DIURNAL AND SEASONAL VARIATIONS IN GROUND LEVEL OZONE (GLO) AND RELATIONSHIP WITH METEOROLOGICAL CONDITION AT RESIDENTIAL AREA, CHENNAI, INDIA

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ABSTRACT

Surface or ground level ozone (GLO) is very essential in atmospheric oxidation processes and hence consequently in air quality and its increase enhances the greenhouse effect in the free troposphere. A study was done to measure the ground level ozone (O3) level during the period from October 2014 to September 2016 at Ashok pillar, Chennai. It is a steamy site on the southeast coast of India which is situated at 13°04’N and 80°7’E. Surface ozone and its variation with meteorological parameters in the urban area of Chennai were analyzed through the sequential pattern. Ground level ozone concentration varies from 5 ppb to 50 ppb. The highest surface ozone concentration was recorded by an advanced version of Aeroqual S500 series in summer and Pre-Monsoon (PM) season and the lowest concentration was recorded in North East Monsoon (NEM) and winter. During the complete period of study, it is found that ground-level ozone was originated to be positively correlated with temperature and negatively correlated with relative humidity and rainfall.

Keywords: GLO, Aeroqual S500, diurnal and seasonal variations, Meteorological parameters

1. INTRODUCTION

Tropospheric ozone is also known as Surface Ozone (SOZ) or Ground Level Ozone (GLO). O3 is also a major component of photochemical smog and is a well known hazardous element for human health. It is has been well proven that human exposure to ozone leads to respiratory problems (Bell et al, 2005) Ground level ozone is not directly emitted into the atmosphere. It occurs as a result of photochemical reactions between oxides of nitrogen and volatile organic compounds in the presence of sunlight (Lin Tang et al, 2009). Surface ozone is a secondary pollutant formed by photochemical reaction of primary pollutants like oxides of nitrogen (NOX), carbon monoxide and volatile organic compounds. Photochemical production, Chemical destruction, Atmospheric transport, Surface dry deposition on vegetation, water and other materials and Stratospheric-Tropospheric exchanges are the five main factors which control the tropospheric ozone levels (Alvim-Ferraz et al, 2010). Surface ozone (O3) is an important well-known secondary pollutant and also a greenhouse gas contributing to the climate change. Even though it is a trace constituent, ozone plays an important role in the atmospheric environment through the radiative and chemical process (Londhe, 2008). High concentration of GLO can cause potential damage to biotic and abiotic factors. Epidemiological and toxicological studies indicate that higher concentration of ozone is harmful to biological health (Avol et al, 1998). The presence of SOZ and its effects on crops are often not visible in contrast with other yield-reducing factors. Ozone pollution poses a growing threat to global food security even under an optimistic scenario of future ozone precursor emissions (Shri Avnery et al, 2011). Ozone levels tend to be higher under hot, sunny conditions which favour the photochemical Ozone production. Conversely, wet and rainy weather with high relative humidity is typically associated with low Ozone levels provided by wet Ozone deposition of the water droplets (Tarasova et al, 2003). Temperature is one of the most important meteorological parameters that controls, influences the speed and amount of photochemical production of Ozone (Elminir et al 2005). In this paper, an attempt has been made to study the impact of O3 on Ground level ozone at heart of Chennai city also residential area Ashok Pillar, Chennai. Ground level ozone
measurements have been carried out for the first time in this study region. Availability of tropospheric Ozone for a period from October 2014 to September 2016 has prompted us to make an attempt to analyze the near-surface Ozone concentration in this region and also to investigate the impact of meteorological parameters. During this study, an attempt has been made to address momentarily some of the essential issues, related to the changing climate situation, with special prominence on sequential (diurnal and seasonal) variations in surface ozone over a tropical semi-urban site. Study related with the interrelation of ozone and available meteorological parameters (Relative humidity, Temperature, Rainfall, and Wind speed) is also carried out and discussed.

