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Identification of Threat to Air Quality in a Tropical Coastal Region, Kerala, India

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Abstract: ***Air pollution and its adverse impacts are one of the greatest problems faced by mankind. The study was conducted to assess the threat to air quality in a tropical region. The diurnal variation of particulate matters ($PM_{10}$and $PM_{2.5}$), SO_2, NO_2, NO_x, NO, CO, ozone, and ammonia in ambient airof the coastal city, Thiruvananthapuram, Kerala, India has been assessed. Factor analysis was conducted to identify the critical factors affecting the air quality. The study reveals that the concentration of carbon monoxide, PM_{10}, and $PM_{2.5}$ is nearing to the limiting standards. Hence, immediate attention should be taken for the reduction of these parameters. Ozone pollution factor, Aerosol pollution factor, and Ammonia pollution factors are the critical factors controlling the ambient air quality in a tropical region.***

Keywords: Air quality, tropical region, Ozone, Aerosol, Ammonia, Carbon monoxide

Highlight

- Discussed about the hourly variation of major pollutants in the atmosphere
- Average variations in the atmospheric concentration of pollutants were observed
- Source contribution estimation was very significantly matching with the pollutants concentration obtained in the field study

1. Introduction

Air pollution is one of the serious environmental concerns of the urban Asian cities including India where majority of the population is exposed to poor air quality (Saxena et al., 2010). Particulate matters of size less than 10µm and 2.5µm (PM_{10} and $PM_{2.5}$) as well as gaseous pollutants can cause impact on metabolic features in blood and which in turncause malfunction of human organs (Vlaanderen et al., 2017, Gupta and Kulshreshta, 2016).Emissions from vehicular exhaust (Nelson et al., 2008, Schauer et al., 2006), industrial stack(Li et al., 2017), domestic heating (in temperate climates)(Giuntoli et al., 2015), burning of garbage(Chen et al. 2017, Zhang et al., 2015) construction and demolition activities (Diapouli et al., 2017, Guttikunda et al., 2014)are potential risks for large air pollution exposures (Larssen, 2016). The rapidity of economic development combined with the lack of emission controls makes Asia's megacities prone to more serious air pollution problems than similar cities in industrialized nations. The routine pollutants in urban air include sulphur dioxide, nitrogen oxides, and suspended particulate matter. There is also a server threat from a range of other air toxins such as carbon monoxide, small particulate emissions, lead, benzene, polycyclic aromatic hydrocarbaons(PAH), and ozone. Generally all the elements exhibited seasonal trend with higher level in the dry season as compared to those in the rainy season(Sehgal et al., 2011). Toxic air pollutants such as benzene and formaldehyde are substances from automobile emissions that are known to cause or are suspected of causing cancer, genetic mutation, birth defects or other serious illnesses in people even at relatively low levels (https://fortress.wa.gov/ecy/publications/documents/0002008.pdf).

Air pollution in many cities around the world is increasingly reaching levels that threaten people's health, according to a study by the World Health Organization. Motor vehicles and fossil fuel power plants are among the major contributors. According to a WHO (2006), more than two million premature deaths each year can be attributed to the effects of urban outdoor and indoor air pollution (caused by the burning of solid fuels). Outdoor air pollution is among the most significant environmental threats to human health(IGU, 2015).India's population is exposed to dangerously high levels of air pollution(Greenstone et al., 2015). The Central Pollution Control Board reveals that 77% of Indian urban agglomerations exceeded National Ambient Air Quality Standard (NAAQS) for respirable suspended particulate matter(PM10) in 2010 (CPCB, 2012). India has the highest rate of death caused by chronic respiratory diseases anywhere in the world (Greenstone, et al., 2015).

In the current research work identification of major air pollutants in Thiruvananthapuram, capital city of Kerala, located at southern part of India and investigated the emission inventory to assess the source contribution impact due to anthropogenic activities near by location.

Climate of Thiruvananthapuram city

Thiruvananthapuram city, through in the tropics enjoys fair weather. http://shodhganga.inflibnet.ac.in/bitstream/10603/6758/10/10_chapter%203.pdf). The average temperature is about 29oC and the annual rainfall is around 1700mm with concentration outbursts during both South-West and North-East monsoons. There is no demarcation of seasons. However, summer period is generally taken from March to May followed by monsoon season(South-West and North-East) which lasts upto November. The post monsoon period from December to February is relatively cool.

