Emergency preparedness in Finland: improvement of the measurement equipment used in the assessment of internal doses

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Abstract: The need for assessing internal radiation doses in emergency situations is evident. Internal exposure can be assessed using direct measurement results or by using information on activity concentrations in inhaled air and in foodstuffs combined with inhalation and consumption data. As a part of the continuous improving of emergency preparedness in Finland, STUK - Radiation and Nuclear Safety Authority has obtained 35 monitors for thyroid measurements in field conditions and initiated a project to revise the radiation measurement equipment in local food and environmental laboratories.

Introduction

External exposure is the dominating one after a nuclear explosion. In a nuclear power plant accident, inhalation is the dominating route of exposure at least during the first days after the accident. Ingestion via food and drink becomes important after the radionuclides enter the food-chains. This process depends strongly on the time of the year and the growing season. In addition to nuclear threats, the malevolent use of radiation aimed at creating disruption in the society must be considered as a possible threat. In this kind of emergency situation casualties will most likely be members of the public and the number of affected people can vary from a few to mass casualties. There is an evident need for rapid measurements of large groups of internally contaminated people.

The aim of this work is to improve the preparedness for direct monitoring of people as well as monitoring of foodstuffs in emergency situations. Direct measurements, which should be done as soon as possible after an alert to give support for decision making, give both individual results and results for groups. With cases of high internal contamination the purpose of measurements is to help to decide whether medical treatment or other types of measurement for more exact dosimetry are needed. By measuring foodstuffs in several locations around the country, important knowledge of the fallout situation is achieved. In Finland, there are about 40 local food and environmental laboratories that can determine activity concentrations in foodstuffs and drinking water. In emergency situations these laboratories - following the instructions given by STUK - measure the food products provided by both local food industry and private persons.

Results

Determination of activity concentrations in foodstuffs

In a fallout situation, Radiation and Nuclear Safety Authority - STUK together with national food authorities plan a sampling and analysis programme for assessing the situation in Finland. In addition to STUK, the programme comprises about 40 municipal laboratories committed to measuring radioactivity of foodstuffs (Figure 1). In emergency situations these laboratories measure the food products provided by both local food industry and private persons following the instructions given by STUK.

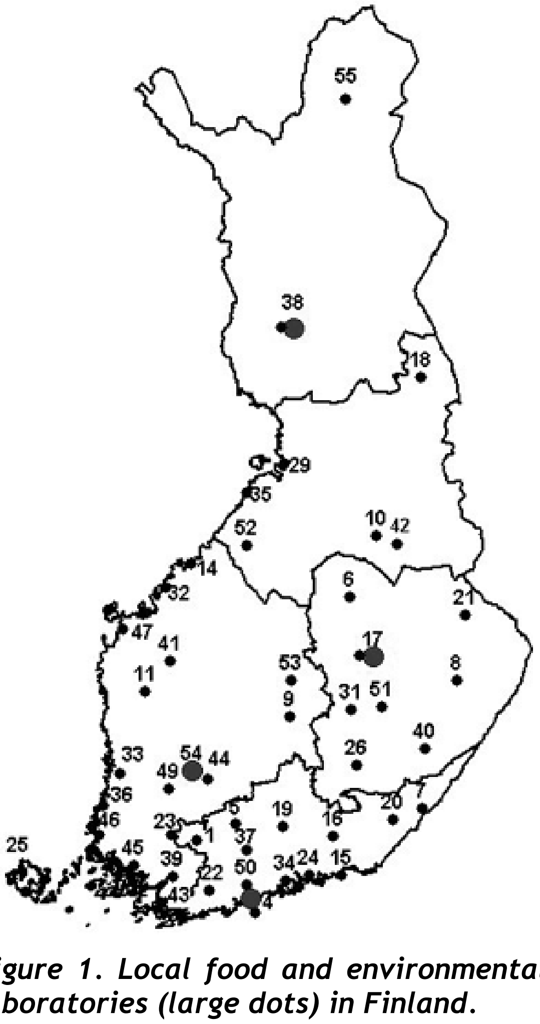

Figure 1. Local food and environmental laboratories (small dots) and regional laboratories (large dots) in Finland.

