Diurnal and spatial variations of condensation particles in Kerala, South India

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The diurnal and spatial variation of concentration of aerosol particles in South India is studied and presented in this communication. Concentration of condensation particles was determined using condensation particle counter (CPC-3007) from different geographical stations, such as coastal, midland and highlands. For each geographical location, we collected data from the south, central and north Kerala regions to obtain the spatial features of the condensation particles. The diurnal patterns for highland in the slope are different from those of other stations. In the coastal, midland and flat terrain of highland stations, the variation in concentration of particles shows two distinct peaks, one in the morning and the other in the evening.

Keywords: Atmospheric boundary layer, condensation particle counter, diurnal and spatial variation, sea breeze, ultrafine aerosols.

Atmospheric aerosols provide an extremely interesting field of research. In the atmosphere, aerosols play an important role in the radiation budget directly by scattering and absorption of solar radiation. They scatter solar radiation back to space, thus enhancing the planetary albedo and exerting a negative (cooling) climate forcing. Aerosols also indirectly cause a negative climate forcing through formation of clouds and affect cloud lifetime. On the other hand, they cause positive feedback (warming) by absorbing reflected radiation from the earth’s surface, and preventing them from escaping to space. Thus, they affect the radiation budget and the regional water cycle through inducing changes in the microphysical properties of clouds by acting as cloud condensation nuclei. Today, this indirect effect of aerosol particles is the largest uncertainty in predicting the future global climate. Hence the study of ultrafine particles, especially those that help in the formation of clouds by acting as cloud condensation nuclei (CCN), is of importance. During the recent decade, a great deal of effort has been devoted to establishing the effects of aerosols on global as well as regional climate. The ultrafine particles consist of products from incomplete combustion, sea salt and end-products from chemical reactions in the atmosphere. They are formed by condensation and evaporation processes.

Murugavel and Kamra found from a study over Thiruvananthapuram during INDOEX (Indian Ocean Experiment) that the number concentration and number distribution of aerosols had two peaks—one during morning (0730 h) and another in the evening (1900–2100 h). Krishnamurthy et al. studied the effect of sea breeze on optical depth and size distribution of aerosols at Thiruvananthapuram and concluded that the small particle concentration has a pronounced bimodal structure associated with sea-breeze frontal activity. Parameswaran et al. found that the aerosol number density in the mixed layer shows a significant dependence on the near surface-wind speed. This dependence is exponential with wind speed in the mixed layer. Parameswaran studied the characteristics of aerosols in atmospheric boundary layer (ABL) at Thiruvananthapuram and found that the ABL processes strongly influence the concentration of aerosols. Babu and Moorthy examined the influence of black carbon aerosols during a festival (Diwali). They reported that the aerosols showed a 3 to 4 times increase from the ambient value. The sea breeze and the associated boundary layer dynamics have a cleansing effect as they help disperse the carbonaceous aerosols; nevertheless, the overall decay of the impact appears to take about a week. Spatial variation of aerosol optical depth (AOD) over India was examined by Girolamo et al. Their analysis revealed that low values of AODs are found in the highland stations of Kerala. The high values in the coastal region are attributed to high population density built up along the coast and high fossil-fuel consumption. This communication focuses on the diurnal and spatial variations of ultrafine aerosol particles with diameter between 0.01 and 1 µm. These microscale aerosols may act as CCN and hence this study acquires importance in cloud physics and climatology.

The data used in the present study were the condensation particle concentrations collected from geographically different stations in Kerala using a condensation particle counter. Measurements were conducted at three coastal stations, three midland (above 75 m amsl) stations and four highland (above 500 m amsl) stations. The stations are listed in Table 1.

Table 1. Stations where measurements were made. Ponnudal and Peeramedu are on the slopes of the Western Ghat mountains.

