A Case Study-Air Ion Variation with Respect to Meteorological Parameters at Rural Station Ramanandnagar (17°4'N74°25'E) India

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***Abstract*- The air ions are generated through thunder clouds, corona discharge, plant transpiration, combustion, waterfalls, wave breaking on water, splashing of raindrops and finally due to friction between two air levels and colliding of two air masses of different density and moisture. Seasonal variations of ions in atmospheric air have been investigated using Gerdien type air ion counter. This air ion counter is indigenously designed and developed at the Indian Institute of Tropical Meteorology Pune and operated at rural site Ramanandnagar. Positive and negative air ion concentration varies according to meteorological parameters temperature, relative humidity, and cloud cover. As average temperature increases from March to May relative humidity and cloud cover in the sky decreases, then both positive and negative ion concentration decreases from March to May and minimum-is observed in May. Meteorological parameters such as rain fall and wind speed also affects the concentration of positive and negative ions. Pollution index in January was 1.48, which is harmful to human health. Lowest value of pollution index is observed in October. Then as compared to all other months October is healthier to human health.**

Keywords- Cluster ions; Plant Transpiration; Aerosol; Pollution Index and Radioactivity

I. INTRODUCTION

The attachment of air ions to the aerosol particles is depending on the mobility of air ions. Therefore high mobility air ions are attached to the aerosol particles [1] and settled down on the ground. Aerosols concentrations are high and air ion concentrations are low at the Tropical place Pune [2]. At the place like Himalaya, it was observed that the concentrations of aerosol particles are low and air ion concentrations are high [3].

Electrical properties of the atmosphere may be determined by air ion concentration in the atmosphere. Thus, the measurement of air ion concentration is required to get complete information about the electrical state of the atmosphere and it may be used for weather prediction in future. On a smaller scale, the emission of aerosol from vehicles and industry is also a pressing issue. Atmospheric aerosol absorbs IR radiation and is significant in climate forcing. Although the science of climate change is largely based on computer modelling, real measurements of aerosol are vitally important to support and corroborate them. There is increasing concern about the health effects of very smallest particles, which are often missed by common measurement methods; despite making up the main body of the aerosol number concentration [4].

There is also provocative evidence to suggest that ion-assisted nucleation is an aerosol-forming process, particularly areas where condensation nuclei may be depleted. Rapid bursts of particle growth are commonly observed at Mace head on the west coast of Ireland [5] and have not been explained. Slower ionic growth has also been reported in Estonia, and it has been suggested this is the first stage of nucleation process [6]. Aerosol concentration and the ionization due to ground radioactivity close to the Earth's surface largely depending upon the prevailing meteorological conditions [7]. Consequently, the air ion concentration depends upon the prevailing meteorological conditions [8] and shows variations with the time day and season. In the rural station Ramanandnagar, climate is marked by clean atmosphere, very less dust particles in the air, low frequencies of calm conditions and high wind speed. At tropical place like Pune climate is marked by highly convective conditions, dusty atmosphere, high frequencies of calm conditions and reduced wind. Moreover, unlike in mid-latitudes, the ground is not covered by snow in the winter at rural station Ramanandnagar. Under such conditions, therefore, properties and distribution of ions in the atmosphere are excepted to be different from that at tropical place like Pune and mid-latitudes like Estonia. The goal of this paper is to observe the effect of meteorological parameters on the air ion concentrations at rural site Ramanandnagar. As India is developing country pollution and climate change is pressing issue throughout world. To see the effect of pollution on rural atmosphere, pollution index is calculated. From the knowledge of pollution index, we also try to highlight at rural site different months, which are harmful to human health.