2. Materials and Methods

The diurnal variation of ambient air quality from the CAQMMS installed by the Kerala State Pollution Control Board at Plamood, Thriuvananthapuram city on 9th December 2015 has been used in the study(Table1). Factor analysis was conducted using SPSS software.

3. Results and Discussion

Variation of air quality parameters

Carbon monoxide (CO)

Carbon monoxide is a colourless, odourless, poisonous gas emitted from the vehicle's exhaust as a result of incomplete combustion. It interferes with the blood's ability to carry oxygen to the brain, heart, and other tissues. Unborn or newborn children and people with heart disease are in greatest danger from this pollutant, but even healthy people can experience head ache, fatigue, and reduced reflexes due to CO exposure. The anthropogenic sources of CO are motor vehicles, coal combustion, fuel oil combustion, industrial processes, solid waste disposal, and refuse burning(http://www.yourarticlelibrary.com/air-pollution/7-air-pollutants-commonly-found-in-urban-atmosphere-of-india/19768/). In motor vehicles air to fuel ratio has a direct impact on carbon monoxide emissions. At lower air to fuel ratio, carbon monoxide emissions are increased due to incomplete combustion in low presence of oxygen. The highest levels of CO typically occur during the colder months of the year when inversion conditions (when the air pollution becomes trapped near the ground beneath a layer of warm air) are more frequent (www.tceq.texas.gov/airquality/sip/criteria-pollutants/sip-co). It is a pollutant than affects methane carbon dioxide, and tropospheric (lower atmospheric) ozone(http://www.giss.nasa.gov/research/briefs/shindell_09/).

CO varies from 1.04ppm(17:00 and 18:00) to 1.64ppm(0:00). The average value of CO is 1.31ppm against the standard of 2 ppm (8 hours).The average value is around 66% of limiting standard (Fig.1).

The concentration of CO reaches to a maximum in the early morning hours due to peak early morning traffic and the second peak of CO concentration is usually observed corresponding to the late afternoon traffic period, and decrease to low levels during the night(http://www.yourarticlelibrary.com/air-pollution/7-air-pollutants-commonly-found-in-urban-atmosphere-of-india/19768/) .

Ozone

Ozone is formed in the atmosphere by photochemical reactions in the presence of sunlight(high levels of ultraviolet radiation) and precursor pollutants, such as the oxides of nitrogen (NOx) and volatile organic compounds(WHO, 2006) . Sunlight, cloud cover, temperature, wind direction, and low wind speed contribute to ozone formation. Sunlight stimulates the volatile organic carbons and NOx chemicals to recombine to create ground-level ozone(http://www.wmcac.org/airquality/factors.html). When there are a few or no clouds, or only high transparent clouds, solar insulation is more able to penetrate to ground level, enabling the photochemistry that generates ground level ozone to occur. When cloud cover increases, the likelihood of elevated ozone levels decreases. High temperature enhance the ozone formation chemistry and increase the evaporative emissions of volatile organic compounds. Low wind speeds (less than 3 m/s) are necessary for the accumulation of precursors of ozone formation and subsequent formation of ozone. Higher wind speeds tend to dilute or disperse emissions. Dry weather allows ozone to remain in the air and therefore low levels of precipitation can contribute to ozone formation. Wide spread rain will cleanse the atmosphere of ozone.

Excessive ozone in the air can cause breathing problems, trigger asthma, reduce lung function and may cause lung diseases. Increased episodes of mortality are associated with high ozone days in cities. Burning of fossil fuels is a major man-made cause of nitrogen dioxide, while use of motor vehicles, solvents, and industrial processes in the petrochemical industry are the sources of volatile organic compounds(http://dwb.unl.edu/teacher/nsf/c09/c09links/www.casahome.org/ozone.htm). These man made emissions are more concentrated in urban and industrialized areas. It can induce breathing problems, reduce lung function, and aggravate asthma and other lung diseases.

Ozone varies from 0(6:00) to 18 microgram/cubic metre (15:00). The mean value is 7.3 microgram/cubic metre against the standard of 100microgram/cubic metre. The average value is around 7% of the limiting standards (Fig.1) .

The variation of ozone in ambient air begin to rise in the morning and then decrease after the Sun set in the evening. Ozone concentration increases as the solar radiation and temperature increase during day. The combination of a favourable environment and high nitrogen oxide emissions makes high ozone concentrations during the day. Solar radiation declines until sunset and the temperature also decreases. As nightfall approaches there is a lower likelihood that ozone will form because there is not enough sunlight (ultra violet radiation) to cause the reactions necessary to form ozone. The nitrogen oxide emissions thus serve an interesting role due to their abundance. Instead of contributing to ozone formation, the nitrogen oxides react with the ozone present in the atmosphere and cause a reduction of ozone concentrations during the nighttime. This occurs because nitrogen oxide molecules, in the absence of heat and strong sunlight, remove the third oxygen atom from the unstable ozone molecule.

