Book of Abstracts

IX. Terrestrial Radioisotopes in Environment International Conference on Environmental Protection

Mecenatúra

19-22 November 2024
Vonyarcvashegy, Hungary

IX. TERRESTRIAL RADIOISOTOPES IN ENVIRONMENT

International Conference on Environmental Protection

ISBN 978-615-81632-3-1

DOI 10.18428/TREICEP-2024

Published by the Social Organization for Radioecological Cleanliness

József Attila str. 7/A 2/10, H-8200 Veszprém, Hungary

Phone: +36-88-624-922

E-mail: info@rttsz.hu

Homepage: http://rttsz.hu/

Organizers:

University of Pannonia, Department of Radiochemistry and Radioecology

Social Organization for Radioecological Cleanliness

Chair:

Tibor Kovács

Secretaries:

Edit Tóth-Bodrogi, Anita Csordás, Gergő Bátor, Erika Nagy, András Bednár

Edited by:

Edit Tóth-Bodrogi, Anita Csordás

The ideal environmental sample to educate novice students in environmental radioactivity measurements using gamma ray spectroscopy

Sheldon Landsberger, Nicholas Asper

University of Texas at Austin, Nuclear Engineering Teaching Lab, Walker Department of Mechanical Engineering, Austin, Texas, USA, 78712

Proper understanding of environmental radioactivity measurements using gamma ray spectroscopy can often be challenging when trying to achieve high accuracy and high precision results. Phenomena such as gamma-ray self-attenuation and disequilibrium can potentially add to the uncertainty, especially for samples that are large (100-500 grams) and that contain high-Z materials. As well, most environmental measurements need long periods of time for measurements typically between 12-36 hours per sample, depending on sample size and radioactivity concentration levels. For more than one decade we have been involved in radioactivity measurements in the oil and gas exploration sector, primarily in analyzing scale, soil and sludges. Our experience has revealed that scale is an environmental sample that can easily be analyzed for Ra-226 and Ra-228 as well as Pb-210 in a relatively short period of time for only 20 grams of material due to the unusually high concentrations of these radionuclides. All the daughter products can also be readily measured. Because of the higher Z elements such as barium and strontium in high concentrations, gamma ray self-attenuation is of paramount importance to elucidate. And finally, there is a clear major disequilibrium in the U-238 and Th-232 chains. All these radiological and chemical characteristics for scale make this an ideal environmental candidate to quickly teach novice researchers about the challenges in radioactivity measurements.

Weekdays of the closed west Mecsek uranium mine – Reusing opportunities, challenges, future vision

Erika Kocsis[1], Éva Bárányné Frucht[1], Szabolcs Tóth[1,2]

[1]Mining Property Utilization Ltd.

[2]Eötvös Loránd University, Faculty of Natural Sciences, Institute of Physics and Astronomy, Department of Atomic Physics

The main activity of the site located in Kővágószőlős focuses on the final elimination of environmental damage caused by uranium ore mining, as well as the aftercare and reusing of the areas where the former uranium mining happened.

In the western part of the Mecsek mountains, between 1955 and 1999, uranium ore mining and ore processing took place. Throughout the process, and ore mill site, two tailing's ponds, more waste rock piles, and percolation areas were created. During the recultivation process, in compliance with official regulations, the mining areas were closed, and the waste rock piles, tailing ponds, percolation areas, former mining buildings, and watercourses impacted by mining were recultivated. As a result of the recultivation efforts, by the end of 2008, the risk of immediate environmental harm was eliminated, and in compliance with the limits outlined in the Environmental Protection Permit for the operation is ensured.

In the former uranium mining and ore processing area, due to environmental protection reasons, we operate an extensive monitoring system in the affected area in order to carry out "long-term" environmental protection activities.

However, in the area of uranium ore mining and ore processing in the western part of the Mecsek mountains, nowadays takes place an exciting and new "life", which causes us many new challenges. There are various possibilities for the use of already recultivated areas for other purposes, such as a solar park, pasture, model airplane airport…etc. However, there are also some kinds of land utilization concepts that bring us some more serious challenges, one of these concepts the utilization of a reclaimed area for industrial purposes.

An overview of industrial enhanced radionuclides dispersion over mining area in Ghana

Lordford Tettey-Larbi, Thomas Onumah, Esther Osei Akuo-ko, Serwaa Adjei-Kyereme, Edit Tóth-Bodrogi, Tibor Kovács, Amin Shahrokhi

Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

This overview examines the dispersion of enhanced radionuclides in mining areas of Ghana, focusing on the radiological landscape and public health implications associated with naturally occurring radioactive materials (NORMs). Recent findings of our five comprehensive radiological surveys in Ghana highlight concerning concentrations of uranium (U-238), thorium (Th-232), and potassium (K-40) in soils, with groundwater sources showing elevated levels of Ra-228 that exceed World Health Organization guidelines. These levels pose significant health risks for local communities relying on these water resources, particularly in regions impacted by artisanal mining. While radiological hazard indices in mining facilities generally remain below global averages, the potential for public exposure underscores the need for continuous monitoring. Additionally, elevated radon emissions in certain areas suggest that the use of local soils as building materials could further endanger public health. Overall, the findings emphasize the urgent need for comprehensive risk assessments and regulatory measures to mitigate the adverse effects of radionuclide dispersion in Ghana's mining regions.

Hiking circumstances near a closed uranium mine in Hungary from radiological point of view

Gergely Tóth, Máté Novák, Edit Tóth-Bodrogi, Dániel Vincze, Anita Csordás, Tibor Kovács

Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

In Southern Hungary, the Mecsek mountain used to have active uranium mining from 1955 to 1997. However, decades later, there is still ongoing recultivation work in the area, to minimize environmental risk and fully restore the active site. Close to the mining sites, there are several popular hiking trails, therefore with the current study, our goal was to evaluate a radiological health assessment of two popular hiking routes in the region.

We collected different types of environmental samples along the routes. Spring waters were sampled, and the activity concentrations of Po-210 were measured by alpha spectrometry with a PIPS detector. Soil samples were also collected, and we determined the activity concentration of Th-232, Ra-226, K-40 and Cs-137 by gamma-spectrometry. Besides these, we also carried out soil radon measurements, to determine the massic radon exhalation rate of the soil samples by closed accumulation chamber method.

Most of the gamma-spectrometry results for the different isotopes were above the world average with Ra-226 activity concentrations ranging from 51.45 Bq/m^3 to 101.60 Bq/m^3, Th-232 from 80.73 Bq/m^3 to 145.03 Bq/m^3 and K-40 from 344.86 Bq/m^3 to 625.7 Bq/m^3. The exhalation results for the radon were between 5 mBq/kgh to 64 mBq/kgh. The Po-210 activity concentrations in the water samples were ranging from 1.17 Bq/kg to 6.17 Bq/kg.

Based on the results obtained, as part of the health assessment, we made an effective dose calculation by the consumption of spring waters. The calculated results were very low ranging from 10 to 54 μSv/year. The overall results suggest that no significant health risk can be associated with the mining sites, the hiking trails are safe and healthy to use.

Lead-210 application in the reconstruction of peat bog carbon dynamics

Róbert-Csaba Begy[1,2], Jovana Nikolov[6], Piotr Szwarczewski[5], Jonas Mazeika[7], Sapassimir Tonkov[4], Agnes Ruskal[1,3], Anca Avram[1,2]

[1]*Faculty of Environmental Science and Engineering, "Babeş-Bolyai" University, Cluj-Napoca, Romania*

[2]*Interdisciplinary Research Institute on Bio-Nano-Science, "Babeş-Bolyai" University, Cluj-Napoca, Romania*

[3]*Department of Geology, "Babes-Bolyai" University, Cluj-Napoca, 400084, Romania*

[4]*Sofia University "St. Kliment Ohridski" Department of Botany, Laboratory of Palynology, Sofia-1164, Bulgaria*

[5]*Faculty of Geography and Regional studies, Department of Geomorphology, University of Warsaw, Poland*

[6]*Faculty of Science, Department of Physics, University of Novi Sad, Serbia*

[7]*Nature Research Centre, Vilnius, Lithuania*

The lead-210 dating method is a widely recognized technique in the reconstruction of high-resolution age-depth models for lacustrine environments. Although it is extensively applied in lake sediments, peat bogs share similar stratigraphical features, thus rendering possible the incorporation and burial of the atmospheric lead in the ecosystem. The growing scientific focus on peat bogs arises from their pivotal role in the global carbon cycle. These long-term carbon stocks formed as a result of the C uptake via plant photosynthesis, which has surpassed the carbon emissions associated with degradation and evapotranspiration in the ecosystem. The anthropically accelerated recent climate changes threaten the equilibrium of these carbon-exchange mechanisms, with considerable potential implications for the stability of peat reservoirs, converting them into carbon sources. The atmospheric release of the stocked carbon as CO_2 is mediated by the establishment of oxidative conditions in peat bogs, themselves induced by the water table level in the ecosystem. The outcome of such alterations would result in positive feedback to climate change, potentiating the radiative forcing and CO_2 levels in the atmosphere. At present, the degradation of peatlands through anthropic intervention is responsible for 5-10% of global annual anthropogenic carbon dioxide emissions (Loisel and Gallego-Sala, 2022). This effect, superimposed on a low potential resilience to climate change, can have disastrous outcomes.

The present work aims to investigate the carbon dynamics of temperate peat bogs from Central and Southeast Europe to establish the balance between carbon uptake and release and to highlight the variations and trends followed in the last 150 years. This time interval is of particular interest, as it encompasses the most intense anthropic development and rapidly shifting climate of the recent period.

Therefore, several peat bogs from Romania, Poland, Bulgaria, Serbia, Bosnia-Hercegovina and Lithuania have been sampled. The lead-210 specific activities were determined by nuclear spectrometric techniques (alpha, beta, gamma) and the age-depth models were constructed using the Constant Rate of Supply model. The organic, inorganic and carbon fractions have been determined by combustion via the loss on ignition method, serving as a basis for the calculation of the recent rates of apparent carbon accumulation (RERCA). Furthermore, a novel methodology has been developed for the estimation of carbon emissions, using humification-derived degradation data obtained via the colorimetric method. Ultimately, the carbon balance was established for each peat bog, using the above results.

The results indicated an upward trend of the RERCA values, suggesting increased carbon uptake, strongly associated with the expansion of the vegetation growth season with up to 30 days in the last century. The values varied between sites, from an average of 6 ± 2 C g/m^2/year (Bulgaria), to 230 ± 260 C g/m^2/year (Serbia). The stocked carbon values for the last 150 years varied between 20.43 to C 7.99 kg/m^2, while the carbon loss was estimated in the 0.33 – 2.85 C kg/m^2 (1.3 - 11.4 kg/m^2 CO_2).

Reference:

Loisel, J., Gallego-Sala, A. Ecological resilience of restored peatlands to climate change. Commun Earth Environ 3, 208 (2022)

Comparison of neutron activation analysis and passive counting for environmental radioactivity measurements

Nicholas Kaitschuck, John Peter Bekker, Derek Haas, Sheldon Landsberger

University of Texas at Austin, Nuclear Engineering Teaching Lab, Walker Department of Mechanical Engineering, Austin, Texas, USA, 78712

Neutron activation analysis is not usually known to be used for environmental radioactivity measurements as compared to low-level passive gamma-ray counting. As part of the new project to design and build a molten salt reactor, local background samples were taken as part of an environmental impact statement. The benefits and drawbacks of each method are explored for soil samples which are in secular equilibrium, including gamma-ray self-attenuation, Compton suppression, sample size and counting time.

Atmospheric remote sensing for environmental sustainability: How radiation sensing can help achieve sustainability during extreme weather events

Amin Shahrokhi, Lordford Tettey-Larbi, Serwaa Adjei-Kyereme, Thomas Onumah, Esther Osei Akuo-ko, Edit Tóth-Bodrogi, Tibor Kovács

Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

Climate change represents one of the most pressing challenges of the 21st century, affecting global ecosystems, human health, and socio-economic stability. As global temperatures continue to rise due to increased greenhouse gas emissions, there is a growing need for innovative technologies to monitor and mitigate its effects. One such technology is radiation sensing, which plays a crucial role in understanding and addressing climate change. Radiation sensors are pivotal in monitoring atmospheric changes, measuring greenhouse gas concentrations, and assessing the impact of solar radiation on the Earth's surface. Remote sensing involves the use of satellites and aircraft to collect data on the Earth's surface and atmosphere. This technology uses different types of radiation, including optical, thermal, and microwave, to measure various environmental parameters. For instance, satellite remote sensing can provide detailed information on temperature, humidity, vegetation health, and soil moisture, which are vital for understanding and mitigating the effects of extreme weather events. While remote radiation sensing could potentially be used for atmospheric events monitoring, there is a possibility to use their potential abilities as an Environmental Sustainability During Extreme Weather Events. The remote sensing radiation technology has the high potential ability to be contributed to environmental sustainability during catastrophic events, not only naturally disaster, but also the man cause disasters, by (i) Assessing Damage and Recovery: Remote sensing can quickly assess the extent of damage caused by extreme weather events and monitor the recovery of affected areas, facilitating targeted and effective response strategies, (ii) Water Resource Management: During droughts and floods, remote sensing provides crucial data on water availability and distribution, supporting sustainable water resource management, (iii) Agricultural Monitoring: Extreme weather can severely impact agriculture. Remote sensing helps monitor crop health and soil moisture, allowing for better management of agricultural resources and ensuring food security. Remote sensing radiation technology is indispensable for enhancing climate sustainability and environmental resilience during extreme weather events. By providing comprehensive and timely data, it supports effective decision-making and promotes sustainable practices across various sectors. As the technology continues to evolve, it will play an increasingly vital role in addressing the challenges posed by climate change and in achieving global environmental sustainability.

Atmospheric radon: Reliability and its potential as an earthquake precursor

Amin Shahrokhi, Esther Osei Akuo-ko, Lordford Tettey-Larbi, Tuvshinsaikhan Ganbaatar, Serwaa Adjei-Kyereme, Thomas Onumah, Edit Tóth-Bodrogi, Tibor Kovács

Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

Atmospheric radon is a naturally occurring radioactive gas released from the Earth's crust, often noted for its fluctuations preceding seismic activities. Scientists have explored its potential as a precursor to earthquakes, as elevated radon levels may indicate increased stress or fracturing in rocks beneath the Earth's surface. However, the reliability of radon as an earthquake predictor is still under debate due to various challenges. There are several studies confirming the Radon as an earthquake precursor with the advantages of (i) the early warning indicator: Radon emissions can increase with tectonic stress, suggesting that monitoring these levels could provide a natural early-warning system for impending earthquakes. (ii) low-cost detection: Radon detection equipment is relatively affordable and can be deployed over wide areas, making it a feasible method for monitoring seismic zones and (iii) supplementary to seismic tools: Radon measurements can complement seismic tools, offering a broader picture of geophysical changes in regions prone to earthquakes. On the contrary, there are several confirmed limitations and challenges, such as (i) inconsistent predictive value: Radon levels can fluctuate due to factors unrelated to tectonic activity, such as weather, soil conditions, and seasonal changes. This inconsistency undermines its reliability as a sole predictor. (ii) difficult data interpretation: Distinguishing between background radon variations and seismic-related changes requires complex data processing and cross-referencing with other seismic indicators. (iii) false alarms and missed events: Because radon anomalies do not always precede earthquakes, there is a risk of false alarms or missed events, which could undermine public trust and the effectiveness of radon-based monitoring systems. While atmospheric radon shows promise as an earthquake precursor, it remains an uncertain and supplementary tool. Its role is best utilized in conjunction with other predictive technologies to enhance accuracy and reliability. Future research, better predictive models, and combined data analysis could improve radon's utility in earthquake preparedness, though challenges in consistency and interpretation still limit its standalone applicability.

The difficulties of radionuclide analysis using mass spectrometry methods

Norbert Kávási[1], Tatsuo Aono[1], Sarata K. Sahoo[2]

[1]Radioecology Unit, Fukushima Institute for Research, Education and Innovation, Fukushima, Japan

[2]National Institutes for Quantum Sciences and Technology, Chiba 263-8555, Japan

In recent years, there have been numerous reports of successful determinations of various radionuclides (such as Sr-90, Cs-137, Ra-226, Am-241, U isotopes, Pu isotopes, etc.) utilizing mass spectrometry instruments. For this purpose, inductively coupled plasma mass spectrometry (ICP-MS), including triple quadrupole, tandem, and high-resolution techniques, as well as thermal ionization mass spectrometry (TIMS) and multi-collector inductively coupled plasma mass spectrometry (MC-ICP MS) with various ion counters capable of detecting low ion currents below 10^{-13} A, are primarily used.

