coal itself. Recovering this element from waste materials not only supports the economy of raw materials but also reduces dependence on traditional sources, which are geographically concentrated.

The study presented here proposes a novel method for recovering uranium from such ashes, based on a combination of chemical leaching and separation using a semipermeable membrane. Radiochemical techniques were used at the beginning of the process to accurately determine the uranium content and monitor its behaviour during extraction. These procedures, known for their high selectivity and sensitivity, played a key role in evaluating the efficiency and controlling each step of the experiment.

The experiments carried out demonstrated a useful methodology for separating and recovering uranium from calcined ash. The process of leaching the ash according to the adopted methodology was found to be extremely effective, with an average efficiency of 96.7%.

Analysis of the kinetics of the process, including both the rate of uranium release and its transport through the membrane, allowed the identification of optimal operating conditions and the development of a predictive model that can be used for further applications. Understanding the dynamics of processes is important for the energy and economic efficiency of the entire solution, especially in the context of processing materials with low but useful concentrations of radioactive elements. This type of data is essential for planning industrial-scale processes, where extraction stability and repeatability are critical.

Importantly, the proposed method can be transferred to other industrial wastes in which the presence of uranium has already been confirmed, for example, phosphoric or metallurgical wastes. This approach not only broadens the base of available uranium sources but also supports the concept of a closed-loop economy and sustainable development of the nuclear sector.

Acknowledgements

The work was created as a result of research project no. 2023/07/X/ST8/01116 financed by the National Science Centre and it was also partly funded by AGH research grant no 16.16.210.476.

# Evaluation of radioactivity in chanterelle (*Cantharellus cibarius*) and health implications

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The contamination, accumulation, spatial distribution, and potential health risk of $^{137}$Cs, $^{210}$Po, $^{210}$Pb, and $^{40}$K in chanterelles collected across Poland were examined using validated methodology and gamma-ray and alpha-particle spectrometric measurements. The values of anthropogenic $^{137}$Cs activity concentration in mushrooms were between 118 and 1647 Bq·kg$^{-1}$ dry weight (dw), while for natural $^{40}$K from 1316 to 1895 Bq·kg$^{-1}$ dw. The activity concentrations of $^{210}$Po in chanterelles were between 2.23 and 8.57 Bq·kg$^{-1}$ dw and in forest topsoil between 11.4 and 83.0 Bq·kg$^{-1}$ dw. Corresponding values for $^{210}$Pb were 1.50-6.14 and 7.74-46.1 Bq·kg$^{-1}$ dw, respectively. The obtained results varied significantly – the highest values of activity concentrations were determined for $^{40}$K, while the lowest were for $^{210}$Po and $^{210}$Pb. Studies have shown that lamellae mushrooms such as chanterelles may contain higher activity concentrations of $^{210}$Po and $^{210}$Pb than tubular mushrooms, but a broader study is recommended. An assessment of the annual radiation doses and cancer risk related to $^{137}$Cs, $^{40}$K, $^{210}$Po and $^{210}$Pb consumed with chanterelle showed that $^{137}$Cs and $^{210}$Po give a similar risk, and 2-3 orders of magnitude higher than $^{40}$K and $^{210}$Pb.

# Novel Extraction Chromatographic Method for Determination of Selenium-79 in Radioactive Waste Samples

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Selenium, as an element, possesses unique characteristics such as high bio-mobility and bio-toxicity. These properties make Selenium-79 ($^{79}$Se), a long-lived fission product, a subject of significant concern in radioactive waste characterization and management for the operation and decommissioning of nuclear power plants. However, due to its low abundance in radioactive wastes, the quantitative determination of $^{79}$Se is challenging.

This work describes an improved method intended to separate selenium from nuclear waste samples using a new extraction chromatography resin (SE Resin), which is currently under development. The SE Resin contains an extractant that allows the isolation of selenium, by forming piaszselenol, an organoselenium compound. Our results demonstrated a significant improvement in selectivity of the SE Resin for Se(IV) species (Table 1), which was validated using UV-Vis spectrophotometry (Figure 1) and Sector Field Inductively Coupled Plasma Mass Spectrometry (SF-ICP-MS). In addition, leaching experiment was performed to enable us to better understand the behaviour and stability of the SE Resin for real sample applications. The method will be applied to resin samples as operational waste from a nuclear power plant, wherein experimental conditions for maintaining Se(IV) oxidation state as well as removal of major interferences from the matrix are optimized.

*Table 1: Comparison between UV-Vis and ICP-MS in a Se(IV)($Na_2SeO_3$) salt sample*

| Pure Se(IV) salt | Yield (Se(IV), UV-Vis) (SCK) | Yield (Total Se, ICP MS) (VUB) |
|---|---|---|
| Loading solution | 13.91% | 23.18% |
| Rinsing solution | 15.28% | 5.41% |
| Eluate | 67.26% | 71.42% |
| Total | 96.45% | 100% |

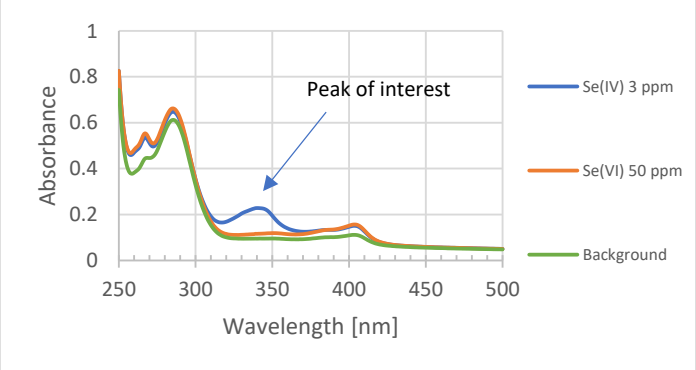



*Figure 1: Selectivity of the UV-Vis method between Se(IV) and Se(VI) species*

# Effects of preferential flow and radiocesium-rich microparticles (CsMPs) on spatial heterogeneity of $^{137}$Cs in forest soils after the Fukushima accident

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Horizontal spatial heterogeneity of $^{137}$Cs in soil is extremely high even within small areas of forest, resulting in reduced accuracy of models predicting downward migration and uptake by plants. Therefore, this study focused on preferential flow and radiocesium-rich microparticles (CsMPs) as factors causing spatial heterogeneity at the centimeter scale. Although the preferential flow pathways occupy only a small proportion of the soil matrix, most of the water and solutes permeate through them. Therefore, preferential flow is expected to have a strong effect on $^{137}$Cs spatial distribution due to its high adsorption ability on soil particles. CsMP has a very high $^{137}$Cs concentration but low solubility and is derived from a mixture of melted nuclear fuels and structural materials. There are some studies on the contribution of CsMPs by region, but there are few studies on the variation in the degree of CsMPs contamination at smaller scales.

In this study, we conducted an artificial rainfall experiment using a dye tracer (2 g $L^{-1}$ rhodamine B solution) in a cedar plantation forest in the former evacuation zone of Fukushima Prefecture to visualize the pathway of preferential flow. After then, soil samples from stained and unstained areas were collected at 2.5 cm intervals and 25 core samples were taken at three depths (0-5 cm, 10-15 cm and 20-25 cm). The $^{137}$Cs concentrations, physico-chemical properties (three-phase distribution, porosity, saturated hydraulic conductivity, bulk density, total carbon, total nitrogen and radiocesium interception potential) and the amounts of CsMPs were measured to discuss the effects on the spatial heterogeneity of $^{137}$Cs in soil and their interrelationships.

As a result, the extracted rhodamine B concentration in the soil of the stained area is more than 100 times higher than that of the unstained area, indicating the occurrence of preferential flow from the surface layer although even with a rainfall intensity of approximately 90 mm and a rainfall rate of 160 mm. The $^{137}$Cs concentration also tended to be higher in the stained area, and in particular, the variability of the $^{137}$Cs concentration in stained area was significantly higher at especially 10-20cm. The variability of the $^{137}$Cs inventory at 10-15 cm of soil depth was largest compared to 0-5 cm and 20-25 cm. In addition, significant negative correlation was found between the $^{137}$Cs inventory and bulk density or saturated hydraulic conductivity, which is associated with preferential flow. In addition, not only the $^{137}$Cs but also carbon, nitrogen and other exchangeable cations were also correlated with bulk density. On the other hand, there was not significant correlation between the $^{137}$Cs inventory and bulk density at depths of 0-5 cm and 20-25 cm. This was thought to be because at 0-5 cm, the pathway of the selective flow was easily changed due to plant root growth and death, and the penetration was uniform, so the variation was small. At 20-25 cm, it was thought to be because the amount of $^{137}$Cs that reached the surface was small compared to the preferential flow. At the surface 0-5 cm layer, a tendency was observed that the higher the Cs concentration, the greater the amount of CsMPs contained. However, the contribution of CsMPs to the total $^{137}$Cs in soil was low, so CsMPs could not explain the large spatial heterogeneity in $^{137}$Cs concentration. These results may suggest that not only rainfall water and the elements such as carbon and $^{137}$Cs but also particles such as CsMPs accumulate in areas where the preferential flow penetrates.

# Baseline Terrestrial Radioactivity around the Potential Nuclear Installation Sites in the Philippines

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The Philippines intends to transition to cleaner energy alternative and diversify its energy mix by adding nuclear energy to its energy mix, In the recent energy development plan, the country intends to have an operating nuclear power plant by 2032. As a licensing requirement, baseline environmental radioactivity measurements are part of the radiological and environmental impact assessment items to identify anthropogenic and natural sources of radiation.

In light with this, the current study aims to establish baseline natural radioactivity measurements in the following selected candidate nuclear installation sites: Puerto Princesa City, Palawan; Jose Panganiban, Camarines Norte; and Zamboanga City. A portable gamma-ray spectrometer (Radiation Solutions RS330) with a thallium-doped sodium iodide detector was used for terrestrial radiometric survey of the candidate sites. The instrument measures dose rate (nSv/hr) and concentration of radionuclides $^{40}$K (%), $^{238}$U (ppm), and $^{232}$Th (ppm) after five minutes in assay mode and Geo_300 method.

Results showed an average dose rate with calculated occupation factor for public exposure of value of 0.22 mSv/yr in Concepcion and 0.07 mSv/yr in Inagawan Villages in Puerto Princesa City. While Jose Panganiban, Camarines Norte, and Zamboanga City measured 0.11 and 0.6 mSv/yr, respectively. The calculated average activity concentrations of the radionuclides are lower than the world average values except for the $^{40}$K, $^{238}$U, and $^{232}$Th measurements from Puerto Princesa and $^{40}$K measurements from Camarines Norte.

Variations in radionuclide concentrations and dose measurements are based on the lithology with the continentally derived slate rocks in Puerto Princesa City and potassic altered rocks in Jose Panganiban recording the highest activity concentrations and dose rate measurements. This study emphasizes the importance of natural radioactivity baselining in potential sites as part of site assessment and planning for potential exposure situations.

**References**

Klemic, G. Environmental Radiation Monitoring in the Context of Regulations on Dose Limits to the Public; US Department of Energy Environmental Measurements Lab.: New York, NY, USA, 1996.

Bautista, U.A., Cervera, R.B.M. 2025. Technical Review and Status of Small Modular Reactor Technologies: Prospects of Nuclear Infrastructure Development in the Philippines. *Energies* 2025, *18*(7), 1862; https://doi.org/10.3390/en18071862

# Seasonal Variation and Radiological Risk Assessment of Naturally Occurring Radionuclides in Water and Fish from Gold Mining regions of the Lake Victoria Goldfields, Tanzania

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**Background:** Limited data exists on the occurrence of naturally occurring radionuclides (NORs) and their potential radiological health implications to human and aquatic ecosystems within the Lake Victoria Goldfields, Tanzania where surface water and groundwater are extensively used for drinking and other domestic purposes, raising concerns about possible radiological exposure to local communities.

**Objective:** This study aimed to assess the activity concentrations of uranium isotopes ($^{234}$U, $^{235}$U, $^{238}$U), thorium isotopes ($^{230}$Th, $^{232}$Th), $^{226}$Ra, $^{210}$Po, and $^{210}$Pb in fish (African Lungfish, Catfish and Tilapia) and water samples collected from selected sites during both rainy and dry seasons. The study further evaluated seasonal variations, bioaccumulation patterns in fish tissues (flesh, gills, and bones), and estimated ingestion doses for infants, children, and adults through drinking water and fish consumption.

**Methods:** Surface water and groundwater samples, along with commonly consumed fish species, were collected from mining-affected regions within the Lake Victoria Goldfields (LVGF). Radiochemical separation techniques were applied, followed by activity concentration determination using Alpha Spectrometry and a low background gas-flow proportional counter. Bioaccumulation factors (BAFs) were determined for different fish tissues, and committed effective ingestion doses for various age groups were estimated based on ICRP-recommended dose coefficients.

**Results:** Preliminary findings indicated seasonal variability in activity concentration of uranium isotopes and $^{226}$Ra in water samples, with generally higher concentrations found in dry season compared to wet season. Groundwater concentrations reached up to 3102.1 ± 822.67692 mBq $L^{-1}$ for $^{238}$U, 7383 ± 1950 mBq $L^{-1}$ for $^{234}$U and 107.59± 0.59 mBq $L^{-1}$ for $^{226}$Ra. In surface water, maximum concentrations were 932.35± 100 mBq $L^{-1}$ ($^{238}$U), 1661.8 ± 176.6 mBq $L^{-1}$ ($^{234}$U) and 46.628 ± 0.57 mBq $L^{-1}$ ($^{226}$Ra). The activity concentrations of $^{210}$Po and $^{210}$Pb in fish samples also showed notable variability $^{210}$Pb ranged from 15.20 ± 2.66 to 62.94 ± 9.65 Bq/kg (dry weight), with the highest concentration recorded in Catfish bones (62.94 ± 9.65 Bq/kg). $^{210}$Po concentrations varied from 0.53 ± 0.47 to 3.43 ± 0.97 Bq/kg (dry weight), with the highest value observed in tilapia gills (3.43 ± 0.97 Bq/kg). Estimated annual ingestion doses from drinking water exceeded the WHO recommended guidance level of 0.1 mSv $y^{-1}$ for infants and children at several sites, in both seasons. Fish consumption contributed to annual radiological exposure, with bones exhibiting the highest activity concentrations of radionuclides among the analyzed tissues.

**Conclusion:** This study provides the first comprehensive dataset on natural radionuclide levels in aquatic systems within the gold mining areas of Tanzania, highlighting potential radiological health risks, particularly for vulnerable groups relying on untreated water and locally sourced fish. The results of this study underscore the need for continuous environmental monitoring and the development of appropriate radiological protection measures in gold mining-affected regions.

# Radiological characterisation of building materials

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In recent years increasing attention has been paid to indoor radon concentrations in buildings. According to several studies, nearly half of the population's radiation exposure from natural sources is caused by indoor radon. As a significant part of radon exposure is originated from building materials, the survey on radioactive content of building materials is crucial in this manner.

EU Council directive 2013/59/EURATOM defines reference levels dose-rate for indoor external gamma-radiation emitted by building materials and for radon and radon daughter element activity-concentrations. In the case of existing buildings, either dose rate or radon level can be measured directly by on-site measurements. In case of building planned or under construction the building materials can be characterised in order to estimate the expected radiation level characteristics of the building to be constructed.

Radiological characterization of building materials is usually done by the activity-concentration index, which is derived from the activity concentration of natural radionuclides. However, these activity concentrations can be determined typically by nuclide-specific laboratory measurements. We intend to develop in-situ measurement techniques, by which besides to the characterisation of buildings, radiological characterisation of building materials can be completed in order to select those materials that are expected to cause radiation levels higher than the reference levels.

The appropriate detection equ

# High-Sensitivity Determination $^{238}$Pu, $^{239}$Pu, $^{240}$Pu and $^{241}$Pu using ICP-MS/MS

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This study aims to optimize measurement conditions of triple quadrupole inductively coupled plasma mass spectrometry (ICP-MS/MS) to improve the accuracy and sensitivity of trace plutonium (Pu) isotope analysis in environmental samples. ICP-MS/MS enhances Pu analysis specificity by selectively filtering masses in the reaction cell to effectively suppress isobaric interference from $^{238}$U.
We thoroughly characterized key parameters for Pu isotope ($^{238}$Pu, $^{239}$Pu, $^{240}$Pu, $^{241}$Pu) measurement - including ion kinetic energy control, ion lens settings, and reaction gas flow rate—and systematically optimized them. Uranium and plutonium standard solutions were used to establish optimal Pu detection conditions, and measurement accuracy was evaluated by comparison with MC-ICP-MS results. Certified reference materials (CRMs) of soil matrices were analyzed under these optimized conditions to confirm improvements in accuracy, precision, and detection limits for Pu isotopes.
The findings of this research are expected to contribute to environmental radioactivity monitoring and nuclear non-proliferation research by providing a highly reliable method for Pu isotope analysis.

# Exploring Anthropogenic Radioisotopes as Tracers in Oceanic and Climatic Studies

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The global ocean is a reservoir for radionuclides, both natural occurring and anthropogenic. The anthropogenic radioisotopes predominantly originate from fallout from historical atmospheric nuclear weapons tests, discharges from nuclear reprocessing plants and releases following accidents at nuclear facilities. In recent years, the application of long-lived anthropogenic radionuclides, such as Tc-99, I-129, U-233 and U-236 as tracers in the marine environment has been increasingly adopted. Due to their conservative behaviour, long residence time and unique fingerprint of their isotopic ratios, these tracers are particularly promising in studying the water mass movement and mixing, tracking ocean circulation pathways and transit times, quantifying water mass composition and estimating pollutant and nutrient dynamics.

The anthropogenic radioisotopes with constrain source terms and release histories also offer a novel perspective for assessing the model-simulated transport and transformation of specific water masses. For example, the well-documented discharges of anthropogenic radioisotopes from the European reprocessing plants, along with their measurements in the Nordic Seas and the Arctic Ocean, supplemented by model simulations, provide quantitative estimates of the advective and diffusive properties of transport pathways and time scales of the Atlantic water to the polar waters.

This paper aims to provide a holistic overview of our series research on exploring anthropogenic radioisotopes (e.g., Tc-99, I-129, U-233 and U-236) in the Baltic Sea, the Arctic Ocean and the Pacific Ocean, in coupling with Earth system models (ESM) for oceanic and climate studies.

# $^{7}$Be and other radionuclides as climate change tracers in the air

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Radioactive isotopes present in the atmosphere continuously vary in concentration due to a series of natural, often repetitive processes. Although the abundance of these elements changes over time, such variations are generally predictable and can be described mathematically.
When the composition of the atmosphere shifts, the dynamics of atmospheric processes also change. These changes inevitably affect the behavior and production of naturally occurring isotopes. Consequently, research in this field focuses on correlating deviations in isotope concentrations from established trends with key meteorological parameters and pollutant levels.
Analyzing climate change is a complex task that involves assessing numerous parameters and their influence on local and global environments. Environmental systems are influenced by a wide array of natural and anthropogenic processes, which often act synergistically and affect other interconnected systems.

The study of climate change is rooted in the analysis of observed trends and correlations between meteorological parameters and the influx of radionuclides such as beryllium-7 ($^{7}$Be) into the atmosphere. Chemometric methods, including Principal Component Analysis (PCA) and other multivariate techniques, provide powerful tools for detailed environmental data analysis and for identifying potential ecological impacts.

However, limited awareness and understanding of these analytical techniques often hinder their broader adoption within the scientific community and beyond. Yet, their application holds great promise for enhancing current practices in environmental monitoring and sensor-based systems. It is anticipated that broader use of these methods will not only advance environmental research but also support informed decision-making by governmental bodies and research institutions.

# The Effect of Radon-222 Escape on $^{210}$Pb-Based Sediment Chronology: Implications for Dating Accuracy in Lacustrine Systems

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The radiochronology method applied to investigate changes in lake ecosystems over the past 150 years is based on the $^{210}$Pb isotope from the $^{238}$U decay series. When using this method, measurable variations in the concentration of $^{210}$Pb deposited from the atmosphere into lake sediments indicate the age of sediment layers (excess $^{210}$Pb). However, the measured $^{210}$Pb activity also includes the in situ produced $^{210}$Pb generated by $^{226}$Ra present in the sediment, assumed to be in equilibrium. In analytical calculations, the atmospheric $^{210}$Pb inventory is determined by subtracting the $^{226}$Ra concentration from the total measured $^{210}$Pb. This concept is only valid if the system is considered closed and the gaseous intermediate decay product, $^{222}$Rn, does not escape from the sediment layers. This assumption holds true mainly for systems with rapid sedimentation, where diffusion distances from the pore space are short. In such cases, radon loss is confined to the topmost centimeter, which does not significantly affect dating accuracy. However, in systems where sedimentation is slow and organic matter content is high, the sediment cannot be regarded as a closed system regarding gas escape.

The present study examined this issue in the sediments of Lake Balaton (Hungary) and two Romanian lakes, Lake St. Anna and Red Lake (Gyilkos). These lakes were selected deliberately: Balaton and Saint Anna are both characterized by low sedimentation rates due to their specific depositional mechanisms. Lake Balaton's catchment area contains rocks with high $^{226}$Ra content. In contrast, Lake St. Anna receives water solely from precipitation, with no inflows, and its upper 10 cm sediment layer has high water content. Meanwhile, Red Lake features higher sedimentation rates and more compact sediments. Thus, these three sites, with differing sediment characteristics, demonstrate that the observed phenomenon is not local but more widespread. We hypothesize that $^{222}$Rn gas escapes from these systems, leading to modified dating results. To test this, we measured radon concentrations in sediment pore water using liquid scintillation counting, taking advantage of its low detection limits.
In Lake Balaton's sediment, radionuclide distributions indicate elevated $^{226}$Ra levels ranging between 25 and 55 Bq/kg. If this enhanced $^{226}$Ra activity is directly used in dating calculations, the dating horizon would appear at only 10 cm depth, which contradicts other independent sedimentation measurements. The pore water $^{222}$Rn concentration profiles confirmed significant radon loss within the upper 30 cm of the sediment column, with values ranging from 3 ± 0.2 to 37 ± 4 Bq/l. This loss is attributed to the high porosity (70-90%) and low sedimentation rate. In Lake St. Anna, radon concentrations ranged from 0.2 ± 0.01 to 3 ± 0.2 Bq/l, corresponding to its lower average $^{226}$Ra content (around 25 Bq/kg). For Red Lake, values ranged from 2 ± 0.2 to 28 ± 4 Bq/l, with $^{226}$Ra content averaging around 35 Bq/kg—lower than that of Balaton sediments. The radon loss and transport processes can be described by a multivariable differential equation.

Our results clearly show that a significant portion of radon escapes from the upper sediment layers, causing a disequilibrium. Consequently, the sediments of Lake Balaton, Lake St. Anna, and Red Lake cannot be regarded as closed systems concerning radon gas. As a result, this research demonstrates that pore water analysis is crucial for reliable $^{210}$Pb dating, especially in systems with slow sedimentation and high porosity accumulated over the last 150 years.

# Investigation of environmental radiation of sand and soil samples from Dead Sea beach, Jordan

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This study's goal is to quantify the levels of naturally occurring radioactivity in Dead Sea (Jordan) soil and beach sand. In addition to enjoying the hot sun, many visitors and residents are used to coming to the Dead Sea coastline to benefit from the salt water's ability to treat a variety of skin conditions. To safeguard individuals, it is crucial to assess the environmental radiation that originates from soil and sand. This problem has been the subject of numerous studies in the past. This work has considerable credibility because it demonstrated that the earlier research are reasonably accurate and meet international criteria.

Fifty samples of soil and fifty samples of sand were collected from different locations along the seashore. Using a high purity germanium detector with a relative efficiency of 40%, the radionuclide concentrations of three naturally occurring radionuclides (232Th, 226Ra, and 40K) were measured separately for soil and sand. The following average radioactive quantities were discovered in Dead Sea beach sand samples: 226Ra, 232Th, and 40K. The corresponding values were 50.96 ± 4.35 $Bq \cdot Kg^{-1}$, 123.93 ± 16.15 $Bq \cdot Kg^{-1}$, and 952.05 ± 122.15 $Bq \cdot Kg^{-1}$. For soil samples, the corresponding radionuclide activity values were 13.98 ± 2.89 $Bq \cdot Kg^{-1}$, 166.34 ± 17.32 $Bq \cdot Kg^{-1}$, and 1265 ± 116.27 $Bq \cdot Kg^{-1}$ on average.

Another significant quantity was computed in order to finish the radiation survey from the measured samples: the rate at which radionuclides in soil and sand samples are absorbed. It was determined that the average absorbed dose rate from radionuclides in sand was 76.33 $nGy \cdot h^{-1}$. It was also determined that the average absorbed dose rate in soil was 110.04 $nGy \cdot h^{-1}$. In order to examine the impact of radiation doses on humans, a set of radiation risk criteria was evaluated. The external hazard index (Hex), gamma radiation representative level index (Iγ), and radium equivalent activity (Req) readings were all below the UNSCEAR and ICRP reports' suggested levels. Conclusion: At least for the purposes of this study, there were no radiological effects on Jordanians or visitors to the Dead Sea shoreline. These findings can be used as a guide for further research.

# Simultaneous determination of $^{93}$Zr, $^{93}$Mo and niobium radionuclides from decommissioning samples, extension of the method for analysis of actinides

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Nuclear reactors must be decommissioned sooner or later after final shutdown, the reactor and its auxiliary devices must be dismantled. During decommissioning, large amounts of radioactive waste with variable chemical composition is produced. The classification and radiochemical characterization of different waste types are crucial regarding their safe long-term storage, radiation protection of the staff and in a broader sense the population and the environment.

In course of the years, a combined radiochemical method to separate long-lived difficult-to-measure (DTM) nuclides has been developed at RADANAL Ltd for the simultaneous determination of the major actinides based on an extraction chromatographic (EC) separation of uranium, plutonium, neptunium, americium and curium on a single DGA resin (containing diglycolamide)[1] followed by measurement of $^{237}$Np by ICP-MS and those of other actinides by alpha spectrometry. Later the method was extended for the determination of $^{93}$Zr by including a purification step using TEVA resin (containing tetraalkyl amine) and measurement by ICP-MS[2]. Recently we have further improved the separation scheme and extended it for the determination of DTM nuclides $^{93}$Mo, $^{93m}$Nb and $^{94}$Nb. Molybdenum and Nb are separated on the DGA resin, Mo is purified on activated alumina column and Nb on TEVA resin, $^{93}$Mo is measured by LSC, $^{93m}$Nb by low energy gamma spectrometry (LEGe) and $^{94}$Nb by standard gamma spectrometry.

Up to now, certified reference materials which represent activated reactor components were unavailable. Recently, an international intercomparison exercise was organized for radiochemical laboratories in order to determine $^{93}$Zr, $^{93}$Mo, $^{93m}$Nb and $^{94}$Nb nuclides from a steel sample originating from decommissioned reactor[3].

Steps of method development, model experiments, sample preparation, as well as the results of the intercomparison test will be presented.

References:

1. Groska J, Vajda N, Molnar Zs, Bokori E, Szeredy P, Zagyvai M (2016) J. Radioanal. Nucl. Chem. 309(3): 1145-1158
2. Papp I., Vajda N., Bokori, Molnár Zs. (2024). J. Radioanal. Nucl. Chem., 333: 3639-3653
3. A. Leskinen et al. (2025) Intercomparison exercise of 93Mo and 59Ni analysis in activated steel. Nordic Nuclear Safety Research, Report NKS-495, ISBN: 978-87-7893-593-9

# Radiological characterization of building materials produced in Spain for compliance with external gamma dose limits

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The Directive 2013/59/EURATOM, transposed into Spanish law (RD 1029/2022), limits indoor external exposure due to gamma radiation emitted by building materials to 1 mSv/year. The aim of this work is the radiological characterization of the most used building materials in Spain, including concrete blocks, bricks, ceramic tiles, marble, and modern materials like synthetic stones and porcelain materials to see if they are compliant.

Fifty-six samples were analysed using gamma spectrometry. Activity concentrations of $^{226}$Ra and $^{232}$Th were estimated through their secular equilibrium descendants: $^{214}$Pb (351.92 keV) and $^{228}$Ac (911.07 keV), respectively. Activity concentration of $^{40}$K was estimated through its peak (1460.75 keV). The European activity concentration index (I) was calculated and, for materials with I > 1, the annual external dose produced was also evaluated using a standard methodology (CEN/TR 17113:2017) that takes into account the density, thickness, and use of the material.

The results show significant variability in radionuclide content, even within the same material type. Those building materials with zirconium silicates and/or red clays in their composition showed higher activities. In terms of the European activity concentration index, marble, concrete, plaster, and terrazzo showed low indices (I < 0.4). Ceramic tiles presented indices below the limit (I = 0.6 - 0.9) and modern materials presented variable indices due to their different composition, sometimes exceeding the index limit (I > 1). Granite and brick presented indices very close to or above 1, sometimes reaching indices of 2. Materials studied that exceeded the activity index (I > 1) obtained dose values lower than 1 mSv/year, confirming compliance with the exposure limits. Therefore, all the materials tested could be used as building materials from a radiation protection point of view. However, for those materials exceeding the limit, a more detailed dose calculation should be performed to establish restrictions on use.

**Keywords:** Building materials, NORM, activity index, external dose.

**Acknowledgements**

The LRA-UPV thanks to the Consejo de Seguridad Nuclear for funding the project “Characterisation, exhalation and remediation of radon in building materials” (SUB-33/2021), and the Universitat Politècnica de Valencia for funding the project “Assessment of the radiological impact of new building materials used in residential interiors” (PAID-06-24).

# Improving the efficiency and performance of electrostatic collection for radon measurement

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Radon ($^{22}$Rn) and thoron ($^{220}$Rn) monitoring systems based on electrostatic collection play a crucial role in environmental radiation safety. In our laboratory, we have been actively engaged for years in the simulation, design and testing of advanced measurement systems that detect radon and thoron through electrostatic collection of their ionized progeny ($^{218}$Po and $^{216}$Po) and alpha spectrometry.
A radon-thoron Reference Chamber is used to carried out experiments with controlled atmospheres and validate the simulation results. In it, we tested and modelled several homemade (such as RaMonA and Ramonino) and commercial (such as RAD7 and Radim3A) chambers. The influence of geometry and two different types of detectors (Surface Silicon and Photodiode detectors) was evaluated.
A study was carried out to simulate and validate multiple radon-thoron detection systems using a hybrid modelling approach combining Geant4 for particle transport and COMSOL Multiphysics for electric field simulation. These simulations provided results in agreement with experimental data and demonstrated that hemispherical geometries provide superior electric field uniformity and detection efficiency compared to other geometries.
Now, a New Reference Chamber is in operation to maintain a constant temperature and humidity, which influence electrostatic collection in a non-negligible manner. The updated results will be the subject of this contribution.

# Environmental and Health Risk Assessment of exposure to elevated Radon levels in highly NaCl / $CaCO_3$ mineralized karst mixed waters: the Case-Study of the Capodifiume Springs Group in the National Park of the Cilento and Vallo di Diano-European Geopark (Southern Italy)


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**Abstract**

This paper investigates the behaviour of radon ($^{222}Rn$) within a complex system involving interactions between groundwater and surface water bodies, and examines its potential environmental and health impacts. The study focuses on the Capodifiume karst spring group—characterized by high NaCl and $CaCO_3$ mineralization - located in the Cilento and Vallo di Diano European Geopark in southern Italy. This site is a Geosite of Primary Relevance and lies near the archaeological area of Poseidon-Paestum, in the plain of the Campania region.

While radon is commonly studied in the context of indoor air pollution, its presence and behaviour in natural aquatic environments, such as lakes and springs, also require close attention. This is due to the complex interactions between groundwater and surface waters, as well as the influence of the local hydrogeological framework. Understanding these dynamic processes is essential for accurately assessing radon-related environmental risks and for implementing effective risk management strategies in natural water settings.

To support this analysis, the study includes the determination of radionuclide activity concentrations in soil and plant samples collected from the Capodifiume spring area. These measurements were conducted using high-resolution gamma spectrometry. Additionally, the environmental risk was assessed using the ERICA (Environmental Risk from Ionizing Contaminants: Assessment and Management) tool.

