Amity Air Quality Study

Odd-Even Initiative of Delhi Government

Phase-I (29th December 2015-20th January 2016)

Study Conducted by:

Amity Centre for Ocean-Atmospheric Science and Technology (ACOAST) &
Amity Centre for Environmental Science and Health (ACESH)
Amity University Haryana (AUH),
Gurgaon (Panchgaon-Manesar) 122413

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Executive Summary

Following the implementation of the Delhi Government's policy of Road-Space-Rationing (Odd-Even) method, the Amity University Haryana (AUH), Panchgaon-Manesar-Gurgaon monitored, from the day one, its efficacy by making systematic high resolution particulate matter (PM1, PM2.5 and PM10) and spectral variation of black carbon (BC) aerosol mass concentration measurements in conjunction with concurrent solar and local meteorological measurements in its campus. These measurements revealed a significant reduction in the pollution levels on implementation of the oddeven scheme. It was found that due to overlapping of some prominent meteorological phenomena like western disturbances (WDs); fogs etc., inherent to the tropical winters, the results were found to be unclear on the days when the sky was not clear. However, the trends were found to be promising and encouraging. The Government has decided to repeat the policy, in a phased manner, during the forthcoming summer and post-monsoon seasons with more advance preparedness. Thus, the policy shows promising results and it is hoped that this useful exercise would bring down the vehicular pollution and associated health hazards to a considerable extent. Added, considering this experiment conducted in the Delhi region as a model, many other States in the Nation are planning to implement similar policy in their regions.

1. Introduction:

Pollution in many Indian cities, Delhi in particular, is rapidly increasing and significantly hazarding the economy and health of population. Studies have indicated excess mortality (and morbidity) in Delhi due to cardiovascular/cardiopulmonary and respiratory causes, based upon occupational related acute exposures alone. Furthermore, additional factors such as variance in solar radiation, toxicity of atmospheric and biogenic emissions, and wind-blown dust and soil, all result in exacerbation of the issue. In order to curb these anthropogenic emissions, and to develop cost-effective methods for health improvements (especially pre-mature deaths), Government of Delhi had recently implemented an odd-even formula. While the debate on the success of this initiative may continue, what cannot be denied is the fact that with the reduction of vehicles on road, the total pollution load during the stretch of twelve hours (08:00am to 08:00pm) has come down by at least a factor of two. This is primarily because of subsequent reduction in traffic congestion resulting in considerable reduction in commuting time. This directly relates to about 50% reduction in the fuel consumption for the same distance traveled on odd-even days. This is by no means an improvement both from the point of view of commuters and human health, and also from the point view of air quality and fuel economy.

2. Methodology and Results:

Scientists at Amity University Haryana (AUH) Air Quality Monitoring Facility, led by Prof. P.C.S. Devara, President, Indian Aerosol Science and Technology Association (IASTA) and Director, Amity Centre for Ocean-Atmospheric Science and Technology (ACOAST) & Environmental Science and Health (ACESH) have carried out high-resolution Black Carbon (BC) and Particulate Matter (PM_1, $PM_{2.5}$ and PM_{10}) mass concentration over AUH campus at Panchgaon near Manesar, Gurgaon. The daily marching of these air quality drivers is portrayed in figures from 1 through 5 below. The time-concentration cross-sections of BC mass variation, observed with Magee Scientific-make 7-wavelength Aethalometer during the study period, are shown plotted in Figure 1. One can clearly visualize the hour-by-hour variation of BC mass and its association with local meteorology, from commencement of the program i.e. 29 December 2015 through 20 January 2016 over AUH, Panchgaon. It may also be interesting to see here that the BC values are lower under clear-sky 2015 and higher under foggy conditions due to the reasons explained in the paragraphs to follow.

