Blind test for verification of the performance of MMXRF

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1. Introduction

IAEA verifies nuclear activity through environmental sampling and analysis in suspected nuclear facilities. Environmental samples can be obtained from suspected nuclear facilities using swipes. To enhance the analysis and cost efficiency, the swipes could be analyzed using non-destructive analysis (NDA), such as gamma and XRF (X-ray fluorescence) [1-3]. XRF is one of the screening method with relatively short time due to the ~ ng scale uranium contents in a swipe. KINAC developed MMXRF [4] for screening of environmental samples prior to detailed analysis for the verification of nuclear activity.

IAEA is interested in the MMXRF method, because environmental samples could be screened after sampling by the inspector in the field. In order to enhance the efficiency of safeguards activity, in-fields use MMXRF has been developed. As prior study, the equipment has to be verified through blind test using IAEA samples in order to obtain performance requirement.

In this study, KINAC and IAEA tested using various swipes for deduction of performance requirement of the portable MMXRF.

2. Methods and Results

2.1 MMXRF

Reducing background radiation due to the continuum of X-ray is important because uranium contents in environmental swipes are ~ ng/cm^2. Monochromatic Micro-focusing X-ray fluorescence (MMXRF) was developed as one of the swipe screening instruments. On this purpose. MMXRF consists of an X-ray generator with an X-ray tube and a DC power module supplying high voltage and silicon doubly curved crystals to generate monochromatic X-ray, a silicon drift detector of 25 mm^2 active area, and a movable swipe stage. The operation tube voltage is 50 kVp and the current is 0.5 mA. X-ray photon flux is 5 x 10^{10} at the focal point with a spot of 110 μm. The monochromatic X-ray energy 22.16 keV which the target material is silver (Ag). The equipment could be controlled and analyze a swipe by a control PC.

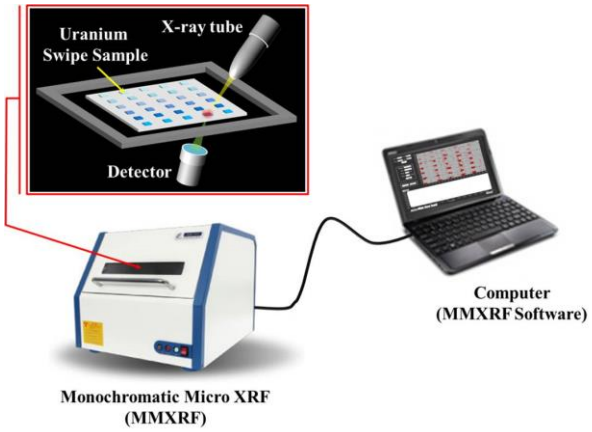

Fig. 1. MMXRF (Monochromatic Micro-focusing XRF)

2.2 Test samples and measurement condition

For testing, IAEA prepared the 22 swipes to KINAC. 11 all-distributed swipes (A-1 to A-11) and 11 point-type swipes (MS-1 to MS-11, 5 points). The examples are shown in Fig. 2.

The measurement mode is coarse and fine mode. The coarse mode is focusing area 3 x 3 mm^2, 5 seconds (1156 spots, 1h 26 min / swipe) and the focusing area is 1 x 1mm^2 in fine mode for 10 seconds per beam spot (10,000 spots, 28h / swipe). The coarse mode would be preferred time for in-field inspection, however, the sensitivity could be relatively lower than the fine mode.

All swipes were analyzed by MMXRF in coarse mode, some swipes re-analyzed in fine mode with longer measurement time.

Fig. 2. Examples of IAEA blind test swipes

2.3 Results

For all area-distributed swipes, the uranium contents in the swipe is possible below detection limit for unit area

(3 x 3 mm^2, 1 x 1mm^2). The measurement results of distributed swipes could not be distinguished from a blank swipe, even in fine mode.

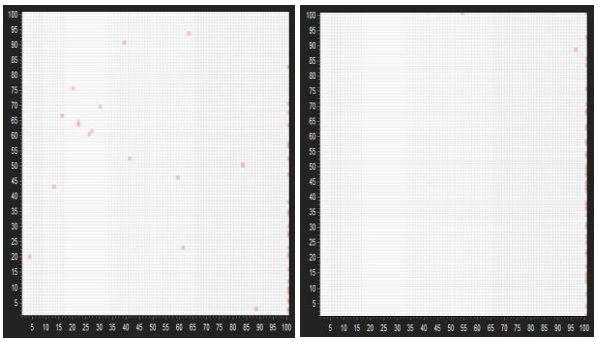

Fig. 3. Example of all-distributed swipe (left) and blank swipe (right)

For point distributed swipes, uranium contents were measured regardless coarse mode and find mode. For example, in Fig. 4, the 5 points uranium represent two dimensional map. On in-field use, coarse mode measurement is preferred due to the efficient inspection i.e., short time measurement. These results show that the coarse mode has feasibility of screening of ~ ng scale uranium contents.

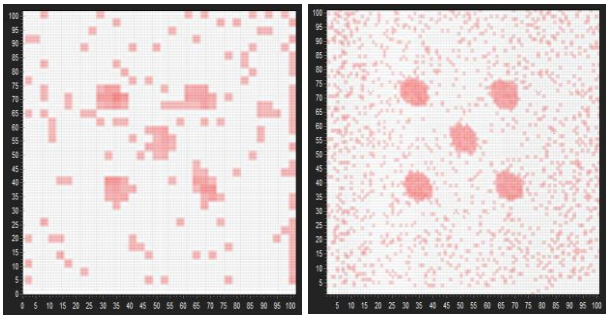

Fig. 4. 2D distribution of uranium in a point distributed swipe measured by coarse mode (left) and fine mode (right)

The sensitivity (equal to detection limit) in fine mode as estimated from 5 points swipes better than 1 ng/mm^2. KINAC and IAEA has concluded that the detection limit is feasible for environment sample screening. The fine mode will be used detailed uranium distribution and selected area due to the measurement time.

IAEA shared a two dimensional uranium distribution (MS-1) of the TRIPOD in IAEA screening equipment to compare with the MMXRF. Compared with TRIPOD, two dimensional uranium distribution have same result as shown in Fig. 5. In this comparison of the IAEA screening equipment, MMXRF has feasibility for the screening of environmental swipes.

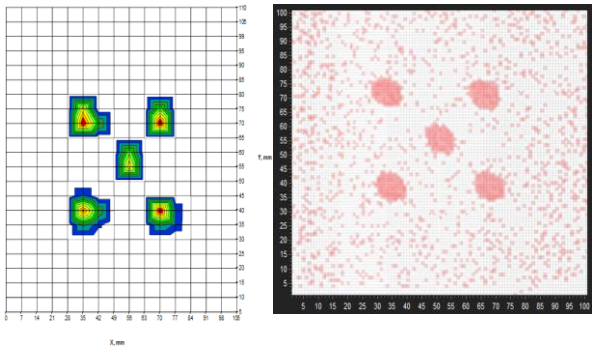

Fig. 5. 2D map uranium contents in a point swipe measured by IAEA TRIPOD (left) and MMXRF (right)

3. Conclusions

In this study, in order to verify of the performance of the MMXRF, IAEA and KINAC tested using IAEA's various swipes. Detection limit confirmed and the equipment has feasibility for inspection-use as comparison with an IAEA's environmental sample screening equipment.

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