# Development of a fast method using PSresins for the determination of $^{210}$Pb in environmental samples

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$^{210}$Pb is a naturally occurring radionuclide that originates from the decay chain of $^{238}$U and can be found in environmental samples. Due to its high radiotoxicity, as indicated by the very low permissible activity levels in natural waters (0.2 Bq/L according to the 213/51 EU Directive and 2/2023 Spanish Royal Decree), monitoring its presence in environmental samples or Naturally Occurring Radioactive Materials (NORM) is essential. Analytical strategies for $^{210}$Pb must address two key challenges: its low-energy beta/gamma emissions and the need for extremely low detection limits (0.02 Bq/L). These requirements necessitate prolonged counting times, complex chemical separations, and/or the handling of large sample volumes, which complicates the efficient processing of a high number of samples. Plastic scintillation resins (PSresin) have recently emerged as an innovative strategy for analyzing beta-emitting radionuclides. By combining separation and measurement, this approach streamlines the analysis process. Additionally, the use of a small amount of scintillator (1 g) results in low background levels, thereby improving the limit of detection. These factors collectively suggest a promising new strategy for the rapid analysis of $^{210}$Pb in environmental samples.

This research presents the development of a novel plastic scintillation resin (PSresin) based on a crown ether and an ionic liquid for the rapid analysis of $^{210}$Pb. Two primary challenges were addressed: enhancing the impregnation of the extractant onto the plastic scintillator to reduce extractant stagnation, thereby allowing high sample volumes; and achieving efficient contact between the sample and extractant at high flow rates to minimize analysis time. To this end, various polymeric supports were studied, ranging from classical scintillating microspheres made of polystyrene to porous particles combining monomers of different polarity.

The results obtained indicate that classical PSresin cannot handle sample volumes greater than 50 mL. Despite achieving high efficiency (>80%), the analysis time remains lengthy (>12 hours/sample). Conversely, the combination of styrene, acrylic acid, and a phosphonic moiety yields scintillators with good efficiency (50-60%), low quenching (SQP of 630), low background (>1 cpm), and a stagnation volume exceeding 1L with quantitative retention. This new PSresin has been applied to the analysis of environmental samples, demonstrating compatibility with fast analysis requirements in terms of accuracy, detection limits, and analysis time for both water samples and complex matrices such as NORM lixiviates.

# Citizen radiation monitoring: Building a resilient society while obtaining valuable data on natural radioactivity

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This article summarizes SÚRO's long-standing involvement in citizen science activities - specifically citizen radiation monitoring. The initial impetus was the establishment of the SAFECAST organization after the nuclear power plant accident in Fukushima, Japan in 2011 and the subsequent acquisition of the first SAFECAST bGeigie Nano citizen detector.

In the following years, more than 50 bGeigie Nano devices were gradually purchased and SÚRO began lending them to interested members of the public. This resulted in a significant increase in the amount of measured data not only in the Czech Republic - data comparable to each other, measured with the same type of device. Thanks to citizen measurements, many interesting localities are now mapped in relatively detail - for some, only much less detailed data from aerial radiation monitoring was available until now. Data from citizen radiation measurements have thus become a useful source for many institutions, including SÚRO.

Thanks to educational activities associated with device lending and establishing connections with the community of "radioactivity enthusiasts", many users now primarily turn to us when detecting higher values instead of asking questions on social networks. Such users could be more resistant to fake news related to radioactivity - both because they can make their own measurements and also because they know they can trust the official radiation protection authorities.

Citizen radiation measurements are part of several current research projects, not only Czech ones within the framework of security research, but also the EU funded PIANOFORTE CITISTRA project, and are also considered as complementary data in the event of a radiological emergency.

This paper was created within the research project ID:VC20232025007 provided by the Ministry of the Interior of the Czech Republic.

# Application of Solid Phase Extraction for Automated Sequential Separation of Radionuclides from Environmental Samples

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Radionuclides ingested by food consumption contribute significantly to annual radiation exposure. Main contributors to the annual ingestion doses for Croatian population, consuming locally grown foodstuff, were assessed within "RiChFALL" project by Laboratory for Radioecology of Ruđer Bošković Institute in Zagreb, Croatia. The largest contributors are $^{40}$K, $^{228}$Ra, $^{210}$Pb, $^{210}$Po and $^{226}$Ra. Therefore, the study of long-term environmental behavior of these radionuclides is of great interest. For determination of-activities by alpha or beta detection, complex sample preparation requires numerous steps such as ion exchanges, precipitations, dissolution, etc. Such time-consuming procedures are expensive, waste chemicals and thus limit the number of analyses in a given time. Novel methods based on solid-phase extraction reduce the work load and consumables, but are still tedious and time-consuming for analyst. Such methods are suitable for automation, which enables efficient use of the analyst's time. In-house automated system for sequential radionuclide separation is being developed at Laboratory for Radioecology of Ruđer Bošković Institute in Zagreb, Croatia. It is comprised of three modules. Control module is Raspberry Pi computer running Linux OS that controls other three modules electronically. Operation of this module is fully programmable via Python programming language. Pumping module is comprised of peristaltic pump connected with plastic tubes between two valves with multiple input tubes. One end of tube network is submerged in various solutions of complexing agents and samples, while the other end is connected to column with resin, e.g. silica-gel modified with crown ether or other complexing agent, which binds radionuclides of interest. The targeted radionuclides, along with all nuclides of specific elements, are retained and concentrated by resin. Separation can be achieved because different radionuclides have different binding constants with various complexing agents. Solutions of those complexing agents, varying in concentration and pH, are sequentially pumped through column. Sampling module is motorized holder for tube coming from the column. It moves in three directions above tray with vessels for different fractions and thus collects eluted radionuclides into separate vessels. Further radiometric analyses such as alpha spectrometry and liquid scintillation counting are carried out "off-line". More than one pumping module and columns with different resins can be interconnected enabling complex separations. Described system minimizes analyst's involvement. It requires only loading of the system with digested, liquefied sample and necessary solutions followed by selection of the desired program with right parameters. Different work modes of the automated system are possible, according to the need, of which two are already considered: 1) Batch operation using single resin and multiple samples and 2) coupling of two resins for complex separations from single sample. Preliminary experiments with reference material and environmental samples from "RiChFALL" project resulted in the separation of radionuclides of Pb, Sr and Ra from foodstuff samples with yields of 65-85% using AnaLig® resin, and the separation of Th radionuclides with a yield of 85-95% using TRU resin. In coupled resins experiments no significant decrease of yields was observed if the order of the resins is AnaLig® then TRU. If the order of resins is reversed, the yield of Ra radionuclides drops to 20%, while yield of Th radionuclides stays the same, so we chose AnaLig® as first resin. The developed methods will be implemented within automated system after programming and individual module tuning. Since the system is modular, it can be rearranged and programmed for new or modified analyses as necessary. The developed system will speed up sample preparation, enable preparations of more samples and reduce analyst's time in the laboratory.

# Radiation Fallout Levels in Coastal Marine Environment Insights from the IAEA-RCA-7028 Project

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The Asia-Pacific region's vast marine coastlines are essential to the livelihoods and economies of its nations, heavily relying on ocean resources like seawater, sediments, and marine life. While natural radioactivity is always present, human-made radionuclides from nuclear testing or accidents can pose significant risks. Continuous monitoring of these radionuclides is crucial for tracking their movement and understanding the impact of human activities on marine ecosystems. Supported by IAEA's technical cooperation, regional efforts have focused on harmonizing protocols, assessing climate change impacts, sharing knowledge, and building local capacity for radiological monitoring. IAEA RCA-TC projects RAS7021 and RAS7028 have provided benchmark data on radionuclide fallout levels, contributing to the Asia-Pacific Marine Radioactivity Database (ASPAMARD), which feeds into the global marine database (MARIS).

India has actively participated in these IAEA projects to assess and benchmark the radioactivity levels along the marine coastlines, required to evaluate the possible impact of the Fukushima radioactive releases in the Asia-Pacific region. Fallout levels of $^{137}$Cs in seawater were previously documented in the RAS7021 project and submitted to ASPAMARD. In the present study, conducted under the IAEA RAS7028 project, the focus shifted understand the temporal variation of long-lived fallout radionuclides like $^{137}$Cs and $^{90}$Sr in seawater and sediments over the period from 2022 to 2024.

Seawater and sediment samples (around 200-300 litres of seawater and 1 kg of sediment) were collected approximately 500 meters off the coast, at a depth of 1 meter. These samples were analyzed using standard protocols. The activity concentration of $^{137}$Cs in seawater ranged from 0.6 to 1.1 Bq/m$^3$, with an average of 0.8±0.2 Bq/m$^3$, consistent with earlier studies conducted in 2012. The $^{90}$Sr activity concentration, which requires tedious radioanalytical protocol and had been sparsely reported before, varied from 0.7 to 1.3 Bq/m$^3$, with a mean value of 0.9±0.2 Bq/m$^3$ which is in the same range as global fallout levels. In sediments, the activity concentrations for $^{137}$Cs and $^{90}$Sr ranged from 0.4 to 2.2 Bq/kg and 1.1 to 1.2 Bq/kg (dry weight), respectively. Notably, the concentration of $^{137}$Cs in sediment was slightly higher than that of $^{90}$Sr, possibly due to the stronger tendency of cesium to adhere to clay minerals commonly found in coastal sediment. The average $^{137}$Cs/$^{90}$Sr ratio in seawater was 0.9±0.1, and in sediment, it was 1.3±0.7, both aligning closely with global fallout patterns, indicating the predominantly fallout nature of the radionuclides.

These projects and the study conducted under their aegis provide vital data for the understanding of fallout radionuclide behavior in the coastal marine environment and contributes to the global database on marine radioactivity, reinforcing the importance of continued monitoring to safeguard marine ecosystems and public health.

**Comparative analysis of spatial and depth wise distribution of uranium in groundwater of South-west & North-east region of Punjab state, India**

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**Abstract**

High prevalence of uranium (U) in groundwater beyond WHO recommendation limit (30 µg/l) may pose severe health issues associated with kidney, liver and bones as they are prominent sites of uranium deposition. Therefore, regular monitoring of uranium content has gained immense attention at global level because of its potential chemical and radiological toxicity. The relation between uranium contamination in water and chronic kidney diseases (CKD) lead to nephrotoxic effects confirmed by epidemiological and toxicological studies. In this study, a heterogeneous distribution of uranium concentration (3.4 – 624.82 µg/L) has been observed in the groundwater of south-west region as compare to north-east region of Punjab (0.1 – 38.71 µg/L). The average uranium concentration was found to be 83.2 µg/L and 4.1 µg/L for south-west and north-east regions, respectively. The high prevalence of uranium concentration in groundwater is only observed in shallow depth (< 200 ft.), which further decreases with increasing depth. The 86% and only 1% samples from south-west and north-east regions of Punjab, respectively, were observed to be above the WHO,2011 recommended safe limit of 30 µg/L for shallow depth (< 200 ft.). In parallel, 20% samples from south-west region of Punjab were exceeding WHO limit for depth more than 400 ft. Gibb's diagram suggested that both rock weathering and evaporation influences the chemistry of the groundwater of south-west region. In addition, Pearson's correlation and PCA studies confirmed the positive correlation of U with its path finder elements (Mo, Cr, Se) revealed the similar enrichment origin and geogenic source (granite rocks) of these elements i.e., primary source of uranium is

geogenic but anthropogenic activities are also responsible for the uranium distribution in groundwater of south-west region of Punjab. Considering the chemical and radiological toxicity of uranium, it becomes consequentially important to provide datasets for uranium in groundwater of the study regions to local communities, State and Central government along with organizations such as PGWB, CGWB, BRNS and DAE for the sake of society and ecosystem.

# Impacts of climate change in the North Pacific: which are the most important anthropogenic radionuclide tracers of oceanic change?

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Increasing anthropogenic greenhouse gas emissions (mainly carbon dioxide and methane) into the atmosphere have accelerated global warming with serious impacts on Earth ecosystems. Changes in precipitation patterns have increased flooding, and draught events on the other sides resulted in melting of glaciers and sea level rise. Oceans have been experiencing serious changes, such as frequent marine heat waves on a global scale, which could slow the Global Meridional Overturning Circulation (GMOC), disrupting thus the ocean circulation with many accompanying changes in biogeochemical processes, including surface ocean acidification. Anthropogenic radionuclides, released to the marine environment mainly after atmospheric nuclear weapons tests, have been used as sensitive tracers, which could register some of the climate-change impacts on the world ocean (e.g., seawater circulation patterns) as well as on regional seas (e.g., processes in the water column). Climate change affects the time revolution and the distribution of anthropogenic radionuclides in the ocean. Therefore, anthropogenic radionuclides ($^{3}$H, $^{14}$C, $^{90}$Sr, $^{137}$Cs, $^{129}$I, $^{236}$U, $^{237}$Np and Pu isotopes) have been useful tracers, providing important information on processes in the Pacific Ocean.

The North Pacific Ocean (NPO) is a key area in the GMOC path because of the return of deep water to the surface. However, there is no clear picture of GMOC in NPO. The subarctic circulation (SAC) is the largest cyclonic circulation in the NPO, which is characterized as an upwelling region high in nutrients. On the other hand, the North Pacific Subtropical Gyre (NPSTG) is an anticyclonic circulation, which is characterized as a downwelling region low in nutrients. Assuming that the subarctic circulation is an outlet of deep water for the GMOC, a weakened deep-water formation in the North Atlantic and Antarctic Oceans would lead to a decline of upwelling of deep water in the NPSAC, which can weaken the cooling of surface waters and supply of nutrients. Therefore, it is important to better understand the changes in NPSAC and NPSTG accompanied by climate change.

Although Pu has been recognized as a useful tracer of biogeochemical processes because of its high chemical reactivity, it has also been an important tool to trace the motion of water masses. Plutonium isotopes in the Pacific Ocean were primarily injected by global fallout from 1961-62 large-scale atmospheric nuclear tests carried out by the Soviet Union in the Arctic at Novaya Zemlya Island, although a significant amount of Pu was also released owing to close-in fallout from the US thermonuclear tests in the Pacific Proving Grounds (PPG) conducted in the 1950s mainly on Bikini and Enewetak Atolls. Global fallout Pu was deposited mainly in the NPSAC, whereas ~~PPG~~ the Pu of PPG origin was injected mainly in the NPSTG. Since the $^{240}$Pu/$^{239}$Pu isotope ratio (0.18) of global fallout was different from that of PPG (0.33), the $^{240}$Pu/$^{239}$Pu isotope ratio and Pu activity concentrations in seawater and sediment have been tracking the time revolution of the water masses in the North Pacific

Ocean.

# Anthropogenic Radionuclides in China Seas and Northwest Pacific; level, distribution, sources, variation and impacts of climate changes

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An overall investigation of artificial radioactivity in China seas and North Pacific has being implemented in the past years to obtain their level, distribution, sources and variation, to understand their dispersion and transfer pathways, impacts of climate changes. The concentrations of $^{129}I$， plutonium isotopes, $^{14}C$, $^{3}H$, $^{137}Cs$ and $^{90}Sr$ in surface and depth profile of seawater, sediment, coral, and marine biota collected from China Seas and some parts of North Pacific Ocean were analyzed in Xi'an AMS center. In general, the level of anthropogenic radionuclides is too low to cause any radiation problem. A relatively high concentration of $^{3}H$, $^{90}Sr$ and $^{129}I$ were observed in the estuary region, which is related to the riverine input these radionuclides which were deposited on the catchment area of the input rivers. A general decline in concentrations of anthropogenic radionuclides with the depth of the seawater was measured in seawater column in most of area, except some locations with maximum values in the subsurface water. Significantly increased $^{240}Pu/^{239}Pu$ ratio in marine samples in the China seas were measured, especially in South and East China Seas, which was traced to the contribution of the re-suspension of regional fallout of radioactive substances in the sediment to above water and long-distance transport along North equatorial current and Kuroshio current. The spatial distribution of anthropogenic radionuclides in the China seas was obtained by analyzed the surface and depth profile seawater samples, the source and transport pathway of radionuclides was discussed. The level of anthropogenic radionuclides in seawater in the China seas are reconstructed by analysis of sediment cores and coral core samples for $^{129}I$, $^{137}Cs$, plutonium, the impact of climate changes to the distribution and variation of radionuclides are discussed.

*Acknowledgement: The contribution of W. Zhou, YK. Fan, LY.Zhang, X. Zhao, N. Chen, Q. Liu, M Zhang, S. Xing, DX. Zhang, YY.Wang, Z. Huang, Y.X. Liu, M. Fang, D. Liu, W. Zhang, T. Zhang, J. Liu, H. Jiang, L. Tang in the Xi'an AMS center, IEECAS and financial support from Ministry of Science and Technology of China (2015FY110800) and Chinese Academy of Sciences (ZDBS-SSW-DQC002) and Natuional Nature Science Foundation of China* (22341603*) are acknowledged.*

References：

Zhao X., Hou X.L., Zhou W.J., Yan H., Wen H.F., Jiang H., Tan L.C. Variation of $^{239,240}$Pu in Coral and Its Response to the Climate System in South China Sea. Environ. Sci. Technol. 2025, 59: 10067–10075

1. Wang Y,Y., Guo T.F., Fan Y.K., Zhang L.Y., Guo X.G., Cheng P., Lan J,H., Liu Q., Hou X.L., Anthropocene $^{129}$I Record in the Yellow Sea Sediments and Its Indication for River-Delivered Radioactive Pollution to Marginal Seas. Sea. Environ. Sci. Technol. 2025, 58:12633-12642
2. Zhang T., Hou X.L., Fan Y.K. Marine dispersion of Fukushima-derived radiocesium in the North Pacific and its implications, Science China-Earth Sciences, 2025, 68:389-406
3. Liu J.L., Zhao X., Chen N., Liu Q., Zhang M.T., Zhang L.Y., Novikau R., Hou X.L. The transport, distribution, and budget of anthropogenic 129I in the Bohai and North Yellow Seas, China. J. Hazardoud Materials, 2025, 487:137101.
4. Zhang M.T., Wang Y.C., Zhao X., Novikau R., Huang Z., Jiang H., Dang H.J., Hou X.L. Insights into plutonium in marine biota along the coast of China. 2025, 486:137097
5. Hou J.X., Zhang T., Wang Y.Y., Zhang H.T., Hou X.L., Prediction of anthropogenic $^{129}$I in the South China Sea based on machine learning, J. Environ. Radioact. 2025, 287:107710
6. Liu J.L., Zhao X., Zhang M.T., Liu Q., Hou X.L. Tracing particulate radioactive pollutant from land to estuary: Insights from $^{129}$I in the Changjiang River Estuary, J. Hazardous Materials, 2025, 138730, https://doi.org/10.1016/j.jhazmat.2025.138730
7. Zhang M.T., Hou X.L., Zhang L.Y., Qiao J.X., Gao R.Q., Liu Q., Distribution of Anthropogenic $^{129}$I in the Western South China Sea and Its Application for Tracing the Sources and Movement of Pollution. Environ. Sci. Technol. 2022, 56(17):12298–12306.
8. Zhang, M.T., Qiao J.X., Zhang W.C., Hou X.L. Plutonium isotopes in the northwestern South China Sea: Level, distribution, source and deposition, Environ. Poll. 2022, 298:118846
9. Zhao X., Hou X.L., Du J.Z., Fan Y.K. Anthropogenic 129I in the sediment cores in the East China sea: Sources and transport pathways, Environmental Pollution. 2019, 245:443-452.
10. Wang J.L., Fan Y.K., Liu D.T., Lu T., Hou X.L., Du J.Z. Spatial and vertical distribution of I-129 and I-127 in the East China Sea: Inventory, source and transportation. Sci. Total Environ. 2019, 652:177-188
11. Zhang L.Y., Hou X.L., Li., H., Xu, X. A 60-year record of $^{129}$I in Taal Lake sediments (Philippines): Influence of human nuclear activities at low latitude region. *Chemosphere*, 2017, 193:1149–1156.
12. Zhao L., Liu D., Wang J., Du J., Hou X.L., Jiang, Y. Spatial and vertical distribution of radiocesium in seawater of the East China Sea. *Marine Pollution Bulletin*, 2018, 128, 361–368.
13. Wang J.L., Baskaran M., Hou X.L., Du J.Z., Zhang J. Historical changes in $^{239}$Pu and $^{240}$Pu sources in sedimentary records in the East China Sea: Implications for provenance and transporation. *Earth Planet. Sci. Lett.*, 2017, 466:32-42.

14. Liu D., Hou X.L., Du J.Z., Zhang L.Y., Zhou W.J. I-129 and its species in the East China Sea: level, distribution, sources and tracing water masses exchange and movement. ***Scientific Reports,*** 2016, 6; 36611, DOI: 10.1038/srep36611.

# Plutonium studies in the Southern Baltic Sea

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Plutonium, a transuranic of the actinide group with an atomic number of 94, is among the most toxic radioactive elements. In the environment, plutonium is an element that comes primarily from anthropogenic sources, which are associated with nuclear weapons testing, the development of nuclear power, and the intensive development of nuclear programs in industry. Thus, plutonium contamination in the southern Baltic Sea has been extensively studied due to environmental and health implications. The subject of this presentation is an overview of studies conducted on the occurrence of plutonium in the southern Baltic Sea ecosystem, and it sums up the results on plutonium radioisotopes activity concentrations and the $^{240}Pu/^{239}Pu$ isotopic ratios and $^{238}Pu/^{239+240}Pu$ and $^{241}Pu/^{239+240}Pu$ activity ratios determined over the years. Research has revealed varying concentrations of plutonium across different marine ecosystem components. Marine organisms exhibit bioaccumulation of plutonium, with distribution varying among species and tissues. Ongoing monitoring and research are essential to understand the long-term behavior of plutonium in the marine environment, especially its remobilization from sediments.

# Vermiculite application to inhibit radiocesium uptake by paddy rice

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In order to ensure the distribution of safe agricultural and livestock products, measures to reduce radiocesium at field level, product testing for radiocesium, shipment restrictions and other measures have been combined after the accident at TEPCO's Fukushima Daiichi Nuclear Power Station. Regarding radiocesium reduction measures, radiocesium (Cs-134 and Cs-137) is absorbed via a part of potassium transport system by plant roots. Low phytoavailable potassium content in the agricultural soil decreases antagonism to radiocesium in the absorption phase and promotes the absorption of radiocesium. Therefore, the application of additional potassium to rice, soybean, buckwheat, and grass fields has been used to suppress the absorption of radiocesium in Fukushima and a few surrounding prefectures. On the other hand, the application of additional potassium supplementation is expensive in terms of labor and other costs, and in the situation that there have been no cases of brown rice produced in Fukushima Prefecture, Japan exceeding the standard value (100 Bq $kg^{-1}$) since 2015, the application of potassium supplementation is being discontinued in rice cultivation. Potassium chloride is mainly used for potassium supplementation, but there have been concerns that the phytoavailable potassium content in the soil increased by potassium chloride is short-lived. In a field survey conducted by the authors, it was found that the exchangeable potassium content (extracted by 1M ammonium acetate solution) decreased over time after the potassium supplementation was discontinued, and that the activity concentration of radiocesium in brown rice increased in the third year after the potassium supplementation was discontinued. In this study, vermiculite, which is expected to be effective in maintaining exchangeable potassium content for a relatively long period of time due to its slow potassium release, was applied to paddy fields to verify the sustainability of the effect.

The field examination was conducted in farmers' four paddy fields located in the Fukushima Prefecture. Three treatments were established in each paddy field. Potassium was applied by potassium chloride with the rate of 2.7 g $m^{-2}$ in 2023 and 4.2 g $m^{-2}$ in 2024 in the control plot. Additional potassium (9.9 g $m^{-2}$, potassium chloride) and vermiculite (1 kg $m^{-2}$, powder generated during horticultural vermiculite production) was applied in the second and third treatments, respectively, in 2023. The same rate of potassium as the control plot was also applied in the second and third treatments in both years. The vermiculite contained 47.2 g $kg^{-1}$ of total potassium and 1.6 g $kg^{-1}$ of exchangeable potassium. Nitrogen and phosphorus were applied at the rate of farmers' practice.

Activity concentrations of Cs-137 in brown rice was lowest in the vermiculite-applied plot followed by the additional potassium-applied plot then control plot in 2023. It was lowest in the vermiculite-applied plot and was similar in the additional potassium-applied plot and control plot in 2024. Exchangeable potassium content in soil sampled at harvest was highest in the vermiculite-applied plot and was similar in the additional potassium-applied plot and control plot in 2023. It was highest in the additional potassium-applied plot followed by the vermiculite-applied plot and then control plot in 2024. The results suggested that the inhibition effect had longer-lived in the vermiculite-

applied plot than in the additional potassium chloride applied plot.

# Discharge of radium isotopes into to the environment as a results of dewatering of underground coal mines in Upper Silesia, Poland

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A peculiarity of Silesian coal mines is the presence of water containing elevated concentrations of radium isotopes $^{226}$Ra and $^{228}$Ra. The ongoing mining of coal seams takes place at levels exceeding a depth of 1,000 meters, where relic water with high radium concentrations is found. These waters, often also contain barium (Ba) ions. Coal mining involves continuous discharge of water to the surface and discharge into the environment in accordance with the relevant water-legal permit. Contact of water containing radium and barium with waters containing sulfate ions results in the precipitation of deposits consisting of radium-barium sulfate.

As part of its statutory tasks, Silesian Centre for Environmental Radioactivity has been conducting comprehensive monitoring of mine discharges since 2023, including studies of water and sediments formed at the site of the water discharge. The measured concentration of radium isotopes in waters varied: $^{226}$Ra 0.07 - 1.71 Bq·dm$^{-3}$, $^{228}$Ra 0.06 - 2.34 Bq·dm$^{-3}$. The measured concentration of radium isotopes in sediments at the water discharge points varied: $^{226}$Ra 7.8 – 1,275 Bq·kg$^{-3}$, $^{228}$Ra 9.5 – 3,460 Bq·kg$^{-1}$. All sampling was carried out at the points of discharge into natural watercourses (rivers). The tests were carried out by liquid-scintillation spectrometry and gamma-ray spectrometry methods in the accredited laboratory (ISO 17025) of Silesian Centre for Environmental Radioactivity.

# Extreme solar and other cosmic events recorded in $^{14}C$ in tree rings

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Solar flares are intense bursts of radiation from the Sun, that particularly occur during solar maximum. These flares can cause changes in the ionization of the atmosphere and geomagnetic effects. This can disrupt electronic communications and cause aurora much further south than normal. However, these are small events compared to some very large events recorded in past tree-ring records. There are historical reports of an intense event associated with solar activity, for example, a historical event recorded in 1859 called the "Carrington event" caused massive disruption to telegraph communications and caused aurora to be observed as far south as Cuba and Panama. One can only imagine the effect of such an extreme event on our society, which depends so much on GPS and electronic communications.

Large and rapid changes on the scale of 1-2 years in the radiocarbon concentration in tree rings have been linked to solar flare events in the past. The best documented is the 774-775 AD event, recorded in over 34 different locations around the world, in both the northern and southern hemispheres. This even caused an increase in the annual radiocarbon signal by about a factor of 5, meaning a much larger flux of solar cosmic rays, perhaps up to 100 times the largest measured ~~observed~~ solar-flare event in 1956. This 774-775 AD event has been confirmed independently in cosmogenic isotopes measured in ice-core records. Ancient chronicles from European and Asian civilizations describe strange atmospheric phenomena in the past as well at about this time. Surprisingly, the Carrington Event is not easily apparent in the $^{14}C$ record.

There are 6 confirmed events in the last 14,500 years, at 993-994 AD, 774-775 AD, 664-663 BC, 5259 BC, 7176 BC and 12,450 BC in the literature. These are mainly independently confirmed from other radionuclide records, such as $^{10}Be$ in ice cores. That seems like a small number, and there are other events that aren't independently confirmed at about 5410 BC, 810 BC, and 1261-1262, 1268-1269 and 1279-1280 AD, although some may be caused by other astronomical processes. We expect there are more that remain to be found, especially the big gap between 664 BC and 5259 BC. For precise timing of these events and effects from the carbon cycle and plant growth also need to be taken into account. In additional to these events, we have investigated whether there are possible rapid increases in $^{14}C$ production due to other phenomena, such as supernovae. We will discuss the possible ramifications of these very large events and their possible climatic and other effects.

This work was partly supported by grants from the US National Aeronautics and Space Administration (grant 80NSSC21K1426) and the European Union and the State of Hungary, co-financed by the European Regional Development Fund (GINOP-2.3.4-15-2020-00007 “INTERACT”).

# Influence of Distribution Coefficients on the Transport of Radioactive Materials in the East Sea

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In the marine environment, radioactive substances exist not only in dissolved form but also adsorbed onto suspended particles or sediments. The extent of this adsorption, represented by the distribution coefficient (Kd), influences the transport, sedimentation, and long-term behavior of radionuclides in the ocean. This study investigates the role of Kd in modeling the fate and movement of $^{137}$Cs and $^{90}$Sr in the ocean. The POSEIDON-R enhanced with an extended BURN food-chain module, was used to simulate the uptake of radionuclides by both pelagic and benthic marine organisms. Region-specific environmental parameters— suspended sediment flux and concentration, bioturbation, and sediment porosity—were estimated, and a wet deposition based atmospheric deposition dataset was incorporated. Kd values were derived from field surveys conducted in both the shallow coastal area and adjacent deep waters of the southwestern East Sea. The study examined how variations in Kd affect radionuclide retention, bioavailability, and vertical redistribution, as well as the behavior of radionuclides in the marine environment and their potential impacts on marine ecosystems, depending on both the radionuclide and regional characteristics. Model experiments incorporating region-specific Kd contribute to enhancing the accuracy of numerical models simulating radionuclide behavior.

# Impact of Soil Organic Matter on the Formation of $^{137}$Cs and $^{239,240}$Pu Secondary Peaks in Vertical Soil Profiles

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Technogenic radionuclides, such as $^{137}$Cs and $^{239,240}$Pu, on the soil surface are transported to deeper levels and may be adsorbed by soil constituents through a variety of processes, including ion exchange, binding to carbonates and (hydro)oxides, adsorption to clay particles, and complexation with organic material. Organic substances act as temporary reservoirs, binding radionuclides before decomposition releases them into the soil solution, potentially forming new compounds with soil adsorbents (Ota et al., 2016). In waterlogged soils, several concentration peaks have been identified in vertical profiles (Łokas et al., 2013; Lukšienė et al., 2014). However, the mechanisms driving radionuclide transfer to deeper layers and the origin of secondary peaks remain unclear.

This study investigates the role of soil organic matter (SOM) in the formation and characteristics of secondary radionuclide peaks in vertical soil profiles. Sequential extraction was employed to determine geochemical forms, while radionuclide activity concentrations were measured used alpha and gamma spectrometry. The results indicate a strong correlation between radionuclide activity and SOM content, highlighting SOM's key role in radionuclide mobility.

Plutonium isotopes exhibited higher mobility in waterlogged, organic-rich soils but were more stable in non-boggy environments. In contrast, clay-rich soils significantly restricted $^{137}$Cs migration but had little effect on plutonium movement (Kazakevičiūtė-Jakučiūnienė et al., 2021) This study emphasizes the complexity of radionuclide migration, revealing that soil structure and organic matter content are critical factors. Understanding these interactions is essential for assessing long-term radionuclide behaviour in ecosystems and can counsel in remediation and environmental risk management strategies selection.

**References**

Kazakevičiūtė-Jakučiūnienė, L., Druteikienė, R., Maceika, E., Lukšienė, B., Juškėnas, R., Pakštas, V., Žukauskaitė, Z., Gvozdaitė, R., Tarasiuk. N., 2021. Impact of soil organic matter on Pu migration in five Lithuanian surface soils. Journal of Environmental Radioactivity 237, 106702.

Łokas, E., Mietelski, J.W., Ketterer, M.E., Kleszcz, K., Wachniew, P., Michalska, S., Miecznik, M., 2013. Sources and vertical distribution of 137Cs, 238Pu, 239+240Pu and 241Am in peat profiles from southwest Spitsbergen. Appl. Geochem. 28, 100–108

Lukšienė, B., Maceika, E., Tarasiuk, N., Koviazina, E., Filistovič, V., Š, Buivydas, Puzas, A., 2014. On peculiarities of vertical distribution of 239,240Pu, 238Pu and 137Cs activity concentrations and their ratios in lake sediments and soils. J. Radioanal. Nucl. Chem. 300, 277–286.

Ota, M., Nagai, H., Koarashi, J., 2016, Modeling dynamics of 137Cs in forest surface environments: Application to a contaminated forest site near Fukushima and assessment of potential impacts of soil organic matter interactions, Science of The Total Environment, 551–552, 590-604.

