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12th South Pacific Environmental Radioactivity Association Conference (SPERA 2012)

Tuesday 16 October –
Friday 19 October 2012
Sydney, Australia

ANSTO's Environmental Radioactivity Measurement Centre (ERMC).

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Welcome

Welcome to the 12th South Pacific Radioactivity Association Conference, welcome back in Sydney.

The conference will be hosted by the Australian Institute for Nuclear Science and Engineering and the Australian Nuclear Science and Technology Organisation.

The program for the 12th SPERA conference is very exciting, with key-note speakers setting the scene for a diverse range of sessions.

The conference will conclude by offering the participants a tour of ANSTO's new facilities.

We would like to thank Jorden Lickiss for her tireless efforts in conference management. We also like to thank our sponsors AINSE, ANSTO and Nucletron for their financial support.

We look forward to your participation and a successful conference.

Henk Heijnis, Convenor

Tim Payne, Conference Secretary

AINSE Funding Opportunities

AINSE welcomes you to the 12th South Pacific Environmental Radioactivity Association Conference. Our support for this conference reflects one aspect of our mission, namely to advance research, education and training in the field of nuclear science and engineering and related fields within Australasia.

AINSE Ltd (the Australian Institute of Nuclear Science and Engineering) facilitates access to the national facilities at Lucas Heights by universities and other research institutions and provides a focus for cooperation in the nuclear scientific and engineering fields. AINSE arranges for the training of scientific research students in matters associated with nuclear science and engineering. Staff and students of AINSE Member Organisations are invited to apply for the following funding opportunities:

Honours scholarships

AINSE offers Honours scholarships of AU$5,000 and will also provide some costs for travel and accommodation at Lucas Heights. To be eligible, a student's supervisor must have an application for a Research Award in process.

Postgraduate top-up scholarships

AINSE offers awards for postgraduate students whose research projects are associated with nuclear science and engineering and who require access to ANSTO's unique national facilities at the Lucas Heights. The award consists of a top-up of AU$7,500 pa, as well as AU$10,000 pa for costs involved in using the facilities and services at Lucas Heights. Certain travel and accommodation costs to enable students to work at Lucas Heights are also provided.

Research Awards

AINSE provides funds to assist researchers to gain access to the national facilities at ANSTO and other AINSE facilities. Funding is provided for one year commencing in January, and consists of costs associated with access to facilities as well as costs associated with travel and accommodation.

Undergraduate students Winter School

AINSE offers scholarships to enable a nominated undergraduate student from each member Organisation to attend a Winter School at ANSTO on applications of nuclear techniques. The scholarship is open to all senior undergraduate students for whom knowledge of nuclear techniques of analysis would be of interest. Such techniques have applications in areas ranging from agriculture to zoology; and include physics, chemistry, biology, environmental science, geography, geology, and archaeology. ANSTO provides for the costs of the experiments, and AINSE pays for travel, accommodation, all meals and social activities during the program. Interested students should contact their AINSE Councillor early in the year.

Contact and further details

For further details, please contact AINSE on +61 2 9717 3376
or email us at ainse@ainse.edu.au

SPERA 2012 Summary Program

	Monday 15 October	Tuesday 16 October	Wednesday 17 October	Thursday 18 October	Friday 19 October
		8:00 Registration			
Session		08:45 Address 09:00 - 10:15 Session 1: Atmosphere	09:00 - 10:15 Session 5: Radiochemistry and Nuclear Forensics	09:00 - 10:15 Session 9: Methods, Facilities and Instruments (Part 2)	09:00 - 10:15 Session 11: Marine Ecosystems
Tea					
Session		10:45 - 12:15 Session 2: Fukushima	10:45 - 12:15 Session 6: Maralinga	10:45 - 12:00 Session 10: Contaminant Transport	10:45 -12:15 Session 12: Radionuclide Uptake and Dose Modelling (Part 2)
Lunch	Arrive in Sydney				
Session		13:45 - 15:00 Session 3: Methods, Facilities and Instruments (Part 1)	13:45 - 15:00 Session 7: Radionuclide Uptake and Dose Modelling (Part 1)	Poster Session	Closing Address Tour of OPAL and ERMC
Tea					
Session		15:35 - 17:15 Session 4: Naturally Occurring Radioactive Materials	15:30 - 16:45 Session 8: Soil, Sediments and Erosion	Public Lecture SPERA Meeting	
			Bus to Sydney Harbour Cruise		

SPERA 2012 Program

Monday 15 October 2012

	Arrive in Sydney	

Tuesday 16 October 2012

08:00 - 08:45	Registration	
08:45 - 09:00	**Opening address by Professor John Dodson, Head Institute for Environmental Research, ANSTO**	
	Session 1: Atmosphere Chair: Tim Payne	
09:00 - 09:25	Applications for ^{222}Rn in atmospheric research	Scott Chambers
09:25 - 09:50	Analysis of ^{7}Be data from five Australian IMS radionuclide particulate stations over 12 years	Che Doering
09:50 - 10:15	Atmospheric Kr-85 activity concentrations measured close to the ITCZ in the Southern Hemisphere	Andreas Bollhöfer
10:15 - 10:45	Morning Tea	
	Session 2: Fukushima Chair: Mathew Johansen	
10:45 - 11:25	Too Much Data, Not Enough Information: Reporting Releases from Fukushima	**Keynote Speaker –** Paul Dickman
11:25 - 11:50	The 11 March 2011 Tohoku-oki Tsunami	Catherine Chague-Goff
11:50 - 12:15	Short-tailed shearwater (mutton bird) dose reconstruction	Julia Carpenter
12:15 - 13:45	Lunch	
	Session 3: Methods, Facilities and Instruments (Part 1) Chair: David Child	
13:45 - 14:10	Radiation Emergency Response – the laboratory perspective	Sandra Sdraulig

Tuesday 16 October 2012 (continued)

14:10 - 14:35	Re-constructing the Sedimentation and Pollution signatures of Mill Creek (NSW) by ITRAX Core-scanning, Geochemical and Radiochemistry techniques	Patricia Gadd
14:35 - 15:00	Isotopic Ratios of Uranium in Uranium Salts and Pitchblende	David Urban
15:00 - 15:35	Afternoon Tea	
	Session 4: Naturally Occurring Radioactive Materials **Chair: Stephen Long**	
15:35 - 16:00	Management of NORM in the Production of Rare Earths from Monazite	Mellodee Anvia
16:00 - 16:25	Identification and analysis of radionuclides in mining and environmental samples by PERALS alpha liquid scintillation spectroscopy	Artem Borysenko
16:25 - 16:50	Modified Bauxite Refinery Residues for Immobilizing U(VI)	Malcolm Clark
16:50 - 17:15	Measurements of environmental background radiation in the surrounding area of a coal-fired power plant	Maria de Lurdes Dinis

Wednesday, 17 October 2012

	Session 5: Radiochemistry and Nuclear Forensics **Chair: Stephen Tims**	
09:00 - 09:25	ANSTO Nuclear Forensics Research Facility: Method development and applications	Andrew Wotherspoon
09:25 - 09:50	Radioanalytical method development to determine polonium-210 and radium-226 activities in bone samples to be used in forensic studies	Jack Goralewski
09:50 - 10:15	UOC Characterisation and 231Pa based Isotope Chronometer Development for Application in Nuclear Forensics	Elizabeth Keegan
10:15 - 10:45	Morning Tea	

Wednesday, 17 October 2012 (continued)

	Session 6: Maralinga **Chair: Tim Payne**	
10:45 - 11:25	Plutonium uptake in wildlife at Maralinga, South Australia	**Keynote Speaker -** Mathew Johansen
11:25 - 11:50	Maralinga Then and Now	Stephen Long
11:50 - 12:15	Plutonium and uranium fallout from the Maralinga and Emu nuclear detonation sites, South Australia, as environmental markers	David Child
12:15 - 13:45	Lunch	
	Session 7: Radionuclide Uptake and Dose Modelling (Part 1) **Chair: Henk Heijnis**	
13:45 - 14:10	BRUCE: A tool for calculating radionuclide transfer factors for Northern Australian bushfoods	Che Doering
14:10 - 14:35	Concentration Ratios in non-human biota inhabiting Australian Uranium Mining Environments	Gillian Hirth
14:35 - 15:00	Biota dose assessment for environmental radiotracer releases in aquatic environments	Cath Hughes
15:00 - 15:30	Afternoon Tea	
	Session 8: Soil, Sediments and Erosion **Chair: Stephen Long**	
15:30 - 15:55	Where is the mud coming from? Radionuclides and GIS: partners in sediment budgeting	Sarah Hobgen
15:55 - 16:20	Soil production rates on carbonate plains of the Northern Territory, Australia, using cosmogenic 10Be	Rajeev Lal
16:20 - 16:45	Uranium isotopic variability during low T redox mineralisation	Melissa Murphy
17:15 - 22:30	**Bus to Sydney Harbour Cruise**	

Thursday, 18 October 2012

	Session 9: Methods, Facilities and Instruments (Part 2) **Chair: David Child**	
09:00 - 09:25	Radon-222 exhalation rate measurement Revisiting the methodology	Sami Alharbi
09:25 - 09:50	Background Measurements in the Environmental Radioactivity Measurement Centre Low-Level Gamma Laboratory at ANSTO	Daniela Fierro
09:50 - 10:15	Determining the pre-mining radiological source term for Ranger uranium mine, Australia	Andreas Bollhöfer
10:15 - 10:45	Morning Tea	
	Session 10: Contaminant Transport **Chair: Henk Heijnis**	
10:45 - 11:10	Factors controlling mobility of radionuclides in tropical soils and groundwaters	Timothy Payne
11:10 - 11:35	Edification of the Iodine releases at the KFKI Campus	Aniko Fšldi
11:35 - 12:00	Radionuclide sorption studies of Co, Cs and Sr onto soils from an Australian legacy radioactive waste site	Katharina Gueckel
12:00 - 13:20	Lunch	
14:00 - 16:00	**Poster Session**	
16:00 - 17:00	**Public Lecture @ AINSE Theatre** Fukushima – Introduction on the Tohoku-oki Tsunami Catherine Chague-Goff Releases from Fukusihima – Too much data, not enough information. Paul Dickman	**SPERA Meeting**

