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Comparative Study of Ambient Air Quality Using Air Quality Index in Kathmandu City, Nepal

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Abstract:*Air pollution is a challenging problem globally and the entire globe is dealing with the hazard caused by it. It harms different environmental factors that directly or indirectly cause health problems. Due to rapid urbanization and various infrastructure development projects, the level of air pollution of Kathmandu city is increasing day by day. We were interested to study air pollution in Kathmandu before and after the lockdown due to COVID-19. We studied ambient air in Kathmandu city applying air quality index (AQI). Data was received from the World Air Quality Index project (https://aqicn.org/).AQI of two major criteria pollutants, viz. Particulate matter PM2.5 and PM10, for the month of January (2020) to April (2020) at four different stations, Phora Durbar, US Embassy, Ratnapark, and Bhaisipati of Kathmandu city were studied. We compared our data with the USEnvironmental Protection Agency(EPA) standard. Varying results of AQIs were obtained. PM10 and PM2.5 were found to be ranged in "Good" to "Very Unhealthy" zone. Interestingly, after the lockdown of the city due to COVID-19 (From 24 March), pollution in Kathmandu was decreased to a moderate zone. The daily, weekly, and monthly variations in air quality indexes were plotted with a possible explanation.*

Keywords*:Air Quality Index, Air Pollution, Ambient Air Quality, Kathmandu city, PM2.5, PM10*.

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I. Introduction

Air Pollution is one of the serious issues faced by humans globally, mainly in city areas of developing countries, which is not only due tothe speedy growth of population but also industrialization. It has a negative impact on the quality of health. Air pollution kills an estimated seven million people worldwide per annum. According to theWorld Health Organization (WHO), 9 out of 10 people breathe air containing high levels of pollutants. Ambient air pollution accounts for an estimated 4.2 million deaths per year due to stroke, heart disease, lung cancer, and chronic respiratory diseases [1]. Therefore, air pollution monitoring and controlling is extremely important. Various monitoring programs have been launched to study the quality of air by producing a large amount of data on the concentration of every air pollutant (e.g., SPM, CO, NOx, SO_2, etc.) in different parts of the world.

In 2020, the Environmental Performance Index (EPI) of Nepal's air quality ranked last among 180 countries [2]. Kathmandu is ranked as one of the most polluted cities in Asia [3]. Nepal is a rapidly urbanizing country. A data of 2020 shows that 6.2 million people of Nepalese are living in urban areas [4]. As this trend is rapidly increasing, it is estimated that the urban population may reach 60 million by 2040 [5]. Kathmandu city has a population density of 13,225 per square kilometers. Accounting for 20% of the urban population in an area of 50.67 square kilometers is the largest urban agglomerate in Nepal [6]. The trend of purchasing new vehicles is also found to be rapidly increased. In the year 2015/16, about 90,000 vehicles were registered in the Department of Transport Management [7]. Emissions from vehicles are particularly toxic as diesel-powered vehicles, which are considered deadly pollutant and carcinogen, are larger than the petrol-powered ones. Besides vehicles, haphazard digging of the road for presently ongoing Melamchi water project, brick kilns, unplanned enlargement of roads, ill-managed dumping of building materials on the busy roadsides, and the old engine automobiles that race regularly on the pothole burdened roads are adding pollution in Kathmandu [8].

Department of Environment published a report on air pollution in 2017. The annual average of Total Suspended Particles (TSP) in a site in Kathmandu was in the range 44 to 227 $\mu g/m^3$ with Ratnapark having the highest value and Pulchowk the lowest one. Also, the average PM10 was in the range between 38 to 91 $\mu g/m^3$ with Ratnapark having the highest and Pulchowk having the lowest value, and PM2.5 was in the range between 31 to 52 $\mu g/m^3$ with Ratnapark having the highest annual average value and Dhulikhel the lowest. [9]. To find out the seasonal variation of air pollution, Karki et al., 2015 [10] conducted a study in Kathmandu Valley that measured NO_2,CO, and PM2.5 concentration daily in all the four seasons of a year. The maximum level of each of these parameters was seen during the winter and spring seasons. Pollutants were found to be maximum in winter and minimum in autumn. Gupta et al., 2016 [11] conducted a comparative study of Air Quality Status in Gida Gorakpur, Talkatora, and Lucknow. They found that air quality status of GIDA, Gorakhpur was comparatively poorer than Talkatora, Lucknow. Rai, 2016 [12] studied air quality index in Jodhpur city and he found that SO_2, NO_2, and CO were lying in good to satisfactory zone while PM10 and PM2.5 were lying in moderate to the poor zone. Other several works were done regarding air quality index (e.g., Hemavani et al, 2020; Toppo et al., 2018; Sarella et al., 2015) [13, 14, 15] in the different cities of India.