Mass spectrometry offers several key benefits compared to radiometric approaches, including reduced analysis times, increased sample throughput, and decreased sample input requirements. However, employing mass spectrometry instruments for the analysis of low-level radionuclide concentration in environmental samples can pose difficulties.

The primary issue is the occurrence of isobaric interference, which refers to the presence of isotopes from various elements that have the same mass. Examples include Zr-90 being interfere for Sr-90, U-238 for Pu-238, Am-241 for Pu-241, Ba-137 for Cs-137, and so on.

The second issue is the occurrence of peak tailing and fronting, which is caused by ion beam scattering and is observed as a peak shape asymmetry on the mass spectra. This tail appears on either the upper or lower mass side of an abundant isotope, such as Sr-88 for Sr-90, U-238 for U-235, Cs-133 for Cs-135, and so on.

The third issue is that certified standards of radionuclides are specifically created for radiometric determination, not for mass spectrometry. However, all standards consist of a combination of various isotopes, and the ratios of these isotopes are not certified. For example, Sr-90 standards contain Sr-88, Am-241 standards contain Am-243, Ra-228 standards contain Ra-226, and so on.

Rapid high accuracy and precision analysis of uranium content in Texas Ores using gamma-ray spectrometry

Christopher Martin, Sheldon Landsberger

University of Texas at Austin, Nuclear Engineering Teaching Lab, Walker Department of Mechanical Engineering, Austin, Texas, USA, 78712

The nuclear fuel cycle relies entirely on the accurate and reliable quantitation of uranium content in naturally occurring radioactive material (NORM) or uranium mines. Typical analytical methods include inductively plasma atomic emission spectrometry (ICP-AES) or mass spectrometry (ICP-MS), x-ray fluorescence, atomic absorption, gamma-ray spectrometry, etc. We present two rapid non-destructive methodology in gamma-ray spectrometry to determine uranium concentrations in ore based on the decay of U-238 to Pa-234m using the 1000.1 keV gamma- ray and the decay of U-235 to Th-231 using the143.7 and 163.3 gamma-rays using passive counting. Both decays belong to the first daughter products. Because of the high density of uranium at 19.1 g/cm^3 an Eu-152 point-source was used to determine the attenuation properties of the ore sample at varying gamma ray energies. Through the comparator method, we show a quantitative, non-destructive method for quantifying the total uranium content in a sample of NORM in the range of 8.207 wt.% in NORM with 2 % error within 2 hours utilizing only 1.4 grams of material after accounting for self-attenuation

Novel method for Po-210 determination in environmental samples

Áron Bálint-Farkas[1], Tibor Kovács[3], Robert-Csaba Begy[1,2]

[1]*Faculty of Environmental Science and Engineering, "Babeş-Bolyai" University, Cluj-Napoca, Romania*

[2]*Interdisciplinary Research Institute on Bio-Nano-Science, "Babeş-Bolyai" University, Cluj-Napoca, Romania*

[3]*Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary*

The Pb-210 ($t_{1/2}$=22.2y, beta emitter) dating method is of paramount importance in environmental and geological sciences. It allows for precise dating of environmental samples such as soils and sediments, covering the past two centuries. Although both gamma and beta spectrometric techniques are widely used for measuring Pb-210 specific activity in the literature, they have several drawbacks, such as process complexity, higher error margins, and challenges in measuring beta radiation. Gamma spectrometry, while non-destructive and requiring minimal sample preparation, has a high detection limit due to the small gamma yield of lead (4.25%). On the other hand, the alpha spectrometry can be use after the Pb-210 reach the secular equilibrium with his daughter radionuclides Po-210. Despite of this method also requires comprehensive radiochemical preparations Po-210 measurements provides significantly lower detection limits and is suitable for low activity samples.

The aim of this work is to develop a new methodology for Po-210 determination using liquid scintillation counting (LSC, beta spectrometry) to counterbalance the shortcomings of the mentioned techniques.

The proposed method, similar in procedure to Po-210 ($t_{1/2}$=138 days, alpha emitter) disk deposition, involves ion implantation between Cu wires and Po-210 in solution. This method provides a more suitable geometry for the LSC spectrometer (Packard Tri-Carb 2300TR liquid scintillation counter) and ensures high chemical yield and low detection limits for low activity, while requiring minimal sample preparation.

The first experiment was conducted using six different diameters of Cu wires: 1 mm, 1.25 mm, 1.5 mm, 2 mm, 2.5 mm, and 3 mm, in a spontaneous deposition of a 112 mBq standard solution of Pb-210/Bi-210/Po-210 in secular equilibrium. The results indicate that the highest deposition yield (88.33%) was achieved with the 3 mm Cu wires, with a repeatability of 5.06% (two sigma standard deviation).

For practical use, a sample digestion procedure was developed for peat moss samples originating from Crveni Potok in Tara National Park, Serbia. The proposed digestion process has an average efficiency of 78.28% with a standard deviation of 7.09%. The overall uncertainty of the proposed methodology remains below 15%, making it suitable for environmental, radiological, and geological measurements.

Naturally occurring radioactive isotopes in groundwater in the northwestern part of Hungary

Reyana Dawn Urbiztondo Garcia[1], Katalin Hegedűs-Csondor[1], Petra Baják[1], Viktor Jobbágy[2], Bálint Izsák[3], Ákos Horváth[4], Viktória Kohuth-Ötvös[5], Márta Vargha[3], Mikael Hult[2], Anita Erőss[1]*

[1]Eötvös Loránd University, Institute of Geography and Earth Sciences, Department of Geology, József and Erzsébet Tóth Endowed Hydrogeology Chair, Budapest, Hungary

[2]European Commission, Joint Research Centre (JRC), Geel, Belgium

[3]Public Health Directorate, National Public Health Institute, Budapest, Hungary

[4]Eötvös Loránd University, Institute of Physics and Astronomy, Department of Atomic Physics, Budapest, Hungary

[5]Sopron Waterworks Ltd., Sopron, Hungary

**Current affiliation: Social Organization for Radioecological Cleanliness, Veszprém, Hungary*

Groundwater accounts to 92% of drinking water sources in Hungary. Through water-rock interactions, different elements can be enriched in groundwater including radioactive elements. This study aimed to identify the cause of gross alpha activity exceeding the parametric value of 0.1 Bq/l in the northwestern part of Hungary using a regional groundwater flow system approach. Geochemical sampling for hydrochemical analyses of springs, drinking water and thermal wells was performed in 2021 and 2024. In-situ water quality parameters were recorded on the field. The concentrations of major ions and trace elements, oxygen and hydrogen isotopic ratios and activity concentration of radioactive isotopes (uranium, radium, radon) were determined by laboratory measurements. Local groundwater flow conditions were characterized by pressure-elevation profiles. In drinking water samples total U activity concentration up to 540 mBq/L was measured that can be connected to local geogenic sources related to the metamorphic outcrop of Sopron Mountains and to the Pannonian sediments in its surroundings. The radionuclide-specific measurements explained that the elevated gross alpha activity identified in several drinking water wells is a result of dissolved uranium favored by the prevailing oxidizing environment of local flow systems and/or recharge areas. Low activity concentrations of Ra-226 and Rn-222 were measured in all samples except sample S12-BK25 where 301 mBq/L of Ra-226 and 219 Bq/L of Rn-222 activity concentration was found. The presence of radium could be attributed to regional flow systems; however, the high concentration of radon activity cannot be accounted for solely by the decay of radium calling for further detailed investigation. The results also confirm that groundwater flow system approach is a powerful tool in understanding the cause of natural radioactivity in groundwater-derived drinking water. The study was supported by the ÚNKP-23-5 New National Excellence Program of the Ministry for Culture and Innovation from the source of the National Research, Development and Innovation Fund. This research was also funded by the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014 project). Furthermore, some radioactivity measurements were supported by the open-access scheme of the European Commission's Joint Research Centre (JRC) (Research Infrastructure Access Agreement No. 36227-1).

Drone-mounted radiology module development concept

Izabella Kakuja, József Csurgai

University of Public Service Ludovika

A wide range of sensor architectures for fixed- or rotary-wing drones, with different purposes and uses, has been or are being implemented.

We, in a presentation, would like to give you a taste of the development of the airborne sensor module for drone-mounted airborne detection to be developed in the framework of the present TKP2021-NVA-16 call.

In this presentation, we will briefly review the operational criteria for the application, the background of the development of the sensor module, the R&D metrology basics, the radio sensor and general-purpose sensor system, and the measurement data of the first tests.

Extremely short and long period variations of radon concentration in underground cavities

István Csige

HUN-REN Institute for Nuclear Research, ATOMKI, Debrecen, Hungary

Although the generation rate of radon in rocks can be considered essentially constant over time, the activity concentration of radon gas in our natural and built environment shows significant temporal variations. On the one hand, the fraction that escapes into the pore space of the rocks changes, and on the other hand, through various advection and diffusion transport processes, a high degree of mixing occurs between the different radon-containing media. The exact detection of very fast changes (on the order of minutes) is a measurement technical challenge. On the other hand, the detection of long-term changes (on a scale of decades) requires persistence. Here, we present some examples of these extremely short and long period variations of radon concentration based on our measurement results of the past decades.

Outdoor radon and its progeny assessment for use in atmospheric research

Mohammad Alem Sultani, Martin Bulko, Markus Helej, Ivan Sýkora, Monika Müllerová, Jozef Masarik*

Department of Nuclear Physics and Biophysics, Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Mlynská Dolina, 842 48 Bratislava, Slovakia

**Corresponding author contact: sultani1@uniba.sk +421944820104*

The investigation of outdoor radon and its progeny is critical due to their significant health risks and their potential role in atmospheric research. This study conducted simultaneous measurements of outdoor radon and its progeny (Po-218, Pb-214, Bi-214, Pb-210) in Bratislava, Slovakia, from 2019 to 2021. We analysed the data to determine the equilibrium equivalent concentration (EEC) of radon, the radon equilibrium factor (F), and the residence time of atmospheric aerosols (TR). The results exhibited a pronounced diurnal cycle in the radon EEC, mirroring the variation in radon activity concentration, with maximum levels observed in the early morning and minimum levels in the late afternoon. Seasonal patterns were also evident, with the EEC values ranging from 1.2 Bq m^{-3} to 12.1 Bq m^{-3}, and an average of 5.4 ± 0.57 Bq m^{-3}. The equilibrium factor F had a mean value of 0.43 ± 0.3, with an interquartile range of 0.28 to 0.55, and showed a low outlier rate (0.3% > 1). Using a steady-state box model, we estimated the atmospheric aerosol residence time based on various ratios of radon progeny. The mean residence times derived from Pb-210/Pb-214, Pb-210/Bi-214, and Pb-210/Rn-222 ratios were 3.17 ± 0.21 days, 3.58 ± 0.18 days, and 3.3 ± 0.90 days, respectively. These findings are consistent with existing studies and provide valuable insights into the behaviour of radon progeny and the dynamics of atmospheric aerosols.

Acknowledgements: 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).

National survey of indoor radon in Indonesia

Eka Djatnika Nugraha[1], Wahyudi[1], Oumar Bobbo Modibo[1], Kusdiana[1], Ilma Dwi Winarn [1], Makhsun[1], Radhia Pradana[1], Ilsa Rosianna[2], Leons Rixson[1], Agus Nur Rachman[1], Rusbani Kurniawan[1], Untara[1], Dadong Iskandar[1], Heru Prasetio[1]*

[1]Research Center for Safety, Metrology, and Nuclear Technology, Nuclear Energy Research Organization, National Research and Innovation Agency (BRIN), South Tangerang 10340, Banten, Indonesia

[2]Research Center for Nuclear Fuel Cycle and Radioactive Waste Technology, Research Organization for Nuclear Energy, National Research and Innovation Agency (BRIN), South Tangerang 10340, Banten, Indonesia

Corresponding author: ekad001@brin.go.id

Indonesia is an archipelagic country with various geological formations and is known as a mining country in the world. In this situation, Indonesia has the potential for radiation exposure, especially radon. This research aims to estimate average indoor radon activity concentrations in Indonesia and the effective dose for the general public. The nationwide surveys on indoor radon were conducted in 2013-2021. This study used systematic random sampling with total dwellings at about 4413 houses in 32 of 38 provinces. Radon measurements used a solid-state nuclear track detector (SSNDT) CR-39, as passive radon monitors were installed in the dwelling with an exposure time of approximately 3–4 months. The radon activity concentration in the dwelling and GPS location are used to make a map of radon concentration using MapInfo Software v.10.5. in the result, the total annual arithmetic (AM), geometric (GM) means, and range of indoor radon concentration were 55.8 ± 30.1 Bq m^{-3}, 32.0 ± 2.5 Bq m^{-3}, 8 to 2751 Bq m^{-3}, respectively. Around 96% of the dwellings are below 300 Bq m^{-3}, and several areas in Indonesia, such as Mamuju, have been classified as radon-prone. These data are useful in the national development plans as the basis for health policy analysis due to radon in Indonesia. Furthermore, this data will be Indonesia's contribution to the international world through the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Radon-thoron exhalation and emanation determinations from mylonitic rock samples collected in north Abu Rusheid, Egypt

Sara Sakr[1,2], Sarata Kumar Sahoo[1,2], Kazumasa Inoue[1], Miroslaw Janik[2]*

[1]Tokyo Metropolitan University, 7-2-10 Higashiogu, Arakawa-ku, Tokyo 116-8551, Japan

[2]National Institutes for Quantum Sciences and Technology (QST), 4-9-1 Anagawa, Inage-ku, Chiba 263-8555, Japan

**E-mail: sarataha248@yahoo.com*

Mylonitic rocks in north Abu Rusheid, Egypt are rich in naturally occurring radioactive materials (NORMs), including uranium mineralization. These rocks are significant sources of indoor radon (Rn) and thoron (Tn) for the general public if used as building materials and they are occupational exposure sources of Rn and Tn for mine workers. Determination of Rn and Tn exhalation and emanation from mylonitic rocks is crucial for an accurate assessment of the risk of exposure to natural ionizing radiation. Determination of Rn exhalation and emanation from rocks is also essential for evaluating geogenic radon potential, a predictive tool for high indoor radon concentration. In the present study Rn and Tn mass exhalation rate (EX) and emanation fraction (EM) were determined simultaneously, based on activity concentrations of Ra-226 and Th-232, in 27 mylonitic rock samples collected from three trenches (TCHA, TCHB and TCHC) in north Abu Rusheid. The mean Rn EX of TCHA, TCHB, and TCHC were 0.73 ± 0.14, 0.49 ± 0.19, and 0.66 ± 0.38 Bq/kg·h, respectively; and the corresponding mean Rn EM were 0.105 ± 0.023, 0.091 ± 0.033 and 0.111 ± 0.038, respectively. The mean Tn EX of TCHA, TCHB, and TCHC were 1626 ± 346, 1098 ± 539 and 1851 ± 1733, respectively; and the corresponding mean Tn EM were 0.042 ± 0.004, 0.034 ± 0.012 and 0.047 ± 0.020, respectively. Correlations of Rn EX and EM with Ra-226 activity concentrations, Tn EX and EM with Th-232 activity concentrations, and Ra-226 with Th-232 activity concentrations were determined.

Status and achievements of the Hungarian national radon program

Zsolt Homoki[1,2], Ágnes Szigeti[1], Gergely Tóth[2], Anita Csordás[3], Tibor Kovács[3]

[1]National Center for Public Health and Pharmacy, Budapest, Hungary

[2]Chemical Engineering and Material Sciences Doctoral School, University of Pannonia, Veszprém, Hungary

[3]Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

The execution of the Hungarian National Radon Action Plan (RAP) was started in 2021. As a part of the radon program, new nationwide indoor and soil gas radon surveys were launched in 2022 coupled with a communication campaign. An additional goal was the development of a new database to collect and join the accessible former results with newer ones from actual surveys. The performance test of radon measuring instruments is also an important element of the radon program. The final goal of this program is to evaluate the contribution of the different radon sources to the exposure of the general Hungarian population and to initiate the reduction of the level of exposure by application of radon remedial measures.