Friday, 19 October 2012

	Session 11: Marine Ecosystems **Chair: Mathew Johansen**	
09:00 - 09:25	Marine ecological risk analysis of radioactive releases from the Fukushima Daiichi nuclear power plant accident	Ron Szymczak
09:25 - 09:50	Weapons test plutonium signatures from a coral archive	Stephen Tims
09:50 - 10:15	Element transport in marine coastal ecosystems - modelling general and element-specific mechanisms	Lena Konovalenko
10:15 - 10:45	Morning Tea	
	Session 12: Radionuclide Uptake and Dose Modelling (Part 2) **Chair: Tim Payne**	
10:45 - 11:25	Radiation protection of the environment: quantifying transfer	**Keynote Speaker –** Brenda Howard
11:25 - 11:50	Is it possible to detect ^{236}U and Pu in European roe deer antlers?	Michael Srncik
11:50 - 12:15	Biota dose modelling: Little Forest Burial Ground Scenario	Mathew Johansen
12:15 - 12:30	**Closing address: SPERA- President**	
13:30 - 15:00	Optional tour to OPAL reactor and Environmental Radioactivity Measurement Centre	

Applications for ^{222}Rn in atmospheric research

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Institute for Environmental Research, ANSTO, Locked Bag 2001, Kirrawee DC, NSW 2232, Australia.

Radon-222 (radon) is a relatively short-lived (half-life 3.82 d), naturally occurring, radioactive gas, with a relatively consistent and well-defined terrestrial flux, and almost negligible oceanic flux. Being a noble, poorly-soluble gas that does not accumulate in the atmosphere, it is an ideal tracer of recent (<2-3 weeks) air mass contact with ice-free terrestrial regions. In conjunction with air mass back trajectory analysis, radon is thus a useful tool with which to perform fetch analyses for observed pollution events. Since radon's half-life is much greater than the turbulent timescale in the atmospheric boundary layer (~1 hour), it can be considered a conservative tracer in such situations. Consequently, radon profiles or gradient measurements in the lower atmosphere also provide valuable insight into vertical mixing processes under a range of atmospheric conditions. This presentation will provide an overview of ANSTO's radon measurement capabilities (including: stand-alone detectors, tall-tower gradient measurements, aircraft profile measurements and flux chambers), with recent examples of their recent application.

Radon's physical characteristics also make it ideal for the evaluation of transport and mixing schemes of weather, climate or chemical models. This presentation will also showcase a radon flux map of Australia, developed at ANSTO to improve the radon source function employed in regional models.

Analysis of ^{7}Be data from five Australian IMS radionuclide particulate stations over 12 years

C. Doering[a], P. Saey[b]

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[b]Vienna University of Technology, Atomic Institute of the Austrian Universities, Stadionallee 2, 1020 Vienna, Austria.

The international monitoring system (IMS) has been established as part of the global verification regime to monitor compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The primary purpose of IMS radionuclide stations is to screen the air for anthropogenic radioactivity indicative of a nuclear explosion. The stations also produce a vast amount of data on naturally occurring radionuclides in surface air. One such radionuclide that is readily detected in routine gamma spectrometric analysis of daily particulate air monitoring samples is beryllium-7 (^{7}Be), which is produced in the stratosphere and troposphere through cosmic-ray spallation of nitrogen and oxygen nuclei. Studies of ^{7}Be can be of both scientific and CTBT verification interest. This is because ^{7}Be maintains a similar vertical concentration profile and activity size distribution to certain particulate-bound anthropogenic radionuclides (eg caesium-137 and strontium-90) present in the atmosphere in the months and years following an above ground nuclear explosion. Being a natural analogue of these fission products means that ^{7}Be measurements can potentially be used in the process to predict or reconstruct the pattern of long-term fallout of radioactive debris from the upper atmosphere. This paper presents an analysis of ^{7}Be data from five Australian IMS radionuclide particulate stations and investigates the observed trends in surface air activity concentrations between 2000 and 2011 in the context of active atmospheric and other processes

Atmospheric Kr-85 activity concentrations measured close to the ITCZ in the Southern Hemisphere

A. Bollhöfer[a], C. Schlosser[b], H. Satorius[b], O. Ross[c], S. Schmid[b]

[a] Environmental Research Institute of the Supervising Scientist (eriss), Darwin, NT 0801, Australia.

[b] Bundesamt für Strahlenschutz, 79098 Freiburg, Germany.

[c] Bundesanstalt für Geowissenschaften und Rohstoffe, 30655 Hannover, Germany.

Kr-85 is an inert radioactive noble gas that decays via β-decay to Rb-85 ($t_{1/2}$=10.7 y). The main source of Kr-85 in the atmosphere is the re-processing of nuclear fuel. Large re-processing plants are located in France, Japan, Russia and the UK, and almost 100 per cent of global atmospheric Kr-85 emissions are emitted in the Northern Hemisphere. Other small sources are power reactors, naval reactors and isotope production facilities. As Kr-85 has no relevant natural sources it can be used as a tracer for clandestine plutonium production. The well known atmospheric Kr-85 activity concentration also allows reliable determination of the age of groundwater. Since it is almost exclusively emitted in the Northern Hemisphere, it is also an ideal tracer to investigate interhemispheric exchange processes.

Weekly samples of atmospheric Kr-85 were collected at the *eriss* laboratories in Darwin, Australia, and measured for their activity concentrations in the noble gas laboratory at the Federal Office for Radiation Protection in Freiburg, Germany. Long time series exist for atmospheric Kr-85 activity concentrations in the Northern Hemisphere. However the Southern Hemisphere time series is sketchy, with Darwin being the only station in the Southern Hemisphere accruing Kr-85 data between August 2007 and May 2010. This paper presents the time series measured in Darwin in the wider context of Southern and Northern Hemisphere trends, and investigates more specifically the variations observed and their dependency on active monsoonal activity in this region, which is close to the intertropical convergence zone (ITCZ).

Too Much Data, Not Enough Information: Reporting Releases from Fukushima

P. Dickman

Argonne National Laboratory, USA

Mr Paul Dickman, a Senior Policy Fellow with Argonne National Laboratory in the USA, was the study director for the American Nuclear Society Special Committee on Fukushima. The committee's report provided an independent, scientifically, and technically informed view on the accident by world-class experts in nuclear science and technology. The leadership of the American Nuclear Society, a scientific and technical organization of 11,600 nuclear professionals, commissioned the Special Committee to provide a clear and concise explanation of what happened during the Fukushima Daiichi accident, and offer recommendations for the nuclear community, for citizens, and for policymakers based on lessons learned from their study of the event. Topics addressed in the report included risk-informed regulation, hazards from extreme natural phenomena, multiple-unit site considerations, hardware design modifications, severe accident management guidelines, command and control during a reactor accident, emergency planning, health impacts, and societal risk comparison.

The 11 March 2011 Tohoku-oki Tsunami

C. Chagué-Goff[a,b]

[a] **Institute for Environmental Research, Australian Nuclear Science and Technology Organisation, Kirrawee DC, 2232 NSW, Australia.**

[b] **School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney 2052 NSW, Australia.**

The 11 March 2011 MW9.0 megathrust earthquake that occurred on the Japan Trench boundary off the East Coast of Japan, generated a devastating tsunami that affected not only over 2000 km of Japan's Pacific Coast, but also other coasts in the Pacific Ocean. The tsunami reached more than 5 km inland in some areas of the low-lying Sendai Plain, with a maximum inundation height of 19.5 m. On the Sanriku coast 50 to 200 km further north, a maximum run-up height of 40.0 m was recorded. The tsunami resulted in nearly 15,900 dead and 2,900 missing, and caused extensive damage to houses, buildings and all types of infrastructure, also leading to the Fukushima Daiichi nuclear disaster.

The size and extent of the 2011 Tohoku-oki tsunami were much larger than expected. This is largely due to the fact that the magnitude of its predecessor, the 869AD Jogan tsunami, was underestimated. An overview of the tsunami impact will be presented, as well as a discussion about lessons learnt from this event for future hazard preparedness.

Short-tailed shearwater (mutton bird) dose reconstruction

J. Carpenter[a], R. Tinker[a], S.Newbery[b], M. Grzechnik[a], S. Sdraulig[a]
[a] Australian Radiation Protection and Nuclear Safety Agency.
[b] Department of Health and Human Services, Tasmania.

The 2011 Great East-Japan earthquake and tsunami and the subsequent nuclear accident at the Fukushima Dai-ichi nuclear power plant resulted in radiation releases to the atmosphere and ocean.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and Tasmanian Department of Health and Human Services (DHHS) received a number of public enquiries regarding the potential health risks associated with harvesting and consuming the chicks born from migratory birds that may have been in the vicinity of the Fukushima Dai-ichi NNP during the austral autumn, 2011. One of these migratory birds is the mutton bird, which migrates each austral autumn from Australia and New Zealand to the Aleutian Islands in the north Pacific and returns to nest in late spring. This annual migration pattern sees the birds passing the coast of Japan during April and May each year.

ARPANSA undertook a radiation dose reconstruction to assess the potential radiation exposure of the mutton bird population during its northward migration from Australia during April-June 2011, and to determine if there was likely to be any health risk associated with consuming the young mutton birds to be harvested in early 2012.

The dose reconstruction utilised the ERICA tool and was conducted in line with the recommendations of ICRP 103 in relation to radiation protection of non-human biota. The focus was on both the protection of humans and the radiation effects on biological diversity and conservation of mutton birds. As the dose reconstruction was a desktop study, assumptions were made based on published literature. A small sample of mutton bird carcasses were tested for radioactive caesium contamination using high-resolution gamma-ray spectrometry.

