Nuclear techniques help European countries understand and preserve cultural heritage

By Jeremy Li

Before a piece of ancient artefact is displayed at exhibitions, experts need to determine its origins and carry out the necessary restoration work. Error or mistake in any of the many steps involved could cause irreparable damage to the artefact. Thanks to various nuclear techniques and IAEA support, several countries in Europe have acquired the skills they need to process and restore their cultural artefacts efficiently and safely.

The technical cooperation programme has supported 3 scientific visits and fellowships in this field in Bulgaria, and 5 scientific visits and fellowships in Croatia.

Such techniques were used on an Apoxyomenos — an ancient bronze statue of a young athlete — in Croatia. After resting 45 metres underwater for some 20 centuries, it was retrieved by archaeologists in 1999 from the seabed near a small island in the Adriatic Sea. When first discovered, the statue was tarnished beyond recognition. Thanks to several techniques involving ionizing radiation, experts were able to analyse the statue's age and the type of metals used, and restore it.

"Restorers need to first characterize the artefact — gather enough information — in order to know precisely what method to use for the restoration to be successful," said Stjepko Fazinić, Research Advisor at the Ruđer Bošković Institute in Croatia. "Insufficient characterization of artefacts can lead to significant damage, because you might apply the wrong technique to restore these objects. Ionizing radiation can help us minimize this risk."

To promote the use of nuclear techniques for the conservation of cultural heritage, the IAEA has been assisting Croatia with training and equipment since 1993 through a series of technical cooperation projects.

Under one such project, the IAEA provided Croatia with mobile X-ray fluorescence spectroscopy equipment (see The Science box), which helped scientists analyse more than 1000 samples of ancient artefacts within the project's first year. "We are able to determine the age of more than 170 archaeological samples every year using nuclear techniques," Fazinić said.

Beating the bugs

But even when all the steps of the restoration process are strictly followed, artefacts of organic origin are still susceptible to severe deterioration due to insects and bacteria, for example.

"Textiles, wood, paper, leather objects and mummies are extremely vulnerable," Fazinić said.

Gamma-ray panoramic irradiation is a frequently used technique for sterilization to destroy biological contaminants. It uses a radioactive source, primarily cobalt-60, to induce chemical changes in the DNA of these harmful organisms and eliminate them. In 2015, the IAEA provided cobalt-60 sources to Croatia to aid this effort.

"Every year, our colleagues from the radiation chemistry and dosimetry laboratory irradiate about 20 m^3 of materials with this technique," Fazinić said. "Over the past 20 or so years, they have sterilized more than 5000 artefacts."

The Ruđer Bošković Institute and the Croatian Conservation Institute are two of the IAEA's main counterparts in the conservation of cultural heritage. Early comers to the game, the Croatians have been using nuclear analytical techniques for decades and are now sharing their knowledge by training scientists from other countries, such as Bulgaria.

Bulgaria: increasing the use of the radiocarbon dating technique

"In Bulgaria, our first sign of human activity dates back to 40 000–50 000 years ago," said Vladimir Dimitrov, professor at the Institute of Organic Chemistry's Centre of Phytochemistry at the Bulgarian Academy of

Sciences. "We have a very rich history, full of cultural heritage, and there is much more waiting to be discovered."

Besides the sheer volume of unexcavated artefacts, lack of funding and equipment are major obstacles in uncovering Bulgaria's past, Dimitrov said.

"We don't have our own laboratory to carry out the dating analysis, so to determine the age of an artefact we must send the samples to other countries, which is not cheap and takes a long time," he said. Transporting the samples can also increase the risk of damage.

One of the most commonly used methods for age determination of organic archaeological finds is the analytical technique called radiocarbon dating (see The Science box). "Our institute has individuals with skills and knowledge in applying the technique, but we don't yet have the capacity to build a full laboratory," Dimitrov said.

An ongoing IAEA technical cooperation project will provide Bulgaria with the necessary support, including equipment to establish a radiocarbon dating laboratory. The laboratory is expected to be fully functional later this year.

The head of the Apoxyomenos statue that was found in the Adriatic sea, after treatment.
(Photo: Ruđer Bošković Institute)

"Once the laboratory is up and running, we expect to spend 20% to 30% less money on determining the age of ancient artefacts," Dimitrov said. "So we can do more with less."

THE SCIENCE

X-ray fluorescence (XRF) spectroscopy

XRF is a method that detects and measures the concentration of elements in virtually all types of material. Scientists normally use a small and mobile X-ray fluorescence spectrometer to bombard a sample of the test material with high-energy X-ray beams. The beam interacts with the atoms in the sample, displacing the electrons in the inner shell of these atoms. When an electron is displaced, it leaves behind a vacancy that will be filled by an electron from the higher orbit. When an electron moves from a higher orbit to a lower one, a certain amount of energy is lost. This energy loss is detected by the spectrometer and is used to identify the element it originates from. The method is accurate because the amount of energy loss is unique to each element.

Radiocarbon dating method

The radiocarbon dating method measures the amount of radiocarbon (carbon-14) in organic material — such as leather and wood — to determine the age of that material. Carbon-14 is an isotope of carbon that is constantly formed in the natural atmosphere. It is quickly absorbed by all living organisms. When organisms die, they stop absorbing carbon-14 and immediately start decaying. Because carbon-14 has a very long half-life (5730 years), the age of the sample can be determined by measuring its radioactivity level.

However, this method can only give an approximate age for the sample, usually a range of a few years.