IRPS-NEWS

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Vol. 2, No. 2 Summer 1988

EDITORIAL

ELECTION TIME

The ballot which the Nominations Committee has prepared for election of the next IRPS Council is enclosed with this newsletter. No additional petition nominations were received. However you are free to write in the names of other members of the Society if you prefer to vote for them for the various offices. Mail the ballot in accord with the mail instructions printed on the ballot. While the ballot shows no contests, we hope that members of the society will nonetheless make the effort to vote. This is important as an indication of support for the new Council. Your advice to the new Council would also be welcome, and we would be glad to receive either private letters for the consideration of the new Council or public letters for presentation in the next issue of this newsletter.

CONTENTS

NEWS

FOURTH INTERNATIONAL SYMPOSIUM ON RADIATION PHYSICS

The Fourth International Symposium on Radiation Physics will be held in Sao Paulo from 3-7 October 1988. The Symposium will cover the following topics

I. Fundamental Processes in Radiation Physics

II. Radiation Sources and Detectors

III. Uses of Radiation in Fundamental Research

IV. Radiation in Biomedicine and in Environmental Science

V. Radiation in Technology

VI. Radiation in Energy Research

The scientific program will include approximately 24 oral sessions of invited papers of 40 minutes each and poster sessions of contributed papers. The invited speakers will include the following:

I. D. Lindle (USA), B.A. Logan (Canada), S. Manson (USA).

II. G.Y. Csikai (Hungary), K.W. Jones (USA), R. Mössbauer (Germany), O. Sala (Brazil).

III. A.G. de Pinho (Brazil), R.J. Prothewe (Australia), W. Schülke (Germany), E. Wolynec (Brazil).

IV. A. Chatterjee (USA), C.M. Sunta (India), V. Valkovic (Yugoslavia).

TOPICS IN RADIATION PHYSICS

CESIUM-137 FOR SNOW COVER WATER EQUIVALENT MEASUREMENT

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Presently soil cesium-137 levels arising from the Chernobyl accident of April 26, 1986 present a significant source of γ -radiation in the Northern Hemisphere (Nuclear Europe, Nos. 6-11, 1986, IAEA Bulletin, Autumn 1986, etc). Deposition has exceeded 20 kBq/m^2 over large areas in a few countries. In comparison the activity of cesium-137 in Finland in 1985 was somewhat uniform at 1.8 kBq/m^2 [1,2]. As an alkali, cesium is strongly absorbed in the uppermost layers of the soil surface. The radiocesium covers all types of ground surface and as a result the 661.6 keV photons of cesium-137 are an especially effective tool for determination of snow cover mass distribution and water equivalent.

The natural ^{40}K, U- and Th-series radiations have traditionally been applied for snow mass determination. The potassium-40 peak (1461 keV) measurement has been found to be marginally more effective in Finland [3]. Note that 1461 keV is less than the energies of the U- and Th-series that are generally used. It is also to be noted that potassium, uranium and thorium are preferentially concentrated to a large degree in mineral soils.

The mass attenuation coefficients [4] for the cesium and potassium photons are compared in Table 1. The coherent scattering contribution is small at 662 keV (about 0.4 %), smaller at the higher energies and mostly in the forward direction; as such coherent scattering can safely be neglected.

Table 1. Mass attenuation coefficients (10^{-3} m^2/kg) for the photon energies 662 and 1461 keV.

Energy	Air	Water	Dry soil
662	7.71	8.57	7.67
1461	5.26	5.84	5.23

For simulation and comparison of the ^{137}Cs and ^{40}K measurements certain source terms have been chosen: for potassium a content of 2.1% by weight has been selected, [5]. The larger global mean values have been determined [6] to be granite, 3.50%, granitic shell, 2.70%, granodiorite, 2.52%, and schist, 2.70%. According to Ref. [6] for granite regional mean contents larger than 4.58% occur, and even larger local values can be found. For those cases in which mineral soil touches the soil surface K-40 has a semi-infinite homogeneous spatial distribution. A soil density of 1500 kg/m^3 has been assumed in calculations. For cesium-137 a plane source of activity 30 kBq/m^3 has been chosen.

