Seasonal Variation of Pollution Index and Air Ions at Rural Station Ramanandnagar (17° 4' N 74° 25' E) India

S.D. Pawar

Department of Physics, A.C.S. College Palus Dist: Sangli, 415310 Maharashtra, India

sdpawar_ath345@yahoo.co.in

Abstract- **Air ions are continuously generated and destroyed by various processes in the atmosphere. Near the surface, nature of ions is very complex and they show large variations. Several factors such as the vertical stability of the lower atmosphere, turbulent wind speed, pollution, radioactivity of plant transpiration and ground influence affect their distribution in the atmosphere. Therefore to see the effect of pollution at rural atmosphere, seasonal variation of air ions was carried out. Air ions in the 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. The pre monsoon period is heavily polluted and dusty period, which results in more negative ions attached to these aerosol particles. Therefore average negative ions decrease from winter to Pre-monsoon season. Pollution index is equal to one or smaller than one in monsoon and post-monsoon seasons. Therefore monsoon and post-monsoon seasons are beneficial to human health. In pre-monsoon pollution index is very high, which is harmful to human health.**

Keywords- Cluster Ions; Plant Transpiration; Aerosol; Pollution Index; Radioactivity

I. INTRODUCTION

In the atmosphere ions diffuse to aerosol particles and transfer their charge to the particles [2], [3]. In rural areas, the auto-mobile exhaust or other human activity causes introduction of large concentration of aerosol particles in the atmosphere [11]. Moreover, the higher concentrations of trace gases and these gases are converted into aerosol particles by gas to particle conversion cause large particles concentrations increases [12]. In a steady condition the total number of ions in any volume of air must remains constant. Though this steady condition generally exists at higher altitudes, close to the Earth's surface situation is complicated due to non uniform conditions of aerosol and ion concentrations. Atmospheric aerosols are highly significant. In the atmosphere they influence natural meteorological processes in clouds [18], artificially they may be associated with pollution (as smokes), or even carry radioactivity [17]. They may transport pollution in weather systems, such as after the nuclear accident at Chernobyl [9], and in large concentrations alter the electrical balance of the air. Aerosol inhalation by humans is mostly unavoidable, and may transport harmful matter [40] into the human body.

Aerosols in the atmosphere are combined with air ions. Ion-induced nucleation is [19] the growth of aerosol particles [31] by vapour condensing onto an ion, has been shown to be theoretically possible by Castleman [10]. This effect has yet to observe in the atmosphere, although it has measured in the laboratory on several occasions. Slower ionic growth has also been reported in Estonia, and it has been suggested that this is the first stage of nucleation process [33]. In ion-induced nucleation, the Coulomb force decreases the energy needed for critical cluster formation. Particles formed via ion-induced nucleation are always charged due to their origin [32].

It is well known that according to the ionic theory molecules of any salt, acid or base being dissolved in water break up into their constituent ions. Similarly in the free atmosphere, the terrestrial ecosystems modulate aerosols (atoms and molecules) the positive radical of molecule of the solution moist air carriers a positive charge and is known as positive ion and negative radical of the molecule carries the negative charge and becomes negative ion. Here we can visualize the rain water as a solution of dissolved air composition. The air ions are ultimately generating through lightning [20], [44], [51], [52], [53] from thunder clouds, corona discharge, plant transpiration, combustion, water falls, wave breaking on water, splashing of raindrops [48], [49], [26] and due to friction between two air levels [37]. In fact the thunders in the atmosphere develop when two dry and wet air mass collide each other.

The goal of this paper is to see effect of various seasons on concentrations of air ions for the long period from 2007 to 2009 at rural station Ramanandnagar. Majority of research on air ions concentrated on urban area as scientific labourites are present in urban area. Therefore measurement of air ion variation at rural area is meagre, which is useful for the comparison between air ion variation at rural and urban areas in India. As India is a developing country, to see the effect of pollution on rural area, pollution index is also calculated for three years from 2007 to 2009 at rural site.

II. MEASUREMENT AND METHODS

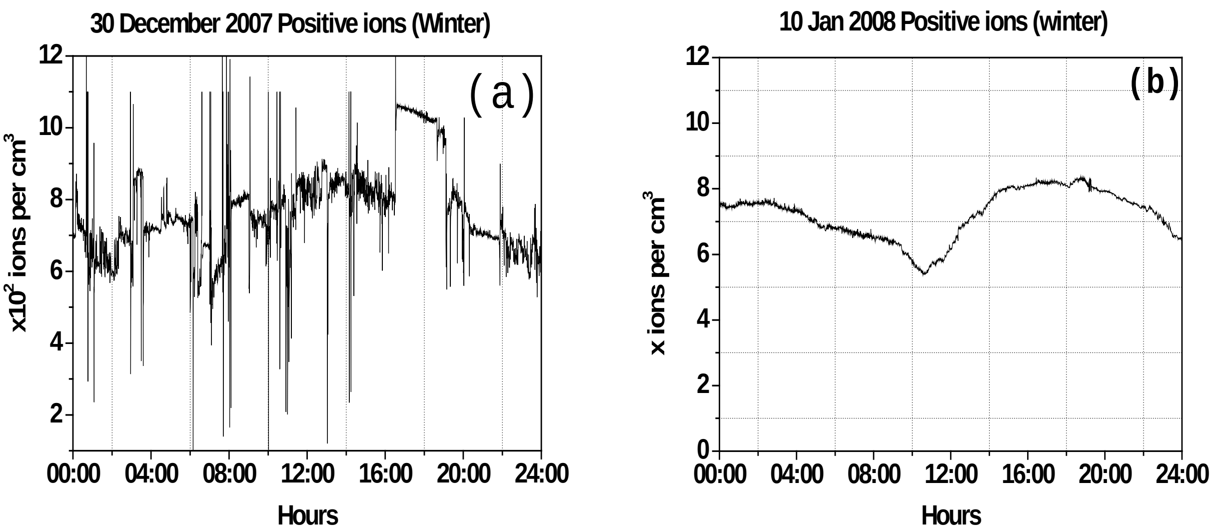
India is a tropical country having about 26 states. The Maharashtra is one of them, in which the Deccan plateau lies with Western Ghats on the western side of the state. On the East of the Western Ghats the River Krishana catchment lies and the District Sangli lies in this catchment. The Western slopes of the western catchment are swept by the Arabian Sea coast from Goa to Gujarat. Ramanandnagar site lies in the Krishna catchment in Sangli District. India experiences two famous monsoons known as South-West monsoon and North-East monsoon. The former occurs during the summer months from June to August and extends up to September, which is autumn season. While latter occurs in the months of early autumn that are October and November. India experiences winter conditions during the months from December to February (dry weather) and sprucing conditions from March to May. It is well known that these seasons over India follow the Northward and Southward march of Sun across the Earth's equator. Whole measuring site was covered with agricultural land with sugarcane, corn crops from July to September; some crops except sugarcane are cut down and final products are obtained in the month of October. Wheat and channa grow from November to February, all these crops including sugarcane were cut down and final products were obtained in March and April. While in the May there were one or two places that agricultural crops were present and majority of land is empty**.** There is 20 feet road in front of observatory connecting to nearest village Burli shown in Fig. 1.

