Natural radioactive isotopes in the atmosphere at Kodiak and Wales, Alaska

By LUTHER B. LOCKHART, JR., *U. S. Naval Research Laboratory, Washington, D.C.*

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ABSTRACT

The concentrations of natural radioisotopes of the radon and thoron series in the air in Alaska have been determined from data collected by NRL air-monitor equipment operated at Kodiak (1950–1960) and Wales (1953–1959). Seasonal variations in the concentrations of these activities at both sites have been observed; the average concentrations are compared with those at other sites where similar measurements have been made.

1. Introduction

As part of a study of methods for the detection of fission products in the air resulting from distant atomic explosions in the atmosphere, a method was developed at the U.S. Naval Research Laboratory for the rather quick evaluation of airborne radioactivity collected by the technique of air filtration (LOCKHART, BAUS, KING & BLIFFORD, 1959). From the measured β decay of these filter samples, or more specifically, from the average counting rates immediately after collection and again during the 5th to 6th hours and 15th to 16th hours, it was possible to estimate the quantities of fission products and natural radioactive products of the radon and thoron series in the air.

Since early 1950 a number of air-monitor units based on this system have been operated in various parts of the world by cooperating groups. The object of this report is to make available the information collected during the period 1950–1960 at sites in Alaska and to document the yearly and seasonal changes that have occurred in the radioactive constituents of the atmosphere in this area of the world.

2. Experimental procedure

The concentrations of radon, thoron (thorium B), and gross fission products in the air were obtained from the measured changes over a 16-hour period in the rate of decay of radioactive particulate matter collected on efficient filters through which a measured quantity of air (about 1000 cubic meters) had passed during the preceding 24 hours, as described elsewhere (LOCKHART, BAUS, PATTERSON, & BLIFFORD, 1958). Filters were changed near the time of the expected minimum in the diurnal cycle of radon activity. The calculations of the concentrations of the longer lived thoron daughter activity and of the gross fission product β activity are less sensitive to the time of filter change.

These calculations have assumed secular equilibrium of radon (3.8-day half-life) with its β-emitting daughters RaB and RaC (half-lives of 26.8 and 19.7 minutes, respectively). Measurements made at Washington, D.C. at an elevation of 40 feet above the ground indicate that, in general, this assumption is justified; however, the growth of the RaC daughter relative to RaB during the collections does lead to an overestimation of the radon content of the air. This aspect of the problem is currently under investigation. The daughters of the thoron activity, due to the extremely short half-life of thoron, cannot be in secular equilibrium with the parent. For simplicity, however, the results are reported in terms of an apparent thoron concentration which is assumed to be equal to that of its daughter product, the 10.6-hour thorium B (ThB).

3. Results

A detailed presentation of the monthly averages of the concentrations of radon, thoron (or ThB), and gross fission product radioactivity in the air at ground level at Kodiak (57°45′ N, 152°29′ W) and Wales (65°37′ N, 168°03′ W),