Radiation Emergency Response – the laboratory perspective

S. Sdraulig

Australian Radiation Protection and Nuclear Safety Agency, Victoria, Australia.

Following the accident at the Fukushima Dai-ichi nuclear power plant in Japan, the radioanalytical laboratory at ARPANSA was called on to support the screening of imported food samples from Japan. Based on the ARPANSA experience in dealing with the number of requests for analysis and the resulting workload and logistics, APRANSA has identified the need to establish a network of laboratories within Australia capable of responding to radiation emergency situations. The presentation will look at the overall preparedness of Australian laboratories for the measurement of radionuclides in radiation emergency situations and a proposed approach for increasing the capacity and consistency in Australia's radioanalytical laboratory response to radiological incidents or emergency situations.

Re-constructing the Sedimentation and Pollution signatures of Mill Creek (NSW) by ITRAX Core-scanning, Geochemical and Radiochemistry techniques

P. Gadd, H. Heijnis, J. Goralewksi, D. Fierro, A. Zawadzki
Institute for Environmental Research, ANSTO, Australia.

In this study, we combine ITRAX Core Scanning, Grain size and Radiochemistry (Pb-210, Cs-137 and Pu-239/240) techniques to investigate pollution and age of sedimentation in Mill Creek. The creek drains a catchment containing the Lucas Heights Waste Management facility, the Lucas Heights Science precinct and the Little Forest Burial Ground.

The ITRAX core scanner non-destructively collects optical and X-radiographic images, and provides high-resolution elemental profiles that are invaluable for guiding sample selection for further detailed sampling. The core from the creek was first scanned on the ITRAX core scanner and further sampled for the other techniques. The chronology for the sediment core was developed using Pb-210, Ra-226 and Cs-137 analysis.

Isotopic Ratios of Uranium in Uranium Salts and Pitchblende

D. Urban

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), Victoria 3085, Australia.

This paper reports the results of a study by ARPANSA to ascertain if high resolution alpha spectrometry could be used to effectively determine the isotopic ratios ($^{234}U/^{238}U$ and $^{235}U/^{238}U$) of a group of uranium salt samples. The aim of this study was to evaluate the use of these ratios as a means of discriminating between different uranium salt samples. A sample of pitchblende was analysed and used for quality control purposes. During the course of the pitchblende analysis, different digestion procedures were evaluated in order to determine the best recovery of the uranium within the ore. Both standard acid digestion and microwave digestion techniques were investigated.

Management of NORM in the Production of Rare Earths from Monazite

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[b] **ANSTO Minerals, Lucas Heights, Australia.**

The rare earth elements are of considerable technological importance. Demand for these elements is increasing and is expected to exceed 190 000 metric tons by 2015 [1]. Monazite is a rare-earth phosphate mineral which contains 50–68% rare earths and is an important source of the rare earth elements. However, monazite is an example of NORM which contains between 4–12% thorium and up to 0.5% uranium [2]. In a conventional industrial process, monazite concentrate is produced by physical beneficiation processes and the concentrate is then chemically processed using either an acid bake or a caustic cracking route followed by an acid leach to extract the desired rare earths. The radioactivity content of the monazite and the resulting process residues create a need to control exposure to workers and members of the public. The International Atomic Energy Agency (IAEA) has published several guidelines [3] on NORM management in the form of standards and regulations. The standards with respect to the extraction of rare earth elements from monazite in conventional industrial processes and the management of the contained radioactivity will be discussed.

[1] D. Kramer, Phys. *Today*. 63, 22. (2010).

[2] Gupta, C. K.; Krishnamurthy, N. *Extractive Metallurgy of Rare Earths*; CRC Press Florida, 2005.

[3] IAEA, Radiation Protection and NORM Residue Management in the Production of Rare Earths from Thorium Containing Minerals, Safety Reports Series No. 68, Vienna, 2011.

Identification and analysis of radionuclides in mining and environmental samples by PERALS alpha liquid scintillation spectroscopy

A. Borysenko, A. Ostrowski, P. Haigh
Radiation Protection Branch, Environment Protection Authority SA, 5000, Australia.

The regulation of uranium and mineral sands mining in South Australia requires efficient, reproducible and rapid analysis for a variety of samples to effectively manage the risks of radiation for occupational workers, the public and the environment.

Detection and identification of both naturally occurring and man-made radionuclides is conducted in the SA EPA Radiation Laboratory via gamma spectroscopy and alpha spectroscopy using the PERALS system developed by ORDELA (USA), which has been designed specifically for alpha liquid scintillation using nuclide specific extractive scintillators.

The sample preparation and PERALS chemical extraction technique have been further developed by the SA EPA for monitoring low level radiation in the environment surrounding uranium and mineral-sand mining and exploration sites, legacy sites and areas undergoing rehabilitation. Cross-calibration by gamma spectroscopy has confirmed efficient detection of the isotopes of uranium, thorium, radium and polonium by alpha counting of these isotopes and their decay products. The PERALS method offers considerable saving in time over conventional methods using chemical separations and plating.

Modified Bauxite Refinery Residues for Immobilizing U(VI)

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Bauxite refinery residues (BRR) are a waste from the production of alumina using the Bayer process, which has high pH and soluble alkalinity. However, a modified BRR (MBRR) can be made using Mg and Ca to precipitate alkalinity as acid neutralizing capacity (ANC), which lowers pH from ≈13 to ≈8.5. The combined effects of a fine-grained mineral mix providing high surface area across a range of minerals for metal removal, and an ANC (3-5 mol/kg), gives MBRR potential for many environmental remediation and wastewater-treatment applications.
We conducted several laboratory experiments that investigate and assess the application potential of MBRR for the environmental remediation U(VI). Isotopic exchange data show that U(IV) is, in part, irreversibly bound and that irreversibility increases with increased surface loading; it is also age- and temperature-sensitive. Synchrotron X-ray absorption techniques (EXAFS and XANES) suggest that a limited number of minerals bind U(VI), and the mechanisms and minerals involved are U(VI) concentration dependent. Data indicate that U(VI) binding is initiated by adsorption, largely to the hematite, but precipitation dominates as U(VI) concentration increases. This in turn suggests that irreversibility in the U(VI) binding is driven by precipitate re-crystallization rather than intra-particulate diffusion into adsorbing minerals. Moreover, the results of this work suggest that MBRR may well be useful in the environmental remediation of U(VI) contaminated soils and waters.

Measurements of environmental background radiation in the surrounding area of a coal-fired power plant

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[b] School of Engineering Polytechnic of Porto (ISEP), Porto, Portugal.

Certain materials used and produced in a wide range of non-nuclear industries contain enhanced activity concentrations of natural radionuclides. In particular, electricity production from coal is one of the major sources of increased exposure to man from enhanced naturally occurring materials. Over the past decades there has been some discussion about the elevated natural background radiation in the area near coal-fired power plants due to high uranium and thorium content present in coal.

This work describes the methodology developed to assess the radiological impact due to natural radiation background increasing levels, potentially originated by a coal-fired power plant's operation.

Gamma radiation measurements have been done with two different instruments: a scintillometer (SPP2 NF, Saphymo) and a gamma ray spectrometer with energy discrimination (Falcon 5000, Canberra). A total of 40 relevant sampling points were established at locations within 20 km from the power plant: 15 urban and 25 suburban measured stations. The highest values were measured at the sampling points near to the power plant and those located in the area within the 6 and 20 km from the stacks. This may be explained by the presence of a huge coal pile (1.3 million tons) located near the stacks contributing to the dispersion of unburned coal and, on the other hand, the height of the stacks (225 m) which may influence ash's dispersion up to a distance of 20 km. In situ gamma radiation measurements with energy discrimination identified natural emitting nuclides as well as their decay products (^{212}Pb, ^{214}Pb, ^{226}Ra ^{232}Th, ^{228}Ac, ^{234}Th ^{234}Pa, ^{235}U, etc.).

This work has been primarily done to in order to assess the impact of a coal-fired power plant operation on the background radiation level in the surrounding area. According to the results, an increase or at least an influence has been identified both qualitatively and quantitatively.

ANSTO Nuclear Forensics Research Facility: Method development and applications

A. Wotherspoon, D. Hill, E. Keegan, T. Evans, N. Blagojevic, E. Loi, K. Toole, G. Griffiths, K. Smith, M. Reinhard
National Security Research Program, Institute of Materials Engineering, ANSTO, Australia.

The IAEA defines nuclear forensic science, commonly shortened to “nuclear forensics” as ‘the scientific analysis of nuclear or other radioactive material, or of other evidence that is contaminated with radioactive material, in the context of legal proceedings, including administrative, civil, criminal or international law’1. In broad terms, the job of the nuclear forensic scientist is to support investigations that involve a nuclear security event. Nuclear forensic examinations will provide information to key questions posed by the investigative authority: What is it? How much is there? Is there any more out there? Is it ours? As an investigation proceeds other questions that may arise are; How old is it? What contaminants are present? Does it pose a threat? Who is responsible for the loss? Where did the material come from? Many of the techniques required to answer these questions are based on environmental radiochemistry.

The Nuclear Forensic Research Facility (NFRF) at ANSTO is developing expertise in analysing nuclear and other radioactive material material based upon the precepts of the ‘model action plan’ of the International Technical Working Group for Nuclear Forensics (ITWG) and other best practices. We are also investigating the validity of traditional forensic techniques (like fingerprints and DNA) on evidence contaminated with radioactive material alongside more novel parameters, e.g. the isotopic composition at the ‘bulk’ material and the micro scale using advanced micro-analytical techniques.

We are moving towards the integration of a range of radio analytical techniques such as mass spectrometry, electron microscopy and the simulation/modelling of material production signatures, to provide a range of different information streams to assist attribution.

With each advance in our technical competencies we enhance our means to ensure the security of nuclear or other radioactive material.

