FIRST RADIOCESIUM PROFILE AND SNOW COVER MASS MEASUREMENTS

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ABSTRACT

The profile of cesium-137 in soil can be gauged nondestructively. In the measurements a scintillation detector has been set in tube or hole in soil (peaty incl.) at different depths from the ground. Radiocesium of Chernobyl (and also the earlier) makes almost a plane at the surface of any soil. – A scintillator or semiconduction detector can be set above the snow cover and the snow attenuation of cesium gamma can be measured. This method is very sensitive to the snow cover mass thickness, i.e., to its water equivalent. The results of the first measurements and evaluations are presented. In relatively large regions some decades the cesium method is more sensitive than its traditional counterpart which have been the most effective when the radiation of potassium-40 is used. The very thick snow covers may attenuate too much. The cesium-137 layer is also at the surface of any swamp.

KEYWORD

Radiocesium; Chernobyl; soil; cesium-137 profile; swamp; peatland; snow; water equivalent.

INTRODUCTION

The distribution and behaviour of cesium-137 from atom bomb experiments in the 50's and 60's have been examined by taking samples and analyzing them, reviewed by Coughtrey and Thorne (1983). Similar works have been done after the catastrophe in Chernobyl. Its fallout had, in addition of ^{137}Cs, also the shorter living cesium isotope ^{134}Cs. The ratio of the activities of these isotopes of the fallout (7.6.1988 the activity of ^{134}Cs is 31 % of that of ^{137}Cs) have been used to separate the old (2 kBq/m^2) and new contamination from each others. Arvela, *et al.* (1987) have determined the areal distribution of the excess (in 1.10.1986) of external dose rate and estimated ^{137}Cs activity. The maximal excess of the external dose rate was 0.35 µSv/h, estimated ^{137}Cs-activity 100 kBq/m^2, and 52 kBq/m^2 that of ^{134}Cs, then.

The vertical distribution (profile) of cesium-137 can be determined by the nondestructive measurements. In this work a scintillation probe measures it from a tube or a hole of soil or bog. Because radiocesium seems to be very close to the surface of any soil, it can be used as a gamma source for the measurement of snow cover mass. The first experimental results to determine the water equivalent with this actual method are the second subject of this paper.

PROFILES

The scintillation probe B in Fig. 1 in the tube or hole is transferred through the soil surface in small intervals. The counting rate of the photons arriving directly from ^{137}Cs atoms is counted. The photons are catched by the scintillation crystal (at the depth d in Fig. 1). The counting rate depends mainly of the vertical profiles of the ^{137}Cs atoms and that of soil density. For the present only some rough calculations of the cesium profile, using very approximate density profiles, are performed. However, the profiles, already calculated, seem to represent that of the ^{137}Cs atoms rather accurately.

The good accuracy of the cesium-137 profile is obtained, when the accurate density profile (that usually is continuous) is in use. The solution of the inversion problem: seeking the ^{137}Cs profile, is found by minimizing the difference between the measured distribution and simulated distribution of the counting rate. Today I do this optimization manually. It is cumbersome. The same is automized easily. It seems, that the development of the counting rate and density (profiles) according to the polynomials of Laguerre is for help when the solution is sought.

Schell and Massey, in IAEA Symposium 1987, shew that the bomb cesium (over 20 years old) in the three bogs in USA is in the first 15-20 cm from the surface. One of the bogs has the ^{137}Cs profile differing from the others. In this bog the ^{137}Cs atoms have diffused, except down, in so high portions up, that in the uppermost new layers and in those, born during the fallout, the concentrations are equal. I have made a relatively rough measurement in a hole of a fresh swamp. There and in the other soils the calculation gives a sharp peak at the depth 0...2 cm. According to my very uncertain results, in the fresh swamp in the depths 2...25 cm there is a tail of over 50 % of ^{137}Cs atoms. The most accurate measurement I made in soil moisture tubes which are in mineral soil. There is 80 % of the atoms in the peak (0...2 cm) and maybe all the atoms above the depth 12 cm.

Using a good instrument and long measuring times the very accurate ^{137}Cs profiles can be achieved. Using the multichannel analyzer the accurate ^{134}Cs profiles can be obtained, as well, and the old ^{137}Cs can then be separated from the new one.

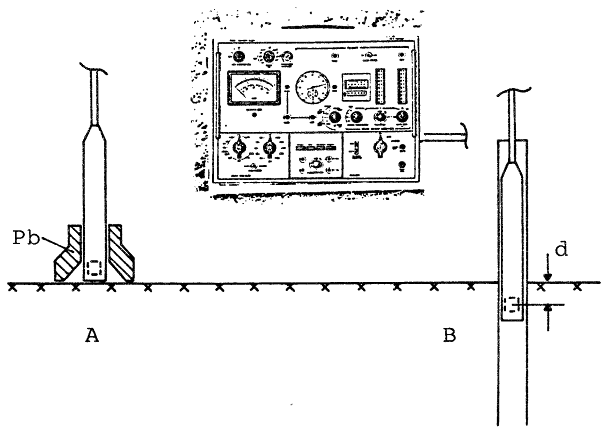

Fig. 1. Radiocesium measurements of the author.