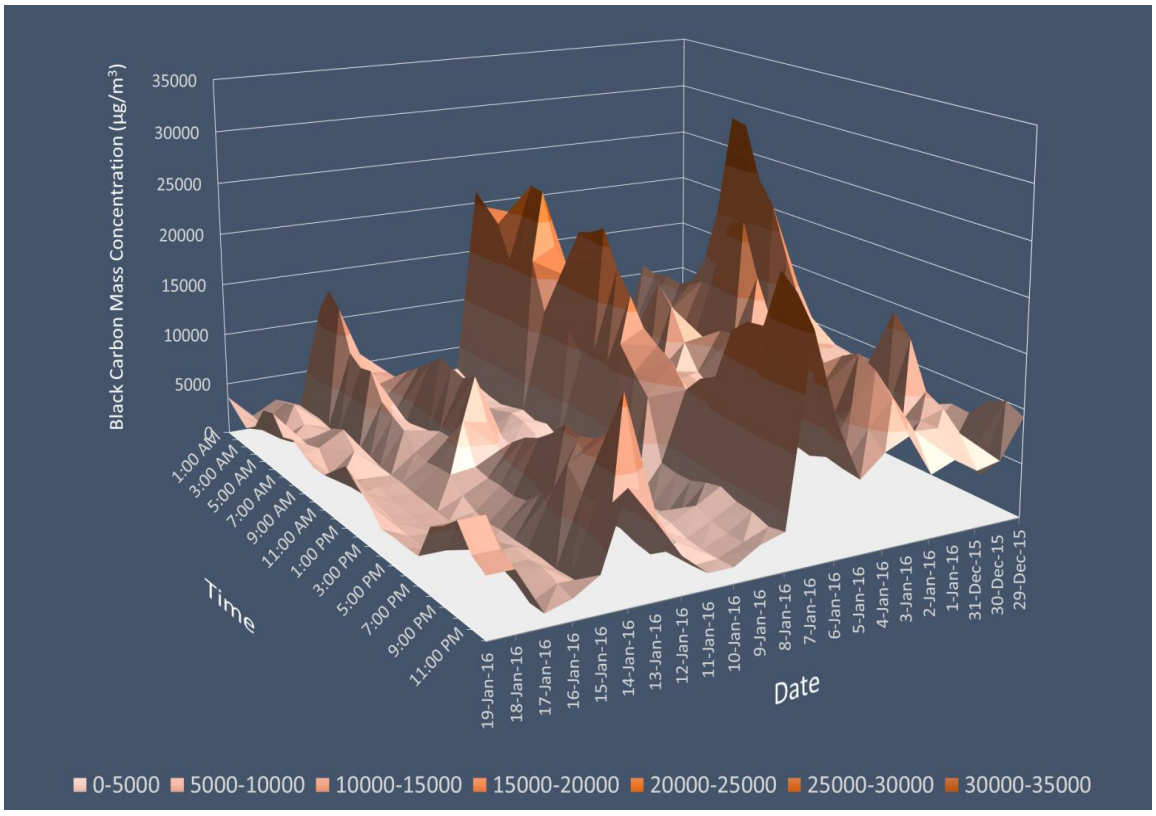

Figure 1: 3-dimensional view of date-wise diurnal variation of BC mass concentration observed over AUH during the study period. Bi-modal distribution with significant enhancement in BC concentration during 6th-8th January 2016, peaking on 7th, due to fog phenomenon may be noted.

Further, it may be noted that the daily mean mass concentration of the black carbon also shows drastic reduction at AUH monitoring station from 15 micrograms per cubic meter on 31 January (before commencement of the initiative) to approximately 1.4 micrograms per cubic meter on 11th January 2016. Figure 2 displays the daily diurnal variation in BC mass concentration during the study period. The common feature that is observed on all the days that BC mass concentration depicts bi-modal distribution with primary peak around 0800 h and secondary peak around 2000 h, both may primarily be due to the transport activities in and around the study region. The black carbon mass concentration was higher on 31 December 2015, and thereafter, it showed gradual decrease during fair weather conditions on remaining days. The minimum black carbon concentration observed on each day around noon hours is ascribed to the local Planetary

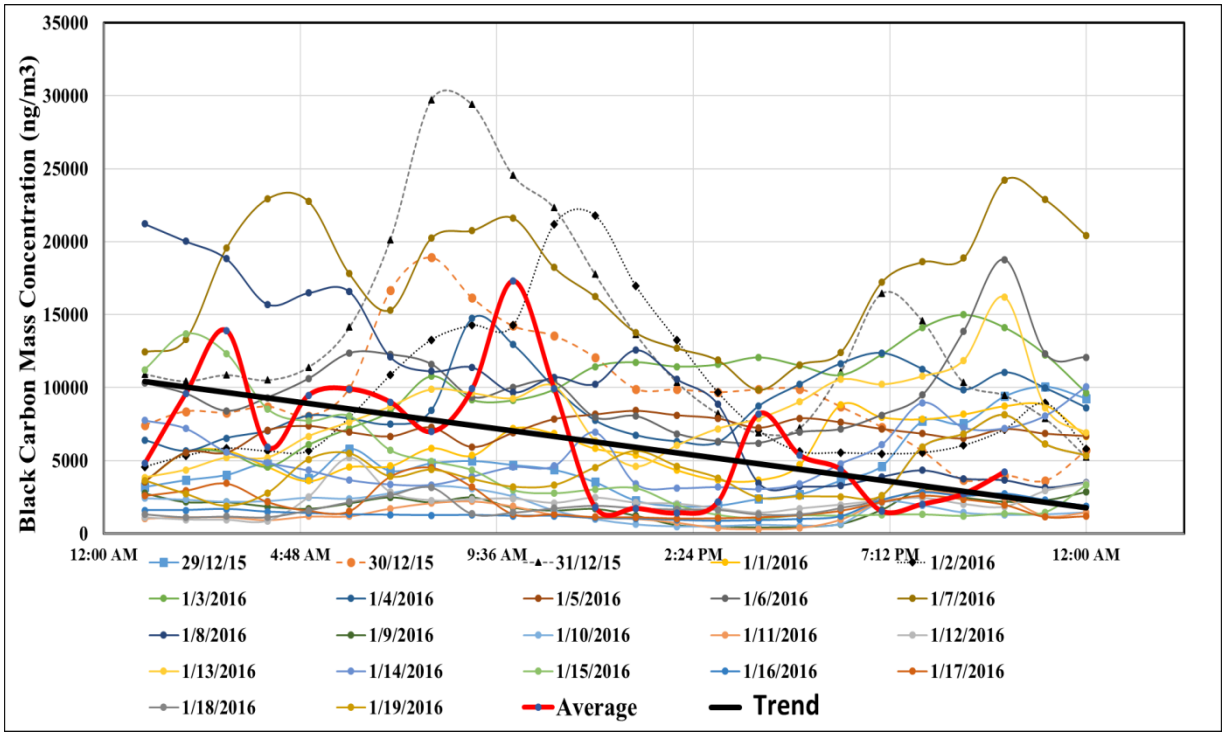

Figure 2: Diurnal variation of BC mass concentration on different observation days over AUH, Panchgaon-Manesar-Gurgaon. The thick curve in red color indicates mean diurnal variation of BC mass concentration for the entire study period, and the solid line in black color passing through it denotes best fit line, depicting the decreasing trend.

Boundary Layer (PBL) height variations. However, local construction activities which may be modulating the observed variations should not be foresight off.