Since ^{40}K/K = 0.0117%, soil contains 5.7 10^{22} atoms(^{40}K)/m^3 ≙ 980 kBq/m^3, and since the 1461 keV emission probability is 10.6% per decay of ^{40}K we find a source density of 103,000 photons/m^3 in the soil. On the ground, γ ray-integrating as in [7] (but not integrating the solid angle), we have the potassium-40 intensity

$$I_p = I_0 \cos\theta = 1040 \cos\theta \ \mathrm{m^{-2} s^{-1} sr^{-1}},$$

from Lambert's law, where the mass attenuation coefficient 5.25 10^{-3} m^2/kg has been used and θ is the angle between the direction of intensity and the normal to the ground surface. In Finland the

upper limit of the regional cesium-137 activity is about 100 kBq/m^2. The 661.6 keV photons emission probability per decay is 85.1% As such the photons from the plane source at the ground surface cause the intensity at the ground surface to be within the range I_c = 100 to 7000 m^{-2}s^{-1}sr^{-1}. For an activity of 30 kBq/m^2 we have a cesium-137 intensity

$$I_c = 2030 \text{ m}^{-2}\text{s}^{-1}\text{sr}^{-1}.$$

The intensities I_p and I_c are illustrated in Fig. 1.

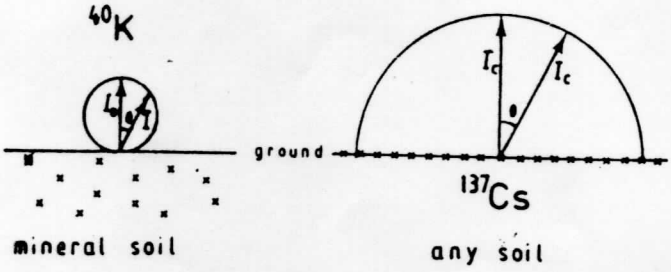

Fig. 1. The intensity distributions of ^{40}K photons (1461 keV) and ^{137}Cs photons (662 keV) on the ground. Mineral soil of 1500 kg/m^3 density and 2.1% potassium content is assumed. The ground has an assessed ^{137}Cs activity of 30 kBq/m^2. Radiocesium nuclides are found to penetrate into soil to an inappreciable extent.

Consider the gauging measurement, where we have the detector D at a distance h above the ground, with the ground covered by snow and H_2O of thickness (i.e., water equivalent) z, (Fig. 2). The intensity from the position x on the ground to the detector is $I(\theta)$, with r the distance of separation. The measurable quantity provided by the product of the intrinsic efficiency and the area of the detector may be called the detector function, denoted here by $D(\theta)$, while in the general case it depends on two angular variables.

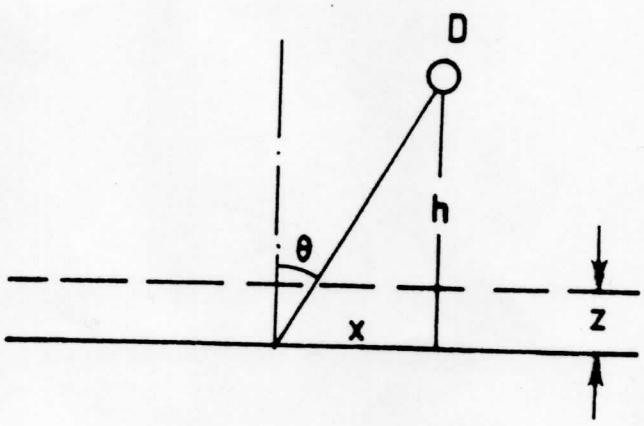

Fig. 2 Schematic of geometry used in measurements. D is detector.

