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Research Article

Time-Dependent Study of Air Ions in Multiple Zones of Urban Environment

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ABSTRACT

The level of air ions considers as an early detection tool for change in the environmental pollutants. The advancement in storage and transportation technology has increased the concentration of air ions in an urban environment. Significant literature reveals that if positive air ions are present in a large number, it has severe health impacts on the human body.

This paper discusses the seasonal scanning of air ions at a traffic junction and green zone. The spot sampling methodology used in this study and assessment of air ions count (AIC) during both summer and winter seasons in 2019 at Nagpur city, India. The study reveals that the critically polluted regions are season invariable concerning air ions as a precursor of pollution. The observation of fewer values in negative ions for both the summer and winter season in traffic intersections grounded the fact that seasonal washout of pollutants is not there, which is observed for green zones. The vehicle counts and its density in the green zone play a critical role in the concentration of negative ions. The air ion ratio (-/+) of the morning, afternoon, and the evening was 1.030, 1.142, and 1.142, respectively in the green zone and having lowest values in the traffic location (morning, afternoon, and the evening was 0.92, 0.83, and 0.77, respectively). The increment or decrement in the ion ratio could help understand the prevailing air quality scenario in the urban macro-environment.

Keywords: air ions count, urban environmental, traffic intersection, green zones, macro-environment

INTRODUCTION

The problem of air pollution is alarming, according tothe latest WHO report for India with other proven health effects on human beings and the environment (Air Pollution, 2019). Today, there is a need to know about the charged particles count as we interact with them in our day-to-day life (Schraufnagel, 2020). Ions are the charged particles that form when atoms lose or gain electrons to fulfil the octet rule and have full outer valence electron shells. When they lose electrons, they become positively charged and after gaining electrons, they acquire a negative charge. It is observed that if the count of positive air ions is found out to be high, then it has severe health impacts on the human body ranging from heart and lung diseases (Ghaly and Teplitz, 2004; Jamieson et al., 2007). It has many other proven health effects on human beings and the environment (Kampa and Castanas, 2008; Skromulis et al., 2017). Hence, there is a need to address such a critical issue (Jayaratne et al., 2015). The negative air ions are favorable to humans and biotic entities, especially in the case of metabolism. This work proposed the seasonal time-dependent scanning of air ions at a traffic junction and green zone in the various macro-environments. The level of air ions is considered an early detection tool for change in environmental pollutants.

Currently, environmental pollutants are increasing day by day. Hence, it becomes necessary to take immediate preventive measures to reduce, control, and spread general awareness among the younger generation (Ghaly and Teplitz, 2004; Jamieson et al., 2007). Air ions are negatively or positively charged particles. Ions are formed when free-flowing electrons collide or stick with the gaseous molecules. There are several states of the art techniques/methods to address the grave issues. In one recent study, the monitoring and assessment of air ions at different places and their implications are critically depicted.

The AIC generally measures 100-200 ions/cm. The emission of chemical gaseous substances, aerosols, and air ions is caused due to fossil fuel combustion. Cluster ions that form due to natural radioactivity can use to identify impurities in the atmosphere. Parametersinvolved in affecting ions concentration are carbon monoxide (CO), nitric oxide (NO), nitrogen oxide (NO_2), ozone (O_3), relative humidity, particulate matter (PM), temperature, wind, and sulphur dioxide (SO_2)

There exists a correlationbetweenthe concentration of air ions, air pollutants, and meteorological conditions (Manisalidis et al., 2020). In the urban cycle, the level of air pollutants is lower at night but higher in the afternoon and evening (Srimuruganandam and Shiva Nagendra, 2010). The majority of negative ions are CO_3- and other negative ions include O-, O_3-, NO_3- (Jiang et al., 2018).

The carbon monoxide (CO) does not affect air ion concentration (AIC) with a considerable amount, decreasing AIC very slowly. There is noeffects of heavy ions and does not have a significant impact on cluster ions and intermediate ions. The ozone (O_3) role has not been clear yetbutreveals that it reduces overall PM 2.5 pollution (Li et al., 2019). The wind direction has not shown any relevance except its speed, which has some positive effects (Hõrrak, 2001). Atmospheric sulfate aerosol particles contribute significantly to poor air quality and the oxidation of SO_2 by H_2O_2 in the liquid water present in atmospheric aerosol particles can contribute to the missing sulfate source during severe haze episodes (Liu et al., 2020). PM10 and PM 2.5 affect the total air ions concentration. It is caused by their common emission sources like vehicular emission, industry, and energy generation (Skromulis, 2019). Skromulis (2019) also reported that relative humidity does not any large or unambiguous impacton AIC directly, while air temperature affects the AIC by increasing it concentration.