2.1 Daily variations in BC and PM mass concentration

The day-to-day variation in BC mass concentration during the study period is shown

plotted in Figure 3. Higher concentration during the turbid-sky conditions and less concentration during the clear-sky conditions may be noted. Figure 4 portrays the diurnal variation of PM_1, $PM_{2.5}$, PM_{10} and Figure 5 displays the daily mean mass concentrations of $PM_{2.5}$ and PM_{10} recorded with TSI-make Aerodynamic Particle Sizer (APS) over AUH, Panchgaon. It is glaringly seen that PM_{10} concentrations dominate as compared to $PM_{1.0}$ and $PM_{2.5}$ concentrations. The higher PM_{10} concentrations are attributed to dust outbreak in and around the experimental site, whenever wind speeds are strong. It may be noted that the observed $PM_{2.5}$ concentrations over Panchgaon are over four times lower than that of concentrations over urban Delhi. $PM_{2.5}$, being particulate matter which adversely affects the health and PM_{10} concentrations influences the earth-atmosphere radiation balance vis-à-vis local short-term climate changes.

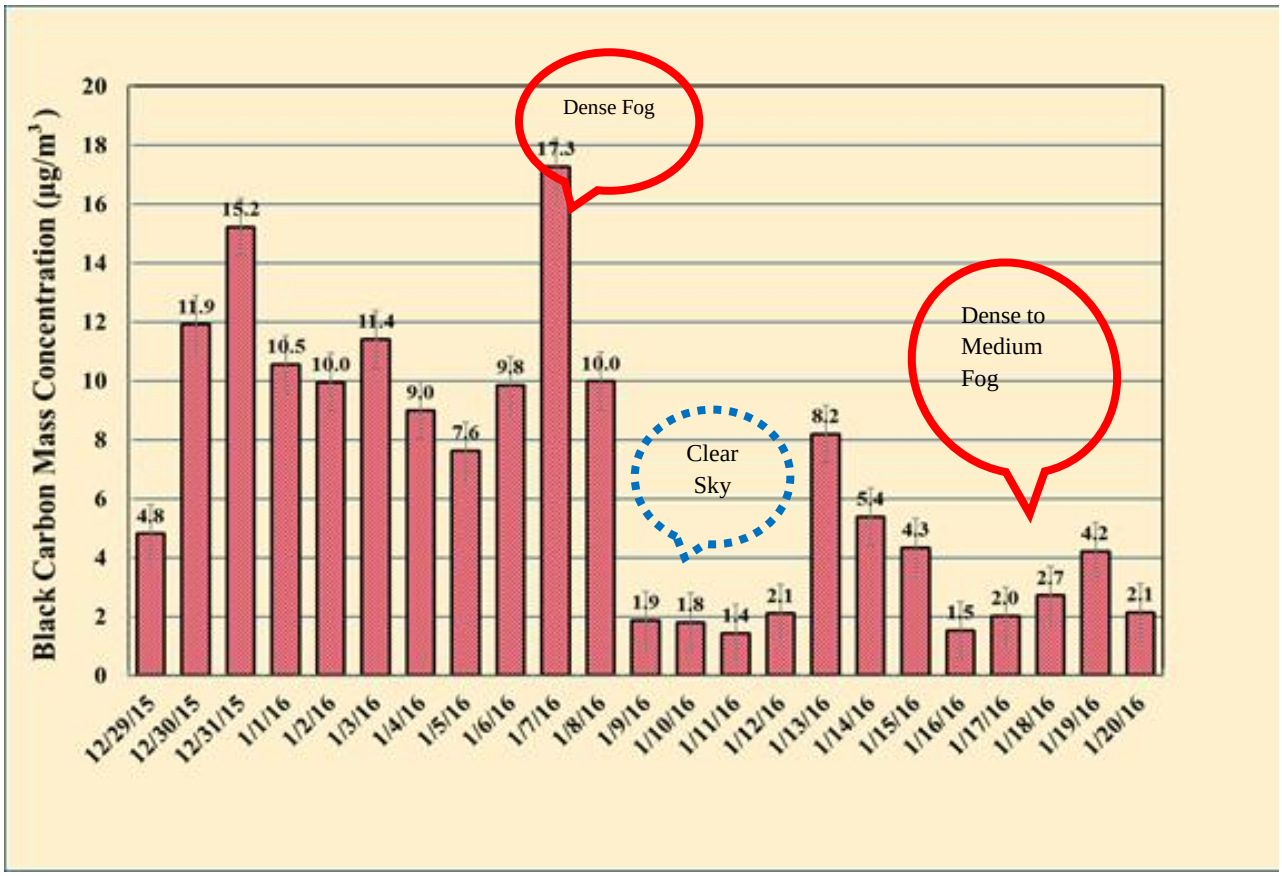

Figure 3: Day-to-day variation in BC mass concentration during 29 December 2015 – 20 January 2016.

2.2 Daily mean variation of $PM_{2.5}$ and PM_{10} during atmospheric turbid conditions

The daily diurnal mean mass concentration values of PM_1, $PM_{2.5}$, PM_{10} and BC are presented in Table 1. It is interesting to note that $PM_{2.5}$ mass concentration is four times lower