# Influence of humification on bioavailable radiocesium concentrations in fallen leaves of Fukushima broadleaf forests

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In the forests of Fukushima, which have not been decontaminated since the Fukushima Daiichi Nuclear Power Plant accident in 2011, radiocesium ($^{137}Cs$) is currently considered to be in a steady state due to translocation. Under such conditions, the organic layer of the forest floor (i.e., $A_0$ layer) is the source of bioavailable $^{137}Cs$ in the forest ecosystem. Therefore, understanding the migration of bioavailable $^{137}Cs$ from the $A_0$ layer and its translocation to organisms is key to predicting the pollution status of forest resources at different locations and times.

The bioavailability of $^{137}Cs$ in the $A_0$ layer depends on the leaching potential of $^{137}Cs$ from the $A_0$ layer into the aqueous phase (rainwater or soil pore water). Since $A_0$ layer is composed of fallen leaves (L layer) and two types of humus (F and H layers), which are products of decomposition of fallen leaves by humification, the leaching potential of layer $A_0$ is expected to vary depending on the degree of humification of the fallen leaves. However, because the F and H layers of the actual forest floor may contain clay minerals that immobilize $^{137}Cs$, information on bioavailable $^{137}Cs$ concentrations in fallen leaves with different degrees of humification (i.e., L, F, and H layers) was limited. In this study, to clarify the effect of humification on bioavailable $^{137}Cs$ concentrations in fallen leaves, fallen leaves of deciduous broadleaf trees were fed to beetle larvae and the resulting excrement was prepared as clay-free humus, and water extraction and $NH_4^+$ exchange experiments were conducted to determine the bioavailable $^{137}Cs$ concentration in fallen leaves and artificially prepared humus.

The concentration ratio of total exchangeable $^{137}Cs$ (i.e., sum of water-extracted and $NH_4^+$ exchanged $^{137}Cs^+$ concentrations/total $^{137}Cs$ concentration in the sample) was the same for fallen leaves (51 ± 9 %) and humus (59 ± 6 %), indicating that humification did not affect the total exchangeable $^{137}Cs$ concentration. On the other hand, the concentration ratio of water-extracted $^{137}Cs$ to total exchangeable $^{137}Cs$ in fallen leaves slightly decreased from 38 ± 3 % to 27 ± 2 % by humification. Since the change in the ratio can be attributed to differences in the degree of competitive reactions of $^{137}Cs^+$ with proton, cation (e.g., $K^+$), and anion (e.g., dissolved organic matters) that leached into aqueous phase, the effect of humification may be explained as differences in leaching of components that react or compete with $Cs^+$. In the presentation, the factors determining the ratio of exchangeable to non-exchangeable $^{137}Cs^+$ in fallen leaves and humus will be also discussed from relation to the chemical compositions of fallen leaves.

# Isotopic signatures of artificial radionuclides: an important tool in today's world

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Radioactive fallout from past releases of radionuclides resulting from above-ground nuclear tests has contaminated the global environment with radioactive materials. Most of these radioisotopes: $^{137}$Cs, uranium, plutonium isotopes (e.g. $^{235,236,238}$U, $^{238,239,240}$Pu), and $^{241}$Am have been identified in various environmental compartments around the world. The half-lives of these radioisotopes are large enough to make radionuclides represent a persistent threat to humans and ecosystems. The concentrations of these radioisotopes and their isotopic compositions in different environmental matrices may reflect nuclear activities in the affected regions. Many countries around the world have recently initiated ambitious nuclear energy programs or declared their intention to generate electricity using nuclear power reactors in the near future. The assessment of the environmental impacts of these programs requires routine monitoring of radioactive fallout. Special attention should be paid to the applications of nuclear materials in space missions, where they provide an alternative to solar power generation. $^{238}$Pu production was restarted in the US for NASA deep space missions and is continued by the Russian Federation. $^{241}$Am has recently replaced $^{238}$Pu due to its lower cost and longer half-life. Since 2009, the production of $^{241}$Am has been under development in Europe as part of the European Space Agency's initiatives.

There is an increasing need to continue detailed analysis of $^{137}$Cs, uranium, plutonium isotopes, and $^{241}$Am in different matrices (e.g., sediments at the surface of glaciers and air filters) to identify sources and distinguish between resuspended or freshly released radioisotopes. In our 15 years of measurements in the Northern and Southern Hemispheres, we observed some isotope anomalies ($^{238}$Pu/$^{239+240}$Pu, $^{241}$Am/$^{239+240}$Pu) that may be related to accidents such as the fall of the Mars-96 spacecraft in the south of the globe, production of radioisotopes as a power source in the north, or other unidentified events.

# Radionuclides in glacier mice and cryoconite on Icelandic glaciers

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Glacier mice are ovoid-shaped conglomerates of bryophytes and mineral particles rarely found on glacier surfaces. They form colonies, host diverse communities of organisms, and exhibit the ability to move across the glacier surface. Their movement appears non-random and displays herd-like behaviour. In addition to glacier mice, cryoconite is also found on glacier surfaces as a dark, biogenic granular sediment. It is composed of minerals and organic matter that accumulate at the bottoms of cryoconite holes.

This study presents the first comprehensive investigation of radionuclide occurrence ($^{137}$Cs, $^{210}$Pb, $^{238,239,240}$Pu, $^{241}$Am) in glacier mice and cryoconite debris on Icelandic glaciers. Ongoing research indicates that glacier surfaces host dynamic ecosystems capable of capturing and processing airborne contaminants. However, glacier mice appear to be less efficient than cryoconite in the bioaccumulation of inorganic pollutants. The objectives of this study are: (a) to determine and compare radionuclide concentrations in glacier mice and cryoconite, and (b) to identify the sources of nuclear contamination in the investigated samples using mass and activity ratios ($^{240}$Pu/$^{239}$Pu, $^{238}$Pu/$^{239+240}$Pu, and $^{241}$Am/$^{239+240}$Pu). Radionuclide analysis was conducted using alpha and gamma spectrometry, and mass ratios were determined using the Agilent 8900 ICP-MS/MS.

We found that glacier mice are characterised by radionuclide activity concentrations ($^{137}$Cs, $^{210}$Pb and $^{241}$Am) that are slightly lower than those in cryoconite, except for plutonium isotopes. Additionally, radionuclide contamination in the studied samples exceeds values previously published for Iceland. The high variability of cryoconite radioactivity among the studied glaciers can be attributed to differences in the exposure times of cryoconite granules to meltwater and fallout radionuclides. An interesting finding of our study is the elevated levels of $^{239+240}$Pu in the analyzed samples compared to other samples from Iceland — a phenomenon of currently unknown origin. Moreover, the plutonium and americium signatures in the Icelandic samples show consistent values, primarily attributed to global fallout.

The results confirm that cryoconite and glacier mice affect cycling of pollutants derived from long-range transport in proglacial ecosystems in Iceland, although likely only on a very limited scale.

# Challenges in Characterization of Legacy Alpha-Emitting Radionuclides in a Norwegian River and Wetland.

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Legacy discharges of long-lived alpha-emitting radionuclides from the Norwegian research reactor JEEP, operated by the Institute for Energy Technology (IFE) since the 1950s, have led to contamination of nearby wetland and river systems (Sogna and Nitelva). Between 1963 and 1967, several megabecquerels of alpha emitters were released to a wetland area, after which discharges were redirected to the river. Although these discharges ceased decades ago, environmental conditions and landscape changes over time have influenced the distribution and potential mobility of the contaminants.

This work presents the planning and scope of an ongoing characterization project aimed at mapping the extent and nature of the contamination. The approach integrates historical data, environmental sampling, and geostatistical tools to support reliable risk evaluations. Special attention is given to understanding factors affecting radionuclide mobility and bioavailability, particularly for plutonium. The sampling campaign also faces logistical and safety challenges, including sediment coring in rivers and wetlands, and the risk of encountering unexploded ordnance from World War II.

Long time intervals since the release, combined with erosion, sedimentation, and human interventions, make interpretation of contaminant pathways highly uncertain. Selecting representative sampling locations across a large and heterogeneous area is critical to avoid under- or overestimation of risk. This comprehensive planning framework provides a template for thorough characterization of legacy radioactive contamination in complex environments, delivering reliable data for environmental risk assessment and potential remediation planning in line with national regulations.

# Radionuclide contaminants as a potential threat to ecosystems from melting Alpine glaciers in high-mountain environments

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Recent studies have reported rapid mass loss of mountain glaciers in response to climate warming, particularly in the Alps, where small glaciers are especially vulnerable to these processes, experiencing significant retreat and shrinkage. Consequently, glaciers are considered as secondary sources of pollutants, including fallout radionuclides ($^{137}$Cs, $^{210}$Pb, $^{238}$Pu, $^{239+240}$Pu, $^{241}$Am), which are transported over long distances through the atmosphere and then deposited with wet and dry precipitation. These radionuclides can originate from nuclear weapons testing and local or regional incidents.

This study focuses on a representative case - the Dosdè Glacier, a small glacier (0.59 km$^2$ in 2016) in the Italian Alps. For this purpose, cryoconite (dark sediment on the glaciers) samples were collected during field expeditions conducted in August 2023, along with proglacial sediments and mosses growing near the glacier front. These additional materials were used to assess the potential transfer of anthropogenic radionuclides in the surrounding habitats. The samples were analysed using alpha and gamma spectrometry, and atomic ratios were determined with the Agilent 8900 triple quadrupole ICP-MS.

The results strongly demonstrate cryoconite's unique ability to accumulate radionuclides, as evidenced by the mean activity concentrations measured at 2,960 Bq/kg for $^{137}$Cs, 8,160 Bq/kg for $^{210}$Pb, 1.34 Bq/kg for $^{238}$Pu, 35.3 Bq/kg for $^{239+240}$Pu, and 24.0 Bq/kg for $^{241}$Am. The activity concentrations of these radionuclides in cryoconite were by magnitude higher than those found in forefield sediments and plants. The activity ($^{238}$Pu/$^{239+240}$Pu) and atomic ($^{240}$Pu/$^{239}$Pu) ratios were determined to identify potential sources of contamination. The reference activity and atomic ratios for global fallout are 0.0249 ± 0.0057 (Perkins and Thomas, 1980; decay corrected to 2023) and 0.180 ± 0.014 (Kelley et al., 1999), respectively. The activity ratios of $^{238}$Pu/$^{239+240}$Pu (0.0390 ± 0.0067) and the atomic ratio of $^{240}$Pu/$^{239}$Pu (0.1608 ± 0.0042) in cryoconite samples suggest that the plutonium pollution at the Dosdè Glacier could mostly originate from global fallout (with a contribution from the re-entry of the SNAP-9A satellite). However, the study also showed possible inputs, such as the redistribution of anthropogenic radionuclides with ash particles and gases in the lower atmosphere and/or low-yielded nuclear detonations (e.g., from Semipalatinsk, Algeria, and Nevada test sites).

Our findings highlight the need for ongoing research into the release of environmental contaminants from glaciers, especially smaller ones like the Dosdè Glacier, which are expected to disappear within decades, releasing radionuclides contained in cryoconites into the surrounding environment when the glaciers begin to recede.

This study was financed by the NCN (Poland) grant no. 2022/45/N/NZ8/01179

**References:**

Kelley, J.M., Bond, L.A., Beasley, T.M., 1999. Global distribution of Pu isotopes and $^{237}$Np. The Science of the Total Environment, 237/238, 483-500

Perkins, R.W., Thomas, C.W., 1980. Worldwide fallout. In: Hanson, W.C. (Ed): Transuranic elements in the environment, U.S. Department of Energy, DOE/TIC-22800, Springfield, Virginia, 53-85

**Dissecting Radionuclide Uptake Pathways: Investigating Radionuclide Transport Mechanisms in Model Plants**

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A mechanistic understanding of radionuclide uptake in plants is essential for accurately assessing risks to the food chain and enabling dose calculations for environmental safety and regulatory frameworks.This study aims to identify specific membrane transporters involved in the uptake of trivalent americium ($Am^{3+}$), focusing on the iron-regulated transporter 1 ( IRT1) and glutamate receptor-like channels (GLRs) in *Arabidopsis thaliana*, *Nicotiana tabacum*, and *Solanum lycopersicum*. Hydroponic uptake assays were performed under iron-deficient conditions in both wild-type and irt1 knock-out lines of *A. thaliana*. No significant difference in $Am^{3+}$ accumulation was observed between the genotypes, a slight increased accumulation was observed in the leaves of the plants cultivated under iron deficient conditions suggesting that IRT1 is not the major pathway for $Am^{3+}$ uptake. Consistently, *N. tabacum* BY-2 suspension cells cultivated under similar conditions also did not show elevated uptake although an increased expression of IRT1 was observed in mRNA level under Iron deficiency, These findings point toward alternative or compensatory mechanisms, e.g. the GLRs. To test this hypothesis, uptake assays in *A. thaliana* GLR knock-out lines are being conducted. In parallel, CRISPR/Cas9-based knock-out lines of *S. lycopersicum* targeting *IRT* and *GLR* genes will be developed. Constructs will be designed using Modular Cloning (MoClo), verified through sequencing, and introduced into cotyledons via *Agrobacterium tumifaciens*-mediated transformation. Follow-up validation will include gene expression analysis, protein quantification, and functional screening of candidate transporters. By delineating radionuclide transport pathways at a molecular level, this work supports more accurate food chain dose assessments and informs risk evaluations in radioactively contaminated ecosystems.

# Measurements of $^{236}U/^{239}Pu$ mass ratio using Inductively Coupled Plasma Mass Spectrometry in cryoconite samples on glaciers of western Norway

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Atmospheric nuclear weapon tests, together with releases from nuclear fuel reprocessing facilities and nuclear reactor accidents are major sources of artificial radionuclides in the environment. Among those, radioisotopes of plutonium and uranium are measured to assess the possible sources of radioactive contamination in different elements of the global ecosystem, including cryosphere. Cryoconite, dark and granule-shaped debris commonly found on glacier surfaces, is known for exceptionally high accumulation of radioactive isotopes, making it a remarkable matrix for studying radioactive contamination in the environment. Among plutonium isotopes, $^{239}Pu$ and $^{240}Pu$ are commonly measured and used in determination of $^{240}Pu/^{239}Pu$ mass ratio, whose value depends on several factors such as type of release (nuclear weapons or reactors) providing more information regarding contamination sources. Out of uranium isotopes, $^{236}U$ is produced via neutron caption on $^{235}U$ and while occurs naturally, the better part of this radioisotope on Earth has anthropogenic origin. Due to low concentrations of $^{236}U$ in the environment, it causes high analytical demands and thus is not commonly reported in the literature. In this study we utilize newly developed, indirect measurement method using inductively coupled plasma mass spectrometry (ICP-MS) to determine the $^{236}U/^{239}Pu$ ratio in cryoconite samples from glaciers of western Norway. In order to avoid analytical problems with the direct determination of the $^{236}U$ concentration, the utilized method consists of three stages: (i) determining $^{235}U$ concentration, (ii) determining $^{236}U$ concentration from $^{235}U$ and $^{236}U/^{235}U$ ratio, (iii) measuring $^{239}Pu$ concentration and ultimately determining $^{236}U/^{239}Pu$. Thanks to separate plutonium measurement, the $^{240}Pu/^{239}Pu$ is also determined and further information regarding radioactive contamination sources is obtained. Besides utilizing brand new ICP-MS measurement method, our study reports radioactive pollution in western Norway and shows further potential threats of environmental contamination.

# Unprecedented radioactive pollution in Spitsbergen air during the 21st century

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Developments in nuclear science throughout the 20th century have led to the systematic production of novel radioactive contaminants on a global scale. Given the risk of increasing background radiation levels, routine environmental monitoring has become necessary. The research presented provides the first Arctic data since 1999 on time series of $^{238}$Pu, $^{239+240}$Pu and $^{241}$Am in the lower atmosphere of Hornsund, Spitsbergen, spanning 2007 to 2021. While the general levels of $^{238}$Pu and $^{239+240}$Pu were comparable to recent observations from different sites, $^{241}$Am was found to be extraordinarily high, with a maximum of 354 nBq/m$^3$ detected in the 1st quarter of 2019. Subsequent analysis of isotopic ratios revealed a frequent enrichment of $^{238}$Pu over $^{239+240}$Pu, inconsistent with previously documented releases. Unexpected single incidents of $^{237}$Np were encountered in 2013, 2014 and 2018.

A multivariate analysis incorporating data on $^{7}$Be, $^{210}$Pb, $^{137}$Cs activity concentrations and a wide range of meteorological factors was applied to explain the behaviour of artificial actinides in ground-level air layers. Evaluation of Spearman correlations allowed explicit links between $^{239+240}$Pu seasonal trends and natural processes, such as local resuspension throughout the year and horizontal tropospheric transport of haze layers from remote areas in the 1st quarter. Similar mechanisms controlled a certain proportion of $^{238}$Pu, but to a lesser extent. The maximum activity concentrations of 6.61 nBq/m$^3$ for $^{238}$Pu and 15.51 nBq/m$^3$ for $^{239+240}$Pu recorded in Hornsund during the 3rd quarter of 2015, and simultaneously registered at middle latitudes, could be related to random events such as fly ash particles remobilised by 2015 wildfires. A majority of the significantly elevated levels of $^{241}$Am, $^{238}$Pu and $^{237}$Np were found not to be environmentally induced. The average annual doses associated with the exposure to investigated alpha emitters were negligible, being about a million times smaller than the typical background radiation doses of 2.4 mSv per year. Therefore, the contamination detected did not pose a radiological threat to the Arctic environment.

Nevertheless, the $^{241}$Am, $^{238}$Pu and $^{237}$Np signals were alarming, as their occurrence could indicate man-made emissions, completely unnoticed by the regular monitoring of gamma emitters in Hornsund air. Trajectory simulations performed for the 1st quarter of 2019 showed the most prominent transport pathways from northern Asia and Europe via the island of Novaya Zemlya. Nuclear aerosols were carried at low levels in the troposphere (below 100 m), resulting in weak dilution and intense deposition. Of note, no radioactive discharges of man-made actinides to the atmosphere have been declared in the last decades. However, a $^{241}$Am incident was identified exclusively in the urban air of central Poland during a few weeks in 2021, possibly generated by the combustion of isotopic smoke detectors. The research highlighted the importance of including alpha emitters in the routine measurements within radiation situation control programmes.

# Activity concentration and atomic ratio of man-made actinides determined by a quadrupole mass spectrometry

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Current practice primarily constrains routine control of the radiological situation to radioisotopes identifiable by gamma spectrometry. Given the potential for the selective release of radioactive contamination, particularly alpha emitters, the existing monitoring strategy may be inadequate for detecting nuclear events. Novel solutions are required to address these challenges. A key recommendation for nationwide and international nuclear safety monitoring networks is to incorporate regular measurements of pure beta and alpha emitters within all environmental contexts. In light of the above concerns, a rapid method was developed and implemented for determining $^{236}$U, $^{237}$Np and $^{239, 240}$Pu by the Agilent 8900#100 ICP MS/MS (Agilent Technologies) in conjunction with the Apex IR desolvating nebuliser (Elemental Scientific). Prior to the measurement process, a sequential radiochemical procedure was employed, encompassing ashing at 600 °C, microwave mineralisation and separation on TEVA or UTEVA resins (Triskem International). Radioisotopic standards of $^{239}$Pu, $^{242}$Pu, $^{239}$Pu/$^{242}$Pu, $^{233}$U/$^{236}$U and $^{236}$U/$^{238}$U (NIST, EC-JRC) were utilised for method calibration, whereas reference materials of IAEA-385 and IAEA-447 (IAEA) were employed for quality assurance purposes. The measurements were conducted in energy discrimination or mass shift modes, using He or $O_2$ gas in the collision-reaction cell, respectively, to eliminate polyatomic and isobaric interferences. The outcomes of this approach included not only activity concentrations of $^{236}$U, $^{237}$Np, $^{239}$Pu and $^{240}$Pu, but also atomic ratios of $^{236}$U/$^{238}$U, $^{236}$U/$^{239}$Pu, $^{237}$Np/$^{239}$Pu and $^{240}$Pu/$^{239}$Pu. The LOD level was calculated to be equivalent to a few femtograms of the radionuclides examined.

# Features of artificial $^{90}Sr$ and $^{239+240}Pu$ accumulation by poultry organs and tissues

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The paper presents the results of the field survey on the transfer factors of artificial $^{90}Sr$ and $^{239+240}Pu$ for the poultry organs and tissues on chronic intake with different components of the diet – contaminated soil and feed.

Despite many years of research on the migration regularities of radionuclides in the body of farm animals and poultry, this issue remains relevant to this day. There are radionuclides whose behavior has not yet been studied, which continues to arouse a great scientific interest.

The present study has used broilers as the study object, which were kept under caged conditions. The poultry was divided into two groups. The conditions for each group were identical except for the source of radionuclide intake, which was added to the daily diet: the first group was fed contaminated soil, and the second - contaminated plant feed. The duration that the poultry was kept for varied from 0 to 70 days. According to the calculations made and proceeding from the reported values of the average activity concentrations of radionuclides of interest in the soil and plant feed, the daily intake by the poultry was calculated. For instance, the average daily intake of $^{90}Sr$ with soil and plant feed was 850 ± 120 and 140 ± 20 Bq/kg, respectively. The average daily intake of $^{239+240}Pu$ with soil was 2,766,000 ± 415,000 Bq/kg, and the one with the plant feed - 220 ± 30 Bq/kg.

As revealed by the conducted experimental studies, the bone tissue is the major organ for $^{90}Sr$ to deposit. $^{90}Sr$ availability, on intake with the plant feed, was found to be higher and its concentration for the longest caging term of 70 days was 3,200 ± 500 Bq/kg, and on intake with soil - 350 ± 160 Bq/kg.

The organ for $^{239+240}Pu$ to deposit is the softer tissues of the parenchymatous organs - the liver. The results show the inverse order of availability. For instance, the concentration of $^{239+240}Pu$ in the liver on intake with the soil is higher being 180 ± 10 Bq/ kg, and on intake with the plant feed - 2.4 ± 0.5 Bq/kg.

As the work proceeded, the transfer factors of $^{239+240}Pu$ in the liver ingested with the soil and plant feed were also calculated, which were $(5.4\pm0.8)\cdot10^{-5}$ and $(9.0\cdot\pm\ 1.8)\cdot10^{-3}$, respectively, and those of $^{90}Sr$ in the bone tissue - 0.4 and 23, respectively.

The study and findings have resulted in the dynamics of the accumulation of radionuclides, which depends on the source of intake, the physico-chemical form (soil, feed) and the type of tissue. The amount of findings is applicable for: calculating radiation burdens from poultry products; calculating the maximum permissible levels of radionuclide intake by the human body; developing recommendations for obtaining products under contamination conditions.

# Intercomparison of Radon Concentration Measurements in Volcanic Touristic Caves

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Radon-222 (Rn) is a naturally occurring radioactive gas that originates from the decay of uranium in rocks and soils. It can accumulate in enclosed environments such as caves, mines, and buildings, posing a potential health risk due to the ionizing radiation emitted by its decay products, which are linked to lung cancer with prolonged exposure. In tourist caves, where visitors and guides may spend considerable time, it is essential to monitor radon levels and assess radiological risks through dosimetry and radiation protection measures [1]. Regular measurements and intercomparison exercises help ensure accurate and reliable data to protect public health and comply with regulatory standards. In this regard, an intercomparison exercise was carried out to measure Rn concentrations in the indoor air of two nearby caves—El Viento and Felipe Reventón caves—in the municipality of Icod de Los Vinos (Tenerife, Canary Islands, Spain). Measurement equipment from the University of La Laguna (ULL) and the Earth Science Institute of the Slovak Academy of Sciences (ESI-SAS) was used. Both continuous monitors and track detectors were employed.

Radon concentrations were monitored at multiple points over 10 days (October 2–11, 2024), alongside microclimatic data (temperature, humidity, and pressure). Continuous measurements were taken using four Radon Scout Plus detectors (SARAD GmbH) and three RPP detectors (Piketronic Co., Czech Republic), both based on a silicon diode diffusion chamber. Integrated measurements used two types of track detectors: CR-39 (Radosys®), analyzed by accredited labs at the Universities of Santiago de Compostela, Cantabria, and La Laguna, and Ramarn detectors with LR-115 Kodak film, processed in the Czech Republic.

The results obtained show good agreement among the different instruments and measurement systems, both in continuous and discrete modes. Higher radon levels were found in the non-public sections (between 6,100 and 11,200 Bq/m³ in the non-accessible section of Cueva del Viento and between 4,000 and 6,700 Bq/m³ in Felipe Reventón) compared to the 1,000 to 5,300 Bq/m³ recorded in the publicly accessible section of Cueva del Viento. These higher values, relative to previous studies in the tourist section [1], are attributed to poorer natural ventilation conditions in the non-tourist sections of Cueva del Viento.

**References**

*[1] Salazar-Carballo, P. A., López-Pérez, M., Martín-González, M. E., Suarez, F. H., & Martín-Luis, M. C. et al. Radon dynamics and effective dose estimation in a touristic volcanic cave: La Cueva del Viento, Tenerife (Canary Islands, Spain)». GeoHealth, 2022, https://doi.org/10.1029/2022GH000704.*

# Progress in the determination of $^{10}$Be using Accelerator Mass Spectrometry in the CENTA laboratory

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$^{10}$Be is a long-lived radioactive cosmogenic isotope of beryllium (half-life 1.387 Ma), produced by high-energy cosmic rays in the Earth's environment, dominantly in the atmosphere. It serves as an important tracer, frequently used for dating in geosciences and has many applications in Earth and environmental sciences. Due to its long half-life and beta decay mode, accelerator mass spectrometry is dominantly used for the ultratrace concentration determination of $^{10}$Be in natural samples.

The CENTA laboratory, founded in 2013, was equipped with a 3 MV Pelletron accelerator. Our initial attempts at measuring $^{10}$Be in 2015 (Ješkovský et al., 2015) were limited by insufficient background suppression in the high-energy part of the beamline. In 2023, a major upgrade of the beam line was implemented, allowing better suppression of interfering ions; however, for suppression of $^{10}$B, the main isobar for $^{10}$Be, additional methods need to be implemented.

For the full suppression of $^{10}$B, an absorption technique in front of the gas ionisation detector was used, while a stack of silicon nitride foils with a defined areal density was used as an absorber. This technique was tested by using a $2^+$ charge state, for higher transmission and a gas ionisation chamber supplied by NEC. Standard reference materials with an isotopic ratio of $^{10}$Be/$^{9}$Be ranging from $2.502 \times 10^{-11}$ to $1.01 \times 10^{-13}$, obtained from University of California (Nishiizumi, 2022), were used for the determination of linearity in this range. When the production of BeH molecules was suppressed by increasing the pressure of the stripper gas in the accelerator, a background level of about $10^{-14}$ was achieved.

References

Ješkovský, M., Steier, P., Priller, A., Breier, R., Povinec, P. P., & Golser, R. (2015). Preliminary AMS measurements of 10Be at the CENTA facility. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, *361*, 139–142. https://doi.org/10.1016/j.nimb.2015.04.072

Nishiizumi, K. (2022). Preparation of new 10Be and 26Al AMS standard reference materials. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, *530*, 43–47. https://doi.org/10.1016/j.nimb.2022.09.014

# Exploiting new advances in micro-extraction to improve the detection and quantification of environmentally relevant radionuclides

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Recent developments in microextraction techniques have significantly enhanced the analytical capabilities for detecting and quantifying trace levels of environmentally relevant contaminants. These techniques have gradually found increasing application in radiochemistry in recent years. This work presents the application and optimization of a sub-category of microextraction, cloud point extraction (CPE) and related micelle-based systems, for the selective preconcentration of actinides and other radionuclides from complex matrices.

This presentation emphasizes overcoming key challenges such as maintaining micellar integrity under acidic conditions, optimizing ligand–analyte interactions, and ensuring compatibility with both mass spectrometric (e.g., ICP-MS/MS) and radiometric (e.g., alpha spectrometry, LSC) detection methods. The study demonstrates the effectiveness of surfactant-mediated extraction systems, including the use of non-ionic surfactants such as Triton X-114 and specialized ligands like bis(2-ethylhexyl) methanediphosphonic acid ($H_2$DEH[MDP]) and diglycolamide analogs, for the efficient recovery of isotopes such as plutonium-239/240 and polonium-210.

Analytical figures of merit, including preconcentration factors, method detection limits (MDLs), and matrix-specific recoveries, are reported for various environmental and biological samples. The results underscore the potential of advanced microextraction strategies to improve throughput, sensitivity, and selectivity in radiochemical analysis, supporting not only routine monitoring and emergency response applications, but also the production of rare radioisotopes.

# Anthropogenic radionuclides as tracers of climate change in the Pacific Ocean and its northwestern marginal seas

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Climate is the statistical description of the mean and variability of its variables (temperature, precipitation, wind, sea surface temperature, ocean circulation, seawater chemical composition, etc.) over 30 years. Climate change is the deviation from the current climate. The increase in anthropogenic greenhouse gas emissions into the atmosphere since the Industrial Revolution has accelerated global warming with significant impacts on Earth's ecosystems. Oceans, consequently, have been experiencing frequent marine heat waves and a slowdown of the Global Meridional Overturning Circulation (GMOC), disrupting ocean circulations with accompanying changes in biogeochemical processes, including surface ocean acidification and poleward migration of trophic organisms. Anthropogenic radionuclides (ARs), released to the marine environment from nuclear activities since the 1940s, have recorded some climate change impacts on the world ocean in the water, bottom sediment, and biota (e.g., Scleractinian corals). Recent developments in radiometric and mass spectrometry technologies have increased sensitivity by more than 10, enabling us to obtain high-resolution data down to the abyssal ocean using standard Rosette water bottle systems with one/two casts only. The Pacific Ocean is the most extensively sampled for ARs over the several decades among the oceans. Several examples of the temporal and spatial changes in ARs (e.g., 3H, 14C, 90Sr, 129I, 134Cs, 137Cs, and Pu isotopes) in the Pacific Ocean and its northwestern marginal seas are shown here to demonstrate the utility ARs as tracers of climate change occurring in the oceans.

The key contributions of ARs to GMOC studies are the confirmation of the role of Indonesian Throughflow (ITF) from the western tropical North Pacific to the Indian Ocean, the accumulation of ARs in the Indian Ocean Subtropical Gyre, the south Indian Ocean as a final reservoir of contaminants transported from the northern Indian and Pacific Oceans on a time scale of several decades, and the discovery of the cross-equatorial subsurface isopycnal mixing of the North Pacific water to the South Pacific Ocean evidenced by the global fallout 137Cs. Vertical distribution of plutonium isotopes records the ongoing climate change impact in the Sea of Japan, as increasing SST reduces winter convection and eddy activities. ARs were found to be varied due to changes in the offshore vertical mixing induced by the changes in the Asian monsoons and ENSO events in Chinese marginal seas. ARs data has provided reference frames to calibrate and validate global ocean circulation models and the Earth System Models in future scenarios of ocean changes and their impacts. High-resolution time and space distribution of the Fukushima-derived 137Cs obtained in the North Pacific Ocean are essential for future studies of climate change impacts. New international large-scale sampling campaigns covering the world ocean using recently developed high-resolution/sensitive radiometric technologies are needed to generate a robust database to complement the earlier several decade-long observations. The Southern Ocean should receive special attention due to its role in global climate and relatively limited anthropogenic radionuclide data.

# Variation of $^{239,240}$Pu in coral and its response to climate system in South China Sea

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With the acceleration of climate change, understanding the behavior of the anthropogenic radioactive substances–particularly their responses to climate system–become critical for assessing their transport, transfer and impact on the ecosystems. However, this remains underexplored, particularly in the South China Sea (SCS), where radioactivity is derived from both close-in fallout of Pacific Proving Ground (PPG) and global fallout. Additionally, this region is quite sensitive to climate change. A coral core collected from Xisha Island, SCS was initially analyzed for high radiotoxic $^{239,240}$Pu. Approximately 72–84% of plutonium in coral originated from close-in fallout of PPG through ocean current compared to the direct global fallout. But $^{239,240}$Pu concentration still remains in background levels and does not show a significant radiation risk. After 1980, a distinct pattern emerged characterized by "higher" concentration but "lower" $^{240}$Pu/$^{239}$Pu atom ratio compared to the levels in the open west Pacific. This is primarily attributed to the seasonal upwelling of subsurface seawater on the continental shelf of SCS, driven by prevailing southwest monsoon. Significantly elevated $^{239,240}$Pu concentrations were observed during typical ENSO years–1983, 1988 and 1997. This is due to the elevated temperature, coral bleaching and the expulsion of symbiotic zooxanthellae. After expulsion, zooxanthellae containing higher $^{239,240}$Pu compared to skeleton rapidly die, and their debris directly deposited onto the coral skeleton, in contrast to the metabolic way of $^{239,240}$Pu during normal years. This finding offers critical insights into ecosystem protection in SCS amid the global changes and potential threat of nuclear contamination.

