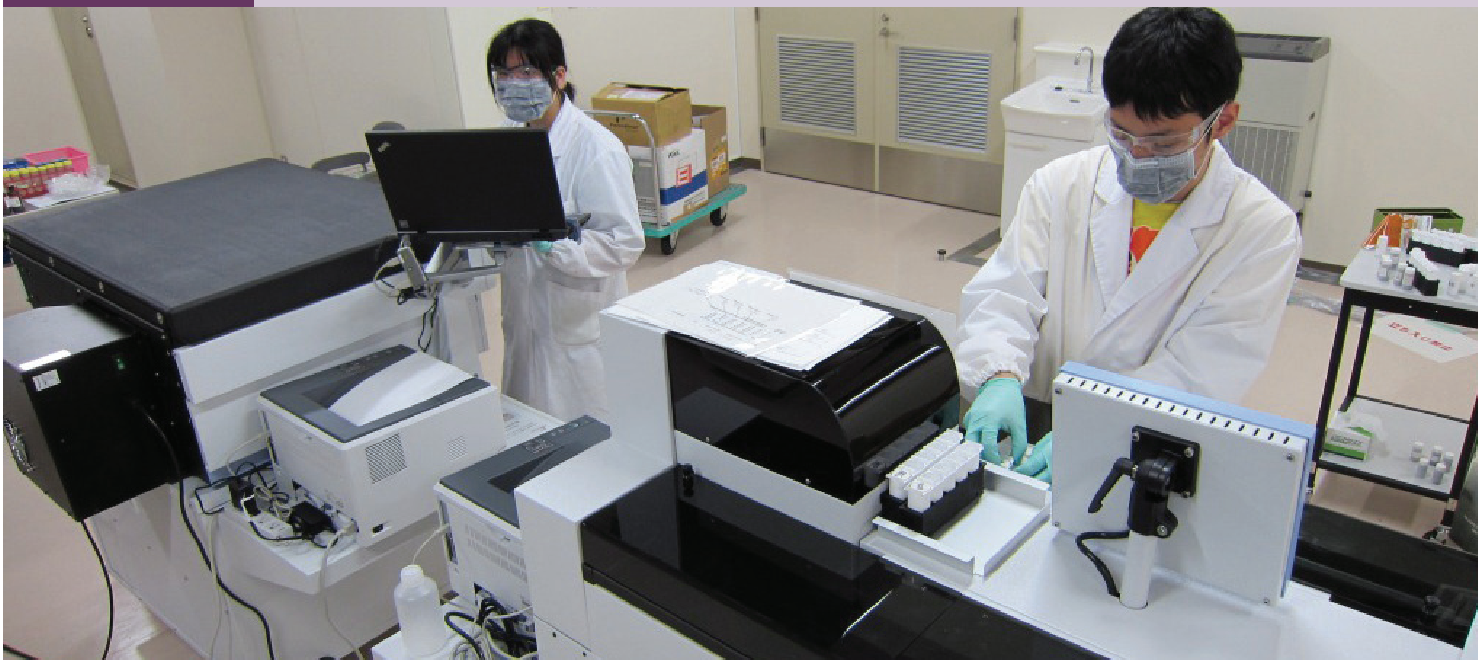
CASE STUDY

Environmental Analysis



Fukushima University Researchers Develop First Map of Radioactive Contamination after Nuclear Accident

Mapping out the parts of Japan that were contaminated by radiation was a major concern in the weeks and months after the nuclear accident at the Fukushima Daiichi Nuclear Power Plant that followed the largest earthquake ever to hit Japan on March 11, 2011. Yoshitaka Takagai, Associate Professor of Analytical Chemistry at Fukushima University, stepped in, without any official government mandate, to produce the first map of radioactive contamination shortly after the accident. Since the tragedy, Takagai's research group has continued to measure radiation before and after decontamination efforts to assess the efficacy of methods used to clean up radiation and provide an independent assessment to citizens of the region. "PerkinElmer technology was instrumental in speeding up the formerly labor-intensive radiation screening of large volumes of soil samples," Takagai said. "The sensitivity of the instruments also helped in developing protocols for removing topsoil to ensure effective decontamination of public areas such as school yards and playgrounds."

