A Short-Term Measurement of $PM_{2.5}$ Concentration During the COVID-19 Lockdown Period in Kathmandu Valley

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ABSTRACT

The Government of Nepal implemented a nationwide lockdown from 24 March 2020 to 21 July 2020 to control the person-to-person transmission of COVID-19. This study was conducted in a traffic-intensified area of Kathmandu valley, where vehicular movement represents one of the main sources of air pollution. Hence, this study was intended to quantify the concentration of particulate matter ($PM_{2.5}$) for 11 hours of daytime from 23 April to 20 May 2020. It was also to evaluate the influences of lockdown on air quality. $PM_{2.5}$ was observed using HAZ-Dust, Environmental Particulate Air Monitor in the 18 different traffic sites of the Kathmandu valley. During the lockdown period, a substantially low mean concentration of $PM_{2.5}$ ranging from 3.69±1.78 µg/m^3 to 7.58±3.98 µg/m^3 was recorded in Kathmandu valley, which reflected improved air quality due to the cessation of vehicular activities. Therefore, the study outcome suggests that controlling the existing vehicular activities and promoting energy-efficient vehicles like electric vehicles in specific locations in the city will improve air quality and benefit public health.

Keywords: Air quality, $PM_{2.5}$, Kathmandu valley, COVID-19, Lockdown

1. INTRODUCTION

Particulate matter with an aerodynamic size of 2.5 microns or less ($PM_{2.5}$) is one of the severe air pollutants constituting different hazardous chemicals that can cause acute and chronic human health effects. These effects include cardiopulmonary disorders, adverse birth effects, and diabetes mellitus (Feng *et al.* 2018). Inhalation of such fine particles comprising heavy metals like Nickel (Ni), Mercury (Hg), Arsenic (As), Zinc (Zn), Copper (Cu), and Lead (Pb) causes hazardous effects on the human reproductive system and metabolism (Ali *et al.* 2020). Fine particulate air pollution is also a vital environmental risk factor in causing cardiopulmonary and lung cancer (Pope *et al.* 2002). Besides the adverse impacts on human health, $PM_{2.5}$ also perturbs the climate system and affects the cryosphere (Fiore *et al.* 2015; Shakya *et al.* 2016; Sadavarte *et al.* 2019). The common sources that release $PM_{2.5}$ are vehicular and industrial emissions, fossil fuel burning, indoor combustion emissions, and the other pollutants formed by secondary processes in the atmosphere. Open garbage burning is another important source of air pollutants contributing to a 30% increase in $PM_{2.5}$ (Saikawa *et al.* 2020).

Local pollution sources (Putero *et al.* 2015) and 20–25% additions from background pollution (Mahapatra *et al.* 2019) contribute to overall air pollution in Kathmandu valley, making the country's capital city a hotspot of urban air pollution. In 2006, the WHO Air Quality Guideline recommended an annual (daily) mean exposure threshold of 10 (25) μg/m^3 for $PM_{2.5}$ (WHO 2006), which has been updated to 5 (15) μg/m^3 in 2021 (WHO 2021) demanding serious global concerns to control the current level of air pollutants and their adverse impacts. However, according to the World Air Quality Report 2018, Nepal stands in the eighth position in the global ranking with the global estimated mean $PM_{2.5}$ concentration of 54.20μg/m^3, while Kathmandu is the seventh polluted city with a $PM_{2.5}$ concentration of 54.40μg/m^3 (IQ AirVisual 2018). According to the US AQI Level, both levels are considered unhealthy for sensitive groups. In 2006-2007 outdoor $PM_{2.5}$ levels in Kathmandu was reported as 69 μg/m^3, 30 μg/m^3, 53 μg/m^3, and 90 μg/m^3 during pre-monsoon, monsoon, post-monsoon, and winter season, respectively (Aryal *et al.* 2009). The mean $PM_{2.5}$ during the monsoonal sampling period was lower (45.92 μg/m^3) than during the drier spring sampling period (Shakya *et al.* 2017), indicating the seasonal variation of the concentration of particulates pollutants in Kathmandu valley. The Thamel area had significantly reduced $PM_{2.5}$ after implementing the vehicle-free zone (Khadgi *et al.* 2020).

In 2011, 195 Gg of $PM_{2.5}$ was assessed from the five energy-use sectors: residential, industry, transport, commercial, and agriculture (Sadavarte *et al.* 2019). Past monitoring of ambient particulate air pollution before COVID-19 showed high pollution concentrations in Kathmandu valley with levels more than five times the accepted WHO and National Ambient Air Quality Standards (Shrestha 2018).