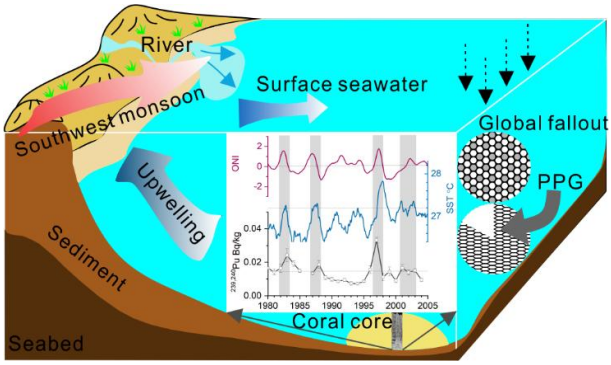



Fig. 1 Temporal variation of $^{239,240}$Pu concentrations in the Xisha coral after 1980, in comparison with ONI index and SST

# "$^{210}$Po in Inhalable Products: Comparison of Committed Doses Using the Human Respiratory Tract Model (HRTM)"

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Naturally occurring radionuclides, particularly the alpha-emitting isotope polonium-210 ($^{210}$Po), are known to accumulate in various types of dried plant matter exposed to environmental deposition. When such materials are subjected to thermal processes for inhalation, $^{210}$Po can be released into the air as part of an aerosol. The extent to which this radionuclide is transferred into the respiratory system is influenced by several variables, including temperature, the presence or absence of filtration systems, and the physical properties of the aerosol particles themselves.

This study aims to evaluate and compare the committed effective doses of $^{210}$Po that result from different modes of thermal aerosol generation. A respiratory tract deposition model developed by the International Commission on Radiological Protection (ICRP), known as the Human Respiratory Tract Model (HRTM), was used to estimate the distribution and retention of inhaled activity in various compartments of the respiratory tract following exposure.

To carry out the assessment, dried plant-based samples were processed using a set of commonly applied inhalation-related techniques, which included open combustion (analogous to burning) and controlled-temperature thermal release (without direct combustion). In each case, desorption of $^{210}$Po was experimentally measured through radiochemical methods involving alpha spectrometry. Sample residues and aerosol fractions were separately analyzed to determine the distribution of radioactive material. Dose calculations were performed using deposition coefficients from the HRTM, incorporating assumptions regarding particle size distribution and respiratory tract airflow.

Results showed that techniques involving direct combustion without any form of particulate filtration yielded the highest transfer rates of $^{210}$Po into the aerosol phase, resulting in the greatest modeled dose values. In contrast, methods relying on thermal volatilization at moderate temperatures released smaller fractions of $^{210}$Po into the aerosol, suggesting significantly lower radiological impact. The differences in calculated committed doses between the most and least intensive methods exceeded a factor of three.

These findings highlight the strong dependency of internal radiation dose on the chosen thermal technique for aerosol production. The combination of elevated temperatures and the lack of filtration significantly increases the availability of radionuclides for inhalation. Conversely, controlled heating and appropriate filtration mechanisms can effectively mitigate this risk. The results emphasize the importance of accounting for both technological and physical parameters when evaluating potential radiological exposures associated with the use of aerosol-generating plant-based materials.

# Measurement of $^{14}C$ in liquid fuels using Accelerator Mass Spectrometry

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Accurate determination of the biogenic-carbon fraction in liquid fuels is essential for compliance with EU renewable-fuel regulations (Directive (EU) 2018/2001 of the European Parliament and of the Council) and for reliable life-cycle analyses of biofuels. Accelerator-mass spectrometry (AMS) offers a rapid, reproducible, and robust method for quantifying fossil versus biogenic carbon fractions, in full conformity with the ASTM D6866-2024 Rev A testing method and EN 16640 standard.

In this exploratory study, we employ a sealed-tube oxidation procedure in which samples are heated to 550 °C for 12 hours in the presence of $MnO_2$, converting all organic carbon to $CO_2$. The produced $CO_2$ is then cryogenically purified (a water trap cooled to -30°C, followed by a liquid nitrogen trap) and reduced to graphite in a catalysed graphitisation reactor.

Our liquid test matrix comprises alcohols (e.g., ethanol), oils and glycerol. Liquid of purely fossil and purely biogenic origin were used to prepare additional samples with varying proportions of the biogenic component. Commercially available fuels were represented by pure fossil and pure biogenic fuels (fatty-acid methyl ester and hydrotreated vegetable oil), as well as by blends differing in biogenic-carbon content. Biogenic fractions were determined with uncertainties, meeting the requirements of fundamental research and economic assessment.

The obtained results demonstrate that the sealed-tube $MnO_2$ combustion method coupled with $^{14}C$ and $^{13}C$ AMS analyses delivers a reliable, precision workflow for routine certification of biofuel blends, thereby supporting the regulatory compliance and sustainability initiatives in the automotive sector.

**Keywords:** CENTA; AMS; $^{14}C$; biofuels; blend-ratio determination

# Radiocarbon dating in wildlife forensics

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Under the international multilateral CITES convention, endangered species of animals and plants are granted various levels of legal protection that regulate trade and other forms of handling. For example, in most EU countries, an exemption from the ban on ivory trade may only be granted if it can be proven that the item originates from before 1947. Trade in raptors and large carnivores is usually also subject to regulation. Unfortunately, crime against protected species is widespread, and law enforcement in this area remains weak. This is due in part to the low priority given to such crimes in many parts of the world, as well as the lack of available forensic methods. Most forensic techniques are derived from human forensic science and require costly adaptation to account for the specific properties of animal tissues.

Radiocarbon dating is a promising complementary tool in wildlife forensic science and can provide crucial analytical evidence to determine whether an animal lived and died before or after the relevant regulations came into effect. However, its use in wildlife applications is subject to the same limitations as any other radiocarbon application.

The first major limitation is reduced temporal resolution, ambiguity in dating samples from the second half of the 20th century, as well as the emerging overlap between the post-2020 period and the pre-1950 era. To mitigate the impact of such ambiguities, we are testing strategies based on single- or multi-tissue chronological analysis and complementary analytical methods with potential for relative or absolute dating, such as electron paramagnetic resonance, Sr90 analysis, or the detection of anthropogenic pollutants.

The second key challenge is presented by heavily processed or contaminated materials, such as tanned hides or taxidermy specimens. These pose analytical difficulties due to chemical alterations and the incorporation of exogenous carbon.

The third major challenge lies in the sampling of artefacts that are claimed to have high artistic or cultural value, typically ivory carvings. Smart, minimally invasive solutions adapted to the specific characteristics of such artefacts are highly desirable, as ivory remains the most frequent sample type in our dataset, and the results indicate that the most of confiscated ivory is of illegal origin, dating back to the infamous and bloody poaching massacres of African elephants in the 1970s and 1980s.

# Assessment of Beta-Emitting Radionuclide Accumulation in Food and Tobacco Products During Long-Term Storage

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According to the World Health Organization (WHO) and the International Agency for Research on Cancer (IARC), by 2030, the number of new cancer cases and cancer-related deaths is expected to increase by more than 20% [1]. In Kazakhstan, cancer incidence rates remain among the highest in the CIS countries, with trachea, bronchus, and lung cancer ranking second among newly diagnosed cases in both genders, accounting for 10.5% (first place among men at 18.4%), and stomach cancer accounting for 7.8% (11.8% in men) [2]. Radon is the leading cause of lung cancer among non-smokers [3], contributing at least 50% to the annual radiation dose. Besides inhalation of radon and its decay progeny (RDP), humans also consume radionuclide-containing food products. Additionally, tobacco smoke not only contains toxic chemical substances but also radioactive heavy elements, which significantly contribute to internal radiation exposure. Many safety standards focus on fresh products, while the effects of long-term storage on the radiation background remain insufficiently studied. Investigating this aspect will allow for the development of new recommendations and regulations to ensure the safety of products stored or sold for extended periods. The aim of this study is to examine the absorption of beta-radionuclides of radon decay products in food and tobacco items during long-term storage.

The objects of the study were food products among the most commonly consumed in the country (according to data from the National Bureau of Statistics [4]) and tobacco products most popular in the Republic of Kazakhstan, with storage periods ranging from 2 months to 3 years. The subject of the study was the specific beta-activity of the samples, as well as the quantitative assessment of Pb-210 and Bi-210 concentrations in the analyzed samples. Radon decay products include beta-emitting radionuclides Pb-210 and Bi-210 with beta particle energies of 0.063 MeV and 1.161 MeV, and half-lives of 22.2 years and 5.012 days, respectively. These are the longest-lived beta radionuclides formed during radon isotope decay, which necessitates accounting for the dose they contribute. Sample preparation for counting was performed according to the standard methodology for counting samples for spectrometric measurements. After sample preparation, beta spectra were obtained using the SKS-99 "SPUTNIK" beta-spectrometric setup equipped with a scintillation detector, with a measurement exposure of at least 10,000 events, followed by calculating the specific beta-activity of the samples. The results showed that when assessing the contribution of long-lived beta radionuclides, the levels of Pb-210 and Bi-210 in the samples did not exceed the permissible values established by the sanitary standards of the Republic of Kazakhstan: 0.12 Bq/kg for Po-210 and 0.2 Bq/kg for Pb-210.

1. Global Cancer Observatory: Cancer Today. Available from: https://gco.iarc.fr/en
2. Kazakh Research Institute of Oncology and Radiology. Available from: https://onco.kz/
3. Jankovic M.M., Todorovic D.J., Todorovic N.A., Nikolov J. Natural radionuclides in drinking waters in Serbia // Appl. Radiat. Isot. – 2012. – Vol. 70. – p. 2703-2710.
4. Bureau of National Statistics https://stat.gov.kz/ru/industries/labor-and-income/stat-life/spreadsheets/

# Nationwide Environmental Radiation Monitoring Programme in Finland

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The objective of environmental radioactivity monitoring is to assess the levels of artificial radiation in the environment to which the public is exposed. Another goal is to detect any significant changes in environmental radiation and radioactivity levels. The Euratom Treaty obliges the member states of the European Union to continuously monitor radioactivity levels in air, water, and soil. In Finland, the Radiation and Nuclear Safety Authority (STUK) is responsible for fulfilling the obligations of the Euratom Treaty under the Radiation Act.

The monitoring programme began in the late 1960s in Finland. Today, it includes nearly 260 automatic external dose rate monitoring stations, as well as the monitoring of airborne radioactive substances and radionuclides in deposition at eight stations. It also covers the monitoring of radionuclides in wastewater sludge, surface water, the Baltic Sea, drinking water, milk, and foodstuffs. Depending on the sample type, gamma emitters, Sr-90, and H-3 are analysed. Additionally, whole-body measurements of individuals are conducted in three cities as part of the programme. In addition to continuous monitoring, separate monitoring projects are carried out, such as Radioactivity of the Ashes of Waste Incinerator Plants in Finland and Radioactivity in Forest Mushrooms.

Results from external dose rate monitoring are updated hourly on STUK's website, and other results are published once they are completed. The compiled results of the monitoring programme are presented in an annual report, which is publicly accessible.

# Environmental radioactivity measurement capabilities at STUK

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Measurement and Analysis laboratory corresponds of STUK's laboratory radioactivity measurements. The laboratory is an accredited testing laboratory (FINAS T167, ISO/IEC 17025:2017) and the fields of testing consist of food, work and living environment and environmental testing.

The laboratory's responsible within STUK is to maintain and develop the analytical methods for radioactive samples. In addition to the routine analytical testing, the laboratory has a significant role as the Finnish national preparedness laboratory regarding the radioactivity. In a radiological emergency, the laboratory's responsibility is to provide radioactivity analyses for the base of decision-making.

The current accredited methods include gamma spectrometric measurements of variety of sample types (environmental and industrial samples, direct measurements of people), radiochemical analyses from several matrices (Pu, Am, Cu, Sr, $^{3}$H, U, Pb, Po, Rn, gross alpha), ICP-MS (inductively coupled plasma mass spectrometry) analyses (U, Th, Sr), airborne Rn measurements and sampling for the environmental surveillance of radioactivity. In addition, the laboratory maintains and develops non-accredited methods, which are either under method development (e.g. $^{3}$H in air) or serve as complementary analytical tools (gross beta).

The testing services are provided for both internal and external customers. The major internal customers are the environmental radiation monitoring in the vicinities of the Finnish nuclear power plants, and the monitoring of environmental radiation in Finland. The external customers include for example international organizations, citizens, industry in Finland and abroad, and other authorities. Besides plain radioactivity measurements, the laboratory provides expert services including e.g. baseline surveys for environmental radioactivity, sampling in the vicinity of nuclear facilities and radon measurements in mines.

Annually the laboratory performs over 2000 gamma spectrometric and approximately 1000 radiochemical analyses. In addition, approximately 400 direct measurements of people and a few hundreds of ICP-MS analyses are conducted annually.

The foresight in future includes the increasing use of mass-spectrometric methods for the analyses of radioactive materials both in routine and emergency situations as well as the possible advantages offered by automation in analytics. The implementation of ICP-MS/MS to the current infrastructure and discussion of its major role in future analytics of certain radionuclides is currently in progress at STUK. Also, the utilization of XRF (X-ray fluorescence) as a complementary technique for the sample matrix characterization has been recognized as a potential addition to the current analytical instruments.

In this poster, the laboratory's current analytical activities are exhibited and future needs and insights regarding environmental radioactivity measurements are reflected. The comments and discussions as well as possible collaboration invitations on these topics are warmly welcomed during the ENVIRA 2025 conference and afterwards by a direct contact to the authors.

# Renewal of Reactor Operation Licenses, without complying with current Regulations at Laguna Verde Nuclear Power Plant - MEXICO.

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On April 10, 2025, Laguna Verde Nuclear Power Plant (LVNPP) of Federal Electricity Commission (FEC) will obtain the renewal of its Reactor Operation License number 2, without having complied with the current regulations, just as it managed to obtain it for reactor number 1, which expired and was renewed on July 24, 2020; The authorization was granted by the National Commission for Nuclear Safety and Safeguards (NCNSS), which is the regulatory body in Mexico on nuclear issues, without having verified compliance with the Official Mexican Standard NOM-034-NUCL-2016, which is monitored by NCNSS and is contemplated in Laguna Verde Quality Assurance Plan, The above, according to Official Letter No. AOO.130/042/2020, dated 13 November 2020. In this letter you can read: “This Authority regularly monitors, through its inspections, that LVNPP complies with this obligation, so once acceptable sanitary conditions exist and NCNSS has sufficient financial resources, Directorate Deputy General of Nuclear Safety (DDGNS) may carry out the corresponding diligence.” Later it says: "It is worth mentioning that this NCNSS granted the "Authorization for operation in nuclear facilities" No. CNLV-1/2020 to Laguna Verde Nuclear Power Plant, on July 24, 2020."

International Atomic Energy Agency (IAEA) carried out a SALTO (Security Aspects Long Term Operation) at LVNPP from March 5 to 14, 2019:
(https://www.iaea.org/sites/default/files/documents/review-missions/41_laguna_verde_salto_executive_summary.pdf )

The team found areas that should be improved to reach the level of IAEA safety standards and international good practices. Fourteen issues (deficiencies) were observed, among which we can mention:
1.- The plant does not have a comprehensive Long-Term Operation implementation program, emphasizing the replacement of equipment that has exceeded its useful life of 30 years.
2.- Periodic Security Review is not exhaustive to identify potential security improvements for Long Term Operation.
3.- Final Security Analysis Report has not been updated for Long Term Operation.
4.- The aging management programs and the aging management review of active components are not exhaustive for Long Term Operation, etc.

The objective of this work is to ensure that the corresponding regulations are applied and thus guarantee the safe operation of the two nuclear reactors of the LVNPP. This work was carried out in Department of Physics of the Faculty of Sciences of the National Autonomous University of Mexico.

# Measurement Strategies and Detection Limits for Particulate Filter Gamma-Ray Spectrometers in Real-Time Monitoring

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The surveillance and monitoring of airborne environmental radioactivity are critical for early detection of artificial isotopes. Gamma-ray spectrometers with particulate filters offer a combined solution for real-time and long-term monitoring that ranges from 10 minutes up to 5 days. We improve the capabilities of these spectrometers, developing measurement strategies and assessing Minimum Detectable Activity Concentration (MDAC) for the different time ranges.

The gamma-ray spectrometers use a scintillating crystal detector ($LaBr_3$(Ce) or $SrI_2$(Eu)) shielded by lead, with a glass fibre particulate filter inside the shielding. An air pump forces air through the filter to collect airborne particles. The monitors record spectra every 10 min and the filter is exchanged every 5 days, allowing the filter monitor to measure at different sensitivity and time resolution ranges simultaneously.

We propose 3 operational modes: **Real-Time Measurements** (isotope activity is measured every 10 minutes); **Measurement Since Last Filter Exchange** (Activity concentrations and MDAC vary depending on the time elapsed since the last filter exchange); and **Long-Term Averaging** (we estimate mean activity over extended periods, providing stable results and lower detection limits).

We show results for 2 different simulated situations:

1. A short, intense detection of $^{137}$Cs by introducing contamination at specific times. The real-time method obtains detection limits in the range of 1 Bq/m³ for 10-minute measurements.

2. A Highly Diluted Cloud of $^{137}$Cs to simulate a continuous low-intensity detection over several days. The detection limit varies significantly, improving as the filter ages. Averaging for 24 hours yielded more stable results, with detection limits reaching the mBq/m³ range towards the end of the filter cycle (MDAC values for $^{137}$Cs reach 0.8 mBq/m$^3$ when using $SrI_2$(Eu) detectors over a 5-day integration period).

The study highlights the advantages of particulate filter monitors in achieving real-time measurements and better sensitivities over different timescales. The combination of measurement strategies allows for distinguishing between low average AC over long periods and high AC over short periods. Filter monitors provide a versatile solution for environmental radioactivity monitoring across various timescales, making them suitable for a wide range of applications, while relying on a single, multifunctional system capable of operating autonomously, unattended, and fully remote.

# Distribution of $^{3}H$ and $^{14}C$ in the Pacific Ocean and its connection with climate change

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Tritium $^{3}H$ ($T_{1/2}$ = 12.3 y) and radiocarbon $^{14}C$ ($T_{1/2}$ = 5730 y) have been long recognized as powerful tools to trace movement of seawater masses, and various physical, geochemical and biological processes in the oceans. Their importance has grown even more after the nuclear weapons testing era, during which their natural inventories were significantly increased; it was estimated that around 3.4 EBq of $^{3}H$ and 0.13 EBq of $^{14}C$, originating from global fallout, are still present in the marine environment (IAEA, 2005). The northern part of the Pacific Ocean was one of the most affected basins due to specific stratosphere-troposphere exchange, high wet deposition rate and its correlation with the latitude. The impact of other anthropogenic sources – namely the Fukushima accident and operation of nuclear power plants and nuclear fuel reprocessing plants – on tritium and radiocarbon levels in the Pacific Ocean has been estimated to be much lower, though still clearly visible, especially on a local or regional scale (Kaizer et al., 2018).

During the last three decades, the content of tritium and radiocarbon in the Pacific Ocean surface and deep waters have been screened several times. The largest set of information was gathered from the World Ocean Circulation Experiment (WOCE) which was carried out in the Pacific Ocean mainly between 1991-1994. The following expedition in the framework of the World Marine Radioactivity Studies (WOMARS) in 1997 was focused only on the western region of the North Pacific Ocean. Part of the GEOTRACES programme, which started in 2010 and should continue in the upcoming years, has also dealt with $^{3}H$ and $^{14}C$ determinations. After the Fukushima accident, the western North Pacific Ocean was investigated once again by the Japan Agency for Marine Earth Science and Technology (JAMSTEC) during winter 2012 to evaluate its influence.

Based on the datasets mentioned in the previous paragraph, we investigated spatial and temporal changes in $^{3}H$ and $^{14}C$ concentrations in the Pacific Ocean over the last thirty years. The main goal of the study was to evaluate whether the distribution patterns of the radionuclides of interest were potentially modified within the prevailing climate change. As was confirmed by recent studies (Li et al., 2020), stratification of global ocean has been increasing due to global warming, which has been directly affecting distribution of some important nutrients. Therefore, it is reasonable to ask a question if the same effect can be observed in the case of tritium and radiocarbon.

References

IAEA, 2005. Worldwide marine radioactivity studies (WOMARS). In: Radionuclide Levels in Oceans and Seas. IAEA-TECDOC-1429, Vienna.

Kaizer, J., Aoyama, M., Kumamoto, Y., Molnár, M., Palcsu, L., Povinec, P.P., 2018. Tritium and radiocarbon in the western North Pacific waters: post-Fukushima situation. J. Environ. Radioact. 184–185, 83–94.

Li, G., Cheng, L., Zhu, J., Trenberth, K.E., Mann, M.E., Abraham, J.P., 2020. Increasing ocean stratification over the past half-century. Nat. Clim. Chang. 10, 1116–1123.

# ARTIFICIAL RADIONUCLIDES IN THE PLANT COVER OF TEST LOCATIONS OF RADIOLOGICAL WARFARE AGENTS AT THE 4 SITE

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The Semipalatinsk Test Site (STS) was one of the largest nuclear test sites (~18,500 $km^2$). Altogether, 340 underground nuclear explosions, 30 ground and 86 air explosions were conducted in its territory. Each type of test was characterized by a certain amount and composition of radionuclides produced during a nuclear explosion, their spread area and localization at various spots, and subsequently by radionuclide speciation in soils. The test locations of radiological warfare agents (RWA) are notable for a unique radionuclide composition. The activity concentration of strontium-90 radionuclide in the soils of this territory reaches several million Bq/kg, whereas the content of radionuclides is significantly lower than that of the rest, which is apparently attributed to the formulation of the substances used in the tests. The RWA tests implied dispersion by detonating individual warheads, bombing areas with mortar shells, dropping bombs from bombers or spraying RWA from airplanes. RWA are liquid or powdered formulations fabricated either from radiochemical waste or by irradiating specially selected substances with neutrons from an operating nuclear reactor. Their activity concentration ranged from tenths to several curies per liter. The RWA tests were carried out at 2 sites – 4 and 4a. This paper presents the findings on the accumulation of artificial radionuclides by plants at the 4 site.

The vegetation cover was studied using individual techniques of geobotanical description identifying the main ecosystems and the species composition of plants. To determine the content of artificial radionuclides in the plant cover, 16 research sites were prepared – the points of duplicate sampling of soils and plants. The aboveground parts of the plants were sampled at each site (sampling area ~1-2 $m^2$), as well as soil samples to assess the dose rate of external radiation. A plant sample represented a mixed sample of steppe motley grasses approximately equally dominated by feather grass (*Stipa capillata*, *S. sareptana*, *S. lessingiana*), sheep fescue (*Festuca valesiaca*) and sagebrush (*Artemisia gracileccens*, *A. frigida*). The soil was sampled by 'envelope' to a depth of 5 cm. The weight of each sample was 200-300 g. $^{137}Cs$ and $^{241}Am$ were determined using a Canberra GX-2020 gamma-ray spectrometer, $^{90}Sr$ and $^{239+240}Pu$ – by radiochemical isolation followed by measuring with a TRI–CARB 2900 TR beta spectrometer and a Canberra alpha spectrometer (mod. 7401), respectively. A Progress beta spectrometer was also applied to determine $^{90}Sr$. The concentrations of radionuclides in plants were determined in the ash followed by converting to dry basis. The measurement error for $^{137}Cs$ and $^{241}Am$ did not exceed 10-20%, for $^{90}Sr$ – 15-25%, $^{239+240}Pu$ – 30%.

According to the findings, the territory of the 4 site was found to be basically represented by ecosystems of low hummocks, deluvial-proluvial plains and anthropogenic ecosystems with ecosystems of high hummocks occurring more seldom. The activity concentration of $^{137}Cs$ in plants does not exceed 1 Bq/kg, that of $^{239+240}Pu$ – 6.8 Bq/kg, for $^{241}Am$ – below the detection limit of the methodological instrumentation in use, and the content of $^{90}Sr$ varies from 7.6 to 18,000 Bq/kg. The excess of the maximum permissible level of radioactive contamination of forage plants was only detected for $^{90}Sr$, which was also found to make the main contribution to the overall dose rate for herbaceous vegetation. At the same time, the maximum value of the overall dose rate from all radionuclides at radioactively contaminated spots of the 4 test location is 220 μGy/day. This research was undertaken as part of special-purpose funding by the Ministry of Science and Higher Education RK (BR21882086).

# NATURAL RADIONUCLIDES IN THE SOIL AND VEGETATION COVER IN THE ZHAMBYL DISTRICT OF ALMATY REGION

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There is a global trend towards transitioning to clean energy sources by increasing the share of energy production with minimal or zero greenhouse gas emissions. Nuclear power generation is considered one of the most promising low-carbon energy sources. According to forecasts by the International Energy Agency, the global share of nuclear energy production will rise to 18% by 2040. Likewise, Kazakhstan views nuclear energy as a stable, low-carbon, environmentally friendly source of power. The decision to construct the country's first nuclear power plant (NPP) was made following a nationwide referendum, with the Zhambyl District of Almaty Region selected as the designated construction site. The aim of this study was to determine the background levels of the specific activity of natural radionuclides $^{40}$K, $^{232}$Th, $^{226}$Ra, and $^{238}$U in the soil and vegetation cover of the Zhambyl District of Almaty Region and assess their potential impact on the health of the local population prior to the construction of the NPP.

Fifteen sampling points were established while considering existing information about local soil types to assess the content of natural radionuclides in key components of terrestrial ecosystems. Composite samples of the aerial parts of herbaceous vegetation and soil samples were collected from approximately 1–2 m$^2$ at each point for analysis of accumulation parameters. Soil samples were collected to a depth of 5 cm using the envelope method. Each sample weighed between 200 and 300 g. Radiation parameters were measured at each sampling point in accordance with standard methodologies, specifically β-particle flux density and ambient dose equivalent rate (ADER) to conduct a preliminary assessment of radioactive contamination. The specific activity of natural radionuclides in soil and plant samples was measured using calibrated equipment following standardised procedural guidelines. The radionuclides $^{40}$K, $^{232}$Th, $^{226}$Ra, and $^{238}$U were measured using a Canberra GX-2020 gamma spectrometer. In plants, radionuclide concentrations were determined in ash, followed by recalculation on a dry matter basis. Measurement uncertainty did not exceed 10–20%.

This study constitutes the first comprehensive investigation into the presence of natural radionuclides in the soil and vegetation cover of the Zhambyl District of Almaty Region. The findings indicate that the concentration of $^{40}$K in soils in the Ulken settlement ranged from 580 to 740 Bq/kg, $^{232}$Th ranged from 22 to 50 Bq/kg, $^{226}$Ra ranged from below the limit of detection (<2.1 Bq/kg) to 84 Bq/kg, and $^{238}$U ranged from 15 to 40 Bq/kg. The specific activity of $^{40}$K in plants ranged from 240 to 900 Bq/kg, $^{232}$Th ranged from below the limit of detection (<1.1 Bq/kg) to 4.2 Bq/kg, $^{226}$Ra were below the limit of detection (<3.9 Bq/kg), and $^{238}$U ranged from below the limit of detection (<1.3 Bq/kg) to 3.2 Bq/kg. Overall, these concentrations corresponded to typical background levels of these radionuclides found in soils globally and in the Republic of Kazakhstan. Radiological hazard parameters were assessed based on the specific activity of natural radionuclides in soils within the study area. All calculated values of radium equivalent activity (Raeq) were below the recommended safety threshold of 370 Bq/kg. Both external (Hex) and internal (Hin) hazard indices remained within the safe recommended limit of 1 for all samples analysed. The representative gamma radiation index (Iγ), based on mean soil radionuclide content, also remained at or below the recommended value. The calculated mean annual effective dose from external gamma exposure did not exceed 0.11 mSv. However, in several

instances, the absorbed dose rate in outdoor air exceeded the global mean of 59 nGy/h.This research was undertaken as part of special-purpose funding by the Ministry of Science and Higher Education RK (BR21882185).

# Simultaneous determination of Pu isotopes, $^{237}$Np, $^{241}$Am and $^{244}$Cm in seawater samples by Accelerator Mass Spectrometry

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There is a growing demand for the determination of transuranium nuclides in seawater samples for environmental monitoring and tracing, as well as nuclear forensic reasons. A sensitive and stable simultaneous analysis method for Pu isotopes, $^{237}$Np, $^{241}$Am and $^{244}$Cm in samll-volume seawater sample (≤10 L) was established using Accelerator Mass Spectrometry (AMS). The simultaneous purification procedure involves actinide separation and concentration from 10 L of seawater sample by co-precipitation with hydrous titanium oxide (HTiO), followed by an extraction chromatography purification with TK200+DGA tandem resin column, and then small-size chromatography column purification of the Pu+Np and Am+Cm fractions with TK200 and DGA resin, respectively. For the determination of actinides ($^{237}$Np, $^{239}$Pu, $^{240}$Pu, $^{241}$Pu, $^{242}$Pu, $^{241}$Am, $^{244}$Cm) by AMS, $An^{3+}$ ions were selected at the terminal voltage of about 260 kV in accelerator. The different ratios of reagents were studied for target preparation to optimize the detection efficiency of actinides, and 0.5 mg Fe was used to co-precipitate the Am, Cm, Pu and Np for target preparation. The chemical recoveries of Pu and Am for the entire procedure were higher than 70% and the recoveries ratio of Pu/Np were proven steadily with an average value of 1.00 ± 0.05 (n>25). With the developed chemical procedure and AMS measurement method, the detection limits were estimated to be $2\times10^5$ atoms for transuranium nuclides. The method was validated by analyzing 10L of seawater samples spiked with known amounts of $^{239}$Pu, $^{237}$Np, $^{241}$Am standard solutions. The measured values of $^{239}$Pu, $^{237}$Np, $^{241}$Am agreed very well with the expected values within a 95% confidence interval. These results confirm the reliability and robust of this developed method based on the use of Pu as a non-isotopic tracer for $^{237}$Np and ultra-low level of determination by AMS. The developed method has been used for monitoring and environmental tracing of $^{237}$Np, Pu isotopes, and $^{241}$Am in the marine environment of China.

# Simulation of particle fluxes and cosmogenic nuclide production in the earth's atmosphere revisited

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Since the publication of our first paper Masarik and Beer [1999], new developments in cosmic ray physics and nuclear parameters applied in our simulations have evolved. Several papers devoted to the cosmogenic nuclide production in the atmosphere were published and some of them put in questions the reliability of our simulations from the point of view of latest developments in the field. Therefore, we revised fluxes of particles in the atmosphere and based on experimental or evaluated cross sections they were used to calculate the production rates of $^{3}$H, $^{7}$Be, $^{10}$Be, $^{14}$C, and $^{36}$Cl. The dependencies of these production rates on solar activity and geomagnetic field intensity were investigated in detail. The obtained production rates agree well with most published experimental and theoretical values and do not differ substantially from previously published ones. This shows that the production rates are not sensitive to some parameters suggested as important in various papers.

The good agreement of calculations with modern measured values shows that our model can be used to obtain reliable production rates of terrestrial cosmogenic nuclides and that our model should be good for samples from very large depths in extraterrestrial objects including those with an atmosphere and magnetic field. These results provide the basis for a quantitative reconstruction of the history of the solar activity and the geomagnetic field intensity using records of cosmogenic isotopes in natural archives such as sediments and ice cores

References:

Masarik, J., and J. Beer, Simulation of Particle Fluxes and Cosmogenic Nuclides Production in The Earth's Atmosphere, J. Geophys. Res., 104, 12 099-12 112 1999.

# Geant4 simulation of geomagnetic field

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Modern experimental techniques, such as Accelerator Mass Spectrometry (AMS), allow us to analyze environmental samples with high sensitivity and resolution. The concentration of cosmogenic nuclides in these samples is the result of the interplay between three processes: production, transport, and deposition. The knowledge of involved processes and their simulations allowed us to obtain production rates of various cosmogenic nuclides. The Monte-Carlo method is a very helpful method to understand and simulate such processes. Our model of extraterrestrial production of cosmogenic nuclide was described in [1]. This model could be used also for simulation of cosmic rays' irradiation of extraterrestrial and also terrestrial objects. Cosmic rays impacting at the Earth highly depends on modulation with a geomagnetic field. The field simulation is not included in our model yet.