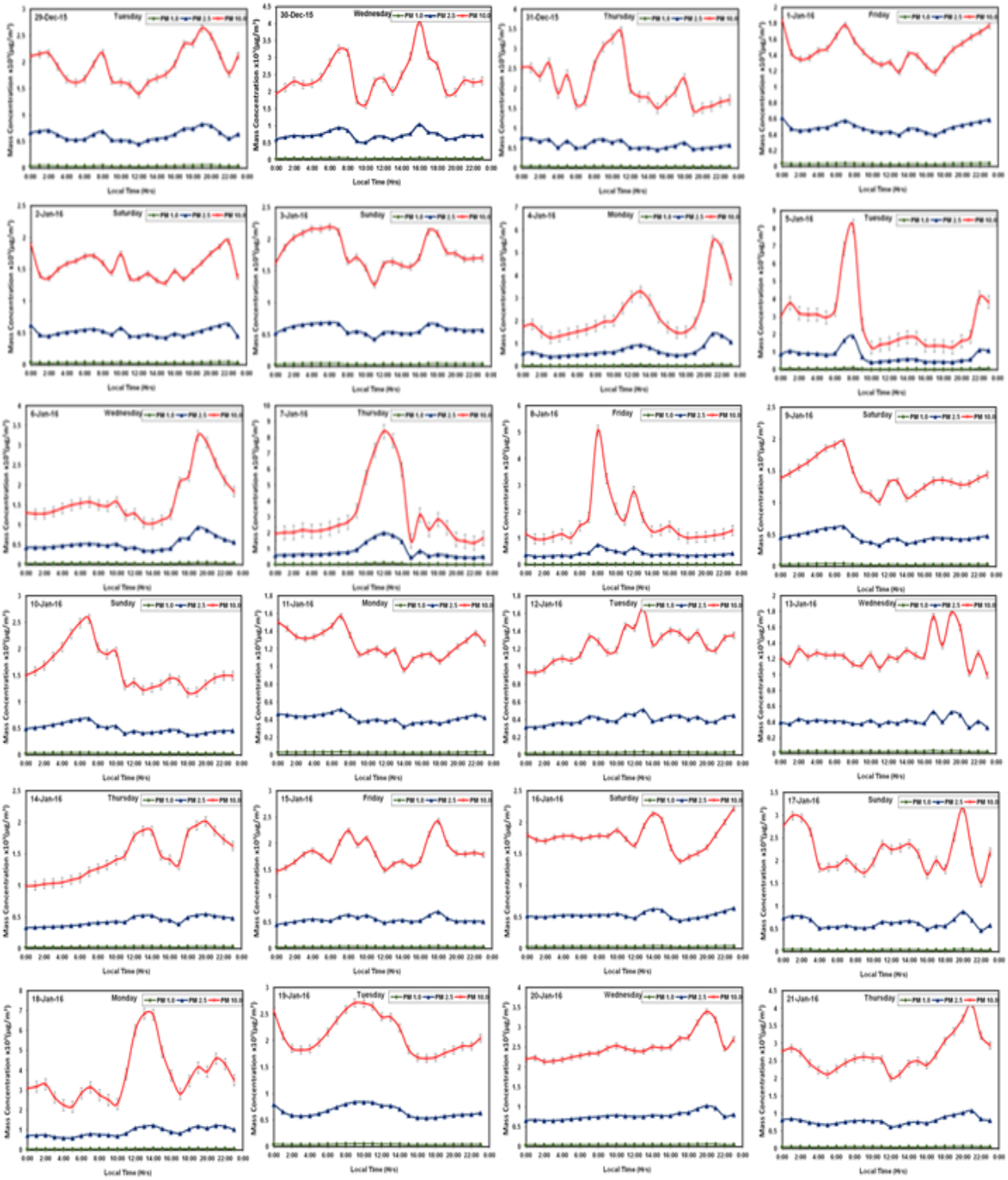

Figure 4: Diurnal variation of Particulate Matter (PM_1, $PM_{2.5}$ and PM_{10}) on different observation days over AUH, Panchgaon-Manesar-Gurgaon.

than that of urban Delhi. Likewise, the major PM_{10} concentration at Amity University Haryana is also less than half of what is reported from urban Delhi. It may be noted here that both PM and BC variations are highly influenced by the meteorological phenomena (associated bidirectional

