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Atmospheric electrical conductivity near the ground surface related to radioactivity and air pollution at three different locations in Mysore, India

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ABSTRACT

The atmospheric electrical conductivity was recorded during 2006 at Mysore(12°N, 76°E), India, in fair weather days. The observations of conductivities were made at three different locations in Mysore. The first location is Maharani's Science College Campus (MSCM), second is the Manasagangotri, University Campus (MGM) and the third is St. Joseph's School campus (SJS). The total electrical conductivity varies from 4.4 to 64.6 $fS.m^{-1}$ 10.4 to 44.5 $fS.m^{-1}$ and 1.6 to 98.8 $fS.m^{-1}$ in MSCM, MGM and SJS respectively. Overall diurnal variation shows that in MSCM campus the concentration of radon and its progeny and electrical conductivity values are slightly higher than in MGM campus. Conductivity values in SJS are higher than the other two locations even though the trend of diurnal variation is similar in all the three locations. We have observed that even though radon concentrations at MGM are slightly higher than that of SJS conductivity values are lower. This may be attributed to air pollution in the area resulting in the loss of small ions due to ion-aerosols and ion –ion recombination processes.

KEYWORDS

Radioactive aerosols;
Ion production;
Gerdien condenser.

INTRODUCTION

Uranium is widely distributed in nature and it occurs as a mixture of mainly three isotopes ^{234}U, ^{235}U and ^{238}U. Through the natural decay series it generates ^{222}Rn. The radon migrates through the mechanism of recoil, diffusion and transport through porosity in soil, fractures in rocks and along with weak zones such as shear, faults, thrust etc. From some geological situations, radon migrates long distances from its place of origin and alpha particle recorders at the earth surface can detect it. This is responsible for ionization of air molecules in the atmosphere. Several types of electrically charged submicroscopic particles are normally found in the atmosphere. Atmospheric ions are of two principal types, small ions and large ions, although classes of intermediate ions are occasionally been reported. The ionization process that forms small ions depends upon two distinct agencies, cosmic rays and radioactive emanations. Each of these consists of energetic particles that ionize neutral air molecules by knocking out one or more electrons from the atoms. The resulting free electron and positively charged atom (or molecule) immediately attaches themselves to one or more number of neutral air molecules, there by forming new small ions. In the presence of aerosol particles, some of the small ions will intern attach themselves to these particles, there by creating new large ions.

The atmospheric conductivity depends on the existence of positive and negative ions and it can be expressed in terms of the ion concentrations and mobilities of the individual ions given by,

$$\sigma = \mathbf{e}\left(\mathbf{n}^{+}\mu^{+} + \mathbf{n}^{-}\mu^{-}\right)$$

where $\mu^{+}$and μ^{-} are the mobilities and n^{+} and n^{-} are the number densities of positive and negative ions, respectively and e is the electronic charge. If several types of ions of different mobility are present in the atmosphere, the above expression become

$$\sigma = \mathbf{e}\sum_{\mathbf{i=1}}^{\mathbf{n}}\left(\mathbf{n}_{\mathbf{i}}^{+}\mu_{\mathbf{i}}^{+} + \mathbf{n}_{\mathbf{i}}^{-}\mu_{\mathbf{i}}^{-}\right)$$

It is well known that, the mobility of large or intermediate ions are a few orders of magnitude smaller than those of small ions. Therefore their contribution to the polar conductivity is relatively smaller than that of the small ions. Small ions of opposite polarity recombine and cause a decrease in the small ion concentration and consequently a reduction in the conductivity of air. In the presence of aerosol particles losses in the small ion concentration are caused both due to the ion-ion recombination process and attachment of small ions to the aerosol particles. Attachment of small ions to the aerosol particles makes them almost immobile and causes a further decrease in conductivity of the atmosphere. This develops inverse relationship between the aerosol concentration and the electrical conductivity[1-5] Due to this inverse relationship between the electrical conductivity and the pollution, the electrical conductivity can act as a pollution index.