Multiple studies experienced that chemical pollution has a more substantial impact on positive ions than negative ions. Many studies conclude that the radioactive background and radar concentration are significant factors for forming air ions; they cannot be neglected. Excess exposure to pollution (large concentration of positive ions) has a hazardous effect on the human organs and the systems. Air pollution has severe and long-term impacts on social well-being, causing inhalation and ingestion via the gastrointestinal and respiratorytract (Kampa and Castanas, 2008). Some closely related and well-distinguished health hazards associated with air pollution exposure are heart diseases, lung cancer, acute respiratory infection, skin irritation, nausea, lung diseases, asthmatic attacks, etc. (Kampa & Castanas, 2008). It is observed that if the count of positive air ions is found out to be high, then it has severe health impacts on the human body ranging from heart and lung diseases (Jayaratne et al., 2015; Kampa and Castanas, 2008).

Likewise, studies of air ions and their co-relation with traffic density, lighting, and aerosol formations have been extensively carried out in Indian cities Pune, Agra, Delhi, Pudukottai, Ramanandnagar, etc. The study in Ramanand Nagar shows pre-monsoon season is harmful to human health due to more negative ions in the atmosphere (Pawar, 2013).

The study by Jha and Chinchore (2006) shows that the concentration of positive air ions is directly related to the traffic density of Pune city. The stability of the atmosphere plays an important role in the concentration of air ions. Similarly, in India, many exposure studies show that air ion concentration can be a preliminary indicator of the poor air quality at the selected location (Subramanian and Jagadesan, 2014). All these studies show qualitative analysis of air ions and their impact in the regional environment. However, the present study aims at quantification of air ion with respect to typical regions having dissimilar emission characteristics (e.g., industrial zone and traffic and green zone).

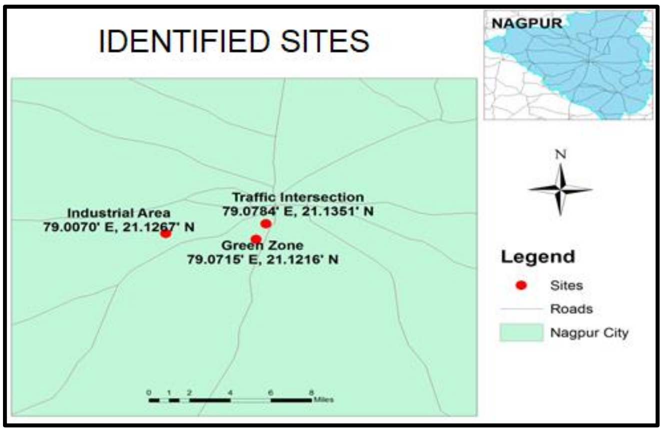

Figure 1. Location map

Whereasnegative ionsdensityplays a vital role in thebody's metabolism, the presence of a significant amount of negatively charged ions in the blood has proved to be useful for the body's metabolism and vice-versa for positive ions. Some of the benefits are strengthened collagen, build-up functionof autonomic nerves, improves metabolism, makes the immune system of the body healthier.

The purpose of the study is to obtain quantified air ion counts over the locations featuring dissimilar emission and their seasonal variablity. The alterations in air ion ratio values for green zones and other regions can be advantageous to establish the prerequisite of mitigation measures for region specific emission control. The present study aims at exploring the new avenues to understand the location/region specific emission control measures. Every region, even having similar geographic features and climate to other region, is unique with respect to their emission characteristics. Air ions and thir ratios can depict nature of local air quality in a comprehensive manner.

DATA SETS AND METHOD

Study Area

The three locations were identified from Nagpur city, which is inthe central part of India and is considered one of India's greenest and developing cities. All the locations are selected in and around the municipal corporation limit of Nagpur city. These locations resemble a similar environment of Nagpur city as depicted in **Figure1**. The green zone located at the nearby CSIR-NEERI campus issituated in the central partof the city, around 100 acres. The Lokamat Square is a busy square of Nagpur city, India, and Hingana MIDC is the most prominent Industrial area near Nagpur city. **Figure 2** depicts the wind rose diagram for Nagpur during winter and summer seasons in 2018-2019, respectively.