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akkulam</td>
<td>8.52°N, 76.91°E</td>
<td>South coastal</td>
</tr>
<tr>
<td>Alleppey</td>
<td>9.3°N, 76.23°E</td>
<td>Central coastal</td>
</tr>
<tr>
<td>Beyapore</td>
<td>11.1°N, 77.5°E</td>
<td>North coastal</td>
</tr>
<tr>
<td>Ponkunnam</td>
<td>9.71°N, 76.7°E</td>
<td>South midland</td>
</tr>
<tr>
<td>Perinthalmanna</td>
<td>10.58°N, 76.13°E</td>
<td>Central midland</td>
</tr>
<tr>
<td>Thamararesery</td>
<td>11.23°N, 75.54°E</td>
<td>North midland</td>
</tr>
<tr>
<td>Ponnudal</td>
<td>9.55°N, 77.05°E</td>
<td>South highland</td>
</tr>
<tr>
<td>Peeramedu</td>
<td>9.3°N, 77.02°E</td>
<td>South highland</td>
</tr>
<tr>
<td>Malampuzha</td>
<td>10.46°N, 76.42°E</td>
<td>Central highland</td>
</tr>
<tr>
<td>Sulthan Bathery</td>
<td>11.12°N, 76.15°E</td>
<td>North highland</td>
</tr>
</tbody>
</table>

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It may be noted that the measurement sites at Ponmudi and Peeramade are on the slopes of the Western Ghat mountains. The other two highland sites are on the top of the mountain. Data were collected every minute on designated days during the hot season of 2007 on a diurnal basis. The one-minute data were averaged over 15 min for smoothing.

The instrument used for the experiment was TSI model CPC-3007. This instrument operates by drawing air continuously through a heated saturator in which alcohol evaporates and diffuses into the sample stream. The air sample and alcohol vapour pass into a cooled condenser where the air becomes supersaturated with alcohol vapour. Particles present in the air sample serve as condensation sites for the alcohol vapour. Once condensation begins, particles grow quickly into large alcohol droplets and pass through an optical detector where they are counted easily. A schematic diagram of the instrument is given in Figure 1. Data from CPC-3007 are of good quality for research in aerosol science.

Measurement samples can be automatically logged in at user-defined intervals, and data analysis can be done using the Aerosol Instrument Manager software supplied with the instrument. It has a continuous inlet flow rate of 700 cubic cm per min, of which 100 cubic cm per min is sampled. Possible errors caused by the flow rate variability are reduced to a minimum since the sample flow is controlled by a pressure drop sensor coupled with the pump (flow control unit), as shown in Figure 1. According to the manufacturer, the concentration accuracy up to 100,000 particles per cubic cm is ±20% of the reading. In this concentration range coincidence is low and no correction is required.

Figure 2 shows the diurnal variation of condensation particles measured using CPC-3007 over coastal stations. Station names are given at the top of each panel in Figure 2. From the figure, we see that the number density of condensation particles varies with time and space. Condensation particles show two distinct peaks during a day, as observed by others researchers. Latha studied the conductivity of air at the surface and found a similar variation, which she attributed to the influence of surface aerosols. We found the first peak around 0800 h and the second one around 2200 h. The nature of the two peaks was different. For the morning peak, the value begins to increase from around 0530 h, reaches a maximum (around 30,000 per cubic cm for Akkulam, ~50,000 per cubic cm for Alappuzha and ~55,000 per cubic cm for Beypore) by 0800 h and returns to normal value by 1200 h. The rate of decrease from this peak is similar to that of the increase. Later, the value begins to increase gradually from 1600 h onwards and reaches a second maximum around 2100 h. Unlike in the case of the morning peak, the concentration falls rapidly compared to the rate of increase.

