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Emergency preparedness of gamma spectrometry laboratories

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Abstract. During a radiological emergency (RE) a large area may be non-uniformly contaminated with a number of radionuclides, the ratios of which will change in course of time. At the beginning the contaminated area, where consumption and distribution of foodstuffs will be prohibited, will be delimitated in a very conservative manner. So it will be necessary to specify and locate more accurate borders defining areas with contamination significantly higher, significantly lower and "close" to the limits for ruling out distribution and consumption of commodities. This task can be fulfilled mainly by laboratories equipped with semiconductor gamma spectrometry. The sample throughput of laboratories with semiconductor gamma spectrometry depends on many factors. The paper is dedicated to the questions of adequate sample throughput of the laboratories equipped with gamma spectrometry, factors witch influence the throughput including human capacity for 24 hours working regime, and to the optimization of the work in the laboratories. The capacity and the organization chart of laboratories in the frame of the Radiation monitoring network of the Czech Republic are shown, too.

1. INTRODUCTION

During a radiation emergency (RE) caused by a release of radionuclides into the environment, a large area may be non-uniformly contaminated with a number of radionuclides, the ratio of which will change in course of time. At the beginning, the contaminated area, where consumption and distribution of foodstuffs will be prohibited, will be delimitated in a very conservative manner. So it will be necessary to specify and locate more accurate borders defining areas with contamination significantly higher, significantly lower and "close" to the limits for the ruling out distribution and consumption of commodities. This task will be fulfilled mainly by laboratories equipped with semiconductor gamma spectrometry. Routinely these laboratories perform low-background measurements and an emergency regime will pose big demands on their measurement capacities. With respect to the amount of monitored commodities, time changes in development of the radiation situation and possible complexity of setting boarders of contaminated areas, it may include hundreds up to thousands measurements daily.

2. EMERGENCY PREPAREDNESS AND SAMPLE THROUGHPUT

The sample throughput of laboratories with semiconductor gamma spectrometry depends on many factors including the most significant:

- types of samples
- laboriousness of samples preparation for measurements,
- minimum detectable activity requirements,
- background values,
- detection efficiency and number of detectors and their connection to relevant computers in a laboratory,
- time needed for analysis of measured spectra,
- time needed for transfer of results into the central database,
- available human resources.

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The whole procedure from sample reception till results assignment into the database can be divided into several stages.

2.1 Type of samples

Analyses of aerosols and gaseous forms of iodine, fallout and surface and drinking water will be predominant in the first days following RE beginning. During the passage of the plume, sampling of aerosols will take place in a few hours' intervals. Types of other samples depend on the time when RE takes place. After the passage of the plume (approximately in days' time) a bigger number of foodstuffs and feedstuffs with possible surface contamination and samples of milk may be expected; later also meat of breeding animals and their products. It will obviously be necessary to check the market if distribution limitation is imposed.

2.2 Reception of samples, preliminary dosimetric control of samples and sample tally

Preliminary dosimetric control of the samples by dose rate (DR) measurement identifies samples with very high activity (for example $>10^5$ Bq/kg) and ensures that personnel, working areas or other samples will not be contaminated in case of a leak.

2.3 Preliminary assessment of sample activities by dose rate measurement

The dose rate (DR) measurement can be used in order to estimate samples activity and sort them out into groups (for example):

1. low DR - activity < units kBq/kg;
2. middle DR - activity units-10 kBq/kg;
3. high DR - activity 10–100 kBq/kg;
4. very high DR - activity > 100 kBq/kg.

It is appropriate to work more carefully with the samples from the 2nd group and at a special place with the samples from 3rd and 4th group. The sensitivity of the method is between hundreds and thousands of Bq/kg for sample volume of 1–2 l for measurement time of 30 s and for "normal" background.

2.4 Sample preparation and choice of the counting geometry

The sample preparation must be simple and quick. The counting geometry must be common for as high as possible number of samples. The information gained by the preliminary measurement of the activity by DR meter will be used for the choice of appropriate geometry.

2.5 Gamma spectrum measurement and analysis and transfer of results to the database

2.5.1 Role of Background

Passage of contaminated air masses through the laboratory location brings along an increase of the detectors backgrounds. A pessimistic expectation that activity concentrations of air mass in the laboratory and outside the building will be comparable cannot be excluded. Contamination of inner walls of the shielding and detector surface and air inside the shielding will dominantly contribute to the background increase of the spectra. Measurements of the detector background will have to be repeated according to the speed of decrease in activity in the environment and for check of possible crosscontamination due to previous samples. The contamination can be limited by covering the surfaces with foil that will be often changed. It may be estimated that about 5% of the measurement capacity of the laboratory will be taken by background measurements.