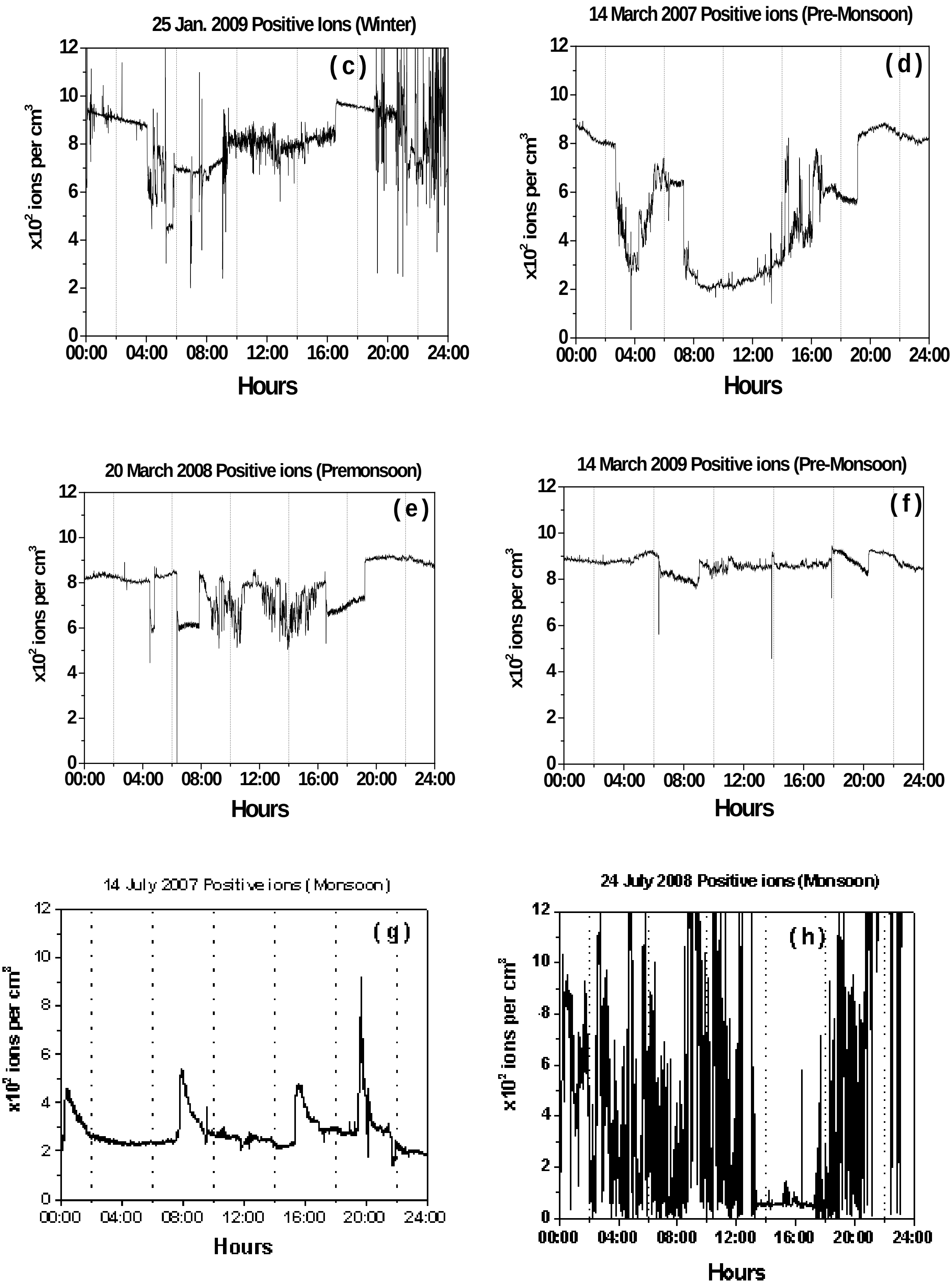
Fig. 1 Road in Front monitoring station at rural station Ramanandnagar

The air ion counter, which is indigenously designed and developed at the Indian Institute of Tropical Meteorology Pune, is being operated at rural station Ramanandnagar [48], [50]. The calibration of the amplifier is done in the laboratory using a resistive method of the generating small currents with a milli-volt calibrator and a resistor. The signal from the ion counter apparatus is amplified with electrometer amplifier – AD549JH. This amplified signal is recorded in data-logger which has a voltage range of ± 15 V with 10 mV resolution. It has facility of averaging the input signal and multiplication. The data stored in data-logger with 30 seconds time resolution. There was only one set of instrument for the measurement of air ions. 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. Air ions are measured for 336 days with 30 second time resolution during three years 2007-2009 for rural site Ramanandnagar. Average air ions are defined as average value of air ions with time resolution of 30 seconds for particular time period. In two hour measurement of air ions average value of air ions calculated from 240 sample points.