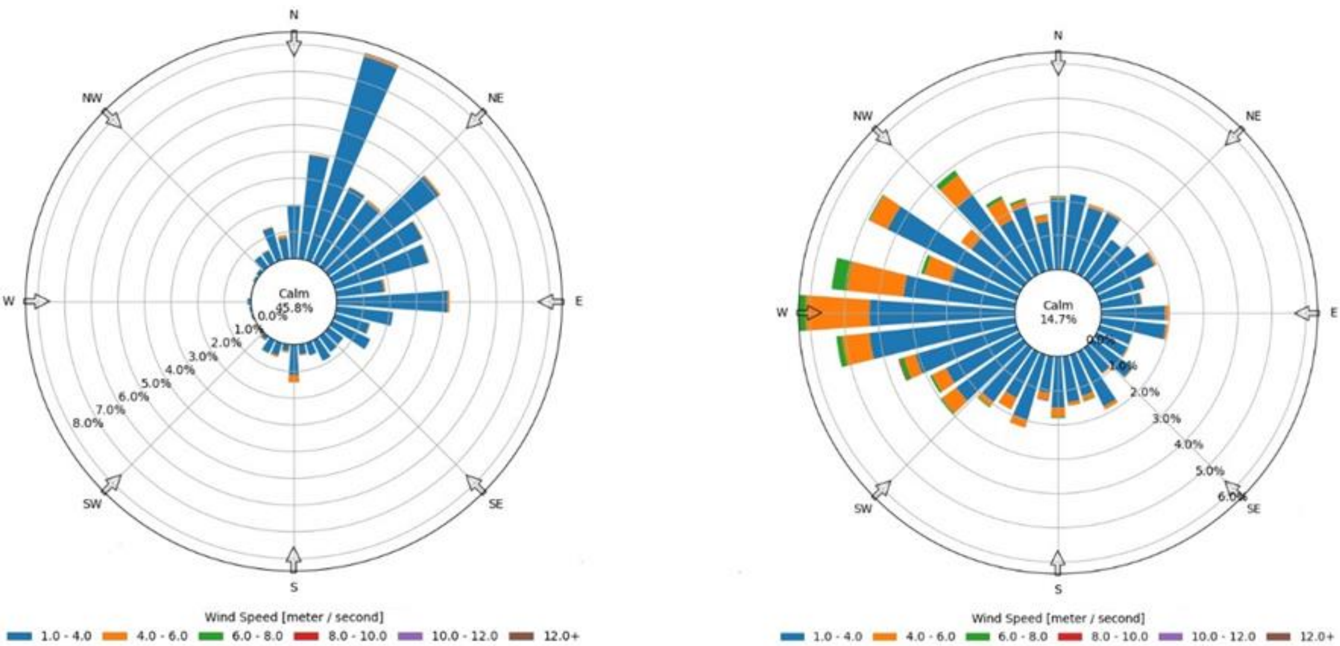

Figure 2. The wind rose diagram for Nagpur during winter (left) and summer (right) seasons in 2018-2019, respectively

Table 1. Air quality status for three different sites

		Summer		Winter	
		PM_{10} $(\mu g/m^3)$	$PM_{2.5}$ $(\mu g/m^3)$	PM_{10} $(\mu g/m^3)$	$PM_{2.5}$ $(\mu g/m^3)$
Industrial zone	Avgerage	95	57	112	62
	Range	(76-124)	(35-83)	(85-160)	(35-98)
Traffic junction	Avgerage	97	55	94	52
	Range	(72-125)	(32-78)	(70-138)	(32-72)
Green zone	Avgerage	73	30	80	32
	Range	(48-98)	(18-48)	(57-103)	(19-47)

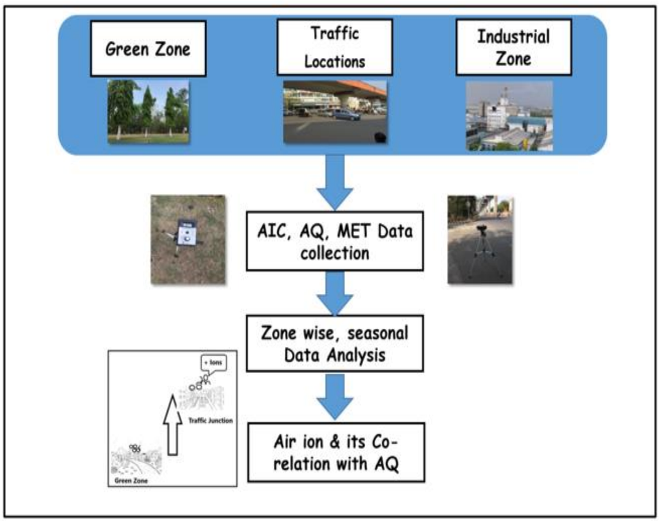

Figure 3. Schematic of work

The distribution of sampling stations in a region depends on the distribution of emission sources and population. The primary objective was identifying various source contributions representing the utmost affected zone of different land use/activity categories. Not simple compliance monitoringactivity-based network design was considered suitable. Monitoring locations representing different activity/land use, namely curbside, residential, industrial, etc. were selected to capture air ions levels under different activity profiles and various air quality statuses. **Table 1** depicts dissimilar air quality statuses for three different sites: industrial, traffic location, and green zone.

