SEMICONDUCTOR GAMMA-SPECTROMETRY SYSTEM FOR AIRBORNE SURVEYING OF CONTAMINATION OF LARGE AREAS.

D. Drábová[1], I. Bučina[2], R. Filgas[2], I.Češpírová[2]

1) State Office for Nuclear Safety
2) National Radiation Protection Institute
Prague, Czech Republic

INTRODUCTION

The Chernobyl accident has clearly demonstrated the importance of establishing environmental monitoring systems for obtaining rapid information in accidental situation on the radiological conditions at the affected area and providing suitable data to the competent authorities for decision making. Mobile units suitable for monitoring of radiological impact at any selected location in the field play an important role in emergency preparedness for various types of nuclear accidents:

1. A major accident in a domestic nuclear power plant.
2. Accidents in nuclear power plants abroad especially in neighbouring countries. To this category should be added the risk from military nuclear power accidents.
3. Re-entry of nuclear powered satellites. The probability is small but it can not be excluded. This type of accident would result in highly radioactive fragments and particles that would have to be located.
4. Accidents when transporting radiation sources.
5. Illegal handling of radioactive sources and nuclear material.

For monitoring of large contaminated areas especially the possibility of airborne monitoring is important. Airborne systems can be used for the measurement of dose and dose rate in wide range, nuclide specific ground surface contamination and nuclide specific activity concentration in air (with special attention to iodine in aerosol) as well as particle size distribution.

METHOD

For the Radiation Monitoring Network of the Czech Republic a prototype of the small system for dose rate measurements and nuclide activity estimates suitable for aerial gamma spectrometric determination of ground contamination was designed calibrated and tested in National Radiation Protection Institute (1).

The system consists of semiconductor HPGe detector, scintillation 3"x 3" NaI(Tl) detector, two multichannel analyzers, high pressure ionization chamber or proportional counter and portable computer working in multitasking mode for storing and evaluating of the spectra as well as for dose rate data handling, recording, storing, searching and presentation. One of three available HPGe detectors with relative efficiency from 15 to 55% can be used. Parameters of detectors are summarized in Table 1.

Table 1 Parameters of semiconductor HPGe detectors used for airborne spectrometry

Detector	Manufacturer	Rel. efficiency [%]	FWHM [keV]	diameter [mm]	length [mm]
JAKUB	Canberra	16.2	1.8	50	37
FERDINAND	Canberra	35.8	1.9	59.5	53.5
ISIDOR	EG&G Ortec	55	1.8	63.3	84.6

For accumulation of spectra the MCA Portable Plus a InSpector (Canberra Inc.) are used. The information about actual position is provided by the global positioning system (GPS) Garmin on-line connected to the computer. This information is used later on to create the maps of contamination using small desktop mapping (GIS) system. The system is powered from inner batteries or from external 12V car batteries.

One of the most important parameters of the system is the time needed for transferring the spectrum from MCA to storage medium (either PC or tape). Storage on tape takes for MCA S10 about 4 minutes which at the aircraft speed about 120 km/h leads to path uncovered by measurement of about 10 km. This time can be substantially shorten using MCA with remote control directly from PC down to about 5s. Further shortening is possible using the plug-in card emulating MCA in computer and communicating directly via bus. This solution is, however, rather demanding from the point of view of power supply on board of the aircraft and also the use of small notebooks is limited. Other possibility is to use special processors e.g. transputters, but this solution is quite expensive. In NRPI the MCA PortablePlus with LapTop computer Toshiba 1600 (PC AT 286, 12MHz, math coprocessor, 3MB RAM, 40MB HDD) were tested. The storage time of the 4K spectrum using ASAP software was optimised to 8s. The use of the MCA InSpector together with 486/DX2-66 notebook with 8MB RAM and with Genie-PC software running under IBM OS/2 operating system led to further shortening of storage time to approx. 4s.

Whole system was repeatedly tested on the deck of both fixed wing aeroplane and helicopter with the flight speed of 120 - 130 km/h. The flight height was 60m for the helicopter and 80m for the aeroplane. Spectra were accumulated 60s which represent about 2.2 km of flight.

The classic scintillation spectrometer for geophysical surveys was used for comparison and verification of calibration. The spectrometer consists of NaI(Tl) detectors with total volume of 33.6 L. One additional detector with the volume of 4.2 L is used for measurement of the cosmic component contribution to the spectrum. Measured spectra are accumulated in 256 channel analyzer GR 800 D (Geometrics). The energy range of measured spectra is 0.2 - 3 MeV. The energy calibration is are stabilized using the ^{40}K peak. Measuring time is 1 s which represents about 40 m of flight. The spectrometer was calibrated on calibration pads with known amount of K, U, Th.

