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SEASONAL VARIATION OF PARTICULATE MATTER IN THE AMBIENT CONDITIONS OF KHANSPUR, PAKISTAN

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ABSTRACT

Concentrations of particulate matter tend to vary with shifting seasons. Levels of particulate matter were monitored during the summer and winter season in Khanspur, a high altitude tourist resort in Pakistan. A DustTrak DRX (Model 8533, TSI Inc.) and Kestrel 4500 Pocket Weather Tracker (Nielsen- Kellerman) were installed at selected site in Khanspur and run for 24 hours. During summer the 24- hour average concentrations of PM_1, $PM_{2.5}$, PM_4, PM_{10} and PM_{Total} were 96 ± 26.42, 106± 29.02, 118± 33.3, 163± 52.5 and 209 ± 79.5 µg/m³ while these were considerably lower during the winter season for the same size fractions (62 ± 48.6, 63± 49.3, 63 ± 49.5, 65.33 ± 50.06 and 66.96 ± 50.78µg/m³). A one way ANOVA was applied on the obtained data and it was concluded that seasons have a substantial impact upon PM concentrations. Moreover, this study provides evidence that seasonal variation of particulate matter is influenced by meteorological parameters.

Keywords: Seasonal variation, Particulate pollution, Meteorological parameters, High altitude, Khanspur, Pakistan

INTRODUCTION

Rapid development, urbanization, enhanced use of vehicles and energy production has produced a dangerous situation in terms of number and types of air pollutants (Gurjar *et al*., 2008). Particulate matter is an air pollutant emitted into the atmosphere either through natural or anthropogenic activities that include industrial activity, domestic fuel burning, automotive exhaust, road erosions as well as secondary aerosols due to chemical transformations of gases released from traffic and industry (Seinfeld and Pandis, 2006). Atmospheric aerosols have many direct and indirect effects. Direct effects include heat balance attributed by absorption and reflection of solar radiation, visibility reduction and health impacts. Indirect effects are caused probably by the changing chemistry of greenhouse gases that results in a change of properties and cloud formation (IPCC, 2007). Several epidemiological studies provide evidence that bronchitis, asthma, heart attack, cancer; low birth weight and premature death are caused by particulate matter. In 2012, approximately 3.2 million premature deaths are attributed to PM pollution annually. PM pollution was ranked 5 in HEI's list entitled as top causes of premature mortality in 2010 (HEI update, 2013).

Aerosol concentration is vulnerable to several meteorological factors, either acting as individually or combined with other parameters (Cheng and Lam, 2000; Buchanan *et al*., 2002; Khan *et al*., 2007). People mostly live in areas, located at low latitudes and monitoring stations are typically located close by. Measurements taken at high altitudes are often seen to be representative of the large-scale regional level pollution. Seasonal and regional variations in aerosol concentrations have been observed on the tops of mountains. Temporal variations provide information about the patterns of boundary-layer and free topographic air around mountains (Nyeki *et al*.1998; Shaw, 2007; Nishita *et al*. 2008). Aerosols are lofted to elevations due to turbulence in the boundary layer and thermal-dynamic structure (Fuelberg *et al*. 1996; Tai *et al*. 2012).

Pakistan is an agricultural country but now its economic base is shifting from agriculture to industry and air pollution has emerged as major public health concern. Natural emissions, industrial processes and burning of fossil fuels are three major sources of particulate matter pollution. Hence it is important to monitor seasonal variations and the influence of meteorological parameters on particulate matter concentrations (Akyuz and Cabuk, 2009).Expenditure costs to Pakistan due to environmental degradation are 6 % of GDP, half of which is accounted for by illness and premature deaths. These results are valuable in order to drive policies to control air quality in Pakistan (Zhang *et al*. 2008).The current study was aimed at measuring PM concentrations at a high altitude location during the winter and summer season.

MATERIALS AND METHODS

Khanspur is one of the most popular tourist hill stations in Hazara region of Khyber Pakhtoonkhawa

province, Pakistan. It is located 23 kilometer (13 miles) westwards of Murree. It is situated at altitude of about 2250 m (7500 feet). Its climate is tropical alpine with snow fall in winter while temperature ranges from 21- 26 ˚C with cool nights during summer. Sampling was conducted at Sir Syed Campus of University of the Punjab in order to monitor the seasonal variation in concentration of particulate matter. Sir Syed Campus, University of the Punjab (N 34 01' 14" E 073 25' 09") is a field facility in Khanspur to support study tours and field research projects (Figure 1).