III. RESULT AND DISCUSSION

In winter (December 2007) Positive air ion count was 8 at 00:00, and it decreases to 5.8 around 02:00. The large fluctuations in the air ion count were observed between 06:00-16:50. The positive ion count reaches maximum (10.2) at 17:00 and remains steady around this value up to 20:00. It starts decreasing again and reaches minimum (6) at 24:00 (Fig. 2(a)). In winter (January 2008) positive ion count starts decreasing from 7.5, reaches minimum (5) around 11:00. After observing dip around 11:00, starts increasing and reaches maximum (8) around 19:00 (Fig. 2 (b)). In winter 2009 (January 2009) Positive air ion count starts decreasing from 9.5 at 00:00, reaches minimum (4.8) around 05:30. Large fluctuations in positive ion count were observed between 05:30-16:40 and 19:00-24:00 (Fig. 2 (c)).




25 Jan. 2009 Positive Ions (Winter)
(c)
x10^2 ions per cm^3
Hours
14 March 2007 Positive ions (Pre-Monsoon)
(d)
x10^2 ions per cm^3
Hours
20 March 2008 Positive ions (Premonsoon)
(e)
x10^2 ions per cm^3
Hours
14 March 2009 Positive ions (Pre-Monsoon)
(f)
x10^2 ions per cm^3
Hours
14 July 2007 Positive ions (Monsoon)
(g)
x10^2 ions per cm^3
Hours
24 July 2008 Positive ions (Monsoon)
(h)
x10^2 ions per cm^3
Hours