The least value observed among the coastal stations is at Akkulam. This could be because Akkulam is a rural area

![Figure 1. Schematic diagram of condensation particle counter, CPC-3007.](image)

![Figure 2. Diurnal variation of condensation particles over coastal stations. The coastal stations include Akkulam (in the southern part of the State), Alleppey (in the central part) and Beypore (in the northern part).](image)
and hence human activities that could influence aerosol concentration are less. In the case of Alappey, the first peak is more prominent than that of the second peak (42,000 particles per cubic cm), which occurs at 2130 h. In the unsmoothed one-minute data, we find that the concentration shoots up for a 5 min period when it goes beyond the morning peak. No significant change in the atmosphere was noticed at that time. This transient signal was lost due to averaging and hence is not seen in Figure 2. However, for Beyapore, both peaks are almost similar in magnitude.

Diurnal variation of condensation nuclei over midland stations is given in Figure 3. The midland stations are Ponkunnam, Perinthalmanna and Thamarassery, from south to north. The diurnal pattern is similar to that at coastal stations, in all the study regions, but compared to coastal stations, the following points may be noted: both peaks occur later, the second peak is lower and the duration of the first peak is less. The first peak is at about 0900 h at Ponkunnam and Thamarassery, but at Perinthalmanna it is a little earlier — at about 0830 h. At Perinthalmanna, the first peak is higher than at the other two stations. The magnitude of the second peak is negligible for Perinthalmanna. For Ponkunnam, the magnitudes of both the peaks are almost equal, and for Thamarassery the first peak is dominant.

Coastal and midland stations show distinct bimodal variation over a day. Over coastal stations the development of the first peak is earlier than at the midland stations. Establishment of the first and second peaks may have a direct relationship with the development of the ABL. Along with sunrise, the ABL develops because of the growth of turbulence due to thermals from the ground. Along with these thermals the microscale aerosol particles are disturbed and spread with the boundary layer. This may be the reason for the first peak in the coastal and midland stations. A similar process occurs during the decay of the ABL after sunset and this may be the reason for the second peak. The earlier development of the first peak in the coastal stations may be due to the coastal effect. At coastal stations, the sea-breeze effect and hence the development of the internal boundary layer (IBL) may influence the condensation particles. Development of the IBL starts along with sunrise or just after sunrise. But over inland stations, the ground heats up when it receives insolation and thereby thermals grow. These thermals provide support for the growth of the ABL in the midland stations. Along with the development of the ABL, the microscale aerosol particles are disturbed and build up in the air near the surface. ABL takes more time to build up with support from thermals in midland stations compared with the time taken for the ABL to develop with help from sea breeze at coastal stations. So the development of the ABL and hence the establishment of the first peak gets delayed at midland stations. The decay of the second peak at midland stations happens earlier than at coastal stations. This may be due to the sudden decay of the ABL after sunset because the heat capacity of the ground is comparatively less than that of water. But in the coastal stations the sea breeze ceases in the early night hours. This cessation of sea breeze will cause a delay of the second peak in the concentration of condensation particles at coastal stations.

Figure 4 gives the variation of condensation particles over hilly areas. Figure 4 includes two stations, viz., Ponmudi and Peermade; the measurement sites at these stations were on the slope of the Western Ghat mountain. The diurnal patterns at these stations were completely different from those at the coastal and midland stations. This difference may be due to absence of the ABL over slanting terrain. The concentration of condensation particles shows a high at midnight and then continuously decreases till early morning hours. The values again begin to increase from mid-day onwards and continue to increase till midnight. The slope of the increasing phase of the condensation nuclei (CN) concentration is much less than that of the decreasing phase. When comparing Ponmudi and Peermade, we found a phase difference between these two stations even though the patterns were similar. The variation in CN concentration at Peermade leads by about

**Figure 3.** Diurnal variation of condensation particles over midland stations. The stations are Ponkunnam (representing south station), Perinthalmanna (representing central station) and Thamarassery (representing north station). Figure shows similar variation as that of the coastal stations. The second peak is suppressed in the case of central station.
2 h from that at Ponmudi. Magnitude-wise, Peermade registers a much higher CN concentration than Ponmudi. During the measurement period, we noticed that there was high wind throughout the day with rather low temperature at Ponmudi. But at Peermade, the atmosphere was almost calm with moderate temperature. The absence of wind may be one of the reasons for the high value of CN at Peermade.