Nitric oxide

At the point of discharge from man-made sources, nitric oxide, a colourless, tasteless gas, is the predominant form of nitrogen oxide. Nitric oxide is readily converted to much more harmful nitrogen dioxde by chemical reaction with ozone present in the atmosphere. Automobile exhaust has more NO than NO2, but once the NO is released into the atmosphere it quickly combines with oxygen in the air to form NO_2 (http://www.windows2universe.org/physical_science/chemis

try/nitrogen_oxides.html&edu=high) NO varies from 0.6 (5:00) to 1.3 μg/m^3(19:00). The average value is 0.9 μg/m^3(Fig.1).

Ammonia

Ammonia is a highly and soluble alkaline agas. It originates from both natural and anthropogenic sources. Anthropogenic sources include agricultural activities(manures, slurries and fertilizer application, break down and volatilization of of urea) and non agricultural sources namely catalytic converters in petrol cars, landfill sites, sewage works, composting of organic matter, combustion, industry, and wild mammals and birds (Wilson et. al., 2004). Ammonia varies from 9.2 (4:00)to 11 μg/m^3 (17:00). The average value is 9.9 microgram/cubic metre against the standard of 100 μg/m^3(Fig.2). The average value is 10% of the limiting standard.

NOx

Nitrogen oxides (NOx) in the ambient air consists of Nitric oxide(NO), and Nitrogen dioxide. These two forms are significant pollutants of the lower atmosphere. Another form, nitrous oxide (N2O) is a greenhouse gas.NOx varies from 5.6 (12:00)to 8.8 μg/m^3 (20:00). The average value is 7 μg/m^3(Fig.2).

Nitrogen dioxide

Nitrogen dioxide is a yellowish-orange to reddish-brown gas with a pungent, irritating odor, and it is a strong oxidant. The automobile exhaust is one of the largest sources of nitrogen dioxide emission in the ambient air, as these are formed during combustion as a result of oxidation of atmospheric nitrogen and organic nitrogen (http://www.yourarticlelibrary.com/air-pollution/7-air-pollutants-commonly-found-in-urban-atmosphere-of-india/19768/). The residence time of NO2 in the atmosphere is about a few days and is scavenged from the atmosphere through the formation of nitric acid, nitrites or nitrates and through their dry dissociation. The effect of NOx exposure on the respiratory system is similar to that of ozone and sulphur dioxide (https://fortress.wa.gov/ecy/publications/documents/0002008.pdf).

NO2 varies from 4.9 (12:00) to 7.7 microgram/cubic metre (20:00). The higher values of NO2 during morning and evening are in agreement with the finding that NO2 peaks coincidewith traffic peaks (http://www.yourarticlelibrary.com/air-pollution/7-air-pollutants-commonly-found-in-urban-atmosphere-of-india/19768/). The average value is 6.1 microgram/cubic metre against the standard of 80 microgram/cubic metre(Fig.2). The average value is around 13% of the limiting standard.

SO_2

The anthropogenic sources of sulphur dioxide emission arise mainly from combustion of fuels because of trace amount of inorganic and organic sulphur contained in the fossil fuels and ores. SO_2 is emitted when fuel containing sulphur is burnt in diesel engines. Sulphur dioxide exposure constricts air passages, creating problems for people with asthma and for young children whose small lungs need to work harder than adult's lungs (https://fortress.wa.gov/ecy/publications/documents/0002008.pdf). SO_2 varies from 3.5 (2:00) to 14.8 microgram/cubic metre (9:00). The average value is 6.1 microgram/cubic metre against the standard of 80 microgram/cubic metre.It is is around 8% of the limiting standard(Fig.3). But it is 30.5% of the standards of 20 microgram/cubic metre (24 hour mean) prescribed by WHO(2006).

Respirable Particulate Matter (PM_{10})

PM with an aerodynamic diameter greater than 10 micrometre known as suspended inhalable particulate matter/Respirable Suspended Particulate Matter (RSPM or PM_{10}), remains in the atmosphere for longer periods because of its low settling velocity(Shivaji, 2013). Particulate matter includes microscopic particles and tiny droplets of liquid. Because of their small size, these particles are not stopped in the nose and upper lungs by the body's natural defenses but go deep into the lungs, where they may become trapped and cause irritation (https://fortress.wa.gov/ecy/publications/documents/0002008.pdf). Exposure to particulate matter can cause wheezing and similar symptoms in people with asthma or sensitive airways. PM can serve as a vector of toxic air pollutants.

