MONITORING MAN-MADE RADIATION USING A 256 CHANNEL PORTABLE GAMMA-RAY SPECTROMETER

R.L. GRASTY[1], J. MULTALA[2], AND H. LEMMELA[3]

[1]Geological Survey of Canada, Ottawa, Ontario, K1A-0E8, Canada.
[2]Geological Survey of Finland, SF-02150 Espoo, Finland.
[3]Finnish Centre for Radiation and Nuclear Safety, Helsinki, Finland.

ABSTRACT

Measurements in Finland with a portable NaI(Tl) gamma-ray spectrometer showed that the natural gamma-ray spectra from potassium, uranium and thorium could be separated from the gamma-ray spectra of ^{134}Cs and ^{137}Cs due to fallout from Chernobyl. A comparison of the portable spectrometer measurements with those from an ionization chamber showed that the dose rate due to ^{134}Cs and ^{137}Cs fallout and the individual dose rates from the three natural components could be determined with a portable spectrometer. Following calibration at one site of known contamination, the portable spectrometer could also be used to measure the deposition of ^{134}Cs and ^{137}Cs.

INTRODUCTION

Portable Na(Tl) gamma-ray spectrometers have been used by geologists and geophysicists for mineral exploration and geological mapping for many years. These spectrometers normally use a 7.6 x 7.6 cm detector and record 3 energy regions for monitoring gamma-ray emissions from potassium, uranium and thorium. Recently, portable spectrometers which record up to 256 channels of gamma-ray spectral data have become available. This paper describes how such a spectrometer (an Exploranium GR-256) can be used for environmental monitoring.

PRINCIPLE OF THE METHOD

Following a nuclear reactor accident, such as the Chernobyl event of 1986, many man-made radio-nuclides with a variety of gamma-ray energies and half-lives may contaminate the environment. Almost all these gamma-ray emitters have energies which are significantly below the 1460 keV gamma-ray peak of ^{40}K. By fitting the calculated potassium, uranium and thorium gamma-ray spectra to the high energy part of measured spectrum, the natural gamma-ray component can be determined. This component can then be removed from the measured spectrum, leaving behind the man-made component.

The procedure was first tested in Canada where the man-made component originated mainly from global atomic weapons fallout. Figure 1 shows a spectrum recorded outside the Geological Survey of Canada headquarters in Ottawa with a 256-channel portable spectrometer using a 7.6 cm x 7.6 cm NaI(Tl) detector. The natural gamma-ray component of the measured spectrum (also shown in the figure) was computed by fitting the calculated potassium, uranium and thorium spectra to the observed spectrum above an energy of 1200 keV. The three natural gamma-ray spectra were determined from measurements on concrete calibration blocks, 1m x 1m x 30cm with known concentrations of the three radioactive elements. The fitted spectrum also includes the background contribution from cosmic radiation, radon decay products in the air and any radioactivity from the instrument itself. The background was measured in a small metal boat on the nearby Ottawa river.

The fallout spectrum shown as the difference spectrum in Figure 2 originates from an estimated 2.5 kBq/m^2 of ^{137}Cs and demonstrates the effectiveness of the spectral fitting method even in areas of low fallout.

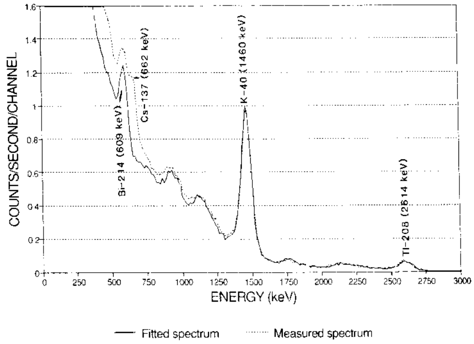

Figure 1. A computer fit above 1200 keV of the potassium, uranium and thorium spectra to a spectrum measured in Canada.

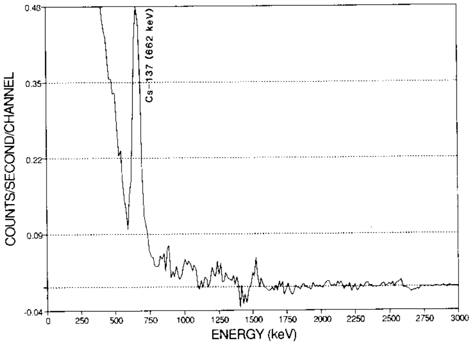

Figure 2. The fallout spectrum obtained by subtracting the natural gamma-ray spectrum from the measured spectrum.

FIELD MEASUREMENTS

In the fall of 1990, a series of gamma-ray measurements were made in the Lammi - Padasjoki - Jämsä area in Finland where the ^{137}Cs contamination was as high as 200 kBq/m^2. Simultaneous measurements were performed with a calibrated Reuter-Stokes ionization chamber and the calibrated portable spectrometer at a measurement height of 80 cm above the ground. Additional measurements were made with the portable spectrometer at ground level to estimate variations in the radioactivity of the ground. At selected locations, soil samples were taken for laboratory determinations of ^{134}Cs and ^{137}Cs.