The new indoor radon survey started with the large-scale involvement of colleagues of Government Offices and placement of passive radon detectors on national scale in 2022. Actually, we have results of 3,150 sampling sites from the territory of 996 settlements. These records are placed in 662 10×10 km grid cells from the total of 1,036. These together cover the whole territory of Hungary. Based on the statistical analysis of the results, we could identify some places where the incidence of elevated indoor radon values exceeding the reference level (300 Bq/m^3) was higher compared to other places. These settled in the Baranya, Békés, Borsod-A.-Z., Heves, Jász-N.-Sz., Nógrád and Vas County, respectively. 4.8% of the annual average values exceeded the reference level. The population weighted average radon concentration was 112 Bq/m^3 according to our calculation.

The geogen radon potential (GRP) was also examined on large-scale using the Neznal method. Until now, the territory of Transdanubia, the middle and north part of Hungary were sampled. The soil gas radon concentration was determined together with the soil permeability during the field examination and the GRP value was calculated from them. The total 2,090 measurements cover 631 grid cells from the 1,036. According to the Czech approach, 45% of GRP values fell into the low potential category, 50,5% fell into the medium and only 4.5% matched with the high radon potential category. The sampling points were also placed on the geogen map of Hungary, and they were analyzed related to the geogen formation. The lowest GRP values were measured on the drift sand, the highest values were found on the fluvial clay and silt formation. We have got the strongest connection between the indoor radon and geogen radon potential values if we used the statistics of districts.

Simulating leaked tritium at the Fukushima Daiichi Nuclear Power Plant site for a comparison with available measurements in the Fukushima coastal sites

Hikaru Sato[1,2], Maksym Gusyev[3], Shigekazu Hirao[3], Naoaki Shibasaki[1,3]*

[1]Symbiotic Systems Science, Fukushima University, 1 Kanayagawa, Fukushima, 960-1296, Japan

[2]Faculty of Life and Environmental Sciences, University of Tsukuba, Ibaraki, Japan

*[3]Institute of Environmental Radioactivity (IER), Fukushima University, Japan; *E-mail: maksymgusyev@gmail.com*

Tritium (H-3) radionuclide leaked at the Fukushima Daiichi Nuclear Power Plant (FDNPP) site on 2013 and 2014 [1] and on 7-Feb-2024 [2] requiring the estimation of tritiated water (HTO) travel times and the evaluation of anthropogenic H-3 influence in the Fukushima coastal sites. We simulated HTO travel times using particle tracking [3] applied particles at the water table, which was simulated on March 2020 in the MODFLOW model of the FDNPP site with the horizontal hydraulic conductivity range of 0.1-1 m/day and the effective porosity of about 0.2 [4]. For the 2024 leakage, simulated travel times demonstrate that it could take a couple of years for HTO to reach the Pacific Ocean coast while it would take longer for the 2013 leakage of the H4 water storage area, which is intercepted by the bypass pumping wells within 1-6 years, and for the 2014 leakage of the H6 tank water storage area that flows through a nearby building within 6-10 years. Using Fukushima Prefectural Government data [5], we compared H-3 measured in water without enrichment twice per year at 27 river and 15 dam sites at the Fukushima coastal area with constructed time-series of H-3 in Fukushima monthly precipitation [6]. As a result, we demonstrate that groundwater flow model with particle tracking provides a rapid scenario assessment based on the real leakage case at the FDNPP site without anthropogenic influence in Fukushima waters.

References:

[1] Shozugawa, K., Hori, M., Johnson, T.E. et al. (2020). Landside tritium leakage over through years from Fukushima Dai-ichi nuclear plant and relationship between countermeasures and contaminated water. Sci Rep 10, 19925, https://doi.org/10.1038/s41598-020-76964-9

[2] IAEA (2024). Japan Informs IAEA About Incident at Fukushima Daiichi Nuclear Power Station, 7 February 2024, https://www.iaea.org/newscenter/pressreleases/japan-informs-iaea-about-incident-at-fukushima-daiichi-nuclear-power-station (accessed on 11 February 2024).

[3] Pollock, D. W. (1988). Semianalytical computation of path lines for finite difference models. Ground Water (26)6, 743-750.

[4] Research Group for Geological and Hydrogeological Issues of Fukushima Daiichi Nuclear Power Station (FDNPS): Current conditions and challenges of 10 years after the nuclear accident. Monograph 61, 228 (2021). ISSN 0912–5760. (in Japanese)

[5] Fukushima Revitalization Portal Site (2024). https://www.pref.fukushima.lg.jp/site/portal/

[6] Gusyev, M., Cauquoin, A., Igarashi, Y., et al. (2024) Anthropogenic and natural tritium radioisotope in terrestrial water cycle of Fukushima, Japan, EGU General Assembly 2024, Vienna, Austria, EGU24-17332, https://doi.org/10.5194/egusphere-egu24-17332.

The radioecology of the highland sources of the Tisza River: Chorna and Bila Tisza (Transcarpathia)

Volodymyr Maslyuk[1], Tibor Kovács[2], Natalia Svatiuk[1], Olesya Symkanich[3]

[1]*Institute of Electron Physics, Nat. Acad. Sci. of Ukraine, Uzhhorod*

[2]*Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary*

[3]*Uzhhorod National University, Pidhirna 46, 88000, Uzhhorod, Ukraine*

e-mail: volodymyr.maslyuk@gmail.com

Radioecological monitoring is a priority in studying the ecological state of territories, as it provides information on the environmental state, structure of ground-level radioactivity, and the isotopic and chemical composition of environmental objects. An important task of radioecological monitoring is selecting the research object, especially rivers. The bottom sediments of the mountains rivers are natural markers of the Carpathian environmental state and reflect the peculiarities and dynamics of changes in the chemical, trace element, and radionuclide composition since they are formed under the action of natural, in particular, geochemical factors, as well as anthropogenic, meteorological and seasonal factors, as a result of the washing of the soils of river banks, etc. The Tisza, the largest river in Europe and the largest tributary of the Danube deserves special attention in this regard. It is essential to study the sources of the Tisza River since it is in the river's upper reaches that the microelemental and chemical composition is formed. The Tisza River is formed by the confluence of the Chorna (Black) Tisza and the Bila (White) Tisza 4 km above the city of Rakhiv. The upper, predominantly right-bank part of the Tisza basin lies on the southwestern slopes of the Ukrainian Carpathians and in the Zakarpattia lowlands. The subject of the study was the bottom sediments collected at fixed sampling points along the Tisza riverbed.

This report presents the results of processing 12 samples of the upper reaches (Chorna Tisza) and four bottom sediments (Bila Tisza) samples. The first sampling point (along the Chorna Tisza riverbed) was at the river's source in the mountainous area above the village of Chorna Tisza, and the last one was near the village of Dilove, outside the city of Rakhiv. The highest sampling point, along the Bila Tisza riverbed, was the end of the village of Vydrychky, and the extreme sampling point was the confluence of the two "arms" of the Chorna and Bila Tisza. The research was conducted on the ORTEC spectrometric complex with a 150 cm^3 HPGe detector. The resolution was not worse than 2.1 keV (Co-60), and the efficiency was 15%. The results of radiological studies of the distribution of daughter isotopes of natural series allow us to estimate the content of their parent chemical elements U, Th, and K and establish the geochemical characteristics of the mountainous areas of the Tisza River sources. Data on their content are important for understanding the fundamental principles of the formation of the Carpathian mountain ranges and for a number of applications, such as the assessment of erosion of surface layers of adjacent territories and meteorological and hydrothermal indicators of the territories.

Determination of tritium activity concentration in environmental samples by various techniques

Máté Novák, Miklós Hegedűs, Gergely Tóth, Anita Csordás, Edit Tóth-Bodrogi, Tibor Kovács

Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

Tritium, the isotope of hydrogen with the atomic number of three, is present in the environment from both natural and artificial resources. It is produced by both cosmic radiation and human activities, such as nuclear weapon testing and nuclear power plant operation. It is present in nature in several forms, as HT or HTO molecules or organically bound (OBT).

HTO, tritiated water can easily migrate into the environment and can enter water intended for human consumption. If the isotope enters the body in the organically bound form, it can be incorporated in tissues over a longer period. Therefore, the measurements of tritium activity concentration in natural waters are not only important for the monitoring of radiation limits, it can be also used as an environmental tracer.

In our study, we compared the efficiency of different sample preparation methods for tritium activity concentration measurements with standard samples, using the liquid scintillation technique, the most used method for the determination of tritium activity concentrations and tried to test different tritium enrichment methods, for detection improvements. Our goal was to be able to achieve good quality enrichment, with the usage of lower sample volumes.

Development of an active alpha particle detector for radon and its daughter products

Szabolcs Tóth[1,3], Ákos Horváth[1], Kálmán Máthé[2], Erika Kocsis [3]

[1]Eötvös Loránd University, Faculty of Natural Sciences, Institute of Physics and Astronomy, Department of Atomic Physics

[2]University of Pécs, Faculty of Engineering and Information Technology, Institute of Engineering and Smart Technologies, Department of Electrical Engineering

[3]Mining Property Utilization Ltd.

In connection with the environmental monitoring activities of the Mecsek uranium ore mine closure, several deep boreholes have been drilled. These deep boreholes are suitable for investigating spatial and temporal variations of radon activity concentrations. Measurements require a large number of radon sensors with data loggers.

Our goal was to develop a device for the energy-selective measurement of alpha particles (in particular radon and its daughter elements).

After the tests, the final electronic design was developed. In order to achieve easy reproducibility at the lowest possible cost the Advanced Photonix SLCD61N5 photodiode was chosen for the final version. In the design of the PCB, we aimed to use a 4-layer PCB, SMD components and to minimize the signal paths by creating ground layers of appropriate size.

The components of the system consist of a photodiode preamplifier circuit, a preamplifier stage, an amplifier stage and a Schmitt trigger. To increase the depleted zone, the photodiode was used in reverse bias mode (9 V). The voltage amplifier block has been designed to amplify the output signal of the charge sensitive transimpedance amplifier from 200-300 mV to a range of 1-6 V at low signal-to-noise ratios. For further signal processing, the pulses were converted into logic signals using a discriminator and a timer.

The final device was mounted in a plastic tube with a diameter of 40 mm coated with a permalloy coil, and the photodiode was light sealed with overlapping metal discs. The same formed the diffusion chamber of the detector, which had a size of 60 cm^3 and a maximum free path inside the chamber of ~ 3.7 cm. Based on the experiments performed in the radon chamber, 1 pulse corresponds to a radon activity concentration of 180 Bq/m^3.

Environmental radioisotopes in hydrogeological studies: natural tracers and drinking water quality parameters

Anita Erőss[1], Petra Baják[1], Katalin Hegedűs-Csondor[1], Bálint Izsák[2], Saeed Bidar Kahnamuei[1], Dénes Szieberth[3], Ákos Horváth[4], Márta Vargha[2]

[1]*Eötvös Loránd University, Institute of Geography and Earth Sciences, Department of Geology, József and Erzsébet Tóth Endowed Hydrogeology Chair, Budapest, Hungary*

[2]*Public Health Directorate, National Center for Public Health and Pharmacy, Budapest, Hungary*

[3]*Budapest University of Technology and Economics, Department of Inorganic and Analytical Chemistry, Budapest, Hungary*

[4]*Eötvös Loránd University, Institute of Physics and Astronomy, Department of Atomic Physics, Budapest, Hungary*

Groundwater may contain different natural alpha and beta emitters, but most often alpha-radiation–emitting uranium, radium and radon can be found in the highest concentrations. Depending on the measured activity concentrations, radiation exposure through the consumption of groundwater-derived drinking water can have a significant impact on human health. To find the most appropriate risk management methods, understanding groundwater flow systems is a key issue, as it helps to explain the origin of radioisotopes. Thanks to the mandatory measurements of gross alpha, gross beta and radon activity of drinking waters in Hungary, a basic knowledge on radioactivity of groundwater is available. These measurements highlight those areas where combined radionuclide-specific measurements and hydrogeological studies are essential further steps for safe drinking water supply. These radioisotopes, however, can be used as natural tracers in hydrogeological studies, due to their different physical and chemical behaviour in the subsurface environment. Our studies showed that elevated uranium values are either associated with recharge areas of groundwater flow systems or can be found in local flow systems, where oxidising conditions prevail. These systems are the most sensible for climate change and exaggerated water abstraction, which may cause both groundwater quantity and quality problems. Both in the surroundings of the Sopron Mountains and the Velence Hills, the siliciclastic sediments are the geogenic sources of dissolved uranium in groundwater, which is mobilized and transported by local flow systems. Beside groundwater resources, relatively high uranium concentrations were measured both in Lake Neusiedl and Lake Velence proving that these lakes are integral parts of groundwater flow systems and receive uranium-containing groundwater. Radium is mobile under reducing conditions; therefore, it can be often found in thermal waters, which are associated with regional flow systems. In their discharge areas iron- and manganese oxyhydroxides may develop due to the change in redox conditions, which efficiently adsorb radium and hence act as a source of radon. In carbonate aquifers, mixing of fluids can be identified with the aid of radium and uranium, which can help in revealing the cave forming processes proved by case studies from the Buda Thermal Karst in Budapest and in the Lake Hévíz spring cave. This research was funded by the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014 project) and was supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences.

Quality Assurance of (radio)analytical laboratories: reflections on standards, validation, metrology aspects and possible confusions

Viktor Jobbágy

Freelance expert, Social Organization for Radioecological Cleanliness, Veszprém, Hungary

The importance of quality assurance together with method validation in the analytical world have been constantly increasing in the past few decades. Reflecting to this process, three important standards in this area were developed and laboratories can be accredited for these standards. The ISO 17025 standard, which is a fundamental quality assurance standard for laboratories performing testing and calibration, was published first in 1999 (valid revision in 2017) followed by the ISO 17043 on proficiency testing (first published in 2010, valid revision in 2023) and ISO 17034 on reference material production (first published in 2016, revised in 2022). It can be also observed that the ISO 17025 applications for accreditation are still increasing globally year by year, which underpins the importance of accreditation and quality assurance. The aforementioned three international standards are interconnected; the link between them and their relevance on the daily laboratory operations and quality assurance will be discussed in the presentation.

One of the most crucial parts for providing reliable measurement data is method validation which is sometimes missing or not performed properly in laboratories. For this reason, the elements of a full-scale validation study would be highlighted as described in EURACHEM guides. Some aspects of the metrological traceability and establishing uncertainty budget will be also presented. In addition, an attempt is made to clarify the common misunderstandings regarding quality assurance like e.g. reference materials-certified reference materials, certification-accreditation, validation-verification, selection of Reference Materials producers and Proficiency Test providers. There is no sufficient time to cover every aspect of the quality assurance in one presentation. Therefore, some selected quality assurance related issues relevant for environmental radioanalytical measurement methods will be briefly discussed.

Dosimetry of high-energy radiation based on undoped lithium tetraborate

Igor Pylypchynets[1], Eugene V. Oleinikov[1], A.V. Rusyn[2], Viktoriya I. Roman[1], Oksana M. Pop[1], Volodymyr T. Maslyuk[1], Ivan G. Megela[1], Vadym M. Holovey[1], O. Papp[1]

[1]*Institute of Electron Physics, Uzhhorod, Ukraine*

[2]*Transcarpathian Cancer Center, Uzhhorod, Ukraine*

Today, ionizing radiation forms the basis of radiation technologies that are widely used in almost all areas of human activity: biology, agriculture, industry, and energy. It is also used for sterilization of medical products and materials, but its most important use is in the field of nuclear medicine for diagnosis and treatment of diseases. Solving such a problem requires an understanding of the nature of the stability of a substance under the action of nuclear particles of various natures, a comparison of the degree of their influence, the nature of radiation defect formation in materials of organic and inorganic origin, as well as the adequacy of modelling damage to biological objects based on the data of dosimetric studies. Radiation therapy combines a range of applications where ionizing radiation effectively treats the presence and spread of cancer and is used in more than 80% of medical procedures.

Recently, there has been a steady trend towards the transition from monoenergetic isotopic Co-60, Cs-137 gamma sources to technical devices – nuclear particle accelerators for medical purposes, X-ray diagnostic devices, linear and cyclic electron accelerators, cyclic proton accelerators, etc. Such circumstances indicate the need to improve dosimetric monitoring of radiotherapeutic treatment under conditions of action of ionizing radiation.

It should be noted that clinical dosimetry is based on the registration of relatively low-energy, less than 2 MeV, ionizing radiation. However, under the conditions of using high-energy irradiation, on modern medical electron accelerators of 6-21 MeV, different types of radiation defects can form in dosimetric materials, which leads to modification of the structure of their energy levels in the forbidden zone. The formed defects can change the kinetics of optical transitions of electrons in irradiated materials, which, accordingly, calls into question their ability to accurately record the absorbed radiation dose. Thus, the formed defects can be additional centers of radiative recombination, or traps, centers of non-radiative recombination for charge carriers, which is manifested in reduced output of thermoluminescence (TL). Therefore, it is important to study the peculiarities of the luminescent characteristics of traditional dosimetric materials in the dosimetry of high-energy nuclear radiation.