Large aerosol particles(usually 1 to 10 micrometre in diameter) are generated when wind blow sea salt, dust, and other debris into the atmosphere(www.learner.org/courses/envsci/unit/pdfs/unit11.pdf). Fine aerosol particles with diameters less than 1 micrometre are mainly produced when precursor gases condense in the atmosphere. Major components of fine aerosols are sulphate, nitrate, organic carbon, and elemental carbon. Sulphate, nitrate, and organic carbon particles are produced by atmosphereic oxidation of SO2, NOx, and VOCs.

Low wind speeds, high pressure air masses, wind direction, high relative humidity, cooler temperatures, mixing heights, atmospheric stability, and winds aloft affect the accumulation of particulate matter. The longer the period of low wind speeds in an area, the greater the likelihood that particulate matter will accumulate (http://dwb.unl.edu/teacher/nsf/c09/c09links/www.casahome.org/ozone.htm). High pressure air masses that last several days may create stagnant conditions that allow for the buildup of particulate matter levels. Accumulation will continue until a change in weather patterns brings less polluted air into the region. High relative humidity enhances the formation of nitrate and aerosol particles. Cooler temperatures promote nitrate formation in winter, and warmer temperatures promote sulphate formation in summer. If the mixing depth is shallow, mixing is restricted and particulate levels will become more concentrated.

High concentrations of aerosols are a major cause of cardiovascular disease and are also suspected to cause cancer. Fine particles are especially serious threats because they are small enough to be absorbed deeply into the lungs, and sometimes even into blood stream (https://www.learner.org/courses/envsci/unit/pdfs/unit11.pd) . Emissions from motor vehicles do not only include exhaust particles, but also include abrasion products from tyres,

breakes, clutches, and the road's surface. Particles are emitted by resuspension of previously deposited particles by vehicle induced turbulence.

Particles of 10 micrometers or less(PM10) particles can penetrate into the lungs and enter the blood stream, can cause heart disease, lung cancer, asthma, and acute lower respiratory infections.

PM10 varies from 13 (13:00) to 68 (7:00) microgram/cubic metre. The average value is 35 microgram/cubic metre against the standard of 100microgram/cubic metre(Fig.3). It is 35% of the standard value. But it is 70% of the standards of 50 microgram/cubic metre(24 hours mean) prescribed by WHO(2006).

$PM_{2.5}$

$PM_{2.5}$ can be formed in the atmosphere as aerosols from chemical reactions that involve gases such as SO_2, NOx, and VOC. Sulphates which are commonly generated by conversion from primary sulphur emissions make up the largest fraction of PM2.5 by mass. PM2.5 can be formed as a result of solidification of volatile metals salts as crystals following cooling of hot exhaust gases from vehicles in ambient air as well. Since the depth to which particulate matter can penetrate the respiratory system is dependent on size, fine particles (PM2.5) have a higher probability of deposition in the alveoli of the lungs and are associated with a greater health risk than larger particles (http://www.ivhhn.org/index.php?option=com_content&view=article&id=87). Particles of this small size also have residences times of days to weeks in the troposphere and can travel distances of hundreds to thousands of kilometres allowing them to be widely dispersed.

Recent studies suggest that, even at low levels(<100 microgram/cubic metre), short term exposure to PM of any size range is associated with health effects(WHO, 1999), and that strong aerosol acidity or high sulphate content may contribute to the effects associated with PM2.5 (http://www.ivhhn.org/index.php?option=com_content&view=article&id=87). Epidemological studies have shown that both daily mortality and hospital admissions increase with increasing particulate matter in the surface boundary layer and the effects fir PM2.5 are amplified over those for PM10.

PM2.5 varies from 6 (13:00) to 50 $\mu g/m^3$(8:00). The average value is 19 microgram/cubic metre against the standard of 60 $\mu g/m^3$ (Fig.3). It is 32% of the standard prescribed by Central Pollution Control Board. But it is 76% of the standards of 25 $\mu g/m^3$ (24 hours mean) prescribed by WHO(2006).

Identification of factors influencing air quality

Principal components with eigen values>1 are considered to be the most important components. Three components have eigen value greater than 1. From the percentages of the total variances of the three extracted components accumulated, it is evident that these three components account for 84.6% of the original data. Thus, the complete variance of the data can be attributed to three components(Table2 and Fig.4).