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Challenge

The 2011 earthquake off the Pacific Coast of Japan was one of the five most powerful earthquakes in the world since modern record-keeping began in 1900. The earthquake triggered powerful tsunami waves that reached heights up to 133 feet (40.5 meters) and traveled up to 6 miles (10 km) inland. At the Fukushima Daiichi Nuclear Power Plant complex, tsunami waves washed over seawalls and destroyed diesel backup power systems, causing level 7 meltdowns at three reactors. The crisis has been ranked as the second worst nuclear accident ever, not as bad as the Chernobyl disaster, but worse than Three Mile Island. Over 200,000 residents in the area of the plant were evacuated.

There was considerable controversy over government decisions to evacuate certain areas of the surrounding countryside but not others. Fukushima University felt an urgency to respond because national organizations that are primarily based in Tokyo had difficulty in reaching the affected areas. The project was based on the needs of local people and local governments who asked that contamination be measured in various objects including wood, household items, animals, etc.

"It was very important for us to provide a good indication of where low-dose radiation areas were to assure local citizens of their safety," Takagai said. "In the immediate aftermath of the earthquake, our research team took the initiative to build the first map of radioactive fallout in response to urgent local anxiety and demands for assurance, as well as taking on the additional vital task of detecting soil contamination to guide cleanup efforts." The Radioisotope Center of University of Tokyo also participated in the urgent task of determining the scope of contamination in the affected areas, as well as devising new methods for detecting radiation in soil, water, and food, to determine their safety and to guide development of decontamination methods.

Solution

The environmental study of radiation was a new field to Takagai but he had a good idea of the instrument landscape because he is a licensed radiation engineer. "We explained to PerkinElmer, what our needs were, what we wanted to do, and we asked for devices with the appropriate specs. If the company had not proactively contributed its instruments, we would have been delayed by the need to file grant applications with government funding agencies, a time consuming process which would have squandered the opportunity to measure uranium and plutonium isotopes with short half-lives." PerkinElmer provided ELAN® DRC II inductively coupled plasma mass spectrometers (ICP-MS) which can detect individual uranium and plutonium isotopes. PerkinElmer also provided WIZARD²® gamma-ray counters and Tri-Carb® liquid scintillation counters for measuring radioactive strontium and tritium in water samples.

The Fukushima University researchers used the ICP-MS technology with a broad range of detection limits to test for metal contamination as well as the presence of uranium and plutonium in drinking water, soil, wastewater and food. Automatic gamma counter technology was used for 270 sample sequential measurements of gamma-ray nuclear species, such as radioactive cesium and iodine, to determine the scope of contamination in the affected areas. Automatic gamma counter technology was also used to devise new methods for detecting radiation in soil, water, and food, to determine their safety and to guide development of decontamination methods. Liquid scintillation counter technology was used for measurement of radioactive strontium and radioactive tritium, to locate contamination patterns and testing environmental water samples.

The ELAN DRC II ICP-MS uses a dynamic reaction cell (DRC) which is a chamber placed before the traditional quadrupole chamber of an ICP-MS device, for eliminating isobaric interferences. PerkinElmer Tri-Carb liquid scintillation analyzers are the most cited liquid scintillation analyzers available with over 1,000 articles in open scientific literature. PerkinElmer WIZARD automatic gamma counters provide unmatched sensitivity because they collect signals from all around the sample rather than from the sides only. This minimizes the variance effect of sample position and volume and provides the best possible counting efficiency.

Outcome

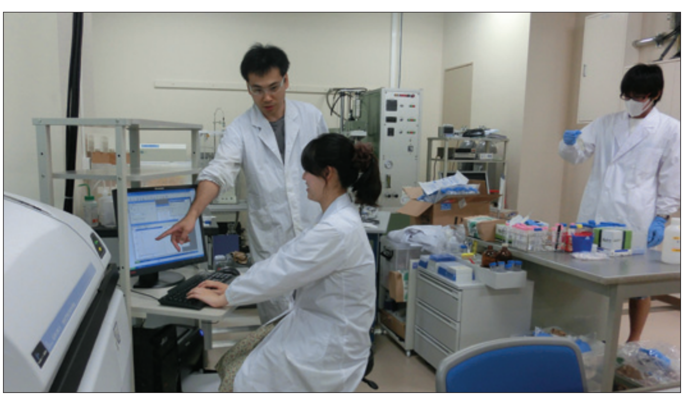
Fukushima University researchers developed a new method for radiation measurement that uses microwave digestion for isotope ratio analysis of U-235 and U-238 in soil samples with ICP-MS. The dissolution of natural uranium in silicate rocks was reduced by using a mixture of nitric acid and hydrogen peroxide to measure the radioactive uranium. ICP-MS determined the ratio of the certificated geochemical reference material to the isotope ratio in real soil samples. In addition, cell-pass voltages were used to make calibrations and to correct the mass bias in the mass spectrometer. This method made it possible to measure the isotope ration of uranium with an accuracy of 0.37% without using a radioactive standard source. U-235 and U-238 were both quantitatively determined at detection limits of 0.010 µg/kg. In the case of an emergency, like a nuclear accident, the new method makes it possible to immediately make more measurements over a larger area as compared with current practice such as a complete dissolution process with an α-ray spectrometer or ICP-MS.