Study area

The area of present study is the city of Mysore, in Karnataka, India. Mysore lies between 12ºC 15" and 12ºC 25" North latitude and between 76ºC 35" and 76ºC 14" East longitude with a height of about 767 m above mean sea level, forming a part of catchment's zone of the cauvery and Kabini rivers. The city has an area of about 37.37 Sq km. A large reservoir namely Krishnarajasagar (KRS) is situated towards the north west of Mysore city. Chamundi hill(1048m) is an important landmark situated to the south. A moderate climate prevails throughout the year. Mysore City has a population of about one million. There are about 2 lacs petrol and diesel powered vehicles. About 50small scale factories, mostly chemical and engineering, make the industrial picture of Mysore.

Mysore has essentially a typical monsoon climate. Bulk of the rainfall is received from south-west monsoon which sets in the month of May or June and continues up to the end of September. When the north East monsoon starts, Mysore records about 760mm rains a year. The north-east monsoon ceases by November and the winter season commences which lasts till the end of February. Summer begins in the month of March and will be intense towards the end of May. The minimum temperature is generally in the month of November and maximum in May. The annual mean daily temperature is 30ºC maximum, and 19ºC minimum. Relative humidity ranges from 49% to 80%. The average maximum wind velocity ($5.5 m.s^{-1}$) was observed in June and July and the average minimum ($1.8 m.s^{-1}$) during the month of December and January.

The atmospheric electrical conductivities in the lower surface at 1m-height radon and its progeny concentration with meteorological parameters were measured at three different locations. One is the Department of Physics, university campus which is covered with green grass, clean surroundings and also less polluted area, Mysore (MGM), the other at Maharani's science college campus known with anthropogenic activities and vehicular traffic, Mysore city(MSCM) and the third one is St Joseph's school campus, Jayalakshmipuram, Mysore (SJS), which is open field and very close to the roadside where vehicles move frequently, Small ions are part of the atmospheric aerosols spectrum, and study of ion-aerosol interactions is fundamental in atmospheric physics[3,6].

The main objectives are comparing electrical conductivity of air near the earth surface in three different locations and correlate that with ion pair production rate due to radioactivity.

EXPERIMENTAL

Gerdien condenser

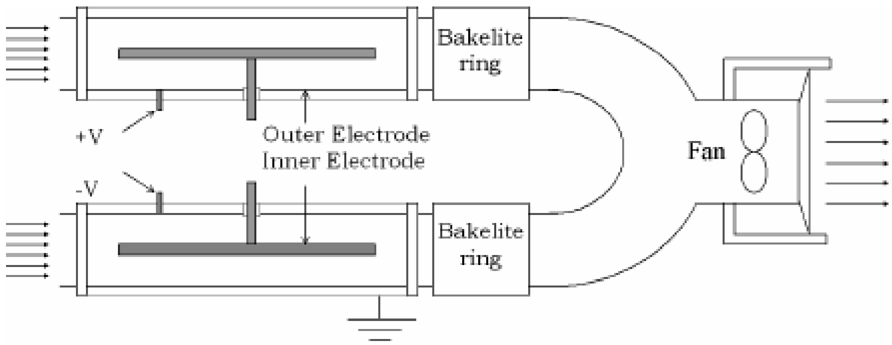

Figure 1: Schematic view of gerdien condenser

The Gerdien condenser is a simple instrument that has been used for the measurement of atmospheric electrical conductivity of both positive and negative polarities simultaneously, which is locally fabricated as per Dhanorkar et al., (1989)[7]. The schematic diagram of the instrument is shown in figure 1. The Gerdien condenser is basically a cylindrical capacitor that collects atmospheric ions. It consists of two coaxial cylinders between which air is allowed to flow. A voltage is applied to one cylinder, known as the driving electrode, with respect to the other. This driving voltage repels ions of one polarity towards the other electrode where ions get collected. The Gerdien condenser is insulated and is kept in a third cylinder, which is electrically grounded. This cylinder shields the measurements from external disturbances. The inner cylinder is used as the collector and the outer one as the driving electrode. The signals from the two condensers are amplified separately with two electrometers, with amplifiers and its output is fed to the computer. The air flow (about 19 litres per second) through the condenser can be achieved by using a fan. To reduce the intensity of turbulent mixing, the ends of the inner electrodes that face the air stream are rounded smoothly. To reduce the effect of atmospheric wind in the condenser, the inner electrode is placed well inside the outer electrode away from the entrance, allowing the initial atmospheric turbulence to decrease considerably.