This presentation will be dedicated to the description of improved modelling of geomagnetic field effects in our model. Geant4 toolkit is suited to simulation of simple magnetics field. On the other hand, the geomagnetic field is highly non-uniform. Modeling non-uniforms field is possible by definition of many small uniform fields in Geant4. The global field will be modeled using Geant4 routines. The results will be compared with existing published works and existing experimental data. The extension of our model allows the investigation of Earth samples.

[1] Čechvala, P., Breier, R. & Masarik, J. Production rates of cosmogenic nuclides in extraterrestrial material using GEANT4 software. *J Radioanal Nucl Chem* **332**, 4403–4411 (2023). https://doi.org/10.1007/s10967-023-09135-5

# Novel Simultaneous Separation and Determination of Seven Radionuclides in Food for the Ingestion Dose Assessment

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Public's concerns in safe food have increased greatly due to nuclear accidents. Radionuclides of both natural and human-made origin are present at various concentrations in food, resulting in exposure to ionizing radiation and an internal radiation dose. Exposure due to radionuclides in food amounts to 0.29 mSv [1]. The natural radionuclides $^{210}$Po, $^{210}$Pb, $^{226}$Ra, $^{228}$Ra and the artificial radionuclides $^{90}$Sr, $^{137}$Cs and $^{14}$C have been identified as the main contribution to the dose of internal exposure [2]. In comparison with the radiochemical separation procedure for single radionuclide, we developed cost-effective procedure for simultaneously separating and measuring two group radionuclides [3, 4]. Further study using one Sr Spec column Sr, Pb and Ra could be separated and measured by liquid scintillation counting within two days. All seven radionuclides detection limits meet equivalent or lower to 10% of the IAEA guidance levels [5], specially for $^{210}$Pb, $^{226}$Ra. We believe that the novel methods will improve the approach for determining the radionuclides in food samples, such as small sample size, short measurement time and lower detection limit. The recovery or overall efficiencies, the minimum detectable activities of radionuclides, and the uncertainty assessment are presented and discussed. (This work was funded by the National Key Research and Development Project, China, No. 2019YFC1604804)

Reference

1. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. New York: UNSCEAR 2016.
2. International Atomic Energy Agency, Exposure due to radionuclides in food other than during a nuclear or radiological emergency, Part 1. Safety Reports Series No.114, IAEA/FAO/WHO, 2023.
3. X Kong, L Yin, Ji Y. Simultaneous determination of $^{210}$Pb and $^{210}$Po in seafood samples using liquid scintillation counting[J]. Journal of Environmental Radioactivity, 2021, 231:106553.
4. Q Zheng, Y Zhang, L Yin, Y Qian, Y Ji. Simultaneous determination of $^{226}$Ra and $^{228}$Ra in food samples using liquid scintillation counting, Food Chemistry, 2024, 438: 137998.
5. International Atomic Energy Agency, Exposure due to radionuclides in food other than during a nuclear or radiological emergency, Part 2. IAEA-TECDOC-2011, IAEA/FAO/WHO, 2022.

# Determination of Cs-137 activity concentrations in soil samples from Hungary

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Some radionuclides in the environment are of natural origin, while others originate from various anthropogenic sources. The two most important artificial sources are nuclear weapons tests and nuclear power plants. Nuclear power plants also emit isotopes (primarily H-3 and C-14) during normal operation. However, radionuclides that are not released during normal operation can be emitted into the environment in the event of an accident. Cs-137 is one of the most important of these isotopes.
Following the Chernobyl accident, large quantities of cesium were released into the atmosphere. These fell out along the path of the radioactive cloud. In Hungary, a relatively small amount of fallout was observed, but Cs-137 is still present in soils.
In this study, Cs-137 activity concentration of 1100 soil samples were determined in the Transdanubian region, Hungary. The measurement was carried out using HPGe gamma-spectrometry.

# A Low-Background Room-Temperature Semiconductor Detection System for the Analysis of Strontium-90 in Seawater

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Strontium-90 (Sr-90) is a fission product primarily released through anthropogenic nuclear activities. It has a relatively long half-life of approximately 28.8 years and is characterized by the emission of high-energy beta particles without accompanying gamma rays. Due to its chemical similarity to calcium, Sr-90 is readily accumulates in bones, where it causes prolonged internal exposure. This physicochemical characteristic makes Sr-90 a significant radiological hazard, as it can lead to serious health effects such as bone cancer and leukemia. Moreover, given its anthropogenic origin, Sr-90 serves as a key indicator for monitoring nuclear activities and assessing radiological contamination.

Due to its high solubility, Sr-90 remains dissolved in seawater and moves with ocean currents. Its concentration in seawater is typically very low, averaging around 1 mBq/L, making its detection particularly challenging. To measure such low levels, both chemical separation techniques and high-sensitive detectors are required. The sensitivity of a detection system is generally evaluated in terms of the minimum detectable activity (MDA), and achieving a lower MDA requires both a low background count rate and high geometric efficiency.

In this study, we developed a detection system based on a PIPS (Passivated Implanted Planar Silicon) detector (Cf. Figure 1). The PIPS is a room-temperature semiconductor detector that operates without any cooling devices. It offers several advantages, including low leakage current, a stable entrance window, and a thin dead layer of approximately 50 nm. The detection system consists of the PIPS detector, signal processing and acquisition electronics, a 10-cm lead and 2-cm copper shield to block ambient radiation, and a veto detector that rejects cosmic-ray-induced background via anti-coincidence counting. The target nuclide is Yttrium-90 (Y-90), chemically separated from a Sr-90/Y-90 equilibrium sample. The Y-90 is precipitated as $Y(OH)_3$ by pH adjustment and subsequently deposited onto a GF/F filter. The filter sample is attached directly to the detector surface to maximize detection efficiency.

The performance of the detection system was quantitatively evaluated through background and spiked sample experiments. Without any shielding, the background count rate was relatively high at approximately 39.38 counts per minute (cpm), but it was significantly reduced to less than one-tenth of the initial value, reaching 3.61 cpm by applying the lead shield and anti-coincidence counting. The detection efficiency, evaluated using a 5-Bq spiked sample, was approximately 43.4%. Assuming a sample mass of 50 kg, a chemical recovery rate of 90%, and a measurement time of 1 hour, the MDA was estimated to be approximately 0.99 mBq/L. This result demonstrates the feasibility of applying this system to practical seawater analysis.

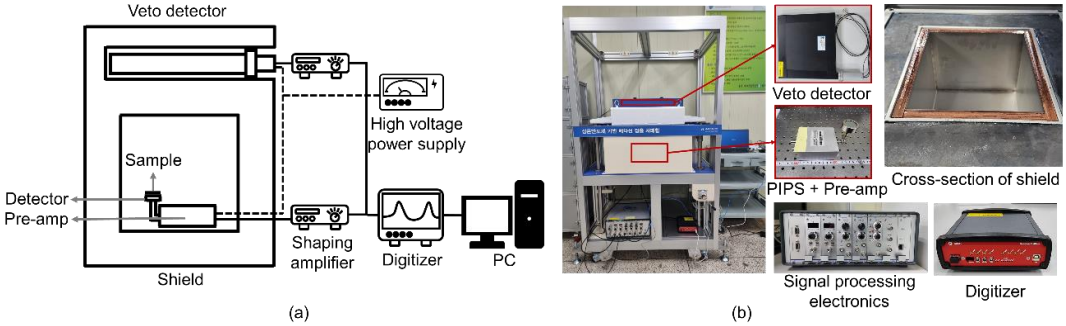



Figure 1. (a) Schematic and (b) photograph of detection system.

# MOBILITY OF ARTIFICIAL RADIONUCLIDES IN SOILS OF SEMIPALATINSK TEST SITE UNDER VARIOUS CONDITIONS OF-RADIOACTIVE CONTAMINATION

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The specific nature of tests, the characteristic natural and climatic conditions of the region, as well as the time factor, in the aggregate, have led to the formation of objects at the STS with unique radioecological characteristics. The STS objects (the main test locations and conventionally 'background' territories) differ in the level and qualitative composition of radioactive contamination. A various pattern of radioactive contamination in the STS territory may result in the non-uniform contamination of the soil cover with radionuclides and to varying degrees of their mobility and migration ability.

As research progressed, speciation of $^{137}$Cs, $^{239+240}$Pu and $^{241}$Am and $^{90}$Sr were studied in soils of the main STS objects. The objects of research were: the epicentral and interepicentral area of the air and ground explosion site 'Experimental Field'; fallout plumes from ground explosions (24.09.1951 (38 kt) and 12.08.1953 (400 kt); the vicinity of the excavation explosion – 'Atomic Lake' object; conventionally 'background' areas of STS (areas beyond test locations that were affected by the global fallout and depositions due to ground nuclear tests); impact sections of radioactive water streams at the Degelen test location; test areas of radiological warfare agents (RWA) at the 4a site. Research was undertaken by the sequential extraction as per a modified procedure offered by F.I. Pavlotskaya.

Based upon findings, differences were revealed between STS objects. The lowest mobility of ARN is specific to test locations of ground and excavation explosions, and, next, it increases on fallout plumes from ground tests, in conventionally background areas. The peak mobility was defined in impact zones of radioactive water streams and at RWA test locations. It was found that the speciation of ARN in soils of STS objects is mainly attributed to the origin and conditions under which the radioactive contamination is formed in the soil cover, as well as to the physic-chemical properties of radionuclides. A low mobility of ARN in soils of fallout-impacted sites and ground and excavation sites is attributed to the initial state of ARN in the fallout from ground and excavation explosions. The behavior of ARN in soils of conventionally 'background' areas, in sections impacted by the radioactive water steams and at the RWA site is defined to a greater degree by physico-chemical properties of radionuclides and mechanisms of their interaction with soil components. Of the radionuclides studied, research data on $^{90}$Sr covers best the difference in the pattern of the radioactive contamination of the soil cover at STS objects, and the fraction of the water-soluble form of $^{90}$Sr may vary from <0.47 to 1.3 %, the exchangeable one – 0.78 to 78.8 %, the mobile one – 0.34 to 38.2 %, the tightly bound one – 7.0 to 99.0%. The content of the exchangeable and acid-soluble form of $^{90}$Sr was revealed to correlate with its accumulation by zonal plants (steppe motley grasses).

# Distribution of radiocarbon in the forest ecosystems soil of the Republic of Kazakhstan

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One of the most reliable methods for assessing climate change is the dating method based on the use of a radioactive carbon isotope – radiocarbon ($^{14}C$) with a half-life of 5730±40 years. To conduct research on the $^{14}C$ distribution in the soil, the sampling sites should not have man-made disturbances and be sufficiently enriched with carbon. Forest soils are more suitable for such research.

Forests of Kazakhstan make up only 5% of the territory and are distributed extremely unevenly. Due to the fact that saxaul forests are widespread on soils that are highly depleted in organic matter, and mountain forests are difficult to access with a high proportion of rock fragments in the soils, flat areas of the forest-steppe zone of Kazakhstan were selected for the research. Birch-aspen forests, island and ribbon pine forests grow in this area. The purpose of this work is a preliminary assessment of the $^{14}C$ content in the forest ecosystems soils at the flat part of Kazakhstan.

The research objects were the soils of aspen and pine forests of the Beskaragay district of the Abai region (eastern Kazakhstan) and birch and pine forests of the Burabay district of the Akmola region (northern Kazakhstan). Forest litter samples and layer-by-layer soil sampling were carried out on sites with an undisturbed surface of 1 $m^2$ using a pit excavation method at intervals of 10 cm to a depth of 50 cm. Laboratory studies included soil sample preparation using a “Pyrolyser-6 Trio” (by Raddec International Ltd, UK). Determination of $^{14}C$ content by liquid scintillation counting using a highly sensitive “SL-300” alpha-beta radiometer (by Hidex). Physicochemical parameters of soils (organic matter and hygroscopic moisture) and mechanical composition were also determined.

According to the obtained results, the $^{14}C$ maximum concentration for all the studied areas was recorded in the forest litter: up to 410 Bq/kg (Beskaragay district) and up to 50 Bq/kg (Burabay district). The results of the $^{14}C$ vertical distribution in the soil profile showed that for the Beskaragay district forests, the maximum values were recorded in the upper layers: in the aspen forest at a depth of 20 cm - 330 Bq/kg; in the pine forest at a depth of 10 cm - 250 Bq/kg. In the soils sampled in the Burabay district forests, the $^{14}C$ content throughout the profile is below the detection limit (DL $<$6 Bq/kg).

High values of $^{14}C$ content in the Beskaragay district soils indicate the presence of "bomb" $^{14}C$ [1], since this area is located in the zone of radioactive fallout from the 1949 nuclear test conducted at the territory of the Semipalatinsk nuclear test site. Although, if we compare the pine forests of the two districts, the organic matter content in the Burabay district soil is an order of magnitude higher than its content in the Beskaragay district soil, while the content of $^{14}C$ in the soil of the pine forest of Burabay district is below the DL, in the soil of the same forest of Beskaragay district it reaches about 250 Bq/kg. Comparatively higher values of $^{14}C$ content in soil and forest litter were found for areas with heavier mechanical composition of soils and increased content of hygroscopic moisture: Beskaragay district aspen forest. In the aspen forest, in contrast to the pine forest of Beskaragay district, a high content of organic component in the soil is also noted (according to the results of determining the physicochemical parameters).

In the absence of $^{14}C$ in the soil of the Burabay district forests, its content in the forest litter reaches 50 Bq/kg, which indicates the entry of $^{14}C$ from the atmosphere (capture in the form of $^{14}CO_2$ by plants during photosynthesis). The $^{14}C$ content in the forest litter of the Beskaragay district forests at levels from 340 to 410 Bq/kg, probably indicates two sources of $^{14}C$ entry both from the atmosphere and from the soil.

# Radioanalytical and emergency preparedness activities at STUK

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STUK is the corresponding authority in Finland for radiation and nuclear safety. Our mission is to promote and supervise the safe use of radiation and nuclear energy. Our duty is to provide expert knowledge and special services regarding the radioactivity and radiation safety to ensure the overall security of society.

Measurements and environmental monitoring unit corresponds of the radiation measurements (field and laboratory) performed at STUK. The laboratory is an accredited testing laboratory (T167, ISO/IEC 17025:2017). The fields of testing include gamma-spectrometric analyses of different objects (e.g., environmental and industrial samples, direct measurements of people), radiochemical analyses, ICP-MS analyses, airborne Rn measurements and sampling for the environmental surveillance of radioactivity.

STUK provides testing services for both internal and external customers. The major surveillance programs consist of the environmental radiation monitoring in the vicinities of the Finnish nuclear power plants, and the monitoring of environmental radiation in Finland. In addition, laboratory radioactivity analyses are provided for e.g., CTBT (comprehensive Nulear-Ban Treaty), citizens and industry (e.g., building materials, mining products).

Besides the routine analyses, the laboratory serves as the national emergency preparedness laboratory which corresponds of providing radioactivity analyses for the base of decision-making during a possible radiological emergency.

This poster focuses on the radioanalytical laboratory and emergency preparedness activities at STUK. It discusses major surveillance programs conducted in Finland and provides an overview of the different analytical services and capabilities of the laboratory.

# Application of sorption method for treatment of contaminated water from $^{238}U$ on the example of STS water bodies

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A characteristic feature of the radioactive contamination of the environment on the territory of the Semipalatinsk Test Site (STS) is the significant levels of contamination of surface waters, including $^{238}U$. Uranium in water is not only a radioactive substance, but also a chemical heat-resistant element. Water is a dynamic environment, into which radioactive substances can accumulate, be redistributed in various components of the ecosystem and migrate over long distances, polluting vast territories. World practice has shown the high importance of research aimed at cleaning water from radionuclides.

There are a number of methods for purifying water from radionuclide contamination, the most effective of which is sorption purification. To remove radionuclides from aquatic environments, various sorption materials are used, which can be divided into organic, inorganic and biosorbents. To purify the studied waters from $^{238}U$, an inorganic sorbent made of synthetic aluminosilicate – zeolite NaX, polymer hydrogels and sorbents based on biomass origin (biosorbents) were selected.

The watercourses of the portal sections of the adits of the "Degelen" site and a reservoir of man-made origin located on the territory of the "Telkem" test site were selected as objects of study for the sorption purification of radioactively contaminated waters from $^{238}U$. Natural waters taken from the watercourses of adits 104 and 165 and the Telkem-1 funnel were used for purification.

Experiments on water purification from $^{238}U$ were carried out under static conditions. To conduct the experiment, 0.4 g of the sorbent was weighed on an analytical scale with an accuracy of up to 4 decimal places, placed in a conical flask, filled with 1 liter of the collected water, tightly closed with a lid to prevent evaporation processes and constantly stirred at room temperature for 24 hours. After mixing, the analyzed solutions were filtered through a blue ribbon filter and the content of radionuclides in the filtrate was determined. The concentration of $^{238}U$ was determined using an ICP MASS Spectrometer "ELAN 9000" inductively coupled plasma mass spectrometer. To assess the efficiency of water purification, calculations of the sorption percentage and sorption capacity were carried out.

According to the obtained results on sorption purification of waters, it was established that the efficiency of $^{238}U$ sorption is determined by a number of factors, among which the key role is played by the chemical composition of the water and the composition of the sorbent. When extracting $^{238}U$, the most effective biosorbents were those modified with KOH and ferrocyanides, with a sorption percentage of up to 50%. The highest values of sorption capacity were achieved in water sample 104 (up to 1100 Bq/g for $^{238}U$). In the water of the Telkem-1 funnel, all sorbents demonstrated reduced sorption efficiency, which is due to high mineralization, hardness and the content of competitive ions, which prevent the binding of $^{238}U$ with sorbents.

As a result of the work carried out, it was established that the efficiency of sorption purification of contaminated water from $^{238}U$ is determined not only by the nature of the sorbent, but also by the chemical composition of the aquatic environment. Applied to $^{238}U$, modified carbon biosorbents have shown the greatest efficiency, demonstrating a developed surface and active functional group that promote complex formation and sorption of uranyl ions. Thus, the work carried out makes a significant contribution to understanding the applicability of the sorption method to the purification of waters exposed to long-term man-made radiation from $^{238}U$.

# Development and validation of a radioanalytical method for analyzing the $^{148}$Gd content in environmental and bioassay samples

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$^{148}$Gd, an alpha emitter (Eα = 3.18 MeV) with a half-life of 74.6 years, is one of the radionuclides formed as a result of the spallation of tungsten and other heavy elements. It is one of the most significant isotopes in the event of a radiological incident at spallation facilities using tungsten targets. Spallation occurs when incoming proton particles (E > 100 MeV) interact with individual atoms in target nuclei. In the case of a disaster involving a spallation source (e.g., the European Spallation Source, ESS, in Lund, Sweden), $^{148}$Gd may be released into the environment, posing a real threat to both the public and the natural environment.

A method for analyzing $^{148}$Gd has been developed using techniques such as coprecipitation, ion-exchange chromatography, and extraction chromatography. The method was designed using measurements of stable gadolinium via the ICP-MS. The efficiencies of individual steps in the radiochemical analysis were determined, and the separation capabilities of gadolinium from the sample matrix and other rare earth metals were evaluated. The results from stable gadolinium-labeled blank samples indicate that the application of a multi-step analysis — separating gadolinium from the sample matrix, actinides, and other alpha emitters, and finally isolating gadolinium from the rare earth metals fraction — allows for a maximum yield of 75%.

The method was validated using environmental samples (water, soil, air filters) and urine samples traced with a $^{148}$Gd standard. The results demonstrate high repeatability and efficiency of the developed radioanalytical method.

# Maximum likelihood spectral reconstruction for real-time gamma-ray spectroscopy

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Among the plethora of analysis strategies in gamma-ray spectroscopy, full spectrum analysis is the only attempt to fully exploit all the information available. However, in environmental radioactivity, the analysis often relies on the least squares fitting of fundamental spectra. Least-squares minimization involves the hypothesis that the fluctuation of the number of counts per channel is Gaussian, which is not true for short-duration spectra, or for channels with low counts (often those of high energies). As a result, long integration times are required, and some energy bands may need to be excluded from the analysis.

In a recent article we showed how we can acquire highly specific fundamental spectra from remote stations, without need of Monte-Carlo, by unfolding the contributions from $^{214}$Bi+$^{214}$Pb, $^{212}$Pb, $^{208}$Tl and a constant background. Here, we show that a fully Poissonian treatment combining these spectral components is possible, resulting in maximum-likelihood reconstruction of spectra recorded by remote stations in just 10 minutes. This allows us to routinely check for benchmark isotopes like $^{131}$I, $^{137}$Cs and $^{60}$Co; Moreover, we can search for $^{234}$Th, whose photo-peaks at 63 and 92 keV are very hard to evaluate using other methods. Last but not least, we are capable of performing a blind search, where the significance of unexpected photo-peaks is evaluated.

Our method enables us to perform a highly sensitive, real-time analysis of the data from the Radiological Surveillance Network of Catalonia. 10-minute measurements achieve a minimum detectable activity concentration of 3.5/3.5/2.0 Bq/m³ for $^{131}$I/$^{137}$Cs/$^{60}$Co using a 2"x2" $LaBr_3$(Ce) detector; and 73 Bq/m³ for $^{234}$Th using a 2"x2" $SrI_2$(Eu) detector. We also show an application to extremely short-duration spectra of 30 seconds recorded by a mobile unit. Finally, we discuss the implementation for unattended operation of networks, and we provide an outlook towards the use in detectors with particulate filter and water detectors.

# Amazonian Wood Traceability by Nuclear Analytical Techniques

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The illegal deforestation is a problem around many parts of the world, and it represents a great threat to the global biodiversity. In Brazil, no other region is more affected by this practice than the Amazon Rainforest. Recently, in 2022, the *Instituto do Homem e Meio Ambiente da Amazônia* (Imazon) published that between January and December of that year an alarming 10 573 km² of forest were illegally cut down, the highest deforestation rate in fifteen years. This illegal wood then enters the market and impacts not only the national economy but also the responsible wood industries because there is no clear distinction between legal and illegal wood during the commercialization. In light of this problem, this project proposes the use of nuclear analytical techniques to investigate the traceability of amazonian wood. The concept of traceability can be defined as the act of identifying the history or origin of a certain product, and, for example, it is very common in the food industry. When talking about wood the main belief is that the log incorporates the chemical elements of it's surroundings (soil and atmosphere), so it would be possible to establish a correlation between the wood and it's place of origin. Finally, once the correlation is established, it would be possible, in theory, to determine if the wood came from a legal site or illegal one, becoming another weapon to be used to fight this problem. This project will use techniques such as Instrumental Neutronic Activation Analysis and Gamma Ray Spectroscopic to investigate and determine the wood composition, and a ray of statistical analysis to establish a correlation between different types of wood that were collected in the same areas/regions. The experiments are being conducted using IPEN's nuclear reactor (IEA-01) and detectors, while samples were catalogued and sent by *Instituto Nacional de Pesquisas da Amazônia* (INPA).

# Radionuclide contamination of fish of different ecological groups in water bodies within the Chornobyl exclusion zone

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The results of the assessment of the levels of activity concentration of $^{90}$Sr and $^{137}$Cs for fish in the Chernobyl Exclusion Zone (CEZ) during period 2010–2024 are presented. The studies were carried out in lakes of western and northwestern radioactive traces that are most contaminated with radionuclides - Azbuchin, Vershina, Glyboke, Yanovsky backwater, as well as in various parts of the Chernobyl NPP cooling pond (CP) and the Pripyat River within the CEZ. The activity concentration (AC) of $^{137}$Cs was measured using a γ-spectrometry complex (Mirion Technologies-Canberra, Japan). The AC of $^{90}$Sr was determined using a low-background alpha-beta radiometer UMF-2000 and beta radiation energy spectrometer SEB-01-70. The estimated error of radionuclide AC fell within 15-20%. The highest levels of the AC of the main dose-forming radionuclides were noted for fish from lakes Azbuchin, Vershina and Glyboke: $^{90}$Sr – 2030-148570 (on average 15960); $^{137}$Cs - 930-31859 (4660) Bq/kg. In the Yanovsky backwater, the concentration of $^{90}$Sr and $^{137}$Cs in fish was, respectively, within the range of 583-8220 (1520) and 340-6040 (1395) Bq/kg. In the CP, the AC of $^{90}$Sr and $^{137}$Cs was, respectively, 40-359 (119) and 540-11270 (2473) Bq/kg. The lowest concentration of radionuclides, among the studied water bodies, was noted for fish from the Pripyat River within the CEZ: $^{90}$Sr – 2-121 (33); $^{137}$Cs – 5-293 (71) Bq/kg. The prey fish species of the studied lakes were characterized by AC of $^{90}$Sr within the range of 4050-148570 (21328), and $^{137}$Cs – 1018-31859 (3749) Bq/kg, while in predatory fish the AC of $^{90}$Sr was 2030-31622 (7994), and $^{137}$Cs – 930-22044 (6228) Bq/kg. The activity concentration of $^{90}$Sr in the fish of the Yanovsky backwater did not exceed 860–4580 (1900) Bq/kg for prey species, and 583-8220 (1140) Bq/kg for predatory ones; the activity concentration of $^{137}$Cs in prey species and ichthyophagous fish was, respectively, within the range of 340-3400 (784) and 1030-6040 (2001) Bq/kg. Thus, the AC of $^{90}$Sr in prey fish of the stagnant water bodies of the CEZ was 1.6–1.7 times higher than in predatory species, while $^{137}$Cs was 2.5-2.6 times lower. Among the studied fish of the CEZ, the highest concentration of $^{90}$Sr was noted for the common rudd and Prussian carp. Different fish species in descending order of average AC of $^{90}$Sr in the CEZ water bodies form the following series: Prussian carp > common rudd > roach > tench > bream > bleak > asp > perch > pike > pike-perch > wels catfish, and in descending order of $^{137}$Cs - perch > pike-perch > pike > asp > wels catfish > bleak > rudd > Prussian carp > roach > bream. The AC of $^{137}$Cs in fish of almost all water bodies during the study period continued to decrease regularly. The level of $^{90}$Sr concentration in representatives of ichthyofauna of the lakes remained practically at the same level. The exceptions were the hydraulically connected CP and Lake Azbuchin, where the AC of $^{90}$Sr in fish tends to increase, which is primarily due to the increase in the AC of radionuclides in the water of these water bodies as a result of the cessation of water supply to the CP since the end of 2014 and the drawdown of water level. The AC of radionuclides in fish of lakes Glyboke, Vershina and Azbuchin during the study period in all cases repeatedly exceeded the permissible levels (PL), according to the standards adopted in Ukraine for fish products - by 58-4245 times for $^{90}$Sr and by 6-212 times for $^{137}$Cs. The excess of the PL in the fish of the Yanovsky backwater for $^{90}$Sr was observed by 16-235 and $^{137}$Cs by 2-40 times, and in the CP for $^{90}$Sr and $^{137}$Cs by 1.4-27.4 and 3.3-33.8 times, respectively. In the fish of the Pripyat River within the CEZ, isolated cases of excess of the PL for $^{137}$Cs by 1.2–2.0 and for $^{90}$Sr by 1.1-3.5 times were observed for both prey and predatory species. This study was supported by the National Research Foundation of Ukraine (Project No. 2023.03/0156).

# Isotopic signatures of the plutonium sources in the Antarctic environment

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The Antarctic is one the most cold and windy place in the world. For this reason, specific ecosystems have developed there, not found anywhere else. At the same time the Antarctic is considered the cleanest place in the world. Moreover activities involving nuclear radiation such as waste storage or nuclear testing are prohibited. Thus all radioactive pollutants came to the Antarctic with the air or sea water movements. One may therefore ask whether there is a difference between the marine and terrestrial ecosystems of Antarctica? Are there any differences in isotope ratios observed in the terrestrial and marine environments? Could the accumulation of radionuclides by mosses and lichens on land from mainly air result in different isotope ratios than in marine organisms that spend most of their lives in water?

This work is an attempt to answer these questions. $^{238,239,240}$Pu was analyzed in over 100 environmental samples. Based on the analysis of plutonium isotope ratios $^{238}$Pu/$^{239+240}$Pu and $^{240}$Pu/$^{239}$Pu, an attempt was made to show the difference between the Antarctic marine and terrestrial environment. Since the contamination in the Antarctic is at a very low level, some measurements showed results below the detection limit. Therefore, in the work an attempt was made to use statistics for censored data to check whether their use provides additional information than using only results above the detection limits.

# Doses to Antarctic biota

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Antarctic is a unique place in the world due to isolation by Antarctic Circumpolar Current and harsh climatic condition. Domestic ecosystems are not very diverse; Antarctic terrestrial flora consists of mosses, lichens and view grass species only. Thus study of the relatively low numbers of Antarctic species can provide information on the state of the entire ecosystem.

Numerous studies show that radioactive global fallout and SNAP-9A (accident of American satellite with nuclear power system) are sources of artificial radioactivity in Antarctic environment. In this work we present not only radioactivity level in Antarctic organisms but also dosimetrical interpretation. More than 100 biological samples were analyzed. Using low background gamma spectrometry (HPGe spectrometers), liquid scintillation counter and alpha spectrometry $^{137}$Cs, $^{90}$Sr, $^{238,240+239}$Pu and $^{241}$Am activity concentration in the Antarctic organisms were determined. Doses to biota, both terrestrial and marine, due to internal exposure to $^{238,240+239}$Pu, $^{241}$Am, $^{90}$Sr and $^{137}$Cs were calculated using ERICA Tool software. The results obtained revealed significant differences in radionuclide accumulation between species in terrestrial and marine ecosystems. The attempt to select some indicator organism was also done.

# Assessing marine pollution in the Black Sea: radionuclide dynamics in marine biota and sediments

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SCIRENA (SCience and Information towards Regional ENvironmental Action for the Black Sea) is a collaboration between Bulgarian and Norwegian environmental authorities aimed at enhancing marine pollution monitoring in Bulgaria. Supported by funding from the EEA and Norway Grants, this project ensures compliance with EU legislation that mandates high environmental standards in Bulgarian waters. Given the heightened risks of marine pollution due to the Ukraine war, SCIRENA's findings will assist Bulgaria and its neighbors in addressing pollution and improving food safety in the Black Sea region. The project emphasizes capacity building and knowledge exchange on EU monitoring requirements under the Marine Strategy Framework Directive (MSFD).

In 2023 and 2024, the SCIRENA project conducted research cruises along the Bulgarian coastline and in deep waters, evaluating seafloor habitats and a range of pollutants in marine biota and sediments. This study focuses on anthropogenic and natural radionuclides.

Activity concentrations of the anthropogenic radionuclide cesium-137 ($^{137}$Cs) in pooled samples of seven fish species ranged from below the detection limit to 0.59±0.06 Bq/kg fresh weight (fw) in Mediterranean horse mackerel (*Trachurus mediterraneus*). The results show a correlation between feeding habits, trophic level and the content of $^{137}$Cs. The levels of $^{137}$Cs are significantly below safety guidelines for food and pose no risk to marine life or human health.

In 36 surface sediments from depts between 12.5 and 97.8 m, $^{137}$Cs concentrations ranged from below detection limits to 90 Bq/kg dry weight (dw), primarily sourced from fallout from nuclear weapons testing and the Chornobyl accident in 1986. The highest concentration was found at the deepest station (97.8 m) off southern Bulgaria. Natural radionuclide levels (radium-226 ($^{226}$Ra), radium-228 ($^{228}$Ra), thorium-228 ($^{228}$Th)) ranged from below detection limits to 40 Bq/kg dw, except for one coastal sample with a $^{226}$Ra concentration of 79 Bq/kg, potentially due to local phosphate production. Additionally, potassium-40 ($^{40}$K) levels range from 158 to 926 Bq/kg dw. Overall, these levels align with other data from this area, though recent information is limited. Four sediment cores from depths between 74.8 and 915 m were analyzed for $^{137}$Cs, $^{226}$Ra $^{228}$Ra, $^{228}$Th, $^{40}$K and lead-210 ($^{210}$Pb). The latter was determined to facilitate $^{210}$Pb-dating. Due to low radionuclide levels and a disturbed $^{210}$Pb-profile, dating was successful for only one core. The sediment cores show no recent increase in $^{137}$Cs levels.

This study examines geographical and temporal trends of radionuclides in Bulgarian sediments and their correlations with Total Organic Carbon (TOC), sediment grain size, and metals like iron (Fe), manganese (Mn) and aluminum (Al). The results provide a comprehensive update on the prevailing levels of radioactive contamination in the western part of the Black Sea, highlighting ongoing

environmental challenges.