In this paper, we will present the study of the AQI at four different stations of Kathmandu city viz. Phora Durbar, US Embassy, Ratnapark, and Bhaisipati. We will see the variation of AQIs on a daily, weekly, and monthly basis from January (2020) to April (2020). We will compare our results with the US EPA standard to see whether AQIs in Kathmandu city exceed US EPA standards or not. We will discuss the methodology in section 2. The results will be discussed in Section 3. Finally, in section 4, we will conclude our study.

II. Material and Methods

We have received data from the World Air Quality Index project, a non-profit project that started in 2007. The mission of this project is to promote air pollution awareness for citizens and provide unified and world-wide air quality information. The project is serving transparent air quality information for more than 100 countries, covering more than 12,000 stations in 1000 major cities, via these two websites: aqicn.org and waqi.info [16]. Government of Nepal, Ministry of Population and Environment, Department of Environment Air Quality Monitoring (pollution.gov.np) provides data of different stations to the many organizations and projects including the World Air Quality Index project. The government of Nepal has established 11 air quality monitoring stations in Nepal. Each monitoring station has Grimm Electronic Dust Monitor (EDM) 180 to measure a particulate matter of different sizes. It uses the light-scattering technology for particle count. A semiconductor-laser serves as the lightsource. The particle size analyzer/dust monitor determines the dust-concentration (counts/liter) through the optical-light-scattering method directly; however, the mass concentration is determined by extrapolation [9]. All the stations are the real-time monitoring stations.

We had filled the data request form and submitted it. After the review of our application and purpose, the World Air Quality Index Project team sent the data of required stations, generating a daily average of PM2.5 and PM10. Data of some days were missing; this might be due to some technical or electrical problems in the monitoring stations. We performed our study using available data. For the data analysis, we used Python3 and Origin9.0. We compared our data with the US EPA standard. We studied daily, weekly and monthly variations in AQI's. Data were plotted and discussed with possible explanations.

U.S. EPA $PM_{2.5}$ AQI

AQI Category	AQI Value	24-hr Average $PM_{2.5}$ Concentration (µg/m³)
Good	0 - 50	0 - 15.4
Moderate	51 - 100	15.5 - 40.4
USG	101 - 150	40.5 - 65.4
Unhealthy	151 - 200	65.5 - 150.4
Very Unhealthy	201 - 300	150.5 - 250.4
Hazardous	301 - 500	250.5 - 500.4

U.S. EPA PM_{10} AQI

AQI Category	AQI Value	24-hr Average $PM_{2.5}$ Concentration (µg/m³)
Good	0 - 50	0 – 54
Moderate	51 - 100	55 – 154
USG	101 - 150	155 – 254
Unhealthy	151 - 200	255 – 354
Very Unhealthy	201 - 300	355 – 424
Hazardous	301 - 500	425 – 604

Figure1: U.S. EPA standard for AQI PM2.5 (left), U.S. EPA standard for AQI PM10 (right)[17].

Air Quality Index (AQI)

The air quality index (AQI) is an index for reporting air quality on a daily basis. It is a measure of how air pollution affects one's health within a short period. The purpose of the AQI is to assist people to know how the local air quality impacts their health. The EPAcalculates the AQI for five major air pollutants, for which national air quality standards have been established to safeguard public health. We can use the following equation for the calculation of AQI from concentration (µg/m³) of pollutants [18].