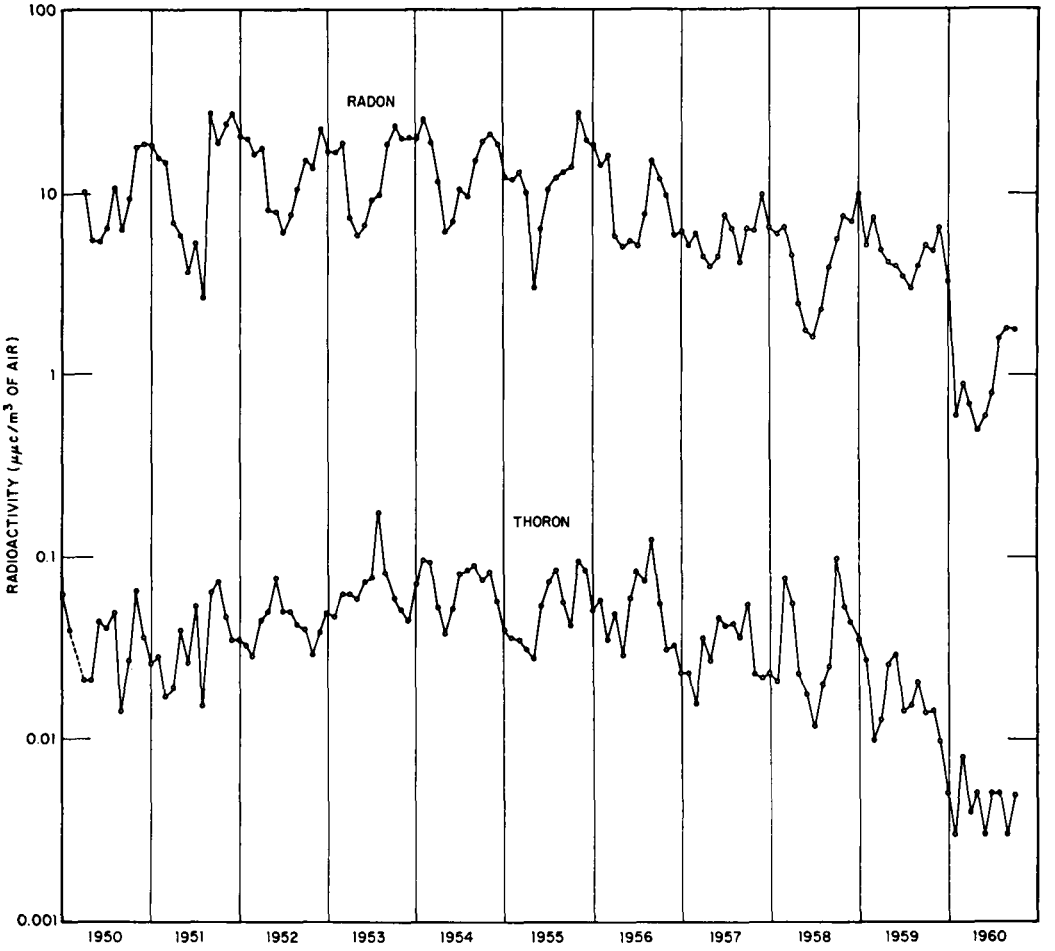

FIG. 1. Natural radioactivity in the air at Kodiak, Alaska.

Alaska, for the periods 1950–1960 and 1953–1959, respectively, is given elsewhere (LOCKHART, 1961).

The monthly averages of the radon and thoron concentrations in the ground-level air at Kodiak, Alaska for the period 1950–1960 are shown graphically in Fig. 1. A certain periodicity in the radon level is evident with maxima in the winter season and minima in the summer. The thoron values show a less consistent pattern. However, when the monthly values for the entire period of the collections are averaged and compared, as in Figs. 3 and 4 (discussed later), definite seasonal variations in both radon and thoron appear which are out of phase with one another. The concentrations of the natural radioactive components of the air at Kodiak during 1960 seem unusually low; the low results do not appear to be associated with any unusual weather conditions at Kodiak during this period. Since a recheck of the data obtained from this field station gave no indication of any systematic or instrumental errors which could account for these results, the data are considered to be valid and are included in the averages; their inclusion causes something less than a 10 per cent decrease in the 11-year average.

The monthly radon and thoron concentrations at Wales, Alaska, for the period 1953–1959 are shown in Fig. 2. Here also strong seasonal variations in radon activity occur with minima in the summer season. The most striking effect is the seasonal variation in the thoron concen-

