Winners of the IAEA crowdsourcing challenge for materials for fusion technology announced

A team of four scientists from the Max Planck Institute of Plasma Physics and the Max Planck Computing and Data Facility in Garching, Germany won the IAEA crowdsourcing challenge for visualization, analysis and simulation of materials to build fusion reactors in October 2018.

Nuclear fusion, the atomic reaction that powers the sun, has the potential to eventually provide an unlimited supply of affordable and clean carbon-free energy using hydrogen isotopes obtained from water and lithium. However, harnessing commercially viable fusion power presents serious technological challenges, such as protecting the wall and other components of the reactor vessel from extremely high temperatures and high-energy particles.

Fourteen research teams from ten countries submitted innovative analyses of simulations of reactor wall damage, which can be caused by high-energy neutrons released by a fusion reaction. The simulations were judged on their scientific benefit, the novelty of the algorithm itself or its use within the domain of material science, and the visualization's utility and expected impact.

"Some of the submissions were quite extraordinary; it was almost like organizing a local football event and then having a World Cup-winning team come," said Sergei Dudarev, Manager of the Materials Programme at the United Kingdom Atomic Energy Authority and one of the initiators of the challenge.

The winning team members — Udo von Toussaint, Javier Dominguez, Markus Rampp and Michele Compostella — applied an existing technique from machine learning and data science for the first time to identify and classify structures of defect in the simulated damaged crystals.

"This solution opens up a new and productive way to automatically categorize defect structures and hence deduce, in a quantitative way, the common factors and differences between materials," explained Arjan Koning, Head of the Nuclear Data Section at the IAEA. "In the context of the study of materials for the vacuum vessel of a nuclear fusion reactor such as ITER, it provides an effective means of measuring, classifying and visualizing the damage done to a particular material by the high-energy neutrons released by the fusion reactor. The search for a suitable material from which to construct the reactor vessel's first wall is a crucial step towards the construction of a viable fusion power plant."

The approach has several advantages over existing methods, including the following:

- new or unexpected defect types can automatically be identified and classified;
- it is based on a combination of robust and clear algorithms from data science;
- it can distinguish between genuine defects and the small, temporary distortions caused by thermal movement of the atoms; and
- it is fast enough to be applied during the evolution of the crystal's simulated damage over time to better understand how defects form, combine and, in some cases, eventually disappear as the atoms return to their initial positions on the crystal lattice.

Until now, defect identification and classification were very labour-intensive and time-consuming tasks and, therefore, were typically carried out only at the end of molecular simulations. This new algorithm can be applied during the simulation of the crystal defect at each stage, which can provide new insights into when certain types of defects occur and vanish. This gives much more information about the system, which up to now was hardly accessible, and allows the types of defects that are likely to remain for a long time to be distinguished from those that are not.

"We hope that our approach will tremendously accelerate the simulation analysis for molecular dynamics simulations," said von Toussaint. "Computing power is increasing and manual capabilities are limited. Anything that can be done by computer rather than by people speeds up scientific development."

The winners will make their code available on a cost-free, open-source basis to any interested party, he added. It could be used by other institutions and experts — mainly material scientists — to analyse the results of their simulations, particularly those relating to radiation damage in solids.

The IAEA is planning to build on the success of this challenge by developing a distributed computing application that can be downloaded by volunteers to run simulations of damage in materials for fusion, Koning said. This has the potential to greatly increase the speed at which new candidate materials for a fusion reactor can be explored and will further enhance scientists' understanding of the behaviour of these materials in such extreme conditions.

— By Christian Hill and Aleksandra Peeva

IAEA neutron activation e-learning course helps scientists in 40 countries

From helping to solve historical criminal cases to determining the cause of a disappearing beach in Jamaica or the air quality at your gym: neutron activation is an established method to find out the composition and origin of materials. An e-learning tool developed by the IAEA is now helping researchers in 40 countries to apply the method.

Neutron activation is a common type of analysis carried out in around half of the 238 operational research reactors worldwide, as well as in some accelerator-based neutron sources. The highly sensitive technique can reveal the concentration of a single atom in a million, without tampering with or destroying the material. Its precision offers advantages over other analytical methods, and it is particularly useful for bulk analyses and studying materials that are unique and need to remain intact.

The technique works by irradiating stable atoms with neutrons and subsequently measuring the decay, or radiation, of the elements in the sample. Scientists use the technique to find the chemical signature of plastics, metals, glass, soil and air particles, among others.

"The main fields of application of this method today are in environmental sciences, archaeology, cultural heritage and even forensics," said Nuno Pessoa Barradas, Research Reactor Specialist at the IAEA. "Researchers in these fields, however, do not necessarily have a background in nuclear physics, so they may not be able to use the technique to its full potential."

Building knowledge

In order to bridge this knowledge gap and to address a growing demand, the IAEA, through the technical cooperation project Networking for Nuclear Education, Training, and Outreach Programmes in Nuclear Science and Technology, designed an e-learning course on neutron activation analysis. Launched in late 2017, the tool caters to both newcomers and specialized advanced-level professionals.

In October 2018, the online training course reached a landmark target, with participants in 40 of the 52 countries with operating research reactors signing up for it in less than a year. Several institutes use the tool to educate staff and students, including at university level.

"We face frequent changes of employees and the training of new staff is quite time consuming, especially in such a specialized field," said Katalin Gméling from the Hungarian Centre for Energy Research. "The e-learning material offers a great collection of information to train newcomers and refresh the knowledge of senior staff."

Discovered in 1935 by Hungarian-born chemist George de Hevesy and German-Danish physicist Hilde Levi, neutron activation originally became a useful tool to measure the mass of rare earth elements.

