Contribution of International Atomic Energy Agency to cultural heritage studies

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Abstract

During the last ten years the International Atomic Energy Agency has organized several activities in support of the characterization and preservation of objects from cultural heritage. Due to the complex nature of the tasks and the relevance of combining complementary information from different fields of humanities and applied sciences, the Agency has promoted the establishment of collaborative links and has guided inter-disciplinary research in this field. This paper presents the main activities carried out within the regular budget program of the Department of Nuclear Applications and the Technical Cooperation projects implemented by the Department of Technical Cooperation.

Keywords:

Nuclear techniques, Archaeometry, inter-disciplinary research, IAEA, technical cooperation, cultural heritage

Introduction

Article III of the International Atomic Energy Agency (IAEA) Statute states that the IAEA is authorized to encourage and assist research on, and development and practical application of, atomic energy for peaceful purposes throughout the world and to foster the exchange of scientific and technical information, as well as the exchange of scientists in the field of peaceful uses of atomic energy.

The Department of Nuclear Sciences and Applications (NA) is responsible for the implementation of the IAEA's Major Programme 2 on Nuclear Techniques for Development and Environmental Protection. The Department assists its Member States in introducing and extending the use of nuclear techniques in different fields of applications, including human health, agriculture, management of water resources, environmental studies and other applications. Providing a technical backstop to all technical cooperation projects at the IAEA, staff in the Department of Nuclear Sciences and Applications is also responsible for a nuclear science programme located in Major Programme 1 on Nuclear Energy, managed by the Department of Nuclear Energy.

Meetings and coordinated research activities are organized to encourage the acquisition and dissemination of new knowledge and technology generated through the use of nuclear technologies and isotopic techniques in the various fields of work covered by the IAEA's mandate. The results are freely available to Member States and the international scientific community through dissemination in the IAEA's scientific and technical publications and in other relevant international or national journals. Technical meetings are organized to review the current status, developments, trends and applications in a particular field of study, and to produce reports and guidelines containing technical information as well as recommendations to the IAEA and to its Member States. The IAEA's coordinated research activities are designed to stimulate and coordinate the undertaking of research by scientists in IAEA Member States in selected nuclear fields. Coordinated research activities are normally implemented through coordinated research projects (CRPs) that bring together research institutes in both developing and developed Member States to collaborate on the research topic of interest.

The Department of Technical Cooperation helps countries to improve their scientific and technological capabilities in the peaceful applications of nuclear technology, thus contributing to sustainable development. All Member States are eligible for support, although in practice technical cooperation activities tend to focus on the needs and priorities of less developed countries. The assistance is provided by implementing national, regional and interregional projects.

The relevance of supporting cultural heritage studies

The cultural heritage of a country is one of the principal sources of knowledge of its past: it is a legacy of the past and a powerful beacon of its cultural identity. As cultural heritage is primarily composed of collectively owned values and assets, the conservation and transmission of this legacy to future generations is a responsibility of society in its entirety.
The classification, preservation and restoration of these objects requires scientific, technical and historical knowledge. The chemical composition of these goods plays a fundamental role in enhancing their characterization: for this purpose, nuclear analytical techniques are especially useful. Many examples have been recorded in literature on the application of these techniques to the study of different types of cultural heritage objects such as ceramics, lithic and metallic artefacts, paintings, sculptures and archaeological remains. In some cases this knowledge can also be useful to fight illegal trafficking by providing complementary information for authentication purposes. With respect to falsifications or illegal traffic of cultural goods, nuclear analytical techniques can help situate the piece within a certain historical period or culture, by direct dating techniques or by comparison with established chemical compositional patterns of objects or with the composition of the raw materials used to make the original objects.

The creation of databases which document historical artefacts through cross-references, documentation evidence and characterization data is also of great importance. Databases allow the use of old museum collections as a new source of information, to compare new findings or dubious pieces with chemically characterized typologies or also to solve problems on conservation, restoration, historic archaeology or research in these areas.
The following Table summarizes some of the nuclear and nuclear-related techniques and their usefulness for the study of cultural heritage artefacts:

Type of information	Techniques
Age, dating	^{14}C, Thermo and Photo-Luminescence
Chemical composition	Neutron Activation Analysis (NAA), X-ray Fluorescence (XRF), Ion Beam Analysis Techniques (IBA), Energy Dispersive x-ray Spectrometry in Scanning Electron Microscopy (SEM-EDS)
Mineral composition	X-ray Diffraction (XRD), SEM-EDS
Structural / morphology	SEM, micro-XRF, X-ray radiography, x-ray tomography
Conservation	Radio-sterilization, radiation treatment

The importance of collaborative links

Access to different facilities as well as the exchange of information and experiences is of great relevance to extend the use of nuclear techniques to different research challenges or specialized analytical services. The interdisciplinary approach is the most productive way of advancing in several scientific fields. It is especially useful in studying objects from the cultural heritage, considering the necessary interaction between archaeologists, history and art specialists, restorers, chemical analysts and other specialists. Great benefits can be obtained from the interactive and interdisciplinary approach, starting from the very definition of the projects through the sampling strategies to the statistical analyses and the interpretation of the data obtained. The possibility of co-operation between groups and the exchange of opinions and points of view enhances the interpretation of each group's results.

