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Temporal variation of radioactivity at NARL, Gadanki.

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ABSTRACT

The activity concentrations of radon were measured using AlphaGuard PQ-2000PRO along with meteorological parameters at NARL, Gadanki, India. The diurnal and monthly variations of activities of radon show maxima in the early morning hours when the turbulence mixing is minimum; whereas in the afternoon the turbulence mixing is maximum and concentrations exhibit minima. The arithmetic mean of radon concentration is 11.67 ± 2.4 Bq m^{-3} for the year 2012. The diurnal variations have reached the maximum concentration of 26 Bq m^{-3} in December 2012. Observations show an increase in the concentration of radon during nighttime compared to the daytime values. Also observed is the diurnal variation of radon that exhibits a positive correlation with the relative humidity and is negatively correlated with ambient temperature of the atmosphere.

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Introduction:

The planetary boundary layer is that region of the lower atmosphere in which the influences of the earth's surface are directly felt. The primary influences of the surface are drag, heating or cooling, and evaporation or condensation. These processes cause vertical fluxes of momentum, sensible heat, and moisture, which penetrate into the lower atmosphere to a finite height. These fluxes, in turn, generate turbulence, ultimately controlling the mean profiles of wind speed, temperature, and water vapour in the planetary boundary layer (Hoppel et al., 1986).

The origin of radon (^{222}Rn) in the earth's crust stems directly from the uranium and its decay products are distributed in minute quantities in the ground within a few meters below the surface (Israelsson et al., 1973). A fraction of the radon gas generated in soil near the earth's surface enters the atmosphere before undergoing radioactive decay (Nazaroff, 1992). The amount of radon that escapes depends on the amounts of radium in the ground, the type of the soil cover, porosity, dampness and temperature of the soil (Pearson and Jones, 1966). The radon daughters are charged particles and are chemically reactive. As soon as they are formed they get attached to the aerosols in the atmosphere (Graustein and Turekian, 1990), their behaviour is similar to that of the behaviour of the aerosols with respect to growth and transport, and in their removal processes in the atmosphere (Turekian et al., 1977).

The present study was carried out in order to understand the nature and extent of the influence of radon on atmosphere over a region near to the earth's surface. Measurements of atmospheric radioactivity at a height of 1 m above the surface of the Earth have been made regularly during the year 2012. All the measurements were made at the National Atmospheric Research Laboratory, Gadanki, India, which is located at the rural area. The nearest road with vehicular traffic is about 200 meters away. The instruments are kept on open ground. The behaviour of radon with time is monitored and analyzed.

Methodology:

The AlphaGuard PQ-2000PRO is used for the continuous monitoring of the radon concentration. The AlphaGuard uses the proven principle of the pulse ionization chamber as in alpha spectroscopy and is shown in Fig. 1. In regular operation the measuring gas gets in diffusion mode via a large-surface glass fiber filter into the ionization chamber. AlphaGuard is also housed with sensors of meteorological variables such as temperature, relative humidity and pressure. Observations were carried out at the National Atmospheric Research Laboratory (NARL), Gadanki (13.5N, 79.2E), a rural tropical warm location in peninsular India, 2 km north east from main residential area with no major industrial activities.

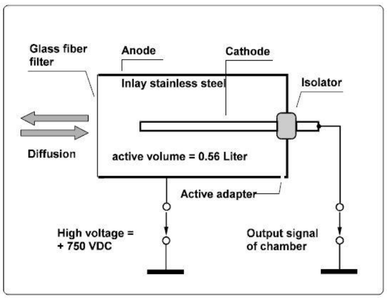

Fig. 1: Schematic diagram of the ionization chamber in AlphaGuard

Results and Discussion:

The concentrations of radon vary from time-to-time and the concentrations of radon at the ground level are governed by its exhalation rate and atmospheric diffusion depending on influence of meteorological variables. The radon emanated from the earth's surface distribute in the atmosphere depending on the geological and meteorological conditions. As temperature inversion occurs in the atmosphere, radon concentration will vary accordingly and show diurnal variations (Nagaraja et al., 2003). Therefore, the variations of radon in air were measured along with the ambient temperature and relative humidity to study the temporal distributions.

Diurnal variations:

The diurnal variation of activity of radon along with temperature and relative humidity for a typical day on 23rd June 2012 is shown in Fig. 2. It is seen from the figure that the concentrations are maxima during the early morning hours, generally between 0500 and 0700 hrs of Indian Standard Time (IST). It decreases after sunrise, attaining minima during the afternoon, 1300 to 1600 hrs of IST. It is observed that the concentration of radon follow the trend of the relative humidity, in general (Wilkening, 1990). The raise of temperature causes increased vertical mixing and rising of aerosols to the higher altitudes resulting in lower concentration of radon at the ground level. If the temperature reduces the vertical mixing and raising of aerosols to the higher altitude also reduces. As a consequence, the aerosol to which radon is attached will be at higher concentrations. This results in the increase of radon concentrations near to the surface of the earth (Porstendörfer, 1994, Lebedyte et al., 2002). Over continents, radon exhaled from the soil is of prime interest for small ion production. During the daytime unstable conditions, the radioactive gases get dispersed to higher altitudes and thus cause small ionization rates close to the earth's surface. Experimental observations of Porstendörfer et al. (1991) confirms such accumulation of radon and its short-lived decay products close to the earth's surface during calm and stable conditions at nighttime. Nagaraja et al. (2003) carried out the similar type of measurements at Pune, and the results obtained are of the same order. The observations of Nagaraja et al. (2003) i.e., maximum concentrations of radioactivity in the early morning hours also support such accumulation of radioactive gases near to the earth's surface. In principle, the similar diurnal behaviour is observed worldwide.