Today, there is a large number of widely used dosimetric materials doped with various impurities. One such promising material for tissue-equivalent dosimetry is lithium tetraborate ($Li_2B_4O_7$, LTB), since its effective number Z_{eff} = 7.3 is close to the same value for the human body. The advantage of such material is also that the TBL matrix contains boron atoms, which allows it to be used for recording neutron or mixed radiation fields. A characteristic feature of undoped TBL samples is the presence of their own structural defects.

The paper presents the results of thermoluminescence research of undoped samples of lithium tetraborate, $Li_2B_4O_7$, irradiated at the M-30 microtron of the Institute of Electron Physics of the NAS of Ukraine. The energy of irradiation (7-15 MeV) and the density of the flow of accelerated electrons were chosen according to the possibility of forming radiation defects in the studied samples.

As a result of the study, two characteristic temperature peaks at 150-160°C and 250°C were found. The obtained peaks are associated with uncontrolled technological defects in the studied samples. It was established that the linearity of the TL signal from the dose in undoped TBL samples varies in a wide range of absorbed doses from μGy to 103 Gy, as well as low fading of dosimetric information. It is shown that the threshold values of absorbed doses are determined both by the energy and density of the flow of accelerated electrons, and by the degree of defectiveness/doping of dosimetric materials. The obtained results should be taken into account during dosimetric control of the operation of medical accelerators, when high-energy nuclear radiation is used.

Study of typical radon progeny parameters measurement and its application on dose conversion factors evaluation

Qiuju Guo

School of Physics, Peking University, Beijing, 100871, China

Radon exposure is the greatest contributor of the natural radiation to human exposure (UNSCEAR, 2019), and also the second cause of lung cancer after smoking (WHO, 2009). For evaluating radon exposure dose precisely, the determination of effective dose conversion Factor, the DCF, is the key issue. The effective dose per unit exposure to radon progeny is strongly dependent on the characteristic parameters of radon progeny, as inhaled radon progenies with different physical parameters will deposit in different areas of respiratory system and cause different inner exposure. ICRP 126 publication recommended that 'doses from radon and its progeny should be calculated using dosimetric models with specified equilibrium factors and aerosol characteristics' in 2014, and ICRP 137 publication provides the typical radon DCFs for mine, indoor workplace and tourist cave, respectively in 2017. However, for environments such as typical dwelling and NORM related sites, DCFs have not yet been given due to the lack of characteristic parameters of radon progeny.

These characteristic parameters include the activity concentration ratio of radon progenies, the size distribution of attached and unattached radon progenies, unattached fraction and nucleation fraction. For the purpose of obtaining the typical parameters of radon progeny in real environments of living room as well as working place in China, a series of new measurement methods and devices were developed, and field measurements were carried out in indoors as well as in NORM environments recently. Results showed that the parameters varied widely, indicating the importance of conducting extensive surveys of typical characteristic parameters for different environments. The DCFs of different environments were evaluated by IMBA software. The typical DCFs were 30.2 nSv(Bq $m^{-3}h)^{-1}$, 22.7 nSv(Bq m^{-3} $h)^{-1}$ and 31.6 nSv(Bq m^{-3} $h)^{-1}$ for indoor, outdoor and NORM environment, respectively, which were quite close to the ICRP given values. Results showed that the unattached fraction has the most significant impact on the DCF among all the characteristic parameters, followed by the particle size distribution.

In my presentation, a series of new measurement methods and devices suitable for field measurement of radon progeny physical parameters developed in my lab will be illustrated. And results of our field measurement of first time will be also introduced. More field measurement will be carried out in the future to enrich databases and to lay foundation for more precise exposure dose evaluations. The typical parameters and the DCFs of thoron progeny will also be given in near future.

The method of Pb-212 measurements in air with the application of the LSC technique

Agata Grygier, Stanislaw Chalupnik

Central Mining Institute, Katowice, Poland

agrygier@gig.eu

Radon has been identified by scientists as one of the most important lung cancer hazards (also confirmed by WHO reports). The most important isotopes of radon are Rn-222 (3.83 days) and thoron Rn-220 (55 s). The hazard for people is mainly due to inhalation of radon/thoron decay products, but usually, only measurements of radon and/or thoron gas are done in dwellings, and dose calculation is done using assumed equilibrium factors.

The long-term measurements of radon and thoron decay products are necessary for dwellings, workplaces, touristic caves, and other places to fulfill the requirements of the Euratom/59/2013 Directive.

For the last two decades, measurements of thoron gas have become more frequently done to estimate thoron contribution to indoor exposure. Measurements of thoron decay products are rather complicated and such measurements are done rarely, although would give the best estimation of the thoron hazard.

The described method allows measurements of Pb-212 ($T_{1/2}$=10.6 h) concentrations in air. At first, Pb-212 is collected on the filter, and the sampling time would be from 12 to 48 hours. Later the filter is immersed into an organic scintillator and measured in a liquid scintillation spectrometer at least 6 hours after the end of sampling. The application of the portable LS spectrometer enables measurements of very low Pb-212 concentrations, 0.5 – 1 Bq/m^3, and estimation of the Potential Alpha Energy Concentration of thoron decay products.

Continuous monitoring of tritium concentration and stable isotope composition in coastal seawater collected at Iwaki City, Fukushima Prefecture located south from Fukushima Dai-ichi Nuclear Power Plant

Naofumi Akata[1], Haruka Kuwata[1], Yuisa Kitayama[1], Yosuke Amano[2], Masamune Endo[2], Sho Watanabe[2], Kazuyoshi Takasaki[2], Kimpei Ichiyanagi[3], Khemruthai Kheamsiri[1], Ryohei Yamada[1], Naoyuki Kurita[4], Hirofumi Tazoe[1]

[1]*Hirosaki University, Japan,*

[2]*Fukushima Prefectural Fisheries and Marine Science Research Centre, Japan,*

[3]*Kumamoto University, Japan,*

[4]*Nagoya University, Japan*

Since the Fukushima Dai-ichi Nuclear Power Plant (FDNPP) accident of March 2011, huge amounts of contaminated water have been produced in decontamination and decommissioning work. Although the contaminated water has been treated by passing it through the multi-nuclide processing system (ALPS), small amounts of radionuclides, especially tritium which is not removed using ALPS are still present. On August 24, 2023, Tokyo Electric Power Company began releasing the treated water through emission pipeline into the coastal Pacific Ocean approved by the Japanese government. However, there are limited to report on tritium concentrations in marine environment along the Japanese coast prior to and after the release near the FDNPP site and in background areas (far from FDNPP). Here, tritium concentration in coastal seawater samples at Iwaki City before and after the releasing treated water from FDNPP were reported.

Coastal seawater samples were collected monthly at Fukushima Prefectural Fisheries and Marine Science Research Centre located Iwaki City, Fukushima Prefecture located approximately 55 km south from FDNPP since May 2021. The seawater is constantly pumped from the adjacent coastal area. Monthly precipitation samples were also collected at same center using rain gage (RS-1D, Palmex Ltd.). After sample collection and transportation to Hirosaki University, seawater samples were distilled with Na_2O_2 and $KMnO_4$. Monthly precipitation samples were measured sample volume, pH and EC, and were distilled. The 800 mL of both distilled sample waters, they were enriched using SPE membrane electrical tritium enrichment system (XZ-001, DeNoraPermelec). After distillation again, tritium concentrations were measured using large volume polyethylene vial with low-background liquid scintillation counter (LSC-LB-5, Aloka) for 1,000 min. After filtered of the part of precipitation samples, major ion species were measured by ion chromatography.

The tritium concentration in coastal seawater samples (until April 2024) ranged from 0.04 to 0.20 Bq/L with mean value (±SD) of 0.09±0.03 Bq/L. Those of precipitation samples (November 2021 to March 2024) ranged from 0.11 to 0.82 Bq/L with mean value of 0.38±0.19 Bq/L. No significant changes in tritium concentration were observed before and after the releasing treated water. And δH-2 and δO-18 composition and ion species in precipitation samples were not have difference before and after. As these results, it seems that there is no impact of releasing treated water to the coastal seawater at Iwaki City from the FDNPP.

Measurement of short-term atmospheric tritiated water vapor in Fukushima

Shigekazu Hirao[1], Masahiro Tanaka[2], Hiromi Kato[2], Hiroki Chimura[2], Nobuhiro Suzuki[2]

[1]Institute of Environmental Radioactivity, Fukushima University, Fukushima, Japan

[2]National Institute for Fusion Science, Gifu, Japan

There is a need for scientific knowledge to evaluate the environmental impact associated with the release of ALPS-treated water stored at the TEPCO's Fukushima Daiichi Nuclear Power Plant (FDNPP) into the ocean. Since the atmospheric transport of radionuclides is the fastest pathway to organisms living on land, it is necessary to first obtain actual measurements of atmospheric concentrations. However, the number of atmospheric monitoring is limited compared to the substantial expansion of ocean monitoring. One reason for the lack of atmospheric monitoring data was that there is no monitoring system for atmospheric tritiated water vapor (HTO) without a commercial power supply. In this study, we developed a portable sampling system for atmospheric HTO to understand the short-term variation of atmospheric HTO concentration. The sampling system consists mainly of water vapor absorbers, their containers with check valves, an air pump, and portable batteries. The result of the preliminary experiment in a laboratory showed that it worked for about 2 days without a commercial power supply. In addition, the relationship between an airflow rate introduced into the absorbers and the mass of water vapor collected was examined to determine the sampling interval of the system. To check the developed system in an ambient environment, we conducted field measurements several times in the vicinity of the FDNPP. As a result, it was confirmed that there were no problems with pump operation, valve switching, and solenoid valve operation using the portable batteries in an ambient environment. Furthermore, the relationship between the measured short-term atmospheric HTO concentration and meteorological conditions were analyzed. It was found that the HTO concentration in the atmosphere ranged within the variation of the past observation although the obtained atmospheric HTO concentration was slightly higher than that of the recent background level in Japan. These results showed that the developed system can be used to assess the environmental impact of tritium near the source.

Distribution of uranium, thorium and rare earth elements in a Cs-137 contaminated soil depth profile affected by Fukushima Daichi Nuclear Power Station accident

Chiharu Nishiyama[1,2], Sara Sakr[1,2], Kazumasa Inoue[1], Thennaarassan Natarajan[1,2], Hideki Arae[2], Sarata Kumar Sahoo[1,2]*

[1]Tokyo Metropolitan University, 7-2-10 Higashiogu, Arakawa-ku, Tokyo 116-8551, Japan

[2]National Institutes for Quantum Sciences and Technology (QST), 4-9-1 Anagawa, Inage-ku, Chiba 263-8555, Japan

**E-mail: 0818junjunjun1765@gmail.com*

The Fukushima Daiichi Nuclear Power Station (FDNPS) accident in 2011 caused a significant deposition of Cs-137 onto the soil surface. In the present study, the depth profile of a soil sample was collected in Futaba city to access the migration of Cs-137 contamination. Cs-137 activity concentration was measured using a gamma spectrometer equipped with a high purity germanium detector (HPGe). A decrease in Cs-137 activity concentrations was observed with the depth layer. After 12 years of the accident, the activity concentrations of Cs-137 in 0-2 cm layer was 250 ± 0.6 kBq/kg whereas 10-15 cm depth was 0.5 ± 0.004 kBq/kg. Soils were digested with a mixture of HNO_3 and HF using microwave digestion method. Uranium (U), thorium (Th) and rare earth elements (REEs) have been measured in the same samples to know their distribution pattern. The concentrations of U, Th and REEs were measured using an inductively coupled plasma-mass spectroscopy (ICP-MS). U and Th activity concentrations at depth (0-2 cm) were 14.3 ± 0.9 Bq/kg and 13.5 ± 0.2 Bq/kg, respectively. The U and Th activity concentrations in the surface sample were compared with other parts of Japanese soils such as Aomori, Miyagi, Hyogo and Hiroshima prefectures. The U and Th activity concentrations did not show higher values compared to other Japanese prefectures. Total REEs concentration for the top layer (0-2 cm) was 53 µg/g and was lower than Aomori prefecture soil. Chondrite-normalized REEs pattern did not show any enrichment of REEs, that could be related to FDNPS accident.

Assessing radioactivity and elemental composition in attic dust from Ózd, a former industrial city in Hungary

Mona Maghsoudlou[1], Davaakhuu Tserendorj[1,2], Gorkhmaz Abbaszade[1,3], Nelson Salazar-Yanez[1], Péter Völgyesi[4], Csaba Szabó[1,5]*

[1]*Lithosphere Fluid Research Laboratory, FFI, TTK, Eötvös Loránd University, Budapest, Hungary*

[2] *HUN-REN Centre for Ecological Research Institute of Aquatic Ecology, Karolina út 29, 1113, Budapest, Hungary*

[3]*Helmholtz Centre for Environmental Research – UFZ Permoserstr. 15, 04318 Leipzig, Germany*

[4]*Nuclear Security Department, Centre for Energy Research, Budapest, Hungary*

[5]*Institute of Earth Physics and Space Science, Eötvös Loránd Research Network, 9400, Sopron, Hungary*

Ózd, a former industrial city in Hungary, played significant role in the Hungarian iron and then steel industry from 1835 to 1990. This study aims to assess long-term contamination in attic dust from residential areas of Ózd, highlighting its importance to reliable record of environmental pollution history. A total of 43 attic dust samples were collected from residential buildings. Major, minor and trace elemental compositions of these bulk samples were analyzed using inductively coupled plasma mass spectrometry (ICP-MS). The activity concentrations of Ra-226, Th-232, and K-40 were determined using gamma spectrometry with a high-purity germanium (HPGe) detector. The results reveal notable variations in the concentrations of U, Th, and K. Samples from a church and two family houses show natural origin indicated by low U concentrations (0.5 to 1.5 mg kg^{-1}) and Th contents (0.2 to 0.9 mg kg^{-1}). In contrast, three other samples from family houses located farther from the industrial center exhibit significant K enrichment, with values of 1.3 m/m %, 1.8 m/m %, and 3.3 m/m %, separately likely due to local agricultural activity. The last sample is also characterized by the highest K-40 content (1493.7 ± 78 Bq kg^{-1}). The activity concentrations of Ra-226 range from 9.5 ± 2.7 to 63.3 ± 0.9 Bq kg^{-1}, averaging 35.7 ± 3.3 Bq kg^{-1}, whereas the Th-232 activity concentrations range from 8.0 ± 6.2 to 27.1 ± 3.4 Bq kg^{-1}. Notably, a subgroup of samples from three family houses and a church shows very low Ra-226 levels (3.3, <dl, 9.5, and 2.6 Bq kg^{-1}, respectively). In addition, some major and minor elements such as Na, K, Mg, Ca, Sr, Ba, P and S are also studied to assess the impact of local environmental conditions, as well as the influence of past industrial activities.

On a possible utilization of the ^{90}Sr to ^{137}Cs ratio to identify the fallout plumes the case of the Karaganda region within the Semipalatinsk Test Site

Yuliya V. Baklanova, Assan Aidarkhanov

Branch 'Institute of Radiation Safety and Ecology' of RSE NNC RK, Kurchatov, Kazakhstan,
baklanova_y_v@nnc.kz

The study addresses the possibility to identify the atmospheric fallout plumes and non-nuclear-explosive experiments conducted in the territory of the Semipalatinsk Test Site (STS) the case of an area in the Karaganda region within STS.

The research object is located in close proximity to the 'Experimental Field' test location at which atmospheric (ground and air) blasts and non-nuclear-explosive experiments were conducted. Tests using radiological warfare agents were also conducted in the Karaganda region within STS, namely, at the '4' site. The soil cover is most exposed to radioactive contamination during such tests, accumulates and retains all the environmental contaminants including man-made radionuclides.

The scientific literature provides sufficient information on activities of Sr-90 and Cs-137 in the global fallout typical of the northern hemisphere. The range of the content of Sr-90 and Cs-137 in the soil, attributed to the global fallout, is fairly small: 4–29 Bq/kg for Cs-137 and 1–19 Bq/kg for Sr-90. The Sr-90/Cs-137 ratio in the global fallout is 0.6. It is worth noting that the yields of Sr-90 and Cs-137 in testing depend on individual parameters of each test (material of a charge, type and so on), location and detonation conditions.