Factor 1(F1) explains 30.7% of the total variance, being mainly contributed by Ozone (0.908), air temperature (0.921), relative humidity (-0.942), wind speed (0.719), and solar radiation (0.933). F1 has strong positive factor loading with ozone, temperature, wind speed, and solar radiation. F1 is denoted as Ozone pollution factor. It increases with temperature, wind speed and solar radiation. This is in agreement with the finding of Tarasova and Karpetchko (2003) that 70% of the day-to-day ozone variability could be explained by changes in temperature, relative humidity, and wind speed. Kovac-Andric et al., (2009) indicated that 67% of the variation in ozone concentrations during the summer of 2002 could be accounted for by changes in temperature, solar radiation, and wind speed. The studies indicate that considerable variability of ozone concentration is not only as a result of changes in precursor emissions, but also of meteorology (Peekay and Ozaslan, 2013; Psiloglou et al. 2013). Low wind speed of less than 3 m/s prevailing in the area favours the formation of ozone. This is in agreement with the finding of Husar and Renard, 1997 that at low wind speeds(<3m/s), ozone levels do not vary substantially with wind direction and that the highest concentrations are found in the northeastern urban corridor. The ozone level in Madras is also in conformity with the present finding (Pulikesi et al., 2005). As per Fig., Ozone pollution factor began to increase at 9AM and becomes maximum at 11AM and then it began to decrease and reached the minimum at 5PM.

Factor 2(F2) explains 30.6% of the total variance, being mainly contributed by NO2 (0.874), NOx(0.841), SO2(0.84), PM2.5(0.768), PM10(0.807), and barometric pressure(0.889). F2 has strong positive factor loading with NO2, NOx, SO2, PM2.5, PM10 and barometric pressure. F2 is termed as Aerosol pollution factor. This indicates the association of NO2, NOx, SO2, with PM2.5, and PM10. It also depends on barometric pressure. The rise in particulate matter with barometric pressure is in agreement with the finding of Langner et al., 2011. Aerosol pollution factor begins to rise at 7AM, increases to a maximum at 9 AM and it reduces to a minimum at 11AM. Again it begins to increase at 6PM, becomes maximum at 8PM and then it begins to reduce to a minimum at 12 Midnight. From the above, it can be seen that the influence of ozone pollution becomes less at the time of aerosol pollution. Aerosol pollution is more intense in the early morning before the occurrence of ozone pollution and in the late evening.

Factor3 (F3) explains 23.3% of the total variance, being contributed by NO(0.805), CO(-0.786), NOx(0.427), ammonia (0.937), wind speed(0.511), and WD(-0.584). F3 has strong factor loading with nitric oxide, and ammonia. It has mean positive factor loading with wind speed and negative mean factor loading with WD. F3 is termed as Methane pollution factor. The variation of CO with NH3 and NO can be observed. This is in agreement with the finding of NASA. According to NASA, CO readily reacts with the hydroxyl radical (OH) forming a much stronger, greenhouse gas-carbon dioxide. This, in turn, increases concentration of methane, and another strong greenhouse gas, because the most common way methane is removed from the atmosphere is when it reacts with hydroxide, and hence the formation of

carbon dioxide leaves fewer OH for methane to react with thus increasing methane's concentration.

Ozone pollution can be reduced by emission from cars, trucks, gas powered lawn, and garden equipment, boats, and other engines by keeping equipment properly tuned and maintained. During the summer, fill the gas tank during the cooler evening hours, and careful not to spill gasoline. Reduce driving, car pool, use public transportation, walk, or bicycle to reduce ozone pollution, especially on hot summer days. Low VOC paints and solvents shall be used and shall be ready to read labels for proper use and disposal.

4. Conclusion

The study was conducted to assess the threat to air quality in a tropical region. The study reveals that the concentration of carbon monoxide, PM_{10}, and $PM_{2.5}$ is nearing to the limiting standards. Hence immediate attention is to be paid for the reduction of these parameters. The factor analysis reveals that Ozone pollution factor, Aerosol pollution factor, and Ammonia pollution factors are the main factors controlling the ambient air quality. Ozone pollution factor is intense during day time. It increases with temperature, wind speed and solar radiation. Aerosol pollution factor becomes intensive during early morning and late evening, whereas Ammonia pollution factor becomes intense in the evening. Aerosol pollution is more intense in the early morning before the occurrence of ozone pollution and in the late evening. CO readily reacts with the hydroxyl radical (OH) forming a much stronger, greenhouse gas-carbon dioxide. This, in turn, increases concentration of methane, because the most common way methane is removed from the atmosphere is when it reacts with hydroxide, and hence the formation of carbon dioxide leaves fewer OH for methane to react with thus increasing methane's concentration.

