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ETERE: A Portable Radioactive Aerosol Monitor capable of Fast Alarm Response and Quantitative Spectrometric Analysis of Artificial Alpha Emitters

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Introduction

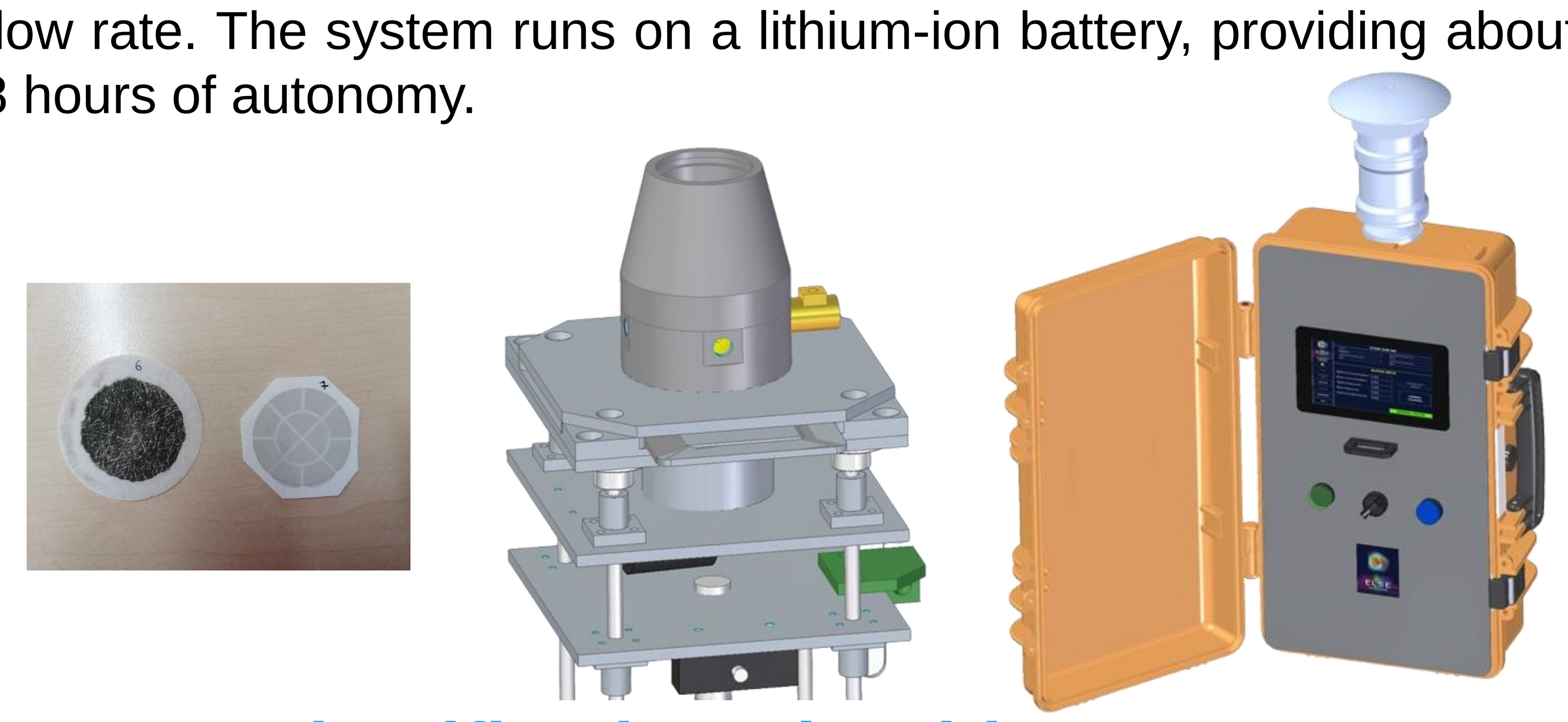
Alpha emitters are common in radiochemistry labs and nuclear plants, posing risks to workers and the public, especially during accidents[1]. Aerosol monitors are mandatory in such environments[2], but are typically fixed stations, limiting their use in emergencies. Additionally, their low energy resolution and weak deconvolution algorithms hinder accurate isotope identification[3], delaying response actions.

A new aerosol monitor is being developed for both routine and emergency use. It features a rugged, compact, battery-powered design and a silicon detector for alpha and beta particle detection. Its analysis software uses an ENEA-patented linear deconvolution algorithm combined with a ROI-based background suppression algorithm for improved isotope identification and detection efficiency in high-background low-counting statistics conditions. This work presents tests on a prototype device, focusing on its spectrometric performance with multi-line alpha emitters simulating artificial contamination, as well as it describes the tests performed with different filters while sampling NORM background, to optimise the ROI-based background suppression methodology.