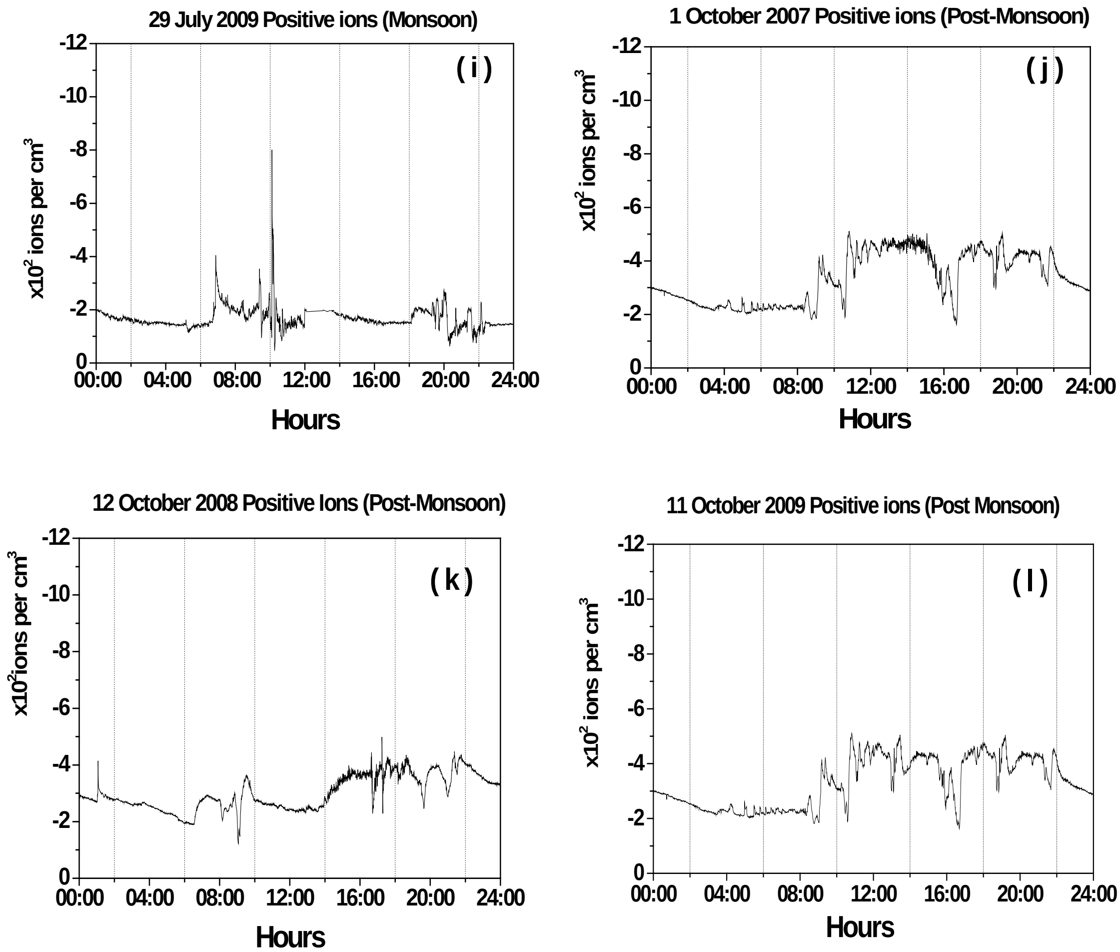
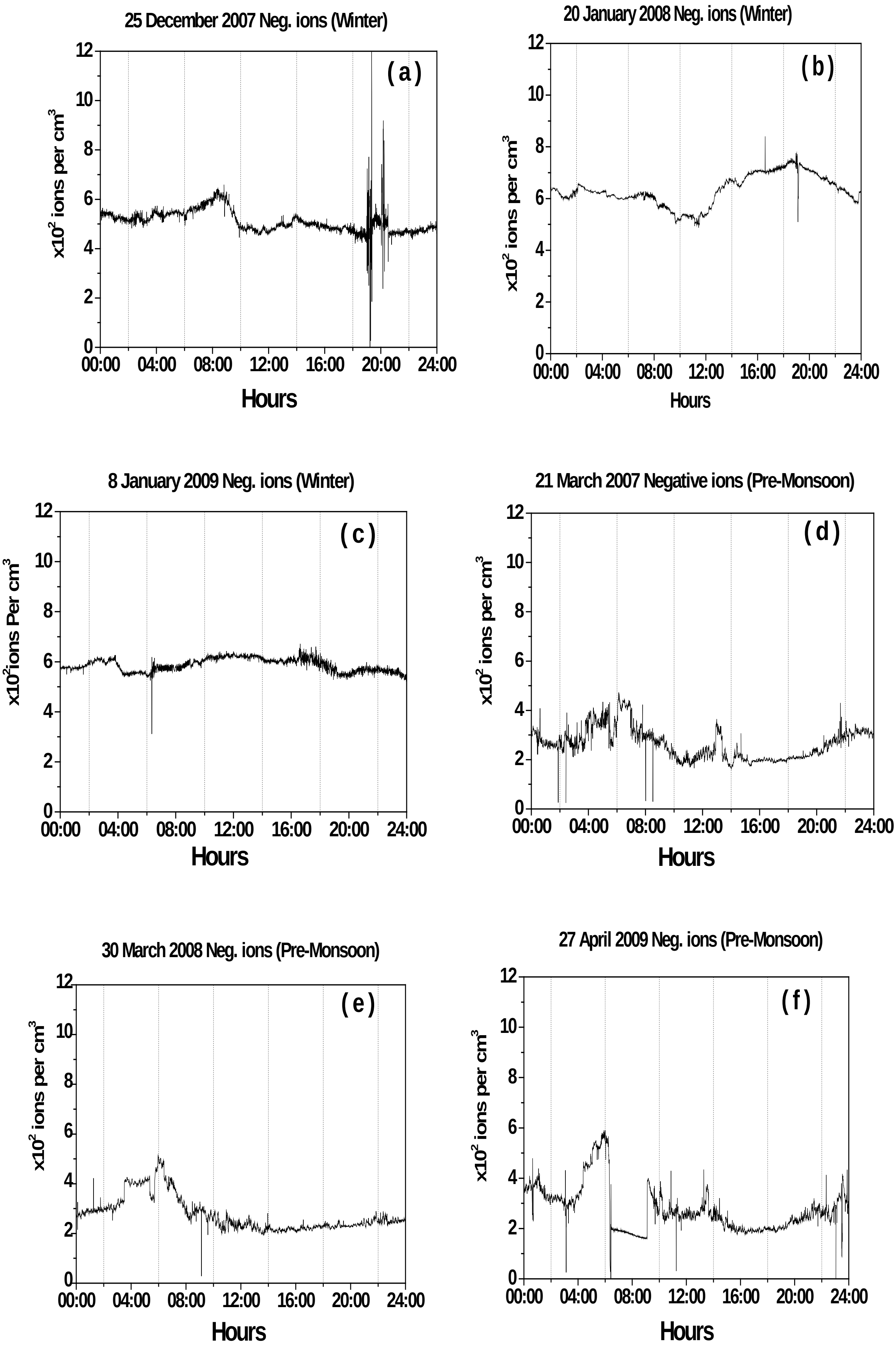


Fig. 2 Seasonal variations of Positive air ions (2007-2009)

In pre-monsoon (March 2007) positive ion count starts decreasing from 8.85 at 00:00, reaches minimum (3) around 04:00 (Fig.2 (d)). The valley type dip is observed between 05:00-19:00. This is because heavy rainfall was observed during this time period at the observation site. (Fig. 2(e)) shows during pre-monsoon (March 2008), dip in positive ion count was observed between 06:00-08:00 and 16:30–19:00. The fluctuations in positive ion count from 5.5 to 8 were observed around 08:00-16:00. In pre-monsoon (March 2009) positive air ion count changes from 7.8 to 9 during 00:00-24:00 (Fig. 2(f)). The large variations in positive ion count were not observed in 2009, as we observed during 2007 and 2008 pre-monsoon season.

In monsoon (July 2007) period, three bursts of positive ion count were observed around 08:00 (5.4), 15:50 (4.8) and 17:45 (8.4) (Fig. 2(g)). These bursts observed may be due variation in wind speed and rain fall at observation site. Large fluctuations in the positive air ion count, varying between 0.1 and 12 units were observed in Monsoon (July 2008) as shown in (Fig. 2(h)). It is very difficult to use any phenomenon to explain this. In Monsoon (July 2009) two bursts of positive ion count were observed from 07:00 (8) to 10:00 (4) (Fig. 2(i)). In the Post-monsoon (October 2007), positive ion count varied between 2 and 5 units. The dip in positive air count (1.8) was observed around 16:55. In Post-monsoon (October 2008) positive air ion count varied between 1.5 and 4.3 (Fig. 2(k)). In October 2009 (Post-monsoon) positive air ion count varied between 1.8 and 4.9 (Fig. 2 (l)). Due to variation in wind speed, large numbers of peaks were observed. More or less similar types of variations in positive air ion count were observed during post-monsoon season for 2007, 2008 and 2009.