Low level radon detection system

The concentration of radon in the atmosphere is measured using the Low Level Radon Detection System (LLRDS) following the well-established procedure[8]. The procedure consists of collecting the air sample in an evacuated chamber and exposing a circular metallic disk of 50 mm diameter to the air containing radon inside the collection chamber. The disc is maintained at a negative potential of 800 V with respect to the body of the chamber, which is grounded. Radon decay products, as they are produced, are known to be positively charged. The decay products formed inside the chamber get attracted to the disc, which is negatively charged. The decay products are collected for 75 minutes. The disc is then taken out and counted for alpha activity typically for about 5000 sec. The advantage of this present system is that, no pump is required for sampling. The evacuated chamber can be taken to the site of sampling and the grab sample taken by opening the stopcock, after which it is sealed automatically. Measurement is done later at a centralized place. The minimum detectable accuracy for radon in LLRDS is as low as 1.7-8.8 Bq m^{-3}, depending on the relative humidity conditions. The concentration of radon Rn (Bq m^{-3}) is calculated with the expression (1)

$$R_n = \frac{1000C}{EFVZ} \qquad (1)$$

Where C is the total number of counts observed during the counting period, E is the efficiency of alpha counting system, F is the efficiency of collection of RaA-atoms on the metallic disc, V is the volume of LLRDS chamber, Z is the correction factor for build up and decay of radon daughter atoms on the metallic disc during the exposure and counting period.

Air flow meter

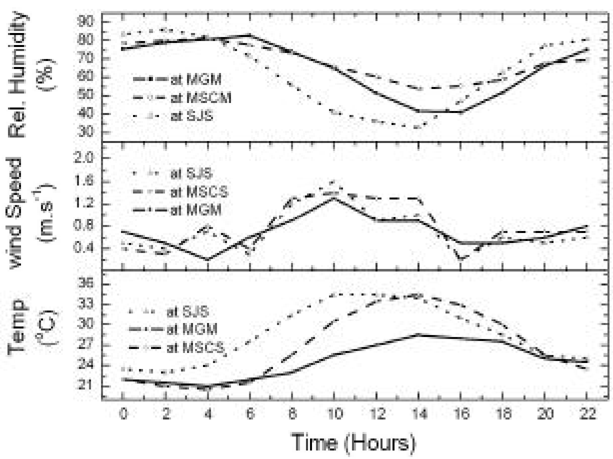

Figure 2: Diurnal variation of relative humidity, wind speed and ambient temperature at three locations in Mysore city

Radon progeny concentrations are measured using an air flow meter[9] of 15cm long and 1 cm diameter. Air is drawn through a glass fiber filter paper by means of a suction pump at a known flow rate. The radon progeny in air sample are retained on the filter paper. Total activity on the filter paper is measured at three different counting intervals of 2-5, 6-20 and 21-30 minutes. Activities of RaA (^{218}Po), RaB (^{214}Pb) and RaC′ (^{214}Po) are calculated using the equations(2),(3), & (4)

$$RaA = \frac{4.249019(C_1) - 2.062417(C_2) + 1.949949(C_3)}{VE}(Bqm^{-3}) \quad (2)$$

$$RaB = \frac{-0.355129(C_1) + 0.006232(C_2) + 0.240618(C_3)}{VE}(Bqm^{-3}) \quad (3)$$

$$RaC' = \frac{-0.215175(C_1) + 0.371319(C_2) - 0.502945(C_3)}{VE}(Bqm^{-3}) \quad (4)$$

Where C_1, C_2 and C_3 are the gross counts during the three counting intervals, E is the efficiency of alpha counting system and V is the sampling rate in liters per minute.