The research methodology involved the analysis of measured activity concentrations of Sr-90 and Cs-137 in topsoil samples (0-5 cm) followed by calculating Sr-90/Cs-137 ratio values, statistical processing of data and mapping.

In the STS 'background' area beyond test locations and the fallout plume, Sr-90/Cs-137 ratio values were previously found to range from 0.01 to 1.6. Values exceeding a mean value of this ratio for the global fallout are specific to land plots that area close to test locations and the axes of passing fallout plumes. Approximately 70% of the Sr-90/Cs-137 ratio values range within 0.5±20%, which suggests that radioactive contamination in study areas is similar.

The distribution of Sr-90/Cs-137 ratio values at technical sites P-1, P-2, P-3, P-5, and P-7 located at the 'Experimental Field' test location varies from <0.8 to >4.8. For example, ~41% of the Sr-90/Cs-137 ratio values range within 1±20%, ~26% - within 1.4±20%. The maximum Sr-90/Cs-137 ratio equal to 4.8 is specific to the epicentral area of the P-1 site, the test location of a high-yield fusion test (400 kt). Abnormally high values for Sr-90/Cs-137 ratio values are approximately equal to 2.0 and are specific to test locations of non-nuclear-explosive experiments or to off-normal tests with a small amount of energy release and minor quantities of fission products.

In the territory of the Karaganda region within the test site outside test locations, values for Sr-90/Cs-137 ratio values range within 0.05–1.7 with a mean value of 0.6. The Sr-90/Cs-137 ratio values that exceed 0.6 are specific to those survey areas that are close to test locations and possible axes of passing fallout plumes. Approximately 30 % of Sr-90/Cs-137 ratio values in the topsoil of the Karaganda region within STS outside test locations falls under the range of 0.4–0.6, which allows for the assumption that Sr-90 and Cs-137 originate from the same source. Approximately 70 % of ratios of test fission products range within 0.6±20%. In places of the intended axes of passing fallout plumes, despite the fact that activity concentrations of Sr-90 and Cs-137 are at the global fallout level, Sr-90/Cs-137 ratio values range within 0.8–1.5. In summary, the possibility to identify fallout plumes by using the Sr-90/Cs-137 ratio as the plume's 'labels' is shown.

Indoor radon and NORM in building materials: Critical analysis of the existing European regulation

Konstantin Kovler[1], Andrey Tsapalov[1], Robert Bobkier[2]

[1]National Building Research Institute, Technion – Israel Institute of Technology, Haifa, Israel

[2]Effective Radon Solutions Ltd., Poole, UK

The primary factors of radiation risk are homes and workplaces, as people spend 80-90% of their time indoors. Inside buildings, internal exposure (to radon) and external exposure (to gamma radiation emitted by building materials) are usually higher (and sometimes significantly higher) than outdoors. This risk can be regulated and should be reduced by fundamental guidelines issued by authoritative international organizations such as the IAEA, ICRP, WHO, and the Euratom Community (EU-BSS). The paper discusses several missing points and challenges within the European regulatory system in the field of NORM in building materials and indoor radon, consisting of three interconnecting functional levels: Legislative, Normative, and Methodological.

Legislative Level: Refers to laws enacted by a legislative body, such as a parliament or congress. Examples include Basic Safety Standards (EU-BSS) at the Euratom Community level and generally applicable laws at the Member State level, such as national radiation protection laws and internal legal acts like national Radon Action Plans. These laws are based on rules and guidelines developed by international organizations, government agencies, and local administrations to implement and enforce the legislation.

Normative Level: Includes documents issued by IAEA, WHO, and ICRP, which establish normative values to protect workers and the public from ionizing radiation, referred to as "Reference Levels" (RLs). The EU-BSS belongs to both Legislative and Normative levels as it also establishes RLs.

Methodological Level: The lower level at the base of the regulatory pyramid of radiation risk due to radon and NORM, covering recommendations and guidelines as well as measurement standards to assess compliance with specific radiation safety requirements within the Normative Level.

An analysis indicates that the Normative Level (mid-tier of the hierarchical regulatory pyramid) is satisfactory. However, the Legislative Level, despite incorporating seven Good Regulatory Practices (GRPs), has five significant drawbacks that need to be addressed. The Methodological Level is underdeveloped, with seven serious deficiencies. The weak development of the Methodological Level greatly hinders the global implementation of GRPs. It is concluded that enhancing radon and NORM regulation can be achieved by developing and globally implementing several pertinent European (international) standards and guidelines within rational ISO/IEC concepts.

Spatio-temporal variations in ^{137}Cs concentrations in water bodies of an urban area in Fukushima

Suzuki Nobuhiro[1], Yoshifumi Wakiyama[2], Hyoe Takata[2]

[1]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, Japan

[2]Institute of Environmental Radioactivity, Fukushima University, Japan

Thirteen years have passed since the accident at the Tokyo Electric Power Company's Fukushima Dai-ichi Nuclear Power Plant on March 2011, and it has been reported that the rate of decrease in Cs-137 concentrations in of suspended solids and dissolved form in urban areas is faster than in forests and agricultural lands. On the other hand, high concentrations of Cs-137 in concentrations in water and sediment in urban areas were also reported. Some authors explored urban-specific substances or environmental conditions for the persistent contaminations. However, there are still uncertainties of Cs-137 dynamics in urban area because of relatively small numbers of researches focusing on urban areas.

This study targeted rivers, waterways, and reservoirs in and around central Koriyama City. The Abukuma River runs through Koriyama City, with the city center to the west and farmland further west. From August 2023 to May 2024, 40 L water samples were collected for 4 times at 17 locations; 7 on a small-flow route that crosses the city center, 2 on the Ouse River without reservoir in its catchment, 3 on in the Minami River with reservoirs in its catchment, 2 on the Abukuma River, and 3 on miscellaneous points within the city. The water samples were filtered to measure the Cs-137 concentration of suspended solids (SS) (Bq/kg), particulate Cs-137 concentration (Bq/L), and dissolved Cs-137 concentration (Bq/L). In addition, stable isotope ratios, δN-15 and δC-13 (‰) and heavy metals (Cr, Cu, Fe, Mn, Pb, V) contents (ppm) were measured and subject to analyses of the factors that influence the Cs-137 concentration of SS.

The particulate Cs-137 concentration was 0.0003-0.5 Bq/L, and the dissolved Cs-137 concentration was 0.002-0.03 Bq/L. The particulate Cs-137 concentration was at the same level in the small-volume flow route and the reservoir and tended to be higher than at other points. In the small-volume flow route, the Cs-137 concentration of SS ranged from 0.7-6.9 kBq/kg and tended to increase toward downstream direction. On the other hand, there was no significant difference in the dissolved Cs-137 concentration between upstream and downstream, suggesting that the inflow of the particulate Cs-137 increased the Cs-137 concentration. Among 4 sampling campaigns, particulate and dissolved Cs-137 concentrations were highest in May 2024 and lowest in March 2024. SS samples collected in August and December 2023 showed a positive correlation between Cs-137 concentration and δN-15. This result suggests that any of anthropogenic substances may be a factor in increasing the Cs-137 concentration. On the other hand, the concentrations of heavy metals were similar from upstream to downstream, and no significant correlation with the Cs-137 concentration in SS was found. At the conference, updated analysis will be presented after completions of planned analyses.

Study of transfer factors for radionuclide in bananas (Musa Paradisiaca) at Taharan-Lampung

Egnes Ekaranti[1], Rusbani Kurniawan[1]*, Radhia Pradana[1], Agus Nur Rachman[1], Ilma Dwi Winarni[1], Riyaz Yusuf[2], Nicha Miranda Sari[2], Ahmad Anggraria Jaya Agung[2], Wahyudi[1], Leons Rixson[1], Oumar Bobbo Modibo[1], Ilsa Rosianna[3], Eka Nugraha Djatnika[1]*

[1]*Research Center for Safety, Metrology, and Nuclear Technology, Research Organization for Nuclear Energy, National Research and Innovation Agency (BRIN), South Tangerang 10340, Banten, Indonesia*

[2]*Department of Chemistry, Sumatera Institute of Technology, Bandar Lampung, Indonesia*

[3]*Research Center for Nuclear Fuel Cycle and Radioactive Waste Technology, Research Organization for Nuclear Energy, National Research and Innovation Agency (BRIN), South Tangerang 10340, Banten, Indonesia*

**E-mail: rusb001@brin.go.id*

The Tarahan-Lampung Coal-Fired Power Plant (CFPP), one of the largest CFPPs on Sumatra, along with other heavy industries in the region, has the potential to produce hazardous trace elements (HTEs) and radioactive waste which could be absorbed by plants. Bananas are a major commodity in Lampung, it's crucial to assess the presence of radionuclides in bananas intended for consumption. This study investigates the presence and transfer factors of radionuclides in bananas (musa paradisiaca), a major agricultural product in Lampung Province. Soil and banana samples were collected from three locations near Tarahan: Srengsem, Mataram, and Rangai Tri Tunggal villages. Using a High Purity Germanium (HPGe) gamma spectrometer, the activity concentrations of Ra-226, Th-228, K-40, and Cs-137 were measured. The radionuclide activities data is analyzed using the Erica Tools to analyze its transfer factor and assess environmental risk. Results revealed that the highest activity concentrations for Ra-226, Th-228, K-40, and Cs-137 in soil were 54, 64, 714, and 0.4 Bq/kg, respectively. In bananas, the highest activity concentrations for Ra-226, and K-40 were 15 and 414 Bq/kg, respectively, with no detectable activity for Th-228 and Cs-137. The average transfer factor values for Ra-226, and K-40 were 0.3 and 1.2, respectively, while those for Th-228 and Cs-137 were not detected. These findings indicate the potential for radionuclide uptake by bananas from contaminated soil, highlighting the need for continuous monitoring and implementation of safety guidelines to protect public health.

Determination of massic exhalation rate and emanation factor of Transdanubian soil samples

Gergely Tóth, Máté Novák, Zsolt Homoki, Lordford Tettey-Larbi, Edit Tóth-Bodrogi, Anita Csordás, Tibor Kovács

Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

In this study the massic radon exhalation and emanation factors of soil samples from the Transdanubian region of Hungary were determined. The 145 selected sampling points were located in the area of populated settlements or in the immediate vicinity of settlements. Our study also serves as a complementary measurement of the National Radon Action Plan, which is currently being implemented to assess the exposure of the population to radon, as required by the European Union. Our study is independent of the legal requirements.

The aim of our work was to investigate the regional occurrence of Rn-222 from soil based on processed samples. Our primary objective in evaluating the results is to identify possible hotspots, which can be used as a basis for further measurements to determine the exposure of the population.

The range of the massic exhalation results from 1.02 mBq/kgh to 275.63 mBq/kgh. The range of the emanation factor of the tested soil samples went from 0.01 to 0.79.

Application of LSC techniques for drinking water monitoring

Stanislaw Chalupnik, Izabela Chmielewska, Damian Stefanski

Silesian Centre for Environmental Radioactivity, Central Mining Institute, Katowice, Poland

E-mail: schalupnik@gig.eu

In October 2013, the European Commission issued Directive Euratom/51/2013, related to the monitoring of radioactivity of drinking water supplies. The demand was to monitor tritium levels, radon concentrations, and the estimation of Total Indicative Dose. In Poland, this Directive was introduced into the national law system in November 2015 as the Ordinance of the Ministry of Health. In the implementation of the Ordinance into practice, the main role-play methods are based on LS spectrometry. This robust technique can be applied for monitoring the majority of the radionuclides, required by the Ordinance, which means tritium, radon, and concentration of radium isotopes in water.

In November 2015 the Ordinance of the Ministry of Health related to the monitoring of radioactivity of drinking water supplies was issued. It is an implementation of the European Commission Euratom/51/2013. The year 2016 was the first year of the implementation of the Ordinance into practice. Very important for the introduction of the Ordinance is the application of LS spectrometry methods for the monitoring of the radionuclides, present in water. Polish Ordinance requires monitoring of tritium, radon and radium isotopes in water. In the Silesian Centre for Environmental Radioactivity, Central Mining Institute, measurement methods for all the above-mentioned radionuclides are based on LSC.

In this paper, the description of the Polish approach to the Euratom Directive implementation is given as well as a brief description of the LSC methods, used in the monitoring system of water supplies, provided by the Silesian Centre for Environmental Radioactivity. Additionally, results of the first years of the monitoring of radioactivity in drinking water supplies are presented. For instance, almost 2000 water samples were analysed within 2016, in most of the samples results of monitoring were below the detection limits of particular methods. No elevated concentrations of tritium have been found, only in several cases the elevated concentration of radon was found, exceeding 100 Bq/l. In the case of radium isotopes, their activities are used to estimate the total indicative dose. For the several water supplies, the estimated annual dose for users exceeded the reference value of 0.1 mSv/year.

The preliminary investigations were continued till the end of the year 2018. At that time, it will be possible to have to final pattern of distribution of radioactivity in drinking water supplies in Poland.

Mobility of artificial radionuclides in soils of Semipalatinsk Test Site under various conditions of radioactive contamination

Assiya Ye. Kunduzbayeva

Branch office 'Institute of Radiation Safety and Ecology' of RSE 'NNC RK', Kurchatov, Kazakhstan

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 Cs-137, Pu-239+240 and Am-241 and Sr-90 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 behaviour 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 Sr-90 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 Sr-90 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 Sr-90 was revealed to correlate with its accumulation by zonal plants (steppe motley grasses).

Soil-to-plant transfer factors of radium for some agricultural plants

Van Thang Nguyen[1,2,4], Lam Xuan Anh Dao[1,2,4], Huynh Truc Phuong[2,4], Nguyen Van Dong[3,4], Cong Hao Le[1,2,4]*

[1]Nuclear Technique Laboratory, University of Science, Ho Chi Minh City, Vietnam

[2]Faculty of Physics and Engineering Physics, University of Science, Ho Chi Minh City, Vietnam

[3]Faculty of Chemistry, University of Science, Ho Chi Minh City, Vietnam

[4]Vietnam National University, Ho Chi Minh City, Vietnam

**E-mail address of the corresponding authors: nvthang@hcmus.edu.vn*

The Ra-226 activity concentrations in plants and corresponding soil samples collected in agricultural fields in Vietnam for analysis varied from 1.4 to 13.2 Bq/kg (dry weight) and 24.5 to 43.1 Bq/kg (dry weight), respectively. Some relationships were found between the soil-to-plant transfer factors of Ra-226 (TF) and the properties of soil. TF positively correlated with clay content in soil (Pearson correlation coefficient (r) = - 0.63) and organic matter in soil (r = - 0.60). A negative correlation was found between TF and activity concentrations of Ra-226 in porewater of soil (r = 0.66). For 7 studied plants, the soil-to-plant transfer factors of radium varied from 0.032 to 0.439 and in the order of tubers (average TF 0.358) > cereals (average TF 0.152) > vegetables (average TF 0.138) > fruits (average TF 0.048).

Simulation results of the WRF-Hydro model in the Niida River basin, Japan

Piotr Kopka[1], Maksym Gusyev[2], Alexandre Cauquoin[3], Maxim Sorokin[4], Mark Zheleznyak[2], Yoshifumi Wakiyama[2], Slawomir Potempski[1]*

[1]*National Center of Nuclear Research of Poland*

[2]*Institute of Environmental Radioactivity (IER), Fukushima University, Japan; *E-mail: maksymgusyev@gmail.com*

[3]*Institute of Industrial Science (IIS), the University of Tokyo, Kashiwa, Japan*

[4]*Institute of Mathematical Machine and System Problems, Kyiv, Ukraine*

This pilot study provides understanding of water cycle with radionuclides in the Niida River basin to be utilized in the future development of radionuclide transport modelling with the Weather Research and Forecasting (WRF)-Hydro modelling system, which is a widely applied open-source modelling tool coupling the WRF and terrestrial hydrological models [1]. The Niida River basin located about 40 km north of the Fukushima Daiichi Nuclear Power Plant (FDNPP) site was affected by the tritium (H-3) and cesium-137 (Cs-137) fallout of the FDNPP accident in March 2011 and had measurements of river water level, river discharge, sediments, and H-3 and Cs-137 radionuclides at Hiso, Wariki, and Haramachi monitoring sites. For the typhoon event on 20-24th September 2011, we utilized simulated H-3 in daily precipitation [2] with hourly H-3 measurement in river water [3] to separate overland and shallow groundwater components in the river discharge. For the Niida River basin, the WRF-Hydro model was setup with 0.01-degree gridded precipitation dataset of Japan and 0.25-degree gridded forcing data of the Global Land Data Assimilation System temperature, wind, pressure, humidity, and solar radiation. We also developed an automated procedure using statistical metrics of Nash-Sutcliffe Efficiency (NSE), Fractional Bias (FB), and Normalized Mean Squared Error (NMSE) to achieve good calibration of the WRF-Hydro simulated river discharge at hourly time step. Prior to the next step of radionuclide transport coding, it is necessary to understand the WRF-Hydro discharge generation processes and to improve the representation of groundwater flow component from the lumped bucket method in the current WRF-Hydro version. Despite the open-source code and scientific community support, the utilization of WRF-Hydro in river basins remains difficult requiring multiple skills for model setup, postprocessing results, and radionuclide transport evaluation.

