Motivated by these considerations, Basic Energy Sciences researchers looked for new techniques that might reduce the need for shipping large samples. Based on earlier work, these scientists were familiar with methods for separating and purifying plutonium and uranium. They were also aware of a unique and highly sensitive process used to test for the presence of trace amounts of plutonium and uranium in waste water effluents at separation and purification plants in the United States. Such effluents are routinely tested to ensure public safety.

The technique used a quantity of granular material through which a sample of the effluent water was required to pass. Each grain, called a resin bead, was no larger than a grain of sand, but had the unique ability to adsorb (attract and attach to its surface) selectively a variety of different chemicals from the solution flowing by it.

The resin beads were known to work for the water effluent sampling process. The question was whether or not they could be modified and made to work in the acid solution of reprocessing.

Researchers hypothesized that under the right conditions the resin beads could be made to adsorb selectively a minute but fully representative sample, consisting mainly of the special materials of interest—plutonium and uranium. If so, the amounts adsorbed would not only be infinitesimally small, but would also consist mainly of elements which by their nature exhibit low levels of radioactivity. Other elements, collectively known as "fission products," exhibit high levels of radioactivity. These would be left behind in solution.

The resin beads could then serve as a proper substitute for the bulk sample. They could be safely shipped for analysis with little or no shielding. In fact, the amount picked up by each tiny bead would be so minute and its radioactivity so slight that the bead could be legally and safely sent through ordinary mails.

Technically, in order for the resin bead to serve as a proper substitute, it had to be both analyzable and contain a full array of information on the relative abundances of all the atomic species of plutonium and uranium found in the original solution. Basic Energy Sciences researchers developed and certified the laboratory methods that would ensure systematic and reproducible results.

At the point of adsorption, such as would be the case at a reprocessing site, the researchers obtained completely satisfactory results by adjusting the acidity of a small part of the reprocessing solution into which a number of resin beads were immersed. These adjustments affected the rate of uptake and the degree of selectivity for the elements of interest.

The adjustments achieved essentially complete separation of plutonium and uranium from the other highly radioactive species in solution. Left behind were not only the fission products, but also the highly radioactive heavier elements. Small amounts of the elements of thorium and neptunium were adsorbed, but these were not highly radioactive, and both elements could be easily distinguished and ignored in later analyses. The entire adsorption process took about 20 minutes.

The researchers verified that the amount adsorbed for each isotope was proportional to its original concentration in the solution. The total quantity of plutonium and uranium adsorbed by each resin bead was less than *three billionth's of a gram*!

At the point of analysis, such as would be the case at the safeguards laboratory, the researchers used a highly sensitive mass spectrometer. In this instrument, the bead was heated on a filament of wire until the adsorbed plutonium and uranium were driven off as electrically charged atoms, or ions. By analyzing and counting the ions, the spectrometer identified and quantified the relative abundances of all isotopes of plutonium and uranium atoms present.

When this technology was first developed, instruments sensitive enough to analyze the tiny samples were found only in a few sophisticated nuclear energy-related laboratories. This tended to limit the technology's application. However, instruments with the requisite sensitivity soon appeared on the commercial market in response to the demand. The manufacturers of these spectrometers also built in special tools and fixtures for handling the tiny resin beads.

Oak Ridge National Laboratory researchers trained staff members of the international program in resin bead technology and installed a high-sensitivity mass spectrometer at the safeguards laboratory in Vienna. Indicative of its success, the resin bead technology is now an important method for