Figure 1: Location of monitoring site, Sir Syed Campus, University of the Punjab, Khanspur

To monitor ambient particulate matter in Khanspur, a DustTrak DRX (Model 8533, TSI Inc.) was installed. The instrument was placed at flat surface with height of 1 m. A Kestrel 4500 Pocket Weather Tracker (Nielsen- Kellerman) was also used. Levels of CO and CO_2 were monitored using a BW Gas Probe IAQ, a portable gas detection device which also monitors temperature and relative humidity. The instruments were run simultaneously for a twenty four hour period during the summer season in the month of May. To study seasonal variation the same procedure was repeated during the winter season in December. Hourly averages were calculated for both seasons and compared with each other. One way ANOVA was applied using SPSS (v. 16.0) to observe any significant relation of PM fractions during the two seasons.

RESULTS AND DISCUSSION

Variation in weather parameters: During the study period, the mean temperature was 0.97 ˚C ranging from -3.2 ˚C to 12.7 ˚C during winter while the average value of relative humidity was 0.61 % with a 0.3 to 0.8 % range. In summer, the temperature ranged between 14˚C and 34˚C with an average of 21˚C. The relative humidity varied from 30 % to 70 % with an average value of 41 %. Wind speed was higher in winter as compared to that in summer. The average value of wind chill was 22.04 ˚C in summer and 0.61 ˚C in winter. Heat index, dew point and wet bulb averaged 20.92 ˚C, 7.92 ˚C, 13.16 ˚C during summer and -3.85, 6.18 and 1.21 respectively, in winter. Table 1 shows weather conditions and their relative variations during summer and winter seasons.

Table 1: Average values of weather conditions during study period

Weather parameters	Summer	Winter
Temperature (°C)	22.04	0.97
Relative humidity (%)	41.60	5.64
Wind chill (°C)	22.04	0.61
Heat index (°C)	20.92	-3.85
Dew point (°C)	7.92	6.18
Wet bulb (K)	13.16	1.21

Variation in levels of CO_2 and CO: The data for 24 hours monitoring revealed CO_2 concentrations to be 337.64 + 22.3 ppm and 387.4 ±15 ppm in summer and winter, respectively. CO value was observed to be below the detection limit in both seasons. Traffic emissions and incomplete combustion are main source of CO pollutants

(Kassomenos *et al*. 2014) which were virtually non-existent.

Variation in particulate matter concentration during the study period: Particulate matter was monitored in terms of different size fractions. The 24-hour average concentration of PM_1, $PM_{2.5}$, PM_4, PM_{10} and PMTotal were 96±26.4, 106±29.02, 118±33.3, 163±52.5 and 209±79.5 µg/m³ in the summer season. These values were observed to be considerably lower during the winter season with the respective average levels of 62±48.6, 63±49.3, 63±49.5, 65±50.1and 67±51 µg/m³.

All fractions were found to be lower in winter as compared to values observed in summer so PM_{Total}also showed this trend, with higher value in summer than concentration monitored in winter.