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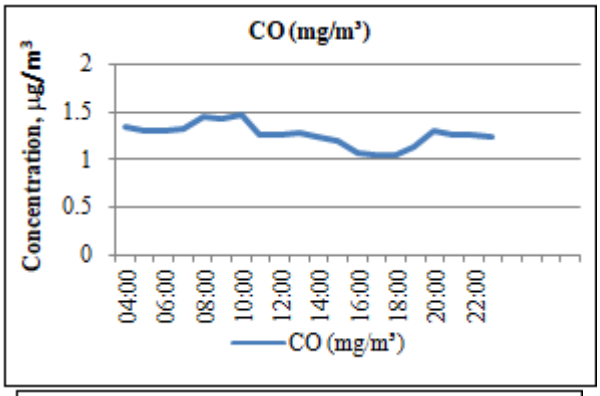
Table 1. Ambient Air Quality Data on 9-12-2015

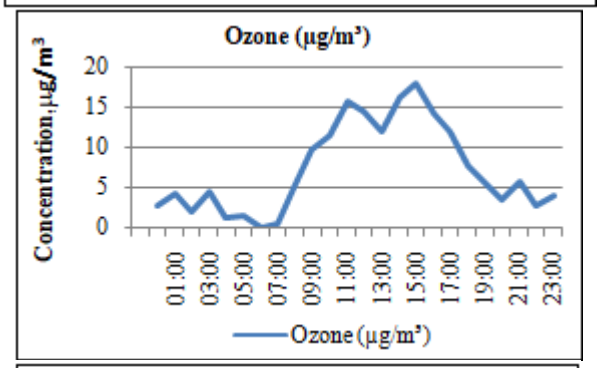
	CO (mg/m³)	Ozone (µg/m³)	NO (µg/m³)	NO2 (µg/m³)	NOX (µg/m³)	NH3 (µg/m³)	SO2 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	T (°C)	H (%)	S (m/s)	D (deg.)	R (W/m²)	BP (mmHg)	RF (mm)
0:00	1.64	2.8	0.7	5.4	6.2	9.4	4.9	10	18	25.9	88	1	240	19	748	0
1:00	1.59	4.2	0.7	5.4	6.2	9.3	3.9	12	22	25.9	87	0.6	212	19	746	0
2:00	1.55	1.9	0.8	5.5	6.3	9.3	3.5	12	20	25.8	87	0.5	177	19	745	0
3:00	1.46	4.4	0.7	5.4	6.1	9.4	3.9	11	23	25.6	88	0.5	224	19	745	0
4:00	1.35	1.3	0.7	5.4	6.1	9.2	3.6	14	28	25.6	88	0.4	295	19	746	0
5:00	1.29	1.4	0.6	5.5	6.2	9.3	5.1	15	28	25.6	89	0.5	252	19	747	0
6:00	1.3	0	0.8	5.6	6.4	9.3	6.1	17	36	25.6	89	0.4	306	20	749	0
7:00	1.31	0.5	1	5.7	6.6	9.3	6.8	41	68	25.9	89	0.5	290	66	750	0
8:00	1.45	5.6	0.8	6.5	7.3	9.3	7.9	50	66	27.5	83	0.5	148	228	752	0
9:00	1.42	9.8	1	6.9	7.9	9.3	14.8	26	53	29.1	74	1.6	94	382	753	0
10:00	1.47	11.4	0.7	6.5	7.2	9.6	11.7	11	27	29.3	72	1.5	124	388	752	0
11:00	1.26	15.8	0.7	6.1	6.8	9.6	7.5	8	18	30.3	68	1.2	218	680	750	0
12:00	1.25	14.6	0.7	4.9	5.6	9.7	3.9	7	17	31	62	1.5	236	557	749	0
13:00	1.27	12.1	1	5.4	6.4	10.4	3.9	6	13	30.7	64	2.3	149	498	747	0
14:00	1.24	16.3	1	5.9	6.9	10.6	4.7	22	42	29.7	70	3.2	83	446	746	0
15:00	1.2	18	1	5.6	6.6	10.4	4.8	9	18	29.2	72	2.8	77	241	746	0
16:00	1.07	14.2	1.1	5.6	6.7	10.7	4.5	10	20	29.3	71	2.5	86	212	746	0
17:00	1.04	11.9	0.9	5.7	6.6	11	3.6	12	26	28.6	76	2.4	96	55	747	0
18:00	1.04	7.7	1.1	6.3	7.4	10.9	6.2	25	55	28.2	78	1.4	112	18	748	0
19:00	1.12	5.4	1.3	7.1	8.4	10.6	7.9	32	57	28.2	79	1.1	66	18	749	0
20:00	1.29	3.5	1.2	7.7	8.8	10.5	7	34	65	28	80	0.7	94	18	750	0
21:00	1.26	5.7	1.1	7.4	8.4	10.4	7.7	28	46	27.8	82	0.7	265	18	751	0
22:00	1.26	2.8	1.1	7.2	8.3	10.3	6.9	31	54	27.6	84	0.5	187	18	751	0
23:00	1.24	4	1	7	8	10.2	6.1	15	29	27.3	83	0.9	303	18	751	0