Since the mid 1980s Mini-Assay 6-20 counters have been used in the local laboratories to determine both radionuclide concentrations in foodstuffs and radon concentration in drinking water. The counters give the total *gamma counting rate in a sample. As the counters started to show signs of deterioration, STUK initiated a project to revise the radiation measurement equipment. The new equipment is a MKGB-01 gammaspectrometer manufactured by STC Radek and it can be used to identify radionuclides in samples (Figure 2). The spectrometer consists of a 2.5"x2.5" NaI(Tl) detector placed in a lead shield with a thickness of about 60 mm, measurement electronics and an analysing program (Figure 3). Two measurement geometries are in use, a one-litre Marinelli container for liquids and a cylindrical container with a volume of 320 ml for solid foodstuffs. The minimum detectable activity concentrations of ^{137}Cs when using a typical measurement time of 1000 seconds in laboratory conditions are approximately 50 Bq/kg and 30 Bq/kg for the 320 ml container and Marinelli container, respectively. The spectrometer is calibrated for a range of densities from 0.2 up to 2.0 g/cm^3.*

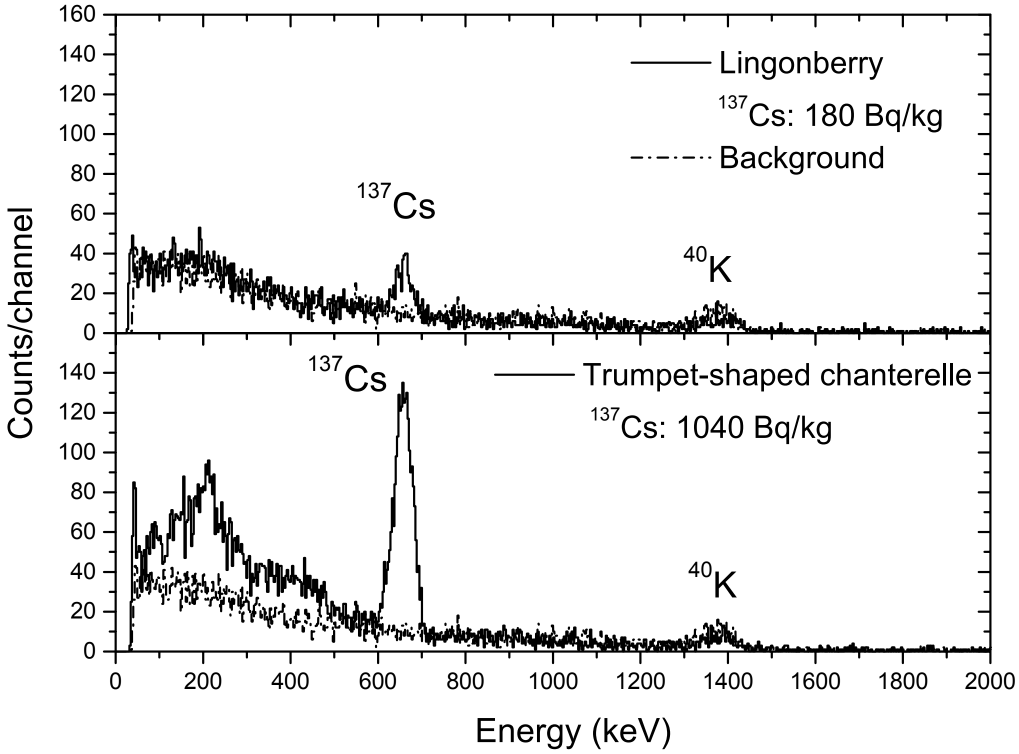

Figure 2. Gamma-ray energy spectra collected using the new gammaspectrometric equipment.

As a part of the quality assurance protocol, control measurements are carried out to ensure the functionality of the spectrometer and to control the background. The energy calibration is checked every day. In normal conditions, the background as well as the sensitivity of the spectrometer is controlled every ten days. In emergency situations, when the background can change rapidly, it is essential to measure new background often enough - in some cases even several times a day. In the background measurements a Marinelli container filled with pure distilled water and a

320 ml container filled with uncontaminated sugar are used. To verify the sensitivity of the set-up, a 320 ml control sample containing known amounts of ^{137}Cs, ^{40}K, ^{232}Th and ^{226}Ra is used. In addition, STUK will arrange intercomparison exercises for the laboratories every second or third year.