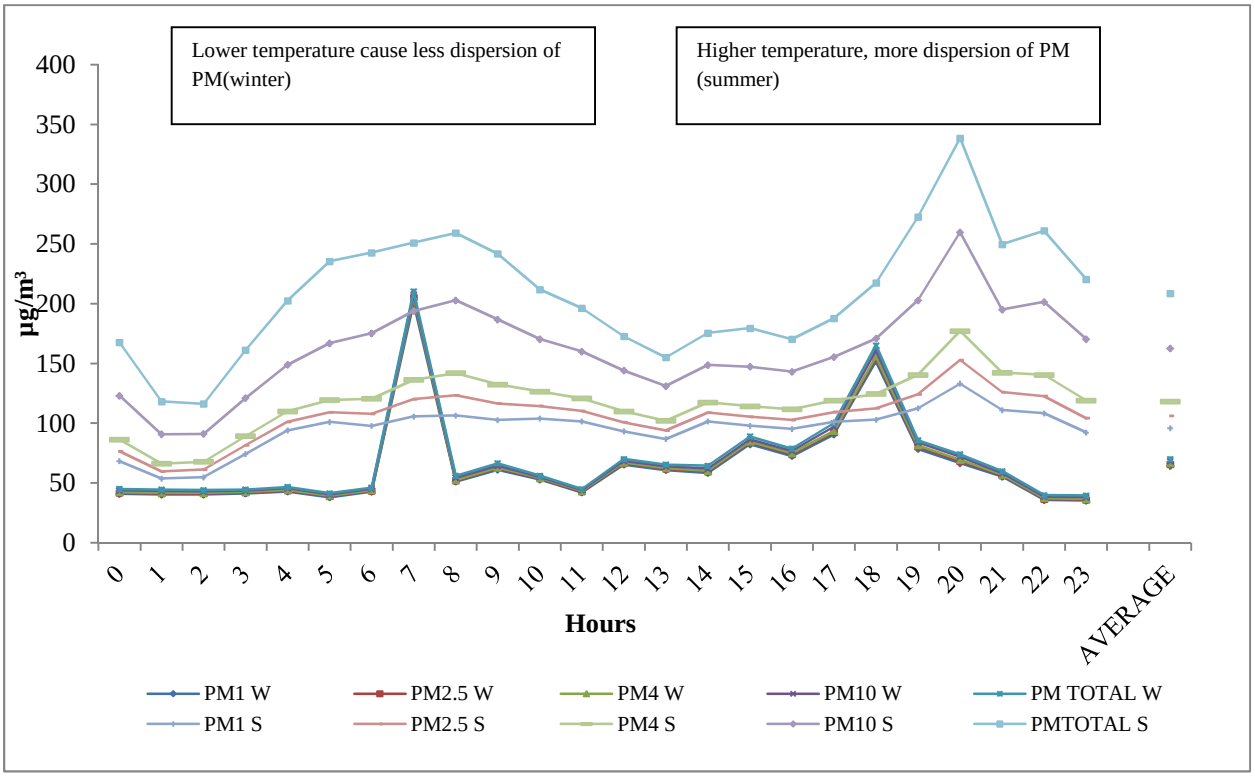

Figure 2: Comparison of various PM levels during the summer and winter season (S = summer; W = winter).

Concentrations of all fractions were less dispersed in winter than values observed during summer as shown in figure 2. Levels of PM_1, $PM_{2.5}$, PM_4, PM_{10} observed in the summer were 0.64, 0.59, 0.54 and 0.4 times higher than their respective values in winter. PM_{Total} levels were found to be 0.32 times higher in summer than in winter. Natural sources (e.g. dust re-suspension) may be primary contributors to these higher values in summer because of ground heating and thermal convention of particles in the dry conditions of the monitoring site. Also a dust storm occurred during the monitoring period which could have contributed significantly towards higher levels of PM_{Total} and PM_{10}. Dust storms have a significant influence upon atmospheric conditions affecting concentration, transportation and/or dilution of particulate matter (Goossenes*et al*. 2011). There is a general assumption that strong winds cause more dispersion of particulate matter. It is also responsible for increasing concentrations of particulate matter due to re-suspension of road dust and soil under certain atmospheric conditions, especially this re-suspension is more pronounced in warm and dry season (Kukkonen *et al*. 2005; Kassomenos *et al*. 2012). Apart from the dust storm, no significant natural or human activity except the movement of the monitoring team was observed in the vicinity. These values were found higher than guideline values established by WHO (World Health Organization, 2005). The 24-hour and annual mean values of $PM_{2.5}$ established by WHO are 25 µg/m³ and 10 µg/m³ while those of PM10 are 50 µg/m³ and 20 µg/m³ respectively.

A one way ANOVA was applied to the measured parameters to observe any seasonal variations. The p-value of all variables was obtained to be below 0.05 leading to the conclusion that the impact of seasons upon particulate matter and weather parameters was subsidizing. Moreover, linear multiple regressions were applied upon the measured variables and it was found out

that the independent variables (temperature, relative humidity, dew point, heat index, chill, and wet bulb) substantially affected the dependent variables (PM fractions). High temperature causes an increase in $PM_{2.5}$ (Jung *et al*. 2002) and our results also showed higher values of fine PM during the warm season. However, the amplitude of $PM_{2.5}$ was higher in winter than their levels in summer because life span of $PM_{2.5}$ is longer and they remain suspended for longer periods due to less wind (Preetha *et al*. 2001). Although values of all fractions of particulate matter were higher in summer peaks were more pronounced in winter. This may be due to enhanced vehicular activity or cooking near the monitoring site.