2.5.2 Role of requirements for minimum detectable activity (MDA)

For foodstuffs, MDA should be substantially lower than the limits (i.e. highest allowed levels of contamination acceptable for distribution imposed by legislation [1, 2]) so that activities near the limits are sufficiently reliably determined; for nuclides as ^{131}I, ^{137}Cs and for other nuclides with a decay time longer than several days, the value of MDA will be between 10–100 Bq/kg.

The relation between times of measurement for given MDA values and background values can be expressed by

$$T_2 \cong T_1 \cdot \frac{\text{“Bckg}_2\text{”}}{\text{“Bckg}_1\text{”}} \cdot \left(\frac{MDA_1}{MDA_2}\right)^2 \tag{1}$$

where

- $Bckg_1$ and $Bckg_2$ stand for the number of impulses per time unit in the background spectra in the energy region of the radionuclide photon
- MDA_1 corresponds to counting time T_1, MDA_2 to counting time T_2

The algorithm for calculation of the MDA can break down for “clean” samples and “normal” background combined with too short time of measurements (shorter than about 5 minutes) due to low number of impulses in the region of the interest (sometimes zero).

2.5.3 Role of detector efficiency, connection of detectors to relevant computers in the laboratory, analyses of measured spectra and transfer of results into the database

In comparison with the normal radiation situation the detector efficiency does not play much significant role in the RE when MDAs at a 100 Bq/kg level are concerned (times of measurement are short).

It is necessary to consider the number of spectrometric chains operated from a single point (computer) as entering the measurement parameters and spectrum handling require time in order of minutes, which determines a minimum time of re-exchange of a sample at the same detector. The minimum time of re-exchange of a sample at the same detector (time exploitable to the measurement of 1 sample) is

$$T_{\text{Re-exchange}} = (N - 1) \cdot T \tag{2}$$

where
N is the number of the detectors operated from a single point
T is the time necessary for replacement of the sample and entering the measurement parameters and spectrum handling.

Analysis of the spectra and verification and transfer of the results into the database should be operated from separated computers connected into a network. Analyses may be partially automated with special software. The transfer of results into the database should be made by software means with verification by an expert and simple confirmation.

2.6 The archivation and liquidation of the sample, the decontamination of the measurement and sampling containers

The samples of aerosols, fall-out and soils should be kept after the gamma-spectrometry analysis. The samples subjected to decay will be liquidated except the samples (or their part) designed for further analyses (analysis of ^{90}Sr and transuranium elements, ...). The waste must be sorted according to the activity and kind of the sample (milk, meat, ...). It will be necessary to decontaminate sampling and measurement vessels due to high number of samples. It is suitable to line the inside of sampling and measurement vessels with plastic bags (in case of solid samples) in order to facilitate the cleansing of the vessels.

2.7 Capacity of human resources

We can distinguish 2 kinds of personnel

- "specialist" – a person highly educated in gamma spectrometry
- "user" – staff members from other laboratories who pass only a brief training in preparation of samples and simple control of the equipment

Capacity of human resources will be probably a main limiting factor, especially when it concerns the number of specialists to occupy a 3-shift operation of a laboratory. In RE most of the acts may be performed by persons who are not specialists and who pass only a brief training but even these persons must be there in great numbers. However, one specialist responsible for results of analyses (verification), who will also be able to solve immediately problems connected with the operation of laboratory should be present always at each laboratory. It must be taken into account that the "specialists" are usually specialists in other fields too, for example in the field of management and general evaluation of the situation, so their engagement in gamma-spectrometry will be not 100%.

3. THROUGHPUT OF LABORATORIES OF THE CZECH REPUBLIC

The Radiation monitoring network (RMN) of the Czech Republic (10,300,000 inhabitants, 78,900 km^2) is coordinated by the State Office for Nuclear Safety (SÚJB, www.sujb.cz) in cooperation with the National Radiation Protection Institute (SÚRO, www.suro.cz). The RMN, which ensures the fulfilment of the EU Commission Recommendation [3], consists of several subsystems, of which one includes 7 laboratories equipped with 31 spectrometric chains with semiconductor HPGe detectors of a relative efficiency of 10–150% placed in steel or lead shielding. In this subsystem 15 specialists in gamma-spectrometry and 70 persons for simpler operations are at disposal.

During an RE, collection and distribution of samples will be ensured by the SUJB, SURO and cooperating organisations surveying foodstuffs and feedstuffs also with respect to non-radiation contaminants and whose capacity is sufficient even for the RE. The estimate of the demands on analyses shortly after the origin of an RE in the case of large contaminated area is in the Table 1.

Table 1. Estimation of the demands on analyses shortly after the origin of a RE in the case of large contaminated area.