II. MEASUREMENT AND METHODS

Terrain is surrounding the observatory some tree groups (about 80-90 trees in radius of 120 m) small woods, grass land and agricultural land. The backyard where outdoor observations are conducted is open agricultural land with sugarcane, wheat, corn fields. Observatory at Ramanandnagar is located in sparely populated rural region as shown in Fig. 1. It is 210 km southeast of Pune and 370 km southeast of Mumbai capital of Maharashtra (India). The river Krishna flows just 4 km to the

Northwest. A 20 feet road with an average traffic frequency of about 1-2 motor vehicles per minute close to the observatory. The observatory, in which we carried out the measurements, is located in the ground floor. The room was used for measurement of air ion concentration. At other time, there were no indoor activities in the laboratory. The floor area and volume of laboratory were 10 m^2 and 42 m^3 respectively. The overall surface area (floor, walls, ceiling and the surface of tables and cabinets) of the laboratory was approximately 63 m^2.

Fig. 1 Agricultral field surrounding the observatory at Ramanandnagar

For the measurement of atmospheric current various amplifiers are tested. As the atmospheric current is very small, therefore for the measurement of small magnitude of current a separate electrometer is necessary. Commercially available instruments exist with resolution of 1 fA [9], but these are bulky and expensive calibration devices unsuited for field work. When measuring such small currents, effects often considered negligible in other circumstances are comparable to the signal, such as leakage current, and also 50 H_z interfaces caused by the AC mains [10]. Care should be taken to minimize these problems whilst maximizing the time response, by careful design and component selection. To measure small currents (AD549JH) amplifier is used by converting it into a voltage, which is usually linearly related to the input current. The simplest form of i-to-v converter is resistor: for example, currents of 1 pA could be converted into 1 v by passing them through a high value resistor. However, a resistor is not ideal for current measurement because its time response is limited by the time constant of the resistor and its own capacitance. There is another way to utilize the properties of operational amplifiers. The output voltage of an op-amp is proportional to the potential difference at the inputs, with the constant of proportionality given by the gain [11]. In conjunction with a fixed resistance, operational amplifier can also be used to convert the voltage.

The calibration of the amplifier is done in the laboratory using a resistive method of generating small currents with a milli-volt (by using 1.5 volt battery supply and potentiometer) calibrator and a TΩ resistor.

The air ion counter, which is indigenously designed and developed at the Indian Institute of Tropical Meteorology Pune, is being operated at rural site Ramanandnagar [12]. There is only one set of instrument for the measurement of air ions.

The flow rate:

$$\Phi = u\,\pi(b^2 - a^2) \quad (1)$$

Where b is radius of outer cylinder, a-is the radius of inner cylinder, u is velocity of air flow. Then air ion concentrations can be calculated by using formula

$$N = I/e\Phi \quad (2)$$

Where, I is input current, Φ is flow rate; e is the charge of air ion. Note that it is not possible to measure positive and negative ion concentration simultaneously at a time. Therefore, we have measured the air ions of particular kind that is positive or negative ion on alternate days or epochs according to our convenience. By changing polarity of outer cylinder we can measure positive and negative air ion concentrations [13].

For fixed bias voltage, the ion current flowing through inner electrode is proportional to the ion concentration. After each bias voltage is switched on settling time is allowed before sampling of ion current flows. Noise may be defined in an electrical sense, as any unwanted signal. Many disturbances of electrical nature produce noise in receivers. Noise sometimes even forces a reduction in the bandwidth of system. To avoid this noise effect amplifier is kept inside the aluminium box. The combination of a greater proportion of charged aerosol causing more noise, and the associated reduced ion signal will diminish the signal to noise ratio. The effect of particulate space charge is thought to be the principal source of noise in the instrument. The main source of ionic noise is fluctuations in the ion concentration itself called as ionization noise. Fluctuations in the ion concentration are damped by self recombination and attachment to aerosol, but ion-aerosol timescales to reach steady state concentrations are of order 100 s [14]. As it takes about one-eighth of a second for an ion to be sucked through the Gerdien at typical flow rates, the effects of a local transient in the ion production rate are likely to be detected before a local steady state in the tube has been reached. Further evidence for the sensitivity of the instrument to ionic fluctuations has been observed directly by sealing the ends of the Gerdien condenser and measuring the current. Small peaks of current are seen, which may be attributed to individual ionization events in the tube, because the sealed tube prevents new ions entering. Air ion counter was constructed by minimizing all the errors present in the measurement of air ions. Positive and negative air ions are measured for 336 days with 30 second time resolution at rural site. The average air ions were calculated from data collected from 2007 to 2009.