Triefield (USA) was used to measure ion density in the air. It measured density separately for both positive and negative ions optionsthrough switching modes. It calculates density in ions per cubic centimeter (ions/cc). The instrument has a capacity for measurement of ions up to two million/cc. It consists of a suction module the sucks the air at the calibrated rate, and then the screen shows the ions density within two seconds, then it continues to show the density until it is switched off. The meter was fitted at a height of 2.8 m from ground level. The readings were recorded for one hour in three-time intervals of approximately 15 minutes each and its average was finalized for the said hour. **Figure 3** depicts schematic of work. Statitistica software was used to plot the two-dimensional scatterplots. These plots are used to actually visualize the relationship between two variables (PM and air ion). The scatterplot can indicate the lack of homogeneity between PM and air ions by forming distinctive clouds of points in the graph. The fitting of functions to scatter points helps to identify and summarize the patterns of relations between PM and air ions. The scatter images suggest the use of piecewise linear regression for two different trends. MS office toolbox were used for seasonal air ions data plotting and analysis.

Figure 4. Identified zones (green zone [left] and traffic intersection [right])

Table 2. Plausible emission sources in the study zones

		Industrial zone	Traffic location	Green zone
Stack emission from industrial process (food industry, packaging, & manufacturing unit)		√	x	x
Vehicular emission	Bus	√	√	x
	Heavy trucks	√	x	x
	Commercial four wheeler	√	√	x
	3 wheeler	√	√	x
	Private four wheeler & two wheeler	√	√	√
Domestic fuel combustion		x	x	√
Open burning		√	√	x
Road dust		√	√	√
Restaurants & eateries		√	√	√

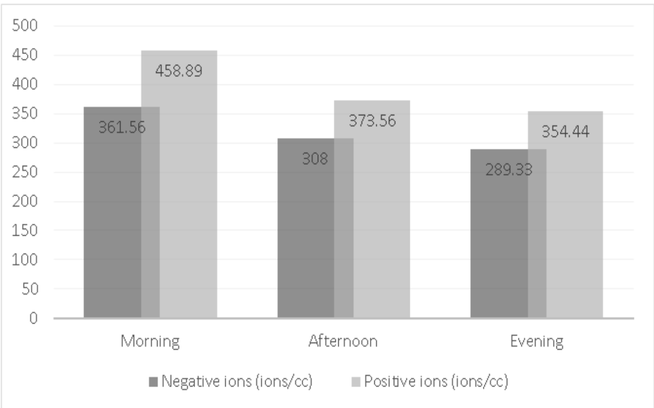

Figure 5. Negative & positive air ion count at traffic junction during winter

Data Collection and Monitoring

During winter and summer 2019, the AIC data was collected to understand air ions trending at the city level. The timing was morning hours between 10:30 am-11:30 am, afternoon and evening between 2:30 pm-3:30 pm and 5:30 pm-6:30 pm, respectively, as mentioned in the locations in **Figure 4**. The AIC count per minute was recorded for said durations. Then the average daily data set was taken into consideration. The total average data set for 54 days was collected. The average wind direction was northeasterlywith average speeds of 4 m/s during the winter. In summer, the wind direction was found to be westerly with average speeds of 6 m/s. The average temperature recorded in the first half of the study during winter was around 24 ^oC, with anaverage humidity of 55%, while during the summer season, it was approximately 40 ^oC and the average humidity was about 24%. **Table 2** shows the accuntable sources of emission and their dissimilar presence in three different study zones.

RESULTS AND DISCUSSIONS

Winter Season

Traffic junction

The collected data as per the ratio of the ions was always less than one, i.e., the higher amount of positive ions was present in the atmosphere at the traffic junction. The air ion ratio (-/+) of the morning, afternoon, and the evening was 0.92, 0.83, and 0.77, respectively. The air ion countis mentioned in **Figure 5**.

Green zone

The common vehicular movement in the green zone was lightweight two-wheelers, four-wheelers, bicycles with an average density of 230 vehicles inside the green zone. The major mode of communication in the green zone was bicycle only. The vehicle movement was poor during the morning and evening hours. The ions count was increasing drastically during evening hours in the range of 1,500-1,700 ions/cc. However, ratio of negative to positive ions was approximately one during the season, i.e., positive and negative air ions increased in proportion. The air ion ratio (-/+) of the morning, afternoon, and the evening was 1.030, 1.142, and 1.142, respectively (**Figure 6**).