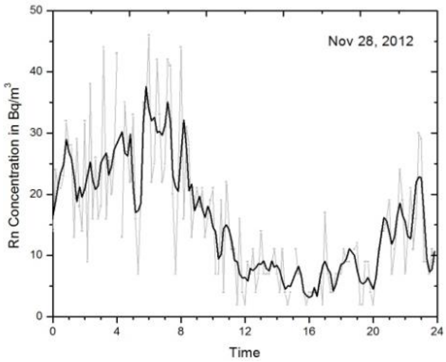

Fig. 2: Diurnal variation of activity of radon

Diurnal variation of radon concentration is universally ascribed to variations in atmospheric stability (Hoppel et al., 1986). Early morning atmospheric temperature inversions lead to an extremely stable atmosphere. This restricts the vertical turbulent mixing which leads to relatively higher near ground level radon concentrations. After sunrise, solar radiations warm the lower atmosphere, breaking up the inversion leading to a substantial decline in concentration. Concentrations remain low until late afternoon when radiant cooling of the surface leads to increase in atmospheric stability and a corresponding increase in radon concentration. It is also seen that the diurnal variation of the concentration of radon shows a positive correlation with the humidity and negative correlation with ambient temperature indicating their incoherence. The relative humidity is usually associated with periods when wind speed is low and atmosphere is stable. The low winds and atmospheric stability are probably the most important factors resulting in increased concentration of radon.

Monthly variations:

Monthly mean values of the concentration of radon for 2012 are shown in Fig. 3. The concentration is maximum during early morning hours, generally between 0500 and 0800 hours of Indian Standard Time (IST). It decreases after sunrise, attaining a minimum during afternoon, 1200 to 1600 hours of IST. Heating of the Earth-surface by the sun during the day and cooling during the night cause a marked diurnal change in temperature near the surface. As a result, cool air near the ground will accumulate radon isotopes from surface flux during the night, while during the day the warm air will be transported upward carrying radon with it. The result is a significant diurnal variation in the concentrations of radon as illustrated in Fig. 2. It is observed that the concentrations show a correlation with the relative humidity and anti-correlation with the temperature. This indicates that the radon concentration is influenced mainly by the turbulent diffusion caused by the changes in temperature.

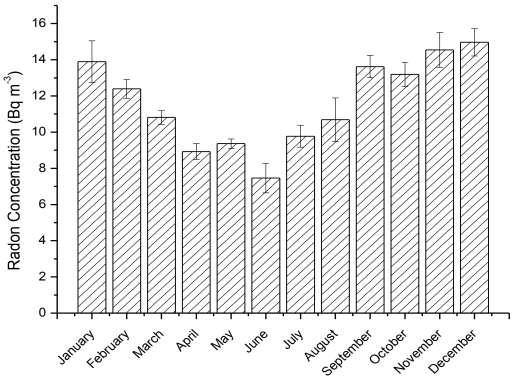

Fig. 3: Monthly variation of radon for the duration from January to December 2012

The values range from 1.26 to 25.43 Bq m^{-3} for the duration from January to December. Their standard deviations are shown through error bars in the diagram. It shows that the concentration is minima during April to June and may be due to increase in temperature during summer months. The concentration increases on either side and shows maximum for the months January to March and September to December of the year 2012.

Table 1: Statistical variation of radon in 2012

Months in 2012	Mean (Bq m^{-3})	Std Dev	Min	Max	Median
Jan	13.89	5.64	6.22	25.41	12.77
Feb	12.39	2.59	7.49	15.84	12.78
Mar	10.81	2.08	6.13	15.83	10.67
Apr	8.93	1.70	6.74	12.50	8.76
May	9.36	1.20	7.15	11.39	9.52
Jun	7.46	2.94	1.26	11.99	7.69
Jul	9.77	1.82	7.53	12.40	10.39
Aug	10.69	4.81	5.60	24.44	9.27
Sept	13.62	3.37	6.66	20.16	13.67
Oct	13.19	3.29	6.84	20.62	12.97
Nov	14.54	5.12	5.39	24.92	15.08
Dec	14.96	4.05	6.03	25.43	15.77
Ave	11.67	2.40	7.87	14.96	11.60

The concentration in the month of December is of twice the observed values during June. Monthly mean values vary from 7.46 to 14.96 Bq m^{-3}. However the absolute deviations from the mean values that suggests variability is less for summer months compared to monsoon months. The detailed statistical variations are shown in table: 1.

Summary:

In the atmosphere above the surface of the Earth the activity concentrations of radon is measured using AlphaGuard PQ-2000PRO along with the meteorological parameters at NARL, a continental location, Gadanki, India. The concentrations show maxima in early morning hours when turbulence mixing is minimum; minima in the afternoon where turbulence mixing is maximum. The diurnal variations in the concentrations of radon are found to exhibit correlation with the relative humidity, and anti-correlation with the temperature.

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