As the diurnal pattern of particulate matter is influenced by seasons so these patterns were observed separately for summer and winter. The diurnal variation of $PM_{2.5}$ showed higher values at night and lower during the day (Zaho *et al*. 2009). A study of seasonal variation was done in Indo-Gangetic plain and similar results were concluded with highest peak in summer and lowest in winter season (Prasad *et al*. 2007).The mean concentration of all fractions was lower than those measured at lower altitude. Our results were similar to those observed in a study conducted by Gajananda *et al*. (2005). Gajananda and co-workers measured particle number concentration at three different altitudes (1150–2530 ma. s. l.) and found that particle number concentration was lower at high altitudes. Our results are comparable to study conducted by Nishita *et al*., (2008) at Mount Norikura (2770 m) in Japan. Particulate matter showed great seasonal impact due to different dispersion levels in summer and winter seasons. All fractions of particulate matter were observed to be greater in summer than in winter, opposite to the plains. The possible reason behind this trend may be formation of warm thermal layer on floor during summer while convection of fine particles to slope of snowy foothills may be due to development of cold layer in winter (Sharma *et al*. 2011).Primary combustion emissions are not intense at the site so seasonal variation may be contributed by natural sources (Pateraki *et al*. 2008) attributing to secondary particles formation during the photochemical season (Grivas *et al*. 2012).

Zaho *et al*., (2009) observed that boundary layer height and wind speed were decreased and accompanied by increased anthropogenic activities in the afternoon. However, the peak appearing in the evening was more prominent in winter than in summer. The variation in $PM_{2.5}$ levels was influenced by development of boundary layer which favored or negatively changed the dispersion of the pollutants. The boundary layer begins to form after sunrise when temperature and wind speed are also higher. An enhanced boundary layer provides more space for pollutants to disperse. The boundary layer remains higher for longer periods that causes $PM_{2.5}$ values to remain unchanged during the afternoon (Guinot *et al*. 2006; Miao *et al*. 2008).This study was similar to the observation conducted by Zaho *et al*. (2009). The boundary layer decreased in the early afternoon due to reduced solar radiation that resulted in an increase of $PM_{2.5}$ concentration. At night, although boundary layer was reduced the decrease in $PM_{2.5}$ was attributed to a lowered source activity and removal of particles attributed by dry deposition due to higher relative humidity at night in summer (Zaho *et al*. 2009).

All fractions of particulate matter showed their highest concentration between 7:00 and 9:00 a.m. during summer. While lower values were observed at noon. This may be due to nucleation bursts of particles which happen to occur more in summer than winter. These bursts of particles are more prominent during sunrise and less frequent during afternoon (Sharma *et al*. 2011). Goossenes*et al*., (2011) determined the relationship between variation in concentration of particulate matter and atmospheric stability which is dependent upon temperature and wind speed. It was found out that PM_{10} concentration was higher when atmospheric parameters were stable but lower while atmosphere was unstable. The atmosphere conditions were more stable in the morning and in the evening so possibly attributing to higher peaks in the morning and evening because of reduced ventilation and lowering of mixing layer (Choularton *et al*. 1982; Chow and Watson, 1997; Zhao *et al*. 2009). Mixing layer is reduced by stable atmospheric conditions and so enhanced the levels of particulate matter (Chatterjee *et al*. 2010).

Higher $PM_{2.5}/PM_{10}$ ratios are contributed primarily by higher combustion activities and secondary particles. Re-suspension of soil/ road dust is a primary source for lower ratio of $PM_{2.5}$/ PM_{10}. $PM_{2.5}$/ PM_{10} ratios were calculated to be 0.65 ± 0.55 in summer and 0.96 ± 0.96 in winter. The results showed that lower $PM_{2.5}/PM_{10}$ ratio in summer may be attributed by re-suspension of soil/ dust and formation of secondary particles as combustion processes were primary source of these higher ratios in winter. All fractions of particulate matter differ in their source of emission. These ratios were determined in order to identify their possible source of emissions (Akyuz and Kabuk, 2009).The coarse particles are significant contributor to total particle mass. About 20 % of total PM_{10} in winter and 50 % in summer are contributed by coarse particles indicating effects of dry weather on re-suspension process during summer (Thatcher *et al*. 1998; Taneja *et al*. 2008). Sources of coarse particulate matter are mechanical processes (Massey *et al*., 2012). The PM_{10} share to PM total was higher of all fractions in both summer and winter season. $PM_{2.5}$ was mainly contributed by combustion processes during warm season (Akyuz and Kabuk, 2009).

Conclusion: Concentrations of all measured PM fractions were less dispersed in winter than during the summer

season. Moreover, the seasonal effect on PM levels was also pronounced. Higher $PM_{2.5}/PM_{10}$ ratios were observed in winters than during the summer season. Being a popular tourist resort and hill station, it is important to monitor air quality at locations such as Khanspur to observe the trends of pollutants and their subsequent levels to which tourists as well as local community may be exposed. Metrology along with anthropogenic and natural sources play major role in PM levels. Further long term studies are needed to explore in detail the observed seasonal variation in PM levels at such remote sites.

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