The Government of Nepal instigated a countrywide lockdown from 24 March to 21 July 2020 as an initial response to limit the spread of the COVID-19 pandemic. All kinds of mobility, industrial, and market activities were banned except for emergency services and essential daily activities during the lockdown period. All over the country, only a few cases of COVID-19 were recorded during the lockdown period. The lockdown has reduced the incidence of COVID-19 and lowered a significant amount of air pollution in many cities (Mishra *et al.* 2021). In Kathmandu, the reduction in exposure to $PM_{2.5}$ during lockdown was mainly due to the large-scale changes in the sources of fossil fuels (Edwards *et al.* 2021). The major contributors to $PM_{2.5}$ remained almost stagnant during the lockdown period, which allowed the researchers to examine the mean $PM_{2.5}$ concentration and its hourly variation in different locations of Kathmandu valley. Hence, this study was intended to quantify the concentration of $PM_{2.5}$ during the lockdowns and to determine its hourly variation in the Kathmandu valley. Since the concentration was measured when the human impacts on air quality were nominal, it is expected that the result can be used as the baseline data for future air pollution research in Kathmandu valley.

2. MATERIALS AND METHODS

2.1 Study Area

Kathmandu (Latitude: 27°24′-27°49′ N & Longitude: 85°11′-85°33′ E), the capital city of Nepal, along with Lalitpur and Bhaktapur districts, forms the bowl-shaped Kathmandu valley with an area of 899 km^2 (Kathmandu: 395 km^2, Lalitpur: 385 km^2, and Bhaktapur: 119 km^2) and a population of about 3.5 million growing at a rate of 4% per year and has the highest population density of 2800 persons/ km^2 in the nation (CBS 2019). The valley is one of the highest occupied cities, with an urban coverage of 139.57 km^2 in 2015 (Rimal *et al.* 2017). This study was conducted in 18 different sampling sites in Kathmandu valley, presented over the Kathmandu valley map in Fig. 1.

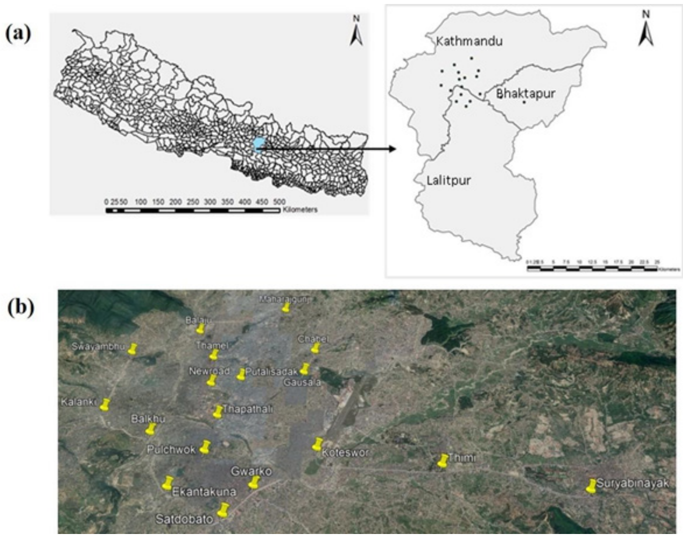

Fig. 1: Map of Nepal (a) showing three districts of Kathmandu valley and sampling points (b) Google earth maps showing sampling sites

2.1 Methods

The particulate matter concentration was monitored using Haz-Dust Environmental Particle Air Monitor Model (EPAM- 5000, Environmental Devices Corporation), allowing for real-time data and filter gravimetric analysis utilizing the FRM 47 mm Cassette located directly behind the optical sensor. This portable sampler was deployed in the eighteen different traffic sites of the Kathmandu valley during the lockdown period to measure the concentrations of $PM_{2.5}$ for 11 hours (7:00 am to 6:00 pm local time) in a day from 23 April to 20 May 2020. $PM_{2.5}$ concentration recorded every minute was later calculated as hourly mean concentration for further analysis. Additionally, weather data, including wind, rainfall, relative humidity, and temperature, were retrieved from the website (https://www.wunderground.com/history/monthly/np/kathmandu/VNKT) and analyzed to present the meteorological conditions during the study period in Kathmandu valley. All the data were analyzed and presented using MS Excel 2013 and Origin Lab 2021.

2.1 Meteorological Conditions During the Study Period

The daily mean temperature, humidity, and wind speed during the study period are shown in Figure 2. The mean temperature during the study period in Kathmandu valley was 20.02±2.56 °C (range: 16.07-24.16 °C) with mean humidity of 75.77±7.58% (range: 61.0-87.05%) and wind speed of 7.28±1.55 km/hr. Humidity was negatively correlated (-0.87 & -0.78) with temperature and wind speed, while temperature and wind speed were positively correlated (0.74).

