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Cesium-rich microparticles from Fukushima Daiichi: Tiny ejecta informing a severe nuclear disaster - *C.C. Patterson Award Lecture*

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The nuclear disaster at the Fukushima Daiichi Nuclear Power Plant (FDNPP) in March 2011 resulted in partial meltdowns of three reactors. During the meltdowns, a type of condensed particle, a cesium-rich micro-particle (CsMP), formed inside the reactors through unknown processes. Typical CsMPs, ranging from submicron to several microns in size, are primarily composed of Si, Fe, Cs, Zn, and O within a glassy matrix. Cesium concentration reached levels exceeding 20 wt.%, leading to an extremely high Cs activity per unit mass, approximately ~10^{11} Bq/g. This Patterson Award presentation provides an overview of a series of articles that encompass *(i)* the quantification of these hazardous microparticles in the environment and *(ii)* the elucidation of meltdown processes, including the evolution of debris.

***(i)* Occurrence of CsMPs in the Environment:**

Using a developed method (QCP method), we quantified CsMPs in surface soils, finding them to be abundant in the high-dose zone northwest from FDNPP, reaching ~318 particles/g of soil. The radioactive fraction (CsMPs vs. bulk) was calculated to be as high as ~80% southward. In an elementary school approximately 3 km from FDNPP, over 2500 particles/g were quantified near the entrance on the first floor, which is two orders of magnitude larger than that outdoor.

***(ii)* CsMPs informing inside the damaged reactors:**

CsMPs are associated with various nanoparticles derived from irradiated fuel assembly and structural materials. Characterization at the atomic scale revealed U dioxide and U-Zr oxide eutectic nanoparticles, along with magnetite adsorbing Tc and Mo on surfaces. Synchrotron micro X-ray analysis demonstrated that Pu is associated with U oxides nanoparticles as oxides. The Pu isotopic ratios are consistent with irradiated fuels, not with MOX fuel or global fallout. The CsMPs also retain evidence of B_4C volatilization during meltdowns based on the B-Li isotopic system evidencing $^{10}B(n,\alpha)^{7}Li$ reaction.

The studies conducted in the last decade showcase that, despite their small size, radioactive microparticles released during severe accidents can be a crucial source of information when state-of-the-art analytical techniques are applied.