In winter (December 2007), the negative ion count was 5 units. The curve was flat from 10:00–19:00. The fluctuations were observed between 19:00 and 20:00 (Fig. 3 (a)). The negative air ion count in winter (January 2008) varied from 6 to 8 units. The variations were almost uniform up to 07:00, thereafter the variations decreased up to 11:00 by 5 units, then increased by 7 units around 19:00 (Fig. 3 (b)). In winter (January 2009) negative air ion count was 6 units (Fig. 3(c)). In Pre-monsoon (March 2007), conspicuously high values of negative ion counts were observed at early morning in pre-monsoon season. Maximum of negative ion counts were observed at afternoon in monsoon and post-monsoon seasons. The most fluctuating negative ion counts occurred in July 2007 (Monsoon); while most stable negative ion count was recorded in winter season. In the post-monsoon, negative ion count was lower during night time, increasing at 07:10 and reached maximum value within half an hour.


25 December 2007 Neg. ions (Winter)
(a)
20 January 2008 Neg. ions (Winter)
(b)
8 January 2009 Neg. ions (Winter)
(c)
21 March 2007 Negative ions (Pre-Monsoon)
(d)
30 March 2008 Neg. ions (Pre-Monsoon)
(e)
27 April 2009 Neg. ions (Pre-Monsoon)
(f)
x10² ions per cm³
x10²ions Per cm³
Hours
00:00 04:00 08:00 12:00 16:00 20:00 24:00
0 2 4 6 8 10 12

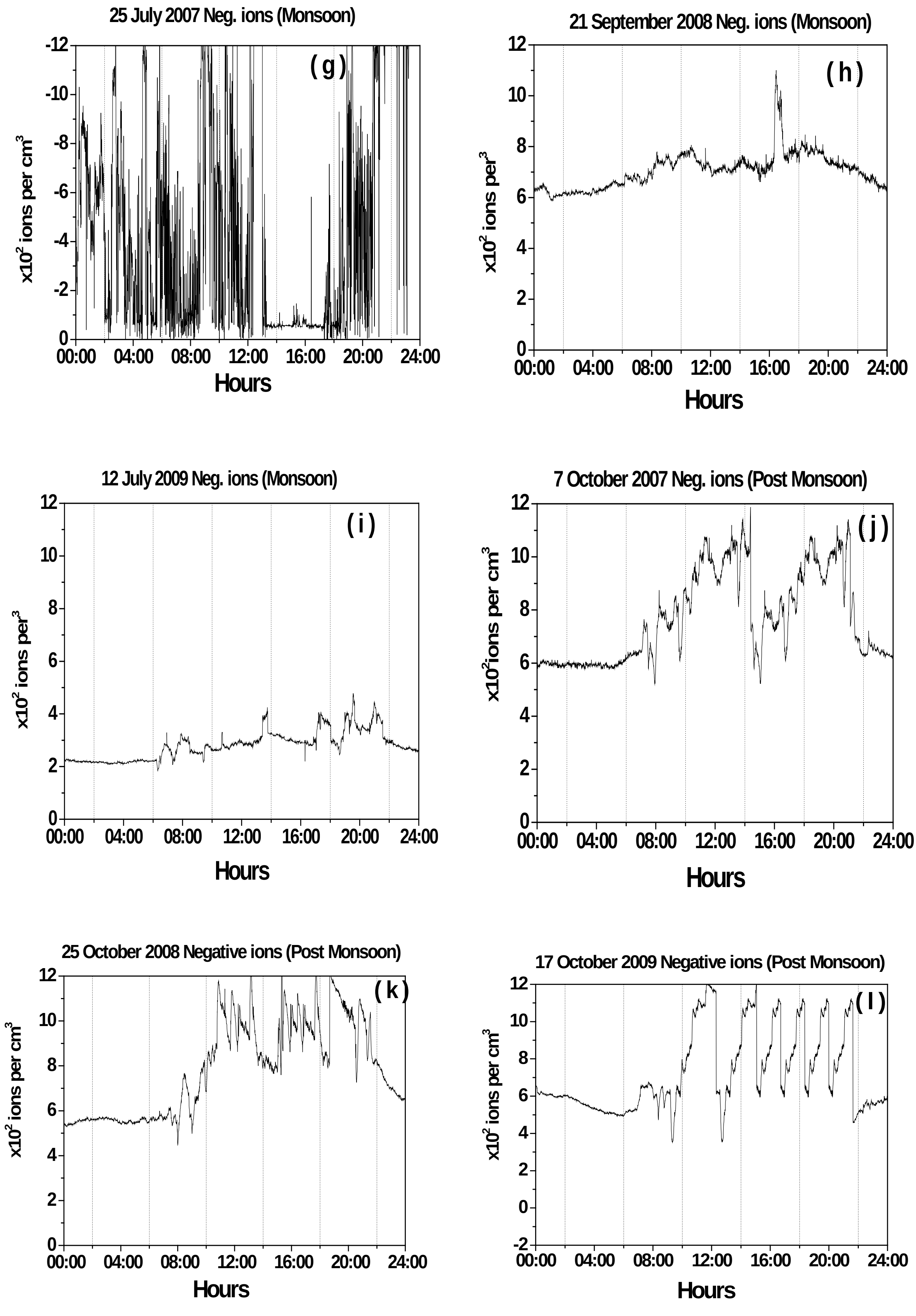
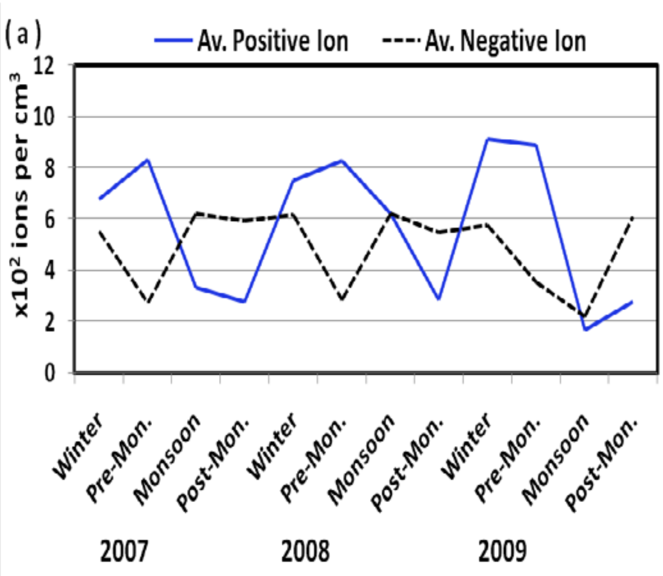
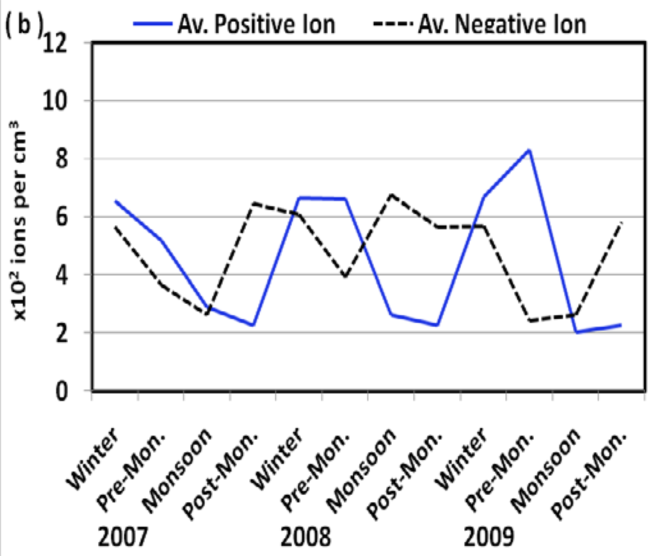