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}} (C - C_{low}) + I_{low} \quad (2.1)$$

Where, $I = Air\ Quality\ Index$,

C = *Pollutant concentration*,
C_{low} = *Concentration breakpoint that is* $\leq$ C,
C_{high} = *Concentration breakpoint that is* $\geq$ C,
I_{high} = *Index breakpoint corresponding to* C_{high},
I_{low} = *Index breakpoint corresponding to* C_{low}.

III. Results and Discussion

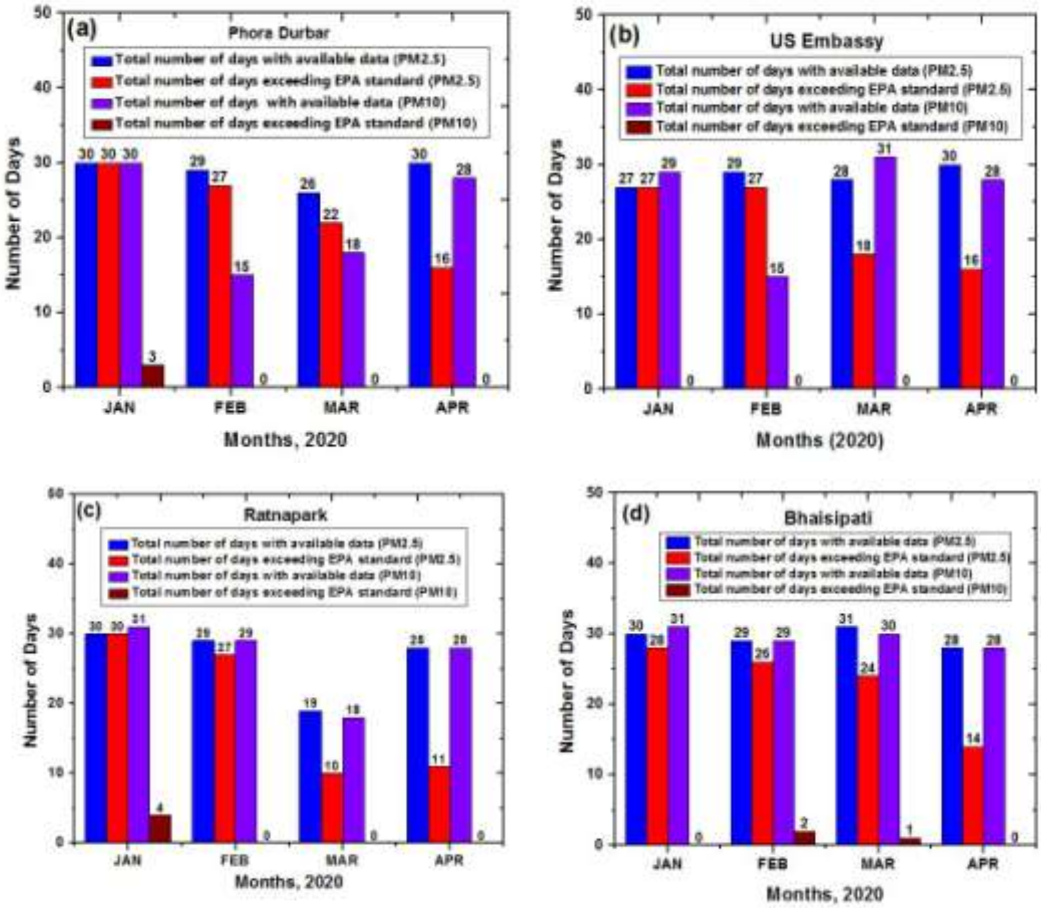

Figure 2:(a), (b), (c), and (d) shows the number of days with available PM2.5 and PM10 data and the no. of days exceeding US EPA standard for the stations Phora Durbar, US Embassy, Ratnapark, and Bhaisipati respectively.

In figure 2, it is seen thatthe maximum number of days in January and February at Phora Durbar, US Embassy, Ratnapark, and Bhaisipati exceeded US EPA PM2.5 standard but in March and April, this trend was found to be decreased. At Bhaisipati station, the number of days exceeding PM2.5 in March was found to be slightly greater than other stations. The number of days exceeding the US EPA PM10 standard at all the stations was found to be minimum. Among four months, the maximum number of days with pollution was seen in January and the minimum in April. After the lockdown of the city due to COVID-19 (from March 24), pollution in Kathmandu is found to be decreased.

