International Standardization of Basic Industrial Radiotracer and Radiation Applications – Current Status

Thorsten JENTSCH[1], Jovan THERESKA[2], Patrick BRISSET[3], Joon-Ha JIN[4],

[1] *Helmholtz-Zentrum Dresden - Rossendorf (HZDR), Bautzner Landstraße 400, 01328 Dresden, Germany,*
[2] *International Society for Tracer and Radiation Applications, Jochen-Rindt-Str. 33, 1230 Wien, Austria,*
[3] *Centre CEA de Saclay, 91190 Gif-sur-Yvette, France*
[4] *EYL, Inc, (06776) 4F, 7-40, Mabang-ro 6-gil, Seocho-gu, Seoul, Republic of Korea*

The International Atomic Energy Agency (IAEA) in cooperation with the International Society for Tracer and Radiation Applications (ISTRA) promotes the international standardization of basic industrial radiotracer and radiation applications. Experts from many countries analyze existing international standards regarding the necessity of their update or amendment as well as the need for new standards in this field.

In June 2020, a new international standard on "Non-destructive testing - Gamma ray scanning method on process columns" was published as ISO 23159 [1]. About three years before, experts realized the need to standardize this method, which is widely used in petrochemical and chemical plants to identify and locate the cause of malfunction inside various process columns.

In the field of flow rate measurements of fluids in conduits using radioactive tracers, a proposal for a new international standard was prepared in 2021. It united several old national and international standards in this technical field: measurement of water flow in closed conduits (ISO 2975), measurement of gas flow in conduits (ISO 4053) and measurement of fluid flow in closed conduits (ASME MFC-13M-2006). The new international standard with the title "Measurement of Fluid Flow Rate in Closed Conduits – Radioactive Tracer Methods" was published as ISO 24460 in 2023 [2].

Another international standard for determining the concentration or density of suspended and deposited sediment in water bodies by radiometric methods has just been published as ISO 6640 with the title "Measurement of density of water-sediment mixture using radiation transmission method" [3].

In addition, two further international standards using radioactive tracer methods are in preparation. One deals with the leak testing in pressured vessels and underground pipelines, the other with the measurement of residence time distribution and flow characterization using radioactive tracers. These two drafts have already passed the New Work Item Proposal (NWIP) stage. The first one being worked on in ISO Technical Committee 135, Sub Committee 6, Working Group 1 (ISO TC 135/SC 6/WG 1), has just reached the stage as a Draft International Standard (DIS) and is expected to be published as ISO 6366 in September 2024. The second draft is currently being worked on in ISO/TC 030/SC 5/WG 7 and is expected to be published as ISO 25056 in 2026 at the latest.

ISO standards are part of accreditation of radiotracer and radiation applications groups, facilitating the promotion and implementation of these competitive technologies in national, regional and international scale.

Email address of corresponding author; *t.jentsch@hzdr.de*

References

[1] ISO 23159:2020, Non-destructive testing – Gamma ray scanning method on process columns
[2] ISO 24460:2023, Measurement of fluid flow rate in closed conduits – Radioactive tracer methods
[3] ISO 6640:2024, Measurement of density of water-sediment mixture using radiation transmission method

Measurements of Radon in Water with CZT Spectrometers

I Kaissas[1,*], K. Karafasoulis[2], A. Kyriakis[3]

[1] *Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece*

[2] *Division of Natural Sciences and Applications, Hellenic Army Academy, 16673 Vari Attikis, Greece*

[3] *Institute of Nuclear and Particle Physics of NCSR "Demokritos", 15341Agia Paraskevi, Attiki, Greece*

Radon (^{222}Rn) is a noble, glowing gas with a tendency to accumulate in enclosed areas. Mainly, due to its radioactive daughters and the α-particles emitted, ^{222}Rn poses a risk of cancer and therefore its concentration in air and water should be kept under certain reference levels. Several methods have been developed to accurately measure ^{222}Rn concentration in water [1]. A well-established method involves γ-spectroscopy using a High-Purity Germanium (HPGe) detector to identify the ^{222}Rn decay isotopes ^{214}Pb and ^{214}Bi, assuming they are in secular equilibrium with ^{222}Rn. This technique requires costly, bulky equipment due to the HPGe's operation at -196°C and the need for substantial shielding.