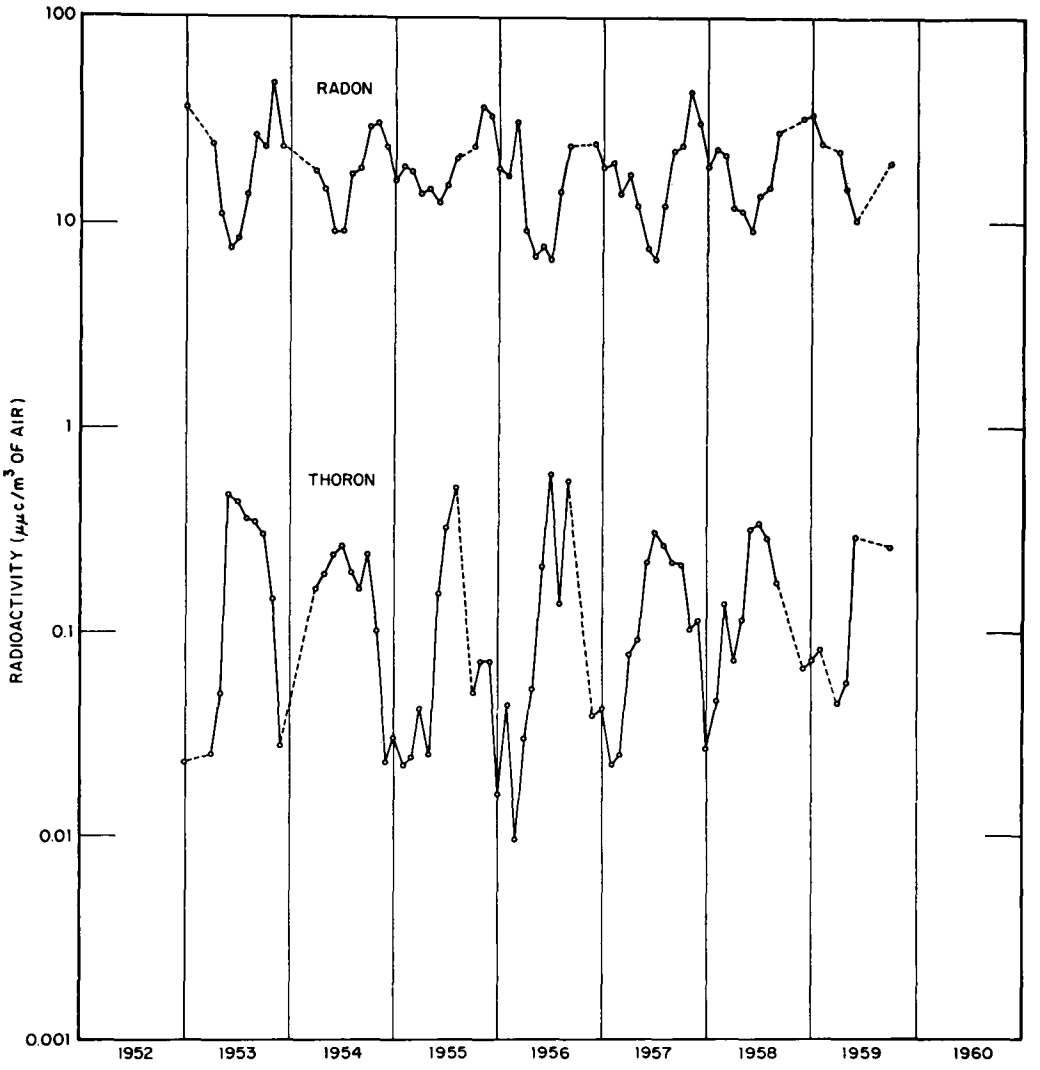

FIG. 2. Natural radioactivity in the air at Wales, Alaska.

tration, the summer maxima being an order of magnitude higher than those of the winter minima.

A clearer picture of the seasonal variations in the natural radioactive components of the atmosphere is given in Figs. 3 and 4 where the averages of the monthly radon and thoron concentrations are compared for the two sites. The radon concentrations at both Kodiak and Wales show summer minima at which time the concentrations are something like one-fourth those of the early winter maxima. It is not unexpected that the radon concentration at Wales, a coastal site, averages about twice that at Kodiak because of the relatively small land mass of Kodiak Island and its distance from the mainland.

