Significant presence of cesium-rich microparticles in an abandoned school close to the Fukushima nuclear power plant

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The school building preserves the scene from the 2011 Earthquake evacuation. The students and teachers did not return to the building after the Earthquake due to the setup of the FDNPP nuclear exclusion zone. Credit: University of Helsinki

Work recently published in the journal *Chemosphere* has documented the

presence of large amounts of highly radioactive, poorly soluble cesium rich micro-particles (CsMPs) in an abandoned school building close to the Fukushima Daiichi Nuclear Power Plant (FDNPP).

The microparticles penetrated the building during the FDNPP nuclear accident of March 2011. They could pose a threat to human health if inhaled. The study shows that indoor CsMPs should be considered in safety assessments and in building clean-up efforts.

The study involved scientists from Japan (Kyushu University), Finland (The University of Helsinki), France (IMT Atlantique, University of Nantes), and the U.S. (Stanford University), and was led by Associate Professor Satoshi Utsunomiya and graduate students Kazuki Fueda and Tatsuki Komiya (Department of Chemistry, Kyushu University).

In recent years, the team have shown that a significant amount of cesium rich microparticles (CsMPs) were released from the damaged FDNPP reactors. These particles have a radius of only a few micrometers, and they are mainly composed of Si-glass, Fe, Zn. The radioactive Cs content of the CsMPs is much higher than any other form of Cs-labeled fallout released from the damaged FDNPP reactor units 1-3.

The team has previously shown that the particles were likely produced temporarily during the FDNPP meltdown events, when molten fuel in each reactor unit escaped primary containment and impacted the underlying concrete base. To date, work on CsMP containing samples has mainly concentrated on CsMPs found outdoors. The CsMPs were entrained in air and carried into the environment from the damaged reactors, becoming widely distributed in the FDNPP exclusion zone.

Recent work by several scientific teams has also shown that CsMP contaminated air masses that passed over the Tokyo region during March 2011. This information, coupled with findings that CsMPs are poorly

soluble, has led to questions over potential health risks posed by internal radiation exposure if CsMPs are inhaled. Utsunomiya states that "given the small size of the particles (generally

In the team's most recent work, they show that CsMPs can penetrate buildings in significant amounts, providing a potential indoor risk and highlighting the need for through cleaning of buildings in the exclusion zone if they are to be eventually returned to public use.

Dust samples from floors

Utsunomiya detailed that the team were given permission to access a school building 2.8 km away from the nuclear power plant that had been abandoned in 2011.

"Fortunately, we got permission to investigate inside an elementary school. When entering the school building, we were all shocked by what we saw. Five years had passed by the time of sampling in 2016, but everything was left as it was at the moment of the 2011 earthquake. It's as if time had stood still," says Utsunomiya.

The team collected dust samples from floors near to the school's entrance, on its second floor, and in the near-by school yard. Using an autoradiography method previously invented by the team, students Kazuki Fueda and Tatsuki Komiya were able to count the number of CsMPs in the school samples and assign how much of each samples Cs radioactivity came from the microparticles.

The Cs radioactivity of the dust on the school's floors ranged from 340—4040 Bq/m^2 (134+137Cs activity decay-corrected to March 15, 2011. This corresponds to 125—1490 Bq/m^2 in 2023), with 4.5—38.9% of that radioactivity coming from the CsMPs.

The highest amount of CsMPs were found near to the school's entrance (up to 2481 particles per m^2), while significant (but lower) amounts of CsMPs were found on the second floor (up to 1273 particles per m^2). This shows penetration of the tiny fallout particles deep into the building. Interestingly, the CsMP numbers and the proportion of Cs radioactivity attributed to CsMPs in nearby outdoor samples were much lower (23–63 particles/g of dust or soil and 1.14–1.61% or total Cs radioactivity, respectively).

The team state that the indoor environment recorded Cs fallout from dry deposition, and as the school had remained undisturbed since the accident, the CsMPs remained there in significant numbers. The outdoor samples meanwhile record Cs fallout from dry and wet deposition.

There, it's likely that some CsMPs may have been washed or blown away by rain and wind, thus Cs remaining in the outside location is dominated by that derived from wet deposition. Those Cs species fell in easily dissolved (soluble) forms, which have now largely become associated with dust and soil particles (e.g., clays).

In the study, the team completed a 'wet test' on the indoor samples to evaluate whether common soluble Cs species, such as CsOH or CsI, were present in the samples. After wetting samples with water, no water-soluble Cs species were found in the indoor dusts.

Utsunomiya states that "the properties of the school CsMPs resemble ones reported in many previous studies; they are even similar to the ones found in Tokyo. These CsMPs were distributed across a wide area, including the Fukushima prefecture and Kanto (Tokyo) region. The CsMPs may present a threat; as shown in our work, CsMPs may accumulate locally and form hot spots, even in indoor environments."

Professor Gareth Law of the University of Helsinki, a co-investigator on

the study, added that "the potential occurrence of CsMPs in indoor environments dictates a need for detailed studies of indoor CsMPs in residential areas impacted by FDNPP fallout." He continues that "further research on the behavior of CsMPs if inhaled, and study of health impacts, were needed."

Useful information to help repair the damage in Ukraine

Law and Utsunomiya added that "considering the fact that microparticles seem to be a universal radioactive contaminant in severe nuclear accidents, detailed knowledge of their properties, new approaches to estimate their amounts, and studies of their behavior and impacts in environmental and biological systems will be critical if we are to understand the true impact of the nuclear disasters."

Recent activities in Ukraine near nuclear installations, make the need for such research more pressing.

Professor Bernd Grambow, a co-investigator from the University of Nantes added, "Any decontamination strategy needs to acknowledge that in close vicinity to the power plant, large differences in contamination levels may be encountered and that both ionic and particle bound Cs needs to be analyzed and removed, with the latter being particularly dangerous to cleaning workers."

Professor Rodney C. Ewing of Stanford University further added, "This study is latest of an extended series of papers that deal with the composition, characteristics, formation, and number of CsMPs. The groundbreaking aspect of these works is the combined application of multiple advanced techniques e.g., the team's autoradiography methods, high-resolution electron microscopy, and isotopic analysis. The atomic-

scale resolution of these studies provides a model for future studies of environmental contamination."

Utsunomiya finally spoke about the team's sampling trip and the history of their work on CsMPs. "I believe it is our duty to conduct rigorous scientific research on the tragic Fukushima events, to find and publicize new knowledge that will be important to society and the next generation."

"Maybe one day time can begin again for abandoned buildings like the school, but for that to happen, significant clean-up efforts are needed, and if that is to proceed, we first need to know about the forms and extent of contamination in those buildings, such that workers and potential occupants can be protected."

More information: Kazuki Fueda et al, Occurrence of radioactive cesium-rich micro-particles (CsMPs) in a school building located 2.8 km south-west of the Fukushima Daiichi Nuclear Power Plant, *Chemosphere* (2023). DOI: 10.1016/j.chemosphere.2023.138566

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