Radioanalytical method development to determine polonium-210 and radium-226 activities in bone samples to be used in forensic studies

A. Zawadzki[a], J. Goralewski[a], H. Heijnis[a], D. Fierro[a], G. Lee[b], J. Watling[b] C. May[b]

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^{210}Pb dating on human skeletal remains has been proposed in forensic studies for the determination of time since death (TSD) or post-mortem intervals. ^{210}Pb and its granddaughter ^{210}Po enter the human body from two main sources, direct ingestion in foodstuffs and the decay of ingested ^{226}Ra which is retained in the bone and bony tissue [1]. One of the methods in dating human bones is based on the decay unsupported ^{210}Pb (total ^{210}Pb minus supported ^{210}Pb) since the time of death. Total ^{210}Pb can be determined from ^{210}Pb granddaughter, ^{210}Po, and supported ^{210}Pb from ^{210}Pb grandparent, ^{226}Ra. A reliable and sensitive method of determining ^{210}Po and ^{226}Ra activities in bone samples is required in order to produce reliable post-mortem intervals. A method was developed, using pig bone samples, to analyse these radionuclides by alpha spectrometry. In this presentation, the methodology employed is discussed, along with some of the difficulties encountered and how these were overcome.

[1] B. Swift, I. Lauder, S. Black, J. Norris. An estimation of the post-mortem interval in human skeletal remains: A radionuclide and trace element approach. *Forensic Science International* 2001; 117, 73 – 87.

UOC Characterisation and ^{231}Pa based Isotope Chronometer Development for Application in Nuclear Forensics

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While environmental sampling is a well established nuclear safeguards tool, the information contained in measurements performed on radioactive environmental samples may also be of use for nuclear forensic purposes. Nuclear forensics (NF) is the scientific analysis of nuclear or radioactive material, or of evidence that is contaminated with radioactive material, in the context of legal proceedings [1]. Piecing together collected evidence, for instance in the case of a detonated radiological dispersal device (RDD), may provide clues as to the provenance of the material involved in such nuclear security events. Research in this area involves profile analysis on radioactive or nuclear materials and debris identifying parameters, such as isotopic composition, which constitute a unique 'signature' of the material, potentially leading to attribution.

This paper will outline the research activities of ANSTO's recently established Nuclear Forensic Research Facility (NFRF) and its endeavors in performing measurements on environmental samples within the context of nuclear forensics. For instance, uranium mining and milling are a potential source of contamination of the environment with radioactive material. Work carried out by the NFRF has demonstrated that even particle sized samples of uranium ore concentrate (UOC) can be tracked back to the mine from which it originated.

New analytical capabilities within NFRF will be presented and discussed. For example, the ^{231}Pa/^{235}U isotope chronometer while being developed for NF purposes can also be readily applied to environmental monitoring.

[1] Hinton, T., 2012. Revision of IAEA Nuclear Security Series No.2 Nuclear Forensics Support. Nuclear Forensics International Technical Working Group Annual Meeting, The Hague, Netherlands, 26-28 June.

Plutonium uptake in wildlife at Maralinga, South Australia

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This study examined accumulation of plutonium (Pu) in wildlife at Maralinga, South Australia, where a 1950s series of experiments dispersed unfissioned Pu onto the landscape. The residual Pu concentrations that remain today are lower than the site clean-up level, but are sufficient to provide a rare opportunity to study wildlife organisms that have been exposed to a food web and soils containing elevated Pu. Analysis was by gamma- and alpha- spectroscopy, and by accelerator mass spectrometry at ANSTO.

Uptake of Pu was quantified by concentration ratios, defined as average concentration in the whole-organism, to that of their host soil ($CR_{wo\text{-}soil}$). The geometric mean of $CR_{wo\text{-}soil}$ values for all organisms was 0.002 (geometric standard deviation – 4.1E00) with mammals<insects<arthropods<reptiles. Within rabbit, activity concentrations of various tissue types ranged from 1.6 to 1700 mBq/kg (with muscle<blood<bone<liver<heart-lung<gastrointestinal tract<skin-fur). The contents within the gastrointestinal tract of rabbit had order-of-magnitude higher Pu concentrations than all organs and tissues indicating most of the ingested Pu is not being absorbed across the intestinal wall. The elevated concentration of Pu in the lung compartment is indicative of an inhalation pathway.

Our results add to international data on transfer of Pu to living organisms, and better define accumulation in specific tissues of various organism types within a Pu-contaminated natural system.

Maralinga Then and Now

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The radioactive contamination at the former nuclear test site at Maralinga was extensively studied prior to the Rehabilitation Project, which commenced in 1994. After the conclusion of the Project in 2000, ARPANSA has conducted many investigations of the residual contamination. This paper compares the current state of contamination to the data obtained prior to the rehabilitation. Three aspects of the residual contamination will be discussed: the contamination from the nuclear weapons tests; the physical extent and contamination levels of the Plutonium plumes; and the results of a long-term study on contamination levels in the Plutonium plumes.

Plutonium and uranium fallout from the Maralinga and Emu nuclear detonation sites, South Australia, as environmental markers

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Atmospheric nuclear testing was performed widely around the world, from the Russian test site at Novaya Zemlya in the Arctic circle to Maralinga in Southern Australia. These detonations introduced radioactive material into the atmosphere which would give rise to a roughly homogenised fallout signal in every topsoil surface and sedimentary archive exposed to the atmosphere during this period.

A large quantity of the radioactive material released was not homogeneously dispersed over the globe however, being released instead into the troposphere and falling out locally around the detonation sites. Each nuclear detonation generates fallout with a signature characteristic of weapon design. Local fallout has been shown to retain this individual signature if distinct from average global fallout.

This study investigated the plutonium and uranium isotopic signatures and deposition patterns of several nuclear detonations carried out by the British government at Maralinga and Emu, South Australia, and in the Monte Bello Islands, Western Australia. These tests are found to have ^{240}Pu:^{239}Pu atom ratios of 0.020 – 0.054, clearly distinguishable from global fallout for the Southern Hemisphere (0.176), and these signatures are distinct and undiluted at distances on the order of 100km from the detonation sites. ^{236}U:Pu atom ratios have also been measured, and vary between 0.008 and 0.02. These findings have potential significance for the use of close-in plutonium and uranium fallout as chronological markers for geomorphological studies.

BRUCE: A tool for calculating radionuclide transfer factors for Northern Australian bushfoods

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The Alligator Rivers Region in Northern Australia is an area of past and present uranium mining activity. It is also an area of customary bushfood harvesting by local Aboriginal people for sustenance. Commonly harvested bushfoods include native fruits and root vegetables, as well as the flesh and organs of animals from terrestrial and freshwater environments. The consumption of bushfoods from mine impacted areas in the Alligator Rivers Region is a potential radiation exposure pathway for members of the public, both now and in the future. Assessment of potential doses via this pathway requires information on bushfood radionuclide content. This information may be obtained through knowledge of the environmental transfer of radionuclides to bushfoods, which is typically quantified as a concentration ratio.

BRUCE (acronym for Bioaccumulation of Radioactive Uranium-series Constituents from the Environment) is a tool for the storage and handling of data on natural-series radionuclide activity concentrations in Northern Australian bushfoods and environmental media samples. It contains more than 2000 individual records, representing more than 25 years of measurements by the Supervising Scientist Division. Query functions within BRUCE enable the calculation of concentration ratios for radionuclide transfer to bushfoods for use in member of the public ingestion dose assessments. The same query functions may also be used in the process to determine organism-to-media concentration ratios for some organism types for use in non-human biota dose assessments. This paper will describe the structure and functionality of BRUCE, as well as discuss preliminary concentration ratio results for selected bushfood items.

Concentration Ratios in non-human biota inhabiting Australian Uranium Mining Environments

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An initial review [1] in 2010 of the ICRP and ERICA frameworks for radiological assessment and protection of non-human biota and their applicability to the Australian uranium mining industry identified that there is currently no consolidation of existing Australian data on concentration ratios to support these assessments in the Australian uranium mining context. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) with support from the Department of Resources, Energy and Tourism (RET) have now undertaken an initial review of existing data for non-human biota inhabiting Australian uranium mining environments that can be utilized to calculate whole body concentration ratios. This paper will discuss the data analysis process and associated uncertainties that arise when estimating whole body concentration ratios. A summary of the whole body concentration ratios that have been calculated during this project and comparison to the internationally assembled dataset will be presented.

[1] C.Doering, *Environmental protection: Development of an Australian approach for assessing effects of ionizing radiation on non-human species.* ARPANSA Technical Report Series No. 154 (2010).

Biota dose assessment for environmental radiotracer releases in aquatic environments

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The intentional release of short lived radioisotopes to trace transport and partitioning processes in the environment has been in decline in recent decades due to negative regulatory and public perceptions of the associated risks. Radiotracing is subject to significant regulatory requirements; in some jurisdictions one of these requirements is to demonstrate that radiation exposure to ecosystems is limited to ensure protection of populations of species.

Radiation exposures from radiotracer studies are localised, transient and infrequent by nature, making it difficult to apply guidelines and biota dose assessment tools that are designed for chronic and widespread exposure scenarios. We will discuss the limitations of available guidelines and dose assessment methodologies when applied to radiotracer studies. A range of case studies for biota dose assessment will be presented using a variety of available tools including the ERICA Assessment Tool, the methodology of Copplestone *et al*. (2001) and a dynamic dose assessment model (Vives I Batlle et al., 2008). These case studies demonstrate that steady state, spatial homogeneity and bioavailability assumptions inherent in available dose assessment tools may lead to an over-estimate of dose to biota from radiotracer studies, and that many radiotracer studies can be conducted with minimal dose to biota.

[1]. D. Copplestone, S. Bielby, S.R. Jones, D. Patton, P. Daniel, I. Gize, *Impact Assessment of Ionising Radiation on Wildlife*, UK Environment Agency, R&D Publication 128 (2001).

[2]. J. Vives I Batlle, R.C. Wilson, S.J. Watts, J.R. Jones, P. McDonald, S. Vives-Lynch. *J. Environ. Radioactiv*. 99(11), 1711-1730 (2008).