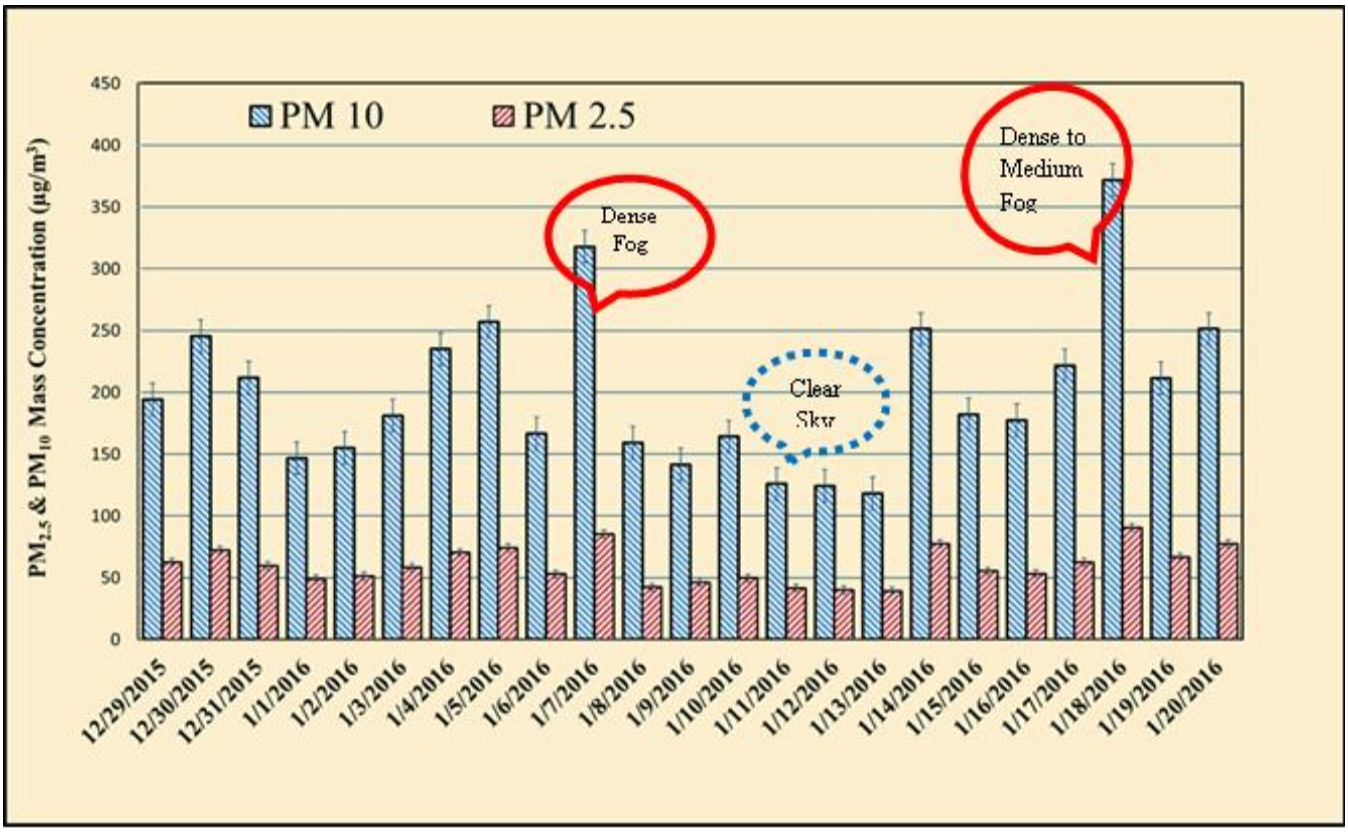

Figure 5: Day-to-day variation in PM mass concentration during 29 December 2015 – 20 January 2016

feed-backs on air pollutants) such as Western Disturbances (WDs) and Fog. The high wind speeds associated with WD (and long-range transport) remove pollutants, resulting in low concentrations in the study region. At the same time, these winds also may bring fresh particles from the surrounding regions and make the study region rich in concentration. On the other hand, fog (associated with low temperature) situations generally enhance the pollution levels due to secondary aerosol (new particle) formations, growth of existing particles (depending on composition) and local boundary-layer dynamics. Therefore, the fluctuations in mass concentration during such complex meteorological situations should be treated with caution.

Table 1: Daily diurnal mean PM and BC mass concentrations from 29 December 2015 to 20 January 2016.

Date	PM1	PM2.5	PM10	BC
	Mass Concentration (μg/m^3)			
29/12/2015	4.14	62.51	194.10	4.81
30/12/2015	4.53	72.30	245.44	11.91
31/12/2015	3.81	59.65	211.72	15.22
01/01/2016	3.31	48.90	146.70	10.55
02/01/2016	3.46	51.25	155.10	9.95
03/01/2016	3.86	58.42	181.14	11.40
04/01/2016	4.39	70.30	234.97	9.00
05/01/2016	4.52	74.05	256.85	7.63
06/01/2016	3.45	52.97	166.51	9.85
07/01/2016	4.94	85.29	317.83	17.27
08/01/2016	2.71	42.28	159.23	9.98
09/01/2016	3.10	46.29	141.56	1.86
10/01/2016	3.25	49.74	164.10	1.80
11/01/2016	2.82	41.57	125.82	1.42
12/01/2016	2.69	40.03	124.34	2.10
13/01/2016	2.67	39.24	118.06	8.19
14/01/2016	4.96	77.44	251.19	5.38
15/01/2016	3.60	55.31	182.15	4.34
16/01/2016	3.45	53.31	177.40	1.53
17/01/2016	3.93	62.42	221.53	2.01
18/01/2016	5.31	90.49	371.75	2.71
19/01/2016	4.32	66.80	211.50	4.21
20/01/2016	4.96	77.44	251.19	2.13

2.3. Day to day variation in AOD, TCO and PWC during 29 Dec.2015-20 Jan.2016

Figure 6 displays day-to-day spectral variations in column-integrated aerosol optical depth (AOD), Ozone (TCO) and Precipitable Water Content (PWC). These observations are representative of atmospheric extinction (attenuation) up to stratospheric altitudes (~50 km). The plot clearly shows the wavelength dependence (more extinction at shorter wavelengths).It is evident from the figure that higher AODs observed on 02 & 04January, 2016, which may be due to combined effect of Western Disturbances-induced Air Mass trajectories (Figure 4).However, because winds can advect foreign particles from upwind regions, and also scavenge existing particles over the study region, the influence of winds on air quality is complex. The measurements of total column ozone and precipitable water content have also revealed a significant decrease while the AOD did not show any trend due to the prevalence of turbid sky conditions.

