Noble gas detection system reaches maturity

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The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization certified the first noble gas detection system at its radionuclide station in Charlottesville, Va., United States, on Aug. 19, 2010. The system is part of a global verification regime to monitor the planet for nuclear explosions. Of the 80 planned radionuclide monitoring stations, 40 are envisaged to be equipped with noble gas detection systems. They can provide conclusive evidence of a well-contained underground nuclear explosion.

The set-up looks rather unimposing to the uninitiated eye: a container, a satellite dish, a generator. Yet this container in the midst of lush green scenery some kilometres to the southeast of Charlottesville, Virginia, United States, houses a highly sensitive apparatus.

It's a fine summer day in 2010, and a group of scientists and engineers put the finishing touches to an unusual installation. The ordinary looking container is home to a monitoring station, part of a global network to watch over the planet. Practically an artificial nose, it can sniff out the tiniest amounts of radioactive material in the air and provide evidence of a recently conducted nuclear explosion.

Radionuclide station RN75 in Charlottesville is one of 80 stations worldwide that can detect radioactive particles in the air that may originate from a nuclear blast. The Charlottesville station has been up and running for over eight years. So, what's new then?

The station is one of 40 that are being equipped with additional detectors that can sniff radioactive gases in the air - another residue of a nuclear explosion. With its certification on 19 August 2010, the Charlottesville station is the first radionuclide station with noble gas detection capabilities to be formally integrated into a global verification regime, designed under the Comprehensive Nuclear-Test-Ban Treaty (CTBT) to detect nuclear explosions anywhere on Earth. The regime encompasses a worldwide network of over 300 monitoring stations, a data analysis centre and on-site inspections.

Noble gases provide "smoking gun" evidence

A nuclear explosion ejects radioactive material - solid and gaseous - into the environment. These substances provide the ultimate evidence that a nuclear detonation has taken place. Their detection depends on many factors, most of all on the setting in which the blast occurred. A well-contained underground nuclear explosion will not release solid radioactive residues into the air. But there is another way to detect such blasts - by finding their gaseous releases, radioactive noble gases, in particular xenon.

What are noble gases? They are chemical elements that very rarely react with other elements to form larger compounds. Their inertia is responsible for the "noble" label. Noble gas atoms are very small and pass easily through rock and sediment. Once in the atmosphere, the gas is dispersed by the winds and can be caught by detection installations such as the one in Charlottesville, providing the "smoking gun" evidence of a nuclear explosion.

Developing a detection system - the INGE experiment

When the CTBT was opened for signature in 1996, noble gas detection technology hardly existed. Matthias Auer is a nuclear physicist working at the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna, Austria, and is in charge of the establishment of the radionuclide monitoring network. "Some ten years ago, the noble gas measuring equipment that existed was only used in laboratories and was not really suitable for CTBT monitoring purposes," he says.

That is when INGE was introduced - the International Noble Gas Experiment, which brought together experts from CTBT Member States and the CTBTO. "A major part of the experiment was to enable a smooth transition in adapting the equipment from the laboratory systems to its use under field conditions," says Auer. Several countries set out to develop a tool to trap and measure xenon.

All current systems work in a similar way. Xenon is isolated from the air by a charcoal-containing purification device resulting in higher concentrations of the gas in its stable and unstable, i.e. radioactive, forms. The isolated xenon is then measured for its level of radioactivity which helps to quantify the radioactive xenon contained in the sample.

The station in Charlottesville uses the SAUNA system, the Swedish Unattended Noble Gas Analyzer, as do the other three radionuclide monitoring stations in the United States that are also equipped with noble gas detection installations. The CTBTO uses two other systems in its network: the Russian ARIX (Analyzer of Xenon Radioisotopes) and the French SPALAX (Systčme de Prélčvements et d'Analyse en Ligne d'Air pour quantifier le Xénon).

North Korea blast confidently detected

Four years ago, the noble gas detection network at the CTBTO was still in its infancy. Only ten of the planned 40 stations tested the new xenon measuring equipment under the INGE framework. Unexpectedly, they had to tackle a real nuclear explosion scenario - the first nuclear blast set off by the Democratic People's Republic of Korea (DPRK) on 9 October 2006.

None of the ten stations in test-mode at the time were anywhere near North Korea. But the system demonstrated its potential when a station in the north of Canada registered radioactive xenon, two weeks after the detonation shook the mountains in the DPRK's North Hamgyong province.

Experts at the CTBTO had predicted the arrival of the telling gaseous debris at the Canadian station in Yellowknife using their in-house developed atmospheric transport model, ATM.

The amounts needed to make a detection are astonishingly small. "The system can detect a concentration of 0.1 g of radioactive xenon evenly distributed within the Earth's atmosphere," explains Auer.

Thirty stations by end of 2010

The impressive performance of the noble gas detection technology in October 2006 gave an additional boost to the installation of the outstanding stations. As of August 2010, 26 of the planned 40 stations had been set up. By the end of the year, there will be up to 30 stations, tripling the number that existed at the time of the 2006 explosion in North Korea.

Certification - end of a process

Following the facility in Charlottesville, five more radionuclide stations are planned to have their noble gas measurement systems certified this year. Certification is the formal end of a process. It recognizes that a station meets certain requirements to become part of the CTBT verification regime's international monitoring network.

These requirements cover technical functionality, detection sensitivity, communication and data availability. Radionuclide noble gas stations are a specific case - they are built at an already existing station. And while the measurement processes for radionuclide particles and radionuclide noble gases are not only different but also separate, they share the station's logistics and the Treaty-defined station name.

Certification is preceded by a period of several months during which the station runs through a final test phase, already transmitting data to the International Data Centre in Vienna. Once the formal step of certification has been completed, monitoring data sent from the station will join the bulk of digital information arriving at the CTBTO in Vienna every day. They will also be shared with Member States.

The certification of the Charlottesville facility is a real milestone in the establishment of the CTBT verification regime. "After 12 years of development, the radionuclide noble gas monitoring system has reached a state of maturity," concludes Auer.

It adds a crucial element to the global system that monitors the planet to ensure that no nuclear explosion goes unnoticed.

Provided by Comprehensive Nuclear Test Ban Treaty Organisation

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