Pollution index is defined as the ratio of positive to negative air ion ratio. It was observed that charge on the aerosol particle is positive. If aerosols in the atmosphere are more the positive air ions are more [15]. The mobility of negative air ions is high as compared to positive ions, these negative air ions are consumed by aerosol in the atmosphere. If there is balance between positive and negative air ion, the atmosphere is clean. If pollution index is greater than one means aerosols in the atmosphere are high. The pollution index nearly equal to one means there is no risk for human health. The pollution index above 1.2 is very harmful to human health.

III. RESULT AND DISCUSSION

Monthly mean percentage distribution of Positive and Negative Air ion at rural site (2007-2009): The monthly percentage distribution of positive and negative ion concentration in different ranges at rural site during 2007-2009 is shown in Table 1. It shows the monthly variations of different ranges of positive and negative ion concentration. For example, the largest positive ion concentration of the range 110-120X10 ions per cm^3 ions is 22.36% in January, attributed to higher Radon close to ground due to lower temperature. The largest negative ion concentration of the range 110-120X10 ions per cm^3 is 12.1% in October. October is mixing of thunderstorms and rain therefore more negative ions are produced. At the same time due to high sun radiation plant transpiration of Radon produces more negative ions. Lowest positive ion concentration of the range 10-20X10 ions per cm^3 covers 78.83% covers 74-83% in March, April and May, attributed to higher temperature and lower humidity.

TABLE 1 MONTHLY MEAN PERCENTAGE DISTRIBUTION OF POSITIVE AND NEGATIVE AIR IONS

Positive ion classx10 ions per cm^3	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
000-010	0.069	0.034	15.27	26	17	0.06	0	0	0	0	0	0.17
010-020	0	0.069	83.13	74	83	0	7	8	0	1.95	0	0
020-030	0	0.069	1.6	0	0	0	34	7.2	0.42	41.8	4	0
030-040	0.03	4.6	0	0	0	0	49.902	6.8	13.12	18.7	16	0
040-050	0.031	83.458	0	0	0	0	7	19.2	9.7	28.8	10	0.2
050-060	0.31	11.6	0	0	0	0.03	1.2	14.3	1.4	0.27	20	23.5
060-070	12.8	0.17	0	0	0	0	0.43	9.2	35.3	0	5	49.5
070-080	9.4	0	0	0	0	56.11	0.255	8.9	9	0	23	19.6
080-090	3.9	0	0	0	0	36	0.15	4.5	11.89	0	17	0.03
090-100	12.9	0	0	0	0	7.8	0.063	15.8	16	8.5	5	7
100-110	38.2	0	0	0	0	0	0	2.7	2.64	0	0	0
110-120	22.36	0	0	0	0	0	0	3.4	0.53	0	0	0
Negative ion classx10 ions per cm^3	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
000-010	0.17	6.97	0.035	20.12	29.1	0.069	7.8	13.7	0.035	0	3	0.035
010-020	0	0.035	0.61	79.72	67.4	0	10.6	9	0.17	0	2	0.37
020-030	0	0.104	40.35	0.139	3.47	0	14.51	7.4	0.1	0	10	0.9
030-040	0	0.38	48.3	0.035	0.04	0	6.5	6.78	0.17	0	0.8	0.2
040-050	0	47.9	10.31	0	0	0	5.2	8.1	0.47	2.22	0.2	4.7
050-060	0.28	40.98	0.3	0	0	0	2.23	13.7	24.75	25.7	4	2.15
060-070	23.5	4.17	0	0	0	0.035	35.095	8.9	23.05	16.9	30	15
070-080	56	0.13	0	0	0	0	14.8	8.4	16.9	17	40	37
080-090	19.13	0.069	0	0	0	56.18	2.9	11.79	13.2	13.3	10	23
090-100	0	0.035	0	0	0	36	0.33	3.73	16	8.5	0	7
100-110	0	0.035	0	0	0	7.8	0.035	3.6	5	4.3	0	8.2
110-120	0	0.035	0	0	0	0	0	4.9	0.13	12.1	0	1.3