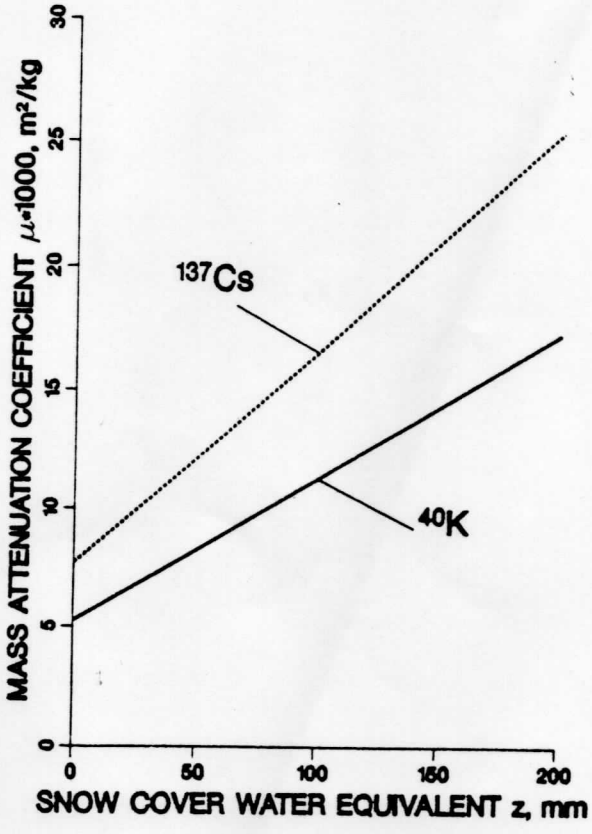

Fig. 3 Mass attenuation coefficients between the ground and the detector at height 75 m for varying snow cover thickness.

The mean mass attenuation coefficient between the ground and detector is presented in Fig. 3 for the case h = 75 m (for h up to 1 m the attenuation of air can be assumed to be insignificant when compared with that of snow). Table 1 and Fig. 3 show that cesium radiation is attenuated 47% more effectively than potassium radiation (comparison was made taking two gauge cases).

In field gauging the detector can be 1 m above the ground. We can assume the detector function D to be constant when the diameter and height of the clyindrical detector are equal and in this situation the counting rate R(z) is easily integrated numerically. In the following calculations the integral exponential functions [8] are convenient to use. We also note that the "spherical" detector used in calculations approximates to an 3" x 3" NaI(Tl) scintillator; it has an area A = 45 cm^2, an efficiency, determined by using Ref. [9], and a detector function as in Table 2.

Table 2. Values of detector at h = 1 m. The detector has an area A = 45 cm^2; the value of D is independent of the direction of the photons.

Energy keV	Intrinsic Efficiency	Detector function D/m^2
662	0.43	0.0019
1461	0.19	0.0009

In an airborne vehicle we have an assembly of several scintillators (Fig. 4). The assembly has an actual area A but presents an effective area A $\cos\theta$ at the point of measurement. We assume A = 0.30 m^2. The approximation

$$D(\theta) = D_0 \cos\theta$$

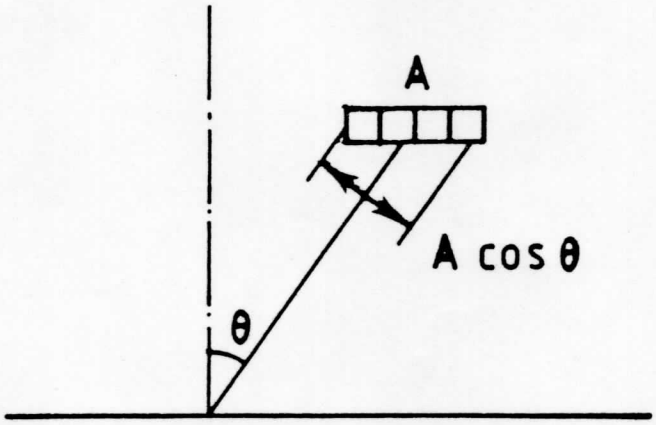

Fig. 4. Schematic of the detector assembly used in airborne measurements.

for the detector function would seem suitable in this case, where D_0 is a constant. For the detector assembly at a height h = 75 m the detector values are identical to those reported in Table 2, where we substitute D_0 for D.

The detailed description of these calculations is intended for publication elsewhere [10] (the paper will contain the first field experiments). Calculations with $D(\theta)$ an arbitrary function or D a function of two variables may also be easily performed.

The calculated results for the comparison of ^{137}Cs and ^{40}K sensitivities are presented in Figs. 5 and 6. Water equivalents are generally below 250 mm (~~with a high value~~ also in Finland). The results indicated that cesium gauging, in the field or by airborne measurement, can be more effective than ^{40}K gauging. If the potassium content of soil is two or more times larger than in these calculations counting rates will be more or less equal. It is clear, however, that ^{137}Cs gauging remains more sensitive to z.

