RADON CONCENTRATION OF AIR OVER THE EASTERN ARABIAN SEA

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ABSTRACT

The radon concentrations of air samples collected during the South West monsoon period at altitudes up to 4 km over the Arabian Sea at two locations, *i.e.*, 0–50 km and 300–400 km west of Bombay, are reported. Radon was extracted from air, using a simple single stage apparatus. The concentration of radon in the monsoon air mass was found to range around 80–100 dpm/m^3 STP, indicative of its recent continental origin. The results suggest that the coastal monsoon air mass, up to 400 km west of Bombay coast, is generally homogeneous and vertically well mixed.

During the post-monsoon condition, a strong gradient in the radon concentration in the vertical is observed. The concentration of radon decreases from 157 dpm/m^3 at sea level to 35 dpm/m^3 at about 3·7 km altitude, suggesting a vertical turbulent diffusion coefficient of $\sim 6 \times 10^4$ cm^2/sec. In contrast, the near absence of vertical gradient of radon in the monsoon air mass indicates that the vertical turbulence is much stronger during the monsoon period.

1. INTRODUCTION

RADON (3·8 day half life), daughter of ^{226}Ra, is an ideal tracer for studying short term processes occurring in the atmosphere and in the oceans (Israel, 1962; Broecker, 1964; Rama, 1969; Wilkening, 1970; Moore *et al.*, 1973). The application of radon as a tracer for studying the monsoon air circulation over the Arabian Sea has already been demonstrated (Rama, 1969).

The concentration of radon in an air sample is usually assessed either by measuring the radioactivity of its daughter products (Fig. 1) obtained

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by filtering air through a suitable filter or by first extracting the radon from air (using charcoal traps) and then assaying it in a scintillation chamber.

$$^{222}\mathrm{Rn} \xrightarrow[3\cdot 8\mathrm{d}]{\alpha} {}^{218}\mathrm{Po} \xrightarrow[3\cdot 1\mathrm{m}]{\alpha} {}^{214}\mathrm{Pb} \xrightarrow[26\cdot 6\mathrm{m}]{\beta^-} {}^{214}\mathrm{Bi} \xrightarrow[19\cdot 7\mathrm{m}]{\beta^-}$$

$$^{214}\mathrm{Po} \xrightarrow[1\cdot 6\times 10^{-4}\mathrm{s}]{\alpha} {}^{210}\mathrm{Pb}$$

Fig. 1. Decay chain of ^{222}Rn

The first method of estimating radon concentration by alpha-beta assay of the filter deposit is very convenient and simple. However, the application of this method to high altitude samples is questionable, due to possible uncertainties in the efficiency of filters for retention of radon daughters. These uncertainties arise because at high altitudes a sizable fraction of the activities may exist as ions, rather than attached to aerosols and may thus escape through the filter. Therefore the safe procedure would be to extract the radon itself from the air sample and assay its activity. Radon can be retained quantitatively on charcoal traps but the method is tedious and time consuming. Radon can also be retained on glass surface cooled to liquid nitrogen temperature.

Here, we report a convenient, single step method for quantitative extraction of ^{222}Rn from air samples (and from ^{226}Ra solutions). The results on radon concentration measured in four vertical profiles of air samples over the Arabian Sea are also reported, along with some indicative conclusions about the structure of the monsoon air mass.

2. Experimental Procedure

2.1. *Sample Collection*

The air samples from different altitudes, between 0–4 km above sea level, were collected at two locations, about 0–50 km and about 300–400 km west of Bombay coast, using Dakota aircraft. The samples were collected by letting in air (at the desired altitudes) into previously evacuated twenty litre round bottom pyrex flasks. The amount of air collected in the flasks was measured in the laboratory, by measuring the pressure in the flask. The amount varied between 10 and 20 litres S.T.P., depending on the ambient pressure at which the sample was collected.

2.2. *Extraction of Radon*

The extraction of radon from air can be carried out satisfactorily by selectively adsorbing it either on activated charcoal at about—80° C (Mosses *et al.*, 1960; Moore *et al.*, 1973) or on glass surface at liquid nitrogen temperature (Broecker, 1964).