# $^{135}Cs/^{137}Cs$ signals from Sellafield reprocessing plant: implications for radiocesium source terms and $^{135}Cs$ inventory in Northern European Seas

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Isotope ratios of $^{135}Cs/^{137}Cs$ have recently become a powerful forensic tool for studying major dynamic mechanisms in the environment. The ratios present in natural samples (e.g., soil, sediments, seawater) record a mixed signal from local sources (e.g., Sellafield and La Hague reprocessing plants), regional sources (e.g., Chernobyl) and diffuse sources such as global fallout.

To investigate the attribution from different source terms of radiocesium in Northern European Seas, here we present the first time-series of $^{135}Cs/^{137}Cs$ isotope ratios from a sediment core collected in the direct vicinity of Sellafield, as well as sediment cores collected from remote locations in the North Sea, Greenland Sea and Lake Geneva (Switzerland-France boundary). By coupling the legacy discharge profile of $^{137}Cs$ from Sellafield with past $^{137}Cs$ monitoring data observed in the adjacent coastal region, we provide a representative $^{135}Cs/^{137}Cs$ ratio during the peak discharge of Sellafield and apply it for source term attribution.

The preliminary results suggest that traces of radiocesium observed in the sediments from the different studied locations of the North Sea are mainly derived from Sellafield. The sediments from Lake Geneva display distinct $^{135}Cs/^{137}Cs$ ratios. The Greenland Sea sediments show generally higher $^{135}Cs/^{137}Cs$ ratios implying significant contribution from global fallout, though with larger uncertainties due to its ultra-low radiocesium abundance. In this study, we provide a preliminary $^{135}Cs$ inventory in Northern European Seas and demonstrate the utility of $^{135}Cs/^{137}Cs$ isotope ratio to disentangle different contamination source terms in Northern European Seas and its potential for future nuclear forensic and environmental tracer studies.

# Proton Exchange Membrane (PEM) electrolytic enrichment system for tritium analysis in seawater

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To ensure public safety, numerous countries have regulations to monitor radionuclide levels in the environment. Among these radionuclides, tritium, predominantly in the form of tritiated water (HTO), is subject to regular surveillance due to its behavior analogous to that of water. With Japan's recent decision to discharge radioactive wastewater into the ocean, the necessity of monitoring and assessing global environmental impacts has become increasingly critical. It is noteworthy that the Advanced Liquid Processing System (ALPS), a multi-nuclide removal system, is ineffective in removing tritium. Consequently, a more extensive and rapid analysis of seawater samples from diverse locations is imperative to ensure comprehensive safety.

The average tritium concentrations in seawater are notably low. For instance, in the Republic of Korea, the annual average concentration of tritium in surface seawater ranges from 0.0872 to 0.448 Bq/L.[1] This low concentration signifies that the direct distillation method is insufficient for accurate measurement, necessitating an additional concentration process. Tritium enrichment using Proton Exchange Membrane Water Electrolysis (PEMWE) presents a promising method for the rapid pre-treatment required for tritium analysis.

In this study, we selected commercially available PEM stacks suitable for the electrolytic enrichment of tritium. We examined the enrichment properties of these stacks based on the type of membrane electrode assembly (MEA) and the number of electrolysis cells. The efficiency of the electrolytic enrichment was assessed under varied conditions. Under optimal conditions, utilizing a triple-cell PEM stack, the tritium enrichment factor exceeding 20 was achieved, reducing the initial sample volume from 2000 mL to 30 mL within four days.

This work was supported by the Nuclear Safety Research Program through the Korea Foundation Of Nuclear Safety(KoFONS) using the financial resource granted by the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea. (No. RS-2023-00231329)

[1] Marine Environmental Radioactivity Survey. KINS/ER-092, 2022; 18, 1-95.

**Radiochemical preparation of marine biota samples for measurement of technetium-99 by iCAP TQ ICP-MS**

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Inductively coupled plasma - mass spectrometry (ICP-MS) has been proven to offer a more sustainable, safer and cost-effective alternative to traditional beta counting of nuclear derived technetium-99 ($^{99}$Tc). In all analytical cases, measurement must be preceded by radiochemical separation, with techniques including ion-exchange, extraction chromatography and commonly via co-precipitation of Tc with stable and commercially available rhenium (Re).

Whilst some ICP-MS equipped with triple quadrupole (TQ) and other detecting technologies have been applied to measure $^{99}$Tc in environmental matrices, neither the performance of the iCAP TQ ICP-MS manufactured by Thermo Fischer Scientific nor the radiochemical challenges associated with the preparation of marine biota prior to ICP-MS analysis have been explored.

This work covers some of the challenges encountered when revisiting traditional radiochemical techniques and incorporating more modern crown-ether type resins to provide effective interference removal and produce an appropriate geometry for assay of $^{99}$Tc by mass.

## TENORM and alpha spectrometry industries: spectra deconvolution

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### Introduction

The final treatment of TENORM waste depends on their radiological characterization. These have high concentrations of activity, a priori unknown, so the establishment of the mass, the average time and the appropriate source-detector distance for this determination is not trivial.

Despite analyzing a very small amount of mass, nevertheless maintaining a compromise between the minimum mass to be used and its representativeness and homogeneity; sometimes, to achieve a good spectrum, it is necessary to adjust the measurement parameters. This adjustment is not easy to get since the mass, despite being small, could have high activity; thus, to avoid the overlap between the unknown peaks and the tracer peak, it is necessary to control the measurement time and/or the distance between source-detector. However, despite this control, an adequate spectrum cannot be obtained, being necessary to repeat the analysis decreasing mass and adjusting again the distance and time, with the consumption of time and material that it entails.

To reduce this repetition of samples and the different sequence of measurements, it has been decided to deconvolve the spectra to, despite the overlaps, determine this activity.

### Material and methods

The samples, once the radiochemical separation has been carried out and have been electrodeposited in the planchette, have been measured by alpha spectrometry in the PIPS detectors that the LMBA (EHU) has, of 450 $mm^2$ of area, approximate efficiency of 25% and background of 6 $10^{-5}$ cps.

Work has been done with high-activity polonium, uranium and thorium residues, emphasizing the deconvolution of Po-210 and Po-209 (tracer), U-235 and U-234 and Th-230 and Th-229 (tracer).
Even if alpha emitters emit particles at discrete energies, due to the possible presence in the planchette of impurities from radioseparation, the different paths that emitted alpha particles follow and the use of a thin film that avoids detector recoil contamination, the spectrum does not correspond to a gaussian and it is displaced towards low energies. After comparing different methodologies, it has been decided to deconvolve by adjusting the peaks to a complementary error function, which shifts the curve of the Gaussian distribution towards lower energy emissions.

### Results and discussions

First, a Po-209 emission spectrum has been fitted, obtaining a very adequate adjustment of it. Subsequently, the adjustment of this function has been applied to Po-209 and Po-210 spectra, deconvolutionizing both satisfactorily. This adjustment is controlled by the analyst in charge of the spectrometric study.

### Conclusions

The approximation of the spectra using the complementary error function provides congruent results, providing an adequate tool for the deconvolution of peaks obtained from TENORM samples.

# Validation of a method for the determination of $^{99}$Tc in environmental samples using TK-TcScint resin

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## 1. Introduction

$^{99}$Tc is a beta emitter and one of the most significant $^{235}$U fission products, since the reaction yield with thermal neutrons is 6 % and its period is $211.5 \cdot 10^3$ years. Therefore, it is under control in the environmental compartments around nuclear power plants (NPPs), undergoing operation or decommissioning, as it is one of the most common isotopes in the radioactive inventory of NPPs.

Thus, this work deals with the validation of a procedure for the determination of $^{99}$Tc activity in solid and liquid environmental samples using TK-TcScint resin, focusing on the assessment of the linearity, accuracy, precision and reproducibility with different concentrations of $^{99}$Tc activity. In addition, the chemical recovery, detection efficiency, background, overall uncertainty, detection limit (DL) – as a function of mass and measurement time – and specificity are analysed.

## 2. Material and methods

For the validation of the $^{99}$Tc method, two sets of 5 water samples were prepared with an activity concentration between 10 and 100 times the expected DL and treated according to the following steps: addition of a few mL of 30 % $H_2O_2$, heating to 90 °C for 1 hour, adjustment to 0.1M HCl and loading in the cartridge containing TK-TcScint resin at 1 mL min$^{-1}$.

Then, the cartridges were placed into polyethylene vials and measured by the Quantulus 1220 Ultra Low Level Liquid Scintillation Spectrometer from Revvity for 3 hours and the C-14 protocol.

Once the validation samples were measured, the linearity, accuracy, precision and reproducibility of the results were assessed; and the uncertainties and achievable DL were established.

A $^{99}$Tc standard solution is used to obtain the detection efficiency and a traced sample to obtain the overall efficiency and the chemical recovery.

Finally, the specificity was analysed by environmental solid samples from some intercomparisons, containing other radionuclides and varying amounts of $^{99}$Tc.

## 3. Results and discussion

The accuracy has been assessed using a t-test, confirming no significant differences between added and measured activity. The results are reproducible, since the dispersion between the mean and partial results is less than 15 %, and overlapping uncertainty bands are observed.

The linear character of the method is consistent, and the DL values are of the order of 0.08 Bq kg$^{-1}$, for 0.1 L of liquid samples and sample and blank measurement times of 3 and 12 hours, respectively.

Regarding the spectral interferences, they are affordable by the window narrowing or deconvolution.

# Uptake of sediment-derived $^{14}C$ into freshwater benthic organisms in a controlled microcosm experiment

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Radiocarbon ($^{14}C$) is a significant radionuclide that can enter the biosphere through nuclear fuel cycles and radioactive waste repositories, making it easily absorbed by organisms. With a long half-life of 5,730 years, it can disperse globally in both dissolved and gaseous forms. In this work, we investigated the proportion of sediment-derived C (from a field-collected peat) in benthic animals, chironomid larvae (*Chironomus riparius*) and blackworm (*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, providing a unique opportunity to track the fraction of C from different sources. Two-pool isotope mixing model was used to estimate the contribution of C from each source in the selected animals. The results revealed a significant incorporation of sediment-derived C in chironomids (40%), while smaller contribution was observed from sediment to feeding (2.6%) and non-feeding blackworm (2%). Despite a notable contribution of C from sediment, fish food remained the dominant C source in chironomids. Lower uptake of sediment-derived C in worms may be attributed to C storage in their tissues from fish food and previous diet with more enriched $^{14}C$ contents (e.g., fish food and towel papers used as the culture materials) as well as their slower C turnover rates. Additionally, feeding worms showed slightly higher sediment-derived C contribution than non-feeding ones, likely due to sediment ingestion alongside fish food particles. In contrast, non-feeding worms may have mostly avoided sediment consumption during the 10-day experiment in the absence of fish food. Overall, the findings highlight the role of sediment in transferring $^{14}C$ to chironomids, even in food-rich environments. This suggests potential $^{14}C$ transfer to higher trophic levels, as these benthic organisms serve as a food source for various species, including fish, which are regularly consumed by humans.

# Transfer of sediment-derived carbon into blackworm (*Lumbriculus variegatus*) and crucian carp (*Carassius carassius*): Implications for $^{14}C$ biosphere assessment in freshwater ecosystems

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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. It has a long half-life (5730 years) and can distribute in forms of dissolved and gaseous species to aquatic environment. In the present work, we investigated the proportion of sediment-derived carbon in a food chain of benthic blackworms (*Lumbriculus variegatus*) and crucian carps (*Carassius carassius*) preying them in a microcosm. Natural abundance of $^{14}C$ was used to estimate the contribution of sediment-derived carbon. The $^{14}C$/total carbon ratio in the sediment was highly depleted and thus ideal to partition the carbon sources between sediment and food. Isotope mixing model was used to estimate the proportion of sediment-derived carbon in the selected animals. The isotopic abundance of $^{15}N$ was also used to further identify the trophic levels in the animals. The findings revealed significant contribution of sediment-derived carbon in blackworms (ranging from 70-80%), while only a small fraction was observed in the carps (1-5%). The findings identified sediment and food as the primary sources of carbon for worms and fish, respectively. Notably, the relative contribution of sediment-derived carbon in these organisms was modulated by food availability. Specifically, the uptake of the sediment-derived carbon was somewhat higher in both species under conditions of limited food availability, and smaller in the fish in the absence of the blackworms. These results are important for understanding the transfer of $^{14}C$ through aquatic ecosystems, particularly from lower to higher trophic levels. Further laboratory and field studies, including predatory fish, are recommended to provide a more comprehensive understanding of $^{14}C$ transfer in higher trophic-level species.

# NPE-free Cocktails for Environmental LSC Measurements

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Nonyl Phenol Ethoxylates (NPEs) are surfactants used in most of the LSC cocktails in the markets. Surfactants are needed for stable microemulsion formation with aqueous samples. NPEs are not readily biodegradable and produce metabolites that are known as endocrine disrupters. For this reason, the use of NPEs is restricted in EU as well as in many other countries.

Hidex has a comprehensive selection of NPE-free cocktails which can be used as alternatives to the conventional NPE-containing cocktails in almost all environmental LSC measurements. We present a comparison of NPE-containing cocktails and NPE-free cocktails for environmental LSC measurements (e.g. $^{3}H$, $^{14}C$, $^{90}Sr$ and $^{222}Rn$). This study shows that the performance of NPE-free cocktails is at high level and NPE-free cocktails are good alternatives for environmental alpha and beta measurements as long as the most suitable cocktail is used and the sample preparation is done properly.

# Long term monitoring of Bratislava aerosol radioactivity.

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Variations of cosmogenic ($^{7}$Be), primordial ($^{40}$K), radiogenic ($^{210}$Pb) and anthropogenic ($^{137}$Cs) radionuclides in Bratislava air studied during 2001–2024 using a weekly sampling and HPGe gamma-spectrometry are presented. A new sampling device (Senya Snow White), recently installed in our meteorological station, was tested and compared with the old sampling system. While $^{7}$Be variations were associated with transport of air masses from the lower stratosphere to the ground level air, an inverse trend was observed for $^{210}$Pb variations due to infiltration of radon from the soil. The $^{137}$Cs activity concentrations (excluding the Chernobyl and Fukushima accidents periods) were decreasing with half-life of 1.9 years, however, during recent years they were almost constant. The increased atmospheric $^{40}$K levels were due to soil resuspension and radionuclide transport by winds.

# Automated Radiochemistry for Environmental Radioactivity

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As the number of nuclear power plants under construction or planned increases, the demand for environmental radioactivity monitoring has been increased to ensure the safety of nuclear energy. For the routine monitoring, a large volume of sample is needed for quantifying the level of radionuclides due to their trace levels. Additionally, the alpha and beta emitters including $^{90}$Sr, $^{241}$Am, Pu isotopes and others require chemical separation. With the development of extraction chromatography technique for specific radionuclides, automated radiochemistry has been increasingly adopted in radiochemical laboratories.

We studied a straightforward and rapid method to determine $^{90}$Sr by measuring its daughter $^{90}$Y in various environmental samples (e.g., soil, sediment, biota, and seawater) using an automated separation instrument with DGA resin. While $^{137}$Cs can be easily analyzed by HPGe detector, its determination, especially in seawater, often requires pretreatment such as sample volume reduction and additional chemical separation. However, employing a Cs-specific ion exchange resin (e.g., AMP-PAN resin) along with automated techniques significantly simplifies 137Cs analysis in seawater.

In this presentation, we will introduce how these automated radiochemistry techniques can significantly enhance the efficiency and accuracy of environmental radioactivity analysis in laboratories.

This work was supported by the Nuclear Safety Research Program through the Korea Foundation of Nuclear Safety (KoFONS) using the financial resource granted by the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea. (No. RS-2023-00231329)

# Radiocarbon dating and PIXE analysis of historical paintings

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Cosmogenic radiocarbon, produced by interactions of cosmic rays with atmospheric atoms, is incorporated into environmental biochemical cycles and thus appears as a tracer in all living organisms. Consequently, materials used in the production of paintings that contain naturally derived carbon (e.g., canvas) can be subjected to radiocarbon dating. This is an important prerequisite for determining the true age of a painting, which may differ in the case of forgeries, commonly encountered on the art market.

We present results from the radiocarbon dating of old, mostly religious paintings, using accelerator mass spectrometry (AMS). The resulting radiocarbon ages span the 16th to 19th centuries, consistent with the expected historical origins of the analyzed paintings.

To further validate the authenticity of the examined artworks, we also developed a method for elemental analysis using particle-induced X-ray emission (PIXE). The bulk samples (oils on canvas) used for the nondestructive PIXE analysis were cut from the paintings prior to their use in the destructive AMS analysis. The PIXE results showed in some paintings a presence of several elements (Mg, Al, P, S, Ca, Ti, Fe, Zn, Ba and Pb) at concentrations ≥1%, while the other elements (Na, Cl, K, Cr, Mn, Co, Ni, Cu, Sr and Cd) were present at lower levels. A potential correlation between radiocarbon ages and elemental compositions will be discussed as a novel approach to identifying forged paintings.

# Activity size distribution of $^{7}$Be in aerosol samples collected in Bratislava, Slovakia

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$^{7}$Be is a relatively short-lived (half-life of 53.3 days) cosmogenic radionuclide produced in the stratosphere and troposphere. The produced $^{7}$Be is attached to fine aerosol particles and is transported within and between individual atmospheric layers and by wet or dry deposition it is transported into terrestrial and marine environment. That makes $^{7}$Be an excellent tracer of these processes and it is extensively used to study vertical transport in the atmosphere, horizontal transport of air masses and changes in the cosmic radiation flux and solar activity.

At the Comenius University in Bratislava, aerosol sampling and gamma spectrometry of the collected samples have been done continuously for several decades. However, no study of particle size distribution and its association with $^{7}$Be activity has been done before. A low-pressure-drop cascade impactor with high flow rate was used to determine the size distribution of the particulate matter in the sampled air with cutpoints of 10, 2.5, 1.4, 0.77, 0.44 and 0.25 µm. The maximum of $^{7}$Be activity was observed in the 0.44 - 0.77 µm range and the activity median aerodynamic diameter (AMAD) was evaluated to be 0.50 ± 0.5 µm.

# Radiocarbon in the gaseous and particulate constituents of the atmosphere in Bratislava, Slovakia

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Radiocarbon is a cosmogenic radionuclide produced primarily in the atmosphere and in the form of carbon gases it participates in the global carbon cycle together with the stable carbon isotopes. This makes it an excellent tracer of both natural and anthropogenic effects on the carbon in the atmosphere and connected carbon reservoirs. Radiocarbon levels in the atmosphere are influenced by natural processes such as transport of carbon between reservoirs and changes in solar activity, but human activities have a significant impact on radiocarbon activity in the environment as well. Nuclear weapon testing in the past and current releases from nuclear power plants increase the radiocarbon activity, however, emissions of $^{14}C$-free fossil $CO_2$ decrease its specific activity. Radiocarbon is also present in the atmosphere in the form of carbonaceous particulate matter. Its sources are biogenic emissions from the biosphere and combustion of biomass and fossil fuels. Based on the different radiocarbon signal of biomass and fossil fuels, analysis of radiocarbon content of aerosols enables source apportionment of these particles.

Three of the carbon-containing fractions of the atmosphere have been sampled and analyzed at the Comenius University in Bratislava - atmospheric carbon dioxide, hydrocarbons, and aerosols. Several decades long record of atmospheric $^{14}CO_2$ activity has recently been supplemented by measurement of radiocarbon content of total suspended particles and $CO/C_nH_m$ gaseous fractions. Comparison of radiocarbon levels in atmospheric $CO_2$ with clean air reference values will be presented, which shows both anthropogenic effects - input of excess radiocarbon and dilution of radiocarbon by fossil carbon dioxide. The amplitude of these effects slowly decreased over the decades. For a period of 10 years, in addition to sampling at the university campus, a sampling station in the middle of the city center was also used and the comparison of these two sites shows significant local differences in radiocarbon levels. The results of radiocarbon analysis of carbonaceous aerosols collected on quartz filters reveals that even in an industrialized and densely populated city, the non-fossil aerosols represent the majority of carbonaceous particulate matter during most of the year.

# Radiocarbon variations in tree rings and climate change

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Current climate models largely downplay the role of solar activity in climate variability, focusing instead on anthropogenic greenhouse gas emissions as the primary driver of recent temperature increases. This is due to the understanding that changes in solar irradiance (±0.1%) are too minor to account for the significant warming observed in recent decades. However, several centuries ago, pronounced solar minima - such as the Maunder, Spörer, Wolf, and Dalton minima - may have had a more substantial impact on Earth's climate. Historically, major climate shifts have been linked to Sun-Earth interactions governed by astronomical cycles (Milankovitch cycles), which drive climate changes over timescales longer than 10 ky. A notable exception is the Holocene epoch (the last ~12 ky), during which Earth's temperature has been unusually high and stable compared to previous periods of rapid changes. The last major cold period (an ice age) ended roughly 11 ky ago. While another ice age would be expected, this natural cycle may be disrupted by human influences as atmospheric $CO_2$ levels reached 423 ppm in 2024 and continue to rise, as no global consensus on reducing emissions has yet been achieved. The recently proposed Anthropocene epoch (beginning in 1950) is likely to continue exhibiting high global temperatures. Other natural factors, such as volcanic eruptions, forest fires, and permafrost thawing, may also contribute to climate changes.

Major climate events over the past millennium, such as the Medieval Warm Period and the Little Ice Age, are clearly reflected in tree-ring $\Delta^{14}C$ records. The aim of our study is to search for similar climate events based on $^{14}C$ records measured for the previous millennia. The future trajectory of Earth's climate will depend not only on our success in curbing greenhouse gas emissions, but also on how natural forces influence long-term climate evolution. Although solar variations are currently considered a secondary factor compared to greenhouse gases, our understanding of their indirect and cumulative effects remains limited. Continued research is needed to better evaluate the full range of natural drivers influencing climate change over various timescales.

# Observation of plutonium isotopes in surface air at Chiba City, Japan from 2016 to 2023: occurrence of anomalous $^{238}$Pu

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Since 2016, we have been conducting measurements of plutonium isotopes in surface air at Chiba City by using alpha and mass spectrometries together with large volume sampling and radiochemical analysis, to identify sources of plutonium in air dust samples and to assess their effects. The level of the monthly activity $^{239+240}$Pu concentration is from a few to some tens of nBq/m$^3$ and have a clear seasonal variation with a maximum in the spring season. Most of the plutonium in surface air at Chiba City is governed by resuspension of global fallout-derived Pu due to dispersion of soil particles at local and regional scales, such as long-lange transport of East Asian continental dust (yellow dust). The levels of monthly $^{238}$Pu were ND (not detected: detection limit : 0.086 nBq/m$^3$) to a few of nBq/m$^3$, which were more than one order magnitude lower than that of the $^{239+240}$Pu concentration. In March 2023, marked peak of the $^{238}$Pu concentration (25 nBq/m$^3$) occurred. In addition, $^{238}$Pu/$^{239+240}$Pu activity ratios in February and March 2023, which are 0.95 ± 0.095 and 1.1 ± 0.05, respectively, were obviously higher than the global fallout ratio (0.02). When the $^{238}$Pu/$^{239+240}$Pu activity ratio varies due to occurrence of nuclear facility accident, It is well-known that the $^{240}$Pu/$^{239}$Pu atom ratio increases. However, the $^{240}$Pu/$^{239}$Pu atom ratios in the corresponding months were 0.17 ± 0.021 and 0.17 ± 0.007, respectively, which is similar to that of global fallout ratio (0.18). In addition, no accident or trouble occurred at domestic nuclear facilities during the corresponding month. Therefore, it is difficult to explain that anomalous $^{238}$Pu during those periods of this study was derived from domestic nuclear facilities including FDNPS and/or global fallout origins. This survey is the result of "environmental radioactivity level survey" which is commissioned project by Japan Nuclear Regulation Agency.

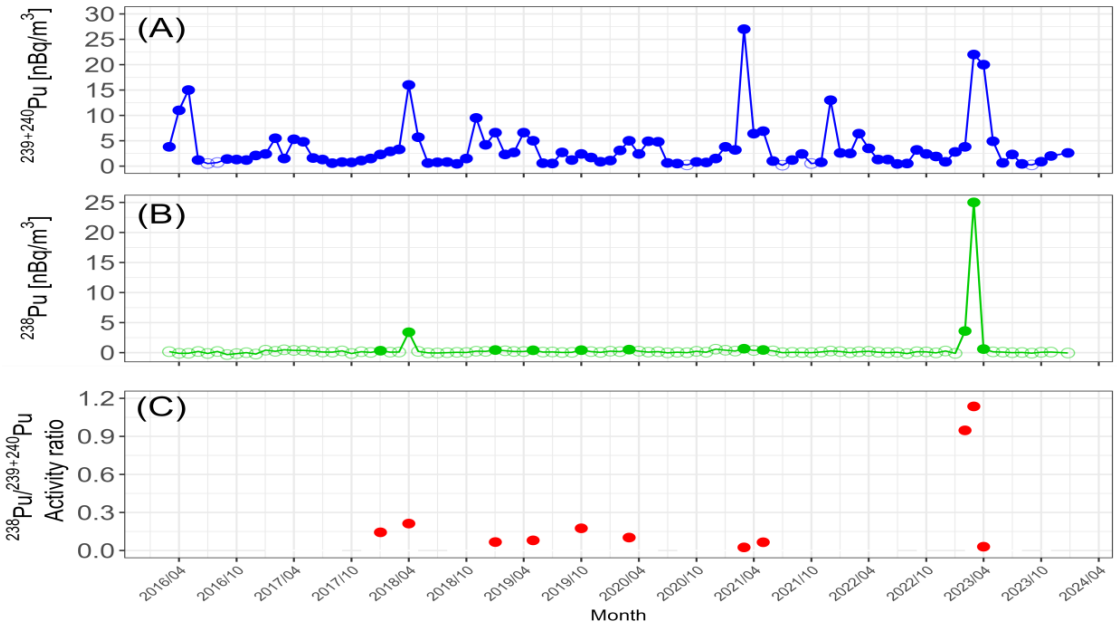



Fig. 1 The temporal variations of $^{239+240}$Pu (A) and $^{238}$Pu (B) activity concentrations and, $^{238}$Pu/$^{239+240}$Pu activity ratio (C) in surface air at Chiba City.

# Measurements of Radioactivity Equilibrium and Disequilibrium in Oil Scale

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Radioactivity equilibrium and disequilibrium in NORM and TENORM are common phenomena that have been studied for many years both from scientific and radioecology points of view. The study of radioactive waste in the oil and gas exploration field has been very well known for many decades with many published papers. However, little research has been undertaken to study equilibrium and disequilibrium. Since oil scale has the significance presence of high Z elements such as Ba and Sr, along with Fe, gamma ray self-attenuation can seriously underestimate radioactivity measurements especially for low energy photon below 100 keV. The usual gamma ray counting techniques to determine U and Th are very difficult in oil scale. We present results for the complete decay chain of U-238 and Th-232 for those radioisotopes that decay via gamma-rays. We also show results for the determination of U and Th via neutron activation analysis.

# Network of CzechRad mobile gamma radiation detectors in Poland – infrastructure for detailed spatial area mapping of dose rates, hotspot identification, and detection of radiation events related to warfare

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Spatial mapping of environmental variables is essential for gaining a comprehensive understanding and identifying spatial patterns, particularly in fragmented zones with exceptionally high values resulting from natural conditions or human activities, such as the deposition following the Chernobyl accident. This can be achieved through multiple measurements or by using multiple devices.

This article presents the initial results of the CITISTRA (Citizen Measurements as a Complementary Radiation Monitoring Strategy in Threats Due to Armed Conflict or Natural Disasters) project, implemented in Poland. The primary goal of the CITISTRA is to establish a network of CzechRad detectors (Geiger-Müller detectors) designed and manufactured in the Czech Republic by the National Radiation Protection Institute (SÚRO). These detectors are equipped with a GPS module and an SD card, enabling simultaneous recording of measurement data and location. The mobile infrastructure created by this project can supplement official monitoring systems and provide rapid local radiation data in the event of armed conflict or natural disasters. Another important outcome of the project will be the visualization of the ionizing radiation dose rate in the project areas, which will offer better resolution than currently achieved by the set of 58 stationary early detection stations used for monitoring the country's radiation situation. In May 2025, the distribution of 200 detectors began across an area of 84,000 km² in southeastern Poland. Measurements of the dose rate have already started and will continue for 12 months in mobile mode. All obtained data are going to significantly expand the existing SAFECAST open dataset released under Public Domain license. The analyses conducted within CITISTRA will complement the results obtained through existing geostatistical methods, allowing us to develop new tools for characterizing and identifying current and future hotspots.

The CITISTRA project has received funding within the PIANOFORTE partnership from the Euratom2027 program under grant agreement no. 101061037



## Anthropogenic U-236 in Arctic and Antarctic moss and lichens

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Above 100 uranium $NdF_3$ alpha spectrometric sources were dissolved and prepared for U-236 analyses by means of Accelerator Mass Spectrometry (AMS) at the Vienna Environmental Research Accelerator (VERA). Original samples were mosses or lichens of different species collected in both Antarctic and Arctic polar regions: In Arctic samples were collected near sea shore during two cruises along the north-west passage in the Arctic in 2012 and 2013. The Antarctic samples were collected mostly in the Southern Shetlands area during several Polish projects in the years 2002-2015. Ten process blanks were prepared along with the environmental samplesFor the first time, uranium was directly prepared in a Fluoride matrix for the AMS measurement and U was extracted as $UF_5^-$ from the ion source. The $^{236}U/^{238}U$ data set of the already intensively studied alpha sources could be obtained with minimal additional effort in sample preparations, thanks to the elevated ionization efficiencies of $UF_5^-$. In combination with the results of previous extensive studies on the mosses and lichens samples by alpha spectrometry or ICP-MS for $^{238}U$, $^{239+240}Pu$ or $^{239}Pu$, it was possible to evaluate isotopic ratios such as $^{236}U/^{239}Pu$ atom ratio. .

Both ratios: $^{236}U/^{238}U$ and $^{236}U/^{239}Pu$ reveal asymmetric distributions. The arithmetic mean values more than double medians (for $^{236}U/^{238}U$ it is 3.23E-07 and 1.28E-07, respectively, whereas for example in case of atom ratios for $^{236}U/^{239}Pu$ it is 0.213 and 0.102, respectively). The spread for $^{236}U/^{238}U$ atom ratio is bigger, from 6.61E(-09) to 7.36E(-06), due to higher maximum value. The mean uncertainty is order of magnitude smaller that mean values so the relative typical uncertainty was close to 10%. In case of $^{236}U/^{239}Pu$ atom ratio the range covers two orders of magnitude, from 0.009 to 0.891. The mean uncertainty is 0.040 what is nearly 19% of mean result.
Comparison of all corresponding atom ratios observed for Arctic and Antarctic samples reveal that all ratios are about twice times lower for Antarctic than for Arctic samples.
Proposed here normalization of $^{236}U$ to $^{239}Pu$ (as either atom or activity ratio) seems to be useful despite additional efforts paid for Pu analyses. Such normalization is based on the assumption that fractionation between Pu and U isotopes from fallout can be neglected.

**Acknowledgments**

The research leading to this result has been supported by the RADIATE project under the Grant Agreement **824096** from the EU Research and Innovation programme HORIZON 2020.

# A new radioactivity system to inspect suspicious material/objects for maritime security needs [*]

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Monitoring radioactive isotopes in aquatic environments is essential for environmental safety, early detection of nuclear accidents and research in various scientific fields like geology, seismology and oceanography. A lot of monitoring activities have been performed in the marine environment have been performed applying low and medium resolution underwater gamma-ray spectrometers such as the KATERINA [1] and GeoMAREA [2] detection systems. In this work a new nuclear detection system (named Mini KATERINA) is develop to be integrated in robotic vehicles for providing data in controlled aquatic environments. The system was tested in the laboratory using reference sources and various simulants prepared to train the system for suspicious objects identification under the hull of the ships. It operates a 2'x2' NaI(Tl) scintillation crystal coupled with a Silicon Photomultiplier to minimize dimensions, weight and maneuverability in the sea. All calibrations were performed with and without its enclosure. Gamma-ray spectra were acquired using point sources in the air environment with a special frame and geometry. The underwater detection system was immersed in a water tank with radioactive isotopes in order to calibrate it in terms of energy, energy resolution and efficiency. The activity concentrations of the gamma-ray emitters enriched into the water was determined by applying the calibrated KATERINA underwater spectrometer [1]. Simulation results were obtained using the MCNP5 code [3] reproducing well the experimental data. The underwater nuclear detection system together with robotic vehicle will be applied first for nuclear security needs and then in cases of identifying nuclear substances under the hull of the ships. The system will be applied in general inspection tasks that would be performed in collaboration with the port authorities. Moreover, the integrated system (robot and nuclear detector) is requested by the private sector to identify potential leak detection in applications related to pipeline inspection where special radiotracers (gamma-ray emitters) are applied.