The lowest negative ion concentration in the range 10-20X10 ions per cm^3 is 79.72% and 67.43% in April and May is shown in Table 1. This is because there is no rain in April and May; therefore negative ions are combined with pollutants. Also due to higher temperature and lower humidity Radon and Thoron gases are escaped in the upper atmosphere. The aerosols particles in the atmosphere have sizes which range from 10^{-3} to 100 micro-meter and even larger. In the month of March, April and May aerosol particles are introduced in the atmosphere by the gas-to-particle conversion, dust storms etc. or by man-made process such as automobile exhausts, industrial processes. As there is no rains in these months' ions diffuse to these aerosol particles and transfer their charge to the particles. Then life time marginally, therefore percent data points of both positive and negative small ions decreased. In the monsoon season both positive and negative ions are distributed in all different intervals, this is because of Plant transpiration of Radon and Thoron gas and rain drop splashing, waves from the river Krishna are the additional sources of ion production. The largest percent data points 22.36% of positive ions in the interval 110-120X10 ions per cm^3 are observed in January. As January is cold month, therefore during the nocturnal calms the accumulated radon and thoron ionization rates up to 100 $cm^{-3}s^{-1}$ and even more below one meter [16]. Additionally, the deposited radon daughters can create air ions close to the ground surface. Willet modelled the atmospheric of ions decreases electric electrode effect over the grass-covered ground and pointed out that the alpha radiation of the deposited Radon daughters is an important ionizing factor despite the fact that the path of alpha rays is only a few centimetres [17]. Radioactive aerosols are formed by two principle processes. In one process they are formed by condensation of a radioactive vapour; in the other radioactive decay fragments become attached to the exterior of a particle's surface. An example of this is the radioactive aerosol produced in the presence of radon gas ^{222}Rn, which consists of the radon daughter nuclide ^{218}Po attached to a pre-existing aerosol.

Radioactive aerosols are charged by the usual mechanism of external ion attachment, but additional external ions are created by the radioactive decay processes. These are formed by the appreciable ionization caused by ejected radioactive decay particles. The amount of ion-production depends on the energy and rate of emission of the emitted particles. A further form of electrification for radioactive aerosol is self-charging. This occurs when a radioactive source is actually within the aerosol particle. Emission of a radioactive decay particle from deep within the aerosol particle will lead to internal ionization. The ejected radioactive particle may also knock valence electrons from the aerosol particle's surface into the surrounding gas, which also charges the particle.

The charge on radioactive aerosols seems universally positive is probably due to the large number of secondary electrons produced. If the particles knocked out the aerosol are electrons, then the charge remaining on the aerosol particle will be positive alternatively, this could be due to positive ion formation around the particle.

Positive and negative air ion concentration varies according to meteorological parameters temperature, relative humidity, and cloud cover. As average temperature increases from March to May relative humidity and cloud cover in the sky decreased, then both positive and negative ion concentration decreased from March to May and minimum is observed in May. Meteorological parameters such as rain fall and wind speed also affects the concentration of positive and negative ions. In the January maximum wind speed is 4 m/sec and rainfall is 0 mm. This is very favourable condition for the production of air ion. Due to very low average wind speed (1.5 m/sec), average temperature (22 ℃) Radon and Thoron gas is close to the ground.

It was observed that impact of surface radioactivity becomes negligible as the turbulence intensity found much weaker Thoron concentrations on windy days than on calm nights. Also there are crops in the vegetated area, therefore plant transpiration of Radon and Thoron is the additional sources of air ion production. There is no rainfall in January. Aerosols produced from the various processes like automobile exhaust cooking coals are not settling to the ground. Therefore, yearly maximum of positive ion concentration of the order of 13 was observed in January Table 2. Since the negative ions are having higher mobility as compared to that of positive ions, more negative ions are combined with aerosol particles and settled to ground. It was also observed that, as compared to positive ion concentration maxima (12.8) negative ion concentration maxima (8.4) was low. Wind speed increases from January-April and a yearly maximum is observed in the May.