Ion pair production rate

The ion-pair production rate is estimated from the measured radon and its progeny concentrations. The total energy released ε(eV $m^{-3}s^{-1}$) due to both radon and its progeny is computed from radon and its individual progeny concentrations and is used to calculate ion-pair production rate Q($\times 10^6$No. $m^{-3}s^{-1}$)

$$\varepsilon = 5.49\times10^6\,Rn + 6.00\times10^6\,RaA + 0.85\times10^6\,RaB + 7.69\times10^6\,RaC' \text{ and } Q = \varepsilon/32 \text{ ion pairs cm}^{-3}s^{-1}$$

Where Rn, RaA, RaB and RaC′ are the concentrations (Bq m^{-3}) of ^{222}Rn, ^{218}Po, ^{214}Pb and ^{214}Po respectively.

RESULTS AND DISCUSSION

Radon and its progeny concentrations and ion pair production rate

Concentrations of radon in the atmosphere are affected not only by the magnitude of the exhalation rates, in general, but also by atmospheric mixing phenomena. Solar heating during the daytime tends to induce some turbulence, so that radon is more readily transported upwards and away from the ground. During night atmosphere is relatively calm with low winds and little convective motion. Radon exhaled from the soil accu-

TABLE 1: Diurnal variation of radon, its progeny concentration, ionization rate and atmospheric electrical conductivity at manasagangotri, Mysore city

Time	Concentration (Bqm^{-3})				Ion. Rate (n)	Conductivity (σ) ($fS.m^{-1}$)		σ/n
(Hours)	Rn	RaA	RaB	RaC′	($no.m^{-3}s^{-1}$)$\times10^6$	Positive	Negative	$fS.m^{-1}(no.m^{-3}s^{-1})^{-1}\times10^6$
0	7.31	2.69	0.28	0.13	1.80	16.9	15.8	18.2
2	9.30	3.62	0.26	0.82	2.48	21.8	20.0	16.9
4	15.24	5.14	0.41	0.16	3.63	25.2	21.2	12.8
6	16.15	5.89	0.35	0.37	3.97	18.6	12.6	7.9
8	6.10	5.53	0.28	0.31	2.17	5.2	5.8	5.1
10	3.15	2.01	0.31	0.22	0.98	5.1	4.8	10.1
12	4.73	2.25	0.28	0.20	1.29	4.2	4.4	6.7
14	4.56	2.79	0.66	0.19	1.37	2.9	1.7	3.4
16	4.65	2.32	0.10	0.79	1.43	8.8	8.1	11.9
18	5.20	1.08	0.46	0.74	1.28	9.1	8.4	13.6
20	7.92	5.49	0.38	0.05	2.41	9.5	9.3	7.8
22	3.99	6.05	0.80	0.01	1.84	17.4	14.2	17.2
GM	6.46	3.31	0.34	0.20	1.88	9.8	8.6	9.8
Min	3.15	1.08	0.10	0.01	0.98	2.9	1.7	3.4
Max	16.15	6.05	0.80	0.82	3.97	25.2	21.2	18.2

TABLE 2: Diurnal variations of radon, its progeny concentration, ionization rate and atmospheric electrical conductivity at Maharani's science college, Mysore city

Time	Concentration (Bqm^{-3})				Ion. Rate (n)	Conductivity σ($fS.m^{-1}$)		σ/n
(Hours)	Rn	RaA	RaB	RaC'	$(no.m^{-3}s^{-1})\times10^6$	Positive	Negative	$fS.m^{-1}(no.m^{-3}s^{-1})^{-1}\times10^6$
0	13.44	7.68	0.15	0.01	3.75	21.8	21.5	11.5
2	14.61	5.42	0.14	0.02	3.53	27.1	26.9	15.3
4	15.00	7.75	0.36	0.10	4.06	31.8	30.8	15.4
6	22.31	9.42	0.71	0.05	5.62	32.4	32.2	11.5
8	16.44	6.02	0.23	0.11	3.98	14.8	14.5	7.4
10	8.83	0.57	0.14	0.58	1.76	2.4	2.0	2.5
12	6.90	4.99	0.09	0.06	2.14	3.5	3.1	3.1
14	9.02	2.06	0.17	0.22	1.99	7.8	7.5	7.7
16	7.54	1.61	0.19	0.19	1.65	10.8	10.5	12.9
18	10.38	5.80	0.22	0.02	2.88	13.9	12.8	9.3
20	10.57	5.89	0.50	0.03	2.94	15.4	15.1	10.4
22	10.81	8.08	0.19	0.07	3.39	16.3	15.8	9.5
GM	11.49	4.36	0.22	0.07	2.95	12.9	12.3	8.6
Min	6.90	0.57	0.09	0.01	1.65	2.4	2.0	2.5
Max	22.31	9.42	0.71	0.58	5.62	32.4	32.2	15.4