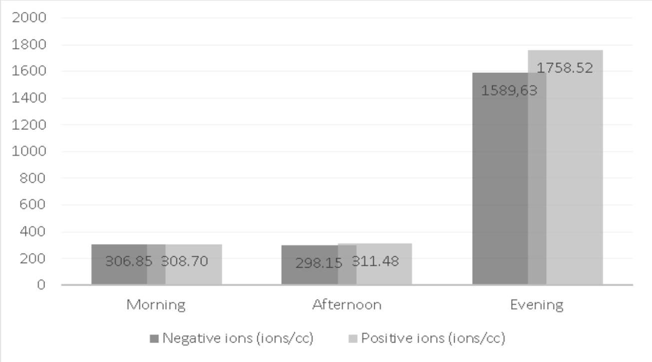

Figure 6. Negative & positive ions count at green zone during winter

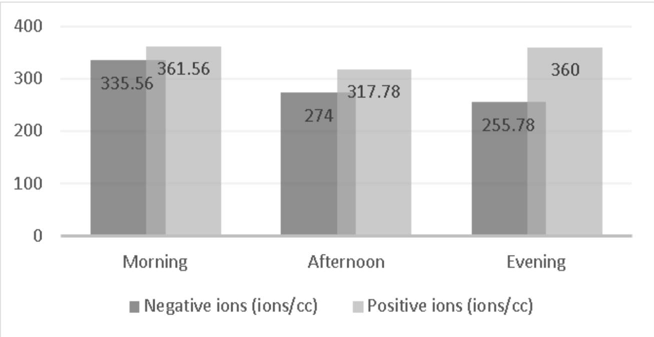

Figure 7. Negative & positive ions count at industrial zone during winter

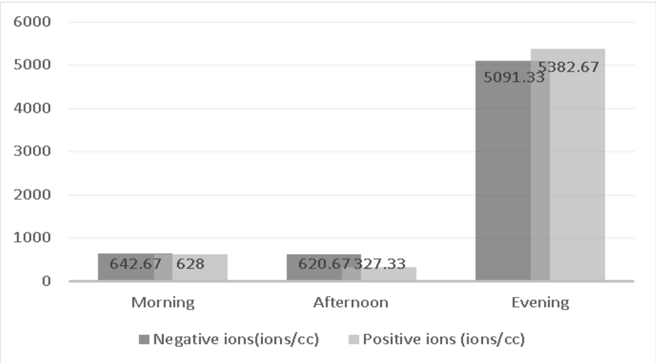

Figure 8. Negative & positive ions count at traffic junction during summer

Industrial zone

The intensity of vehicles was high during morning and evening hours. The count of air ions was normal in the range of 250-300 ions/cc. The ratio of negative to positive ions was approximately one during the day. The morning, afternoon, and evening air ion ratio (-/+) was 1.841, 1.132, and 0.909, respectively. **Figure 7** shows the negative and positive ions count at industrial zone during winter.

Summer Season

Traffic junction

Compared to winter, the ratio of negative to positive ions in summer was greater than or equal to 1. While in winter, the ratio of the ions was not following any trends. The ion count

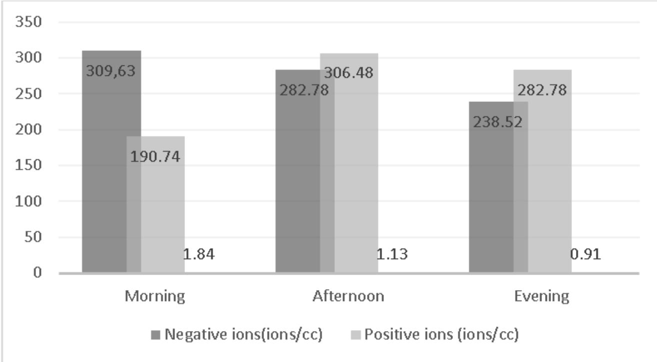

Figure 9. Negative & positive ions count in green zone during summer

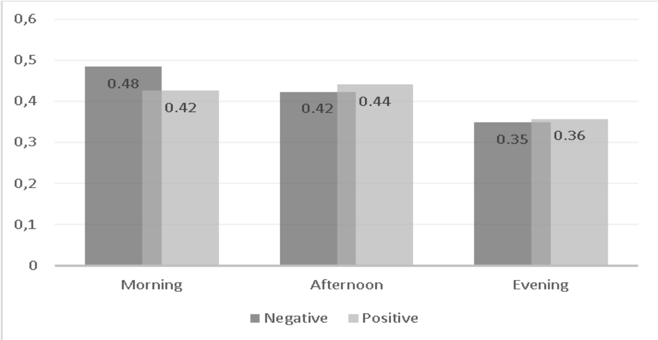

Figure 10. Negative & positive ions count at industrial zone during summer

was decreasing from morning to evening. Also, not many differences were seen in the count of air ions as in **Figure 8**, where the negative and positive ions count at traffic junction during summer is shown. The air ion ratio (-/+) of the morning, afternoon, and evening were 0.916, 0.876, and 0.712, respectively.

Green zone

The trend followed in both seasons for the ratio of theionswas the same. In comparison to winter readings, the count of positive and negative ions was almost double in the summer season except in the afternoon for positive ions. The morning, afternoon, and evening air ions ratio (-/+) was 1.007, 1.348, and0.949, respectively (**Figure 9**).

Industrial zone

The thing in both cases is the ratio of the ions, which is approximately one during both the seasons. Hence, positive and negative ions are in proportion, but the count of ions was increased during the summer days by approximately one hundred ions at each time. The air ion ratio of the morning, afternoon, and evening was (-/+) 1.183, 0.955, and 0.978, respectively. **Figure 10** shows the negative and positive ions count at the industrial zone during summer.