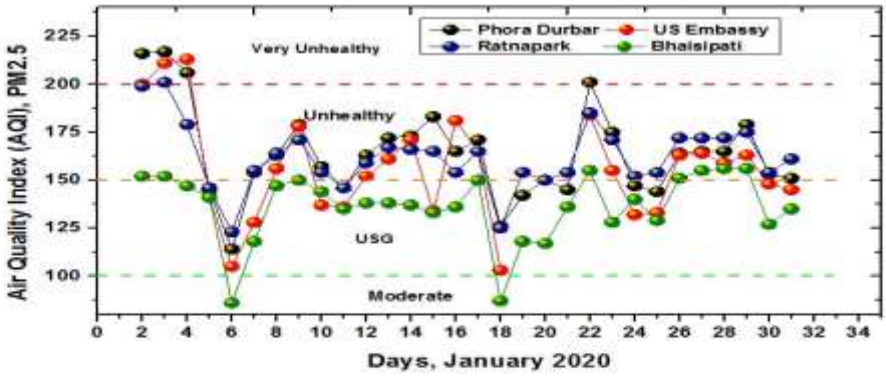

Figure 3: Daily AQI (PM2.5) at different stations in January of 2020.

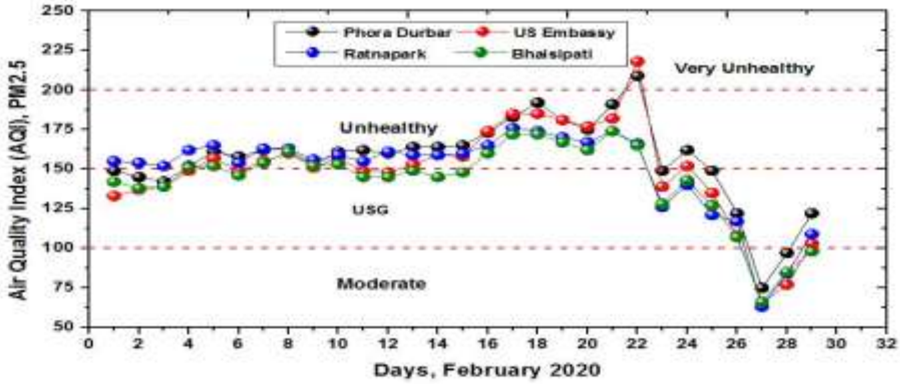

Figure 4: Daily AQI (PM2.5) at different stations in February of 2020.

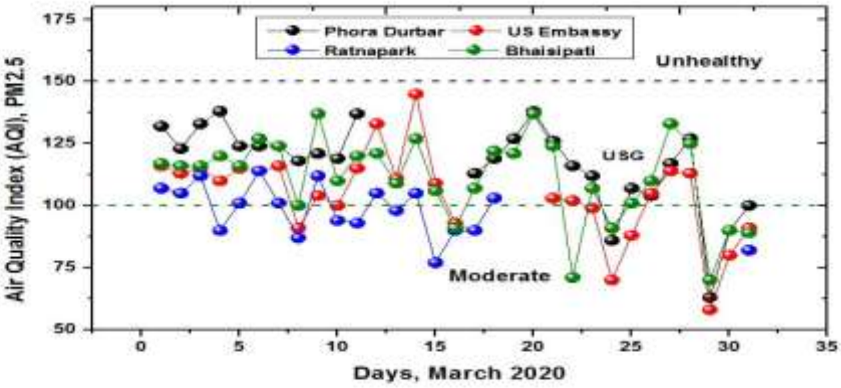

Figure 5: Daily AQI (PM2.5) at different stations in March of 2020.