A survey of how radioactive uranium spreads was conducted from 7 to 80 km around the Fukushima Daiichi Nuclear Power Plant at 115 points in Fukushima prefecture. The values of the uranium isotope ratio for those soils were mostly similar to the naturally occurring levels although higher than normal concentrations of uranium were detected at several sampling points. The Fukushima University researchers determined that uranium and plutonium contamination was limited to the immediate vicinity of the reactors. Radioactive iodine has disappeared from the affected sites due to its short half-life and the bulk of the remaining contamination consists of long half-life cesium isotopes Cs-134 and Cs-137.

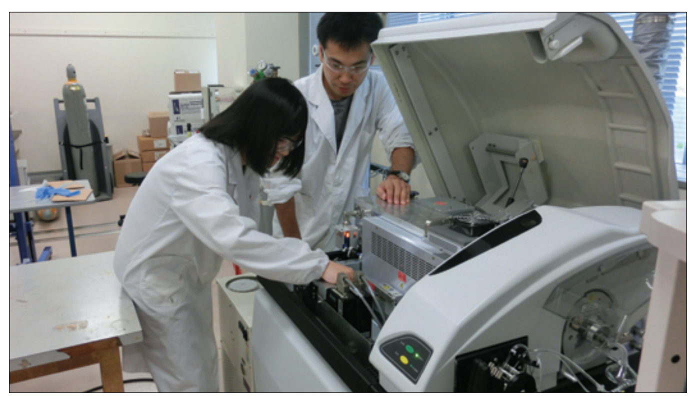
The instruments also played a role in the development of protocols for removing contaminated topsoil in public areas such as school yards and playgrounds. "I do think there would have been much more confusion without PerkinElmer's equipment when we tested the effectiveness of decontamination by high-pressure water sprayers," Takagai said. "During our contamination survey from June though August, soil samples were assembled at Fukushima University, but we were not sure where to start. PerkinElmer's gamma-ray counter helped us prioritize the sampling order since our germanium semiconductor detector takes a long time to provide a measurement." Toshiyuki Tadenuma, radiation detector group leader, PerkinElmer, commented: "PerkinElmer has also deployed these technologies in collaboration with the National Institute of Health Sciences in Japan, to create screening methods for testing radiation levels in beef products in the affected areas, which will be expanded into other food ingredients."

PerkinElmer hosted a seminar entitled: "Environmental Radiation Monitoring" to provide opportunities to share information on radiation measurement and monitoring techniques as well as true stories from the affected area. The seminar was attended by 182 people and included two presentations by guest speakers from Tokyo University and Fukushima University and two presentations by PerkinElmer Japan employees in the areas of bio-discovery and analytical science. Dr. Nogawa from Tokyo University gave a presentation entitled: "Methodologies of Measuring Radioactivity from a Nuclear Power Plant." Takagai and his team gave a presentation on the use of ICP-MS for measuring radioactivity in food and soil: "Introduction to the Activities of the Fukushima University Radioactivity Measurement Team."

PerkinElmer's contribution of equipment for measuring radiation helped Fukushima University researchers kick-start research projects about the extent of contamination from the nuclear accident at the Fukushima Daiichi Nuclear Power Plant. These projects helped to reassure residents by providing an independent assessment of the extent of radioactive contamination and also led to the development of new methods that provide more efficient radioactivity measurements over large areas.



Samples from various industries, agriculture, environmental and private farms from Fukushima Prefecture were collected and tested to determine the scope of contamination.



Dr. Takagai teaches his students at Fukushima University how to operate the ICP-MS with a broad range of detection limits, to test for contaminants in soil, water and food samples.

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