RESULTS AND DISCUSSION

The system was calibrated using standard method for in-situ spectrometry, elaborated by Beck. The calibration was verified by measurement with detector ISIDOR (55% relative efficiency) on the deck of MI-17 helicopter hanging 50m above the area with known deposition and depth distribution of ^{137}Cs and known specific activity of ^{40}K. For ^{40}K the homogeneous depth distribution was assumed. The activity of ^{137}Cs and ^{40}K and the depth distribution of ^{137}Cs activity were determined by the on-ground in-situ spectrometry and by soil samples measurement in the laboratory. Detection limits for two tested detectors for ^{137}Cs with various depth distribution in the soil, measuring time 60s and height of flight 80m are summarized in Table 2.

Table 2 Detection limits for two tested detectors for ^{137}Cs

Detector	**relaxation depth [cm^{-1}]**	**MDA [kBq.m^{-2}]**
FERDINAND	0.3	5.6
	∞ (plane source)	3.3
ISIDOR	0.3	2.9
	∞ (plane source)	1.7

The system was intercompared with scintillation spectrometer for geophysical surveys on two partly overlapping areas of about 100 km^2 each. The areas were chosen with regard to level and inhomogeneity of Chernobyl fallout i.e. there was spots both high and low deposition of ^{137}Cs. The minimum deposition of ^{137} Cs in chosen area was about 2 kBq/m^2, the maximum deposition was about 40 kBq/m^2. The average activity of ^{137}Cs was about 15 kBq/m^2, i.e. high enough to be reasonably measured also by semiconductor spectrometer. The distance of flight lines was 250 m. For comparison the mean values of activity of ^{137}Cs and ^{40}K from 60 measurements by scintillation spectrometer covering the measuring intervals of semiconductor detector were used. The example of ^{137}Cs activity along one flight line as determined by detector ISIDOR is in Figure 1.

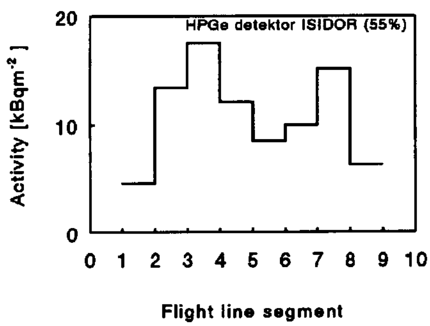

Figure 1 ^{137}Cs activity along one flight line

For detector FERDINAND (36% relative efficiency) the results of 65 measurements of ^{137}Cs deposition were compared with scintillation spectrometer, the mean ratio of activity determined by the system with semiconductor detector and the activity determined by the scintillation spectrometer is 1.11 with minimum of 0.55 and maximum of 1.97. It should be noted that due to the extreme inhomogeneity of fallout in chosen area there were also places where the activity of ^{137}Cs was very near or even below the detection limits of both systems. The extreme values of the ratio were found on such places.
For detector ISIDOR (55% relative efficiency) the results of 214 measurements of ^{137}Cs deposition were compared with scintillation spectrometer, the mean ratio of activity determined by the system with semiconductor detector and the activity determined by the scintillation spectrometer is 1.28 with minimum of 0.55 and maximum of 3.13 (Figure 2). Again it should be noted that due to the extreme inhomogeneity of fallout in chosen area there were also places where the activity of ^{137}Cs was very near or even below the detection limits of both systems. The extreme values of the ratio were found on such places. Efficiency of detector ISIDOR is high enough to enable also the determination of activity of ^{40}K in soil.Results of 214 measurements of ^{40}K activity were compared with scintillation spectrometer, the mean ratio of activity determined by the system with semiconductor detector and the activity determined by the scintillation spectrometer is 0.86 with minimum of 0.53 and maximum of 1.41 (Figure 3).

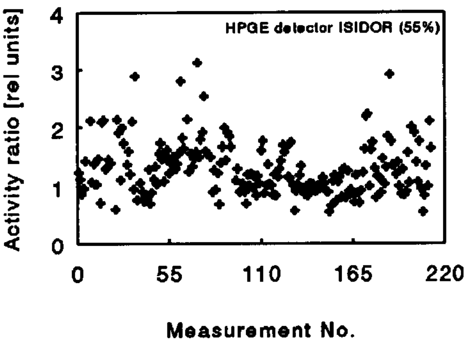

Figure 2 Ratio of ^{137}Cs activity determined by the system with semiconductor detector and by the scintillation spectrometer

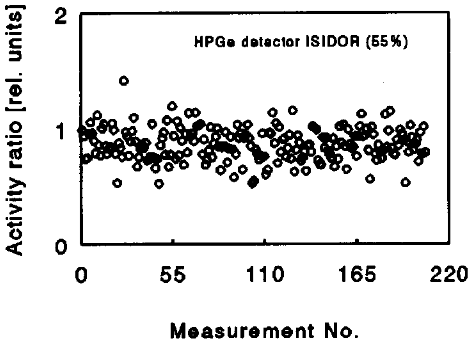

Figure 3 Ratio of ^{40}K activity determined by the system with semiconductor detector and by the scintillation spectrometer

CONCLUSION

The test use of the system with HPGe detector proved that it can be used for contamination mapping on large areas especially in the case of a nuclear accident when its lower sensitivity (in comparison with scintillation spectrometer) can be even an advantage and when one can make full use of its excellent energy resolution for analysis of complex spectra.

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