Fig. 6 also includes results of calculations for the source plane of ^{137}Cs photons at various depths d below the soil surface (d = 1, 2, 3 and 4 cm). As in the case of Fig. 5 similar results are found. If all of the deposited ^{137}Cs nuclides were to penetrate 4 cm below the ground surface, then for most depths of

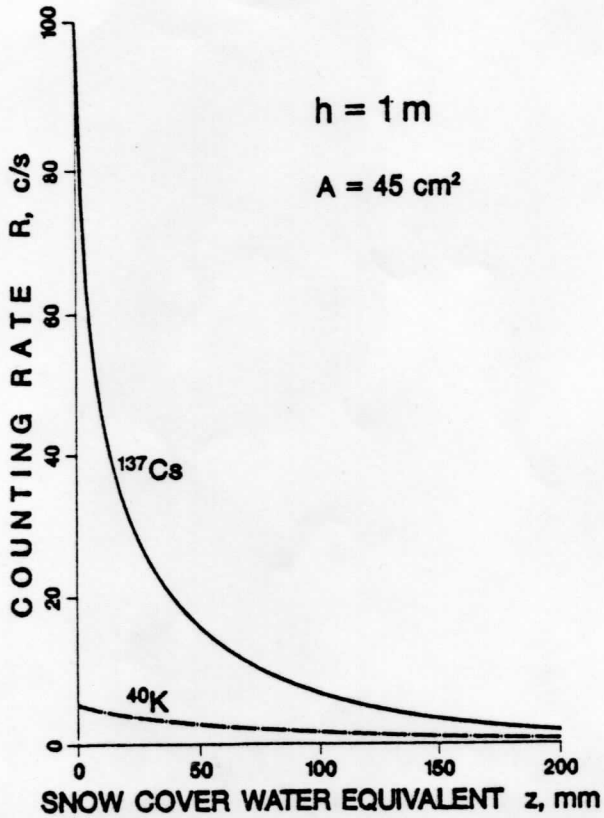

Fig. 5 Calculated counting rates for the ^{137}Cs and ^{40}K measurements, in which the "spherical" detector is at the height 1 m above the ground.

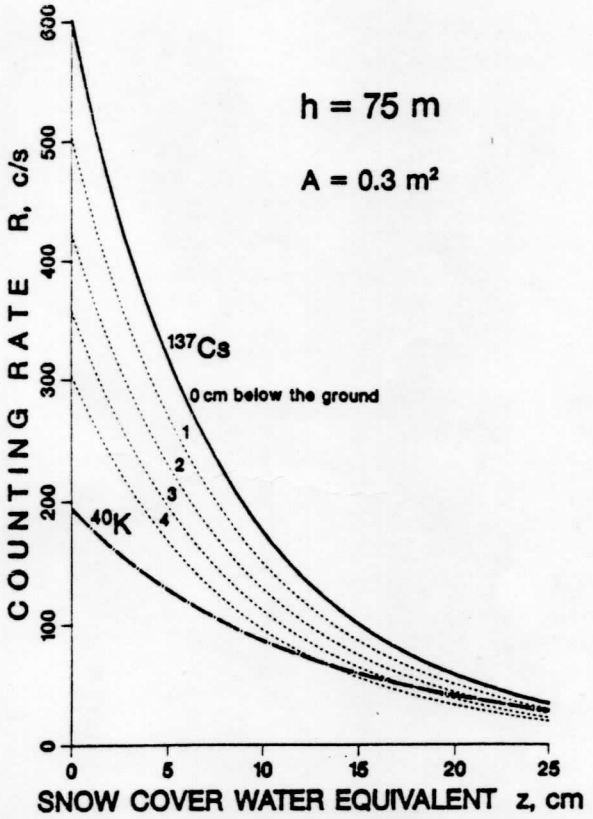

Fig. 6 Simulation of measurements where the detector is as in Fig. 4, at the height 75 m. The source plane of ^{137}Cs is assumed to be on the ground and 1, 2, 3 and 4 cm below it in soil.

snow, the cesium photon measurement would still remain the more sensitive one.