The thoron concentrations (Fig. 4) at the two sites show quite different seasonal behavior. At Kodiak there is a slight increase during the summer, but the seasonal effect is not very pronounced. At Wales, on the other hand, there is a tremendous increase in thoron in the late spring. Examination of the daily records showed that in the late spring sudden, almost explosive, bursts of ThB appeared in the collections,

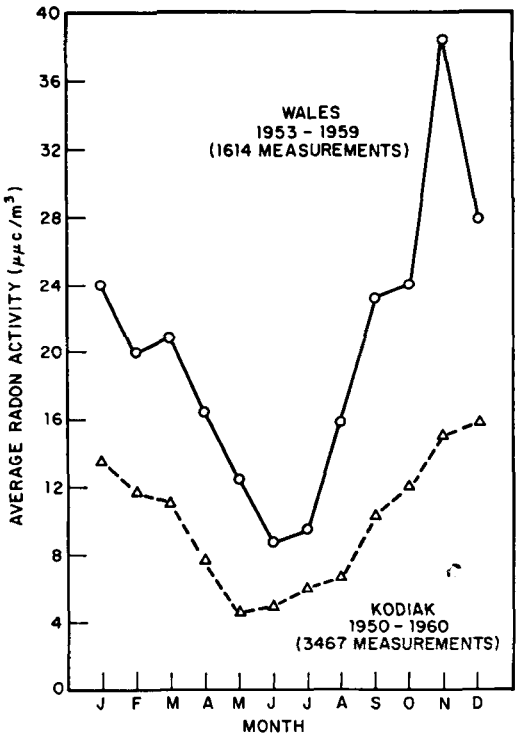

FIG. 3. Seasonal variation of radon activity in the air at ground level.

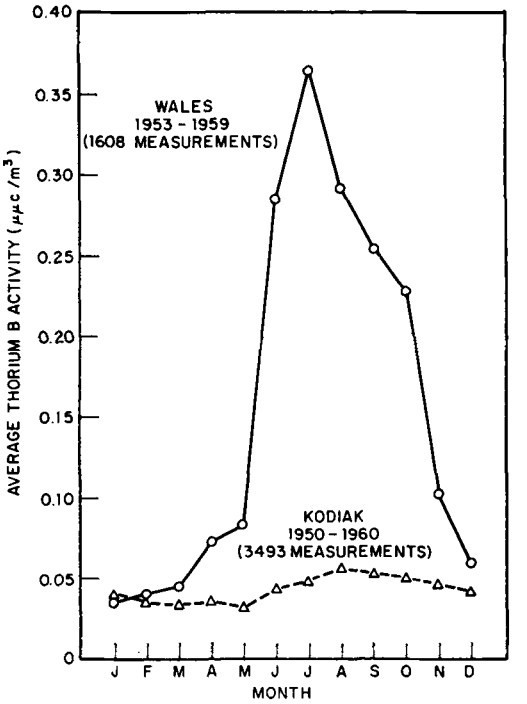

FIG. 4. Seasonal variation of thoron (or ThB) activity in the air at ground level.

separated by days of more normal low ThB values. The frequency of these high values increased rapidly through May, and they were commonplace throughout the summer. These changes may be associated with changes in the condition and temperature of the soil in the vicinity of this site.

A comparison of the natural activity levels in Alaska with those in some other areas where similar measurements have been made is given in Table 1 (LOCKHART, 1959, 1960). In addition to the different average concentrations of radon and thoron at the various sites, each location has its own peculiar seasonal variations in these activities and a more or less characteristic radon to thoron ratio. The highest activity ratios and lowest activities are found, as might be expected, at localities where release of these materials to the atmosphere is limited by geographical features.

4. Discussion

Geographical location has an important bearing on the patterns and levels of atmospheric radioactivity. The natural radioactive isotopes have their primary sources in the earth from which the rare gas precursors of the solid decay products diffuse; the surface of the sea is lower by several orders of magnitude as a source. As a consequence, the natural radioactivity observed at a given site will be related to the area of land surrounding the site, the distance to the sea, the varying speed and directions of the winds, etc., through the manner in which these parameters permit additions of fresh radioactivity to the air before its arrival at the site, as well as to the competing mechanisms which cause its removal or dilution.