Methodology

Hardware

The prototype aerosol monitor features a 450 mm² PIPS CAM 450 silicon detector. Its signal is processed through a Charge Sensitive Amplifier, shaped (1 µs semi-Gaussian), and digitized by a 125 Ms/s 14-bit FPGA-based Multichannel Analyser, storing data in a histogram. It supports MCE or PTFE circular filters and includes an industrial Single Board Computer for data acquisition, real-time processing, local display, and remote communication (WiFi, BLE, 4G). A low-voltage diaphragm pump ensures a 3 m³/h sampling flow rate. The system runs on a lithium-ion battery, providing about 8 hours of autonomy.



Isotope Identification Algorithm

Alpha-emitting isotopes produce discrete energy peaks when detected by a silicon detector, but peak overlap – especially in air – can cause ambiguity in isotope identification[4]. To address this, the patented ENEA deconvolution algorithm[5] is used.

The method involves:

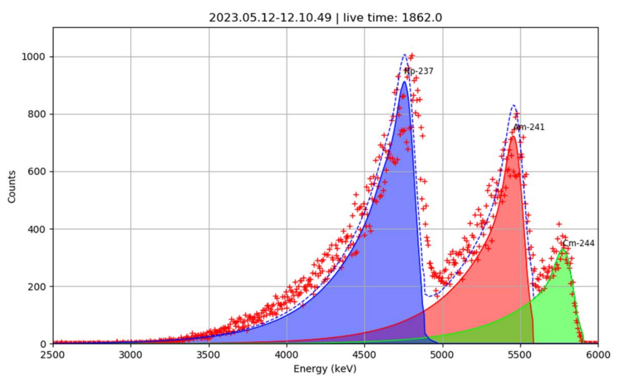
1. Determining the detector's response function from a reference alpha spectrum
2. Generating a library of synthetic spectra using modified Gaussians[6]
3. Deconvolving the measured spectrum by fitting it to a linear combination of synthetic spectra.

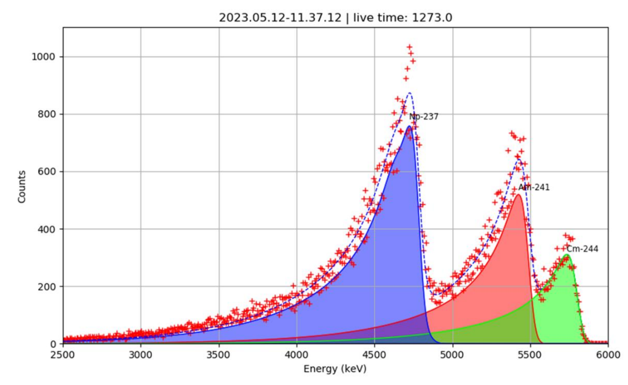
Originally developed for vacuum measurements, the algorithm enhances isotope identification and activity quantification compared to traditional methods.

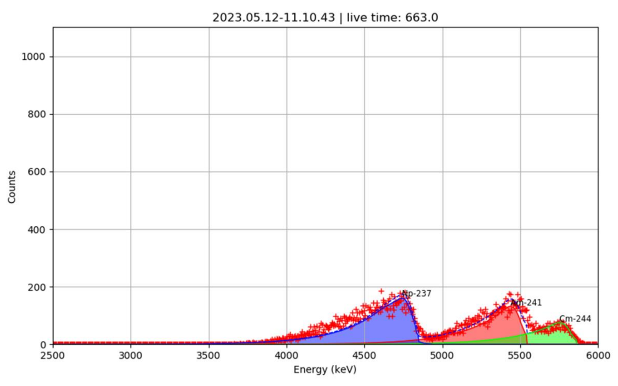
Experimental setup

Tests were conducted at ENEA Casaccia Research Centre using certified multi-line alpha sources, including mixtures of ^{237}Np, ^{241}Am and ^{244}Cm at different activities. Sources were placed 2 mm from the silicon detector, with additional tests for the ^{237}Np-^{241}Am-^{244}Cm source at 5 mm and 10 mm to assess distance effects on the deconvolution algorithm. Eventually, tests were performed by sampling ambient air, accumulating NORM on different filters in order to optimise the ROI-based background suppression algorithm, and to identify the optimum filtering medium.

