§15. Radiation Sources Fabricated from Kelp Powder for Educational Purposes

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Many materials contain naturally occurring radioisotopes such as ^{40}K, ^{232}Th, and ^{238}U. Those materials include monazite, sinter (hot-spring deposit), chemical fertilizer, and kelp. These materials are often used in educational courses on radiation.

In the present study, a disk-shaped radiation source was fabricated from kelp. The kelp radiation sources were examined by performing two tests on the dependence of the radiation count rate measured by a GM survey meter on distance and shielding[1)].

In the distance dependence test, net count rates were obtained at 11 distances in the range 0 to 30 cm. The results are shown in Fig. 1, where circles indicate the count rates measured as a function of distance. An initial steep decrease in the count rate was followed by a more moderate decrease

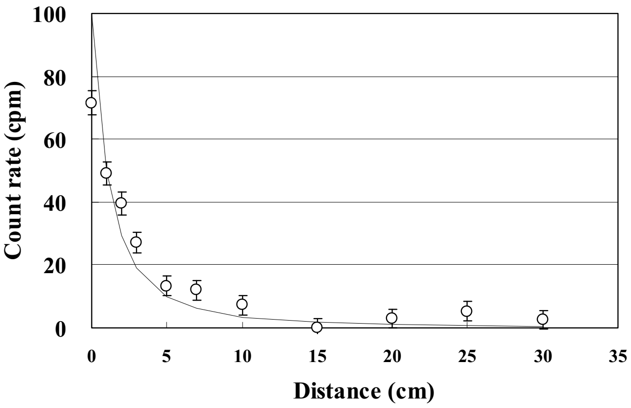

Fig. 1 Dependence of radiation counts on distance.

with distance in accordance with the inverse-square law. For reference, a typical inverse-square curve, $Y = A/(a+X)^2$, is also plotted in Fig. 1, where X is the distance and Y is the count rate, and A and a are constants with values of 500 cpm·cm^2 and 5 cm, respectively. These values were determined by fitting the curve to the data points in Fig. 1 by trial and error. The physical meaning of the constant a is the effective depth from the detector surface to the point where radiation is detected. Since the measured count rates are distributed about the curve, the experimental results can be semiquantitatively explained by the inverse-square law.

The dependences of the shielding effectiveness on the thickness and type of material used were examined using paper, plastic, and aluminum. Kent paper (thickness: 0.25 mm, mass density: 0.93 g/cm^3) was used as shielding paper. Similarly, commercially available plastic sheets (vinyl chloride resin, thickness: 0.4 mm, mass density: 1.35 g/cm^3) and aluminum plates (thickness: 0.5 and 1.0 mm, mass density: 2.7 g/cm^3) were selected as shielding materials. The paper sheets, plastic sheets and aluminum plates were cut into 50×50-mm^2 sheets or plates and they were stacked to produce shielding of various thicknesses (0.5, 1, 2, 4, and 8 mm).

During this test, the distance between the kelp radiation source and the probe of the survey meter was fixed at 15 mm. Shielding materials of various thicknesses were placed between the source and probe and the net count rate was measured with the GM survey meter. The respective transmissions were obtained by dividing the shielded net count rates by the unshielded rates. Transmissions for the 0.5-mm-thick and 1-mm-thick plastic sheets were estimated by interpolating the values obtained for plastic plates with thicknesses of 0.4 and 0.8 mm, and 0.8 and 1.2 mm, respectively.

Figure 2 shows the transmission results. It indicates that all the transmissions decrease dramatically at first and then moderately as the thickness increases. The rate of decrease is in order: aluminum > plastic > paper. Since the mass densities of aluminum, plastic, and paper are respectively 2.7, 1.35, and 0.93 g/cm^3, the results demonstrate the general

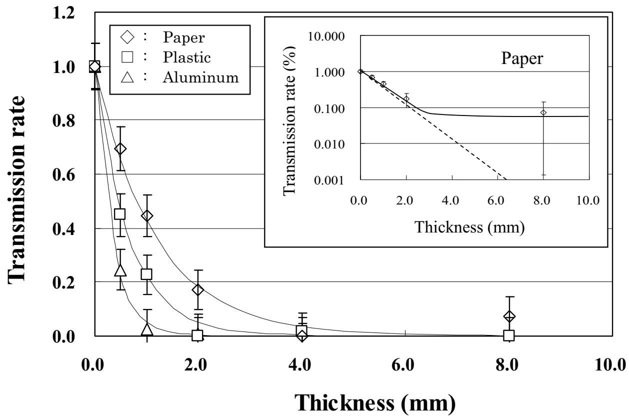

Fig. 2 Dependence of transmission on shielding thickness and type of materials.

principle of radiation shielding that materials with a larger mass density provide greater radiation shielding. This experiment semiquantitatively demonstrates the relationship between the mass density and the effectiveness of shielding against radiation.

In addition, it was examined if an experiment to determine the half-value layer of material for radiation could be conducted in an educational course on radiation based on the transmission data for paper shown in Fig. 2. Equation for calculating the half-value layer ($X_{1/2}$) is as:

$$X_{1/2} = 0.693 / \rho\beta m \qquad (1)$$

Using Eq. (1), the half-value layer of paper for radiation can be calculated in the following manner. By substituting the values of the mass density (0.93 g/cm^3) and the mass absorption coefficient (0.96 cm^2/g) into Eq. (1), the half-value layer of paper was determined to be 0.78 mm. This result is reasonable from Fig. 2. Thus, the kelp radiation sources can be used to explain the concept of the half-value layer as a characteristic of radiation shielding.

It is concluded that the kelp radiation source will be a useful aid for courses on radiation and its characteristics and it will allow students to easily experience radiation and better understand its characteristics.

1) Kawano, T.: Radiation Safety Management 8 (2009)1.