**Capacity building for nuclear forensics through participation to the Collaborative Material eXercises (CMX) organized by NF-ITWG**

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**Abstract**

Since the first Collaborative Materials Exercise (CMX) organized by the NF-ITWG in 1999, the CEA participated to the whole series, including to the last one to date, CMX-7, during fall 2021. During these couple of decades, the panel of techniques and number of people implemented by CEA, representing France in the CMX exercise, have increased with the broadening of the scenarios. In that way, since CMX-6, French Police and Gendarmerie units were included for R/N contaminated classical evidence analysis. Indeed, for both CMX-6 and CMX-7, three sequential sessions of work were organized : the first one for nuclear materials (from opening to the 2-month report), the second one for the Police on classical evidence, and the third one for the Gendarmerie, on a second set of classical evidence. The different sessions took place in the same CEA nuclear facility, in a radiological controlled area especially converted for exercise's duration. The CEA ensured also the radiological protection support for both Police and Gendarmerie during the exercise. About a dozen specialists (CEA/Police/Gendarmerie) were fully involved in each session, and another dozen for the 1-week and 2-month nuclear analysis, expertise on results, and reports.

The first session lasted about two full days for categorization and sub-sampling of the nuclear materials, more precisely the first day for fast and non-destructive measurements for the 24-hour report, and the second day to fractionate each material in several sub-samples. For contaminated classical evidence, two days were planned for each of the two sessions. Besides, several additional weeks were necessary for organisation and logistic before each session and for dismantling and radiological controls afterwards.

Regarding the SNM analysis during CMX exercises, the operational sequence was the following one: i) reception; ii) storage; iii) analyses for categorization by X-rays / gamma spectrometry / X-ray fluorescence / LIBS (Laser Induced Breakdown Spectroscopy) / dimension, weight / pictures; iv) sub-sampling v) destructive analysis (1-week and 2 month phases); vi) interpretation based on the analytical results and other information; vii) report using notably the GDF.

The N/R confinement was ensured by four disposable glove boxes. Since they are made of a thin plastic layer, a complementary confinement "tent" was set up around them, assuming four confinement barriers are necessary : the facility, the cell, the tent and the glovebox, each one with dynamic air flux, except for the glovebox.

After the non-destructive characterizations during the 24-hour phase of the exercise, samples were transferred to the analytical laboratories, to carry out numerous highly sensitive and mostly destructive assays : low-level gamma spectrometry, ICPMS, SIMS, SEM-EDX, Raman spectrometry, TIMS, etc. CEA used innovative techniques like in SEM - Raman spectrometry and more recently laser ablation - ICPMS coupling for U isotope composition measurements on micro-fragments of the materials.

A network of subject matter experts (SME) was requested to provide interpretation based on all the available information (analytical results, scenario, etc.) and databases.

Regarding the contaminated classical evidence, the various analytical techniques implemented (fingerprints revelation, photography, documents, IT, DNA) allow finding links between suspects, items and locations. Conclusions of both the Police and the Gendarmerie matched well with those of nuclear materials experts.

For CMX-6, CEA was amongst the four participants that gave accurate and non-ambiguous answers about the origin of the nuclear materials. For CMX-7, skills and experience of all the involved teams, notably coming from feedback of the previous CMX exercises, allowed us to analyse precisely and within the alloted time both the nuclear materials and the contaminated classical evidence.