development and delivery of new capabilities in nuclear security designed to meet the current and emerging needs of our national security partners in government.

The NFRF houses a combination of expert staff, specialised instrumentation and a quality system established with due consideration of forensic requirements. Key focus areas of the NFRF include:

- Provision of an operational nuclear forensics capability in support of investigations, (categorisation, characterisation, analytical analysis and interpretation of radioactive or other nuclear material and/or examination of evidence contamination with radioactive material),
- Development of standard operational procedures (SOPs) which are integral to ensuring the quality and reliability of our analytical forensic analysis,
- Provision of specialised training in nuclear forensics,
- Research which leads to new capabilities in areas such as radio-chronometry (age dating of nuclear materials) and the provenance of uranium ore concentrates.

ANSTO also provides international leadership in nuclear forensics through our chairing role of the Nuclear Forensics Working Group of the Global Initiative to Combat Nuclear Terrorism (GICNT).

In the field of nuclear detection we have developed a range of new technologies to assist border security authorities in the interdiction of trafficking of illicit nuclear and other radioactive materials. New algorithms designed to reduce the rates of false positive alarms in spectroscopic portal monitors (SPMs) have been developed along with algorithms that improve the correct identification of radionuclides in handheld radioisotope analysers.

We have also contributed to the capability of our border security agencies in the detection of contraband through the development and implementation of new imaging standards now in use around Australia at the Container Examination Facilities. The AUS series X-ray Test Piece technology is a series of X-ray imaging standards used to ascertain the on-going imaging performance of medium and large X-ray screening systems. The technology was recently licensed to a company that specialises in border security for world-wide distribution.

This talk will share some of our recent successes and ongoing challenges in the fields of nuclear forensics and nuclear detection.

PAPER 4

Plutonium Uptake in Biota at Former Nuclear Sites

Dr Mathew Johansen

Institute for Environmental Research
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BIOGRAPHY

Mat Johansen has more than twenty-five years of experience in environmental assessment, monitoring, and remediation of hazardous and radioactive contaminated sites. He is currently a senior researcher at the Australian Nuclear Science and Technology Organisation. His work focuses on the use of radioactive and stable isotopes in freshwater, marine, and terrestrial environments. Key analysis tools include the Australian Synchrotron, Accelerator Mass Spectrometry, and Isotope Ratio Mass Spectrometry. His collaborations are within the International Atomic Energy Agency framework, with international research laboratories and with Australian organisations and universities.

Dr Johansen's research is designed to answer key questions of importance to Australia including risk assessment for public and environmental health, assessment of nuclear issues and disposal of radioactive wastes, and impacts on groundwater and surface water supplies in our changing world.

Plutonium Uptake in Biota at Former Nuclear Sites

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Plutonium (Pu) is of ongoing interest as worldwide inventories continue to increase and plans for permanent storage of Pu wastes have stalled in many countries leaving large amounts in temporary storage. Pu also remains as environmental contamination at various locations due to: accidents (e.g., Chernobyl, UKR; Thule, GRL); research and processing releases (e.g., Los Alamos, USA, Mayak, RUS); and former weapons testing (e.g., Nevada Test Site, USA; Semipalatinsk, KAZ; and Maralinga, AUS).

We assessed the availability and uptake of Pu in a range of wildlife types at legacy sites with the focus on new data from outside of the remediation zone at the former Taranaki site, Maralinga, South Australia. Of key interest are the uptake and biokinetics of Pu in mammals, particularly from environmental exposure to the undetonated Pu-oxide forms at Taranaki that are representative of much of the worldwide inventory.

Our results confirm that environmentally dispersed Pu can remain accessible for uptake by biota over decadal time scales. For example, after more than 50 years since deposition at Taranaki, 62% of Pu has remained in the 0-2 cm surface layer, and nearly 100% in the 0-10 cm of soil depths. Although a small fraction of the Pu is migrating downward at ~0.2 cm per year, it appears that most Pu will continue to remain accessible into the future for plants and animals that inhabit the surface, or shallow soil layers.