Where is the mud coming from? Radionuclides and GIS: partners in sediment budgeting

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Radionuclides are often used in sediment studies, but rarely are they paired with Remote Sensing and Geographic Information Systems (GIS). The two used together provide a useful holistic research tool, radionuclides Pb-210, Cs-137 and Pu-239+240 indicate the relative contribution of topsoil and subsoil to sediments, while remote sensing and GIS indicate the location of sediment sources.

This method is trialed on the Kambaniru River Catchment in East Sumba, Indonesia. The Kambaniru Weir is an important source of agricultural water for rice production in the poorest region of Indonesia. This weir and many others in the region are rapidly filling with sediment, impacting on agricultural production. To reduce sediment loads it is essential to understand sediment sources.

This is also the first reported application of Pu 239+240 as a topsoil tracer in Indonesia with promising preliminary results indicating a strong correlation between Pu239+240 and Cs-137 concentrations.

Soil production rates on carbonate plains of the Northern Territory, Australia, using cosmogenic ^{10}Be

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The northern Australian river basins are largely unexploited for intensive agriculture. Climate change, however, is predicted to make the traditional Australian agricultural areas in the south drier, and to cause an increase in the frequency of extreme weather events. Hence, coupled with the demands from an increasing population, it is likely that the northern river basins will increasingly be targeted for agricultural development [1]. These landscapes are mantled by a thick veneer of soil which has developed under varying rates of erosion, uplift, bedrock type and climate. If the development of these catchments is to be sustainable, then the rates of soil loss and soil production from the underlying bedrock must be comparable. There are, however, very few measurements of soil production rates in northern Australia. Here we apply two independent methods for determining soil production rates to the carbonate plains of the Daly Basin, in the Northern Territory, Australia. First, we measure the geological denudation rates from measurements of in situ produced cosmogenic ^{10}Be concentrations in surface rocks sampled across the catchment. Second, we measure the soil production rates from measurements of meteoric 10Be inventories in soil cores [2]. Results from both methods agree well thus providing evidence that this landscape is in morphological equilibrium over geological timescales and are comparable to rates measured in other parts of monsoonal Northern Australia.

[1] F.P. O'Gara, *Striking the Balance – Conservation Farming and Grazing Systems for the Semi-arid Tropics of the Northern Territory*. Second Edition. Northern Territory Government,Australia, (2010)

[2] R. Lal, L. K. Fifield, S. Tims, R. Wasson, D. Howe, *EPJ* (in press)

Uranium isotopic variability during low T redox mineralisation

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Variations in uranium isotopic compositions are well documented in groundwaters and uranium ores as a result of the very different geochemical and radiogenic behaviours of uranium nuclides. Additionally, natural 236U is produced in-situ in high-grade uranium ores as a result of neutron capture processes.

In order to gain a better understanding of the behaviour of uranium nuclides during ore formation processes within sandstone-hosted uranium deposits, U concentrations and ($^{234}U/^{238}U$) activity ratios were analysed in a suite of groundwaters in the vicinity of the South Australian Pepegoona sandstone-hosted uranium deposit. The groundwaters show significant disequilibrium, resulting from preferential leaching, α-recoil processes and the congruent dissolution of ore minerals.

Additionally, $^{238}U/^{235}U$ ratios were characterised in mineralised sediment samples and groundwaters from the Pepegoona deposit. Groundwaters are characterised by $^{238}U/^{235}U$ ratios enriched in the light isotope (^{235}U), whilst mineralised sediments showed a preferential enrichment in the heavier isotope (^{238}U). This can be attributed to the nuclear field shift effect during reduction of U(VI) to U(IV). Poor correlation between ($^{234}U/^{238}U$) activity ratios with $^{238}U/^{235}U$ ratios in the groundwaters indicates that the fractionation processes are independent of each other.

Lastly, based on $^{236}U/^{238}U$ ratios measured in uranium ores, the detection of appreciable quantities of ^{236}U in groundwaters may reflect local uranium mineralisation, and thus prove useful in uranium exploration. In order to test this, $^{236}U/^{238}U$ ratios were determined by accelerator mass spectrometry in groundwaters and uranium ores from the Pepegoona deposit. Preliminary results will be presented.

Radon-222 exhalation rate measurement using activated charcoal canisters: Revisiting the methodology

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The measurement of ^{222}Rn exhalation rate using activated charcoal canisters is a popular technique in use for several decades. For practical reasons, the exposure times in the field measurements are generally limited for a few days. In the present study, activated charcoal canisters were examined to investigate the relationship between ^{222}Rn exhalation rate and exposure time under constant humidity and temperature conditions, as well as the distribution of the adsorbed radon in the charcoal bed. The ^{222}Rn exhalation rate from uranium tailings and ore samples was measured under laboratory conditions for exposure times of 1, 2, 3, 5, 7, 10, and 14 days. A reduction in the ^{222}Rn exhalation rate was observed as the time of exposure increased. This reduction was perhaps related to factors such as back diffusion of ^{222}Rn gas that occurs in the canister-soil interface or absorption site saturation.

The distribution of ^{222}Rn in the charcoal bed was investigated by dividing the charcoal bed into six layers before exposure, and counting each layer separately after the exposure. ^{222}Rn was found to be more uniform in the charcoal bed with longer exposure times. Hence, a correction may be required in actual application, where calibration standards are often prepared by uniform mixing of ^{226}Ra in a charcoal matrix.

Background Measurements in the Environmental Radioactivity Measurement Centre Low-Level Gamma Laboratory at ANSTO

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At SPERA 2010, the results of a study on the low-level building materials including a special concrete mix for the development of a basement gamma spectrometry laboratory at Ansto were presented.

Since the completion of the Environmental Radioactivity Measurement Centre using these ideal materials at ANSTO in early 2012, there has been a reduction of approximately 30% in the background counts.

In this presentation, the success in achieving the reductions will be compared to the previous gamma laboratory setting. This will reflected particularly through the radionuclides tested using an IAEA Quality Assurance method, as well as the counts per second across a broad energy range for the detectors in the laboratory.

Determining the pre-mining radiological source term for Ranger uranium mine, Australia

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In a high natural background radiation area such as the area around Ranger uranium mine, where orebodies 1 and 3 were outcropping and several other anomalies known to exist, an accurate knowledge of the pre-mining radiological conditions is essential to quantify changes in effective dose rates post-mining, especially in the event of deterioration compared to the pre-mining situation. Although there have been some studies that assessed pre-mining radiological conditions at Ranger, these focus largely on determining the localised radiation levels and extent of outcropping anomalies or orebodies. In particular, they provide relatively little quantitative data that are appropriately spatially referenced to allow the estimation of baseline radiological conditions over the greater Ranger region. If spatially referenced pre-mining airborne gamma survey (AGS) data were available and could be retrospectively groundtruthed at an area that has not been disturbed since the AGS was flown, these AGS data can then be incorporated into a Geographic Information System (GIS) to determine the pre-mining radiological conditions in the region.

In this study historic airborne gamma survey (AGS) data were acquired and intensively groundtruthed by *eriss* over an undisturbed radiological anomaly just south of the Ranger lease. Ground data were then upscaled in ArcGIS using various algorithms, to account for the different footprints and resolution of the ground survey and AGS data. Correlations were established, allowing to retrospectively determine pre-mining gamma dose rates, soil radionuclide activity concentrations and radon exhalation fluxes in the region. In this paper results from the pre-mining radiological GIS for various features on and off site will be presented, together with an example of its application to determine the pre mining radiological conditions across the greater Ranger region.

Factors controlling mobility of radionuclides in tropical soils and groundwaters

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Due to the possible expansion of nuclear power into equatorial regions, there is an imperative to better understand the mobility of radionuclides in the tropics. The migration of radionuclides in tropical soils and groundwaters is subject to the same basic scientific principles as many other environments. However, the behaviour of radionuclides is also modified by many unique features of tropical systems, including: climate and rainfall characteristics, soil mineralogy and properties, content and cycling of organic matter, specific land-use practices and the presence of unique, potentially impacted environments (for example, coral atolls in the case of weapons tests). Many tropical environments involve combinations of climatic and geochemical conditions not experienced elsewhere, and are also subject to environmental modifications including urbanisation and climate change. These characteristics will influence the impact of potential radionuclide releases in the tropics. An increased focus of scientific research is required to enhance knowledge on this topic

Edification of the Iodine releases at the KFKI Campus

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There are two controlled facilities in operation at the KFKI Campus: the Budapest Research Reactor (BRR) and the level ”A” isotope laboratory operated by the Institute of Isotopes Co. The Company produces radioactive iodine (^{125}I, ^{131}I) containing products for medical purposes. While the level “A” laboratories emits radioactive iodine isotopes by their normal operation, it can be occurred at the BRR only in the case of emergency situations. The two facilities have a common chimney. Emissions of both facilities are monitored by continuous monitoring and by periodic sampling. The monitoring of the radiological parameters at the campus is the task of the Environmental Protection Service (EPS). The Service has on both continuous (on-line) and periodic (off-line) measuring systems.

The total emitted ^{131}I activity of the Company. was 624 GBq in 2011 year, which is only 39% of the emission limit. At late spring and late autumn higher releases were detected because the filters were worn-out. In the 13-14th weeks the EPS measured higher ^{131}I activity concentrations: that time ^{131}I was emitted from the Company. and the ^{131}I of Fukushima origin was reached Hungary also. ^{137}Cs was detected also in the samples. The second higher releasing from the Company was at the and of the 2011 year: the EPS found approximately two times higher level ^{131}I activity concentrations compared to the spring period (~200 mBq/m^3, the investigation level is 4600 mBq/m^3). The weather conditions in the period in question were not favored for the mixing of the emissions.

At the end of 2011. higher ^{131}I activitity concentrations were measured by other institutes also. Initiated by these measurements the official inspections were performed by the authorities several times. Neither the communication between the different authorities nor the public relations were proper enough all the time.