MEASUREMENT SITE

India is a tropical country. The southern part of India is a peninsula surrounded by three major seas. Chennai city is the capital of Tamil Nadu state in south India and is located on the eastern coast. Chennai lies on the thermal equator and is also a coastal city. The latitude and longitude of the center of the city are 80°14′51″E and 13°03′40″N.

Chennai has tropical wet and dry climate conditions. The minimum temperature recorded is 19°C with maximum temperature 42 °C. The annual average rainfall in Chennai was about 1400 mm. This study area was conducted at Ashok pillar. The most important entry-exit point of the city. Ashok Nagar is a residential locality situated at the southern part of Chennai, India.

MEASUREMENT CLIMATE

According to the frequency of rainfall, a year can be divided into four seasons. The period between January and February represents the winter months and the period between March to May summer months. The climate at study area during May is very hot due to intense solar radiation. The daytime temperature reaches about 45°C and night time above 30 °C. Pre-monsoon (PM) is between June and September, and October to December is the period of North East Monsoon (NEM). Low concentrations observed during the winter season as a result of higher NOx scavenging, lower photochemical reactions due to lower intensity of solar radiation and lower ambient temperature lead to a decrease in the concentration of O3. The destruction of O3 is increased in NEM was attributed to the non-availability of adequate solar radiation due to cloudy skies, and also the reduction in precursors species from the atmosphere by rain which took place during this season.

DATE COLLECTION

Measurements of SOZ were made for a period of three years from October 2014 to September 2016. Measurements were carried out using Aeroqual monitors S500 employing various GSS sensor heads.
This particular instrument was chosen for its simplicity and reliability in operation, ease of handling, and quickness in obtaining the gas concentration directly. The measurement units are in ppm or μg/m³. The ozone sensor was calibrated against a certified UV photometer. At sampling site located near traffic, the monitor was placed a few meters from the closest road or parking lot in order to minimize perturbations from the vehicular exhaust and the monitor was placed in an open space. Aeroqual ozone monitors were used for the measurement of ozone and nitrogen dioxide by Akram Ali, 2008, Su Lee and Shih-Wei Tsai, 2008 (Akram Ali et al, 2008 & Su Lee et al, 2008). Ground level ozone measurements were made from October 2014-september 2016 comprising 24 months, 8 seasons and 2 years. The Meteorological data were collected from Indian Meteorological Department (IMD) and Tamilnadu Pollution Control Board (TNPCB), Chennai.

RESULTS AND DISCUSSION

The measured data of ground level ozone is analyzed on the basis of diurnal, seasonal and annual variations. All hourly values were used to analyze diurnal variability and daily averaged values were used to analyze the day-to-day variability. Monthly averages are calculated from the daily values, to study the seasonal cycle.

GLO Frequency distribution:

Frequency distribution of O₃ in different concentration ranges at Ashok pillar, Chennai is shown in Fig. 3. It shows that 71% of all O₃ measurements lie in the range 5–35 ppb and remaining 29% of measurements lie in the 36–50 ppb range. It also shows highest 23.47% of all O₃ measurements lie in the 26–30 ppb range and lowest 0.3% measurements lie in the 5–10 ppb range. The frequency distribution is clearly shown in Table 1 and figure 3.

<table>
<thead>
<tr>
<th>Range(ppb)</th>
<th>Number of Data points</th>
<th>Distribution %</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 10</td>
<td>62</td>
<td>0.35</td>
</tr>
<tr>
<td>11 to 15</td>
<td>642</td>
<td>3.67</td>
</tr>
<tr>
<td>16 to 20</td>
<td>1335</td>
<td>7.63</td>
</tr>
<tr>
<td>21 to 25</td>
<td>2472</td>
<td>14.13</td>
</tr>
<tr>
<td>26 to 30</td>
<td>4107</td>
<td>23.47</td>
</tr>
<tr>
<td>31 to 35</td>
<td>3811</td>
<td>21.78</td>
</tr>
<tr>
<td>36 to 40</td>
<td>2833</td>
<td>16.19</td>
</tr>
<tr>
<td>41 to 45</td>
<td>1877</td>
<td>10.73</td>
</tr>
<tr>
<td>46 to 50</td>
<td>357</td>
<td>2.04</td>
</tr>
</tbody>
</table>
Diurnal Variation of ground level ozone Concentration:

The diurnal variation of ground level ozone is important to understand the different processes responsible for ozone formation and destruction at the particular location. In the Fig. 4 it shows the diurnal variation of O₃ averaged over the period from October 2014 to September 2016. During the entire study period, the ground level ozone concentration varied from 5 ppb to 50 ppb.