SNOW COVER MASS

The radiocesium of Chernobyl (and also the earlier) makes almost a plane on the surface of any soil. The attenuation of the radiation is very sensitive to the snow cover mass, i.e., to its water equivalent, z in Fig. 2. Then

$$m = t_w z = t_s z_s \qquad (1)$$

is the areal mass density of snow. t_w = 1000 kg/m³. t_s is the mean density and z_s the thickness of snow.

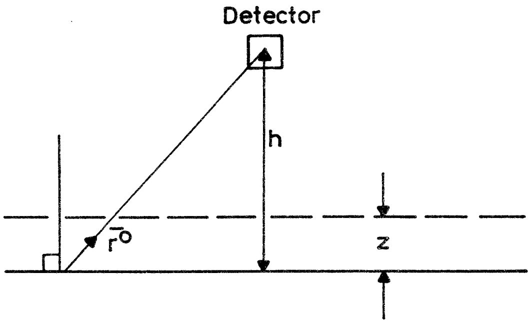

Fig. 2. The gamma measurement of snow cover mass distribution.

In the gamma measurement we have the counting rate

$$R = 2\pi \int_h^\infty D(\bar{r}^o) I(\bar{r}^o) \exp(-\mu t_a r) dr/r, \qquad (2)$$

where the effective mass attenuation coefficient

$$\mu = \mu_a + \left(\frac{\mu_w}{t_a} - \frac{\mu_a}{t_w}\right) \frac{m}{h}. \qquad (3)$$

μ_w and μ_a are the mass attenuation coefficients of water and air, respectively.

t_a is the density of air.

$\bar{r}^o$ is the unite vector from point of the ground to the direction of the gamma detector. r is the distance between the point and detector.

The function $D(\bar{r}^o)$ is the detector area (perpendicular to the vector $\bar{r}^o$) times the probability to detect the photon.

$I(\bar{r}^o)$ is the intensity distribution of the counted photons at ground point.

The dependence of the intensity $I(\bar{r}^o)$ on $\bar{r}^o$ is determined by the radioatom distribution, soil density and, in a smaller degree, its elemental (H) composition. When the atoms are on the ground then $I(\bar{r}^o)$ does not depend on the direction of photon emission.

In Finland where the water equivalent in common is below 250 H_2Omm the measurement above the ^{137}Cs surface 30 kBq/m² is more accurate than that above the semi-infinite ^{40}K soil (Kasi 1988a, 1988b). Also the source of the ^{40}K gamma (1461 keV) radiation is often below the organic soil surface. For instance, the bogs may attenuate the ^{40}K photons entirely. Though the cesium photons attenuate more, the cesium method (because the ^{137}Cs atoms are so near the soil surface) is now very useful.

For water catchment basin (the area A) the total snow mass

$$M = \int_A m \, dA$$

surely is an important quantity. For (e.g. the models of) any basin the mass distribution m is also useful.

I have performed the first experiments in the southern part of the fallout region in the central Finland. The curves in Fig. 3 are optimized to the experimental results. Kasi, 1988b, explains them in detail.

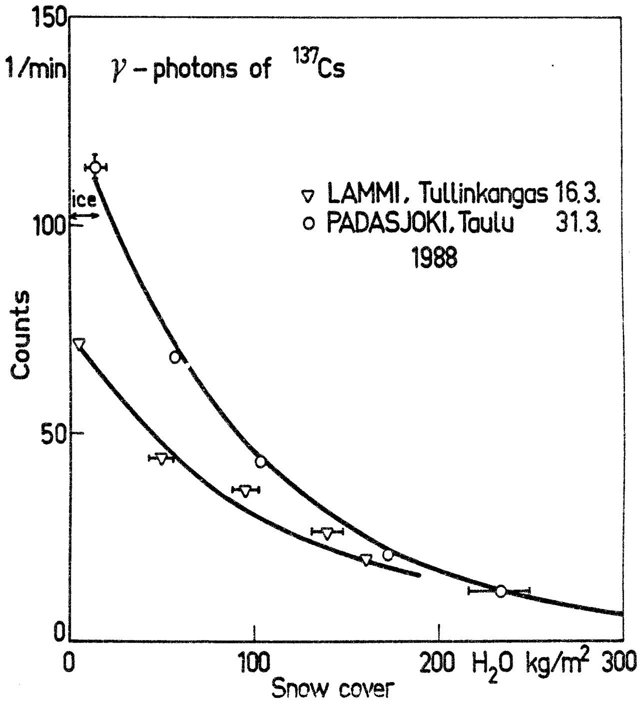

Fig. 3. Experimental evidence of the method

In these preliminary measurements with the probe A of Fig. 1 the scintillation crystal has a very minimal size, 13 cm^3. Therefore the counting rates in Fig. 3 are small. The sum volume of the crystals used in the aeroplane measurements in Finland is 25 dm^3. The sensitivity of the latter is almost 1000 times greater.

The gamma radiation above the ground can be measured in a vehicle in air or, e.g., on snow. The lead around the probe A of Fig 1 confines the directions of the incoming photons so that $D(\underline{r}^o)$ is more optimal, and diminishes the radiation from the space. In the measurement the counts caused by the Compton scattered photons must be subtracted. They include scattered photons of the radon daughters. It is important that the window of the cesium-137 peak in scintillation measurements should be at so sufficiently high energies that the strong 609 keV photon of ^{214}Bi is not counted. Bristow, 1983, gives introduction in the spectrometry of the terrestial gamma radiation gauges.

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