The significance of the communication is higher that was taught earlier, the more effective co-operation and communication between the Company, the EPS and with the authorities can assist to avoid ambiguous cases. In the near future the measuring system in the chimney will be reconstructed, the data will be sent on-line to the Company, EPS and at the BRR control system simultaneously.

Radionuclide sorption studies of Co, Cs and Sr onto soils from an Australian legacy radioactive waste site

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This paper discusses results of radionuclide sorption studies on a soil profile taken from a low level radioactive waste site in South Eastern Australia, known as the Little Forest Burial Ground. Low level radioactive waste was buried at this site in a series of shallow trenches in the 1960s, and the site has been the focus of a field study in recent years. Measurable amounts of Co-60, Sr-90, Cs-137 and traces of actinides have been observed at this legacy waste site in some soils, groundwater and vegetation samples taken in close proximity to the disposal area.

The sorption of Co, Cs and Sr was studied at four depth intervals from one corehole located near the trenches using radioactive tracers and a batch sorption method. Strong sorption was observed for Cs over the entire pH range studied, whereas the sorption of Co and Sr on the soils was pH dependent with sorption edges between pH 3 and pH 6. Distribution coefficients (K_d values) for Cs sorption were similar for each soil over the entire pH range, with variations of less than one order of magnitude between samples. However, the Kd values for Sr and Co sorption varied over two and three orders of magnitude, respectively, over the pH range studied. The bulk mineralogy of the soils was found to be similar with quartz, kaolinite and interstratified illite/smectite to be the main mineralogical phases with iron oxides and anatase as minor minerals in some soils. The BET surface areas of the bulk samples varied from 27 m^2/g to 47 m^2/g and no strong correlation of surface area with sorption was observed. The CEC of the bulk samples range between 10 and 24 cmol/kg. The CEC of the clay fractions were significantly higher, ranging from 21 to 34 cmol/kg and 34 to 55 cmol/kg for the < 2 µm and < 0.2 µm fractions, respectively. Further studies to elucidate the role of the various minerals with respect to sorption are in progress in order to assess the key site characteristics governing contaminant release and transport.

Marine ecological risk analysis of radioactive releases from the Fukushima Daiichi nuclear power plant accident

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Ecological risk analyses (ERAs) were undertaken of the impact on marine biota of radioactive releases from the Fukushima Daiichi Nuclear Power Plant (NPP) accident in March 2011. Radiological doses were estimated using the Radiological Impact Assessment for Coastal Aquatic (UK) software and assessed against International Commission for Radiological Protection (ICRP) guidelines. These guidelines recommend three reference animals and plants (RAPs) for marine ecosystems, i.e. macroalgae, crabs and flatfish. Whole-of-ecosystem probabilistic ERAs were performed using AQUARISK™ software developed in Australia. Both approaches utilise the FREDERICA database on the impact of ionising radiation on non-human species (European Commission's 6th framework project on Environmental Risk from Ionising Contaminants: Assessment and Management - ERICA). Several constraints exist for an effective ERA. For example; only 134-cesium, 137-cesium and 131-iodine data received from the Japan Ministry of Education, Culture, Sports, Science & Technology (MEXT) were used and biological concentration factor data are limited, often referring to 'similar taxonomy/ biogeochemistry' or reference organisms not endemic to Asia. Finally, these risks must be revised in the future due to on-going releases from the Fukushima NPP, atmospheric fallout, catchment retention and highly variable local oceanographic phenomena. Responding to the 2011 Fukushima Daiichi nuclear power plant accident and the rapid expansion of nuclear power facilities in Asia, the International Atomic Energy Agency has established a project, coordinated by Australia, titled *Marine benchmark study on the possible impact of the Fukushima radioactive releases in the Asia-Pacific Region (2011-15)* to address regional gaps in knowledge and capabilities for monitoring, risk analysis and response. The project involves 23 Asia/Pacific countries with Australia as Lead Country.

Weapons test plutonium signatures from a coral archive

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An extensive series of nuclear tests were carried out by the USA at Enewetak Atoll in the Marshall Islands between 1952 and 1958, including two of the largest H-bomb tests. A coral core collected from the atoll lagoon shows pronounced peaks in the ^{14}C content. The core chronology suggests these are close to the times of individual tests, but peak intensities do not appear to correspond to the explosive yields from each test. We have measured the bomb products $^{239,240}Pu$ and ^{236}U using accelerator mass spectrometry and find a similar pattern of peaks in the isotopic concentrations. Further, the $^{240}Pu/^{239}Pu$ and $^{236}U/^{239}Pu$ ratios are found to be very different for the different tests. The relationship between these observations and the properties of individual test will be discussed.

Element transport in marine coastal ecosystems – modelling general and element-specific mechanisms

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Radionuclide transport models are a part of radiological assessments which provide predictions of concentrations of radionuclides in the foodweb and prediction of doses to humans and biota. Usually concentration ratios (CRs) are determined from measurements as a ratio of the radionuclide concentration in an organism to the concentration in water in natural ecosystem. Seasonal and spatial variations can be several orders of magnitude in radionuclide CRs even for the same element within the same functional group of marine organisms. Measured CRs of important radionuclides for risk assessments are missing for many marine species. Thus modeling is alternative way of estimating CR values. In our study a dynamic stochastic compartment model for radionuclide transfer in a coastal brackish water ecosystem was applied in a marine sub-basin (Örengrundsgrepen, Baltic Sea, Sweden). In the model the radionuclide flow was assumed to follow the flow of organic matter. Radionuclide-specific mechanisms such as radionuclide uptake by aquatic plants and adsorption of radionuclides to organic surfaces were connected to the ecosystem model. Most input parameters were represented by log-normally distributed probability density functions. Using our model the CRs for grazers, benthos, zooplankton and fish for 26 elements were predicted and compared with site-specific data. The uncertainty variations were reduced when the model was parameterised with site data and elements with higher sorption capacity had higher CRs for all organism groups. Prediction of CRs was most successful for lower trophic levels.

Radiation protection of the environment: quantifying transfer

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To assess the exposure of wildlife to ionizing radiation an approach is needed which contains the following components: (i) transfer of radionuclides to wildlife; (ii) dose conversion coefficients relating internal and media activity concentrations to estimate absorbed dose rates to wildlife. The risk to wildlife is then considered using knowledge of the biological effects of ionizing radiation which has been compiled in the FREDERICA database.

The IAEA initiated the Biota Working Group within its Environmental Modelling for Radiation Safety programme to compare and improve the growing number of approaches to estimate the exposure of wildlife (both plants and animals) to ionizing radiation. Differences in the transfer components resulted in large variation in predicted whole organism activity concentrations and resultant internal doses.

The transfer from contaminated media to organisms is most often quantified using the Concentration Ratios ($CR_{wo\text{-}media}$) between the whole organism (fresh weight) and either soil (dry weight), water or air, at equilibrium. An online database has been used to collate $CR_{wo\text{-}media}$ values for both an IAEA wildlife transfer handbook and an ICRP report on transfer to Reference Animals and Plants (RAPs). These two compilations are now being increasingly used in assessments to estimate internal dose rates to wildlife from whole body activity concentrations for different exposure conditions.

The ICRP document collates CR values for the Reference Animals and Plants (RAPs) reporting values based on both data and derived values. The IAEA handbook, currently going through the IAEA publication process, presents collated $CR_{wo\text{-}media}$ data values for a range of wildlife groups (classified taxonomically and by feeding strategy) in terrestrial, freshwater, marine and brackish generic ecosystems. A critical evaluation will be given of currently available data in both of these major international sources.

There are currently many $CR_{wo\text{-}media}$ values in the ICRP report and available assessment tools which are derived. We need to prioritise which $CR_{wo\text{-}media}$ gaps are most important to fill, which values based on data need improving and which values are less important. Such evaluations need to consider the (i) different sources of radionuclides in the environment (ii) relative importance of internal and external doses that would arise for different wildlife groups and (iii) stakeholder opinion. Recently, we have been developing criteria which might be applied to aspect (ii) for the ICRP RAPs. The initial outcome of the application of some criteria will be described and evaluated.

Is it possible to detect ^{236}U and Pu in European roe deer antlers?

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It is known that uranium can deposit in the skeletal tissue and due to the fact that the antler histology is similar to that of bone, one can assume to find also uranium in antlers. Therefore we investigated its concentration with special emphasis to ^{236}U and also plutonium in European roe deer antlers between 1955 and 1977. The radiochemical procedure is based on a Pu separation step by anion exchange (Dowex 1x8) and a subsequent U purification step by extraction chromatography using UTEVA®. The samples were finally measured by Accelerator Mass Spectrometry (AMS) at the VERA facility. Our study has shown that the isotopes of both bone-seeking elements (^{236}U as well as Pu) are readily detectable in antlers. In addition, the concentrations observed in the antlers studied here show a marked increase through the period of nuclear testing and then a decrease after the implementation of the nuclear test ban treaty. Additionally the ^{240}Pu/^{239}Pu isotopic ratios were determined in these samples with a mean value of 0.166 ± 0.019. Our investigations have shown the potential to use antlers for the analysis of ultra-trace pollutants in the environment: antlers are a temporally resolved archive for the uptake of actinides from the environment into higher animals.

Biota dose modelling: Little Forest Burial Ground Scenario

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Radiation doses to terrestrial wildlife were examined in a model inter-comparison study on a diverse range of terrestrial plants and animals at the Little Forest Burial Ground, NSW, Australia. This inter-comparison was one in a series conducted under the IAEA Environmental Modelling for Radiation Safety Programme (EMRAS), which indicated general agreement among available biota dose models in the use of dose conversion parameters for standard organisms and geometries [1,2,3]. However, notable variation in dose estimates emerged when the models were applied to a terrestrial deposition scenario (Chernobyl exclusion zone, Ukraine [4]); a freshwater aquatic scenario (Perch Lake, Canada; [5]), a low-level burial ground scenario (Little Forest Burial Ground, Australia; [6]), as well as additional aquatic (Beaverlodge, Canada) and wetlands (various locations) scenarios currently underway.