TABLE 3: Diurnal variations of radon, its progeny concentration, ionization rate and atmospheric electrical conductivity at St. Joseph's School, Mysore city

Time	Concentration(Bqm^{-3})				Ion. rate(n)	Conductivity σ($fS.m^{-1}$)		σ/n
(Hours)	Rn	RaA	RaB	RaC'	$(no.m^{-3}s^{-1})\times10^6$	Positive	Negative	$fS.m^{-1}(no.m^{-3}s^{-1})^{-1}\times10^6$
0	12.05	7.18	0.91	0.34	3.52	26.8	20.2	13.4
2	13.20	3.66	1.12	0.74	3.16	26.6	22.6	15.6
4	10.67	5.49	1.24	0.56	3.03	32.9	31.0	21.1
6	38.39	3.23	1.38	0.98	7.46	53.2	45.6	13.2
8	7.92	9.99	1.15	0.20	3.31	1.6	2.1	1.1
10	2.60	5.33	1.04	0.47	1.59	1.8	1.4	2.0
12	5.32	3.69	1.38	0.47	1.75	8.1	5.9	8.0
14	4.62	6.10	0.99	0.39	2.06	5.9	9.1	7.3
16	6.46	4.92	1.62	0.28	2.14	3.3	2.4	2.7
18	2.20	16.35	1.85	0.01	3.49	1.5	1.3	0.8
20	2.40	8.12	0.78	0.30	2.03	32.0	29.0	30.1
22	17.88	5.00	0.98	0.49	4.15	33.0	30.3	15.3
GM	7.22	5.91	1.17	0.32	2.86	9.9	9.0	6.6
Min	2.20	3.23	0.78	0.01	1.59	1.5	1.3	0.8
Max	38.39	16.35	1.85	0.98	7.46	53.2	45.6	30.1

mulates near the ground leading to gradual increase in the concentrations. Diurnal variations of radon and its short-lived progeny concentrations, ion pair production rate due to radon and its progeny concentrations and atmospheric electrical conductivity measured at Manasagangotri (MGM), Maharani's Science College (MSCS) and St. Joseph's School (SJS) are shown in TABLES 1-3. The radon concentrations gradually increases and reach maxima in the early morning, 03-07 hrs and decrease after sunrise, attaining minima in the afternoon, 12 to 16 hrs at all locations. After sunrise, as temperature increases, the humidity decreases(figure 2) resulting in the decrease of relative humidity in the atmosphere. This causes increased vertical mixing that result in lower concentration of radon and its progeny at the ground level. As a consequence at ground level, the aerosol to which radon and its daughters are attached will be present at higher concentrations during night and in the early morning hours, which in turn increases the ionization rate in the atmosphere[10-14].

It is also interesting that the concentrations of radon follow the trend of the relative humidity, in general. This is due to the fact that as temperature increases, the humidity decreases resulting in the decrease of moisture content in the atmosphere. This causes increased vertical mixing and rising of aerosols to the higher altitudes resulting in lower concentration of radon at the ground level. When the temperature decreases and hu-

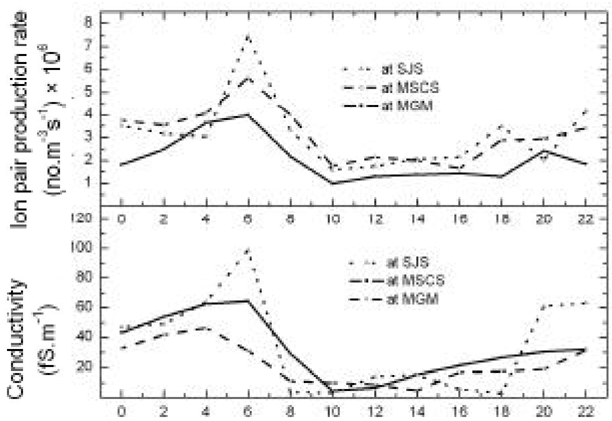

Figure 3: Diurnal variation of ion pair production rate and atmospheric electrical conductivity at three locations in Mysore city

midity increases, the vertical mixing and raising of aerosols to the higher altitude reduce. As a consequence, the aerosol to which radon is attached, will be present at higher concentrations during night and in the early morning hours at ground level. This results in the increase of radon concentrations near the surface of the Earth[15,16].