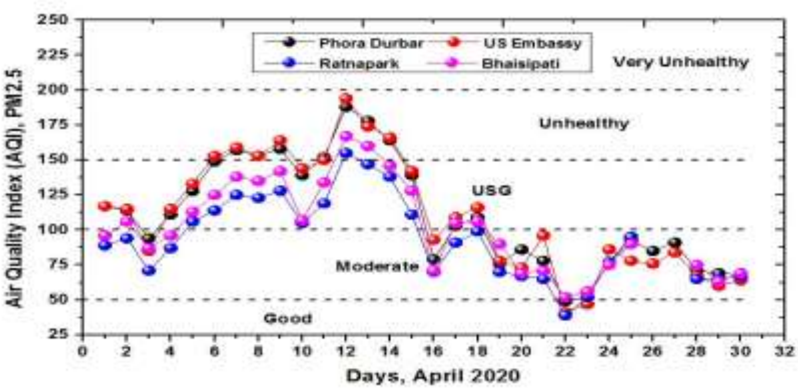

Figure 6: Daily AQI (PM2.5) at different stations in April of 2020.

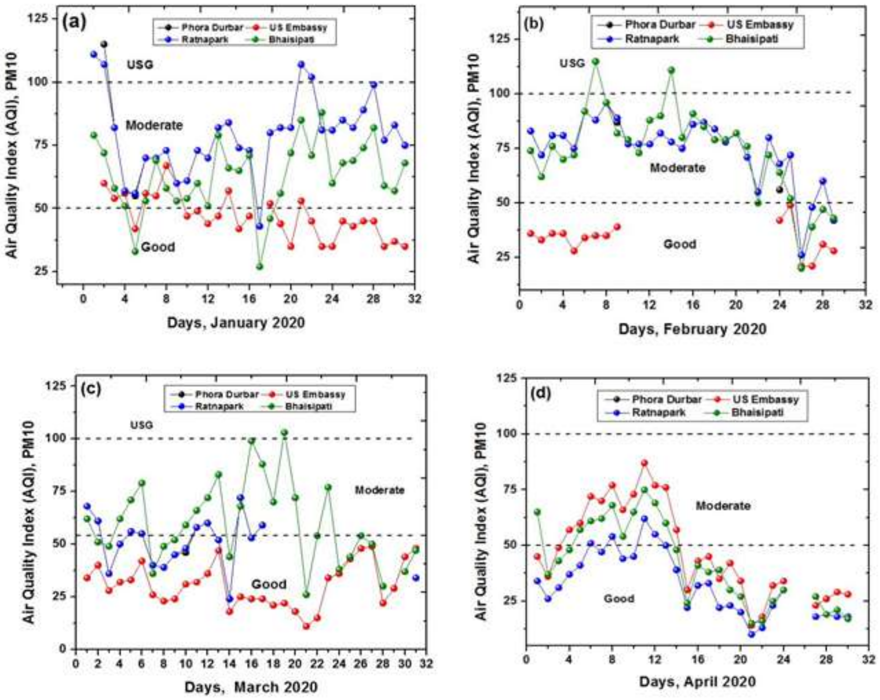

Figure 7: (a), (b), (c), and (d) represent the daily AQI (PM10) at different stations in the month of January, February, March, and April respectively.