This study introduces a more affordable, compact alternative using CdZnTe (CZT) crystals, which offer exceptional energy resolution in the 300 to 600 keV range—nearly eight times the Full Width at Half Maximum (FWHM) of HPGe. Two experimental setups were tested: the first with a single CZT detector housing a 0.5 cm³ crystal, and the second with four stacked CZT detectors, each with a 0.5 cm³ crystal. These were compared against measurements from an HPGe detector. Water samples were collected from several boreholes and taps with care for the values of radon concentration to vary in the range of 10 Bq/l to 800 Bq/l. The samples measured at the laboratory: (a) with HPGe spectrometer at -196ºC and (b) with the CZT spectrometers at room temperature (25ºC).

The results, shown in Figure 1 for a sample with 190 Bq/l measured by the first CZT setup, are promising for further exploration of this technology by the Institute of Nuclear and Particle Physics of NCSR "D", including potential in-situ use given its portability.

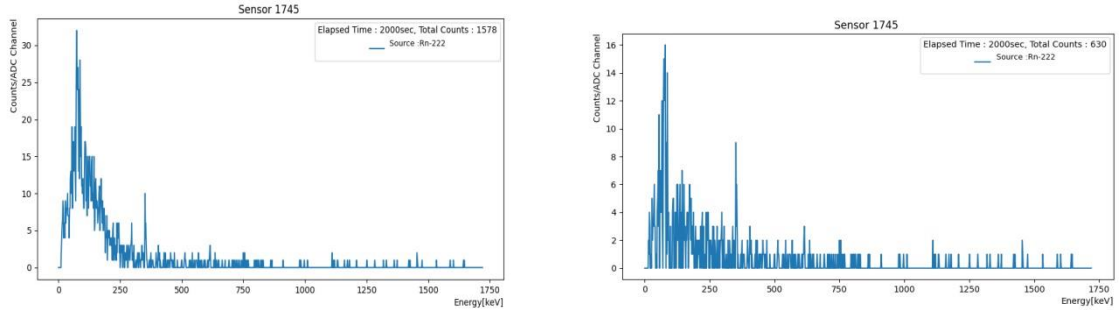

Figure 1: Left: A water sample with radon concentration about 190Bq/l yields a CZT spectrum exhibiting the photopeak of ^{214}Pb at 352 keV and a shorter photopeak of ^{214}Bi at 609 keV. Right: The same spectrum after background subtraction

References

[1] M. Omirou et al, Metrology aspects (sampling, storage, transportation, and measurement) of radon in water, Journal of the European Radon Association (2022), 3: 8643

* Presenting author email: ikaissas@ece.auth.gr

Characterization of a Novel, Large Volume CdZnTe Detector for Marine Applications*

V. Lagaki[1], G. Siltzovalis[1,†], I. Madesis[1], T.J. Mertzimekis[1]

[1] *Department of Physics, National and Kapodistrian University of Athens, 15784, Athens, Greece*

Spectrometers equipped with CdZnTe (CZT) crystals can offer various advantages to nuclear applications due to their high efficiency, good energy resolution and room-temperature operation. However, the manufacturing of large uniform CZT crystals is currently a challenging task. Defects created during the crystal growth limit the charge (electron-hole pairs) collected, thus resulting in deterioration of the energy resolution of the instrument. Nevertheless, latest technology advancements have enabled the growth of larger than usual crystals. Up till now, studies have focused on investigating the response of either small-sized CZT crystals (individually operating or in the form of arrays) or pixelated matrices. In the current work, the characterization of a monolithic, quasi-hemispherical large (4 cm^3) CZT crystal will be reported. The final goal of this work is to investigate the response of this instrument when operating within an underwater housing, surrounded by large volumes of water, making it suitable for deployment and operation in aquatic environments.

Experiments in the laboratory were carried out to examine the efficiency and energy resolution of the detector under various setup geometries. For comparison purposes, results from the characterization were evaluated against the response of a spectrometer featuring a smaller size CZT crystal (1.6 cm^3). Results from an aquatic experiment, which aimed to validate the ability of the detector for underwater operation, are reported. In addition, an extended set of Monte Carlo simulations focusing on the deployment of the large-CZT spectrometer in the marine environment are presented.