In the past few decades, several other uses have been found for the method, including providing additional evidence for historical criminal cases. In 2013, neutron activation was used on a moustache hair to disprove the theory that Danish nobleman Tycho Brahe was killed by mercury poisoning. His valuable notes were inherited by his assistant, and prime suspect, mathematician and astronomer Johannes Kepler, who discovered planetary motion laws.

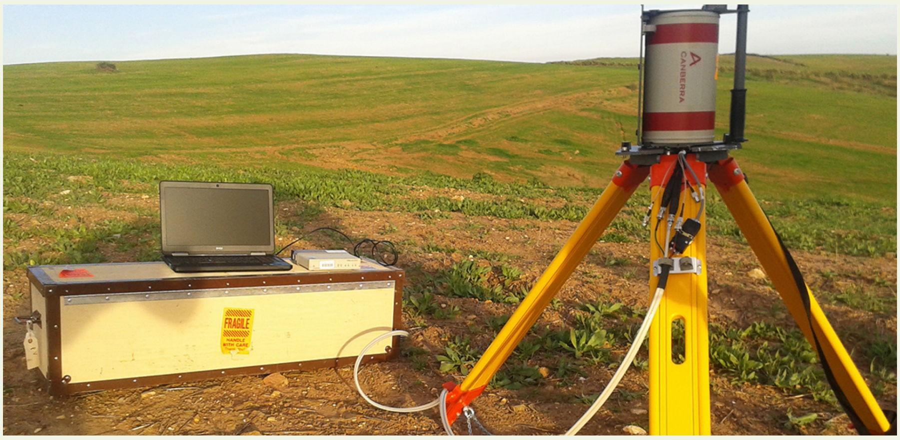
More recently, following the theft of an estimated five hundred truckloads of sand from the Coral Springs beach in Jamaica, local authorities teamed up with the International Centre for Environmental and Nuclear Sciences to apply neutron activation to test the origin of sand at suspected receptor beaches, providing additional evidence for the case.

Today, neutron activation is also used to research and test indoor air quality (e.g. at schools and fitness centres) by helping to determine the quantity and origin of pollutants in the air.

The neutron activation analysis e-learning tool was reviewed at a workshop in September 2018 at the IAEA Headquarters in Vienna. “The tool is intended to be a living book that can be constantly updated and extended as this field evolves to include different laboratory protocols and research areas,” Barradas said. The launch of the first revision is planned for early 2019.

— By Luciana Viegas

Egypt and Senegal receive gamma detectors to help combat soil erosion



Experts in Egypt and Senegal will be better able to fight soil erosion thanks to two gamma spectroscopy detectors which were delivered in November 2018 through the IAEA’s technical cooperation programme. The detectors will be used for soil erosion assessment in areas that have experienced severe land degradation, a phenomenon that jeopardizes agriculture in many regions of the world, including in arid and semi-arid lands in Africa.

Egypt and Senegal are both suffering from severe land degradation, with soil productivity in most of the northeast Nile Delta in Egypt, for instance, having decreased by more than 45% in the last 35 years, according to recent studies. Land degradation is the result of several factors, including overexploitation of land, unsustainable agricultural practices and extreme weather events, which have occurred more frequently in the last few decades. Soil erosion — a major type of land degradation caused by both human and environmental factors — can lead to the complete loss of the fertile topsoil, leaving the affected land unfit for agriculture.

Agriculture is an important economic sector in most African countries, accounting for approximately 12% of Egypt’s gross domestic product (GDP) and 17% of Senegal’s GDP. Low-input farming from subsistence farms run by families represents a significant component of this sector. It accounts for a high proportion of jobs, and provides livelihoods to subsistence farmers and their families. As this type of farming typically takes place on arid and semi-arid land with marginal agricultural potential, such as drylands and mountains, it is particularly susceptible to soil erosion.

The IAEA, in cooperation with the Food and Agriculture Organization of the United Nations (FAO), has been assisting countries for more than 20 years in combating land degradation by supporting the use of isotopic techniques to assess soil erosion.

Fallout radionuclide tracers, such as caesium-137 (Cs-137), have been used extensively in assessing soil erosion and sedimentation. This radionuclide is present in the atmosphere from where it falls to the ground in precipitation and accumulates in the uppermost soil layer. During erosion, the topsoil is washed away, which can be measured as decreased levels of Cs-137. At the same time, where the eroded soil settles, increased levels of Cs-137 are seen.

The erosion assessment using Cs-137 has many advantages compared to traditional methods, said Emil Fulajtar, a soil scientist in the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. This method provides long-term mean erosion rates, while conventional methods provide mostly short-term data. Using this nuclear technique, there is therefore no need for long and resource-demanding monitoring programmes: soil redistribution can be assessed in a single sampling campaign. It also helps to determine the spatial distribution of erosion, which is essential input for soil conservation programmes aimed at sustainable land management and thereby food security.

The provision of gamma spectrometers, which are used to carry out the Cs-137 measurements, is part of an ongoing initiative by the Joint FAO/IAEA Division to help African countries enhance their capacity to control soil erosion; this also includes the training of scientists on the use of the Cs-137 method and the establishment of gamma spectroscopy capacities across the continent. Another three table-top gamma detectors — for Madagascar, Algeria and Zimbabwe — and three portable gamma detectors — for Morocco, Tunisia and Madagascar — have already been delivered.

“We will use the gamma detectors for the ‘fingerprinting’ of sedimentation in the Nile River to trace the origin of contamination from different sources, such as drainage from industrial and agricultural bodies located on the riverbank,” said Mohamed Kassab, a lecturer at the Egyptian Atomic Energy Authority’s Nuclear Research Centre. “We also plan to help other countries in Africa to build capacity in gamma measurements and analytical services.”

— By Matt Fisher