The past history of the air masses sampled must be reflected in the concentrations of these two natural radioactive materials. Because of the short half-life of thorium B (10.6 hours) its concentration is closely related to local soil and meteorological conditions and is more or less independent of the history of the air mass except for the past day or two; the concentration of radon on the other hand represents the combined effect of accumulation and depletion of this isotope over a period of several weeks.

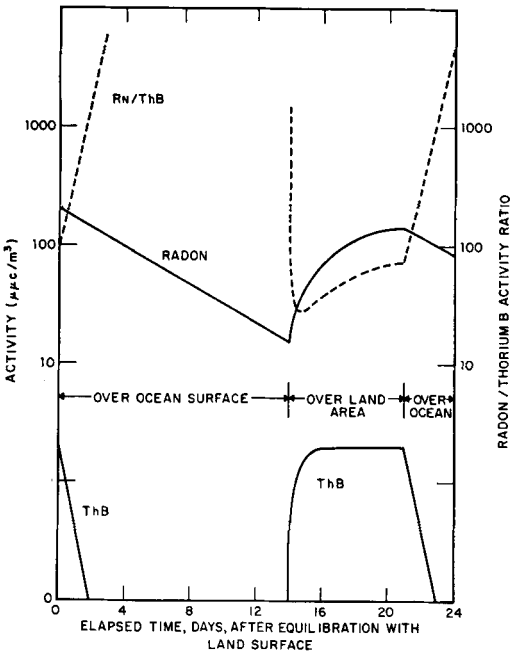

FIG. 5. Effect of continental and oceanic environments on natural radioactivity levels in the air.

A highly idealized picture of the changing radon and ThB concentrations in an air mass as it passes over land and sea areas is shown schematically in Fig. 5. The only processes considered are the addition of radon and ThB at a uniform rate from land surfaces and depletion by radioactive decay; changes in concentration due to vertical mixing with air of lower activity and to deposition processes have been neglected, though they can radically modify the general picture.

The routine collection by weather stations of such data on the natural radioactive products in the air should supply meteorologists with another tool for studying atmospheric processes. It would seem to be indicated that a more comprehensive study of the behavior of thorium B in the atmosphere involving its vertical distribution and its variation with time of day and with local meteorological phenomena would be desirable. The quick reaction of the ThB concentrations to changing conditions should serve to make it a generally more useful tracer than radon.

5. Conclusions

The concentrations of the naturally occurring radioisotopes radon and thoron (ThB) in the air at the two sites in Alaska have been found to be lower than at most other locations where similar measurements have been made. These concentrations and the corresponding radon/thoron activity ratios are definitely related to the geographical locations and to the meteorological environments of the areas under study.

The large observed variations in activity levels with time and season and the independent behavior of these tracers of different effective lifetimes suggest that together they provide an extremely useful tool for studying the movement and mixing of air masses.

TABLE 1. *Summary of measurements of natural radioactivity in the ground-level air.*

Site	Period of observation	Radioactivity (μμc/m³) Radon[a]	Thoron	Activity ratio Radon/Thoron
Washington, D.C.	1950–1961	122	1.34	91
Yokosuka, Japan	1954–1958	56	0.48	117
Rio de Janeiro, Brazil	1958–1960	41	2.41	17
Chacaltaya, Bolivia	1958–1960	39	0.53	74
Lima, Peru	1959–1960	31	1.34	23
Wales, Alaska	1953–1959	20	0.16	125
Kodiak, Alaska	1950–1960	9.9	0.04	250
Little America, Antarctica	1956–1958	2.5	< 0.01	> 250
South Pole	1959–1960	0.55	< 0.01	> 55

[a] Activity at time of minimum in the diurnal cycle.

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