The negative ion counts were collected as per the summer and winter season. **Figure 11** and **Figure 12** depicts the negative air ion count in the winter and summer season, respectively. The negative ion count in both seasons was higher in the green zone. It shows the green zones are a crucial factor in the urban planning.

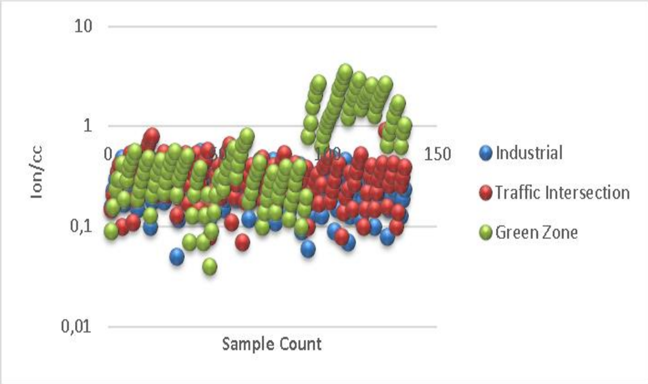

Figure 11. Negative ions count during winter season

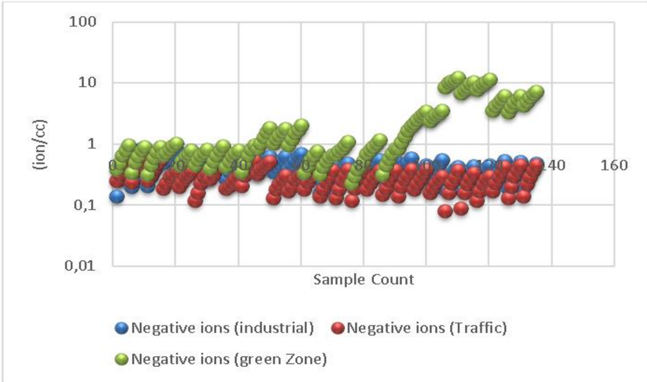

Figure 12. Negative ion counts during summer season

The scatter plots (**Figure 13** and **Figure 14**) with 95% confidence bound between negative ions and ambient particulate matter (PM10 & PM2.5) show an inverse relationship between them except in traffic location winter season. The analysis revealed that with an increase in negative ions concentration, particulate matter pollution decreases. The anomaly observed in traffic location (Lokmat Square) in the winter season may be due to dynamic changes (like local air turbulence, rapid charge dissipation, etc.) The green zone shows an increase in the negative ion count at multiple locations in different seasons and has a poor impact on local air turbulence and PM counts.

Apart from gaseous pollutants, particulate matter (PM) is a major air pollutant that affects human health. Controlled negative ion generation can help in reducing the impact of PM on local air quality. The present study points out diurnal variation of negative ions in typical regions having dissimilar emission characteristics (e.g., industrial zone, traffic zone, and