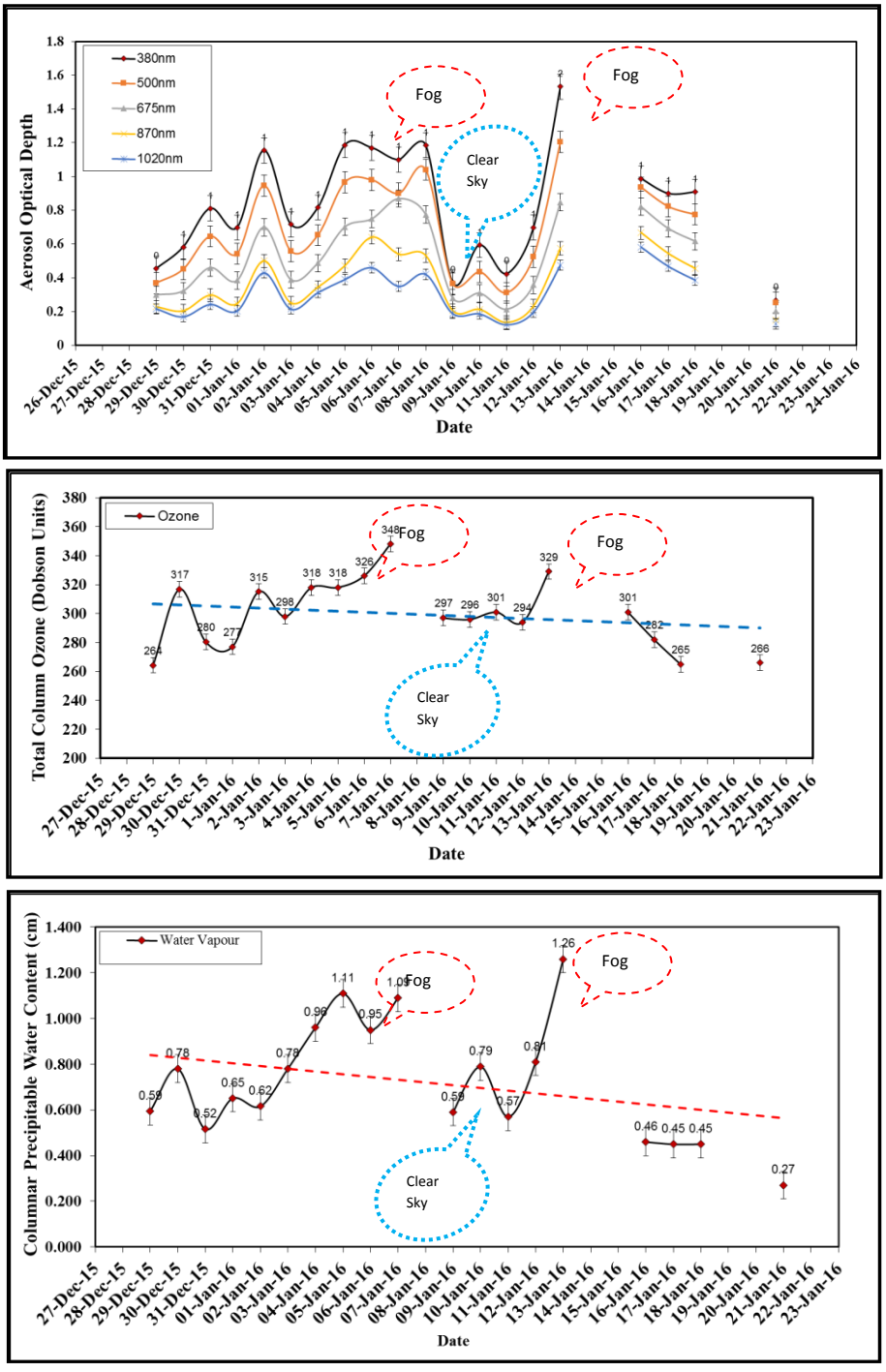

Figure 6: Solar Radiometric observations for AOD, TCO and PWC during 29 December 2015-20 January 2016. The data gaps in the plot are due to obscuration of Sun either due to clouds and/or fog. The dashed lines in the TCO and PWC frames indicate linear trend in the variation.