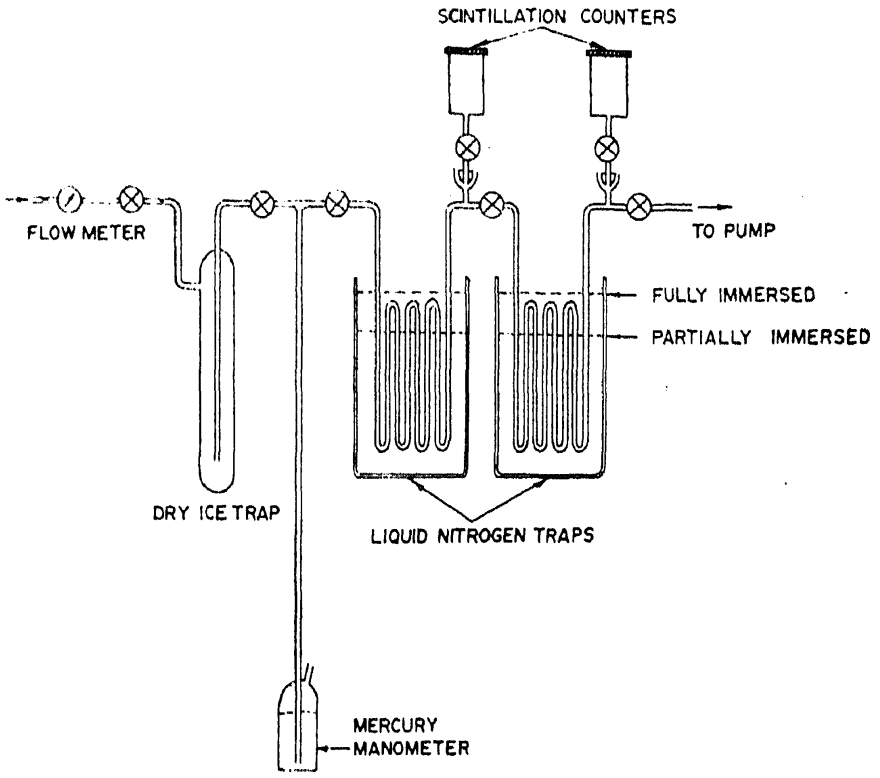

FIG. 1. Glass system used in the estimation of radon.

The second method is simpler, more convenient and better suited for samples containing small amount of radon. But the adsorption of radon on glass surface is comparatively inefficient. Therefore, quantitative extraction is usually achieved by circulating the carrier gas over a glass surface cooled to liquid nitrogen temperature for sufficiently long time. We have modified this method suitably to achieve near quantitative adsorption of radon in a single step; no circulation in a closed system is required. Radon is adsorbed on a small volume multi-U-tube trap at liquid nitrogen temperature. This trap is operated as a single stage collector without any pre-concentration step and has been found very convenient and reliable for near quantitative extraction. Figure 2 shows the glass system employed. Air first passes through the dry ice trap which removes its moisture. Dry air then passes successively through two identical multiple-U-tube traps (tube i.d. 6 mm; wall thickness 1 mm; limb length 12 cm) immersed partially in liquid nitrogen. Radon, along with any minor condensible constituents like carbon dioxide, is effectively adsorbed by these traps.

After the passage of carrier gas (air, in this case), the trapped radon is desorbed from the traps by warning them to room temperature. It is then transferred, with the help of He carrier gas, into previously evacuated respective ZnS counting chambers by a simple manipulation of stopcocks (Fig. 2).

2.3. *Assay of Radon*

After the radon is transferred to the ZnS counting chambers, its activity is assessed using a method which is essentially identical to that employed by earlier workers (Mosses *et al.*, 1960; Broecker, 1964). The counting efficiency of the system is estimated using radon from ^{226}Ra standards and was found to be 205%. The >100% efficiency arises because three alphas per decay of radon are involved (Fig. 1). Comparison of the counting rates in the two successive chambers provides an estimate for the adsorption efficiency of the traps.