Given the range in outcomes from the various modelling approaches of the previous EMRAS studies, the Little Forest Burial Ground scenario focused on quantifying the factors causing variation. The dominant variable factor (up to three orders of magnitude on mean total dose rates) was the soil-to-organism transfer of radionuclides. Additional variation was associated with: exposure configurations (two orders of magnitude when considering trees growing on the waste trenches); inclusion/exclusion of progeny in Th and U isotopes (typically less than one order of magnitude); and radiation weighting factors and dose conversion coefficients (typically less than one order of magnitude).

At Little Forest, results suggest radionuclide uptake is occurring in wildlife, but at low levels as most organisms only access the relatively clean surface soils above the buried wastes. Doses to acacia tree were elevated, however, due to its deeper roots having direct access to the buried wastes, with predictions of 95th percentile doses above the screening levels indicating further study is warranted.

Our study confirms and adds to the outcomes of previous EMRAS studies in quantifying the sources of variation in biota dose modelling, and highlights soil-to-organism transfer as a key source of uncertainty [7]. It prompts continued evaluation of the underlying mechanisms governing soil-to-organism transfer of radionuclides to improve estimation of dose rates to terrestrial wildlife.

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Analysis of food samples following the Fukushima incident

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Following the accident at the Fukushima nuclear power plant the ARPANSA radiochemistry laboratory was involved in the screening of hundreds of food samples as part of the Australian Quarantine and Inspection Service (AQIS) Imported Food Program. Selected food samples, imported from specific prefectures within Japan, were received for analysis. Immediately following the incident the samples were analysed for ^{134}Cs and ^{137}Cs and ^{131}I, but in the later phase this was modified to include only ^{134}Cs and ^{137}Cs. This poster will outline the results of the testing of different types of food imported to Australia from Japan and the application of the guideline levels recommended by the FAO/WHO Codex Alimentarius.

Radon Concentrations at a Radioactive Waste Storage Facility

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Radon-222, a decay product of radium-226, is an inert gas and may become airborne by diffusing into the air. Radon and its short-lived decay products in the atmosphere are the most important contributors to human exposure from natural sources. Inhalation of radon (222Rn) represents the main contribution to the effective dose received by the workers.

The Waste Management Department of Nuclear and Energy Research Institute – IPEN is responsible for safety management of the wastes generated at all internal research centers and other waste producers as industry, medicine and universities around the country. These wastes, after treatment, are stored in an interim storage facility. Among them, are: ^{226}Ra needles used in radiotherapy; siliceous cake arising from conversion process; and, several other classes of wastes from nuclear fuel cycle which contain radionuclides that have ^{222}Rn as daughter.

In order to estimates afterwards the effective committed dose for the workers due to radon inhalation, it is being assessed the radon concentrations at the storage facility.

Radon measurements have been carried out through the passive method with SSNTD (CR-39), due to their simplicity and long-term integrated read-out. The detectors exposure period is three months, covering one year at minimum.

The radon concentration results, covering the period from April 2011 to March 2012, varied from 830 ± 66 Bq/m^3 to 2080 ± 145 Bq/m^3.

The impact on Australia from the Fukushima Dai-ichi nuclear power plant accident

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During and after the 2011 nuclear reactor accidents at the Fukushima Dai-ichi nuclear power plant (NPP) in Japan, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) undertook a range of measurements and studies to assess the impact of the accident on Australians in Japan and people and the environment in Australia.

A technical report has recently been developed to provide a comprehensive record of the data collected and the range of work undertaken as a result of the accident. The report includes an assessment of the risk and likelihood of radioactive materials reaching Australia through natural processes as well as through anthropogenic processed. Data and methods are provided for the xenon-133 detections in Darwin during April 2011, Australia's testing program for imported foods, and contamination testing of shipping vessels, ship ballast water and imported vehicles. Dose assessments were also undertaken for a family living 60 km north-west of the Fukushima Dai-ichi NPP and for migratory birds.

The Impact of Alpha-Emitting Contamination on the Handling and Analysis of Forensic Evidence

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A nuclear security event, where for example radioactive material is used in a malevolent act or where material is found outside of regulatory control will require an investigation. That investigation may require the collection, handling, and analysis of forensic evidence and hence it is highly likely that some of the physical evidence associated with such an event would have been exposed to radiation and possibly be contaminated with nuclear or other radioactive material. These scenarios present significant challenges to traditional approaches to crime scene investigation and it is well recognised by the international nuclear forensics community for the need to assess the application of existing forensic techniques to radiation-exposed samples and the implementation of procedures for safe and efficient examination of evidence contaminated with radioactive material.

Previously, at the Australian Nuclear Science and Technology Organisation's Nuclear Forensics Research Facility the effect of gamma radiation on forensic evidence as well as the impact of decontamination on evidence has been explored. This presentation will report on considerations for handling evidence contaminated with radioactive material and detail the latest developments in evaluating the application of forensic techniques to evidence exposed to, or contaminated with alpha-emitting radionuclides.

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Methodology improvement: Separation and measurement of uranium, thorium, americium, plutonium and strontium in large mass environmental samples

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This paper outlines recent method modifications implemented for the radiochemical analysis of large volume groundwater, soil and ashed tree samples. The issues addressed include the formation of silica gel, interference of polonium-210 (^{210}Po) with the uranium-232 (^{232}U) tracer peak in U spectra, and broadening of alpha peaks in thorium (Th) and americium (Am) spectra due to chemicals derived from separation resins.

A silica gel forms in evaporated groundwater samples that increases co-precipitate volumes and sample load solution volumes. If not effectively removed, this silica gel will clog the separation resin cartridges. The addition of polyethylene glycol (PEG) followed by high speed centrifugation and filtering after co-precipitation enables the removal of this silica gel.

^{210}Po, present in some ashed vegetation samples with activities up to 500 Bq/kg, was sometimes found in the U fraction. The ^{210}Po alpha emission peak overlaps the ^{232}U tracer peak, preventing accurate chemical yield determination. An additional wash step between Am and U elution was implemented to remove ^{210}Po from the U fraction.

Organic compounds from the TEVA™ and TRU™ separation resins are leached into the Th and Am fractions respectively, resulting in broad alpha peaks. Evaporation and dilution of the fractions prior to alpha source preparation or the use of an Eichrom Pre-filter cartridge during elution is required.

Identification and quantification of ^{233}U at a legacy waste site

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The Little Forest Burial Ground (LFBG), located within the Australian Nuclear Science and Technology Organisation (ANSTO) buffer zone, was used to dispose of low level radioactive waste in shallow trenches during the 1960s. Operational records suggest that natural and anthropogenic radionuclides were disposed of, including uranium-233 (^{233}U), a fissile isotope of uranium. This paper outlines how ^{233}U was identified and then quantified in environmental samples from LFBG in the presence of other uranium isotopes.

Alpha spectrometry sources were prepared using ^{232}U as a tracer and counted to give a qualitative indication of 233U from the combined $^{233+234}U$ activity. The primary region of interest (ROI) of ^{233}U is a doublet peak, with emission energies of 4.784 MeV (13%) and 4.824 MeV (84%). This peak, if present in an alpha spectrum, will overlap with the primary ROI of ^{234}U, also a doublet of 4.722 MeV (28%) and 4.775 MeV (71%).

Based on alpha spectrometry results, samples thought to contain ^{233}U were then prepared for Accelerator Mass Spectrometry (AMS). AMS was used to measure the $^{234}U/^{233}U$ isotope ratio. The isotope dilution method, with ^{236}U spike, was not able to be used with samples from this study site as low levels of this anthropogenic isotope have also been detected. Instead, the isotope ratio $^{234}U/^{233}U$ from AMS was used with the combined $^{233+234}U$ activity from alpha spectrometry to derive the ^{233}U activity. This combination of techniques enables ^{233}U to be quantified in these types of environmental samples.

Using hydrogeochemistry and isotopes to trace groundwater flow from Little Forest Burial Ground and surrounding landfills

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Multiple tracer-element and isotope approaches were used to study groundwater near a legacy low-level radioactive waste burial site surrounded by municipal and industrial waste sites. The interaction of rainfall, with its marine-derived major ion ratios, and waste from the sites is apparent, however, clay-rich soils and shale at the site tend to retain many contaminants via ion exchange and other processes. High permeability of the disposal trenches provides a pathway for groundwater recharge, with discontinuous perched groundwater lenses found in their vicinity.

Within the trenches, the degradation of organic matter results in localised methanogenesis, as suggested by enriched δ2H and $\delta^{13}C_{DIC}$ in adjacent subsurface water. Movement of contaminants from the waste sites is indicated by Na+, Br^- and I^- concentrations, variations in $^{87}Sr/^{86}Sr$, enriched $\delta^{13}C_{DIC}$ and evolution of $\delta^{34}S$ of dissolved sulfate in perched water bodies above the shale. There is clear evidence of a tritium plume from the LFBG trenches, although the adjacent landfills provide an additional tritium source. Waste burial records show that over 1000 kg of Be (mostly BeO) were disposed in the LFBG trenches. However, beryllium concentrations in groundwaters near the trenches are quite low, and appear more likely to be controlled by the host lithologies and the other sources of contamination in the vicinity, rather than by leaching of Be from the LFBG waste. Past removal of the shale layer in an adjacent site, Harrington's Quarry, has led to the mixing of municipal waste leachates into the underlying groundwater system as suggested by high TDS, Cl−/Br− ratios, Be, and ^3H found in deeper wells. The multiple tracer approach addresses the complexities of transport at the site and differentiates various municipal, industrial, and radioactive waste sources.

Behavior of Cs and Sr in sewage treatment plant

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Radionuclides were released into the environment due to the nuclear accident at the Fukushima Daiichi Nuclear Power Plant (FDNPP). A part of these radionuclides flowed into sewage treatment plants through sewer systems.