Fig. 3 Seasonal variations of Negative air ions (2007-2009)

In the curve of average positive ions, the air ion count shows constant variation from winter to pre-monsoon: a sharp decreasing tendency from pre-monsoon to monsoon, and a slight increase from monsoon to post-monsoon. While on the curve of average negative ions, the air ion count shows a sharp decreasing tendency from winter to pre-monsoon, a further slow increase from pre-monsoon to monsoon and again a sharp rising tendency from post-monsoon. Average positive ion count goes to maxmum in pre-monsoon period and goes to minimum in post-monsoon seasons all the time period. In 2009 average postive air count remains high and flat from winter to pre-monsoon seasons for 00:00-02:00 (Fig. 4(a)). Averge positive ion count starts increasing from 2007 and reaches maximum in 2009. Average negative air ion count starts increasing from 00:00 to 02:00 (Fig. 4(a)) and reaches maximum during 12:00-14:00 (Fig. 4(c)). The average negative ion count starts decreasing from winter and reaches minimum during pre-monsoon (Figs. 4(a-c)). From premonsoon to monsoon again starts increasing and reaches maximum during post monsoon. Such type variation is repeated from 2007 to 2009 (Figs. 4(a-c)).

As negative ions having higher mobility as compared to positive ion, aerosols or volatile organic compounds are attached to negative ions and settle down on ground [57]. Positive to negative air ion ratio is also defined as pollution index. Pollution index increases from winter to pre-monsoon from 2007 to 2009 (Fig. 5). Pollution index starts decreasing from pre-monsoon to monsoon season and reaches minimum during post-monsoon. It was observed that pollution index increases from 2007 and reaches maximum in 2009.This may be due to increase in vehicles frequency on the nearest road. As compared to 2007, in 2008 pollution index is high during pre-monsoon and post-monsoon season and low during winter and monsoon season. As compared to 2008, in 2009, pollution index is high during winter, Pre-monsoon and monsoon seasons having same value during post-monsoon season.





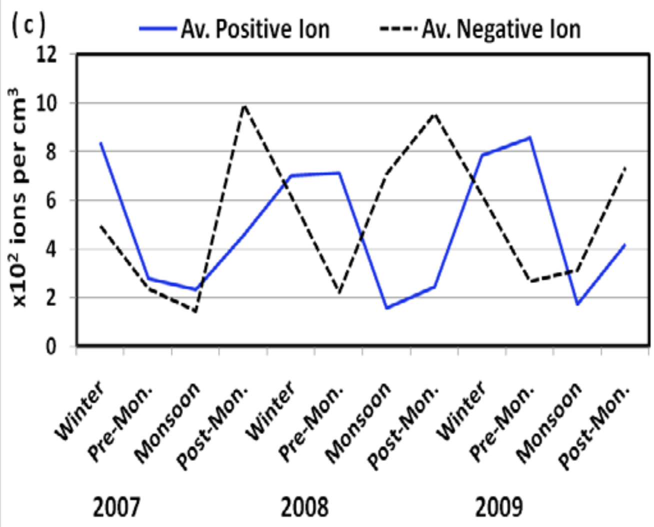
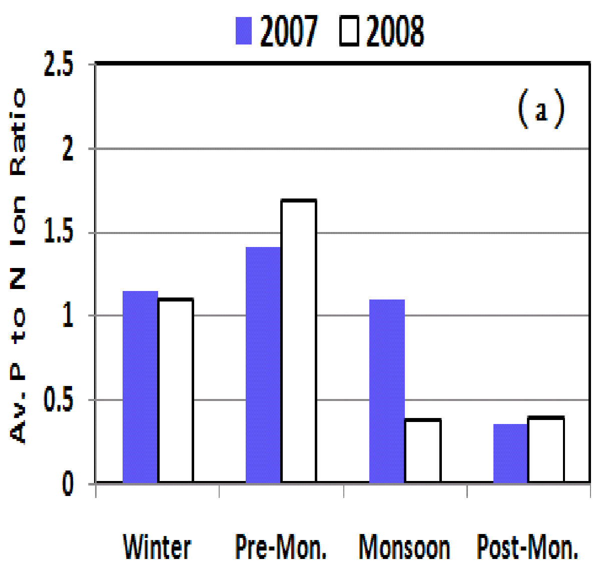