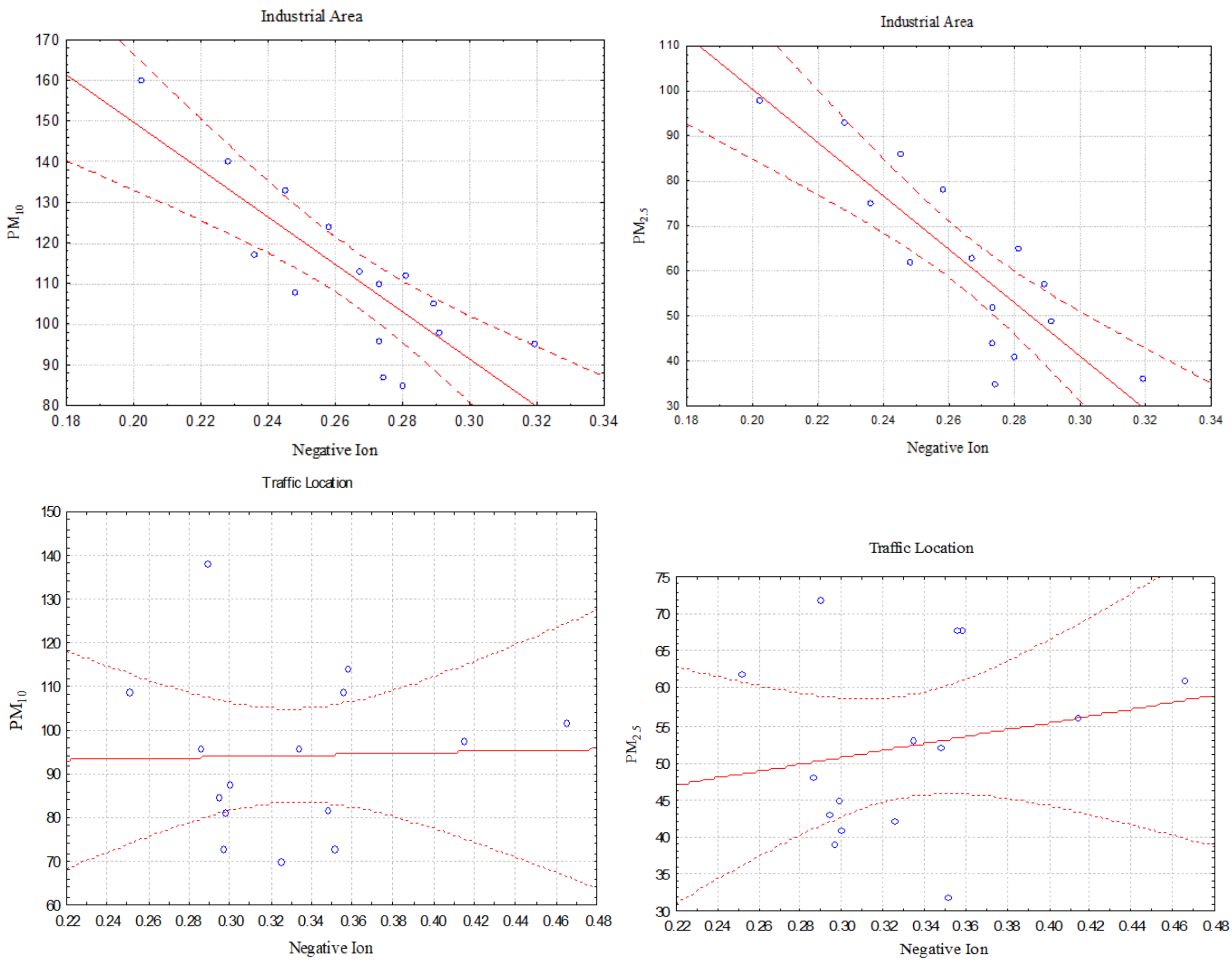

Figure 13. Scatter plot with 95% confidence band for negative ions and PM concentrations (PM10 & PM2.5) for three different locations during winter season

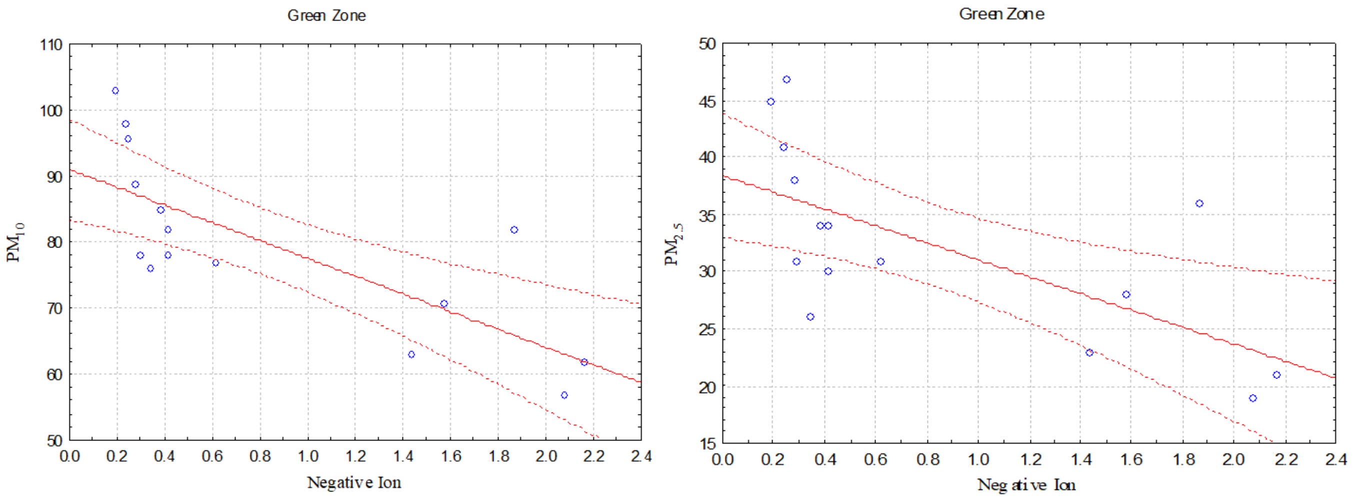

Figure 13 (continued). Scatter plot with 95% confidence band for negative ions and PM concentrations (PM10 & PM2.5) for three different locations during winter season