References:

[1] Gochis, D.J., et al., (2018). The WRF-Hydro modeling system technical description (Version 5.0). NCAR Technical Note. 107 p., https://ral.ucar.edu/solutions/products/wrf-hydro-modeling-system

[2] Ueda, S., et al. (2015). Nuclear accident-derived ^{3}H in river water of Fukushima Prefecture during 2011-2014. *Journal of Environmental Radioactivity* 146: 102-109.

[3] Cauquoin, A., et al. (2024). Simulation of tritium releases into the atmosphere during the Fukushima accident and into the ocean due to planned discharge of treated water, EGU General Assembly 2024, Vienna, Austria, 14–19 Apr, EGU24-7089, https://doi.org/10.5194/egusphere-egu24-7089

The migration simulation of natural radionuclides in groundwater of Ghana with help of Comsol Multiphysics modelling program: a case study of the greater Accra region

Serwaa Adjei-Kyereme, Lordford Tettey-Larbi, Thomas Onumah, Esther Osei Akuo-ko, Edit Tóth-Bodrogi, Tibor Kovács, Amin Shahrokhi

Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

The study examined the potential migration of radionuclides from a borehole repository located approximately 20 km from the Akwapim fault line, an area known for its high seismic activity. It considered the possibility that seismic events could lead to the rejuvenation or initiation of fractures and faults, potentially causing container failure and the release of radionuclides. Using a two-dimensional finite element code (Comsol Multiphysics) and accounting for heterogeneities, a numerical model was employed to analyze the scenario. The results revealed that the fractured medium created preferential pathways, particularly through fault zones, for the potential migration of released radionuclides from the repository. Additionally, variations in hydraulic conductivity, influenced by the domain's heterogeneity, were found to significantly impact the direction of flow.

Improvement of gamma efficiency curves

András Kocsonya

Centre for Energy Research, environmental protection Service

The precise efficiency calibration of gamma-spectrometers is crucial for accurate quantitative radionuclide analysis. Although computational calibration is becoming more widely available, but due to its limitations the classical calibration with physical standards is still essential, either as starting point of computational calibration or to verify it experimentally. This lecture discusses that how to establish a reliable calibration curve with as many data points as possible and covering wide energy-range.

As the efficiency calibration curve is changing with energy in a variable manner. Therefore, to describe the energy dependence accurately, enough data points are needed. We discuss, how can we obtain as many data points as possible from measurement of standard radionuclide reference sources. How to manage the rapidly changing low energy-range when gamma-lines and X-ray lines are occurring in the spectra and these lines can overlap with each other. We also discuss the possibilities to extend the calibration curve to higher energies.

Additionally, to the absolute calibration curve measured on certified reference sources, we discuss the possibility to establish a relative calibration curve by natural uranium-ore sample in which the whole decay chain is present in secular equilibrium, providing many available gamma-emission lines. As extension of the calibration for point sources we discuss the calibration transfer for different geometries, as flat surfaces and volumetric sources.

General methodology for assessing the content of artificial radionuclides in livestock products produced in areas polluted by nuclear tests

Zhanat A. Baigazinov[1], Sergey N. Lukashenko[2], Nobert Kávási[3], Tibor Kovács[3]

[1] Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

[2]Russian Institute of Radiology and Agroecology, Obninsk, Russia

[3]Radioecology Unit, Fukushima Institute for Research, Education and Innovation, Fukushima, Japan

The Semipalatinsk Test Site (STS) in Kazakhstan, used for nuclear tests from 1949 to 1989, is now a significant source of environmental radioactivity, posing long-term health risks through contaminated livestock products. Following the site's closure, unauthorized agriculture, including livestock grazing, has continued in these regions. This study investigates the accumulation and transfer parameters of critical artificial radionuclides – Cs-137, Sr-90, Pu-239+240, and Am-241 -from contaminated soil, water, and feed into livestock and poultry products.

The research was conducted at two STS sites with animals exposed to various contaminated environmental elements. Experimental subjects included rams, horses (mares and yearlings), and broilers, which were exposed to radionuclide-contaminated feed, soil, and water. Key objectives included measuring radionuclide transfer rates and understanding their accumulation dynamics in different animal tissues.

Results indicate a marked variation in radionuclide transfer depending on age, species, and contamination source. In horses, younger animals demonstrated a significantly higher transfer of Cs-137 and Sr-90 than adults, and radionuclide presence was detected in fetal tissues, raising concerns over prenatal exposure. In rams, radionuclides Pu-239+240 and Am-241 showed the highest accumulation in liver tissue, while Cs-137 and Sr-90 accumulation varied by contamination source, with vegetation posing a greater transfer risk than soil.

For broilers, accumulation dynamics revealed differential tissue absorption rates, with muscle tissue showing lower levels of Am-241 compared to liver and bones. This study established transfer coefficients (Ff) and concentration ratios (CR) for poultry, providing critical data for dietary risk assessment.

These findings emphasize the importance of continuous monitoring of radionuclide levels in animal products, as well as the need for predictive models to assess potential health risks from contaminated food sources in STS areas. This research offers a framework for risk mitigation strategies and informs guidelines to protect public health from radionuclide exposure in agriculture. This study enhances understanding of radionuclide transfer mechanisms in radioecology, serving as a foundation for future investigations on environmental contamination and food safety.

Parametric description of HPGe detectors efficiency for measuring of shielded sample activity

Igor Pylypchynets, Alexander Lengyel, Oleg Parlag, Eugene Oleinikov, Vadym M. Holovey

Institute of Electron Physics, Ukrainian National Academy of Sciences,21, Universitetska St, Uzhgorod, 88017, Ukraine

e-mail: igor.profi@gmail.com

One of the essential tasks of environmental research is reliable gamma spectrometric measurements of highly active samples (for example, nuclear materials and their decay products) to analyze their isotopic and quantitative composition. Typically, these samples are kept in sealed stainless steel containers. The accuracy of spectrometric measurements depends on the accuracy of the HPGe detector calibration for energy efficiency, which must take into account corrections associated with the measurement geometry and the absorption and scattering of gamma radiation by the materials of the sealed containers (screens).

As a rule, empirical formulas for describing the absolute efficiency of detectors for cases of various geometric measurement conditions with and without absorbing screens, obtained from sets of experimental data using detectors, take into account geometric corrections and corrections associated with transmitting γ-radiation by absorbing screens.

The presented work proposes universal empirical formulas for describing the dependence of detector efficiency on energy for fixed values of the distance between the source of γ-radiation and the detector surface in the presence of absorbing screens of different thicknesses based on experimental studies.

The proposed parameterization, obtained based on experimental data, allows us to obtain numerical values of the HPGe detector's efficiency for a wide range of energies with absorbing screens of different thicknesses. It should be noted that parameterization allows one to obtain numerical efficiency values for a wide range of energies up to 3000 keV (i.e., energies whose values are greater than the values that ensure the use of standard calibration sources up to 1408 keV).

Based on the semi-empirical model describing the dependence of efficiency on energy at various fixed distances (detector surface - gamma radiation source), the computer program "NPMU Detector efficiency version 1.0.2301" was created. It can be used by a wide range of end users since it does not require the use of large computer resources.

The obtained parametric dependencies (on the thickness of the absorber at fixed distances: the surface of the detector - the source of gamma rays) were tested and experimentally confirmed on another detector. The results of the studies (parameterization and program) are necessary to provide technical regulations for γ-spectrometric measurements of highly active samples, which are in sealed stainless steel containers when analyzing their isotopic composition.

The practical value of the obtained results lies in the possibility of testing experimental data (efficiency for fixed energy values in the presence and absence of absorbing screens) for various types of detectors when carrying out gamma spectrometric measurements for applied applications.

Does desert sand have an effect on the concentration of Po-210 in aerosols in Hungary?

Edit Tóth-Bodrogi[1], Beatrix Jancsek-Turóczi[2], Máté Novák[1], Anita Csordás[1], Tibor Kovács[1]

[1]Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

[2]Air Chemistry Research Group, University of Pannonia, Veszprém, Hungary

Po-210 is a naturally occurring radionuclide, part of the decay chain of the isotope U-238. It is very mobile and can be found in both soil and air as a decay product of Rn-222, making it an excellent isotope for environmental monitoring.

The aim of the study was to determine the Po-210 activity concentrations of different aerosol samples collected from different parts of the Transdanubian region of Hungary. Our aim was to compare the results and to investigate possible anthropogenic effects on the concentration of the isotope in the samples.

An important aspect of the study was that the samples were taken before and after a heavy rainfall, which carried large amounts of desert sand from the Sahara. Therefore, in our study we compared the results of the two samplings to investigate the effect of sand on Po-210 concentrations.

We measured different fractions of the aerosol samples by alpha spectrometry. First, we used combined acid digestion for sample preparation and then spontaneous deposition for alpha source preparation. Alpha spectrometry was performed using a PIPS semiconductor detector.

The research was funded by the Sustainable Development and Technologies National Programme of the Hungarian Academy of Sciences (FFT NP FTA).

Investigation of uranium accumulation in Asian green mussels (Perna viridis) in Binh Thuan province

Van-Hao Duong[1], Thanh-Xuan Pham Thi[1], Tien Chu Trung[1], Anita Csordás[2], Csaba Gyöngyösi[2], Miklós Hegedűs[2], Tibor Kovács[2]

[1]*VNU School of Interdisciplinary Sciences and Arts, Vietnam National University, 144 Xuan Thuy, Cau Giay, Hanoi, 100000, Vietnam.*

[2]*Department of Radiochemistry and Radioecology, University of Pannonia, Veszprem, Hungary -*

**Corresponding email author: kovacs.tibor@mk.uni-pannon.hu*

The Binh Thuan province gives home to significant titanium placer deposits, titanium-zircon mixed deposits and zircon deposits located on its coast, the exploitation of which is raising ecological concerns, as well as a large nickel mine and off-shore oil and gas mining facilities. The Asian green mussel (Perna viridis) is not only an important food source in Asian countries, like Thailand, Indonesia, Philippine and Vietnam, but like other filter feeding bivalves, it is also a good bioindicator for heavy metal contamination. However, there is little information available on the radioecological status of the Binh Thuan coastal region, and on the uranium accumulation in green mussels. To assess the radioecological health of the region, uranium activity concentrations were determined by alpha spectrometry in the edible muscle tissue and hepatopancreatic organs of Perna viridis graded by shell size. The observed activity concentrations ranged between 1.4 and 53.2 Bq/kg for U-234 and 0.9 and 57.2 for U-238, decreasing rapidly with body size. Activity concentrations in large mussels were comparable to those reported in other countries without heavy industrial influence for the Mytilidae family. The calculated annual effective dose from the consumption of uranium in Asian green mussels in the area had an average value of 0.049 $\mu Sv.y^{-1}$, and a maximum of 0.193 $\mu Sv.y^{-1}$, which is within WHO and UNSCEAR recommendations.

Assessment of ^{226}Ra, ^{232}Th and ^{40}K and natural gamma radiation dose in Bathinda, Punjab (India): Insights from car-borne survey

Satoshi Ito[1], Kazumasa Inoue[1], Thennaarassan Natarajan[1], Sarata Kumar Sahoo[1], Satvir Singh[2], Bikramjit Singh Bajwa[2], Rakesh Chand Ramola[3]

[1]Tokyo Metropolitan University, Tokyo, Japan

[2]Guru Nanak Dev University, Punjab, India

[3]H.N.B. Garhwal University, Tehri Garhwal, India

Email id: congzhiyiteng@gmail.com

The shallow groundwaters of the Bathinda region in Punjab, India are known to contain abnormal high concentrations of uranium (U). The Quaternary alluvium (clay, silt, and sand) in the regional geology of Bathinda was formed through weathering of U-rich granitic rocks, which could significantly contribute to the high concentration of U in groundwater. Therefore, it is necessary to understand the distribution of the natural radionuclide U-238 (Ra-226) in the surface soils of Bathinda, along with the distribution of Th-232 and K-40, and the associated absorbed dose rate. The absorbed dose rate in air was directly measured by a car-borne survey using a NaI(Tl) scintillation spectrometer, ranging from 36 to 115 nGy h^{-1} with an average of 66 nGy h^{-1}. Based on the car-borne survey data, the estimated average annual indoor effective dose (IAED) and annual outdoor effective dose (OAED) were 0.32 mSv y^{-1} and 0.08 mSv y^{-1}, respectively. In this study, IAED and OAED was lower and slightly higher than the UNSCEAR world average values of 0.41 mSv y^{-1} and 0.07 mSv y^{-1}, respectively. The activity concentrations of Ra-226, Th-232, and K-40 in soil samples were measured using gamma spectroscopy equipped with a high purity germanium (HPGe) detector, yielding averages of 41 Bq kg^{-1}, 64 Bq kg^{-1}, and 220 Bq kg^{-1}, respectively. The average radium equivalent activity (Ra_{eq}) in the soil samples was 150 Bq kg^{-1}, which is lower than the world average value of 370 Bq kg^{-1} reported by the Organization for Economic Cooperation and Development (OECD). Despite slightly higher activity concentrations of Ra-226 and Th-232, the estimated radiological hazard parameters were found to be lower than the UNSCEAR world average values.

Preliminary investigation of Po-210 and heavy metals in cigarettes sold in Kazakhstan

*Miklós Hegedűs[1], Juzsakova Tatjána[2], Svetlana Zh. Kuzhamberdieva[3], Bakhytbek B. Abzhalelov[3], Máté Novák[1], Gergely Tóth[1], Edit Tóth-Bodrogi[1], Tibor Kovács[1]**

[1]Department of Radiochemistry and Radioecology, University of Pannonia, Veszprem, Hungary

[2]Sustainability Solutions Research Lab, University of Pannonia, Veszprem, Hungary

[3]Korkyt Ata Kyzylorda University, Kyzylorda, Kazakhstan

Corresponding email author: kovacs.tibor@mk.uni-pannon.hu

Smoking various tobacco products is a well-known lung cancer risk, with cigarettes containing risk factors such as natural radioactive isotopes and heavy metals. Kazakhstan has a tobacco consumption rate close to the world average, 20% of the population smokes, with tobacco use reaching 36.5% amongst men [1]. Despite its importance for public health, there are relatively few studies on the radionuclide content of cigarettes sold in Kazakhstan, with some data available for Pb-210 content [2], showing levels comparable to previously reported in Hungary [3].

To better evaluate the risk posed to the local population Po-210 concentrations were measured with alpha-spectrometry and heavy metal concentrations (As, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sn and Zn) were determined by ICP-OES measurement in 5 different brands of cigarettes commercially available in Kazakhstan.

As, Cu, Mo, Se and Sn were not detected in the evaluated samples, while Cd ranged between 0.5-1.4 mg/kg, Co 0.5 and 1.0 mg/kg, Fe 540-1444 mg/kg, Mn 135-213 mg/kg, Ni 0.2-1.5 mg/kg, and Zn 24 – 33 mg/kg, while Pb concentrations up to 0.7 mg/kg were measured. Observed Po-210 concentrations and the resulting risks from smoking were comparable to values reported for Hungary and other countries.

References:

[1] Glushkova et al. (2023). Prevalence of Smoking Various Tobacco Types in the Kazakhstani Adult Population in 2021: A Cross-Sectional Study *International Journal of Environmental Research and Public Health* 20:1509 doi: 10.3390/ijerph20021509

[2] Zaripova et al. (2024). The activity of ^{210}Pb in cigarette smoked in Kazakhstan *Radiation and Environmental Biophysics* 63:125–131 doi:10.1007/s00411-023-01048-x

[3] Kovács et al. (2007). Po-210 and ^{210}Pb concentration of cigarettes traded in Hungary and their estimated dose contribution due to smoking Radiation Measurements 42:1737-1741 doi:10.1016/j.radmeas.2007.07.006

Influence of the physical characteristics of soil samples on radon exhalation rate

Anita Csordás, Edit Tóth-Bodrogi, Miklós Hegedűs, Gergel Tóth, Máté Novák, Tibor Kovács

Department of Radiochemistry and Radioecology, University of Pannonia, Veszprém, Hungary

The natural background radiation is from outside the Earth (cosmic radiation) and from terrestrial radioactive isotopes on Earth. Terrestrial radionuclides can cause external exposure or internal exposure via ingestion and inhalation of these isotopes. One of the most significant sources of external radiation is soil, where the most important isotopes are the member of U-238, U-235 and Th-232 decay chains and K-40.