Figure 5 gives the diurnal variation of CN concentration at two hill stations Malampuzha and Sulthan Bathery. The measurement site was located on the flat region of the high range stations, which facilitates the site to develop IBL and hence the structure of the condensation particles. The diurnal structure of the hygroscopic particles showed peaks in the morning hours and in the night hours around 2000 IST. These variations were similar to those in the coastal and midland stations. Sulthan Bathery showed abnormal high values during daytime. Waste materials were being burnt near the measurement site. Wind over the site was nearly calm. The high concentration of aerosol particles may due to diffusion of aerosols from burning. Contribution of the condensation particles from the burning of waste was large. In the case of Malampuzha, an additional peak in the noon hours is evident. The measurement site in Malampuzha is located in a calm environment and nearly 500 m away from the Malampuzha dam. During this period no water was let out from the dam. The reason for the peak in the noon hours cannot be related to the ABL formation or dissipation.

Concentration of aerosol particles in coastal, midland and highland stations in the south, central and north Kerala was studied during summer. From the study we found that coastal and midland stations followed almost similar diurnal variation, but the magnitude was different for different stations. Concentration of aerosol particles was mainly based on the nature of the station. The observed variation in a day for coastal and midland stations was bimodal. The morning peak was around 0800 h and evening peak around 2100 h. Development of the first peak was earlier in the coastal stations than in the midland stations. In the sloping region of the mountain, the diurnal feature was different from that of the coastal and midland stations. However for the stations in the flat part of the hilly area, the variation was bimodal.

Figure 4. Diurnal variation of concentration of condensation particles for highland stations, Ponmudi and Peermade.

Figure 5. Diurnal variation of concentration of condensation particles for highland stations, Malampuzha and Sulthan Bathery.

Detection of biomarker in breath: A step towards noninvasive diabetes monitoring

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Along with more than two hundred volatile organic compounds (VOCs), acetone is also a normal constituent of breath of healthy individuals, albeit in the sub-ppm range, and its concentration increases in diabetic patients. Considering the importance of breath acetone as a biomarker of diabetes, some studies have already been made to measure breath acetone concentration (and correlate with blood sugar level) using GC–MS. There are a few reports of measuring breath acetone concentration using semiconductor sensor in the background of air (i.e. in the absence of VOCs present in normal breath and hence the question of selectivity remains in the real situation) and at a higher concentration (above 10 ppm). We report excellent sensitivity of sonochemically prepared nanosized γ-Fe₂O₃ sensors towards sub-ppm acetone (pathological range) in the background of human breath. Our preliminary results should stimulate further research towards developing cheap, rugged and compact semiconductor sensors for noninvasive monitoring of diabetes.

Keywords: Acetone sensor, biomarker, diabetes, noninvasive monitoring.

DIABETES mellitus, a consequence of failure to metabolize the body’s glucose, is a global epidemic of recent times. India has the maximum number of diabetes patients in the world; around 37.1 million Indians are known to be suffering from diabetes¹ and the number is expected to increase at a rapid rate to 79.4 million in the year 2010. It is the need of the hour to develop a simple, noninvasive diagnostic procedure which would revolutionize diabetes management.

The age-old standard technique of diabetes detection is blood sugar monitoring, which requires blood collection and is an invasive technique. Noninvasive techniques²–⁵ are primarily based on IR spectroscopy, radio-wave impedance and optical rotation of polarized light. However, these techniques are either cumbersome, expensive or non-standardized and not so popular with patients.

Since the time of Hippocrates, it has been known that the sweet odour of breath of a patient is an indication of ketosis. Later it was discovered that the sweet odour comes

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15. TSI Incorporated, Model 3007 Condensation Particle Counter. Operation and Service Manual, 1930035, Revision D, 2002; www.tsi.com