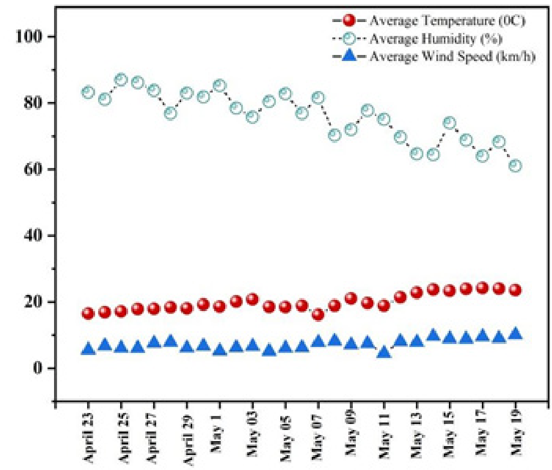

Fig. 2: Meteorological condition in Kathmandu valley during the study period

3. RESULTS AND DISCUSSION

During the study period, a substantial reduction in $PM_{2.5}$ concentration in Kathmandu valley has been observed, which may have been the impact of the lockdown imposed in response to COVID-19. The mean concentration of $PM_{2.5}$ was observed to be 5.59±1.01 µg/m^3, which is lower than the daily mean exposure threshold value of WHO (15 µg/m^3). The mean $PM_{2.5}$ concentrations for 18 sampling sites revealed that the $PM_{2.5}$ concentrations in these areas are also well below the daily mean exposure threshold value of WHO (15 µg/m^3) and National Ambient Air Quality Standards (40 µg/m^3) (CBS 2019). Based on $PM_{2.5}$ data from World Air Quality Index, an online platform for global air pollution data, it was projected that Kathmandu would increase the $PM_{2.5}$ concentration by 11% during the lockdown (quarantine) (Rodríguez-Urrego & Rodríguez-Urrego 2020). However, this study noted low $PM_{2.5}$ concentration during the lockdown period in all sampling sites of Kathmandu valley, as presented in Fig. 3.

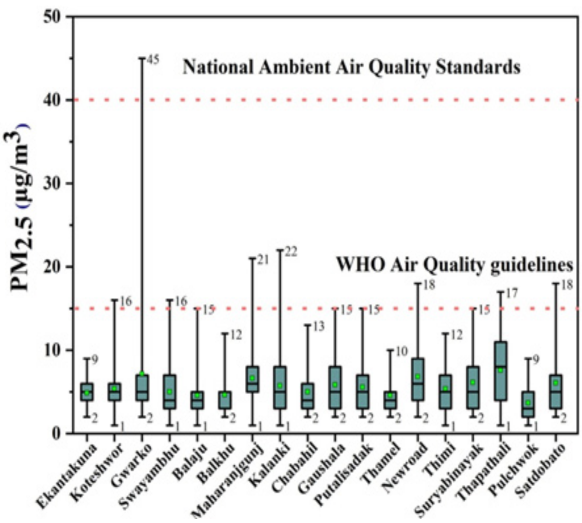

Fig. 3: $PM_{2.5}$ (µg/m^3) across sampling locations in Kathmandu valley. The green boxes indicate the mean values of the $PM_{2.5}$ concentration. The dotted lines show the standard level of air quality as per National Ambient Air Quality Standards (40 µg/m^3) and guidelines recommended by the WHO

A study conducted using web data (www.aqicn.org) also noted a decline in $PM_{2.5}$ concentration by 51% during the COVID-19 pandemic lockdown periods in 2020 in comparison to three previous years (2017, 2018 & 2019) in Kathmandu valley (Mishra *et al.* 2021). The reduced concentration of $PM_{2.5}$, as observed during this study in Kathmandu valley, was also noted by several studies to measure the criterion air pollutants like $PM_{2.5}$, PM_{10}, NO_2, SO_2, etc., in different urban cities of the world during the lockdown period. For instance, a study conducted for 44 cities in northern China found a strong association between travel restrictions during pandemics and the reduction of air pollution (Bao & Zhang 2020). Wuhan city, China, the first city to impose the lockdown, also observed improved air quality (Zheng *et al.* 2020). During the lockdown, about a 43% reduction in $PM_{2.5}$ was noted in India (Sharma *et al.* 2020), and air quality in Delhi, a megacity of India, was also significantly improved, with the concentrations of PM_{10} and $PM_{2.5}$ reduced by half as compared to the pre-lockdown phase (Mahato *et al.* 2020). Similarly, as a consequence of the security measures and control actions undertaken, the emissions from vehicle exhaust and industrial production were significantly reduced, which contributed to the decrease in the concentrations of the air pollutants (PM_{10}, SO_2, and NO_2) during the lockdown in Salé City, NW Morocco (Otmani *et al.* 2020).