At MGM radon concentration varies from 3.15-16.15 Bq m^{-3} with a geometric mean of 6.46 Bq m^{-3} showing significant diurnal variation by a factor of 5-6. It is seen from the TABLE 1 that the concentration is maximum during the early morning hours, between 04 and 06hrs of IST at Mysore[11]. It decreases after sunrise, attaining a minimum between, 10 to 16hrs. The individual radon progeny such as RaA(^{214}Po), RaB (^{214}Pb) and RaC(^{214}Bi) also exhibit maxima in the early morning hours between 4 to 6 and minima during 12 to 16 hours in the afternoon. The individual concentrations are measured since each will contribute separately in the ionization of the atmosphere. Ion pair production due to radon and its progeny concentrations at MGM varies from 0.98×10^6 to 3.97×10^6 ion pairs m^{-3}s^{-1} with a geometric mean of 1.88×10^6 ion pairs m^{-3}s^{-1}.

Slightly higher radon and its progeny concentrations were observed at MSCM and SJS locations. This may be due to higher radium content in soil at these locations. At MSCM the radon concentration varies from 6.90 to 22.31 Bq m^{-3} with geometric mean of 11.49 Bq m^{-3}. Ion pair production due to radon and its progeny concentrations varies from 1.65×10^6 to 5.62×10^6 ion pairs m^{-3}s^{-1} with a geometric mean of 2.95 ion pairs m^{-3}s$^{-1}\times10^6$. Where as at SJS radon concentration varies from 2.20 to 38.39 Bq m^{-3} with geometric mean of 7.22 Bq m^{-3}. Ion pair production due to radon and its progeny concentrations varies from 1.59×10^6 to 7.46×10^6 ion pairs m^{-3}s^{-1} with a geometric mean of 2.86×10^6 ion pairs m^{-3}s^{-1}.

It is observed that conductivity of both polarities and ion pair production rate show maxima in the early morning hours and attain minima after sunshine. The positive and negative conductivities are approximately equal and their diurnal variations are generally mirror images of each other. The average positive and negative conductivity measured at MGM are 9.8 and 8.6 fS.m^{-1}, in MSCM are 12.9 and 12.9 fS.m^{-1} and at SJS are 9.9 and 9.0 fS.m^{-1} respectively. We can also observe that during day time even though radon concentrations at MGM are slightly higher that of SJS conductivity values are lower. This may be attributed to the effect of aerosols near SJS.

Diurnal variation of electrical conductivity, ion pair production rate due to radon and its daughter products and total conductivity measured at three locations are shown in figure 3. It is observed that the conductivity of both polarities and ion pair production rate show maxima in the early morning hours and attain minima in the afternoon at all the locations. This is due to the fact that as temperature increases, the humidity decreases and causes increased vertical mixing and rising of ions to the higher altitudes, that result in lower value of conductivity at the ground level.

The increase in conductivity during the early morning (04-06 hours) is mainly because of the ionization produced by radioactive substances present in the atmosphere. As the day advances the temperature increases and hence the turbulence increases and thereby reducing ionization leading to the decrease of conductivity in the afternoon. Hence, the diurnal variation of conductivity follows the trend of ion–pair production rate especially in the early morning hours as shown in the figure 3. Also, during day time the UV radiation stimulates gas to particle conversion and generates ultra fine aerosol particles which are main sink of small air ions[17]. This process results in depression of conductivity during day time. During daytime in MSCM variations is attributed entirely to the effect of airborne

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pollution due to large number of motor vehicles traveling near the station, reducing small ion concentrations and consequently the atmospheric electrical conductivity. In MGM the atmosphere is relatively calm, less polluted and less anthropogenic activities and their conductivity values remains constant after the depression.