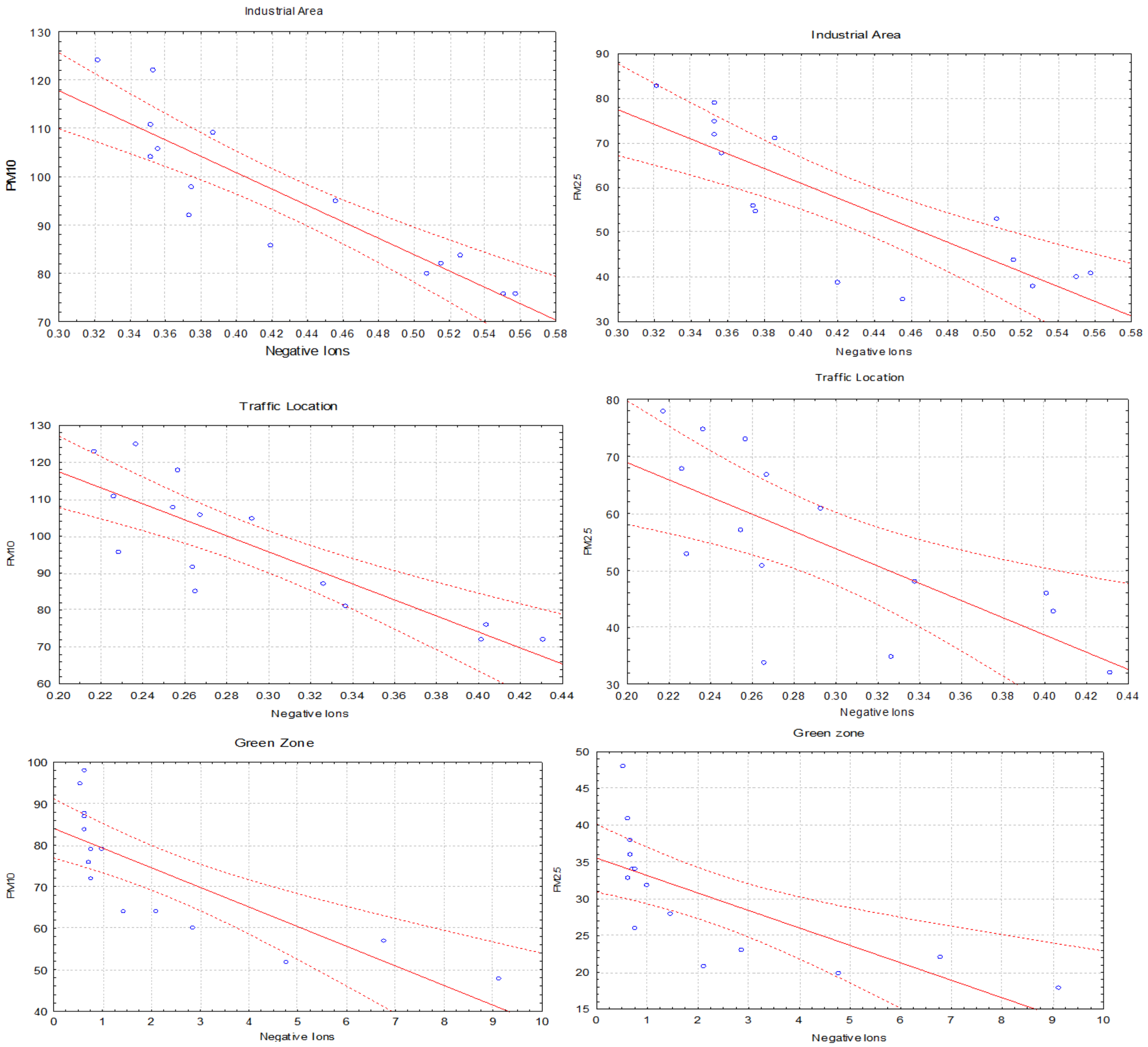

Figure 14. Scatter plot with 95% confidence band for negative ions and PM concentrations (PM10 & PM2.5) for three different locations during summer season

green zone) and also quantifies prevailing amount of positive and negative ions ratio that could indicate the air pollution status of the locality. As shown in the present study, such assessment in day to day changes in air ion ration can help in decision making and proper mitigation measures in the region.

This study shows that the AIC can strongly help in the decision making and identification quality of environment. The study has few limitations of locations like transmission lines high air ion zones.

CONCLUSION

The effects of various pollutant sources on air ions in different seasons are depicted in the present study. The study reveals that the critically polluted regions are season invariable concerning air ions as a precursor of pollution. More negative ions are usually a specific characteristic of the cleanliness of any location/region. The observation of fewer values in negative ions for both the summer and winter season in traffic intersections grounded the fact that seasonal washout of pollutants is not there, which is observed for green zones. The degree of reduction or increment in the ion ratio could help understand the prevailing air quality scenario and can be used for early warning systems for air quality deterioration.

The plants, density of vehicles plays a crucial role in improving negative air ions in the green zone. More studies are essential to understand air ions and their interactions with the urban spaces' green zone environment. The differences in ion ratio values for green zones and other regions can be useful to demonstrate the requirement of mitigation measures.

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Availability of data and materials: All data generated or analyzed during this study are available for sharing when appropriate request is directed to corresponding author.

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