CHARACTERIZATION OF PM$_{2.5}$, PM$_{10-2.5}$ and PM$_{>10}$ IN AMBIENT AIR, YOKOHAMA, JAPAN

Introduction: Deterioration of urban air quality has now become a prime issue both in developed and developing countries. Air pollution due to airborne Particulate Matter (PM) in the urban atmosphere has been identified to be severely harmful for human health$^1$. Airborne particles are also largely responsible for reducing visibility in urban atmosphere$^2$, material decay, and global climate change. Particulate Matter by mass does not provide a clear understanding of a local PM pollution problem as well as its potential impact on human health. Therefore, current situation demands the need for further studies to explore the behavior of chemical species in PM. Present study aims to investigate the level of ambient PM$_{2.5}$, PM$_{10-2.5}$ and PM$_{>10}$ and study the characterization of carbonaceous aerosol and water soluble ions in the above size segregated PM, Yokohama, Japan.

Material and Methods

Sampling site: The main study area of the current research is focused on Yokohama, Japan. The city of Yokohama is located about 18 miles to the southwest of central Tokyo. Currently sampling site has been selected and operated at the rooftop of a three stored building of Yokohama National University campus.

Analysis of PM samples: MCI air sampler accommodated with a NILU impactor (Norwegian Institute for Air Research) has been used to collect PM$_{2.5}$, PM$_{10-2.5}$ and PM$_{>10}$ and study the characterization of carbonaceous aerosol and water soluble ions in the above size segregated PM, Yokohama, Japan.

Results and Discussion

PM$_{2.5}$, PM$_{10-2.5}$ and PM$_{>10}$: A total of 58, 54 & 46 samples of PM$_{2.5}$, PM$_{10-2.5}$ and PM$_{>10}$ are collected in the current sampling location. The average concentration of PM$_{2.5}$, PM$_{10-2.5}$ and PM$_{>10}$ ranged from 3.63 to 47.77 ug/m$^3$, 2.07 to 46.14 ug/m$^3$ and 4.44 to 15.33 ug/m$^3$, respectively. The overall mean concentration has also been reported for the period of Sep 27, 2007 and Apr 26, 2008 as 20.18, 9.43 and 5.16 ug/m$^3$ for the above fractions. The overall mean concentration of PM$_{2.5}$ has shown significantly high concentration in the current study area. The current level of particle pollution is found above the US EPA (15 ug/m$^3$) and WHO (10 ug/m$^3$) annual ambient air.

Figure 1 Time series of 24 hr PM$_{2.5}$, PM$_{10-2.5}$ and PM$_{>10}$
quality guidelines. Therefore, the current level of PM$_{2.5}$ has become significant and informative to the Ministry of Environment, Japan. It will help them out to include PM$_{2.5}$ as a criteria pollutant. The PM$_{2.5}$ shows a very good seasonal pattern with frequent sharp decrease as shown in Figure 1, because of the high frequency of rain events. The mean PM$_{2.5}$ has been found elevated in Dec, 2007 because the atmosphere is very stable due to low and steady wind speed during winter months. Temperature was also found lowest level with low relative humidity. Thus, stable, cold and dry meteorology in winter months favors the prolonged life of PM$_{2.5}$ in ambient air. However, there are some low concentration days due to several days of snowfalls in Yokohama (Jan 23, Feb 03 and Feb 9, 2008). Similar trend has been found for PM$_{10-2.5}$ and PM$_{3-10}$. The concentration levels of PM$_{2.5}$ and PM$_{10-2.5}$ are also shown high during Mar 13, 2008 and Apr 21, 2008. During the above period as exemplified in Figure 1, wind speed is reported highest in the whole sampling period. It is also assumed that the arrival of spring dust storm originated from East Asia has a suspected role to exhibit maximum concentrations$^3$.