TABLE 2 MONTHLY POSITIVE ION, NEGATIVE ION, TEMPERATURE, RELATIVE HUMIDITY, CLOUD COVER, WIND SPEED AND RAIN FALL AT RURAL SITE RAMANANDNAGAR (2007-2009)

Month	Temperature			Relative Humidity			Cloud			Wind speed			Rainfall			Positive ions			Negative ions		
	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average
Jan	39	15	22	82	27	40	80	0	50	4	0	1.5	0	0	0	12.8	0	9.4	8.4	0.01	6.31
Feb	34	16	25.36	89	23	53.54	80	0	16	6	0	2.6	0	0	0	6.96	0.83	4.606	13.4	0.27	5.11
Mar	38	18	28.69	89	19	49.93	50	0	19	6	0	2.7	0	0	0	2.18	0.02	1.4	5.14	0.28	2.77
Apr	39	23	30.83	90	18	52.17	80	0	26	8	0	3.29	2.5	0	0.04	2.01	0.02	1.313	3.03	0	1.35
May	37	22	29.02	93	28	65.28	80	0	36	12	0	5.06	46.6	0	2.59	2.49	0.32	1.39	2.05	0.2	1.21
Jun	35	22	26.74	100	43	79.53	80	30	62	8	0	4.06	127	0	5.35	9.5	0.2	8.7	10.1	0.15	9.03
Jul	33	23	25.31	93	56	82.28	93	56	64.91	8	0	5.08	6.5	0	0.74	9.17	1.41	2.7	11.2	0	3.50
Aug	29	23	24.66	97	65	84.39	90	30	65.4	8	0	3.93	22.8	0	2.7	6.5	0.74	3.4	9.2	0.4	3.2
Sep	31	22	24.9	95	55	82.42	80	0	57	8	0	2.35	47.8	0	1.8	13.1	2.91	6.69	11.8	0.45	7.55
Oct	32	20	26.32	92	27	65.16	70	0	42	6	0	0.91	21.4	0	0.35	5.11	1.62	3.34	12.1	4.57	7.63
Nov	30	14	23.94	92	27	60	90	0	60.92	4	0	0.62	8.7	0	0.18	4.6	2.3	3.45	10.2	3.9	7.5
Dec	31	16	23.61	86	30	62.12	70	0	31	6	0	2	0	0	0	8.4	0.01	6.31	13.2	0.73	7.87

Seasonal Variation of Pollution Index (2007-2009): Pollution index is one or below one meaning that atmosphere is aerosol free. In January pollution index is 1.48 Table 3, which is harmful to human health [18, 19].

TABLE 3 MONTHLY VARIATION OF POLLUTION INDEX (2007-2009)

Month	Pollution Index	Month	Pollution Index
January	1.48	July	0.77
February	0.9	August	1.06
March	0.55	September	1.2
April	1	October	0.43
May	1.14	November	0.77
June	0.96	December	0.8

As negative ions have higher mobility as compared to positive ion, aerosols or volatile organic compounds are attached to negative ions and settled down on ground [20]. Due to rain fall in July large numbers of aerosols were settled down on the ground, at the same time negative air ions were not consumed by aerosols. Therefore pollution index in July was 0.77, which is healthy for human health. The lowest average cloud cover 16% is observed in February corresponding positive ion concentration 4.66 $x10^2$ ions per cm^3 and negative ion concentration 5.11 $x10^2$ ions per cm^3. As percentage of average cloud cover increases production of air ions from the cosmic ray decreases, therefore positive and negative air ion concentration decrease. In Monsoon rain fall scavenges aerosols presents in the atmosphere. Therefore pollution index is equal to one or below one in the month of June, July and August Table 3. In October rain fall was observed with thunder storms. Then as compared to positive air ions more number of negative air ions was introduced in the atmosphere. Therefore lowest value of pollution index is observed in October. Then as compared to all other months October is healthier to human health shown by Hedge and Eleftherais [21]. The peak in pollution index is observed in January may be due to temperature inversions radon gas close to the surface [22, 23, 24], which is source of air ions. Due to turbulence and higher temperature positive and negative ion concentration decreases and minimum is observed in May. Month of May is dustier, therefore pollution index 1.14, which is harmful to human health. The daily average highest relative humidity 84.39 is observed in August corresponding average positive ion concentration 3.4 and negative ion concentration 3.2. Pollution index in August is 1.06. That is less number of aerosols present in August as compared to May [25]. The lowest relative humidity 40 is observed in January corresponding to positive ion concentration 9.4 and negative ion concentration 6.3. This indicates that air ion concentration changes inversely with relative humidity. This is because as relative humidity increases both positive and negative ions are combined with water vapour.

