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# 30 years Nuclear Forensic Analysis at the JRC Karlsruhe – Support provided to EU Member States and Other Partner Countries

At the beginning of the 1990's, incidents of illicit trafficking of nuclear materials generated a serious concern: An unexpected threat appeared and effective countermeasures based on nuclear forensic capabilities had to be quickly deployed. The first seizures of smuggled radioactive material were reported in 1991 in Switzerland and in Italy. In the subsequent years numerous similar incidents were reported in Germany, Czech Republic, Hungary and other central European Countries. Apart from the need of determining the nature of the illicitly trafficked materials and their intended use, the authorities requested information about the materials' origin. With its range of advanced chemical and isotopic analytical methods that had been established mainly for nuclear safeguards purposes, as well as using its long-standing expertise on nuclear material analysis, JRC Karlsruhe was in an excellent position to help addressing the nuclear security challenge of European citizens. Therefore, EURATOM approached the JRC Karlsruhe and the first nuclear forensic analysis was performed there in 1992. During the following three years, twenty-one investigations of materials seized in Germany were performed. The majority of those cases concerned uranium fuel pellets that were intended for use in early-generation graphite-moderated or pressurized-water nuclear power reactors. However, the most serious incidents involved kilograms of highly enriched uranium, several hundred grams of mixed uranium-plutonium oxide, and weapon-grade plutonium. In the early years, most of the investigated incidents were related to intentional unauthorized movement of nuclear or other radioactive material. More recently, the materials found out of regulatory control and subject to nuclear forensic analysis were linked to unauthorized acts such as illegal possession or unauthorized disposal of radioactive waste.

As the phenomenon of "illicit trafficking" persisted, the JRC Karlsruhe established a specific nuclear forensic research and development program in 1997. The research concentrated first on the analysis of trace elements as indicators of environmental contamination, e.g. measurements of the oxygen-18/oxygen-16 isotopic ratio in uranium oxides, to gather information on the geolocation of the production site, and surface roughness characterization of fuel pellets in connection with grinding processes. In order to narrow down the number of possible production places of nuclear materials, the "age" (i.e. the date of last chemical separation) of U and Pu is a very important factor. The age determination method for Pu was developed using multiple parent/daughter ratios by thermal ionization mass spectrometry and additionally the method was also demonstrated to be applicable for particles using Secondary Ionization Mass Spectrometry. In the beginning of 2000s, the work on age determination methods by mass and alpha spectroscopy was extended to uranium. Later, research was conducted on the propagation of metallic impurities in various uranium materials at the front end of the nuclear fuel cycle. Similarly, rare earth elements (REE), anionic impurities, and stable isotope ratios of Pb, Sr, S and Nd have been investigated as potential signatures for the origin determination of uranium and they have been tested using a comprehensive set of uranium ore concentrate (UOC) samples from mines around the world.

In the run-up to the FIFA World Cup 2006, which was hosted in Germany, JRC jointly with German Law enforcement started developing capabilities at the interface of nuclear forensics and traditional forensics (e.g. fingerprint, DNA). In the preparation phase of the event, the issue of collecting and examining radioactively contaminated evidence, e.g. after a dirty bomb explosion, was raised. Together with the German Federal Criminal Police (BKA), a dedicated glove box was designed and set up at JRC Karlsruhe, where latent fingerprints can be developed for radioactively contaminated items following the established protocols of the police. Ongoing studies include the particles formed during a dirty-bomb detonation. Fundamental studies on formation mechanisms using laser heating devices are complemented by real explosion tests on non-radioactive surrogate materials.

The presentation will review the trends observed in the type and nature of incidents, the analytical methodologies used in the casework and highlight some of the nuclear forensic signatures that were identified as useful for the nuclear forensic investigations.

**Primary authors:** Dr WALLENIUS, Maria (European Commission, Joint Research Centre); Dr MAYER, Klaus (European Commission, Joint Research Centre); Dr LÜTZENKIRCHEN, Klaus (European Commission, Joint Research Centre)

**Presenter:** Dr WALLENIUS, Maria (European Commission, Joint Research Centre)

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