NEW WAYS OF RADIATION MIGRATION INTO NATURAL ENVIRONMENT BY MEANS OF CESIUM-RICH CONDENSED MICRO-PARTICLES (CsMPs).

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Summary: *Cesium-rich micro-particles - CsMPs - generated at the Fukushima nuclear power plant were first detected in atmospheric particles 170 km southwest of the plant. Particle formation took place during melting inside the reactor. These particles provide important information about the physical and chemical properties of radioactive materials inside the reactor. A high-resolution transmission electron microscope as well as conventional radio-analytical techniques were used for their study.*

Key words: *Cesium-rich micro-particles, radioactive materials.*

Each disaster is an unique event. The second most significant nuclear disaster in the world history occurred in 2011 in Japan. It was preceded by an earthquake and tsunami. The accident posed a serious environmental threat: in the Fukushima prefecture 5.2×10^{17} Bq radionuclides were released from a nuclear power plant into the environment [1].

As a result of the processes, developed at the Fukushima Daiichi nuclear power plant, the catastrophe destroyed the complex and interdependent security systems. Clearly, the study of contamination process will help to increase security of power generation facilities in Japan and around the world. The most serious environmental consequences of the accident, including surface pollution by radioactive cesium, have not yet been explored. The big challenge of modern technologies is to control cesium nanoparticles in nature. Besides, the processes, currently going on inside the reactors, are not known, as it is impossible to get there due to the high radiation field. To prepare for the worst-case scenario and increase the sustainability of the space "at risk", the scientists considered the catastrophe from different angles.

To date, conclusions about reactions, developed in the Fukushima reactors, have been based on indirect studies. It is believed that after the shutdown of the cooling system, the temperature in the reactor rise to 2,200 K and from the irradiated fuel the radioactive Cs was released. All CsMPs (2.0-3.4 µm in size) contain SiO_2 glass and Zn-Fe-oxide nanoparticles associated with a wide range of Cs concentrations. Uranium U traces are also associated with Zn-Fe-oxides. Cesium-rich micro-particles of CsMPs generated at the Fukushima Nuclear Power Plant were first discovered in the atmosphere 170 km southwest of the plant [2]. These particles are solid body objects. Their formation took place during melting inside the reactor and they carry important information about the physical and chemical properties of the radioactive materials inside the reactor. CsMPs formation process studies use a high resolution electron microscope combined with conventional radio-analytical techniques and chemical and structural properties on an atomic scale.

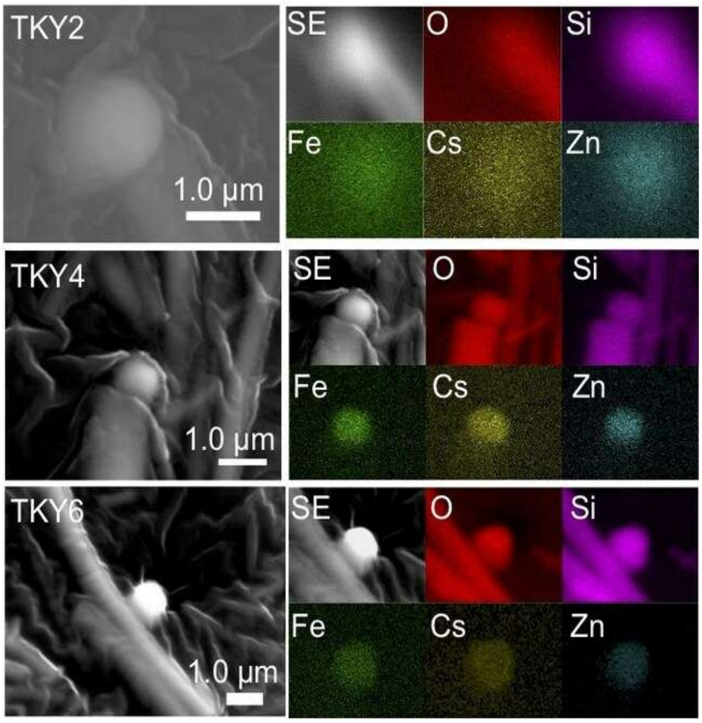

Image above: Secondary electron images from Utsunomiya et al. 2019, of CsMPs discovered in atmospheric particles trapped on a Tokyo air filter from March 15, 2011, with major constituent elements displayed.

Photo from internet source https://safecast.org/2019/08/fukushima-cesium-enriched-microparticle-csmp-update/

The nanoscale texture of CsMPs reveals the process of their formation in the melting area of the active part of the reactor.

Interestingly, the process of formation of CsMPs at Fukushima is markedly different from the presented above process of microparticle formation. It take place as a result of interaction of the melted active zone of the reactor in experiments [3,4,5] with concrete particles (a process known as molten core concrete interaction - MCCI).

The atmosphere inside the reactor housing was to be filled with Cs-related aerosols, gaseous Cs particles, water vapor, and gaseous hydrogen. The interaction between the metal structures and the melting active zone of the reactor, when the reactor housing failed, resulted in the formation of large amounts of Zn-Fe nanoparticles.

Due to the extremely high radioactivity per unit mass, ~ 10^{11} Bq / g, CsMPs particles can be an important source of radiation dose in the Fukushima environment. In addition, CsMPs are important carriers, through which volatile radionuclides, such as uranium (U), reach the environment [2].

It is very important to determine, whether artificial nanoparticles and specifically CsMPs retain their properties (size, original structure, reaction properties) in water, air, soil or sediment. Accidentally produced man-made CsMPs pose a significant environmental challenge in terms of both discovery and modeling of further migration pathway.

Conclusions

There are two mechanisms – natural and man-made - of environment contamination by nano-particles. The natural processes, such as forest fires, sand storms, dust and aerosols, bio-objects (viruses) are the sources of nano-particles' contamination by the last millenniums. In the case of man-made CsMPs, the produced nano-particles are radiation sources, but it is impossible to monitor their concentration by usual radiation detectors. The CsMPs detection is not the only technical problem: besides expensive specific equipment and highly technical qualification of the staff, one need to know the particles complex migration path in the media. The investigation of CsMPs infiltration into environment and its further migration is one of main ecological and eco-toxicological challenges of modern science.

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