**References**

[1] C. Tsabaris *et al*., App. Rad. Iso **66**, 1419 (2008), doi: 10.1016/j.apradiso.2008.02.064
[2] C. Tsabaris *et al*., App. Rad. Iso **142**, 100 (2018), doi: 10.1016/j.apradiso.2018.08.024
[3] X-5 Monte Carlo Team, MCNP – A General Monte Carlo N-Particle Transport Code, LA-UR-03-1987, Los Alamos National Laboratory, 2003.

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# Assessing Chlorine Contamination in Marine Fish Tissue Using Instrumental Neutron Activation Analysis

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Monitoring chlorine levels in marine fish tissue is critical for assessing environmental contamination, ecosystem health, and potential risks to human health through seafood consumption. Chlorine, often present as organochlorine compounds or inorganic chloride, can accumulate in marine organisms due to anthropogenic activities such as industrial discharges and agricultural runoff. Elevated chlorine levels may indicate exposure to pollutants like polychlorinated biphenyls (PCBs) or pesticides, which pose toxicological risks. Instrumental Neutron Activation Analysis (INAA) is a highly sensitive, non-destructive analytical technique justified for measuring chlorine in fish tissue due to its ability to detect trace elements with high precision and minimal sample preparation. INAA's multi-elemental capability allows simultaneous analysis of chlorine alongside other elements, providing comprehensive data on contaminant profiles. Its non-destructive nature preserves samples for further analyses, and its low detection limits ensure accurate quantification of chlorine even at trace levels. This study underscores the importance of chlorine monitoring in marine fish and advocates for INAA as a robust method to support environmental and public health research.

# Introduction of the k0-INAA method to the research workshop of the MARIA Research Reactor

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The $k_o$-standardization method in Instrumental Neutron Activation Analysis ($k_o$-INAA) is a highly sensitive, non-destructive technique for multi-elemental trace analysis, with significant applications in environmental radioactivity studies, particularly for quantifying uranium (U) and thorium (Th) in exploration rock samples. By employing a single comparator, typically gold, and utilizing well-characterized neutron flux parameters and nuclear constants ($k_o$-factors), $k_o$-INAA enables precise determination of radionuclide and trace element concentrations without multi-elemental standards. Its robustness makes it ideal for analyzing complex environmental matrices such as soils, sediments, and rocks to assess radioactive contamination. $k_o$-INAA enables accurate multi-element and radionuclide analysis, including Cs-137, U and Th[1]. Combining $k_o$-INAA with the IENAA (Instrumental Epithermal Neutron Activation Analysis) technique allows for the determination of U and Th concentrations in exploration rock samples[2]. The $k_o$-INAA method's minimal sample preparation reduces contamination risks and eliminates corrosive reagents, unlike ICP-MS[3]. Available software like $k_o$-IAEA for Windows enhances automation, facilitating large-scale studies. The $k_o$-INAA method remains essential for environmental research, providing critical data for pollution monitoring and regulatory compliance.

The laboratory is focusing on introducing this method and building team capabilities. In future, the k0-INAA technique will be used to analyze air particulate, marine environmental samples, geological samples.

References (for context, not included in abstract word count):

1. De Corte, F., Simonits, A. *Recommended nuclear data for use in the $k_o$ standardization of neutron activation analysis*. Atomic Data and Nuclear Data Tables, 2003.

2. Adesanmi, C. A., Tubosun, I. A., Balogun, F. A., Oladipo, A. A. *Advantages of combined IENAA and $k_o$-factor technique in the determination of U and Th concentrations in exploration rock samples*. Applied Radiation and Isotopes, 1997

3. Greenberg, R. R., Bode, P. De Nadai Fernandes E.A. *Neutron activation analysis: A primary method of measurement*. Spectrochimica Acta Part B, 66(3–4), 193–241, 2011

# Low-background, digital gamma-rays spectrometer with active shield equipped with beta plastic scintillation detector – a system for the simultaneous detection of gamma and beta radiation emitters and cosmic rays

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In various fields of science, industry, and medicine, researchers aim for analyses that yield the most detailed knowledge about the subjects they study. The most desirable analyses are non-destructive, allowing for measurement planning based on the acquired results. Such methods are invaluable in emergencies or when studying extremely valuable and unique material samples, such as meteorites and historical artifacts.

In 2018, at the Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN) a low-background digital gamma-ray spectrometer equipped with a Broad Energy Germanium (BEGe) detector (by Canberra, USA), a multi-layer passive shield and five large plastic scintillators (by Scionix, The Netherlands) as a cosmic veto system was developed. The system is used for detecting gamma emitters, as well as muon flux registration [1, 2, 3]. Data acquisition is conducted using the CAEN DT5725 digitizer with CoMPASS software, while off-line analysis is performed with specially developed code, VETO [1]. In 2024, the additional small scintillation detector (model number: 20BM100/0.75-E2-EJ200-X, by Scionix) was installed inside the passive shield and integrated with the system as the seventh detector. The measured sample is located between this scintillation detector and the BEGe detector. Due to the event-by-event registration with time resolution of 5 ns this system allows for off-line analyses of any logical condition between the detectors, in particular to study the simultaneous detection of gamma quanta and beta particles. It also allows to investigate delays between signal registrations in different detectors, providing insights into nuclear source processes. Furthermore, the addition of the scintillation detector improved the efficiency of the active shield. Performed tests indicated that the new system (consists of 6 scintillation detectors) reduced the background count rate from 1.43 cps to 0.85 cps, representing a reduction of 40.4% across the entire spectrum. The contribution of the beta detector was estimated to be at 7.4%.

The preliminary results obtained from the newly developed system in the context of environmental samples as well as both the advantages and disadvantages of the approach taken will be presented.

This work has been partially carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion) and in the framework of the international project co-financed by the Polish Ministry of Education and Science, as program "PMW", contracts 5235/HEU - EURATOM/2022/2 and 5253/HEU-EURATOM/2022/2.

1. J. Radioanal. Nucl. Ch., 322 (2019) 1311–1321, doi: 10.1007/s10967-019-06853-7
2. J. Radioanal. Nucl. Ch., 333 (2024) 3529-3539, doi: 10.1007/s10967-024-09412-x
3. Appl. Sci., 11 (2021) 7916, doi: 10.3390/app11177916

# The climate on Earth – do we understand it well enough?

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It is well-known that the climate on Earth has undergone big changes during geological times. These can be reasonably well reconstructed from a variety of geological archives which carry time series of proxies (e.g. stable- and radio-isotope ratios, trace gases) that are sensitive to the respective climatic conditions. Useful archives are for example cores from lake and ocean floor sediments, glacial and polar ice sheets, and loess deposits. Also tree rings, glacial moraines, cave deposits (speleothems), ground water and ocean currents, etc., provide signatures of past climatic conditions.

Some basic phenomena are reasonably well understood, such as the coming and going of the ice ages which are mainly due to the variation of Earth's orbital parameters and its concomitant variations of solar insulation on Earth. This theory was developed by Milutin Milankovich during the first half of the 20$^{th}$ century and was confirmed by measurements of the above mentioned proxies in several geological archives (Hays et al. 1976, EPICA Community Members, 2004). Another phenomenon which is well recognized is the heat transport by global ocean currents (Broecker 1991).

However, all this information stems essentially from times when human influence was absent. Today, we are clearly interested to understand how human's presence influences the climate on Earth. But since it is the first time that humans can make an impact on climate changes, we are faced with the problem to disentangle its influence from natural variations. And here we encounter a polarization of opinions rarely seen before. The reason is that besides the science of climate change – with all its recognized uncertainties (Koonin 2024) – there are strong economic and political issues at stake. This makes it particularly difficult to evaluate the scientific background and to predict what will happen in the near future.

The majority of climate scientists support the conclusion of the IPCC (Intergovernmental Panel on Climate Change) that man-made emission of greenhouse gases, particularly $CO_2$ from combustion of fossil-fuel, causes the increase of the Earth`s surface temperature. This goes back to some early prediction more than 100 year ago (Arrhenius 1896). Opposed to this view is a collection of scientists from different fields, who strongly believe that natural causes - and not humans – are the main drivers of the climate changes we observe today. A particularly prominent figure is John Clauser, a Nobel Laureate in Physics of 2022, who claims that water vapor far outpaces the influence of $CO_2$ on climate, which he calls the 'cloud thermostat'.

In this presentation, I will try to present a "balanced" view of how much we understand about the complex interplay of human-induced and natural climate changes.

References

Arrhenius, S., On the influence of carbonic acid in the air upon the temperature of the ground, Philosophical Magazine and Journal of Science, Series 5, Volume 41 (1896) 237-276.

Broecker, W.S., The great ocean conveyor, Oceanography 4 (1991) 79-89.

EPICA Community Members, Eight glacial cycles from an Antarctic ice core, Nature (London) 429 (2004) 623-628.

Hays, J.D., J. Imbrie, N.J. Shackleton, Variations in the earth's orbit: pacemaker of the ice ages, Science 194 (1976) 1121-1132.

Koonin, S.E., Unsettled, updated and expanded edition: What climate science tells us, what it doesn't, and why it matters, Recorded Books (2024)

# Effects of radon exposure on the bioactive compound profile of *Mentha spicata L.*

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Understanding the effects of exposure to natural sources of ionising radiation (IR) in living organisms is an ongoing and complex task, particularly when dealing with a naturally occurring radioactive gas in particular radon. The short- and long-term consequences of this exposure require continuous investigation, especially to clarify the mechanisms underlying repair mechanisms involved. In plants, the antioxidant (AO) system and the regulation of reactive oxygen species (ROS) are key protective responses against oxidative stress triggered by environmental threats. This stress subsequently leads to the activation or repression of enzymes, proteins, or phenolic compounds involved in the detoxification of ROS. This study is an experimental investigation based on environmental toxicology and plant physiology. Its main objective is to evaluate the response of *Mentha spicata L.* (MS) when exposed to airborne radon, using both active and passive detectors in isolated chambers. Chamber A (experimental) contains not only the plants but also a mineralised rock with pitchblende, a known source of radon exhalation. Chamber B (control) has a similar setup but without the rock. The assays conducted on MS extracts included HPLC-DAD analysis, Total Flavonoids (TF) quantified using an adapted $AlCl_3$method, and an adapted DPPH radical scavenging assay. The exposure system developed for this study simulates different environmental conditions, with Chamber A showing high levels of radon and Chamber B maintaining significantly lower levels. Both chambers remain sealed for 15 days during the exposure period (Cycle: #5 – Sept 2024; #6 – Dec 2024). The HPLC-DAD results as part summarised in Table 1, indicate a decrease in concentration for rosmarinic acid and myricetin compounds in plants from Chamber A compared to the control. This suggests that higher radon concentrations are associated with stronger protective responses. In other words, AO capacity, as indicated by the DPPH assay and as confirmed by the TF assay, both decrease under higher exposure. Two hypotheses can be considered: first, the activation of the plant's defence signalling pathway may have been repressed; second, the consumption of AO may have increased to counteract oxidative stress. It is known that IR leads to increased ROS production in plants; however, the aim of this study is to extrapolate these findings to animal cells. Therefore, our next step is to determine whether the reduction in these compounds occurs via enzymatic or non-enzymatic pathways, and to establish correlations with potential cellular alterations.

**Table 1** – Partial HPLC-DAD result of two compounds for comparison of exposed (Chamber A) and non-exposed (Chamber B) plants.

| | *Chamber A* | | | *Chamber B* | | |
|---|---|---|---|---|---|---|
| *Cycle* | Radon[a] | Rosmaniric Acid[b] | Myricetin[b] | Radon[a] | Rosmaniric Acid[b] | Myricetin[b] |
| *5* | 52000 | 1029,56 | 121,83 | 176 | 2103,07 | 200,64 |
| *6* | 82000 | 3345,51 | 312,11 | 620 | 4680,77 | 361,04 |

Note: a – $Bq/m^3$; b - μg/mL of extract.

**Acknowledgments:** The authors L. Lopes and S. Soares received funding provided by RURALThings (DOI identifier https://doi.org/10.54499/UIDB/50008/2020) for publication and conference participation.

# Rooks as bioindicators of radioactive contamination in the vicinity of the Mayak facility

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The region surrounding the Mayak facility was the site of three major radioactive events: the release of radioactive waste into the Techa River (1949–1956), the Kyshtym disaster (1957), and the dispersal of radioactive dust from the drying Lake Karachay (1967). Between 1949 and 1956, the Mayak facility released approximately 76 million $m^3$ of liquid radioactive waste containing over 100 PBq of Sr-90, along with significant quantities of Cs-137, Ce-144, and Pu-239. The Kyshtym disaster, caused by an explosion in a high-level waste storage tank, released about 740 PBq of radioactivity. Contamination extended across 23 000 $km^2$, with the East Ural Radioactive Trace (EURT) marking the most heavily affected area. In 1967, radioactive dust from Lake Karachay contaminated an additional 1800 $km^2$. The persistent presence of radionuclides such as Sr-90, Cs-137, Am-241, and Pu isotopes continues to pose environmental and health risks.

Birds are recognized bioaccumulators and serve as effective biomonitors of environmental contamination, including radioactive pollutants. Migratory birds are particularly valuable in this context due to their ability to transport contaminants over long distances. The accumulation of trace elements such as radionuclides in avian tissues is influenced by ecological, physiological, and behavioral factors, as well as environmental exposure routes. Certain species may be especially suitable for bioindication due to their ecology and exposure profiles. This research investigates the use of two migratory corvid species—*Corvus frugilegus* (rook) and *Corvus monedula* (jackdaw)—as bioindicators of radioactive contamination. Rooks wintering in Poland are known to nest in the southern Ural region, an area severely affected by historical nuclear contamination. Simultaneously utilizing the jackdaw (*Corvus monedula*) as a reference sample due to its different migration range and habitat preferences. Analyses are focused on soft tissues, bones, and feathers. Given the ecology, diet, and synanthropic behavior of corvids, they are exceptionally well-suited for studying radionuclide bioaccumulation and long-range transport. This study are employed gamma spectrometry, beta spectrometry (LSC), alpha spectrometry, and radiochemical methods to quantitatively determine the levels of radionuclides such as Cs-137, Sr-90, Am-241, uranium isotopes, plutonium isotopes, and other short-lived gamma emitters.

The research will involve only *Corvus frugilegus* and *Corvus monedula* individuals that died from natural causes or circumstances independent of the researchers (e.g., roadkill). The project team holds a valid permit issued by the General Directorate for Environmental Protection, authorizing the collection, storage, transportation, and preparation of deceased specimens of these species within the Małopolskie, Podkarpackie, and Lubelskie voivodeships. The project addresses a key gap in current research: the lack of comprehensive studies on migratory birds as vectors of transboundary radionuclide movement. It will provide novel insights into the effectiveness of avian biomonitoring in post-nuclear contamination zones.

# Ordered mesoporous silica SBA-15 functionalized with phosphonic acid groups for strontium removal from radioactive contaminated wastewater

M. Laskowska, A. Karczmarska, A.A. Ahmed, T.M. Mróz, B. Wąs and J.W. Mietelski

The effective removal of strontium radionuclides from contaminated water remains a critical challenge, particularly in the context of nuclear power plant operation and environmental remediation. Strontium-90, a fission product of uranium and plutonium, has a long half-life of 28.8 years, high biological toxicity, and significant mobility in aquatic environments, posing a serious risk of contamination to groundwater and surface waters. Modern nuclear power plants and facilities involved in the processing and storage of radioactive waste generate liquid waste streams containing strontium, which require efficient purification before release into the environment. Effective and selective adsorbents can significantly improve the remediation of radionuclide-contaminated water, reducing the need for costly and energy-intensive chemical or physical treatments. For this reason, materials with high affinity for $Sr^{2+}$ ions, resistant to radiation and the presence of interfering ions, are being actively developed and for use in future purification systems in nuclear power plants, waste storage sites and emergency situations, such as contamination following an accident [1].

Various forms of silica-based strontium adsorbents have been tested to date, proving that the search for the ideal adsorbent for waste water remediation among silica-based materials is a valid approach [2, 3]. This research focuses on the development and evaluation of mesoporous silica-based adsorbents, with a particular emphasis on SBA-15. A comparative analysis with structurally related materials such as SBA-16 and MCM-41 highlights the superior properties of SBA-15, including its large, uniform mesopores, high surface area, and thick pore walls, which together ensure enhanced chemical stability and adsorption performance.

Solutions based on functionalized silica nanostructure are considered very and currently, ongoing research is being conducted to determine the best form of functionalisation leading to selective strontium adsorption [1]. Our research aimed to investigate the effectiveness and selectivity of phosphonic acid functional groups placed in the ordered mesoporous structure of SBA-15 silica. The synthesis of SBA-15 was followed by surface functionalization with phosphonic acid groups capable of binding divalent metal ions. The success of the functionalization process was confirmed using energy-dispersive X-ray spectroscopy (EDS) and Raman spectroscopy. Adsorption experiments were conducted using strontium-containing aqueous solutions, and the extent of strontium uptake was quantitatively evaluated via EDS. The results demonstrate the high potential of phosphonic acid functionalized SBA-15 as an efficient adsorbent for strontium ions, with significant advantages over other mesoporous silica frameworks. Moreover, its versatility allows for fabrication in powder, pellet, or thin-film forms, enabling adaptation to various application scenarios. These findings support the continued development of SBA-15-based materials for advanced water purification systems in nuclear and environmental applications.

1. Zhang, Shichang, et al. "Phosphination of amino-modified mesoporous silica for the selective separation of strontium." *Journal of Hazardous Materials* 467 (2024): 133741.
2. Chen, Zi, et al. "Selective removal of Sr2+ by cation exchange using silica-based titanate adsorbents." *Journal of Solid State Chemistry* 312 (2022): 123247.
3. Chen, Z., et al. "Preparation of silica-based titanate adsorbents and application for strontium removal from radioactive contaminated wastewater." *Journal of Radioanalytical and Nuclear Chemistry* 307.2 (2016): 931-940.

# Modeling of Neutron-Induced Air Activation in a Compartment Intended for the Installation of the HRNS Diagnostic System at ITER

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This study presents a numerical investigation of neutron-induced activation of air within one of the compartments designated for the installation of detection systems of the High-Resolution Neutron Spectrometer (HRNS). The HRNS is one of the diagnostic systems currently in the design phase for ITER (International Thermonuclear Experimental Reactor), a large-scale nuclear fusion facility under construction in France. Neutron spectra for both deuterium-deuterium (2.45 MeV) and deuterium-tritium (14 MeV) plasma discharges were simulated using the Monte Carlo N-Particle (MCNP) code. The resulting spectra were used in activation calculations with FISPACT-II — an inventory code capable of modeling activation, transmutation and depletion processes induced by neutrons and other particles.

The analysis focused on dominant radionuclides such as Ar-41, Kr-83m, C-14, and H-3, with activity evaluated both per gram of air and for the total air mass (~5.74 kg) within the HRNS compartment. Ar-41 was identified as the dominant contributor to short-term activity. In contrast, long-lived radionuclides such as tritium and carbon-14 were produced in much smaller quantities.

For the most radiologically significant of these, tritium (H-3), the maximum predicted concentration in air was approximately 31 Bq/m³. This value is over four orders of magnitude below the Derived Air Concentration (DAC) for tritium established by the International Commission on Radiological Protection (ICRP), which is 740 kBq/m³. It is also seven orders of magnitude below the action limit for tritium concentration in room air adopted in ITER's engineering safety approach.

These findings confirm that even under conservative operational assumptions - including no air exchange - neutron-induced activation of confined air volumes will not pose a radiological hazard. The results support environmental safety assessments for future fusion reactors and contribute to modelling-based evaluation of environmental processes in enclosed air spaces exposed to neutron radiation.

*This work was done as part of a project co-financed by ITER Organization, France and the Polish Ministry of Science and Higher Education under the program entitled "International Projects Co-financed". The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.*

**Photonuclear Neutrons from Synchrotron Linac: Bridging Environmental Science and Isotope Technology at SOLARIS**

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This study explores the feasibility of utilizing the electron linear accelerator (linac), currently integrated into the synchrotron infrastructure at the SOLARIS National Centre for Synchrotron Radiation, as a compact and versatile photoneutron source. The objective is to evaluate its potential for two key applications: neutron activation analysis (NAA) of environmental samples and the production of select radioisotopes for medical and industrial use. Traditionally, these applications have relied heavily on reactor-based neutron sources, which pose logistical, regulatory, and operational challenges. Accelerator-driven systems, particularly those based on electron linacs, offer a promising alternative by generating high-energy bremsstrahlung photons capable of inducing (γ,n) reactions in high-Z target materials such as tungsten or beryllium.

The proposed concept involves adding a experimental line to the existing SOLARIS linac to operate in pulsed or continuous mode to produce photonuclear reactions in a designated target assembly. Neutron yield, energy spectrum, and flux distribution are evaluated through preliminary Monte Carlo simulations and theoretical modeling. Considerations include target geometry, shielding requirements, and moderation systems tailored for maximizing thermal or epithermal neutron availability, depending on the application.

For environmental analysis, the focus is on establishing protocols for instrumental neutron activation analysis (INAA), enabling the detection of trace elements in soil, water, and atmospheric particulates. The compact footprint and controllability of the linac-based source could support rapid, decentralized testing in response to environmental monitoring needs, pollution events, or scientific studies

**LVis & tRAYcy: Laboratory Management & Monte-Carlo Software for gamma and alpha spectroscopy applications**

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A comprehensive approach to gamma and alpha spectrometry data acquisition and analysis is presented through the integration of the LVis laboratory management system with the newly developed **tRAYcy** Monte Carlo simulation code. LVis supports a modular workflow for laboratory operations, incorporating customizable measurement routines, structured data handling within a unified file format, and advanced quality assurance tools. It facilitates both standard and specialized applications, including whole-body counting, automated sample changers, and GMP-compliant workflows, while offering a simplified interface for routine monitoring tasks.

The tRAYcy code, embedded within the LVis platform, implements a multi-threaded ray-tracing Monte Carlo algorithm to simulate detector response functions with high fidelity. It supports geometry and cascade-related corrections, summing effects, and mathematical efficiency calibration, and enables synthetic spectrum generation based on nuclear decay schemes, including α, β, γ, X-ray, and conversion electron emissions. Spectral components are derived using Bateman solutions for activity evolution, and the simulated data can be directly compared with experimental spectra to support quantitative corrections, method validation, and virtual instrument prototyping.

This integrated software environment aims to improve accuracy, reproducibility, and traceability in spectrometric measurements, particularly in applications requiring complex geometry corrections and high-throughput analytical workflows.

# Environmental radiation surveys of FIR1 research reactor decommissioning

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FiR1 TRIGA Mark II type research reactor by General Atomics (USA) was the first reactor in Finland. FiR1 was commissioned in 1962 and shut down in 2015. During the over 50 years of operation, FiR1 had a key role in Finland's nuclear energy program and in training of nuclear energy and technology professionals. More specifically, neutron beam research, activation analyses, isotope production, and Boron Neutron Capture Therapy (BNCT) treatments were carried out. Decommissioning planning began promptly, and dismantling was carried out 2023-2024.

Environmental aspects have been an important part of the decommissioning project, which began with an Environmental Impact Assessment showing that the FiR1 decommissioning will not cause a significant impact on the environment. However, potential releases would be possible in accidents. The decommissioning licence application detailed the measures which were put in place to restrict and monitor environmental releases. The main release pathways to the environment during the operations and dismantling were the same; via wastewater and air ventilation. During the operations, wastewater characterisations showed no measurable amounts of main contaminants (i.e., Mn-54, Co-60, Cs-134, Cs-137). The air ventilation surveillance showed that only gaseous Ar-41 was released during operation hours. Therefore, it was concluded that the environmental impact of FIR1 regarding release of artificial radionuclides had been negligible.

In order to verify the environmental impact of FIR1 decommissioning, the approach included three phases with different measurement points:

1) Collection of environmental samples prior to dismantling and their analysis for decommissioning relevant artificial radionuclides namely H-3, Co-60 and Cs-137 in 2017. Samples were collected from air, soil, plants (moss and fern), sediment (pond), and water (sea and pond). The results showed that none of the samples contained Co-60 or H-3 whereas Chernobyl related Cs-137 was measured in the soil samples (max 80 mBq/g), the moss sample (50 mBq/g), and the sediment sample (40 mBq/g). Additionally, a narrowed environmental survey was conducted during spent nuclear fuel removal in 2019.
2) During dismantling, the environmental measurements were focused on air samples taken regularly from the air ventilation and from the roof of a nearby building. The results showed that no measurable amounts of Co-60, Cs-137 or Eu-152 activities were detected in the air ventilation. The results were similar for the roof of the nearby building. Additionally, direct gamma exposure measurements were carried out during removal of most activated components.
3) The final environmental survey was carried out in September 2024. The content was the same as in the initial survey, but additionally artificial Eu-152 was analysed. The results showed that no H-3, Co-60 or Eu-152 activities were detected in any of the samples. Cs-137 activities were measured in all soil samples, in one fern sample, and one air sample (roof). However, the soil and fern sample Cs-137 activities were similar to the initial survey results (15-80 mBq/g and 15-76 mBq/g, respectively). However, the Cs-137 activity in the air sample was detected only due to a significantly longer measurement time after STUK announced that they had detected small amounts of Cs-137 in their air sample stations. The pollution was postulated to originate from Ukrainian forest fires.

As a conclusion, no artificial radionuclides from FiR1 decommissioning had been released to the environment during the decommissioning project.

# IAEA-RCA: Role in fostering Technical Co-operation in Nuclear Technologies in the Asia-Pacific region

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The RCA (The Regional Cooperative Agreement) for Research, Development and Training has been established in 1972 under the auspices of the International Atomic Energy Agency (IAEA). The Technical Cooperation Programme of RCA facilitates collaborative, peaceful applications of nuclear science and technology across Asia and the Pacific. 22 countries from this region are the members of RCA currently and are referred to as Government Parties (GPs). RCA promotes shared developmental goals through joint research, training, capacity building, knowledge exchange, and technical cooperation among the RCA GPs. It contributes to the socio-economic development of its GPs through application of the established nuclear technologies, provision of physical and financial resources and support in form of technical expertise for utilization of these technologies. The RCA Regional Office (RCARO) inaugurated in 2002 in Daejeon, Republic of Korea, has played a critical role in furthering nuclear science collaboration across Asia–Pacific. RCARO has facilitated capacity-building, technology adoption, regional outreach, and intergovernmental partnerships across multiple domains.

RCA realises multifaceted programmes mainly in four thematic areas, agricultural, environmental, human health, energy and industrial sectors. The challenges facing the billions of people living in this Asia-Pacific region are multivariate, including climate change, food production and marine pollution, energy demand, plastic pollution, zoonotic diseases, cancer etc. IAEA has launched Key programmes likes Ray of Hope-Cancer diagnosis and treatment, Atom for Food-food security, ZODIAC-Zoonotic disease prevention, NUTEC Plastics-Plastic pollution, ATOM for Net zero-Energy security, decarbonization to address these issues. RCA is in its sixth decade, and to date it has delivered more than 170 projects, launched over 650 regional training courses and 560 workshops, engaged over 10,000 national participants, and recruited over 4,500 experts and lecturers across the region. It remains an indispensable platform for addressing evolving challenges, ranging from climate change, food security to health emergencies and industrial applications, safety, water and environment, through peaceful, scientific cooperation. Among the various Technical Cooperation projects (TCP) related to the health of Marine environment RAS7021, RAS7024, RAS7028, RAS7031 to name a few have been successfully completed and RAS7038 are ongoing with the support of RCA. RAS7028 focussed on Enhancing quality-assured regional capabilities for marine radioactivity monitoring and impact assessment of both routine and accidental radioactive releases in Asia-Pacific marine ecosystems. The project led to development and use of the Asia and Pacific Marine Radioactivity Database (ASPAMARD), hosted in the Philippines, and integrated with the IAEA's global marine database (MARiS). During the Fukushima Daiichi accident, ASPAMARD served as a crucial tool for assessing radioactive dispersion and aiding member states in understanding the marine impact of the releases. Ongoing project on Marine Plastic Pollution Monitoring focusses on enhancing understanding of marine plastic pollution and harmonization of assessment methodologies etc. These collaborative projects involved extensive training-courses, workshops, meetings to assess the capabilities of the GPs and their needs, encouraged sharing of resources and expertise among the members. Financial, technical support was extended to develop and enhance capacity of GPs enabling collective assessments of regional marine environmental health. Quality Management Systems (QMS) were implemented to ensure data integrity. Thus IAEA-RCA plays a major role in fostering Technical Co-operation in Nuclear Technologies in the Asia-Pacific region.

Acknowledgement: Author acknowledges IAEA RCARO for selection in the IAEA expert program and supporting participation in ENVIRA2025.

# A need to revise radiological standards for building materials as a result of the obligatory use of bio-fuels

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Monitoring the levels of natural radioactive isotopes such as $^{40}$K and those of uranium and thorium series in building material samples is crucial for the assessment of potential exposure of the population to ionizing radiation. Since the building materials are made of material taken directly or indirectly from geosphere (rocks or mineral wastes from industrial processes), in Polish regulations, only natural radionuclide are taken into consideration. The Environmental Radioactivity Laboratory of the Institute of Nuclear Physics (ERL IFJ PAN) in Krakow has been analyzing radioactive isotopes in building materials for many years, during the last 13 years (2012-2025) within the ISO 17025 accreditation regime. The results on activity concentration of natural radionuclides for samples of fly ash, blast furnace slag, cement (II, III, IV, and V), calcareous stone, and synthetic gypsum showed significant differences in their activity concentrations. Recently, the regulation changed the critical nuclide in the Th series, which is subject of measurement. Previously it was $^{228}$Th (from January 2, 2007 to February 6, 2021, in the Ordinance of the Council of Ministers (Polish Journal of Laws/Dz.U. No. 4/2007)[1]). In contrast, currently it is $^{232}$Th (from February 7, 2021, the Ordinance of the Council of Ministers (Polish Journal of Laws/Dz.U. No. 33/2021) [2]).

The second change is the in the calculated parameters $f_1$ and $f_2$. The $f_1$ is a weighted sum of the activity concentration of $^{40}$K, Th and U series critical radionuclides. The weights are reciprocal of maximum activity concentrations of those radionuclides in the absence of the others. The interpretation of this parameter is the limit for external gamma dose rate sources. The $f_2$ is simply the $^{226}$Ra concentration and the interpretation of this parameter is the maximum concentration permitted due to $^{222}$Rn inhalation risk. Along with changes in chosen nuclide of concern in the Th series, the novel regulation changed the values of parameters $f_1$ and $f_2$. Accordingly to the reformed law, the $f_1$ value should range between 0 and 1.2 (instead of previous condition <1) , whereas $f_2$ should be lower than 240 Bq/kg (previously < 185 Bq/kg). These values determined the suitability of the mentioned materials for various construction application. The poster will summarize results of our measurements.

In recent years, a new observation has emerged regarding the presence of artificial radioisotopes, primarily $^{137}$Cs in some building materials. This feature is a result of the obligation to use of the biomass component in all fuels including solid ones. The ashes from the combustion of solid fuels are one of the components which are used to produce building materials. This situation indicates a need to revise radiological standards for these materials. Additionally, the algorithms used to assess potential external radiation exposure should be updated to include a component that accounts for the dose contribution from $^{137}$Cs [3].

References:

1. The Ordinance of the Council of Ministers (Polish Journal of Laws/Dz.U. No. 4/2007)
2. The Ordinance of the Council of Ministers (Polish Journal of Laws/Dz.U. No. 33/2021)
3. J.W. Mietelski, E.Tomankiewicz, E. Łokas , Tomasz Mróz, Kamil Brudecki Spalanie biopaliw w energetyce węglowej, a konieczność rewizji norm radiologicznych dla materiałów budowlanych Abstr. z VII Krajowej Konferencji Radiochemii i Chemii Jądrowej, Lublin, 17-20 kwietnia 2016, p. P-64

# Monitoring of radioactivity in air and total atmospheric precipitation at IFJ PAN in Krakow between 2021 - 2025

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Routine monitoring of natural and anthropogenic radioactive isotopes in the ground - level air has been conducted since 1990 at the Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN) using high-volume aerosol sampling station (ASS-500) and low background gamma spectrometry. The ASS-500 was produced by the Polish Central Laboratory for Radiation Protection (CLOR). Since 1995, two such stations have been operational on the institute's premises. Atmospheric aerosols are collected weekly on the Petrianov filters (FPP-15-1.5), at the height of 1.5 m above ground level, with a total volume of filtered air of approximately 80 000 $m^3$. During emergencies, such as in the weeks following the Fukushima accident, the collection frequency was increased to one or two days. Exposed air filters, before measurement are compressed into a disc with a diameter of 51 mm and a thickness of 4 to 8 mm, depending on the amount of dust collected. Additionally, one of the ASS-500 station was modified to collect the gaseous $^{131}I$ using a charcoal double cartridge trap.