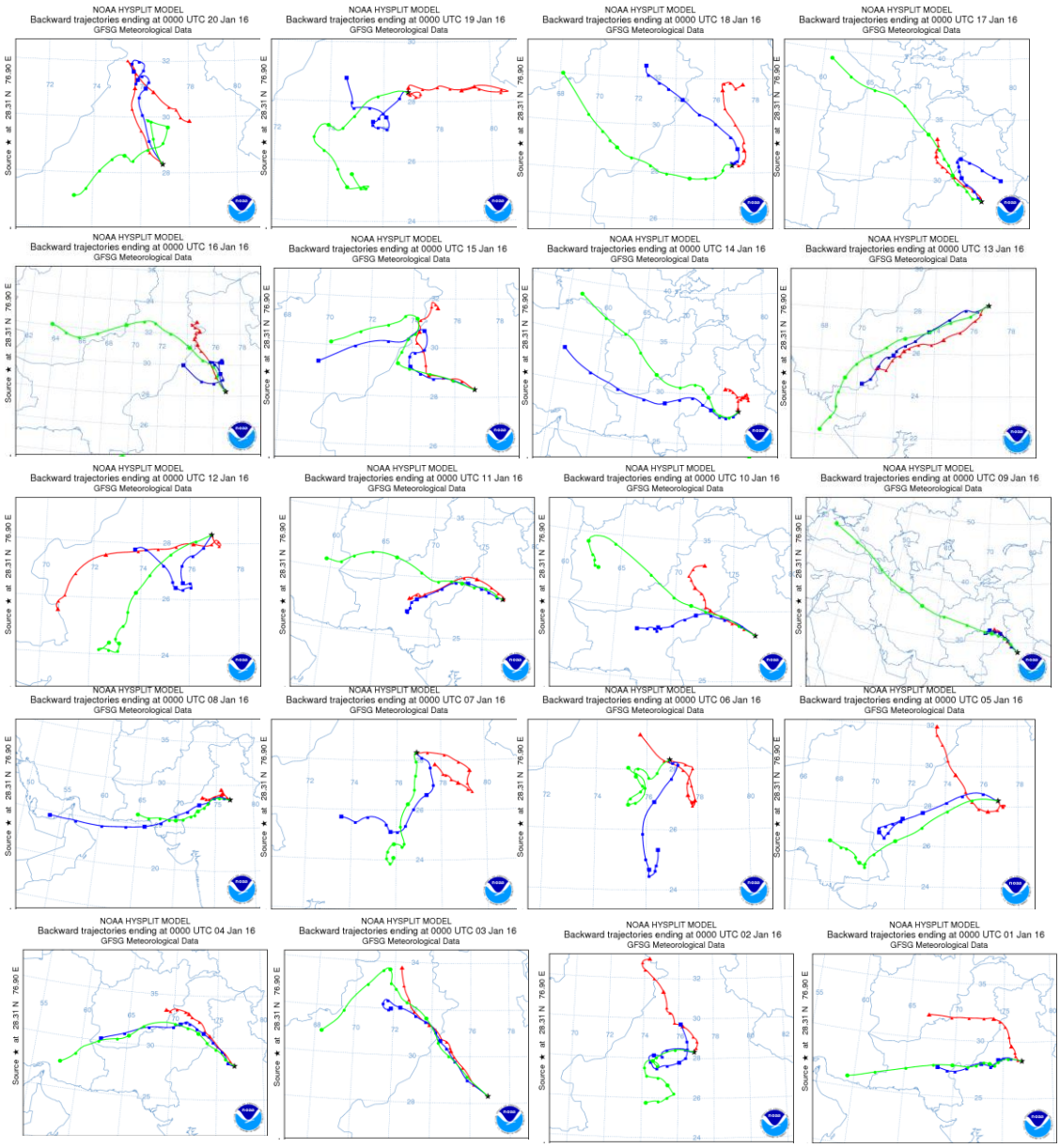

Figure 7: 5-Day Back Trajectories using NOAA HYSPLIT Model from 29-Dec-2015 to 20-Jan-2016.The asterik in each frame indicates location of the observation site (AUH, Panchgaon). The red, green and blue colored trajectories refer to 500, 1000 and 1500 m above ground level,

2.4. Air-mass back-trajectories during the study period

The air-mass back-trajectories of 5-day (120 hours) have been obtained using the NOAA-ARL HYSPLIT (Hybrid Particle Lagrangian Integrated Trajectory) model for all the observation days and shown plotted in Figure 7. Evidently, on 02, 06, 07, 12, 19 and 20 January 2016, particulate fraction is relatively dominant from the land-origin. On the remaining days, the contribution to the pollution at the observing site comes from both land and marine sources.

From the above, it can be said that the study of air quality monitoring clearly reveals the benefit of odd-even campaign. The study, however, continues to bring out a clearer picture in respect of the correlation between weather condition and air quality. The above pilot results appeared as news items in several magazines such as Times of India, The Hindu, The Indian Express and some regional news-papers like Amarujala, Hindustan Hindi etc. These press clippings are also appended below.

3.0. News Headlines

सम-विषम फार्मूले से प्रदूषण में कमी

खुलासा

गुड़गांव | कार्यालय संवाददाता

दिल्ली में सम-विषम फार्मूले का असर गुड़गांव में दिखा है। फैसला लागू होने के बाद से ही गुड़गांव के प्रदूषण स्तर में लगभग 40 फीसदी की कमी आई है। एमिटी यूनिवर्सिटी की ओर से किए गए शोध में यह खुलासा हुआ है। पीएम 2.5 के अतिरिक्त ब्लैक कार्बन में भी कमी दर्ज की गई है।

मानेसर स्थित एमिटी यूनिवर्सिटी की ओर से सम-विषम फैसले के लागू होने से प्रदूषण पर पड़े प्रभाव को लेकर शोध किया गया था। इसके लिए सम-विषम फैसले के लागू होने से पहले और बाद में प्रदूषण का स्तर मापा गया।

शोध में 29 दिसंबर 2015 से लेकर 15 जनवरी 2016 तक के प्रदूषण स्तर का आकलन किया गया। इसमें खुलासा हुआ है कि प्रदूषण के स्तर में 40 फीसदी तक की कमी दर्ज की गई है। जहां 30 दिसंबर को वातावरण में जहां पीएम 2.5 की मौजूदगी 72.30 (प्रति घन मीटर) थी। वहीं 15 जनवरी को वह घटकर 38.02 रह गई। ठीक इसी तरह 30 दिसंबर को पीएम 10 की मात्रा 245.44 था जो कि 15 जनवरी को 122.37 दर्ज की गई है।

वहीं, दूसरी तरफ ब्लैक कार्बन के स्तर में भी भारी कमी दर्ज की है। इससे साफ होता है कि सम-विषम के लागू होने के बाद सड़कों पर पहले के मुकाबले काफी कम वाहन उतरे। 30 दिसंबर को ब्लैक कार्बन वातावरण में 11.91 था। जबकि 15 जनवरी को घटकर यह महज 5.01 रह गया है। गौरतलब है कि इंडियन एयरोसेल साइंस एंड टेक्नोलोजी के अध्यक्ष पीसीएस देवरा, डॉ. मधु जोशी, पावेल सहित टीम ने यह शोध किया है। दिल्ली समेत अन्य क्षेत्रों से यहां कार्य करने आते हैं

दिल्ली सहित एनसीआर के अन्य हिस्सों से बड़ी संख्या में लोग गुड़गांव में कार्य करने आते हैं। जिनमें से अधिकांश दिल्ली के रास्ते शहर में प्रवेश करते हैं। ऐसे में सम-विषम लागू होने से अपेक्षाकृत कम गाड़ियां गुड़गांव आईं और गईं। जिससे प्रदूषण स्तर में भारी कमी आई। ऐसे में इस फैसले से पर्यावरण संरक्षण में काफी निर्णायक मदद मिली है। ऐसे में पर्यावरण में मिलने वाले हानिकारक तत्व भी कम हुए हैं।

पिछले सत्रह दिनों में प्रदूषण में आए बदलाव के आंकड़े

दिनांक	पीएम 1.0	पीएम 2.5	पीएम 10	ब्लैक कार्बन
30 दिसंबर	4.53	72.30	245.44	11.91
31 दिसंबर	3.81	59.65	211.72	15.22
1 जनवरी	3.31	48.90	146.70	10.55
2 जनवरी	3.46	51.25	155.10	9.95
3 जनवरी	3.86	58.42	181.14	11.40
4 जनवरी	4.39	70.30	234.97	9.00
5 जनवरी	4.52	74.05	256.85	7.63
6 जनवरी	3.45	52.97	166.51	9.85
7 जनवरी	4.94	85.29	317.83	17.27
8 जनवरी	2.71	42.28	159.23	9.98
9 जनवरी	3.10	46.29	141.56	1.86
10 जनवरी	3.25	49.74	164.10	1.80
11 जनवरी	2.82	41.57	125.82	1.42
12 जनवरी	2.69	40.0	124.34	2.10
13 जनवरी	2.76	41.00	127.00	7.18
14 जनवरी	2.85	43.63	144.92	5.37
15 जनवरी	2.50	38.02	122.37	5.01