Numerous measurements of the vertical distribution of ^{137}Cs have indicated that the deposited radio nuclides remain just below the ground surface when the ground is in its natural ambient condition. Some gaugings of the ^{137}Cs distribution made by the author, for various soil types, give the same result. The ^{137}Cs nuclides are to be found within the first few millimeters. Further, it has been reported that even after the passage of 20 years, ^{137}Cs nuclides still remain just below the surface of uncultivated ground [1,11].

The cesium-radiation attenuation measurements thus may now serve as a basis for water catchment basin modelling.

References

[1] Studies on environmental radioactivity in Finland 1984-1985, Annual Report. STUK-A54, Finnish Centre for Radiation and Nuclear Safety.

[2] Salo, A., Saxèn, R., Puhakainen, M. (1984), Transport of airborne ^{90}Sr and ^{137}Cs deposited in the basins of five largest rivers in Finland. Aqua Fennica 14(1), 21.

[3] Kuittinen, R., Autti, M., Perälä, J., Vironmäki, J. (1985), Snow water equivalent determination by means of natural gamma radiation and satellite imagery. Technical Research Centre of Finland, Research Reports 370 (in Finnish).

[4] Hubbell, J.H. (1969), Photon cross sections, attenuation coefficients, and energy absorption coefficients from 10 keV to 100 GeV. NSRDS-NBS 29, U.S. Department of Commerce, National Bureau of Standards.

[5] Krauskopf, K. (1967), Introduction to geochemistry. McGraw Hill, New York.

[6] Beus, A.A., Grigorian, S.V. (1977), Geochemical exploration methods for mineral deposits. Applied Publishing Ltd., Wilmette.

[7] Larionov, V.V. (1963), Jadernaja geologija i geofizika. Gostoptehizdat, Moscow.

[8] Czubek, J.A. (1987), Simulation of geophysical profiles and γ-ray logs. Nuclear Geophysics 9(1), 83.

[9] Knoll, G.F. (1979), Radiation detection and measurement. John Wiley and Sons.

[10] Kasi, S. (1988), submitted to Nordic Hydrology.

[11] Lance, J.C., McIntyre, S.C., Naney, J.W., Rousseva, S.S. (1986), Measuring sediment movement at low eroision rates using cesium-137. Soil. Sci. Soc. Am. J. 50, 1303.

The United Kingdom National Radiological Protection Board (NRPB) Advises Reductions In Radiation Exposures*

On the basis of a reassessment of fatal cancers in the survivors of the atomic bombs at Hiroshima and Nagasaki, the National Radiological Protection Board (NRPB) has advised that an increase of a factor of two or three should be anticipated for risk estimates used for radiological protection purposes.

The International Commission on Radiological Protection (ICRP) issued a statement on the matter of risk assessments following a recent meeting.

The commission concluded that the results of a definitive study of the new calculations of doses--allowing for, amongst other things, the relative humidity in the air (which reduced neutron doses), coupled with the longer follow-up time to 1985 of the survivors--has raised the risk estimate for the exposed population approximately twofold. This, the commission considered, was not sufficient to warrant a change in dose limits.

Dr. Clarke, the NRPB director, said the new information from Hiroshima and Nagasaki provides data on risks from high doses received in a short period of time (figure 1). With some allowance for the differences between exposures at high doses and high dose rates and those at low doses and low dose rates, the practice in radiation protection has been to assume linearity between dose and risk, right back to zero dose. Therefore, any exposure to radiation--however small--is assumed to carry a proportionate amount of risk. He saw no reason to change this assumption. There is no real evidence of a response greater or less than linear. It follows that the discussion of the limitation of individual doses must include consideration of risk per unit dose and what risks are acceptable.

For both workers and the public a wide range of individual risk is accepted under different circumstances. Industrial risks vary between a few in a million per year in shops and offices to over 100 per million per year in coal mining. These figures conceal the higher risk sub-groups that exist in these broad categories. There is no simple single dividing line to distinguish between risks which are clearly acceptable and those that are clearly unacceptable. There is a broad range within which the dose limit is set. The process of the management of risk, including setting dose limits, does not solely depend on the risk per unit dose, but is a complex procedure involving judgements on many factors.