The ratio of total atmospheric conductivity to ion pair production at MGM, MSCM and SJS are 9.8, 8.6 and 6.6 (10^6 ion pairs.$m^{-3}s^{-1}$) $(fS.m^{-1})^{-1}$ respectively. Lower value of the ratio observed at SJS and MSCM may be because of decrease of small ions and conductivity due to the effect of air pollution and anthropogenic activities near these stations.

CONCLUSION

The atmospheric electrical conductivity measured over three locations shows similar type of diurnal variations. At MGM radon concentration varies from 3.15-16.15 Bq m^{-3} with a geometric mean of 6.46 Bq m^{-3}, at MSCM from 6.90 to 22.31 Bq m^{-3} with geometric mean of 11.49 Bq m^{-3} and at at SJS from 2.20 to 38.39 Bq m^{-3} with geometric mean of 7.22 Bq m^{-3}. The average positive and negative conductivity measured at MGM are 9.8 and 8.6 fS.m^{-1}, in MSCM are 12.9 and 12.9 fS.m^{-1} and at SJS are 9.9 and 9.0 fS.m^{-1} respectively. The ratio of total atmospheric conductivity to ion pair production at MGM, MSCM and SJS are 9.8, 8.6 and 6.6(10^6 ion pairs.$m^{-3}s^{-1}$) $(fS.m^{-1})^{-1}$ respectively. Lower value of the ratio observed at SJS and MSCM may be because of decrease of small ions and conductivity due to the effect of air pollution and anthropogenic activities near these stations.

REFERENCES

[1] R.C.Sagalyn, G.A.Faucher; Quart J.R.Met.Soc., **82**, 428 **(1956)**.
[2] M. Misaki; J.Geophy.Res., **69**, 3309 **(1964)**.
[3] W.E.Cobb, H.J.Wells; Journal of Atmospheric Sciences, **27**, 814 **(1970)**.
[4] A.Mani, B.B Huddar; Pure.Appl.Geophys, **100**, 154 **(1972)**.
[5] W.A.Hoppel, R.V.Anderson, J.C.Willet; 'Atmospheric electricity in the planetary boundary layer In: The earth's electrical environment', National Academy Press, Washington DC USA, 149 **(1986)**.
[6] R.G.Harrison, K.L.Aplin; Journal of Atmospheric Environment, **36**, 4037 **(2002)**.
[7] S.Dhanorkar, C.G.Deshpande, A.K.Kamra; Atmospheric Environment, **23**, 839 **(1989)**.
[8] G.K.Srivastava, M.Raghavayya, A.H.Khan; Health Physics, **46**, 225 **(1984)**.
[9] M.Raghavayya; Radiation Protection Environment, **21**, 127 **(1998)**.
[10] J.Porstendorfer, C.Zock, A.Reineking; J.Environ Radioactivity, **51**, 37 **(1991)**.
[11] J.Sannappa, L.Paramesh, P.Venkataramaiah; Indian Journal of Pure Physics, **73B(4)**, 629 **(1999)**.
[12] M.A.Shenber; Sci.Tot Environ, **119**, 243 **(1992)**.
[13] S.B.Debaje, T.V.Ramachandran, K.G.Vemekar; Ind.J.Environ Protection, **16**, 755 **(1996)**.
[14] K.Nagaraja, B.S.N.Prasad, M.S.Madhava, M.S. Chandrashekara, L.Paramesh, J.Sannappa, S.D. Pawar, P.Murugavel, A.K.Kamra; Radiat Meas, **36**, 413 **(2003)**.
[15] M.Wilkening; 'Radon in the environment', Elsevier Science Publishers, PO Box 211, 1000 AE Amsterdam, The Netherlands, 1-137 **(1990)**.
[16] J. Porstendorfer; J.Aerosol.Sci., **25**, 219 (1994).
[17] U.Kikas, Mirme, E.Tamm, T.Raunemaa; Journal of Geophysical Research, **101**, 19319 **(1996)**.