Table 2: Rotated Component Matrix of air quality data on 9-12-2015

Rotated Component Matrix[a]			
	Component		
	1	2	3
CO	-.210	-.016	-.786
Ozone	.908	-.187	.285
NO	-.014	.479	.805
NO2	-.082	.874	.309
NOX	-.075	.841	.427
NH3	.231	.037	.937
SO2	.285	.840	-.224
PM25	-.348	.768	.147
PM10	-.321	.807	.231
ATC	.921	.107	.313
RH	-.942	.046	-.259
WS	.719	-.273	.511
WD	-.466	-.155	-.584
SR	.933	-.016	-.207
BP	.184	.889	-.233

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.





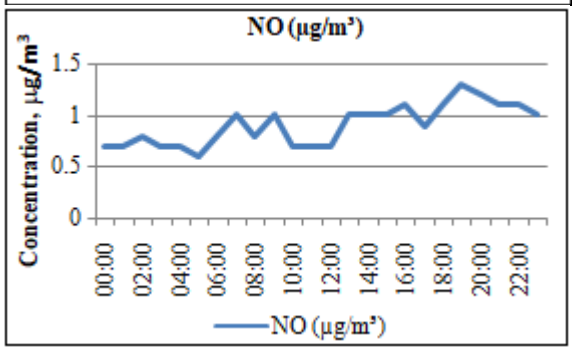
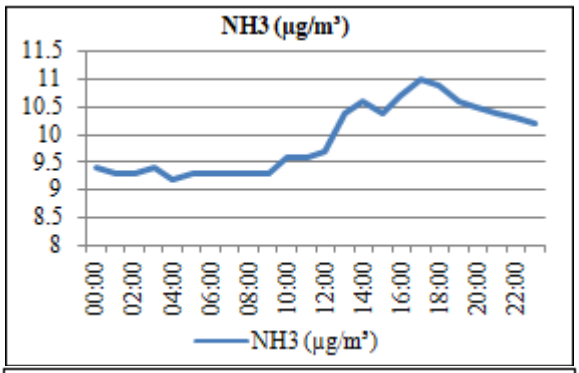
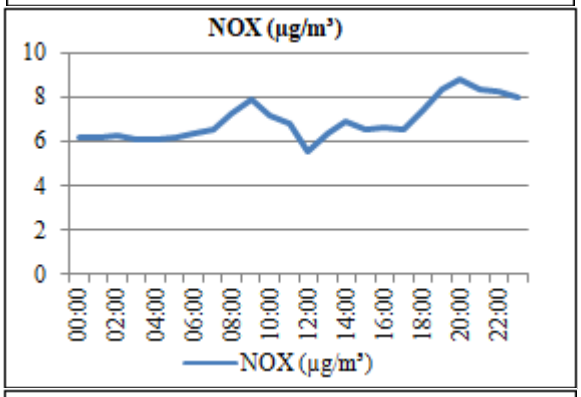