While comparing the mean concentration of $PM_{2.5}$ between the sampling sites, there is heterogeneity in the estimated concentration. The maximum $PM_{2.5}$ concentration reached 45 µg/m^3 in Gwarko, followed by 22 µg/m^3 and 21 µg/m^3 in Kalanki and Maharajgunj areas. The mean concentration was slightly higher in Thapathali (7.58±3.98 µg/m^3), Gwarko (7.18±6.76 µg/m^3), New-Road (7.80±3.94 µg/m^3), and Maharajgunj (6.63±3.32 µg/m^3) than other sites. The lowest mean concentration was found in Pulchwok (3.69±1.78 µg/m^3). The hourly mean concentration shown in Fig. 4 depicts the hourly variations in concentration in the study sites. Among the study sites, the maximum mean concentration was found to be 23.90±11.97 µg/m^3 at 10-11 am in the Gwarko area, while Ekantakuna, Satdobato and Pulchwok areas during the same time had concentrations of 4.07±1.02 µg/m^3, 6.12±1.45 µg/m^3 and 2.73±1.25 µg/m^3 respectively. The Thapathali area had a higher mean concentration (12.55±1.83 µg/m^3) than the Putalisadak area (3.38±0.83 µg/m^3) at 11-12 noon. Similarly, the Thimi area had a concentration of 2.40±0.64 µg/m^3, while the Suryabinayak area recorded 11.65±2.04 µg/m^3 at 11-12 noon. These variations in the concentration of pollutants may have depended on the sources and weather conditions prevailing during the study period. During the lockdown period, there may be an increment in vehicular movements for a short duration, leading to a higher concentration of $PM_{2.5}$ for a short period. On the other hand, meteorological factors influence the aggregation, diffusion, and spread of $PM_{2.5}$ (Li *et al.* 2017). However, this study could not predict the impacts of meteorological conditions on the concentrations of $PM_{2.5}$ as it was carried out for a short duration only.

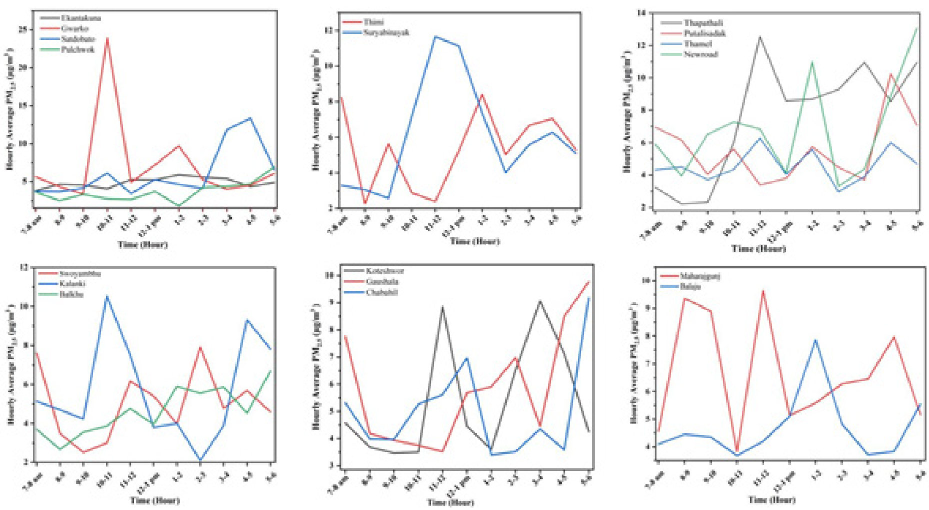

Fig. 4: Hourly variation of $PM_{2.5}$ in the study sites

4. CONCLUSION

This study based on short-term observation reveals that the $PM_{2.5}$ concentration of Kathmandu valley was significantly reduced with a low mean concentration of $PM_{2.5}$ ranging from 3.69±1.78 $\mu g/m^3$ to 7.58±3.98 $\mu g/m^3$ during the lockdown of the COVID-19 pandemic in Nepal. The study conducted in 18 sampling sites with continuous monitoring of $PM_{2.5}$ for 11 hours a day reflected improved air quality due to the cessation of vehicular activities. Therefore, the study outcome suggests that controlling the existing vehicular activities and promoting energy-efficient vehicles like electric vehicles in specific locations in the city will improve air quality and benefit public health. During lockdown, less mobility and Work from Home (WFH) have shown the way of sustainable living and cut-off mobility to reduce air pollution.

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