दिल्ली का सम विषम प्रयोग काफी हद तक कामयाब रहा है। अब आसपास के राज्य हरियाणा और उत्तर प्रदेश को भी प्रयोग शुरू करना चाहिए।
-प्रो. पीबी शर्मा, कुलपति (एमिटी यूनिवर्सिटी, गुड़गांव)

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Black carbon level in air down 50% since Dec 31, study shows

TNN | Jan 9, 2016, 02.17 PM IST

Gurgaon: A week into the odd-even experiment, the levels of black carbon in the air have decreased by almost 50% according to a study by Indian Aerosol Science and Technology Association and students of Amity University, Gurgaon.

The study shows that the mass concentration of black carbon - carbon particles released by incomplete combustion of fuel - reduced from 15 micrograms per cubic metre on December 31 to 7.6 micrograms per cubic metre on January 5. The test was conducted at the monitoring station on the university campus in Manesar.

"Vehicles are a major source of black carbon after wood burning. Stranded vehicles, in particular, are responsible for emitting black carbon. We have noticed that due to reduction in traffic jams during the odd-even scheme, the level of unburnt carbon in the atmosphere has come down," said Dr P C S Devara, president of Indian Aerosol Science and Technology Association, who mentored the students during the study.

According to the United Nations Environment Programme, black carbon is a sooty substance, which is a solid component of fine particulate matter (PM2.5). It has severe health impacts, including cardiovascular and respiratory diseases, and also contributes to climate change. Vehicles are responsible for nearly 20% of black carbon emissions globally, and diesel vehicles, in particular, are a major contributor to emissions.

Talking about the mechanism used for the study, Munshi Pavel Alam, a student of BSc (Earth Sciences) said, "We used data from the air monitoring system installed on our campus in Manesar and data provided by SAFAR (System of Air Quality and Weather Forecasting And Research) of the ministry of earth sciences. The team comprising two mentors and three students used a Seven Beam Aethalometer

THE HINDU

CITIES » DELHI

GURGAON, January 9, 2016

Updated: January 9, 2016 05:33 IST

Amity registers dip in pollution on campus

ASHOK KUMAR

: The Amity University in Gurgaon has claimed that the levels of pollution have gone down in its campus since Delhi started the odd even experiment.

Scientists at Amity University Gurgaon Air Quality Monitoring facility, led by Dr. P.C.S Devara, president of the Indian Aerosol Science and Technology Association and Head of Amity Centre for Environmental Sciences and Health, have revealed that the mass concentration of the black carbon showed drastic reduction at Amity University monitoring station at its campus from 15 micrograms per cubic meter on December 31, 2015 to approximately 7.6 micrograms per cubic meter on January 5, 2016.

The study also claimed that the levels of PM 2.5 and PM 10 concentration over Amity University campus have also gone down considerably. The measurements of columnar Aerosol Optical Depth (AOD), Total Column Ozone (TCO) and Perceptible Water Content (PWC) have also revealed a significant decrease.

Prof P B Sharma, Vice Chancellor of Amity University, said that the reduction in pollution due to odd-even formula was primarily because of subsequent reduction in traffic congestion resulting in considerable reduction in commuting time.

"For example, a distance of 70 km from Amity University Gurgaon to Amity University Noida that was earlier covered in more than two hours can now be covered in just over an hour. This directly relates to approximately 30% reduction in the fuel consumption for the same distance traveled on odd/even days," said Prof Sharma

4.0. Recommendations

- We need to march beyond odd-even initiative as major gains shall be obtained by initiatives like re-routing the traffic in mega and metro cities like Delhi and Gurgaon. Further, it will be important for the Government of Delhi to consider segregating the mixed traffic as at present. Initiatives like battery operated rickshaws in certain areas of Delhi and CNG in the others, bringing back electric trams to Delhi and motivating the automobile industry to produce cost-effective battery operated automobiles and hybrid vehicles which will go a long way to solve further the problem of air pollution.
- The Government of Delhi may offer free charging of batteries from solar-powered charging stations to the battery-vehicle owners and even reduce the road tax by 50% for such vehicles. The Government of Delhi may also be well advised to offer say approximately 20% fuel subsidies to whoever opts for car-pooling. It may also be pertinent to note that while on one hand the odd-even initiative has created a hope for improving air quality, the regulators must come down heavily on Delhi metro and other major construction agencies who are contributing heavily to ever rising dust.
- In-ordinate delay in completion of projects like construction of flyovers, re-construction of East Kidwai Nagar etc. is also a matter of grave concern.
- As the sample size is small and perturbed by varied meteorological conditions, we need to collect more data, covering from the surface through to earth observation, during fair weather conditions, to make more useful conclusion. We also need to understand the toxicity of pollutants and develop biomarkers that help setting-up of permissible respiratory levels for human health.

Acknowledgements – The Amity Centre for Ocean – Atmospheric Science and Technology (ACOAST) and the Amity Centre for Environmental Science and Health (ACESH) are highly grateful to Dr. Ashok K. Chauhan, Honorable Founder President Sir; Dr. Aseem Chauhan, Honorable Chancellor Sir, for their continue inspirational leadership, encouragements and support for this study. This study was possible due to joint research collaboration and support extended by the Aryabhatta Research Institute for Observational Sciences (ARIES), Nainital, and Indian Institute of Tropical Meteorology (IITM), New Delhi Unit. The role played by the Press Media, in this regard, is gratefully acknowledged.

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