The samples can be divided into various soil types and therefore have a large range of physical and chemical characteristics. These properties can affect the transport and accumulation of radionuclides in different soil layers.

The soil samples were collected from the Transdanubian region (Hungary). The samples were analysed by HPGe gamma spectrometry to determine the Th-232, Ra-226, K-40 and Cs-137 concentration. The radon exhalation capacity of the soil was measured by closed accumulation technique using AlphaGUARD radon monitor. In addition to the radiological measurements, physical and chemical properties of the samples were determined.

The aim of the study is to investigate the influence of the physical characteristics of soil samples on radon exhalation rate.

Funded by the Research Fellowship Programme (Code: 2024-2.1.1-EKÖP) of Ministry of Culture and Innovation from the National Fund for Research, Development and Innovation

Tracking the influence of the Núi Pháo Masan Mine on the surrounding area by Po-210 measurements in aerosol

*Van-Hao Duong[1], Tien Chu Trung[1], Thanh-Xuan Pham Thi[1], Miklós Hegedűs[2], Gergely Tóth[2], Tibor Kovács[2]**

[1]*VNU School of Interdisciplinary Sciences and Arts, Vietnam National University, 144 Xuan Thuy, Cau Giay, Hanoi, 100000, Vietnam.*

[2]*Department of Radiochemistry and Radioecology, University of Pannonia, Veszprem, Hungary*

**Corresponding email author: kovacs.tibor@mk.uni-pannon.hu*

Natural and industrial sources can significantly influence the radioisotope content of aerosols. In Vietnam, one of the potential sources of radioisotope bearing dust emissions is the Núi Pháo Masan Mine complex, which is a polymetallic mine with ore processing and waste rock disposal facilities, and one of the world's major source of tungsten. To determine the potential impact of the mine to the area Po-210 activity concentrations were determined from samples taken at 34 different sampling points in the mine and the surrounding residential areas by alpha spectrometry. The observed 210Po activity showed some dependence with the distance from the facility, with the observed values ranging from 18.1 to 1950 μBq/m3 with a mean of 160 μBq/m3. The elevated 210Po were mostly limited the 1 km vicinity of the factory. The results suggest, that the transport of dust from the mine are limited due to the climate and topography of the area, but the mineral processing increases air 210Po concentrations, causing elevated 210Po levels in aerosols for local residents and especially factory workers.

Identification of possible contributors to the radioecological situation around the Soumalkol settlement as a result of uranium mining at the Grachevskoye deposit

Sergey Borisovich Subbotin, Pavel Ye. Krivitskiy, Natalya V. Larionova, Almira K. Aidarkhanova, Ainur S. Mamyrbayeva, Zh. Ye. Tleukanova, I.A. Aleksandrovich, M.V. Skripnikov, I.A. Bachurina, R.G. Yermakova.

Branch office 'Institute of Radiation Safety and Ecology' of RSE; NNC RK', Kurchatov, Kazakhstan,
e-mail: Subbotin@nnc.kz

The development of uranium deposits within the Republic of Kazakhstan began in the 1940-50s of XX century. Uranium mining in Kazakhstan annually increases. In 2009, Kazakhstan became the world's top in uranium mining. To provide power safeguards for the Republic of Kazakhstan, a decision was made to construct and commission a nuclear power plant. In this regard, the study of the behavior of radionuclides in the environment became particularly important to our country.

As part of this paper, the processes of radionuclide entry from the mothballed uranium mining facility (MUMF) Grachevskoye into the Soumalkol settlement were studied. The uranium deposit Grachevskoye, as administratively divided, is located in the North Kazakhstan region. Uranium at the deposit was mined underground from the late 1960s to the early 1970s of the past century. Next, ore was partly dressed by heap leaching after which it was transported in containers by rail to the Stepnogorsk mining and smelting plant. Changes in conditions that followed with respect to uranium raw materials lead to uranium mining curtailing and mothballing in the North Kazakhstan.

The Soumalkol settlement is a regional center located 5 km away southeast of MUMF Grachevskoye. To evaluate a possible entry of radionuclides from the Grachevskoye deposit into the settlement territory, the following potential pathways were studied: via the ambient air, contamination due to ore transportation by motor vehicles and rail, the entry of contaminated ground waters from locations of mine workings into ground waters of the settlement.

The pattern of radionuclide transport by ambient air was studied in the warm season by pumping the air through the filter at points in the vicinity of the Grachevskoye deposit and Soumalkol settlement. In vitro analyses demonstrated that uranium concentration in the ambient air is at the level of extreme low values from 1.6×10^{-4} to 3.0×10^{-4} Bq/kg, which is two orders of magnitude lower than the permissible annual average volumetric activity set by health standards. In summary, the transport of radionuclides by ambient air could not have essentially affected the progression of the radioecological situation around the settlement.

The contamination pattern of the settlement area as a result of ore transportation from the mine premises by motor vehicles and rail was studied by measuring EDR at fixed points. EDR measurements were performed on the premises of MUMF Grachevskoye, in the settlement and on the premises of the building material open pit, which is on the northern edge of the settlement. EDR measurements on the open pit premises and around the settlement showed that EDR values range from 0.09 to 0.8 μSv/h with the background specific to this terrain – 0.09 μSv/h. Gamma field outliers were noted within the construction open pit and at 4 local spots in the settlement. To assess the nature of anomalous sites within the settlement, the EDR distribution pattern at these sites was analyzed. EDR measurements were plotted on the graph, which was analyzed and showed that the EDR distribution pattern in the settlement is bimodal. The left mode corresponds to the background values of the region and the right one matches the EDR distribution mode at the construction open pit. EDR values within

MUMF range from 0.13 to 14 μSv/h. The presented preliminary data indicates that local spots in the settlement are attributed to the utilization of the open pit crushed rock during building operations.

The possibility of ground water contamination was assessed by carrying out in vitro analyses of water samples from water bodies of the Soumalkol settlement. The thing is that according to hydrogeological conditions ground waters in this area move southward and southeastward, i.e. from the locations of mine workings at the MUMF Grachevskoye toward Soumalkol. According to in vitro analyses, uranium concentration in wells of the settlement is at the level of 20 μg/l. Uranium concentration in the tap water reaches 240 μg/l, which is 16 times the maximum permissible concentration (15 μg/l). At the same time, values of the gross alpha-activity reach 8.0 Bq/l, which is 40 times the level set by health standards.

In summary, ground water contamination due to uranium mining at the Grachevskoye deposit is one of the major contributors to the radioecological situation around the Soumalkol settlement.

Comparison of radiometric techniques and ICP-MS determination of Ra-226 in water samples

Ivana Coha[1,2], Norbert Kávási[1,3], Leja Rovan[1], Ivana Tucaković[2], Marko Štrok[1]

[1]Department of Environmental Sciences, Jožef Stefan Institute, Ljubljana, Slovenia

[2]Laboratory for Radioecology, Division for Marine and Environmental Research, Ruđer Bošković Institute, Zagreb, Croatia

[3]Radioecology Unit, Fukushima Institute for Research, Education and Innovation, Fukushima, Japan

Radium-226 ($t_{1/2}$=1600 years) is one of the most widespread alpha-emitters present in environmental samples. Assessing the activity concentration of Ra-226 is essential for determining its potential impact on internal radiation dose. Since Ra-226 emits both, alpha particles and gamma radiation, it can be determined in water samples by alpha-particle spectrometry, liquid scintillation counting (LSC), the sorption-emanation technique and gamma-ray spectrometry. Recently, a novel method was developed for the determination of Ra-226 in water samples using ICP-QQQ-MS. The sample preparation process is straightforward and quick. If not at the sampling site, samples should be filtered and acidified to 2% nitric acid. Two parallel samples are then prepared: one spiked with a known activity concentration of Ra-226 and another with an equivalent volume of 2% nitric acid to ensure match of the matrix conditions in both samples. This simple addition procedure helps to overcome matrix effects that can either increase or decrease the m/z 226 signal, depending on the content of macro and trace elements in the sample. The method was validated through participation in an IAEA proficiency test exercise. Notably, this was likely the first time an ICP-MS method met the accuracy and precision criteria for such a proficiency test.

Ra-226 was further determined in environmental samples from closed uranium mine Žirovski Vrh using both ICP-QQQ-MS and alpha spectrometry. The performance metrics of both techniques were evaluated and compared, emphasizing the strengths and potential limitations of each approach. This comprehensive comparison underscores the evolving role of mass spectrometry in advancing radionuclide analysis and its potential to complement and enhance existing radiometric techniques.

Acknowledgements:

This work was supported in part by the Croatian Science Foundation under the project number HRZZ-MOBODL-23-08-3540, the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 101003359, the Slovenian Research and Innovation Agency programme P2 0075 and the project 21GRD09 MetroPOEM.

Estimation of the unattached fraction of radon progeny and its contribution to the annual effective dose in Hungarian workplaces

Biljana Vučković[1], Norbert Kávási[2], Ljiljana Gulan[1], Janja Vaupotič[3], Tibor Kovács[4]

[1]Faculty of Sciences and Mathematics, University of Priština in Kosovska Mitrovica, Kosovska Mitrovica, Serbia

[2]Radioecology Unit, Fukushima Institute for Research, Education and Innovation, Fukushima, Japan

[3]Department of Environmental Sciences, Jožef Stefan Institute, Ljubljana, Slovenia

[4]Department of Radiochemistry and Radioecology, University of Pannonia, Veszprem, Hungary

Exposure to radon and its progeny was investigated in five different workplaces in Hungary: tourist and hospital caves, a manganese mine, a radioactive waste repository site, and a radon bath. In the first step, measurements of radon and its progeny were conducted, with a focus on the unattached fraction (f_{un}) of radon progeny, the key parameter in radon dosimetry. In the second step, annual effective doses were estimated for periods when a large number of both professional staff and visitors/patients were present at the locations. It was found that f_{un} varies over a wide range, from 0.05 to 0.31, significantly affecting the annual effective doses. The annual effective dose for professional staff during working hours ranged from 0.2 mSv y^{-1} to 49 mSv y^{-1}, while for visitors/patients, the annual effective dose per hour of exposure ranged from 0.1 μSv y^{-1} to 37 μSv y^{-1}. The results show certain deviations from the recommended values from current epidemiological studies and legal regulations (ICRP-137, 2017; EURATOM/59/2013).

Self-healing ability and radiological assessment of fly ash concrete system

Goran Markovski[1], Toni Arangjelovski[1], Marko Gjorgjioski[1], Goce Prangovski[2], Aleksandar Zurovski[3], Jovan Janusheski[4], Emilija Fidanchevski[5]

[1]Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering Skopje, R.N. Macedonia

[2]Civil Engineering Institute Macedonia, Skopje, R.N. Macedonia

[3]Ss. Cyril and Methodius University in Skopje, Institute for earthquake engineering and engineering seismology, Skopje, R.N.Macedonia

[4]Institute of Public Health of the Republic of North Macedonia, Skopje, R.N. Macedonia

[5]Ss. Cyril and Methodius University in Skopje, Skopje, R.N. Macedonia

Climate change has a major impact on concrete structures through increasing rates of severe deterioration mechanisms which question the durability of concrete. Concrete exhibits diverse types of cracks during service life of concrete structures and its origin comes from: plastic shrinkage, chemical shrinkage, autogenous shrinkage, drying shrinkage, thermal shrinkage (weathering cracks) and mechanical cracks due to loads on the structure. Meanwhile manufacturing ordinary Portland cement is the main provider of emitted greenhouse gases in the atmosphere up to 6-7% of total CO_2 emissions.

The substitution of cement content in concrete with certain amount of cement supplementary materials presents the one of approaches for CO_2 reduction. This research investigates the self-healing ability of fly ash cement concrete in which part of cement content has been replaced with 16% of mechanically activated fly ash. Because of prolong hydration of fly ash after 28 days, fly ash modifies the microstructure of the concrete, seal cracks and enhanced the serviceability of concrete structures. In addition, the influence of adding 1% of crystalline admixture was studied. Compressive strength and self-healing and self-healing efficiency were evaluated. Fly ash cement-concrete system has an increased compressive strength of 15% compared to ordinary cement-concrete system with same workability of concretes. But both concretes have the same coefficient of self-healing efficiency 45,2%.

A radiological analysis of mechanically activated fly ash and concrete samples was performed, with determination of the activity concentration of Ra-226, Th-232 and K-40 using gamma ray spectrometry analysis. The radiological assessment was made by calculating the dose assessment of the examined samples through the gamma index, Radium equivalent activity, External and internal hazard index, External and internal absorbed gamma dose rate and Annual effective dose for the indoor occupancy. Mechanically activated fly ash has been shown to have higher values in terms of radiological characteristics as a raw material but has no adverse effect when used in certain amounts (16 wt.%) in concrete.

Radon-222 diffusion in sediment-water interface and it's effect under Pb-210 dating method

Adrienn Németi[1], János Korponai[3], Enikő Katalin Magyari[4], Róbert-Csaba Begy[1,2]

[1]Faculty of Environmental Science and Engineering, "Babeş-Bolyai" University, Cluj-Napoca, Romania

[2]Interdisciplinary Research Institute on Bio-Nano-Science, "Babeş-Bolyai" University, Cluj-Napoca, Romania

[3]National University of Public Service, Baja, Hungary

[4]Department of Environmental and Landscape Geography at Eötös Lóránd University, Budapest, Hungary

The radiochronology method used to study changes in lake ecosystems over the last 150 years is based on the Pb-210 isotope. When applying the method, the measurable change in the concentration of Pb-210 that has fallen from the atmosphere into the sediment indicates the age of the sediment layers (excess Pb-210). The sediment also contains Ra-226, which, during its decay, generates in situ Pb-210 over time. This is only valid if the system is considered closed and we assume that the intermediate gas phase element of the decomposition, Rn-222, does not leave the sediment layers. This assumption is almost true for systems characterized by rapid sediment formation since the diffusion length from the pore space is short. Thus, only the uppermost centimeter is where the effect can be detected, and this does not significantly influence the dating results. However, if sediment formation is slow and the sediment is rich in organic matter, the system cannot be considered closed from the perspective of gas outflow.

The present work examines this problem in the sediment of Lake Balaton (Hungary), where the atmospheric Pb-210 concentration follows an exponential decrease, but the Ra-226 concentration is higher than the presumably generated in situ Pb-210 concentration. Our hypothesis is that radon-222 gas escapes from the system, causing erroneous dating results. This was investigated by measuring the radon gas concentration in pore water. The radon concentration in pore water clearly shows that a significant portion of radon escapes from the upper sediment layers, creating an imbalance. Therefore, the sediment cannot be considered a closed system for radon gas in the case of Lake Balaton sediments.

The distribution of radionuclides in the sediment indicates that the Ra-226 content is quite elevated, ranging between 25 and 55 Bq/kg. If this elevated Ra-226 concentration is considered as in situ produced Pb-210 and subtracted from the total lead content, the dating would be restricted to the upper 10 cm of the sediment. This would imply that 150 years of sediment accumulation is compressed into just 10 cm, which is an unrealistically small value (based on unpublished data). Therefore, to construct the age model, a different value for in situ produced Pb-210 needs to be used.

The examination of radon-222 concentration in pore water revealed a significant radon loss in the upper 30 cm of the sediment column, with values between 3 ± 0.2 and 37 ± 4 Bq/l. This is due to the high porosity (70-90%) and low sedimentation rate. The radon loss and transport can be described using a multivariable differential equation. The pore water radon studies were conducted on two separate sediment columns.

Through this research, it was proven that pore water studies are crucial for Pb-210 dating in cases where sedimentation rates are very low and when the porosity of the sediment accumulated in the upper layers over the past 150 years is very high.