Fig. 4 Average Positive and Negative air ion variation (2007-2009) for a) 00:00 to 02:00 b) 06:00 to 08:00 c) 12:00-14:00



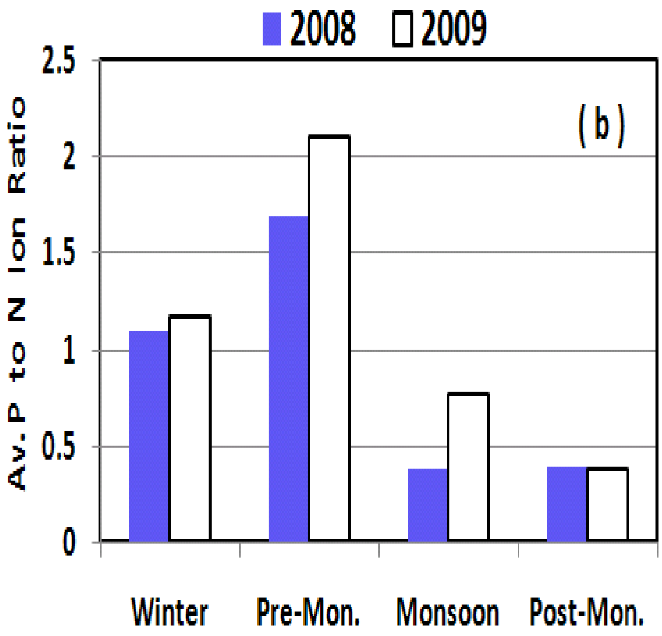


Fig. 5 Comparison of seasonal variation of Pollution Index for a) 2007-2008 and b) 2008-2009 year

The emanation of radioactive gases from the ground varies with soil porosity, soil humidity, soil temperature, ground coverage, air pressure, solar radiation and plant transpiration. In our site, few days in the monsoon season ground are covered with water due to heavy rain. In all remaining months, ground is open for radioactivity emanation [13]. Therefore during these months both positive and negative ion concentration curves are lower [43], [45] as compared to other months (Fig 2 and Fig. 3). The area around the site is crops of sugarcane, corn, etc. Therefore plant transpiration comes in the picture during monsoon [26]. Plant transpiration produces Radon and Thoron gases [1], which in turn produce ion pair production. Therefore air ion count curve of both the polarities increases from early morning and reaches to maximum at noon time rather than night [35], [36]. Positive ions can be produced by various kinds of friction; between air masses, between the air and sand or dirt particles swept up by the wind, between weather fronts that march endlessly across the face of the globe. Friction tends to knock off the negative electrons and produce overdose of positive ions. On a dusty or humid day this overdose may be massive because the negative ions [22] promptly attach themselves to particles of dust, pollution or moisture and lose their charge [50]. Therefore as shown in Fig. 4 in the pre-monsoon season (2007-2009) average negative ions were low. The energy in moving water also generates a lot of negative ions. As water breaks up, the positive charge remains with the larger drop and the negative charge flies free with the fine spray, forming negative ions. As river Krishna four km in west direction from monitoring station and it is flooded with water in monsoon period. The waves from this river water, water drops also produce air ions of both the polarities. Wind is flowing from West-East direction with very high velocity, which brings air ions with it [4], [5], [6], [23], [24]. Therefore air ion concentration changes with respect to wind speed. Due to these reasons air ion concentrations of both the polarities are fluctuating during the monsoon period (Fig. 2(h) and Fig. 3 (g)).

Great variations with time and place are noticed in the concentration of air ions. The lower atmosphere varies markedly in its content of gaseous and suspends impurities from place to place. It is cleanest over the ocean. If this standard is taken as unity, then the average pollution of rural air would be 10 times greater, pollution over small towns would be about 35 times as much and over cities pollution would be 150 times greater than that of ocean. Pollution, for instance is not seasonal. Besides which, men build cities and cover the land with asphalt and concrete that prevents the normal generation of ions, so there would be fewer ions in the urban area. Therefore at rural area like Ramanandnagar, magnitude of air ions is very high as compared to the urban area like Pune [15], [16], which is 210 km in the north-west direction. As winter season of every year is Radon peak season [14] in which large cluster ion pair produces. This may be due to intensive temperature inversions during the cold and leads to the accumulation of more Radon near the Earth's surface and increasing in ionization rate [47]. Therefore as compare to all other seasons we observe more positive and negative air ions in winter (2007-2009). 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 (Black, 1990). Aerosols, which are radioactive, acquire charge, in general, more readily than a comparable non-radioactive aerosol. Radioactive aerosols charged by the usual mechanism of external ion attachment, but additional external ions are created by radioactive decay particles. A further form of electrification for radioactive aerosols is self-charging. This occurs when a radioactive source is actually within the aerosol particle. The self-charging of a beta-active aerosol radioactive decay causes electrons to be emitted from the particle's surface and ions are produced of both signs. Positive ions are nothing but these radioactive aerosols [17], which are accumulated near the ground surface in the winter season. Therefore in winter Fig. 3 average positive ion count is very high of the order of 7 to 9 during all the time periods as compare to average negative ion count. The pre monsoon period is much polluted and dusty period, which results more negative ions attached to these aerosol particles [21]. Therefore as shown in Fig. 4 average negative ions decrease from winter to Pre-monsoon season for each year. As agricultural crops go on decreases from February to April 2008 plant transpiration of Radon and Thoron [42] and hence ion pair production go on decrease. During pre-monsoon the gases move upward carrying Radon with it thereby reducing ionization [47] near the earth's surface. Therefore, both polarities of air ions decrease from winter to pre-monsoon season. This type of variation in air ions repeated for 2007, 2008 and 2009. The main cause of reduction of the ion concentration is increasing aerosol, which is removing ions therefore the aerosol is acquiring charge [28]. From this it can be seen that increasing the aerosol concentration reduces the air ion concentration. Many observations have been carried out in atmospheric air since polluted or fog laden air is known to have a lower air ion concentration than clean mountain air. Therefore as shown in the Fig. 3 average ions are decreasing from winter to pre-monsoon. Due to high temperature Radon escapes to higher altitudes [14], [47], therefore in pre-monsoon, minimum of average air ions is observed for all the time periods.