IV. CONCLUSIONS

The largest percentage of negative air ions in the range of concentration of 110-120x10 ions per cm^3 is 12.1% and occurs in October. October is associated with mixing of thunderstorms and rain, therefore more negative ions are produced, at the same time due to high sun radiation plant transpiration of Radon produces more negative ions. Lowest positive ion concentration of the range 10-20 x10 ions per cm^3 covers 74-83% in March, April and May, attributed to higher temperature and lower humidity. The lowest negative ion concentration in the range 10-20x10 ions per cm^3 is 79.72% and 67.43% in April and May. This is because there is no rain in April and May; then negative ions are combined with pollutants. Also due to higher temperature and lower humidity Radon and Thoron gases escapes in the upper atmosphere. In winter season due to very low temperature Radon and Thoron gas and their radio active decay products in the lower atmosphere produces more positive ions than negative ions. Thus in the winter average positive ions are greater than average negative ions. Due to temperature inversions pollution index in January was 1.48, which is harmful to human health. Lowest value of pollution index is observed in October. Then as compared to all other months October is healthier to human health. The charge on the aerosol particle is positive. If aerosols in the atmosphere are more the positive air ions are more. The mobility of negative air ions is high as compared to positive ions, these negative air ions are consumed by aerosol in the atmosphere. If there is balance between positive and negative air ion, the atmosphere is clean. If pollution index is greater than one means aerosols in the atmosphere are high. In this case study by measuring air ion concentrations, we can calculate pollution index in the atmosphere.

REFERENCES

[1] Harrison, R.G. and Aplin, K.L.: Water vapour changes and atmospheric cluster ion Atmospheric Research 85: 199-208, 2007.

[2] Dhanorkar, S., and A.K. Kamra, Diurnal and seasonal variations of the Small-, Intermediate-, and Large ion concentrations and their contributions to Polar conductivity, Journal of Geophysics Research, 98(D8), 14895-14908, 1993.

[3] Herve Venzan, Karine Sellegri, Palo laj, Paolo Villani, Paolo Bonasoni, Angela Marinoni, Paolo Cristofanell,Francesopiero Calzolari, Sandro Fuzzi, Stefano Decesari, Maria-Cristina Facchini, and Elisa Vuillermoz.: High frequency new particle formation in the Himalayas PNAS vol. 105, iss. 41 15666-15671, 2008.

[4] Kolarz, P.M., Filipovic, D.M. and Marinkovic, B.P. Daily variations of indoor air ion and radon concentrations. App. Radiat. Isotopes. 67(11): 2062-2067, 2009.

[5] O'Dowd C.D., Smith M.H., Lowe J.A., Harrison R. M., Davison B., Hewitt C.N.: New particle formation in the marine environment In:

Kulamala M. and Wagner P.E., Proc. 14th Int. Conf. on Nucleation and atmospheric aerosols, 925-928, 1996.

[6] Horrak U., Salm. J., and Tammet H.: Bursts of intermediate ions in the atmosphere air, J. Geophys. Res, 103, 13909-13915, 1998a.

[7] Hoppel, W.A., Anderson R.V. and Willet J.C.: Atmospheric electricity in the planetary boundary layer, The Earth's Electrical Environment, 149-185, National Academy Press, Washington, D. C. 1986.