The uptake of Pu into terrestrial animals occurs mainly by inhalation and ingestion, and can be persistent over time as indicated by constant uptake rates for mammals, and a potential increase for reptiles, in data spanning 30 years. The rates of soil-to-animal transfer at Taranaki, align well with those from similar sites where undetonated Pu was tested (e.g., Nevada Test Site, US). However, the uptake values at these sites are lower than general world-wide values, likely due to the presence of less-absorbable forms of Pu. The importance of the physico-chemical form of the Pu on uptake was also seen in data from fish exposed to more absorbable forms of Pu in liquid discharge ponds near processing facilities in the US. These fish had two orders of magnitude higher uptake values than those for similar species receiving Pu solely from atmospheric fallout.

The physico-chemical form of the Pu can also influence how it is distributed among mammalian organs. The relatively insoluble forms at Taranaki, which include particulates, led to elevated concentrations of unabsorbed Pu in the lung, gastrointestinal tract, and adhered to skin/fur of mammals. This elevated Pu can provide a secondary source during human, and ecological, food-chain consumption. Of the Pu that was absorbed within the body, much higher accumulation was measured in the skeleton, and much lower in the liver, in mammals at Taranaki as compared with the standard model of 50% skeleton, and 30% liver (ICRP 1986).

Our data provides specific quantification of Pu uptake rates in wildlife and the subsequent accumulation in various mammalian organs. These will aid future assessments of the Maralinga site, as well as more general evaluations related to the low-solubility forms of Pu that make up a large share of the worldwide inventory.

*ICRP 1986. The Metabolism of Plutonium and Related Elements. International Commission on Radiological Protection, Publication 48, vol. 16, ICRP, Elsevier.

PAPER 5

Innovative Health Solutions using Nuclear Techniques

Professor Dale Bailey, *PhD FIPEM FACPSEM ARCP(Lond.)*

University of Sydney

BIOGRAPHY

Dale Bailey is Principal Physicist in the Department of Nuclear Medicine, Royal North Shore Hospital, Sydney and Professor in Medical Radiation Sciences at the University of Sydney. His main area of interest is in the development of quantitative techniques using imaging of *in vivo* radionuclide tracers in both SPECT (single photon emission computed tomography) and PET (positron emission tomography). Dale is currently CI for a number of grants including studying the micro-vascular changes in pulmonary arterial hypertension using ventilation & perfusion SPECT, and improving imaging and dosimetry techniques in selective internal radionuclide therapy (SIRT) in liver cancer using SIR-Spheres using SPECT & PET.

ABSTRACT

Australian nuclear medicine is currently amongst the highest standard of anywhere in the world. Its origins here are firmly entrenched in Internal Medicine, with its emphasis on physiology and function, unlike many other countries such as the USA where a Radiology orientation dominates. In addition, Australia has been well served by extremely competent and innovative physical scientists working in universities, government research facilities (*e.g.*, AAEC, ANSTO) and tertiary referral hospitals who have established their main affiliations as being within the highly multidisciplinary nuclear medicine community.

Nuclear medicine in the past 10-15 years has experienced a massive shift towards "hybrid" imaging – where two (or more) complementary imaging modalities, such as X-ray CT and a Positron Emission Tomography (PET) or Single Photon Emission Computed Tomography (SPECT) scanner, are combined into a functionally single device which provides high resolution spatial anatomical (form, or structure) and radionuclide distribution (function) images. In addition, the nuclear imaging techniques maintain their quantitative characteristics and thus combined structure-function imaging results in a significant improvement in diagnostic capability – looking beyond simple forms to quantifying degree of disease, *e.g.*, malignancy of a cancer. Recently, PET scanners have been combined with NMR Imaging (MRI) and these will provide new areas of application, especially in magnetic resonance spectroscopy and radionuclide imaging. The techniques are extremely valuable in monitoring response to treatment, allowing treatments to be changed if proving ineffective. In addition,