Commodity	Number of analyses per day	Note
Aerosols	60	10 × 6 = 60, 10 sampling places in 4-hours' intervals
Gaseous iodine	60	10 × 6 = 60, 10 sampling places in 4-hours' intervals (sampled together with aerosols)
Fallout samples	28	14 × 2 = 28, 14 sampling places in 12-hours' intervals
Noble gases	24	1 sampling place in 1-hour intervals
Size distribution of aerosols	28	2 × 2 × 7 = 28, 2 sampling places in 12-hours' intervals, every sampling = set of 7 samples
Drinking and surface water	Hundreds	
Foodstuff, feed	Hundreds	Depends on the time of an RE origin
Other samples	Hundreds	Market inspection, survey of soil contamination, …
In total	Hundreds - thousand	

Contrary to some interlaboratory comparisons, where speed and accuracy of measurements of only a few samples are evaluated, example of which is described e.g. in [4, 5], we organised an emergency exercise with large number of samples in all our 7 laboratories so as to find out the real throughput of the laboratories. 140 different samples spiked ^{137}Cs and ^{60}Co with the activities up to

2 kBq/kg were prepared. Measurement time was about 5 minutes per sample for the achievement of the MDA $< 100\,\mathrm{Bq/kg}$. The Table 2 shows the times needed for individual actions.

Table 2. The time needed for individual actions.

Action	Time [min]
Sample preparation by a couple of persons including filling out of analysis assignment form (electronically or in the paper form)	5
Physical exchange of samples at the detector	1–1.5
Recording information concerning the sample and parameters of a spectrum measurement including sample exchange at the detector	1.5–2
Analysis of 1 spectrum (by software)	2
Verification of the results of 1 spectrum	1–2
Entering results into database – by hand	4–5
Entering results into database – by software	1

4. CONCLUSION

4.1 General conclusions

- Crucial and a long-term problem would in many laboratories lie in ensuring 3-shift operation during a radiation emergency.
- It is advisable to measure with more then 4 detectors in each laboratory for optimum utilization of the human capacity.
- The counting time of one sample should be longer than 5 minutes; the algorithm for calculation of the MDA can break down for “clean” samples and “normal” background combined with too short time of measurement due to low number of impulses in the region of the interest.
- It is useful to operate separate workstations of spectrometric chains control, of spectra analysis and of entering results into the database. The transfer of results into the database should be in electronic form with the possibility of their quick verification.
- In order to increase the throughput of the system, it will be suitable to include pre-classifying mechanisms, for example division into higher activity and less activity samples using dose-rate meter calibrated for a given mixture of radionuclides, which can sort out the samples almost certainly exceeding the limits for distribution of foodstuffs (the sensitivity of the method is between hundreds and thousands of Bq/kg for sample volume of 1–2 l for measurement time of 30 s and for “normal” background); these samples can be measured later. However, in these cases it is necessary to respect the changing composition of the contaminant in time.
- The throughput of laboratories should be periodically checked by emergency simulation exercises with number of different spiked samples.

4.2 Conclusions of the emergency exercise in CR

- The number of spectrometric chains with HPGe detectors is sufficient.
- Human resources are insufficient to ensure a 3-shift operation at all laboratories.
- Our system is able to ensure analyses of about 1000 samples per day with our present technical and staff capacity (one 12 hours’ work shift, with the MDA $< 100\,\mathrm{Bq/kg}$ in “normal background” condition).
- The analysis shows that eight persons per a shift is optimum for a laboratory.
- The capacity is sustainable for 2 weeks.
- Most of the false values occurring in the exercise were clarified
- However, 1–2% of mistakes, caused mainly by tiredness of the staff, have still remained in the end. Their elucidation and removal will be rather difficult.

Acknowledgments

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References

[1] Council regulation (Euratom) No. 2218/89 of 18 July 1989 amending Regulation (Euratom) No 3954/87 laying down maximum permitted levels of radioactive contamination of foodstuffs and feedingstuffs following a nuclear accident or any other case of radiological emergency
[2] Commission regulation (Euratom) No. 770/90 of 29 March 1990 laying down maximum permitted levels of radioactive contamination of feedingstuffs following a nuclear accident or any other case of radiological emergency
[3] Commission Recommendation of 8 June 2000 on the application of Article 36 of the Euratom Treaty concerning the monitoring of the levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole, 473 Euratom, (2000)
[4] K.G.W. Inn, I. Outola, S. Nour, H. Kurosaki, L. Albin and A. Berne: Radioanalytical emergency response exercise, Journal of Radioanalytical and Nuclear Chemistry, Vol. 269, No.2 (2006), p.351–360
[5] Analytical Laboratories Monitoring Environmental RAdioactivity (ALMERA), http://www.iaea.org/OurWork/ST/NA/NAAL/pci/che/almera/pciAQCSalmera.php