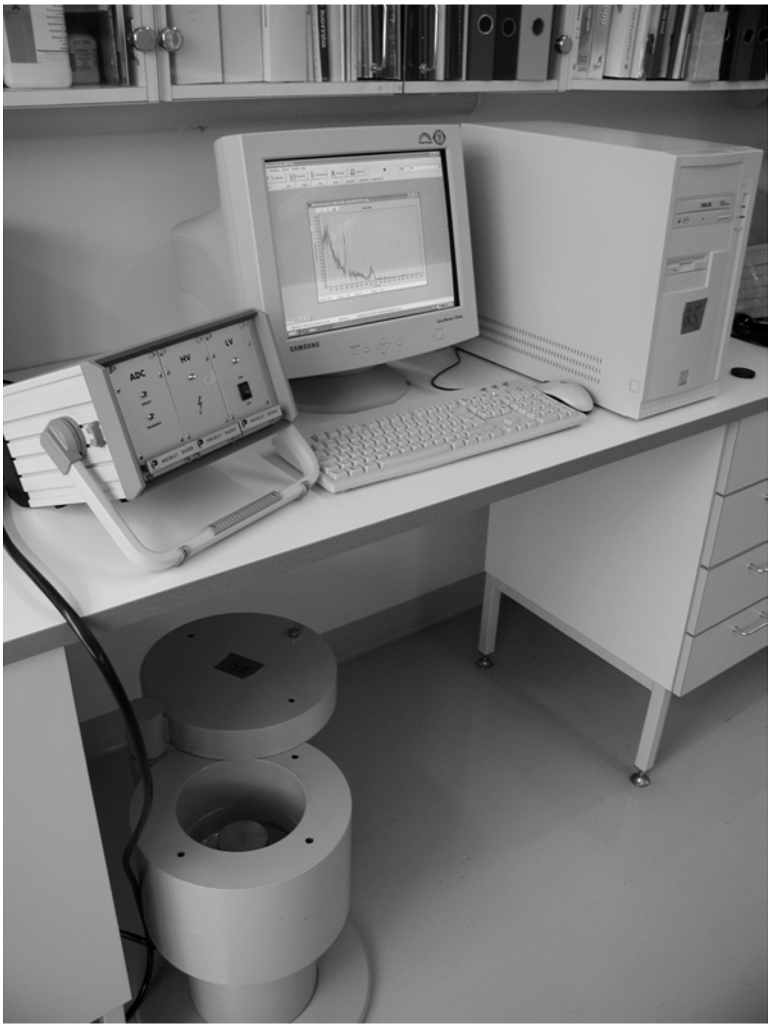

Figure 3. The MKGB-01 gammaspectrometer

Thyroid monitoring

After adequate efficiency calibration many simple hand-held instruments can be used for measurement of internal contamination after accidents resulting in environmental contamination. Registration of a few kBq ^{131}I in the thyroid is possible using instruments with NaI-detectors corresponding to an effective dose below 1 mSv.

In the recent years, STUK has obtained 25 Atomtex RKG-AT1320 monitors and ten Canberra InSpector 1000 monitors for thyroid measurements in field conditions. The AT1320 thyroid monitor consists of a detector with a 1”x1” NaI(Tl) crystal, a control unit and a lead collimator (Figure 4, left). The construction of the InSpector 1000 thyroid monitor is similar apart from the size of the NaI(Tl) crystals which is 2”x2” (Figure 4, on the right). The monitors work as spectrometers allowing a real time spectrum analysis in the field. The collected spectrum is shown on the display of the control unit. It is possible to store spectra in the detection unit from where they can be later on transferred to a PC. The energy stabilization is done before starting the measurements using a ^{137}Cs source. Likewise, the background control and sensitivity check are carried out before the measurements.

The aim of thyroid monitoring is to determine the ^{131}I activity in the thyroid with a minimal interference from the activity in the rest of the body. This is achieved by placing a shielded or a collimated detector near the neck at the position of the thyroid. However, both RKG-AT1320 and InSpector 1000 thyroid monitors are planned to be movable and easy to carry. During measurement the RKG-AT1320 detection unit is planned to be held in hand, although it can also be placed to a stand. Thus, the weight of the detection unit can not be more than a couple of kilograms. The collimator used in the present RKG-AT1320 measurement set-up is made of 5 mm thick lead and it weights about 1 kg. Assessment of the contribution to the detector response from radioiodine in blood and in surrounding measurement area can be made by placing the detector over a different area of the body (e.g. thigh) [1, 2]. For thyroid measurements, InSpector 1000 detector is positioned into a table-top lead shield of 12.5 kg weight (Figure 4).