Figure 1: Variation of CO, Ozone and NO in ambient air on 9-12-2015





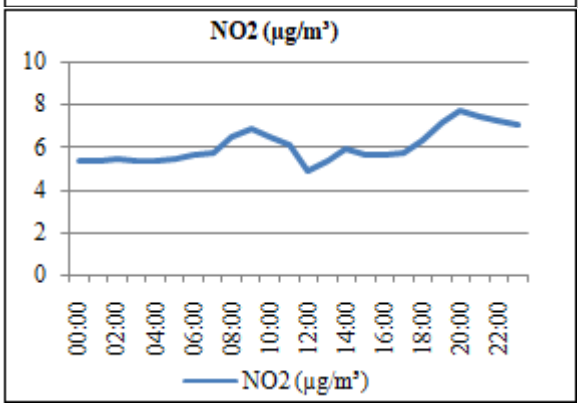
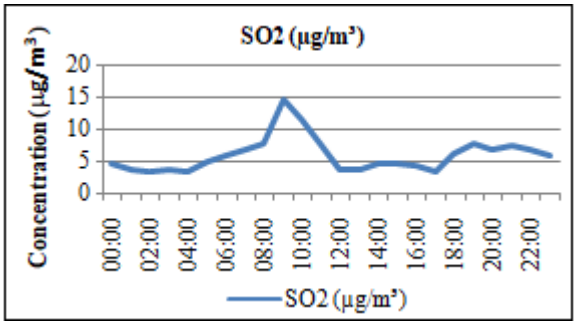
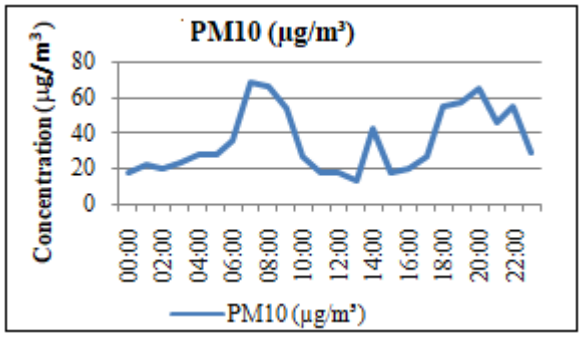


Figure 2: Variation of NH3, NOx, and NO2 in ambient air on 9-12-2015





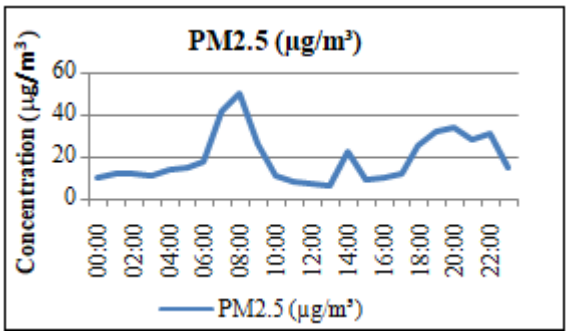


Figure 3: Variation of SO_2, PM_{10} and $PM_{2.5}$ in ambient air on 9-12-2015

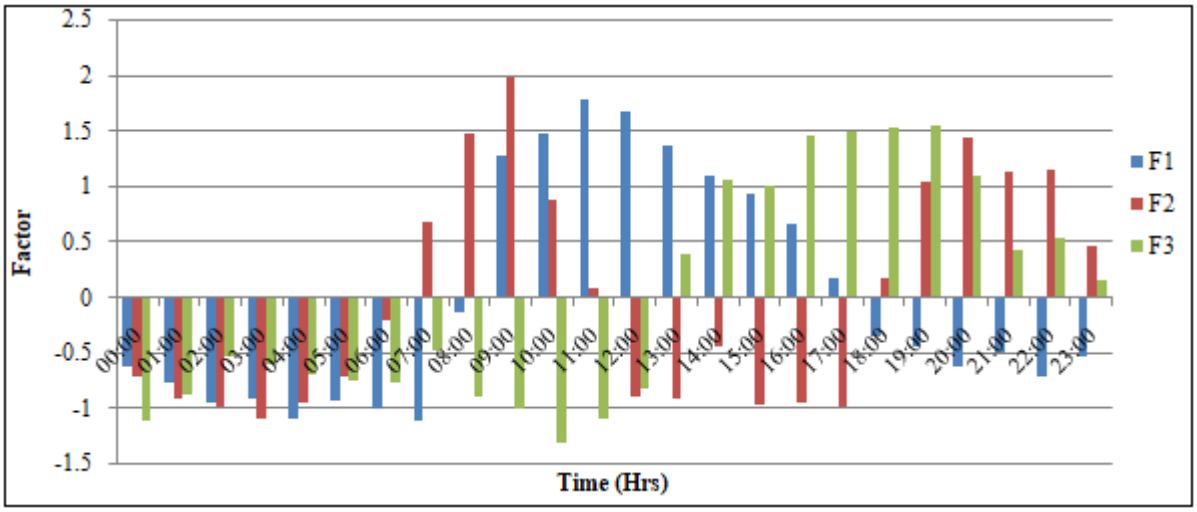


Figure 4: Variation of factors on 9-12-2015