We observed the fate of radiocesium ($^{134+137}$Cs) in the sewage treatment process. The fates of stable Cs and Sr in the sewage treatment process were also observed as a means to predict the fate of radiocesium and radiostrontium. Concentrations of radiocesium, stable cesium, and stable strontium were determined in sewage influent, effluent, sewage sludge, and sewage sludge ash collected from a sewage treatment plant located about 280 km north of FDNPP once a month from July to December 2011.

Radiocesium was detected in the sludge and the ash samples while the concentration in influent was under the detection limit. Given that radiocesium was not detected in the sludge and the ash samples collected before the accident, radiocesium released to the environments from FDNPP entered the sewage treatment plant, and then concentrated in the sludge. From the results of monitoring of stable Cs, 11 % of the total Cs entering the plant was transferred to the sewage sludge on average.

In the mass balance of Sr in the sewage treatment plant, 76 % of the total Sr entering the plant was discharged to the water environment on average. Additionally, 21 % of the total Sr entering the plant was transferred to the sewage sludge and then concentrated in the sludge ash.

Developing and calibrating a method for analysis of Pb-210 via Liquid Scintillation Counting: A technical perspective

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In many publications of radioanalytical methods there is a lack of detailed information, that hinders the ability of other laboratories to reproduce the published methods in entirety. In particular, the initial steps required for calibration of a new method can be difficult to extract and then reproduce from a publication, particularly for small laboratories, without contacting the authors.

In this presentation, the process of method development for analysis of ^{210}Pb via liquid scintillation counting (LSC) is detailed and initial results will be presented. In particular, emphasis is given on preparation for development and calibration of the new method and lessons learned in the development process. The method will be used to determine ^{210}Pb activity concentrations in a range of samples, with a focus on biota samples from projects investigating naturally occurring radionuclides in Australian bush foods.

The current method used for analysis of ^{210}Pb in our laboratory involves two separate measurements of ^{210}Po. The first measurement is made after separation of Po from the sample, and the second measurement is performed after separation of Pb then allowing time for ingrowth of ^{210}Po. Alpha spectrometry is used to measure ^{210}Po in both cases.

With LSC, ^{210}Pb is measured directly via its beta decay. Although LSC has significantly higher background count rates than alpha spectrometry, the method developed has comparable detection limits to our current technique. Switching to the new LSC method will significantly reduce the sample handling time, turnaround time and operating costs compared to analyses of ^{210}Pb using the ingrowth method with alpha spectrometry.

Methods for isolating plutonium particles in Maralinga soils

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A combination of density-separation and gamma testing methods was used to isolate a plutonium (Pu)-containing particle from the host Maralinga soils. Such separation is necessary in order to reduce or eliminate interference from other elements in the host soils that may occur during analysis methods (e.g., synchrotron XANES) used for determining physico-chemical information such as compound speciation and oxidation state.

Soil samples were obtained from the Taranaki test area, at Maralinga, South Australia, where Pu had been dispersed by high explosive detonation and through burning in the 1950s. Bulk soil samples were first screened using HPGe gamma-ray spectrometer for detection of Am-241 (0.060 Mev gamma emission) which co-exists with the Pu in the dispersed particles at a concentration ratio of approximately 1:7.5 (Am-241 to Pu-239). The sample was sieved (125 µm) to remove large sand particles and debris. Density separation was accomplished by repeated sonification (0.5 in. probe tip sonifier) and centrifugation of mixtures of soil and lithium heteropolytungstate (density of 2.9 g/ml). The various density fractions were tested for Am-241 through gamma counting. This process was repeated until a small mass (<0.01 g) of heavy particles remained. Further isolation was accomplished using microscope, physical separation, and gamma counting.

The result of the process was isolation of a small particle, containing Am and Pu isotopes that had been originally part of a non-critical nuclear weapons test. The particle had been dispersed approximately two kilometres through the air pathway, and has been subjected to +60 years of weathering and chemical interaction processes. The isolation process allows for further testing of the Pu, without interference from natural soil elements, to provide a range of pathway, biological uptake, and dose information.

Detection of radioxenon in Darwin, Australia following the Fukushima Dai-ichi nuclear power plant accident

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A series of ^{133}Xe detections in April 2011 that were made at the Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO) International Monitoring System noble gas station in Darwin, Australia were analysed to determine the most likely source location. Forward and backwards atmospheric transport modelling simulations using FLEXPART were conducted. It was shown that the most likely source would have originated from the Fukushima Dai-ichi nuclear power plant accident. Other potential sources in the southern hemisphere were analysed, including the Australian Nuclear Science and Technology Organisation (ANSTO) radiopharmaceutical facility, but it was shown that sources originating from these locations were highly unlikely to be the source of the observed ^{133}Xe Darwin detections.

Cesium-137 Activity Concentrations in Soil and Brick Samples of Mirpur, Azad Kashmir; Pakistan

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Background, aim, and scope Human beings are continuously irradiating from background radiations, coming from naturally occurring and man-made radionuclides. Radiations emanated by these radionuclides acts as an etiologic agent allied with disease. ^{137}Cs is one of the most significant fallout radionuclide present in the environment. Higher activity concentration of ^{137}Cs in the environment may pose certain detrimental effects associated with health. This study aims at the measurement of ^{137}Cs levels in soil and brick samples and to set the baseline data for this part of world. Activity concentration of ^{137}Cs in soil and brick samples will be the indicator of fallout radioactivity in the area. Current study will help to probe, if there is any health threat posed by ^{137}Cs exposure to the residents of the area.

Materials, methods, and results This paper presents the measurements of activity concentration of ^{137}Cs in soil and brick samples collected from district Mirpur of Azad Kashmir. Thirty one samples (25 samples of soil and 6 samples of bricks) were collected from different locations of Mirpur. A P-type HPGe detector was used to measure gamma spectra of soil and brick samples Results shows that for soil samples activity concentration range from 0.076±0.071 to 2.94±0.17 Bq. Kg^{-1} with average value of 1.39±0.17 Bq. Kg^{-1}. Similarly activity concentration of ^{137}Cs in Brick samples range from 0.22±0.09 $BqKg^{-1}$ to 2.14±0.13 $BqKg^{-1}$ with average value of 0.73±0.10 Bq. Kg^{-1}. For soil samples the average values of outdoor, indoor and annual effective dose are found as 5.12 10^5, 20.47 10^5 and 25.58 10^5 mSv. y^{-1} respectively. For brick samples specific activity of the ^{137}Cs ranges from 0.22±0.09 to 2.14±0.13 $BqKg^{-1}$. The average values of outdoor, indoor and annual effective dose for brick samples are 2.71 10^5, 10.52 10^5 and 13.23 10^5 mSv. y^{-1} respectively.

Discussion and conclusions The results obtained from the current study demonstrates that these measured values are extremely small when compared with the annual dose rate recommendation of 1.0 mSv set by ICRP, as well as the annual external gamma radiation dose (0.48 mSv. y^{-1}) received per head from the natural sources of radiation assessed in UNSCEAR (2000) report. To conclude, ^{137}Cs exposure to the local population will not pose any significant health threat.

Ground Surveys in an Inhabited Area Adjacent to Granitic Massif of High Terrestrial Background Radiation, Hail Province, Saudi Arabia

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Airborne surveys showed that Jabal Aja Massif of granitic composition is a radiometric anomaly area and should be of interest for ground surveys, in a purpose of radiation protection. Hail city, and some nearby scattered villages represent an inhabited area lies in the northern central region of Saudi Arabia and adjacent to Jabal Aja Massif. Ground surveys have been conducted, covering the populated sites in the area to assess the radiation dose rate to inhabitants, and hence the associated risk. A map showing the predominant geology, the location of the study area and the measurement sites is presented. The results showed that the dose rate due to terrestrial γ-radiation varied from 0.7 to 2.86 mSv/y, with an average value of 1.25 mSv/y. This average value is about 2.7 times greater than the average annual external effective dose (0.46 mSv/y) that estimated in normal background areas and reported in UNSCEAR 2000 report. Based on the average dose rate value, the excess lifetime cancer risk due to terrestrial γ-radiation, was estimated by 4.4 $x10^{-3}$. The radiation dose rate was found to be linked with the surface geology where higher doses are released from the monzogranite rocks and the soils derived from.

Radionuclide bioaccumulation patterns in vegetation at a legacy low-level waste site

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This study focuses on uptake of radionuclides (RN) into trees at a legacy low level radioactive waste site (the Little Forest Burial Ground (LFBG) near Lucas Heights in southern Sydney). Tree species included: *Acacia longifolia longifolia; Syncarpia glomulifera; Eucalyptus paniculate; Leptospermum polygalifolium;* and *Banksia serrata.* Branches – (wood and foliage) were sampled, and soil cores were collected around each tree. Analytical techniques included Inductively Coupled Plasma Atomic Emission Spectrometry and Mass Spectrometry, alpha and gamma spectrometry, Accelerator Mass Spectrometry and Cerenkov counting. Anthropogenic RN measured in trees and soils were ^{90}Sr, ^{137}Cs, ^{233}U, $^{239+240}$Pu and ^{241}Am.

Median concentrations of RN in trees growing on, or near, the trenches (^{90}Sr - 9.855 Bq/kg, ^{137}Cs - 0.220 Bq/kg, $^{239+240}$Pu - 0.004 Bq/kg) were significantly higher than background trees (^{90}Sr – 0.001 Bq/kg, ^{137}Cs – n.d., $^{239+240}$Pu - 0.002 Bq/kg). Most trees had higher levels in foliage compared to wood. However; there was large variation among branches within the same tree. Uptake of radionuclides was quantified by the concentration ratio (CR), defined as average concentration in the tree to that of the surrounding soil. CR's for trees growing around the trenches were an order of magnitude higher than for background trees, which is attributed to the trees taking up radionuclides directly from the subsurface. Our results better quantify the bio-available fraction of radionuclides in the environment at the LFBG, and reveal that site trees are bio-monitors of multiple radionuclides sourced from the sub-surface wastes.

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