The diurnal cycle of ozone showed a universal pattern and was characterized by the minimum ozone concentration in the early hours of the morning (01:00 hrs to 06:00 hrs) and maximum ozone concentration in the afternoon hours (12:00 hrs to 14:00 hrs). A gradual decrease was observed in the evening hours (17:00 hrs onwards). After sunset, the concentration declined further.

Seasonal Variation of Surface Ozone

Seasonal variations in the amplitude of the diurnal ozone cycle are shown in Fig. 5. It is observed that the ground level ozone concentrations are lower in North-east Monsoon and winter and higher in summer and Pre-Monsoon respectively. For all the two years (October 2014-september 2016) summer season recorded the maximum concentration of surface ozone. This was primarily due to the availability of solar flux and its intensity during this season.
Fig. 5. Seasonal Variation of Surface Ozone

High temperatures, heat waves accelerate the ground-level \( \text{O}_3 \) production \((\text{EEA, 2009})\). Pre-Monsoon (PM) receives less rainfall than North East Monsoon (NEM). Also, PM is characterized by monsoon winds that play an active role in the transport of pollutants. As the study area experiences the lower ozone concentration levels seen in northeast monsoon and winter seasons can be attributed to the rainfall effect. Rainfall cleanses the atmosphere, which is clearly reflected by the reduction in ozone concentration during both these seasons.

Table. 2 Annual Average of ground level ozone

<table>
<thead>
<tr>
<th>Year</th>
<th>2014-2015</th>
<th>2015-2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Ozone</td>
<td>27.82</td>
<td>31.51</td>
</tr>
<tr>
<td>Concentration(/ppb)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig 6 shows obviously the growing trend of ground ozone. The annual average variation of surface ozone shows an increasing trend in the ozone concentration at the study area. It is found that the percentage of increase is about 4% in the study area.

Fig. 6. Annual Average of ground level ozone concentration

Variations of \( \text{O}_3 \) with meteorological parameters

Fig. 7 shows the average monthly variations in minimum and maximum temperature, relative humidity, wind speed, and rainfall during the observational period. The study area records wind speed its maximum value during June & July 15 and minimum during September 15. It is evident from the Fig. 7 the observational site is strongly influenced by the northeast monsoon rainfall. During the measurement period, the average highest relative humidity was found during November’ 15 and lowest during August ‘16.
Fig. 7. Average monthly variations of meteorological parameters.

The site records an average minimum temperature of 20˚C (January ‘15) and an average maximum of 38˚C (July ‘15). The average difference between the maximum and minimum temperature among the seasons differs only by less than 2˚C.

CONCLUSION

Ground level ozone measurements were made at Ashok pillar, Chennai, a tropical urban site, in the southeastern coastal region of India for a period of two years from October 2014 to September 2016. During the entire study period, GLO varied between 5 ppb to 50 ppb. The frequency distribution showed that around 65% data points lied between 16 ppb and 35 ppb. The diurnal pattern of surface ozone concentration clearly indicates its dependency on the photochemical production process rather than from on-site vertical or horizontal transport.

In common the surface ozone concentration is observed to the maximum in summer and PM and least in winter and northeast monsoon. From this study, it is found that there is an increasing trend in ozone concentration. This increasing trend is supported by the general pattern of variation and trend observed at south Indian continent. This is an indication of the increasing concentration of ozone precursor species. The investigation confirms that the ozone concentration was mostly positively correlated with wind speed and temperature (min & max) and negatively with the relative air humidity and rainfall.
References


