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Nuclear verification: helping to find a needle in a hay stack

The European Commission Joint Research Centre (JRC) is among the few laboratories in the world that can provide the highly specialised analytical methods and techniques needed for nuclear safeguards and forensics purposes. In Europe, the JRC's Institute for Transuranium Elements (JRC-ITU) supports Euratom Safeguards, whose mission is to ensure that within the EU, nuclear material is not diverted from its intended use and that safeguarding obligations agreed with third parties are complied with. At international level, the JRC cooperates with the International Atomic Energy Agency (IAEA) on the control of nuclear materials and facilities in order to avoid proliferation or diversion. Soon, JRC will enhance its capabilities to find nuclear materials in aerosol particles, this will be like finding a needle in a hay stack…

A key international topic today is the work of preventing the spread of nuclear weapon technology and illicit trafficking of nuclear materials that can be used for the production of nuclear weapons or so-called dirty bombs.

The JRC's capabilities in this field were the basis for the recent agreement concluded with the American Association for the Advancement of Science (AAAS) to work together on science and technology for safety, security and sustainability. In particular, nuclear forensics and safeguards technology for combating illicit trafficking of nuclear material is a primary area of common interest.

Environmental sampling – high sensitivity particle analysis: strengthening the nuclear safeguards regime

Nuclear safeguards also include environmental sampling to verify the absence of undeclared nuclear activities. The JRC provides the safeguards authorities with experimental evidence by analysing micron-sized particles in dust material; hence, enabling the detection of a single uranium particle among millions of ordinary dust particles.

Sample collection and analysis of environmental particles is a key means of control and verification (figs.1-3), as these tiny particles reflect the nature of the work at a nuclear installation and especially reveal the enrichment of uranium, in the range from depleted up to weapons grade.

These techniques have proven to be effective for safeguards measures and are a cornerstone in the implementation of IAEA's Additional Protocol, which gives the Agency complementary inspection authority.

To further strengthen this activity, the JRC and Euratom Safeguards have decided to jointly establish a high-sensitivity particle analysis laboratory.

Its core facility will be a large geometry – secondary ion mass spectrometer (LG-SIMS) for trace analysis of aerosol particles. It will allow the detection speed and sensitivity of nuclear material to be increased by at least a factor of ten. The minor isotopes of uranium will become accessible, which is important for identifying the source of the material.

In addition, the LG-SIMS instrument will play a key role for research projects to strengthen safeguards particle analysis and the production of certified particle reference materials, which will allow other laboratories to improve their analysis. The new laboratory is a crucial element to move towards in-depth characterisation and nuclear forensics of micro-particles.

Nuclear forensics

Together with the verification of the absence of undeclared nuclear activities, nuclear forensics techniques are increasingly applied in safeguards. JRC is a key player in this field and is working on a co-authored follow-up report to the recent APS (American Physical Society) and AAAS study on "*Nuclear Forensics: Role, State of the Art, and Program Needs*". It will focus on the need of international work to improve nuclear forensics, both on sample libraries and databases and on sharing best practices, tools, and technologies.

A nuclear forensics example: shedding light on Germany's first nuclear programme

JRC's experience is vast in this domain and it has carried out various nuclear forensic investigations in recent years. It has examined material detected in 2009 at a scrap metal yard near Rotterdam (The Netherlands) and two samples dating back to the first German nuclear project, shortly after the discovery of nuclear fission in 1938.

From these two samples, JRC found out that the first one (a uranium metal cube), originated from Werner Heisenberg's experiments and was produced in late 1943 from uranium ore of the "Joachimsthal" mine in the Czech Republic. The second one (a uranium metal plate) originated from the work of Karl Wirtz (a close collaborator of Heisenberg) and was produced from the same uranium ore but during different production batches in the mid 1940s.

JRC-ITU analysed a large number of parameters providing information on the production date and material's properties. The results will be published and will provide experimental evidence on the history of the material in the context of Germany's first nuclear program.

