GEOMETRIC EFFECTS IN ALPHA PARTICLE DETECTION FROM DISTRIBUTED AIR SOURCES*

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SUMMARY

Geometric effects associated to detection of alpha particles from distributed air sources, as it happens in Radon and Thoron measurements, are revisited . The volume outside which no alpha particle may reach the entrance window of the detector is defined and determined analitically for rectangular and cylindrical symmetry geometries.

Introduction

Geometric effects influencing detection of α-particles, emitted at distributed air sources, are well known since long; the purpose of this communication is to discuss a few aspects that are usually neglected or overlooked. The point to be discussed is related to the existence of a "sampling volume", *i.e.,* a volume of space around a detector such that α-particles of a given energy, emitted from positions outside that volume, cannot be detected.

Previous knowledge about that volume and the geometric efficiencies are required for reduction of data and any further calculations referring to extended sources, such as Radon and its progeny in air samples . Observed quantities are the activities, c_i, and, in SSNTD, the surface track densities, ρ_i; let n_i be the volume density of the i^{th}-nuclide, with disintegration constant λ_i, dispersed in a uniformly distributed mixture of α-emitters; let ε_i, v_i be the geometric detection efficiency and sampling volume, respectively, for that nuclide and T the exposure time, one has:

$$\begin{aligned} c_i &= \varepsilon_i \, v_i \, \lambda_i \, n_i \\ \rho_i &= c_i T / S \end{aligned} \qquad (1)$$

where it is supposed that track densities are observed in a detector the same shape and area as that used for counting activities; S is the detector area where tracks are scanned for1 .

Parameters ε_i and v_i in (1) depend on the range of the particles detected; therefore, when assessing values of nuclide concentration, n_i, or activity concentration, $\lambda_i n_i$, it is necessary to take into account correctly the values of those parameters. The question raises in importance when the case involves summations over isotope concentrations and/or activity concentrations, as in work level and equilibrium factor computations, where individual errors also add up. We have treated examples in calibration of SSNTD's and in calculating the ventilation rate, when it is larger than other disequilibrium factors, showing the contribution of those parameters and analyzing the influence of meteorological variables that might affect results throughout ranges.

Geometric Efficiencies and Sampling Volumes

Of course $\varepsilon_i = 0$ for all emission positions outside v_i and $\varepsilon_i \leq 1$ elsewhere, the actual value depending upon range of α-particles, shape and dimensions of the detector. Geometric efficiency values are more easily obtained by Monte Carlo computations. Sampling volumes can also be obtained

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1 It is omitted for simplicity a factor taking into account the relative *intrinsic* efficiencies.

by Monte Carlo calculations as the set of all emitter positions connected to detector's surface by a straight line segment delimiting a length smaller or equal to the range of α-particles. However they can be shaped and dimensioned, for simple detector geometries at least, by means of geometrical constructions.

In the case of a disk shape SSNTD of radius R_d, or of detectors with a circular entrance window, as most semi-conducting and similar devices, one proceeds in the following way: l) project the detector boundary onto a plane parallel to its surface at a distance equal to the range of the particles, R; 2) concentric with the detector, in the same plane, draw another circle of radius $R+R_d$; 3) with the center on any point at the detector's circumference draw a circular quadrant of radius R, beginning at

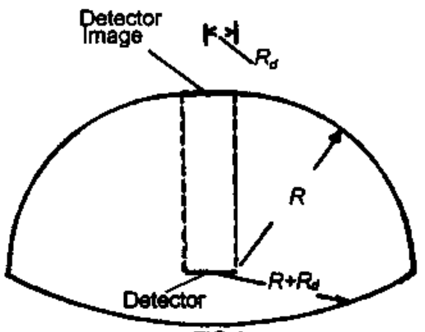

FIG 1

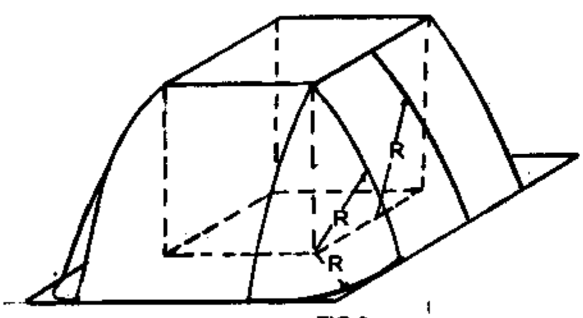

FIG 2

the circumference of the outer circle and stopping at the detector's image border (Fig.1); 4) The revolution surface obtained by turning that arc around the axis joining the center of the detector to that of its'projected image delimits the sampling volume: any particle emitted from outside that volume would have to fly over a distance greater than its range, to intersect any point at the detector's surface.

The case of square (or rectangular) shape, more frequent with SSNTD, is handled similarly. 1) first of all an image of the detector surface is created in a plane parallel to that surface, at a distance R; 2) straight lines are then traced parallel to the sides of the detector, in the same plane and at distance R to them, creating in this way a second square shaped figure with side length $2R+l$, where l is the detector side length; 3) the homothetic corners at detector's border and at this extended square surface are joined by straight line segments, thus generating a truncated pyramid; 4) finally the lateral surface of that solid is involved with a cylindrical surface obtained by rotating around each side of the detector, as a rotation axis, the corresponding sides of the outer square, following a circular movement with radius R (Fig.2); at each corner one has to close the figure by turning the arc of circle of radius R, joining homothetical corners in the detector and the outer square, around the straight line joining homothetic corners in the detector and its image, (maximum circle at the bottom plane has also radius R (Fig.2)).

The sampling volumes for those simple geometries can be found by calculating the volume of the solids in Figs. 1 and 2. Those volumes can be obtained by handling volumes of simple solids such as right prisms, cylinders, spheres, spherical sectors, in proper combinations; results are:

1.disk shape detector of radius R_d :
$V=(2\pi/3)R^2/(R^2 + R_d^2)^{1/2}[R^2+3RR_d+3R_d^2]$ (2)

2.square shape detector, side length a
$V=R\ [\ a^2 +\pi R\{3a +2R\}/3]$ (3)

Conclusion

Values for the sampling volumes for a disk shape detector with radius 0.5 cm are plotted in Fig.3 as a function of α-energy. It is seen that observed activities of α-particles of different energies and track densities, as given by equ. (1), may be severely affected by sampling volumes, if their effects are not taken into accout properly. Same may be said about geometric efficiencies.

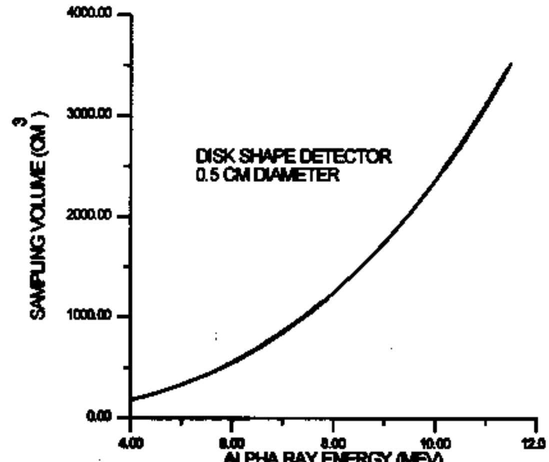

FIG 3