**Water soluble ions:** The concentration of water soluble ions in PM$_{2.5}$ accounted for 34.9%. The concentration of sulfate, nitrate and ammonium found highest among all ions in PM$_{2.5}$. The mean level of ions in PM$_{10-2.5}$ accounted for 31.3% and major ions are shown Cl$^-$, NO$_3^-$ and Na$^+$. The ions concentration in PM$_{3-10}$ accounted for 23.6%. The individual ion concentration in PM$_{3-10}$ is shown relatively low. The mean molar ratio of NO$_3^-$/SO$_4^{2-}$ (autumn and winter) has been calculated as 0.80. The molar ratios of NO$_3^-$/SO$_4^{2-}$ suggested that stationary and mobile emissions are equally important for PM$_{2.5}$ in Yokohama. In winter months, SO$_4^{2-}$ level has shown significantly low due to low temperature and relative humidity. Although NO$_3^-$ level had high episode during the end of Nov, 2007 and Feb, 2008. Therefore, the molar ratio of NO$_3^-$/SO$_4^{2-}$ exhibited high during winter months and suggests that the contribution of mobile sources is predominant over stationary sources in winter months. The molar ratio of Cl$^-$ and Na$^+$ has also been calculated in all three size fractions. PM$_{10-2.5}$ has a good agreement with the molar ratio of Cl$^-$ and Na$^+$ for the pure sea salt (1.17). Therefore, Cl$^-$ in PM$_{10-2.5}$ in the current study may originate from Tokyo Bay. The ratio of Cl$^-$/Na$^+$ for PM$_{2.5}$ has shown very high during winter. This fact can be explained that the consumption of coal contributed Cl$^-$ of PM$_{2.5}$ into ambient aerosol since coal contains about 0.1% Cl$^-$ $^4$. Contribution of sea salt particles i.e. nss-SO$_4^{2-}$ and nss-K$^+$ $^5$. The contribution of nss-SO$_4^{2-}$ and nss-K$^+$ ranged from 92 - 95% and 95 - 98% in PM$_{2.5}$. The contribution of nss-K$^+$ in PM$_{10-2.5}$ ranged 46 - 76% and 76% - 97% in PM$_{3-10}$. The above fact suggests that the major sources of SO$_4^{2-}$ and K$^+$ in PM$_{2.5}$ are non-marine sources. However, the dominant source of K$^+$ ion in PM$_{10-2.5}$ is marine sea salt.

**Elemental Carbon (EC) and Organic Carbon (OC):** The average OC and EC concentration found in PM$_{2.5}$, PM$_{10-2.5}$ and PM$_{3-10}$ are 3.20 and 1.99 ug/m$^3$, 1.11 and 0.24 ug/m$^3$ & 0.49 and 0.25ug/m$^3$, respectively. The OC and EC have shown a clear seasonal pattern in PM$_{2.5}$. OC shows strong shifting in winter whereas EC level is found steady in PM$_{10-2.5}$ for the whole period. EC and OC level are shown very low in PM$_{10-10}$ with maximum OC concentration in winter months. Strong linear and similar OC-EC correlations are found in PM$_{2.5}$ for autumn and winter giving an indication that the sources may be similar. OC-EC correlations in PM$_{10-2.5}$ and PM$_{3-10}$ are varied markedly indicating the presences of various sources. The contribution of secondary organic carbon (SOC) concentration to total OC and their seasonal pattern has exhibited similar as the OC/EC ratio drops sharply in winter due to high EC level in PM$_{2.5}$. SOC in December and January are shown little high concentration compared with other months as the total OC is strongly shifted in that months for PM$_{10-2.5}$ and PM$_{3-10}$.

**Conclusion:** The mean concentration of PM$_{2.5}$, PM$_{10-2.5}$ and PM$_{3-10}$ and chemical compositions in the above size fractions have shown significant variation during autumn and winter in Yokohama, Japan. The overall mean concentration of PM$_{2.5}$ has exceeded USEPA and WHO annual guidelines. The PM$_{2.5}$ has accounted highest content of water soluble ions. The molar ratio of NO$_3^-$/SO$_4^{2-}$ exhibited high during winter and concluded that the contribution of mobile sources predominant over stationary sources in winter months. Cl$^-$ content in PM$_{10-2.5}$ of the current study may originate from Tokyo Bay and it is also concluded that the consumption of coal contributed Cl$^-$ into ambient PM$_{2.5}$ aerosol. The major sources of SO$_4^{2-}$ and K$^+$ in PM$_{2.5}$ are non-marine sources. However, large proportion of K$^+$ in PM$_{10-2.5}$ may originate from marine source. The concentrations of EC and OC are dominant in PM$_{2.5}$. It also suggests that the concentration OC and EC in PM$_{2.5}$ may originate from the similar type of sources whereas OC and EC in PM$_{10-2.5}$ and PM$_{3-10}$ may have multiple sources.

**Key words:** Particulate matter, water soluble ions, carbonaceous aerosol.

**References**
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