The method of monitoring mentioned above is enhanced by monitoring radioisotopes in total atmospheric precipitation. Since 2005, samples primarily consisting of rainwater, snow, hail, etc. have been continuously gathered in a fallout funnel, which is a standalone station with an area of 2.28 $m^2$. The collected samples are stored in 160-liter plastic barrels. To preserve research material, 50 ml of concentrated nitric acid is added to each barrel. The procedure for preparing samples for measurements using low background gamma spectrometry involves evaporating the samples to dryness to the same geometry as the aerosol filters.

Determination of gamma emitters in our laboratory is subject to a measurement procedure in accordance with the ISO 17025 standard. Research conducted over a period of 20 years on a monthly basis for total atmospheric precipitation, and 35 years on a weekly basis for aerosol samples, has revealed significant signals from the Fukushima accident [1], the presence of $^{106}Ru$ in October 2017 [2,3], and numerous forest fires in the Chernobyl zone [4]. Additionally, radiochemical analyses for plutonium isotopes were performed on the majority of archive samples [5].The results presented in the poster focus on a more recent time frame, covering 4.5 years from January 2021 to June 2025. This includes a set of activity concentrations of isotopes such as $^{7}Be$ and $^{22}Na$, $^{137}Cs$ and $^{40}K$, with a seasonal variation trend visualization.

References:

1. Mietelski J.W. et al., J. Environ. Radioactiv., 166 (2017) 10-16, doi: 10.1016/j.jenvrad.2016.02.010
2. Masson O. (Gorzkiewicz K., Kierepko R., Tomankiewicz E., Mietelski J.W.) et al (2019), PNAS. 116, 16750-59, doi: 10.1073/pnas.1907571116
3. Bossew P. (Gorzkiewicz K., Kierepko R., Mietelski J.W.) et al., J. Environ. Radioactiv., 205-206 (2019) 79-92, doi: 10.1016/j.jenvrad.2019.05.004
4. Kierepko R. et al., 2016 Nov 1;569-570:937-947. doi: 10.1016/j.scitotenv.2016.05.222. Epub 2016 Jul 20. PMID: 27450248.
5. Kierepko R. (Mietelski J.W, Blazej S.) et al., Radiochimica Acta, vol. 97, no. 4-5, 2009, pp. 253-255. https://doi.org/10.1524/ract.2009.1606
6. Blazej, S., Mietelski J.W., J. Radioanal. Nucl. Chem. 2014, 300, 747–756.
7. Masson O., (Kierepko R., Mietelski J.W.) et al., *April 2020*,Environ. Sci. Technol., 55 (2021) 13834-48, doi: 10.1021/acs.est.1c03314

# NOR in NORM: naturally occurring radionuclides in naturally occurring radioactive materials – characteristics, principles of measurement organization, and interpretation of measurement results

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NORM-related activities encompass a wide range of industries that result in human exposure to radiation and generate substantial solid residues, as well as gaseous and liquid effluents often containing particulate matter. These materials are then subjected to environmental factors and affect various biota. While these residues share similarities with industrial waste, they consistently contain natural radionuclides undergoing radioactive decay, leading to the formation of isotopes of diverse elements and often coexisting with additional contaminants, thereby creating complex exposure scenarios.

Radionuclides from decay series commonly exist together in both NORM and environmental samples, making data analysis more challenging than with artificial radionuclides. Existing regulations mainly target parent radionuclides U-238 and Th-232, omitting U-235, hence overall trend is observed to evaluate activity concentrations of these radionuclides. Under rare secular equilibrium conditions, measuring any single radionuclide can represent the whole series, including parent radionuclides but this is uncommon due to frequent disturbances. Phenomena like leaching, sorption, diffusion, precipitation, emanation etc., as well as human or non-human biota activities can alter mutual radionuclides dependencies determined by the radioactive decay law and affect their final distribution.

When secular equilibrium cannot be assumed, radionuclide-specific analytical techniques must be applied. However, directly measurable naturally occurring radionuclides do not always correspond to those most relevant for NORM characterization from a radiation protection perspective. Therefore, accurate interpretation of results demands thorough evaluation of the NORM source history, composition, and assumptions regarding radioactive equilibrium to ensure meaningful assessment of potential radiation hazards in both occupational and environmental contexts.

## Environmental research at Southampton – four decades of environmental radioactivity

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The environmental radioactivity laboratories at Southampton were founded in 1987 in response to the Chernobyl accident and the demand for independent environmental monitoring. Since then, the laboratory has been involved with a wide range of research in environmental monitoring and remediation and in the use of radiotracers to study environmental processes. An overview of this research is presented along with a discussion on future research directions supporting nuclear decommissioning, new build and waste disposal.

# Transfer parameters in Mediterranean ecosystems

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Transfer parameters are key variables that play a significant role in the development of mathematical models for the transfer of radionuclides in the environment, which are essential in the management of radiological events and emergencies. These parameters are usually defined as the ratio between activity concentrations in the receptor compartment (plant, tissue, animal, etc.) and in the media (soil, water, …). This simple concept in appearance, present some unexpected complexities and difficulties, there is no universal agreement on nomenclature or the definition of the extent of media to be considered, i.e. soil. Additionally, transfer parameters are highly dependent of the environmental and climatic conditions, which can be observed in the huge variability of their values, up to seven orders of magnitude for some radionuclides. International compilations of transfer parameters also present a geographical bias, reporting data mainly from temperate ecosystems. There is a certain lack of data for Mediterranean climate areas, which present great variation over the year in temperature or precipitation, among others. In this work, comparison between transfer parameter data reported from Mediterranean ecosystems and temperate ones will be carried out.

Acknowledgements
This study was partially funded by the agreement between Consejería de Agricultura, Ganadería y Desarrollo Sostenible de la Junta de Extremadura and the University of Extremadura “Realización de actividades relativas a la protección radiológica ambiental, a la vigilancia de las emisiones industriales y al mantenimiento de la red de medición de calidad del cielo nocturno y contaminación lumínica en Extremadura. Anualidades 2024-2027”.

## Anthropogenic radioactive substances in poultry eggs

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The aim of the study was to study any possible potential seasonal variability of anthropogenic radionuclides ($^{137}$Cs, $^{90}$Sr) in chicken eggs from the farm when half of a year the hens are freely feeding on semi natural environment and in the another half of the year they are living in enclosure. Samples were collected monthly from June to December from a free-range farm where hens are confined in late autumn and winter. Albumen, yolk, and shell were separated; albumen and yolk were freeze-dried (~20 g after drying). After homogenization, samples were analyzed by low-background HPGe gamma spectrometry. To reduce detection limits, samples were ashed at 400°C and remeasured for $^{137}$Cs and $^{40}$K. They were then ashed at 600°C and $^{90}$Sr activity was determined radiochemically using $^{85}$Sr as a tracer, with measurements performed by liquid scintillation spectrometry. Since the matrixes were specific, some modification of the radiochemical procedures have to be made.

| Id | Submitter/Presenter | Authors | Accepted type |
|---|---|---|---|
| 6 | Natalia Alegria | Natalia Alegria; Andima Freire; Miguel Ángel Hernández-Ceballos; Jose Miguel Muñoz; Igor Peñalva | ORAL |
| 7 | Natalia Alegria | Natalia Alegria; Adriana Merello; Igor Peñalva; Charles Pinto | POSTER |
| 8 | Sangyun Lee | Sangyun Lee | POSTER |
| 9 | Chndrasekaran Anandanarayanan | Chndrasekaran Anandanarayanan; Ismail M. M. Rahman Rahman | POSTER |
| 10 | Peggy Hofmann | Peggy Hofmann | POSTER |
| 11 | Samuel Odumu Ogana John | Samuel Odumu Ogana John | POSTER |
| 12 | Pilar Blanco Rodríguez | Pilar Blanco Rodríguez; Juan Carlos Lozano; Feliciano Vera Tomé | POSTER |
| 13 | Weihua Zhang | Eric Pellerin; Morten Sickel; Kurt Ungar; Jing Yi; weihua zhang | ORAL |
| 14 | Michaela Achatz | Michaela Achatz | POSTER |
| 15 | Jacques Bezuidenhout | Jacques Bezuidenhout | POSTER |
| 16 | Jeremy Pomare Douglas | Jeremy Pomare Douglas | POSTER |
| 17 | Myung Ho Lee | Myung Ho Lee | POSTER |
| 18 | Abimbola Odudu | Moromoke Adelayi; Abimbola Odudu; Oluwakemi Oyebanjo | POSTER |
| 19 | Elisa Gordo Puertas | Elisa Gordo Puertas; Esperanza Liger; Esperanza Macarena Navarro; Javier Rodríguez | POSTER |
| 20 | Magdalena Gembal | Magdalena Gembal; Paweł Czerski; Małgorzata Warenik-Bany | POSTER |
| 21 | Paweł Czerski | Paweł Czerski; Magdalena Gembal; Małgorzata Warenik-Bany | POSTER |
| 22 | Yuichiro Kumamoto | Yuichiro Kumamoto | ORAL |
| 23 | Amin Shahrokhi | Amin Shahrokhi | POSTER |
| 24 | Yutaka TATEDA | Yutaka TATEDA | POSTER |
| 25 | Andrew Maddison | Amna Al Maazami; Andrew Maddison | ORAL |
| 26 | Seung-Tae Lee | Seung-Tae Lee; Yang-Ki Cho; Kyeong Ok Kim; | POSTER |

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|---|---|---|---|
| | | Seongbong Seo | |
| 28 | Vandana Pulhani | Vandana Pulhani | ORAL |
| 29 | Thennaarassan Natarajan | Thennaarassan Natarajan | ORAL |
| 30 | Martin Martschini | Martin Martschini; Silke Merchel; Karin Hain; Laura Frost; Andreas Gärtner; Oscar Marchhart; Peter Steier; Alexander Wieser; Stella Winkler; Robin Golser | ORAL |
| 31 | Mauritius Hiller | Mauritius Hiller; Natalia Semioschkina; Gabriele Voigt | ORAL |
| 32 | Marina Konstantinova | Marina Konstantinova; Laima Kazakevičiūtė-Jakučiūnienė; Andrius Puzas; Zita Žukauskaitė; Nikolaj Tarasiuk; Šarūnas Buivydas; Evaldas Maceika | POSTER |
| 33 | Marc Caffee | Marc Caffee | ORAL |
| 34 | Dimitrios C. Xarchoulakos | Dimitrios C. Xarchoulakos | ORAL |
| 35 | JALAL SHARIB | JALAL SHARIB | ORAL |
| 36 | JALAL SHARIB | JALAL SHARIB | POSTER |
| 37 | Airi Mori | Airi Mori | ORAL |
| 38 | JALAL SHARIB | JALAL SHARIB | POSTER |
| 39 | Hideki Tsuji | Hideki Tsuji | POSTER |
| 40 | Djamel Taieb Errahmani | Djamel Taieb Errahmani | ORAL |
| 41 | Djamel Taieb Errahmani | Djamel Taieb Errahmani | POSTER |
| 42 | Francisco Pinero Garcia | Eva Forssell-Aronsson; Mats Isakssson; Timmy Nordqvist; Francisco Pinero Garcia; Rimon Thomas | ORAL |
| 43 | Francisco Pinero Garcia | Francisco Pinero Garcia; Emma Sanderson | POSTER |
| 44 | Carmel Mothersill | Carmel Mothersill | ORAL |
| 45 | Carmel Mothersill | Colin Seymour | ORAL |
| 46 | Matthew Isinkaye | Paulinah Oyindamola Fasanmi; Matthew Omoniyi Isinkaye; Muyiwa Michael Orosun | ORAL |
| 47 | Hyunmi LEE | Hyunmi LEE; Jaeeun LEE | POSTER |

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|---|---|---|---|
| 49 | Daniel Lienhard | Jérémy Beuret; Pierre Beuret; Sybille Estier; Daniel Lienhard; Matthias Müller; Philipp Steinmann | ORAL |
| 50 | Lee Jaeeun | Lee Jaeeun | POSTER |
| 51 | Lee Jaeeun | Lee Jaeeun | POSTER |
| 52 | Sheldon Landsberger | Sheldon Landsberger | POSTER |
| 53 | Jacques BEZUIDENHOUT | Jacques BEZUIDENHOUT | ORAL |
| 54 | Alua Kabdyrakova | Assan Aidarkhanov; Yuliya Baklanova; Erlan Batyrbekov; Alua Kabdyrakova; Assiya Kunduzbayeva; Nataliya Larionova; Sergey Lukashenko; Ayan Mendubayev; Anna Toporova; Vladimir Vityuk | POSTER |
| 55 | hanna kim | Hanna Kim; Kyeong Ok Kim | POSTER |
| 56 | Hikaru Miura | Hikaru Miura | ORAL |
| 57 | Konstantina Kehagia | Konstantina Kehagia | POSTER |
| 58 | Henry Moll | Henry Moll | ORAL |
| 59 | Raúl Eduardo Linares Jiménez | Raúl Eduardo Linares Jiménez | ORAL |
| 60 | Caroline Licour | Caroline Licour | ORAL |
| 61 | Yutaka TATEDA | Yutaka TATEDA | ORAL |
| 62 | Soichiro Suzuki | Soichiro Suzuki | ORAL |
| 63 | Soichiro Suzuki | Soichiro Suzuki | POSTER |
| 64 | Katsumi Hirose | Katsumi Hirose | ORAL |
| 65 | Katsumi Hirose | Katsumi Hirose | ORAL |
| 66 | Philipp Steinmann | Sybille Estier; Daniel Lienhard; Philipp Steinmann | ORAL |
| 67 | Takaki Tsubono | YAYOI INOMATA; Kazuhiro Misumi; Takaki Tsubono; Daisuke Tsumune | POSTER |
| 68 | Junko Takahashi | Junko Takahashi | ORAL |
| 69 | Satvir Singh | Dr. Satvir Singh; B S Bajwa | POSTER |
| 70 | Kerneese Ramjarrie | Kerneese Ramjarrie | POSTER |
| 71 | Guillaume Pedehontaa-Hiaa | Guillaume Pedehontaa-Hiaa | ORAL |

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| 72 | Olivier MASSON | Olivier MASSON | ORAL |
| 73 | YAYOI INOMATA | YAYOI INOMATA | ORAL |
| 74 | Sanghan LEE | Sanghan LEE; M. J. Lee; Y. Jung | ORAL |
| 75 | Sanghan LEE | Sanghan LEE; M. J. Lee; Y. Jung; D. J. Kim; M. S. Choi | ORAL |
| 76 | Jennyvi Ramirez | Jennyvi Ramirez | POSTER |
| 77 | Joanna Najman | Joanna Najman; Katarzyna Szarłowicz; Filip Jędrzejek; Szymon Kwaciszewski | POSTER |
| 78 | Terezia Eckertova | Terezia Eckertova | POSTER |
| 79 | Alžbeta Brandýsová | Alžbeta Brandýsová; Martin Bulko; Terézia Eckertová; Monika Müllerová; Mohammed Alem Sultani | POSTER |
| 80 | EROL SARI | EROL SARI; Tuğçe Nagihan Arslan Kaya; Zeynep Çetin; Narin Sezer; Murat Gül; Yusuf Can Gerçek | ORAL |
| 81 | Hannah Keßler | Hannah Keßler | POSTER |
| 82 | Ali Hosseini | Ali Hosseini | ORAL |
| 83 | Inna Iarmosh | Inna Iarmosh | ORAL |
| 84 | RAFAEL Garcia-Tenorio | Cristina Bañobre; Laura Fornaro; Rafael Garcia-Tenorio | POSTER |
| 85 | Franck Dal Molin | Franck Dal Molin | ORAL |
| 86 | Angel Bautista VII | Angel Bautista VII; Mary Margareth Bauyon; Anne Drew Carrillo; Angela De Guzman; Edwin Dumalagan, Jr.; Mary Rose Gabuyo; Caroline Marie Jaraula; Haruka Kusuno; Sophia Jobien Limlingan; Remjohn Aron Magtaas; Hiroyuki Matsuzaki; Jeffrey Munar; Rachelle Clien Reyes; Fernando Siringan; Miwako Toya; Jeff Darren Valdez | ORAL |
| 87 | Jan Mihalik | Jan Mihalik | ORAL |
| 88 | Julia Maetzkow | Frank Bok; Julia Maetzkow; Susanne Sachs; Robin Steudtner; Thorsten Stumpf | ORAL |
| 89 | Muyiwa OROSUN | Muyiwa Michael Orosun | ORAL |
| 90 | Christelle Antonelli | Christelle Antonelli; Béatrice Boulet; Laurent Pourcelot | ORAL |
| 91 | Ana Noguera Rocha | Ana Noguera Rocha; Rodolfo Reboulaz; Heinkel Bentos Pereira; Laura Fornaro | POSTER |

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| 92 | Sara Taha Sayed Sakr | Sara Taha Sayed Sakr | POSTER |
| 93 | Daisuke Tsumune | Kato Hiroaki; Abe Hiroshi; Kazuhiro Misumi; Yuichi Onda; Okamura Tomomi; Takaki Tsubono; Daisuke Tsumune | POSTER |
| 94 | Irka Hajdas | Irka Hajdas | ORAL |
| 95 | Paul Grzegorczyk | Paul Grzegorczyk | ORAL |
| 96 | Seongbong Seo | Seongbong Seo; Seung-Tae Lee; Igor Brovchenko; Kyeong Ok Kim; Young-Gyu Park | ORAL |
| 97 | Motoki Terashima | Motoki Terashima | POSTER |
| 98 | Kotaro Saito | Kotaro Saito | ORAL |
| 99 | Vasyl Yoschenko | Vasyl Yoschenko | ORAL |
| 100 | Yumiko Ishii | Yumiko Ishii | POSTER |
| 101 | hyemi cha | hyemi cha; Jaehyeon Seo | POSTER |
| 102 | Yoshimura Kazuya | Yoshimura Kazuya | POSTER |
| 103 | Shizuho Miki | Shizuho Miki | ORAL |
| 104 | Alexandra Ioannidou | Konstantinos Eleftheriadis; Eleftheria IOANNIDOU; Alexandra Ioannidou; Manousos Ioannis Manousakas; Jussi Paatero; Stefanos Papagiannis; Mika Vestenius | ORAL |
| 105 | Sanghan LEE | Cheol Su Kim | POSTER |
| 106 | Shigeto Fujimura | Shigeto Fujimura | ORAL |
| 107 | Klaudia Lanczewska | Klaudia Lanczewska | POSTER |
| 108 | YOSHIKAZU KIKAWADA | YOSHIKAZU KIKAWADA | ORAL |
| 109 | Michal Fejgl | Michal Fejgl | ORAL |
| 110 | Yihong Xu | Yihong Xu | ORAL |
| 111 | Olivier Radakovitch | Olivier Radakovitch | ORAL |
| 112 | Gabriele Wallner | Gabriele Wallner; P. Rohrbach; L.J. Krammer; A. Wiederin; P. Steier; K. Hain | ORAL |
| 113 | Anita Csordás | Anita Csordás; Tibor Kovács; Máté Novák; Gergely Tóth; Edit Tóth-Bodrogi; Anna Tóth-Merényi | ORAL |
| 114 | Anita Csordás | Anita Csordás; Tibor Kovács; Edit Tóth-Bodrogi; Dániel Vincze | POSTER |

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| 115 | José Luis García León | José Luis García León; Manuel García León; Guillermo Manjón Collado | ORAL |
| 116 | Adam Kimak | Adam Kimak | POSTER |
| 117 | RAFAEL Garcia-Tenorio | Jose Galván; RAFAEL Garcia-Tenorio; Ole Christian Lind; Ignacio Vioque | ORAL |
| 118 | Yoko Shimada | Yoko Shimada | ORAL |
| 119 | Agata Oszczak-Nowińska | Agata Oszczak-Nowińska | POSTER |
| 120 | Rikus le Roux | Rikus le Roux | ORAL |
| 121 | Yuichi Onda | Yuichi Onda | ORAL |
| 122 | Farkas-Áron Bálint | Farkas-Áron Bálint | ORAL |
| 123 | Daisuke Tsumune | Frank Bryan; Katsumi Hirose; YAYOI INOMATA; Keith Lindsay; Kazuhiro Misumi; Takaki Tsubono; Daisuke Tsumune | ORAL |
| 124 | Katarzyna Szarłowicz | Katarzyna Szarłowicz | POSTER |
| 125 | Fern Rose Peregrino | Fern Rose Peregrino | POSTER |
| 127 | Jakub Buda | Jakub Buda | ORAL |
| 128 | Francisco Javier Guillén Gerada | Francisco Javier Guillén Gerada; JOSE LUIS FIGUEREDO; ALEJANDRO SALAS; ANA MARIA GATA-JARAMILLO | POSTER |
| 129 | Francisco Javier Guillén Gerada | Francisco Javier Guillén Gerada; LAURA CABEZAS-VINAGRE; ALEJANDRO SALAS | POSTER |
| 130 | Americus Perez | Americus Perez | ORAL |
| 131 | Konstantinos Kanoutos | Konstantinos Kanoutos; Nick Petropoulos; Marios Anagnostakis | ORAL |
| 132 | Liangliang Yin | Yanqin Ji; Liangliang Yin | POSTER |
| 133 | Konstantinos Kanoutos | Konstantina-Maria Triantafyllou; Konstantinos Kanoutos; Marios Anagnostakis | POSTER |
| 134 | István Papp | Szabolcs Osváth; István Papp; Nóra Vajda | ORAL |
| 135 | Ruslan Cusnir | Ruslan Cusnir | ORAL |
| 137 | Claudia Landstetter | Krystle Elbers; Rainer Kadan; Claudia Landstetter; Dietmar Roth | ORAL |
| 138 | Daniel Janecki | Daniel Janecki | ORAL |
| 139 | Maksym Gusyev | Maksym Gusyev | POSTER |

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| 140 | Botvinnik Palattao | Botvinnik Palattao | POSTER |
| 142 | Sergiy Dubchak | Sergiy Dubchak | ORAL |
| 143 | Stella Winkler | The MetroPOEM Collaboration; Stella Winkler | POSTER |
| 144 | Katarzyna Szarłowicz | Filip Jędrzejek | ORAL |
| 145 | Dagmara Struminska-Parulska | Dagmara Struminska-Parulska | POSTER |
| 146 | Lígia Lopes | Lígia Lopes; Sandra Soares | ORAL |
| 147 | Matic Dokl | Matic Dokl | ORAL |
| 148 | Dorice Seif | Dorice Seif | ORAL |
| 149 | Fern Rose Peregrino | Jessie Samaniego | ORAL |
| 150 | András Kocsonya | András Kocsonya | ORAL |
| 151 | Jixin Qiao | Jixin Qiao | ORAL |
| 152 | Magdalena Długosz-Lisiecka | Magdalena Długosz-Lisiecka | ORAL |
| 153 | Robert-Csaba Begy | Robert-Csaba Begy | ORAL |
| 154 | Mefleh Hamideen | Mefleh Hamideen | POSTER |
| 155 | Mireia Pérez Baeza | Mireia Pérez Baeza | POSTER |
| 156 | MISBAH JAVED | MISBAH JAVED | POSTER |
| 157 | Michele Guida | Michele Guida | POSTER |
| 159 | Alex Tarancón Sanz | Héctor Bagán; Isaac Giménez; Aindara Herranz; Martina Pujols; Alex Tarancón Sanz | ORAL |
| 160 | Jan Helebrant | Jan Helebrant | ORAL |
| 161 | Tomislav Ilievski | Tomislav Ilievski | ORAL |
| 162 | Satvir Singh | B S Bajwa; Dr. Satvir Singh | POSTER |
| 163 | Dagmara Struminska-Parulska | Dagmara Struminska-Parulska | ORAL |
| 164 | Michal Bonczyk | Michal Bonczyk | ORAL |
| 165 | Timothy Jull | Timothy Jull; Fusa Miyake | ORAL |
| 166 | Edyta Łokas | Edyta Łokas | ORAL |
| 167 | Katarzyna Kołtonik | Katarzyna Kołtonik | POSTER |
| 168 | Dariusz Sala | Dariusz Sala | POSTER |

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| 169 | Anna Banel | Anna Banel; Marte Holmstrand | ORAL |
| 171 | Kamil Wojciechowski | Kamil Wojciechowski | ORAL |
| 172 | sohini bose | sohini bose | POSTER |
| 173 | Anna Cwanek | Anna Cwanek; Agnieszka Burakowska; Ewa Nalichowska; Magdalena Długosz-Lisiecka; Marek Kubicki; Tomasz Wawrzyniak; Edyta Łokas; Michał Gryziński | POSTER |
| 174 | Anna Cwanek | Anna Cwanek; Kamil Wojciechowski | POSTER |
| 175 | Ainur Mamyrbayeva | Ainur Mamyrbayeva | POSTER |
| 176 | Pedro Ángel Salazar-Carballo | Pedro Ángel Salazar-Carballo; María Candelaria Martín Luis; María López Pérez; María Martín-González; Xiomara Duarte Rodríguez; Eduardo Pérez González; José Luis Rodríguez Marrero; Iveta Smetanová | POSTER |
| 177 | Miroslav Jeskovsky | Miroslav Ješkovský | ORAL |
| 178 | Dominic Lariviere | Dominic Lariviere | ORAL |
| 179 | GiHoon Hong | GiHoon Hong | ORAL |
| 181 | Xue Zhao | Xiaolin Hou; Xue Zhao; Weijian Zhou | ORAL |
| 182 | Jarosław Wieczorek | Jarosław Wieczorek | ORAL |
| 183 | Boris Bobáľ | Boris Bobáľ | POSTER |
| 184 | Kateřina Pachnerová Brabcová | Kateřina Pachnerová Brabcová | ORAL |
| 185 | Yuliya Zaripova | Yuliya Zaripova | POSTER |
| 186 | Sinikka Virtanen | Sinikka Virtanen | POSTER |
| 187 | Valtteri Suorsa | Valtteri Suorsa | POSTER |
| 188 | Bernardo Salas Mar | Bernardo Salas Mar | ORAL |
| 189 | Elena Prieto | Elena Prieto; Ignasi Reichardt; Marçal Salvadó | ORAL |
| 190 | Jakub Kaizer | Jakub Kaizer | ORAL |
| 191 | Natalya Larionova | Natalya Larionova | POSTER |
| 192 | Pavel Krivitskiy | Pavel Krivitskiy | POSTER |
| 193 | Maoyi Luo | Maoyi Luo; Yang Wu; Ni Yuan; Tong Peng; Zhijie Gu; Pei Zhu | ORAL |
| 194 | Robert Breier | Robert Breier; jozef Masarik | ORAL |

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| 195 | Robert Breier | jozef Masarik; Robert Breier | POSTER |
| 196 | Yanqin Ji | Yanqin Ji | ORAL |
| 197 | Dániel Vincze | Anita Csordás; Tibor Kovács; Gergely Tóth; Edit Tóth-Bodrogi; Dániel Vincze | POSTER |
| 198 | hyemi cha | Younghak Kim; Hyuncheol Kim; Mee Jang; Jaehyeon Seo; Gahyun Kim; hyemi cha | POSTER |
| 199 | Hyehyun Kim | Hyehyun Kim | POSTER |
| 200 | Assiya Kunduzbayeva | Assiya Kunduzbayeva | ORAL |
| 201 | Almira Aidarkhanova | Almira Aidarkhanova | POSTER |
| 202 | Kaisa Vaaramaa | Valtteri Suorsa | POSTER |
| 203 | Zhanna Tleukanova | Zhanna Tleukanova | POSTER |
| 204 | Grzegorz Olszewski | Grzegorz Olszewski; Alexandr Malusek; Mats Eriksson; Håkan Pettersson | POSTER |
| 205 | Ignasi Reichardt | Elena Prieto; Ignasi Reichardt; Marçal Salvadó | ORAL |
| 206 | Otavio Vieira | Otavio Vieira | POSTER |
| 207 | Dmitri Gudkov | Dmitri Gudkov | ORAL |
| 208 | Xiaolin Hou | Xiaolin Hou | ORAL |
| 209 | Katarzyna Szufa | Jerzy Mietelski; Maria A. Olech; Dariusz Sala; Katarzyna Szufa | ORAL |
| 210 | Katarzyna Szufa | Jerzy Mietelski; Maria A. Olech; Katarzyna Szufa | POSTER |
| 211 | Hilde Elise Heldal | Hilde Elise Heldal | ORAL |
| 212 | Tzu-Hao Wang | Tzu-Hao Wang | ORAL |
| 213 | Jakub Kaizer | Jakub Kaizer | POSTER |
| 214 | Paul Blowers | Paul Blowers | POSTER |
| 215 | Concepción Olondo Castro | Asier Gamarra; Margarita Herranz; Raquel Idoeta; Concepción Olondo Castro | ORAL |
| 217 | Saroa Rozas Guinea | Imanol Pérez | ORAL |
| 218 | Zahra Shirani | Sayed Tariq Uzzaman | POSTER |
| 219 | Soroush Majlesi | Soroush Majlesi | POSTER |
| 220 | Elmo Wiikinkoski | Teija Hovirinta | ORAL |

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| 221 | Ivan Sykora | Ivan Sykora | ORAL |
| 222 | Hyuncheol Kim | Hyuncheol Kim | ORAL |
| 224 | Pavel Povinec | Pavel Povinec | POSTER |
| 225 | Ivan Kontuľ | Ivan Kontuľ | POSTER |
| 226 | Ivan Kontuľ | Ivan Kontuľ | ORAL |
| 227 | Pavel Povinec | Pavel Povinec | POSTER |
| 229 | Joseph Lapka | Sheldon Landsberger | ORAL |
| 230 | Renata Kierepko | Renata Kierepko | POSTER |
| 231 | Jerzy Mietelski | Jerzy Mietelski; Karin Hain; Peter Steier | ORAL |
| 232 | Christos Tsabaris | Stylianos Alexakis; Effrosyni Androulakaki; Ioanna Kora; Christos Tsabaris | ORAL |
| 233 | Michał Dorosz | Michał Dorosz; Alicja Suszczyńska; Karolina Wójciuk | POSTER |
| 234 | Michał Dorosz | Michał Dorosz; Karolina Wójciuk | POSTER |
| 235 | Renata Kierepko | Renata Kierepko | POSTER |
| 236 | Tomasz Mróz | Walter Kutschera | ORAL |
| 237 | Mikołaj Wielgat | Mikołaj Wielgat | POSTER |
| 238 | Tomasz Mróz | Magdalena Laskowska | POSTER |
| 239 | Anna Wójcik-Gargula | Jakub Bielecki; Jarosław Błądek; Jan Dankowski; Axel Jardin; Ryszard Kantor; Krzysztof Król; Agnieszka Kulińska; Arkadiusz Kurowski; Dariusz Morawski; Marek Scholz; Grzegorz Tracz; Urszula Wiącek; Anna Wójcik-Gargula | POSTER |
| 240 | Tomasz Mróz | Jacek Biernat; Tomasz Mróz; Michał Silarski; Adriana Wawrzyniak | POSTER |
| 241 | Tomasz Mróz | Spencer Behling; Marc Breidenbach; Felix Diel; Herwig Marschelke | POSTER |
| 242 | Anumaija Leskinen | Tommi Kekki; Anumaija Leskinen | POSTER |
| 243 | Anna Wójcik-Gargula | Vandana Pulhani | POSTER |
| 244 | Sylwia Błażej | Sylwia Błażej | POSTER |
| 245 | Sylwia Błażej | Sylwia Błażej | POSTER |
| 246 | Bogusław Michalik | Bogusław Michalik | ORAL |

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| 252 | Phillip Warwick | Phillip Warwick | ORAL |
| 253 | Javier Guillén | Javier Guillén | POSTER |
| 254 | Sylwia Błażej | Katarzyna Wichucka; Jerzy W. Mietelski; Sylwia Błażej | POSTER |