[8] Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, and d. Xiasosu: Climate Change 2001: The scientific basis, 944., Cambridge Unov. Press, New York, 2001.

[9] Keitley: Low Level Measurements, 4th edition, Keithley Instruments Ltd. 1992.

[10] Hatakeyama H., Kobayashi J., Kitaoka T., Uchilawa K.: A radiosonde instrument for the measurement of atmospheric electricity and its flight results, In: Smith L.G. (ed.), Recent advances in atmospheric electricity, Pergamon Press, Oxford 1958.

[11] Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, and d. Xiasosu: Climate Change 2001: The scientific basis, 944., Cambridge Unov. Press, New York, 2001.

[12] Pawar, S.D., Meena, G. S. and Jadhav, D. B.: Diurnal and Seasonal air ion variability at rural station Ramanandnagar, India. J. of Aerosol and Air Quality Res. 10: 154-166, 2010.

[13] Pawar S.D. Meena G.S. and Jadhav D.B.: Week Day and Week End Small Air Ion Variability at Rural station Ramanandnagar (17°4′N, 74°25′E) India. Journal of Global NEST, vol. 13, iss. 1, pp. 65-73, 2011.

[14] Grinshpun, S.A., Mainelis, G., Trunov, M., Adhikari, A., Reponen, T. and Willeke, K. :Evaluation of ionic air purifiers for reducing aerosol exposure in confined indoor spaces. Indoor Air 15: 235-245, 2005.

[15] Dua, S.K., Kotrappa, P. and Bhanti, D.P.: Electrostatic Charge on Decay Products of Thoron. Am. Ind. Hyg. Assoc. J. 39: 339-345, 1978.

[16] Black A., The hazards of Radon In: proceedings of IV annual conference, The aerosol society, Guildford, 101-116, 1990.

[17] Willett, J.: Atmospheric-electric implications of ^{222}Rn daughter deposition on vegetated ground, J. Geophys. Res., D90, 5901-5908, 1985.

[18] Krueger, A.P. and Reed, E.J.: Biological Impact of small Ions. Science. 193 (4259): 1209-1213, 1976.

[19] Takahashi, K., Otsuki, T., Mase, A., Kawado, T., Kotani, M., Ami, K., Matsushima, H., Nishimura, Y., Miura, Y., Murakami, S., Maeda, M., Hayashi, H., Kumagai, N., Shirahama, T., Yoshimatsu, M. and Morimoto, K.: Negatively charged air conditions and response of the human psycho-neuro-endocrino-immune network. Environ. Int. 34: 765-772, 2008.

[20] Wu, CC., Lee, GWM.: Oxidation of volatile organic compounds by negative air ions. Atmos. Environ. 3. 2004.

[21] Hedge A, and Eleftherais E,: Negative Air Ions Affect Human Mood and Performance?, Annals of Occupational Hygiene vol. 31, iss. 3, pp. 285-290, 1987.

[22] Debaje S.B., Ramachandran T.V., and Vernekar K.G.: Study of atmospheric radon-222 concentrations at pune, Indian J. Environmental Protection, vol. 16, iss. 10, pp. 755-760, 1996.

[23] Crozier, W.D., and N. Biles, Measurement of radon 220 (thoron) in the atmosphere below 50 Centimeters, J. Geophysics. Res., 71, 4735-4741, 1966.

[24] Nagaraja, K., Prasad, B.S.N., Madhava, M. S., Chanddrasekara, M. S., Paramesh, L., Sannappa, J., Pawar, S.D., Murugavel, P., and Kamra, A. K: Radon and its short lived progeny: variations near the ground, Radiation measurements, 36, 413-417, 2003.

[25] Pawar S.D. Meena G.S. and Jadhav D.B.: Air Ion Variation at Poultry-farm, Coastal, Mountain, Rural and Urban Sites in India J. of Aerosol and Air Quality Res. 12: 440-415, doi: 10.4209/aaqr.2011.09.0148 2012.