As monsoon forwards from July to September height of the crops around site increases and pollution goes on decreasing [21] plant transpiration of Radon and Thoron introduces more negative ions as compare to positive ions in the atmosphere **[7].** Due to these reasons average negative ion graph increases from pre-monsoon to monsoon season In monsoon few thunderstorms were observed, which generate corona discharge negative air ions from the trees [28]. Due to this, additional source of negative ions results large increase in negative ions [46], [55]. Therefore, in monsoon, average negative ion in Fig. 3(a) shows sharp increases [27] as compare to pre-monsoon. Then monsoon season is beneficial to human health [39], [34].

In the post-monsoon season, the average positive ion curve shows deep dip from monsoon to post-monsoon, while there is sharp rise in average negative ion from monsoon to post-monsoon season Fig. 4. This is very healthy for human health [30], [41]. This conspicuous change may be occurring due to change in season from South-West monsoon to North-East monsoon due to transition. Nevertheless, the ions count season after season differing between them, which is also quite conspicuous and the positive ion count seems slightly higher than the negative ion count in some seasons. From October onwards the weather situation changes considerably and the ionic concentration also changed conspicuously depending on the R.H. [29] and consequent cloud, rainfall and wind speed. The thunder cloud generates an air ion in the atmosphere, the rainfall scavenges the ions and winds carry the ions from one place to another. So, that the ion concentration, at any rural site like one we observed, is always hampered by the above process in addition to the chemical production and decay of the ions. Sun is the source of energy at the Earth's surface; it has its apparent motion with respect to the Earth responsible for the generation of the ions on the earth's surface [56].

During winter season, Radon gas is accumulated [38] near the surface and the same time plant transpiration produces more air ions in the atmosphere. Therefore in winter pollution index was one. In pre-monsoon as result of high temperature, Radon gas was escaped to upper atmosphere. The crops in the agricultural decreases, therefore ion production due to plant transpiration also decreases. Pre-monsoon season is dustier; therefore negative ions removed by aerosols present in the atmosphere. Therefore as compared to all other seasons in pre-monsoon, the pollution index was very high (1.5). As negative ions having higher mobility as compared to positive ion, aerosols or volatile organic compounds are attached to negative ions and settle down on ground [57].When pollution index is one then air ions and aerosols are equal in number. Pollution index above one meaning that as compared to ions aerosols are more in the atmosphere. Pollution index above 1.2 is harmful to human health [54]. Therefore pre-monsoon season is harmful to human health [25]. During the monsoon period rain clears the pollutants and aerosols. Splashing of rain drops, plant transpiration, waves of river Krishna introduce more negative ions as compare to positive ions that are introduced in the atmosphere. Due to these reasons there is balance between positive and negative air ions and hence pollution index was one or below one in monsoon. When a radioactive nuclide decays, electrons are stripped from the parent atom by its recoil and decay products were formed as positive ions. Radioactivity however has been shown to have a large effect on aerosol charging, since it is accompanied by the emission of charge and the production of large quantities of ions [28]. Therefore Pollution index was equal to one or smaller than one in monsoon and post-monsoon seasons. Then monsoon and post-monsoon seasons are healthy for human health [8].

IV. CONCLUSIONS

Great variations with time and place are noticed in the concentration of air ions. The lower atmosphere varies markedly in its content of gaseous and suspends impurities from place to place. As winter season of every year is Radon peak season in which large cluster ion pair produces. This may be due to intensive temperature inversions during the cold and leads to the accumulation of more Radon near the Earth's surface and increasing in ionization rate. Therefore as compare to all other seasons we observe more positive and negative air ions in winter (2007-2009). The pre-monsoon period was much polluted and dusty period, which results more negative ions attached to these aerosol particles. Therefore average negative ions decrease from winter to Pre-monsoon season. Plant transpiration of Radon and Thoron introduces more negative ions as compare to positive ions in the atmosphere. Due to these reasons average negative ion graph increases from pre-monsoon to monsoon season. In monsoon, few thunderstorms were observed, which generate corona discharge negative air ions from the trees. It was observed that pollution index increased from 2007 and reached maximum in 2009. As compared to 2007 in 2008 pollution index was high during pre-monsoon and post-monsoon season and low during winter and monsoon season. As compared to 2008, in 2009, pollution index is high during winter, Pre-monsoon and monsoon seasons and having same value during post-monsoon season. As compared to all other seasons the worst condition observed in pre-monsoon, the positive to negative air ion ratio is above 1.5, which is harmful to human health.

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