Figure 4. Left: RKG-AT1320 thyroid monitor: NaI(Tl) detector, control unit, charger, ^{137}Cs control source and cables. Right: InSpector 1000 thyroid monitor in a table-top lead shield.

The detection efficiency depends greatly on the distance between the detector and the thyroid. To get good statistics in a short time the detector should be placed as close to the neck as possible. The exact position of the thyroid must be known in order to get accurate results in the close geometry. If the detection distance is longer, it is not so crucial to place the detector exactly on the thyroid.

Distances of 7 cm and 20 cm from thyroid to neck were used in the calibration of the RKG-AT1320 thyroid monitors. Three calibrations were done for both distances: adult, teenager (14 years old) and child (6 years old). The St. Petersburg thyroid phantom and whole body phantom [3] with ^{40}K rods were used in the calibration. Two capsules filled with ^{131}I solution were placed in the thyroid phantom. The minimum detectable activities (MDAs) when using a measurement time of 100 s in laboratory conditions were about 2000 Bq and 330 Bq for detection distances of 20 cm and 7 cm, respectively. If a longer time of 600 s is chosen, the MDAs are significantly lower: 760 Bq and 120 Bq for distances of 20 cm and 7 cm, respectively. The set-up with the 7-cm detection distance is about six times more efficient than that with the 20-cm distance (Figure 5).

The Inspector 1000 monitors were calibrated in a similar way. The minimum detectable activity in laboratory conditions is about 150 Bq for with a distance of 10 cm from thyroid to neck. In emergency situations the MDAs are higher due to the higher background from the environment.

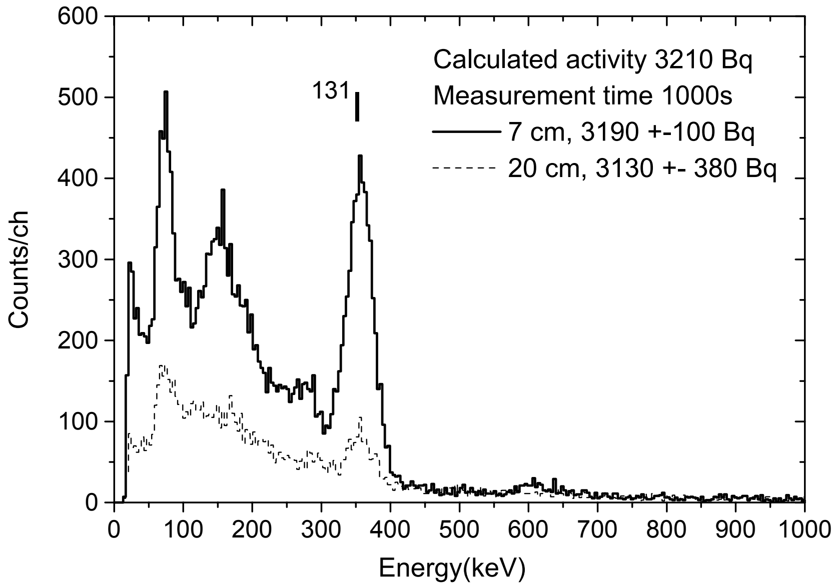

Figure 5. Gamma-ray energy spectra collected from a ^{131}I thyroid phantom using RKG-AT1320 thyroid monitor.

Conclusions

Internal doses can be assessed using information on activity concentrations in inhaled air and in foodstuffs combined with inhalation and consumption data or by using results from direct measurement. During the first days after a nuclear accident, inhalation is the dominating route of exposure. Ingestion via food and drink becomes important after the radionuclides enter the food-chains which depend strongly on the time of the year and the growing season. In many countries the general public knows that it is possible to do direct measurements on people and will not accept prognoses based only on external radiation and foodstuff measurements. In the future it will be *necessary to perform also direct measurements on people for reassurance of the public even if such measurements would not be necessary from a strict radiation protection point of view. STUK - Radiation and Nuclear Safety Authority in Finland has initiated a project to revise the radiation measurement equipment in local food and environmental laboratories and obtained 35 monitors for direct thyroid measurements in field conditions.*

References

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[3] A.N. Kovtun, V.B. Firsanov, V.I. Fominykh and G.A. Isaakyan, Metrological parameters of the unified calibration whole-body phantom with gamma-emitting radionuclides. Radiation Protection Dosimetry 89(3-4), 239-242 (2000)