ANALYSIS OF RESULTS

Measurement of fallout

Figure 3 shows a measured spectrum and the fitted natural spectrum from a site where the ^{137}Cs deposition was approximately 120 kBq/m^2. The background spectrum, included in the fitted natural spectrum, was measured in a small boat on the Gulf of

Finland. The man-made difference spectrum (Figure 4) shows the 662 keV gamma-ray peak of ^{137}Cs as well as the gamma-ray peak at 795 keV due to ^{134}Cs which has a half-life of approximately 2 years. The gamma-ray windows used to measure ^{134}Cs and ^{137}Cs are shown in the difference spectrum. A correlation of the ^{137}Cs window count rates from the man-made spectrum with those from ^{134}Cs (Figure 5) shows that the $^{134}Cs/^{137}Cs$ ratio is the same for all sites measured. A similar correlation coefficient of 0.998 was also found from the laboratory analyses of the soil samples.

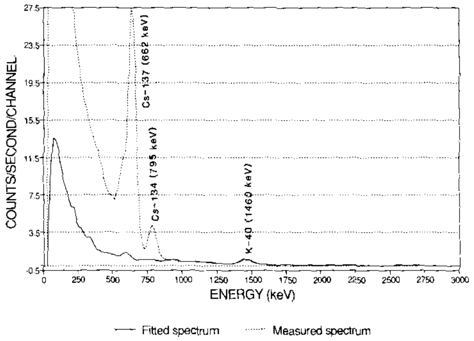

Figure 3. A computer fit above 1200 keV of the potassium, uranium and thorium spectra to a spectrum measured in Finland.

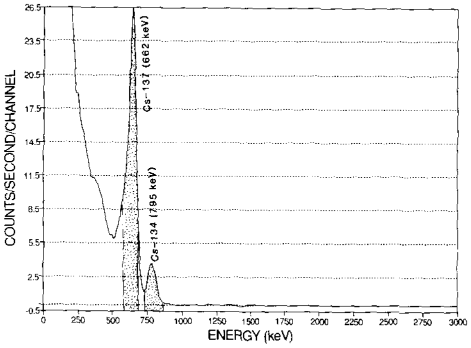

Figure 4. The fallout spectrum obtained by subtracting the natural gamma-ray spectrum from the measured spectrum.

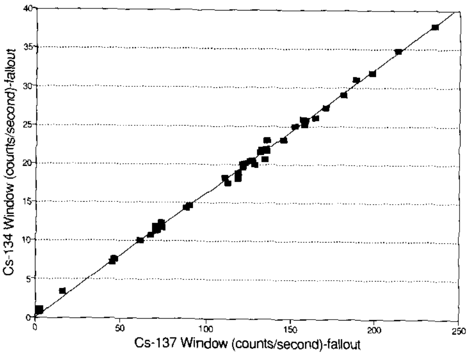

Figure 5. Correlation of the ^{134}Cs and ^{137}Cs window count rates from fallout.

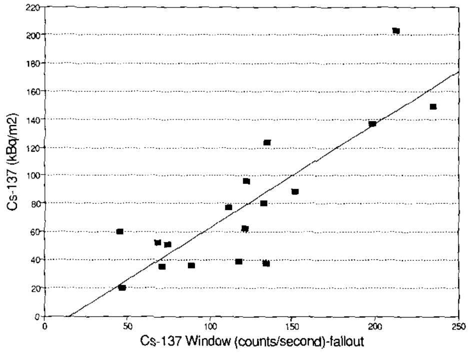

Figure 6. Correlation of the ^{137}Cs window from fallout with ^{137}Cs deposition.

The laboratory measurements of ^{137}Cs deposition were compared with the calculated count rates in the ^{137}Cs window from fallout (Figure 6). The scatter about the least squares line was attributed to localized variations in the deposition of ^{137}Cs

which were found by analyzing the ground-level gamma-ray measurements. The results show that following calibration at one site where the contamination is uniform, a NaI(Tl) gamma-ray spectrometer can be used to measure ^{134}Cs and ^{137}Cs.

Measurements of dose rate from fallout

In the spectral fitting procedure, the gamma-ray spectral shapes from unit concentrations of potassium, uranium and thorium are used to calculate the concentrations of the three radioactive elements in the ground. The individual air absorbed dose rates can then be calculated from these concentrations using the relationship:

1 percent potassium = 0.0131 μGh^{-1}
1 part per million of uranium in equilibrium = 0.00543 μGh^{-1}
1 part per million of thorium in equilibrium = 0.00269 μGh^{-1}

The ionization chamber measurements include radiation from fallout and natural gamma radiation as well as a background component from cosmic radiation and radon decay products in the air. This background was also measured on the Gulf of Finland. The radiation dose from fallout can therefore be determined from the ionization measurements by subtraction of the background plus the calculated natural radiation dose.

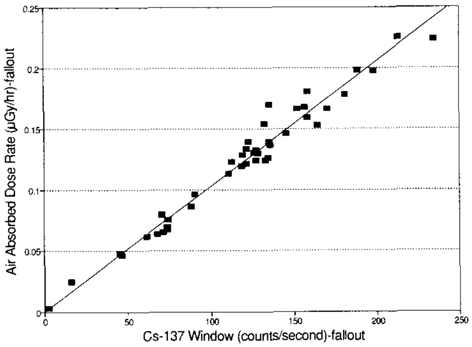

Figure 7. Correlation of the ^{137}Cs window count rate from fallout with the dose rate due to fallout.

The fallout component of the radiation dose, deduced from the ionization chamber measurements is compared with the portable spectrometer ^{137}Cs window count rates from fallout in Figure 7. The good correlation (R = 0.95) shows that a NaI(Tl) spectrometer can be used to measure the radiation dose from fallout, following calibration at one site with an ionization chamber. At the same time, the calculated ground concentrations of potassium, uranium and thorium can be used to estimate the radiation dose from each natural radioactive element.