For example, while analysing archaeological pottery it is extremely important to ensure the participation of a geologist with knowledge of the geochemistry of the areas being studied to contribute to both the problem formulation and the interpretation of the variability in the data observed in the studied artefacts. A statistician and/or geo-statistician are also very useful for the handling and interpretation of the data.

Research activities coordinated by the IAEA in support of cultural heritage studies

Due to the growing interest in cultural heritage study and preservation, since 1997 the IAEA has organized several research collaborative projects. A number of technical and consultancy meetings were organized to discuss different topics related to this field of application. The following coordinated research projects (CRPs) were successfully implemented:

- Nuclear analytical techniques in archaeological investigations (F 23015, 1997-2000)

Participating countries: Argentina, Brazil (2), Chile, Cuba, Mexico, Peru, United States of America.
This CRP was aimed at promoting interdisciplinary research between analytical chemists using nuclear analytical techniques and archaeologists in Latin America. The CRP demonstrated the synergistic effects emerging from a close collaboration between analytical chemistry and archaeology. Mutual recognition of their specific needs and requirements were displayed within well defined archaeological problems. The collaborative efforts opened new perspectives for scientific investigations in the region using the available nuclear analytical facilities for problem solving approaches. The introduction of statistical treatment techniques (cluster analysis, analysis of variance, principal component analysis) for large data sets interpretation helped to enhance the understanding of inter-element correlation and for the interpretation of analytical results from archaeological artefacts. A technical report summarizing the experiences in the application of instrumental neutron activation analysis for the characterization of archaeological pottery in Latin America was published [1].

- Applications of nuclear analytical techniques to investigate the authenticity of works of art (F23023, 2004-2009)

Participating countries: 16 laboratories from all over the world.
The CRP focused on enhancing the quality of results of nuclear analytical laboratories and on assisting the Member States in accreditation of their practice of nuclear analytical techniques. The latter contributed to train radio-chemists for sustainability of nuclear knowledge and promoting new developments in nuclear analytical techniques. Results of the investigations carried out were then published in book form [2].

- Unification of nuclear spectrometry applications: integrated techniques as a new tool for material research (G42002, 2006-2009)

The CRP assisted Member States in improving and enhancing utilization of the nuclear spectrometries through development of integrated/unified instruments and analytical methodologies for better characterisation of materials, combining several techniques. New special applications were implemented in support of environmental pollution monitoring, industry, study of cultural heritage, human health, agriculture, among other fields. The results obtained in several applications, including cultural heritage-related, were published [3].

- Application of large sample neutron activation analysis techniques for inhomogeneous bulk archaeological samples and large objects (F23027, 2008-2012)

Nuclear techniques based on X-ray and neutron probe principles play a very important role in both applied research and practical applications. Non-destructive X-ray fluorescence techniques are often applied for trace element characterisation but this technique provides information on the surface layers but not on the bulk composition of objects. Neutron activation analysis (NAA) is a well established nuclear technique, ideally suited to investigate the microstructural or elemental composition and can be applied to studies of a large variety of samples. However, there are limitations due to sample size for application in bulk analysis, in particular for archaeology and cultural art artefacts, findings, forensic materials as well as geological studies. This is due to the lack of verified and validated experimental procedures which are required for NAA implementation in bulk sample studies.

The CRP initiated concerted efforts to support the planning, harmonisation and implementation of large sample neutron activation analysis (LSNAA) techniques, to enable new areas of applications. The CRP focused primarily on the application of LSNAA in the areas of archaeological and geological programmes, with the possibility to be open for further utilisation in other subjects in industry and research.

IAEA technical cooperation projects implemented.

Several national technical cooperation projects were implemented to introduce the use of nuclear techniques for characterization and conservation of archaeological and art objects. The implemented techniques included radio-sterilization and radiation polymerization of art objects; large sample neutron activation analysis for elemental analysis; INAA and/or XRF for chemical characterization, and radiocarbon or thermo-luminescence for dating, among others. TC national projects benefited institutions from Albania, Croatia, Greece, Lebanon, Peru, Syrian Arab Republic, The Former Yugoslav Republic of Macedonia, Turkey and the United Arab Emirates.

Regional collaboration was strengthened by the organization of a number of regional technical cooperation projects, including:

- RLA 8043: Use of nuclear analysis techniques and development of databases for characterization and preservation of national cultural heritage objects (ARCAL XCIV, 2007-2011).