Comparative studies of radiocaesium in selected Japanese prefectures wild vegetables from the viewpoint of Fukushima Daiichi Nuclear Power Plant accident

Shinzo Kimura[1], Hitoshi Sato[2], Toshimi Matsumoto[3], Mykhailo Buzynnyi[4], Toshihiro Takatsuji[1,5], Norbert Kávási[6]

[1]Fukushima Branch of the International Epidemiology Laboratory, Dokkyo Medical University, 2-69 Wakamiya, Nihonmatsu-city, Fukushima 964-0906, Japan, abshinz@gmail.com

[2]Ibaraki Prefectural University of Health Sciences, 4669-2 Ami, Ami-machi, Inashiki-gun, Ibaraki 300-0394, Japan, ipu.sato@gmail.com

[3]nihonmatsu.basecamp@gmail.com

[4]State Institution The Marzieiev Institute of Public Health NAMS of Ukraine, 50 Hetman Pavlo Polubotka (former Popudrenko) Street, Kyiv, 02094, Ukraine, michael.buzinny@gmail.com

[5]Nagasaki University, 1-14 Bunkyo, Nagasaki City 852-8521, Japan, delbosianquarts771@yahoo.co.jp

[6]Radioecology Unit, Fukushima Institute for Research, Education and Innovation 1 Hikarigaoka, Fukushima-city, Fukushima 960-1295, Japan, norbert.kavasi@gmail.com

A systematic study was undertaken for consecutive three years and results of radiocaesium (Cs-137, Cs-134) contamination will be presented in wild vegetables from Tohoku prefectures (Akita, Aomori, Fukushima, Iwate, Miyagi, Yamagata) and neighbouring five prefectures e.g. Gunma, Ibaraki, Nagano, Niigata and Tochigi. However, there will be a full-scale investigation of five years. The wild vegetables were collected on market-basket method from food stores. Location is marked on food products in Japan.

Samples were dried and placed in U8 standard plastic containers. Concentration of Cs-137 and Cs-134 were measured with a germanium detector (Ortec GMX30) gamma spectroscopy. The detection efficiency was determined using mixed large volume calibration standards sealed in the same container (Isotope products laboratories EG-ML) containing radionuclides of Cd-109, Co-57, Ce-139, Cr-51, Sr-85, Cs-137, Mn-54, Y-88 and Co-60, the uncertainty of the activities was certified less than 5%. Most samples were measured for 8 hours, but some samples were measured for longer hours to improve the accuracy of the measurements.

The Ministry of Health, Labour, and Welfare (MHLW) Japan on its website provides information about radionuclides in food products. The accepted value for radioactive caesium (Cs-137) in food products should be below 100 Bq/kg however for infants it is set at 50 Bq/kg to avoid exposure risk.

Results of Cs-137 in a few wild vegetables collected from Fukushima, Iwate, Miyagi and Yamagata Prefectures were more than 100 Bq/kg, even 13 years after the nuclear accident. During the investigation, it was noticed that harvest affected due to weather conditions. Half-life of radioactive caesium in wild vegetables change under the influence of weather conditions

Testing of new detection techniques for Pb-210 and Po-210 laboratory measurements

Máté Novák, Dániel Vincze, Edit Tóth-Bodrogi, Anita Csordás, Tibor Kovács

Department of Radiochemistry and Radioecology, University of Pannonia, Hungary

Both Pb-210 and Po-210 are naturally occurring radionuclides, part of the U-238 isotope's decay chain. Both radionuclides are very useful for environmental monitoring besides the fact that higher activity concentrations in nature may pose a health risk to the public, therefore monitoring is important. Our goal was to improve the currently implemented practices in our department's laboratory for the two isotopes. Since most of the sample preparation methods in the literature allow the determination of the radionuclides side by side, we started along this line.

For the Po-210, which is one of the most measured isotopes in our environmental laboratory, our main goal was to improve our sample preparation duration, (currently it is a several days long practice), to a couple of hours. After sample preparation, the polonium is deposited spontaneously on a nickel containing steel plate surface from the stock solution prepared after exploration. The prepared source was measured by semiconductor (PIPS) detector alpha spectrometry.

In our department, Pb-210 is determined by measuring Po-210. After source preparation, the polonium-free stock solution is set aside and allowed to reach secular equilibrium between the two isotopes which takes approximately 1 year. A Po-210 source is then prepared again from the solution, from which the Pb-210 concentration can be determined. For lead, our aim is therefore to implement a direct method, with liquids scintillation counting (LSC), where the Pb-210 isotope is separated directly from the sample.

Radiological assessment of soil samples from Transdanubia, Hungary

Dániel Vincze, Máté Novák, Edit Tóth-Bodrogi, Anita Csordás, Tibor Kovács

Department of Radiochemistry and Radioecology, University of Pannonia, Hungary

Most of the natural background radiation comes from crustal origins. The most commonly occurring radionuclides are part of the uranium-238 decay chain. The goal of our study was to carry out a radiological assessment of a smaller part of the Transdanubian region from Hungary, to investigate possible radiation hotspots, which can be strongly beneficial to identify possible health risk situations too for the population. We collected 20 soil samples from uncultivated spots in populated settlements.

Th-232, Ra-226 and K-40 activity concentrations were measured by gamma-spectrometry with an ORTEC HPGe semi-conductor detector. We also determined the massic radon exhalation rates and emanation factors of the samples with an AlphaGUARD radon detector, using an accumulation chamber.

We also selected 3 soil samples, to carry out Po-210 and Pb-210 measurements. The sample preparations were carried out by combinated acidic digestion. We used Sr-resin columns for isotope separation with HCl and HNO_3. After preparations, the Po-210 activity concentrations were measured by alpha spectrometry with a semiconductor PIPS detector. The Pb-210 activities were measured by liquid scintillation counting (LSC) with a Perkin Elmer Tricarb 3170TR detector.

How the biomonitoring indicators can be used as a management tool in contaminated sites: case study earth worms

Amin Shahrokhi, Tuvshinsaikhan Ganbaatar, Serwaa Adjei-Kyereme, Lordford Tettey-Larbi, Thomas Onumah, Esther Osei Akuo-ko, Edit Tóth-Bodrogi, Tibor Kovács

Department of Radiochemistry and Radioecology, University of Pannonia, Hungary

Biomonitoring, the use of living organisms to assess environmental pollution and ecosystem health, is a key tool in managing contaminated sites. Earthworms, due to their sensitivity to soil pollutants and role in ecosystem functions, are frequently employed as biomonitors. They offer early detection of contamination, help assess soil health and provide insights into the effectiveness of remediation efforts. Earthworms can detect pollutants such as heavy metals, pesticides, and hydrocarbons, and their population dynamics, such as mortality, reproduction, and biomass, can indicate soil degradation. They are also valuable in monitoring remediation progress, with their recovery often signaling successful cleanup. Additionally, earthworm-based biomonitoring is relatively low-cost and easy to implement. However, several limitations affect the accuracy and applicability of earthworms as biomarkers. Species-specific responses to contaminants, environmental variables like temperature and moisture, and slow recovery after severe contamination complicate their use. Earthworms are primarily indicators of soil health, limiting their ability to assess contamination in other environmental compartments. Moreover, external factors such as predation or habitat changes can confound results, requiring careful interpretation. Despite these challenges, when integrated with other monitoring techniques, earthworms remain a useful, cost-effective tool for environmental management, offering valuable data for assessing contamination and guiding remediation strategies.

Rare earth element geochemistry of spring waters from Garhwal Himalaya: Tracing sources and hydrodynamic processes

Thennaarassan Natarajan[1], Sarata Kumar Sahoo[1], Kazumasa Inoue[1], Nimelan Veerasamy[1,2], Sara Sakr[1], Norbert Kávási[3], Abhishek Joshi[4], Rakesh Chand Ramola[4]

[1]Tokyo Metropolitan University, Tokyo, Japan

[2]Queens University, Kingston, Canada

[3]Fukushima Institute for Research, Education and Innovation, Fukushima, Japan

[4]HNB Garhwal University, Tehri Garhwal 249-199, India

Email: nthennarassan@gmail.com

Rare earth element (REE) patterns in groundwater arise from complex interactions between water and rocks, providing valuable insights into tracing their source. Fresh groundwater from springs serves various purposes, including drinking and agriculture. In the Tehri Garhwal (TG) region, where natural springs are the primary drinking water source, the dynamics and geochemical behaviour of REEs in these spring waters were thoroughly investigated and reported in this study. The total REE concentrations ranged from 16.25 to 296.61 ng L^{-1}, with most samples exhibiting a shale-normalized REE pattern enriched in heavy rare earth elements (HREEs). While the majority of samples displayed a negative Ce anomaly, indicative of oxic conditions supported by redox-sensitive elements (RSTEs) such as Fe, Mn, and U, a few samples showed contrasting behaviour. The slight negative Ce anomaly observed in these spring waters, along with elevated Fe and U concentrations, suggested a reducing condition influenced by water-rock interactions. Soil samples collected from different geological groups in the TG region provided further insights into the behaviour of soil's REEs and RSTEs. Analysis revealed that REEs, Th, and U, along with other trace elements, helped distinguish the source and redox conditions of TG soil samples. The soil and shale-normalized REE patterns of spring water samples exhibited considerable similarity, suggesting the potential use of soil REE compositions for normalizing TG spring waters. The REE patterns of spring waters from single geological formations further aided in understanding groundwater mixing from different sources, supported by a tri plot analysis utilizing light, middle, and heavy REEs.

Development and testing of polymer-encapsulated, amine-functionalized iron-based contrast materials in animal model

Fatemeh Heydari[1,3], László Forgách[1,3], Zoltán Varga[1,2], Noémi Kovács[1,3], Ildikó Horváth[1,3], Ágnes Mária Ilosvai[4,5], Ferenc Kristály[6], Lajos Daróczi[7], Zoltán Kaleta[8,9], Béla Viskolcz[4,5], Miklós Nagy[4], László Vanyorek[4], Domokos Máthé[1,3], Krisztián Szigeti[1]

[1]*Dept. Biophysics and Radiation Biology, Semmelweis University, Budapest, Hungary*

[2]*Research Center for Natural Sciences, ELKH, Budapest, Hungary*

[3]*In Vivo Imaging ACF, Hungarian Center of Excellence for Molecular Medicine, Szeged, Hungary*

[4]*Institute of Chemistry, University of Miskolc, 3515 Miskolc, Hungary*

[5]*Higher Education and Industrial Cooperation Centre, University of Miskolc, 3515 Miskolc, Hungary*

[6]*Institute of Mineralogy and Geology, University of Miskolc, 3515 Miskolc, Hungary*

[7]*Department of Solid State Physics, University of Debrecen, P.O. Box 2, 4010 Debrecen, Hungary*

[8]*Institute of Organic Chemistry, Semmelweis University, 1092 Budapest, Hungary*

[9]*Pro-Research Laboratory, Progressio Engineering Bureau Ltd., 8000 Szekesfehervar, Hungary*

Magnetic nanoparticles (NPs), particularly superparamagnetic variants such as magnetite, maghemite, and various ferrite NPs, emerge as promising alternatives to traditional Magnetic Resonance Imaging (MRI) contrast agents (CAs). Their heightened specificity and biocompatibility make them attractive candidates [1,2]. The escalating demand for stable and precisely tuned magnetic NPs in biomedical applications highlights their significance. However, the preparation of these NPs remains a persistent challenge.

Two different solvothermal methods (12 h reflux and a 4 min microwave, MW) were used to synthesize amine-functionalized ferrite, superparamagnetic NPs, doped with Zn^{2+} and Cu^{2+} ions. To overcome stability problems in the colloidal phase, the ferrite NPs were embedded in polyvinylpyrrolidone and could be easily redispersed in water.

The morphological characterization of the NPs was executed by High Resolution Transmission Electron Microscopy, Atomic Force Microscopy (AFM) and Dynamic Light Scattering (DLS). For detecting the supramolecular interactions and crystalline structure, Fourier Transform Infrared Spectroscopy and X-ray Powder Diffraction was utilized. The in vitro and in vivo MRI measurements were performed with a PET/MR system (Mediso, Budapest, Hungary).

In case of the Zn-doped NPs, the conventional solvothermal synthesis ($ZnFe_2O_4$-NH_2 Refl.) resulted in a more stable system as compared to the microwave-assisted synthesis ($ZnFe_2O_4$-NH_2 MW). These results were supported by DLS and AFM measurements, as well as in vitro MRI measurements, where inhomogeneities in the signal were detected.

The $CuFe_2O_4$-NH_2 MW samples however showed increased colloidal stability as well as homogenous MRI signal in vitro and in vivo. After injection, consistent with other SPION NPs, both samples exhibit a concentrated presence in the hepatic region of the animals, with comparable biodistribution and pharmacokinetics suspected.

Our investigation shows that the ferrite NPs are a feasible candidate for a new generational, multimodal MRI CA. Their chemical properties, owning an -NH_2 group holds great options for surface

modifications with chelators for isotopes or fluorescent pigments for multimodal molecular imaging purposes. It must be highlighted that the preparation method as well as the nature of the applied precursors play a crucial role in the synthesis of a stable system.

References:

1. Vallabani, N.V.S.; Singh, S. Recent Advances and Future Prospects of Iron Oxide Nanoparticles in Biomedicine and Diagnostics. 3 Biotech 2018, 8, 279.
2. Nasrin, S.; Chowdhury, F.U.Z.; Moazzam Hossen, M.; Islam, A.; Kumar, A.; Manjura Hoque, S. Study of the Suitability of Manganese-Substituted Cobalt Ferrites Nanoparticles as MRI Contrast Agent and Treatment by Employing Hyperthermia Temperature. J. Magn. Magn. Mater. 2022, 564, 170065.

Development, in vitro characterization & in vivo testing of multimodal Prussian Blue nanoparticles in an animal model

László Forgách[1,3], Nikolett Hegedűs[1], Zoltán Varga[1,2], Noémi Kovács[1,3], Ildikó Horváth[1,3], Krisztián Szigeti[1], Domokos Máthé[1,3]

[1]*Dept. Biophysics and Radiation Biology, Semmelweis University, Budapest, Hungary*

[2]*Research Center for Natural Sciences, ELKH, Budapest, Hungary*

[3]*In Vivo Imaging ACF, Hungarian Center of Excellence for Molecular Medicine, Szeged, Hungary*

The most commonly used Gd (III) materials lack the in vivo stability, causing toxic side-effects for the patiens; materials other than Gd (III) available lack the required in vivo contrast for the Magneti Resonance Imaging (MRI).

A possible candidate for high performance MRI contrast materials could be the FDA authorized Prussian blue (PB), which is used to treat heavy metal poisoning since 2003. Its unique structure allows the control of size, shape and biocompatibility, nevertheless, non-functionalized PBNPs show less significant T1 and T2 signal changes in vitro; their measured longitudinal and transversal relaxation times did not suggest their in vivo use. Therefore, functionalizing PBNPs, to achieve multimodal contrast would highly increase their impact for preclinical applications, thus in the routine procedures MRI is oftentimes coupled with other modalities providing greater functional contrast.

Native PBNPs were synthesized according to as described by Shokouhimehr, with modifications. For citrate coated PBNPs, the process as described by Shokouhimehr was applied. A two-step PBNP preparation was made.

The fluorescent labelling of PBNPs was conducted using Eosine Y, Rhodamine B and Methylene Blue (MB) that adsorbed onto the particle surface. For near infrared (NIR) fluorescent labelling, IR820 was used. For particle characterization, Dynamic Light Scattering (DLS), Atomic Force Microscopy (AFM) and Transmission Electron Microscopy (TEM) was used.

The in vitro and in vivo imaging was performed using a nanoScan® PET/MR system with a 1T permanent magnetic field, and a Fluorescence-labeled Organism Bioimaging Instrument (FOBI) for the fluorescent measurements.

Polyethylene glycol (PEG) stabilization was required for the fluorescent labelling of the PBNPs. Only MB conjugated PBNPs demonstrated promising in vitro stability and fluorescence. In vivo, the particles accumulated in the liver, spleen and gastrointestinal tract.

For the NIR labelling, IR820 was successfully adsorbed onto the surface, facilitated by the porous nanoparticle surface. The particles showed similar characteristics in vivo, as compared to the MB labelled PBNPs. The in vivo MRI measurements confirmed the presence of the particles in the thoracic region and the liver.

This study demonstrates the synthesis and modification of biocompatible, stealth, fluorescent, and MRI-contrast-capable MB- and IR820-labeled PBNPs. The nano-system, including IR-820-conjugated PBNPs, exhibits enhanced in vitro and in vivo T1-weighted MR contrast. The study aims for clinical translation, utilizing QbD during synthesis and validating with nude mice, offering a finely tuned platform for clinical applications with potential for further development and implementation.