Accountancy verification of nuclear material at reprocessing facilities

Last but not least, accountancy verification of nuclear materials is also one of the basics of nuclear safeguards. The Joint Research Centre operates two on-site laboratories at the European reprocessing plants in La Hague (France) and Sellafield (UK) - which will celebrate their 10th anniversary this year - on behalf of Euratom safeguards.

The JRC also supports the IAEA in the operation of the on-site laboratory at the Rokkasho reprocessing facility in Japan. In addition, it has provided scientific and technical support to this International Agency for over a quarter of a century, with over 50 scientists and technicians working on more than 25 projects.

Training for nuclear security

Illicit trafficking of nuclear material is a topic of substantial international concern and it demands a qualified and comprehensive response. JRC has been playing an active role in enhancing the European Union (EU) member states' capabilities to combat illicit trafficking for many years. An extensive training programme was developed covering all aspects of the entire response process from the development of a national response plan to nuclear forensic analysis with advanced analytical techniques.

As a follow up of these activities, the JRC has been tasked by the European Commission to explore the feasibility of a nuclear security training centre with a mixture of lectures and hands-on laboratory work. This will forcefully pursue the past training activities and assure that the expertise available at the JRC and in the EU Member States is disseminated for the benefit of enhanced nuclear security in the European Union and abroad.

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Fig. 1: Swipe sampling technique used to collect dust at a nuclear facility. The sampling locations will differ according to the type of facility that is inspected. Typical sampling locations can be tube connections for UF_6 at enrichment facilities or ventilation conducts. Environmental samples are taken in the search for non-declared nuclear activities or for the verification of declared ones. The samples are either analysed in bulk, giving the average isotopic composition of the material, e.g., uranium, or analysed individually as particles.

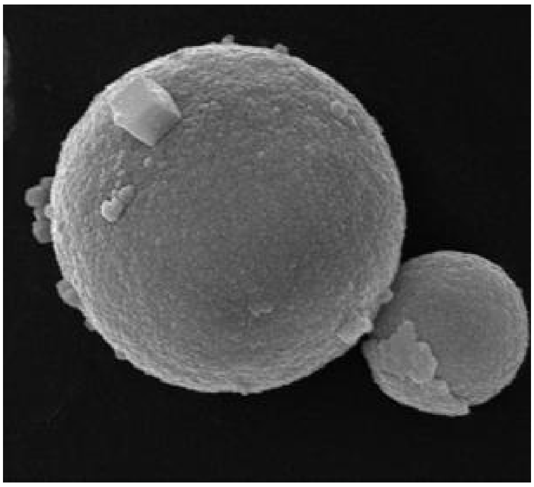

Fig. 2: Uranium oxide particles of micrometer size analysed by Scanning Electron Microscopy

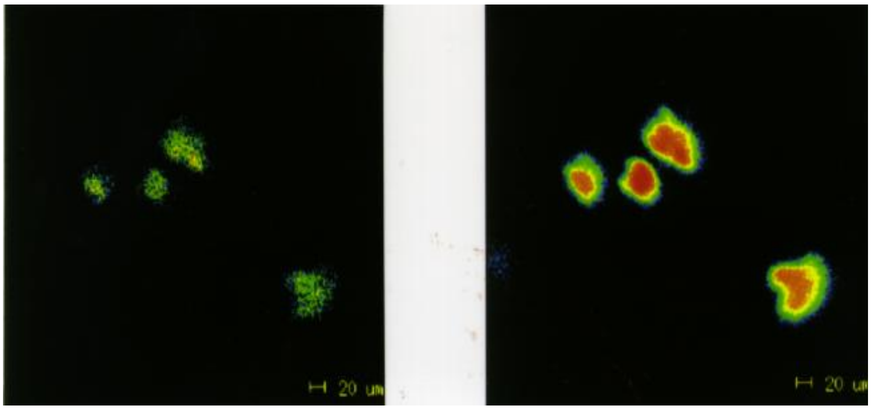

Fig. 3a and 3b: Four micron-size uranium particles analysed by SIMS (Secondary Ion Mass Spectrometry) for enrichment detection. The brightness scales with the abundance of the fissile isotope uranium-235 (left) and of uranium-238 (right).