Institutions from Argentina, Brazil, Chile, Costa Rica, Cuba, Ecuador, Mexico and Peru, especially agencies and institutes that deal with cultural and historical heritage, conservators, curators and researchers from national, provincial and municipal museums, researchers in archaeology and art history benefited from the project achievements. Regional knowledge of cultural heritage objects was strengthened, as well as their contextualization, conservation and preservation. Regional awareness of the benefits of application of nuclear analysis techniques was increased.

Thanks to the quantitative information generated, regional preservation professionals as well as decision makers now have additional tools to develop strategies and policies to better identify, classify and preserve cultural heritage objects. Human capacities to use nuclear techniques in studying and preserving cultural heritage were improved, especially regarding the use of statistical tools. Regional technical capabilities to generate information for the study and preservation of cultural heritage were strengthened.
A database was created with advanced search interfaces to access the analytical results stored (1787 samples). Several papers were published, and a book was published by the Instituto Nacional de Patrimonio Cultural (INPC) of Quito (Ecuador, ISBN: 978-9978-92-968-1) to disseminate information on the benefits and achievements of the project.

- RER 1006: Nuclear techniques for the protection of cultural heritage artefacts in the Mediterranean region (2006-2009).

A better understanding and cooperation between cultural and nuclear institutions was established at the national level in Albania, Armenia, Croatia, Cyprus, Greece, Malta, Montenegro, Romania, Serbia, Slovenia, The Former Yugoslav Republic of Macedonia and Turkey.
A sub-regional network of conservators and nuclear scientists was established and developed through this project, thus contributing to increasing the regional cooperation. The use of gamma rays for cultural heritage preservation, the upgrade and repair of nuclear instrumentation and systems and improvements in nuclear analytical techniques were also achieved in many countries through the project. Staff from the participating laboratories was trained on different techniques and research methodologies, including portable X ray fluorescence, ion beam analysis, in situ measurements and chemometrics.

- RAS 1010: Use of small accelerators as nuclear analytical tools in art and archaeology (2006-2010).

The project was aimed at establishing the authenticity and provenance of objects of art and archaeology making use of ion beam accelerators as nuclear analytical tools. As a result, the capability of the use of nuclear techniques for contextualization, conservation and preservation of cultural heritage objects was enhanced in the region. The project contributed to increasing awareness of the benefits of application of nuclear techniques for cultural heritage objects among end users and beneficiaries (museums, universities etc.). Collaborative work between scientists in different Member States was initiated. Lebanon and Syria who have already some experimental facilities, are now providing their expertise to the other participating Member States. As an example, samples from Yemen, Iraq, UAE were sent to Lebanon for measurements, and the analysis on the results was done jointly between Lebanon and the respective country.

- RAS 1011: Using ion beam analysis and complementary nuclear techniques for material characterization in ARASIA state parties (2006-ongoing).

RAS 1011 aimed at enhancing and promoting the use of ion beam analysis and complementary nuclear techniques, such as X ray fluorescence, to study the characteristics of materials related to archaeology, and new elaborated materials. In some cases, samples related to the environment will also be considered. Institutions from Iraq, Jordan, Lebanon, Saudi Arabia, Syrian Arab Republic, United Arab Emirates and Yemen participate in the project.

- RER 8015: Using nuclear techniques for the characterization and preservation of cultural heritage artefacts in the European region (2009-2011).

Institutions from Albania, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Greece, Hungary, Malta, Montenegro, Poland, Portugal, Romania, Serbia, Slovenia, The Former Yugoslav Republic of Macedonia, Turkey and Ukraine participated in the project.

The project established a sub-regional network of nuclear science and conservation institutions working in the field of Cultural Heritage (CH) characterization and preservation. Intra-country collaborations between nuclear specialists and conservators in all participating Member States were consolidated, as well as bi- and multi-lateral collaborations between participating Member States were established. The analytical capabilities in all participating Member States were substantially improved through national TC projects and in-kind, national contributions in support of procurement of up-to-date equipment. In line with the TCEU core values of “inclusiveness” and “solidarity”, the accessibility to specialized facilities in partner Member States, including non-recipient countries such as Switzerland and France, were increased for the benefit of the whole region. Initial steps were taken towards the harmonization of analytical and CH inventory data at the regional level, especially through the sharing of reference materials and cataloguing methodologies produced within the project and targeted expert mission.

Relevant IAEA Publications in the field

1. STI/DOC/010/416: Nuclear Analytical Techniques in Archaeological Investigations, IAEA, Vienna, Austria, 2003.
2. STI/PUB/1501: Nuclear Techniques for Cultural Heritage Research, IAEA, Vienna, Austria, 2011
3. TECDOC 1669: Integration of Nuclear Spectrometry Methods as a New Approach to Material Research, IAEA, Vienna, Austria, 2012.