

Quantifying the airborne release fraction of plutonium oxide surrogate in a small-scale fire experimental facility

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In the event of fire in nuclear facilities containing radioactive material, thermal stress can become the transporter of resuspended particles and lead to the exposure of workers in the surrounding areas or to a potential release in the environment. The IRSN programme “Fires Involving GloveBoxes with Aerosol Release Occurrences” (FIGARO) focuses on glovebox (GB) fires with the aim of quantifying aerosol releases (Zavaleta *et al*, 2024). GB are used in both industrial processes and laboratory research involving radioactive materials, such as plutonium dioxide, PuO₂.

This paper summarises the methodology developed in the FIGARO project to quantify the aerosol resuspension through the measurement of the aerosol release fraction (ARF) in a small-scale experimental facility named ARTEMIS (IRSN, Saclay, France), which is a thermal degradation facility for the study of aerosol airborne resuspension by fire. The resuspension is characterized by the quantification of the ARF from GB wall slabs, which is defined as the ratio between the airborne release mass (release rate $Q_{\text{airborne release}}$ by sampling time Δt) and the initially dispersible aerosols by the thermal stress of the fires (M_i):

$$ARF = \frac{Q_{\text{airborne release}} \times \Delta t}{M_i}$$

The airborne release mass flow rate can be determined as the ratio between the particle mass concentration measured at the sampling point and the transfer function of the particles (which takes into account the dilution by the air flow rate and the deposition between the emission source and the sampling point).

To carry out experiments without radioactivity, experimental investigations were done to identify the best PuO₂ surrogate. Similarity criteria based on PuO₂ density (11480 kg/m³), as well as chemical proximity along with thermal stability, led to the choice of hafnium oxide (HfO₂), of density 9680 kg/m³, as the suitable surrogate. Furthermore, to evaluate the transfer function, a tracer which offered similarity criteria, particularly in terms of aerodynamic behaviour with the surrogate, has also been identified. For the study presented here, an Al₂O₃ tracer was injected cold, outside of the fire tests. The results showed a collection yield of 94% ± 3%, indicating a very good transfer of the simulant. Hafnium oxide powders which were purchased in the form of coarse fragments have been micronized to

reach a specific mean (optical) diameter, around 5 µm. Their size distributions were studied by dry diffractometry.

To explore the aerosol resuspension mechanisms at small scale, the fires took place in the ARTEMIS facility, where 9x9 cm² polycarbonate samples were set on fire (see Figure 1). The samples were previously contaminated with surrogate particles with a repeatable and qualified contaminating system: the deposited concentration was around 0.4 mg/cm² ± 0.03 mg/cm². The deposited size distribution was also studied by diffractometry after collecting the deposited samples with a wet scrubbing method.

The ARF values calculated from the experiments are below 1% and showed a good repeatability between 3 experiments (variation coefficient < 15%).

Another part of the project consists in carrying out experiments on real GB at medium and large scale in the experimental facilities of the IRSN's GALAXIE platform (see companion paper from Sow *et al*, 2024). In this regard, the study at small scale made it possible to identify the most relevant surrogate/tracer pair to better constrain the tests on real GB. The small-scale and larger scale experiments will provide a comparison between laboratory/analytical mechanisms and give information on the scale effect. It also will provide a database for resuspension model improvement.



Figure 1. Left: ARTEMIS facility. Right: Thermal degradation of a polycarbonate sample in ARTEMIS.

Zavaleta, P., Coutin, M., Gelain, T., Lacoue, J. March, P., Mastori, H. et al. (2024) *Mech. Eng. J.* 23-00463.

Sow, M., Piller, M., Costa, D., Wiszniowski, P., Porcheron, E., Zavaleta, P. (2024) *European Aerosol Conference, EAC2024, Tampere.*