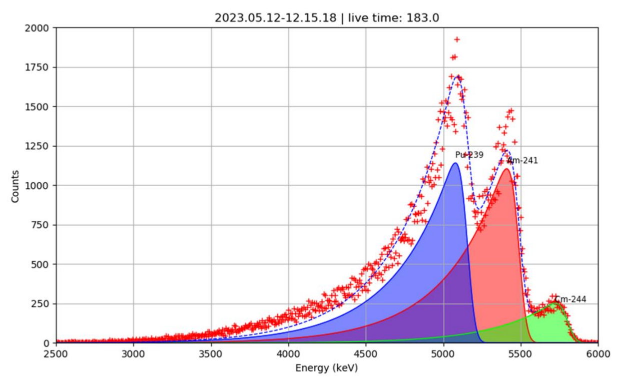
Results

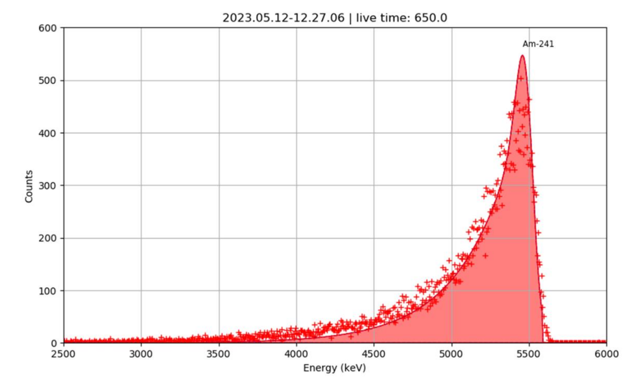




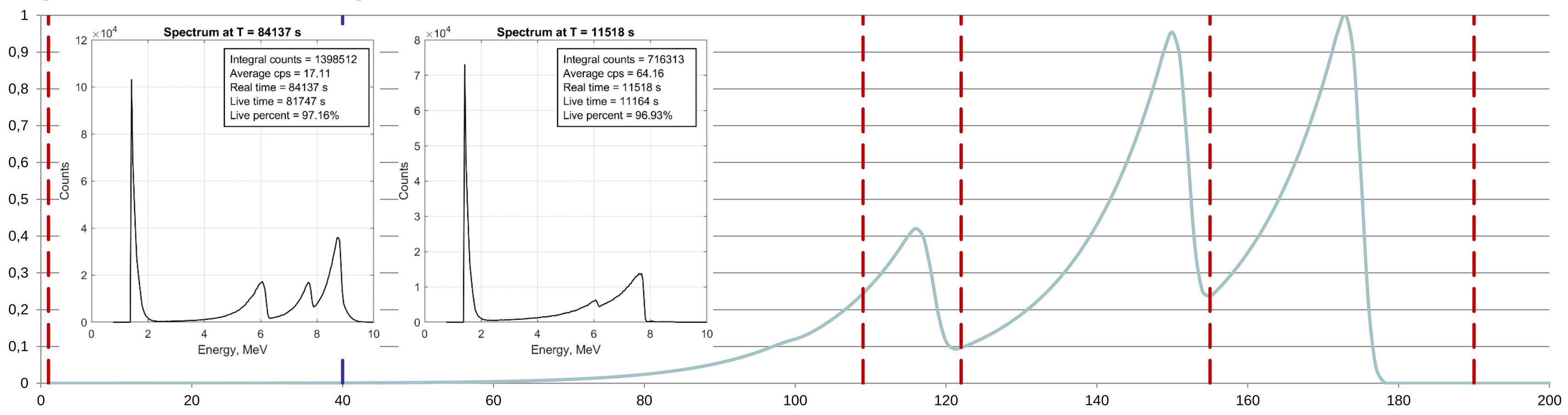


The device shows excellent spectrometric performance even at larger source-detector distances, despite the degraded resolution. It correctly identifies nuclides across various distances and counting statistics.





Tests with the ^{239}Pu-^{241}Am-^{244}Cm multi-peak source and a single ^{241}Am standard confirmed its reliability, even with significant spectral overlap.



The optimisation of the ROI-based background suppression algorithm allowed the proper selection of the sampling medium, and demonstrated the good performance of the system by completely rejecting the contribution of NORM.

Conclusions

A novel alpha-beta aerosol monitor is being developed for both fixed and emergency use. Tests with multi-peak sources confirmed its reliable isotopic recognition, even under poor peak resolution conditions, demonstrating strong spectrometric performance. Tests performed using different filtrating media allowed selecting the best filter to optimise the complementary ROI-based background suppression algorithm.

The device proved to be equivalent to a fixed monitoring station, with the advantage of being designed also for emergency use.

References

(1) IAEA Incident and Trafficking Database. Annual fact sheet. 2020. (2) Annual limits on intake (ALI) and derived air concentrations (DAC) of radionuclides for occupational exposure. USNRC 10 CFR 20 Regulations, Appendix A. (3) M. Blaauw et al. Nucl. Instr. Methods A, 428:317–329, 1999. (4) E. Garcia-Toraño. Applied Radiation and Isotopes, 64:1273–1280, 2006. (5) Ministero dello Sviluppo Economico n. 102018000007610 (6) G. A. Marzo, Nucl. Inst. Methods A. 832:191-201 (2016).

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