Prior to the use of the multi-U-tube traps, experiments were conducted using two single-U-tubes for radon adsorption. They were found to be rather inefficient (< 50 per cent adsorption) even at small flow rates of a carrier gas (0·5 litre/min). The U-tubes were then replaced by two spirals whose tube length was increased several fold. The improvement in the radon adsorption was marginal and completely incommensurate with the increase in length. The adsorption on extra length was very small, as also became evident from visual inspection of atmospheric CO_2 deposit. This behaviour could possibly arise due to the fact that the diffusion coefficient decreases by about an order of magnitude when the carrier gas cools down to liquid nitrogen temperature and this results in a very inefficient adsorption on the walls of the trap. It was therfore decided to use a bunch of four U-tubes for each trap and to keep their heads exposed to the atmosphere so that the air gets warmed up while it passes in between the successive limbs. This resulted in a very satisfactory performance of the traps. For the sake of comparison, the experiments were also conducted by immersing the traps completely in liquid nitrogen. Results of these experiments showed that

(i) the adsorption of radon is more efficient when the traps are partially immersed compared to the case when the traps are completely immersed in spite of the fact that the available tube length for adsorption is more in the latter case;

(ii) the adsorption decreases slowly with increasing flow rate of air when the traps are partially immersed; it stays better than 90 per cent up to a flow rate of about 2 litres/min.

These experiments suggest that warming of the carrier gas in between the successive limbs certainly results in more efficient adsorption of radon, probably due to faster molecular diffusion or perhaps simply due to the flow becoming more turbulent. Filling the U-tubes with glasswool was not considered practical because of the possible blocking of the tube even by small quantity of carbon dioxide and residual water vapour.

3. Results and Discussion

The results on concentrations of ^{222}Rn measured in four vertical profiles over the Arabian Sea are given in Tables I and II.

TABLE I

Concentrations of ^{222}Rn over the Arabian Sea

Date of collection	Distance west of Bombay (km)	Altitude (km)	^{222}Rn concentration (dpm/m^3)	Remarks
26 August 1969	0–50	0	157±10	Easterly winds
		0·9	104±7	
		1·5	53±5	
		2·1	35±3	
		2·7	28±3	
		3·7	35±3	

The net counting rates of air samples ranged between 60–120 counts per hour. Blanks, done using stored air and nitrogen samples, gave negligible activity; the blank counting rates were less than 2–3 counts per hour.

The concentration of radon in the easterly continental air mass (Table I) decreases from 157 dpm/m^3 at ground level to about 35 dpm/m^3 at 2·1 km. Between 2·1 and 3·7 km the concentration is nearly constant at 30±5 dpm/m^3,

TABLE II

Concentrations of ^{222}Rn over the Arabian Sea

Date of collection	Distance west off Bombay (km)	Altitude (km)	^{222}Rn concentration (dpm/m^3)	Remarks
27 June 1970	10–50	1·2	98±10	Cloudy, with a little rain
		2·4	92±15	
		3·7		
	350–400	1·2	103±15	
		2·4	75±10	Clear weather
		3·7	115±15	
10 July 1970	0–50	0	73±10	
		1·2	85±10	Cloudy
		2·4	90±15	
		3·7	110±20	
	350–400	1·2	83±10	
		2·4	72±12	Cloudy
		3·7	83±15	
29 July 1971	0–50	0	60±10	
		1·2	110±10	
		2·4	115±25	
		3·7	110±15	
	350–400	1·2	65±10	
		2·4	140±15	
		3·7	160±25	

Samples were collected between 10·00 a.m. to 12 noon.

From the observed gradient up to 2.1 km an estimate of the turbulent diffusion coefficient has been made. The estimated mean value of the eddy diffusion coefficient is 6×10^4 cm^2/sec, which is consistent with the values reported for the normal atmosphere (Junge, 1963).

The results presented in Table II show that the concentration of radon in the monsoon air mass over the coast (0-50 km) and at 400 km west of Bombay are similar, approximately 80 ± 20 dpm/m^3. The vertical gradients are small except in the profile of 29 July 1971, where an inverse gradient in the concentration over the Arabian Sea is observed. The results in Table II are preliminary, and hence only the following indicative conclusions have been derived:

(i) the monsoon air mass is homogeneous and well mixed, often up to 400 km west off Bombay. The absence of normal vertical gradient in the radon concentration suggests very strong turbulence in the air mass, a result not unexpected.

(ii) the high concentration of ^{222}Rn in the samples even at 2-3 km altitudes indicates recent continental origin of the monsoon air mass.

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