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

† Presenting author email: gsiltzo@phys.uoa.gr

OVERVIEW OF RADIOMETRIC TECHNOLOGIES AS APPLIED TO INDUSTRY AND ENVIRONMENT

Prof. Dr. J. Thereska

International Society for Tracer and Radiation Applications (ISTRA), Vienna, Austria

Radiometric technologies such as radioactive tracers and sealed radiation sources have been widely used in various industries and environmental installations to optimize processes, improve product quality, save energy and reduce pollution release.
The basic concept for radioactive tracer methodology is injecting a radionuclide into a moving fluid and employing radiation detectors downstream to measure the Residence Time Distribution (RTD) of the injected tracer inside the processing reactor or installation. The obtained RTD experimental data are becoming an important tool for diagnosing and modelling of processing units. Radioactive tracers are also tools of choice for online calibrating flowmeters in open and closed streams as well as for leak detection in pressured vessels, valves, heat exchangers and underground pipelines.
Radioactive tracers are the most competitive tracers employed for online (non-invasive) field investigations; radioactive tracers have high detection sensitivity for extremely small concentrations; they offer the possibility of in-situ measurements, from the outside of a pipe or vessel.
Today, most of the radioisotopes employed as radioactive tracers are still produced in nuclear reactors. However, cyclotron produced radioactive tracers and radioisotope generators are increasing in frequency due to their availability worldwide.

Neutron and gamma ray sealed radiation sources are largely used for online troubleshooting of processing vessels and inspection of columns, pipes and storage tanks in petrochemical and chemical plants.

Radiometric technologies will continue to constitute an important role in modern industry for diagnostics and process control. Though these technologies are applicable across a broad industrial spectrum, the petroleum and petrochemical industries, mineral processing and wastewater treatment sectors are identified as the most appropriate target beneficiaries. These industries are widespread internationally and are of considerable economic and environmental importance.

Radiation dose received by an operator during a radiometric field application is in the range of 0.1-0.30 mSv, this dose for an occupational radiation worker, considering a normal annual workload, is far below maximum permissible dose of 20 mSv a year (0.5-1,5%). New developments in radiation detector sensitivity and availability of short life radioactive tracers make radioactive tracer applications safer.

Quantification of ^{90}Sr contamination in cow milk after a nuclear accident

Q. Rogliardo[1], A. Kanellakopoulos[1], H. Corcelle[1], F. Malek[1], S. Pallada[1], M. Zsely Schaffter[1] and G. Triscone[1]

[1] *Nuclear Physics & Chemistry Laboratories, HEPIA, HES-SO Genève, University of Applied Sciences and Arts of Western Switzerland, Rue de la Prairie 4, CH-1202, Switzerland*

Since the Russian invasion of Ukraine in February 2022, the threat of a potential nuclear accident is looming of Europe, with the Ukrainian nuclear power stations at the epicenter, particularly following the capture of the Chernobyl site by Russian forces on 24 February 2022 [1]. In response, multiple European countries and (inter-)national agencies are composing environmental monitoring protocols in case of emergency [2, 3].

Many of these protocols focus on basic food products, with milk being a key concern due to its widespread consumption and role as a staple in children's diet. Radio-contaminated milk with ^{90}Sr is especially problematic because of its potential to transfer significant contamination up the food chain. ^{90}Sr, a major radioisotope released during nuclear accidents, is a high-energy beta emitter with chemical and biological properties similar to calcium, making it a primary concern for incorporation and long-term fixation into teeth and bones.

This work presents two physico-chemical treatment protocols for determining the radioactive content of ^{90}Sr in milk. Both protocols involve 3 key steps: elimination of the organic matter, separation of strontium and measurement of the extracted radioactivity. Strontium separation is achieved through chromatography and the extracted radioactivity is measured via liquid scintillation spectrometry. The primary difference between the two protocols proposed by our laboratory lies in the elimination procedure of organic matter and the procedure duration (72 vs. 8 hours). The first protocol involves lyophilization followed by calcination at 700°C, while the second utilizes centrifugation of the sample mixed with various chemical reagents [5]. This study validates and compares the results of both treatment protocols.

References

[1] World Nuclear Association, Ukraine: Russia-Ukraine war and nuclear energy, 2022
[2] International Atomic Energy Agency, Nuclear safety, security and safeguards in Ukraine, 2022
[3] Y. Duliba, J.Energy & Natural Resources Law, **41**(3), 1–13 (2022), doi: 10.1080/02646811.2022.2145018
[4] G. Michon, Le Lait **49**(485-486), 250–265 (1969), doi: 10.1051/lait:1969485-48613
[5] N. Guérin *et al.*, J. Environmental Radioactivity **175**, 115–119 (2017), doi : 10.1016/j.jenvrad.2017.05.007