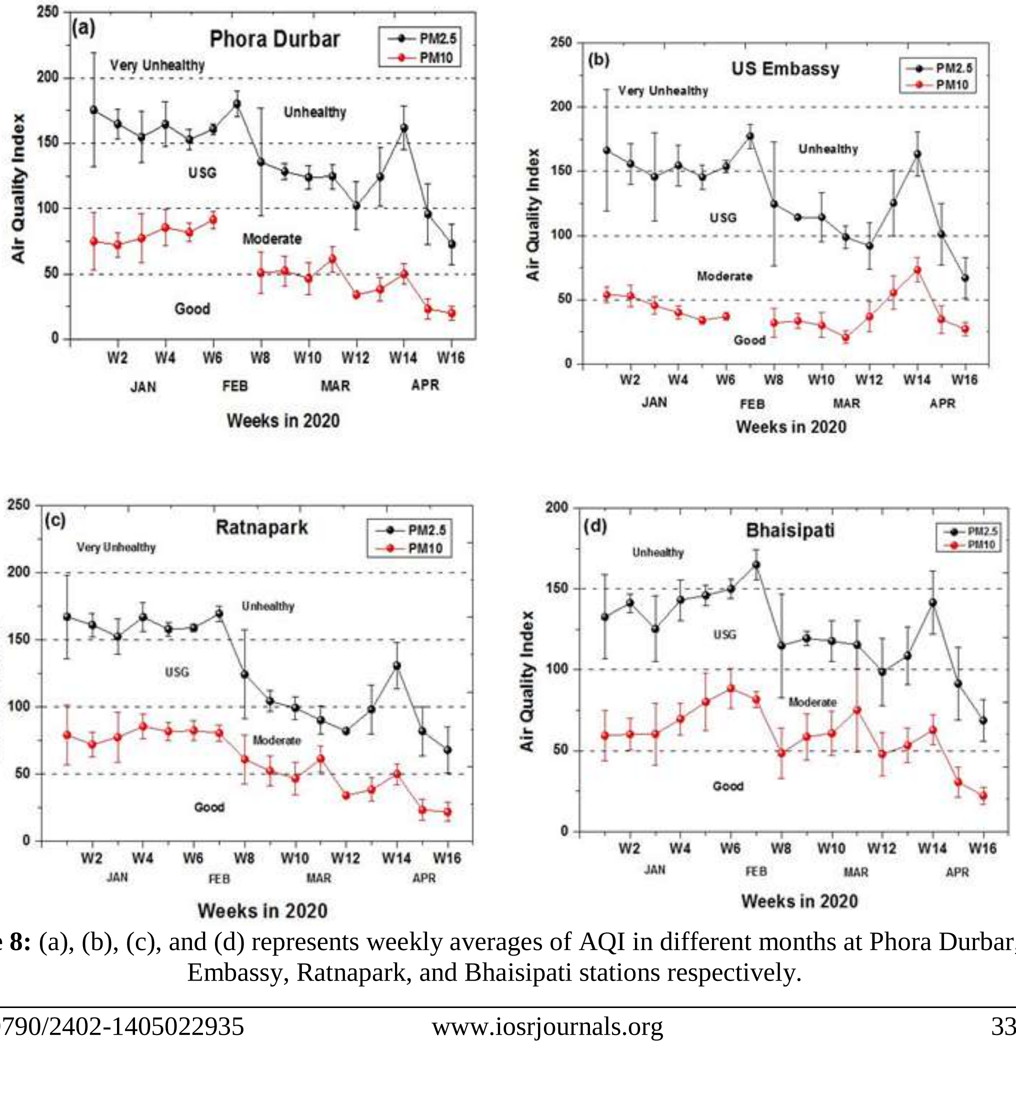

Figure 8: (a), (b), (c), and (d) represents weekly averages of AQI in different months at Phora Durbar, US Embassy, Ratnapark, and Bhaisipati stations respectively.

Figure (3), (4), (5), and (6) show the daily AQI (PM2.5) at different stations inJanuary, February, March, and April respectively. We compared our data with the US EPA AQI standard (figure 1). In January and February, maximum data fell into the “Unhealthy for Sensitive Groups” (USG) and ‘Unhealthy’ categories. Few days were also found to lie within the “Very Unhealthy” category. Some days in these two months were also seen in the “Moderate” zone. In March, pollution was found to be fallen within the “Moderate” and “USG” zone at all the stations. InApril, some days were in the “Unhealthy” zone but maximum days are found tolie within the “Moderate” and “USG” zone. Data in April showed that few days were fell within the “Good” category. Figure 7 shows daily AQI (PM10) at different stations in different months. Some days in January, February and March were found to lie within the “USG” category. But maximum days of all the months at all stations were found tolie within the “Moderate” and “Good” zone. Figure 8 shows the weekly AQI (PM2.5 and PM10) at different stations of Kathmandu in different months. We had simply calculated the weekly average of AQIs at different stations based on available data. Moving from January to April, we found that AQI (PM2.5) was decreased from the “Unhealthy” zone to the “Moderate” zone at different stations of Kathmandu. AQI (PM10) was found tolie within the “Moderate” and “Good” zone. From the study of daily and weekly variation in AQIs, we found that pollution in Kathmandu was decreased significantly in March and April.

Figure 9 represents the monthly averages of AQIs at different stations in different months. Error bars show the calculated standard deviation. From the figure, we see that the monthly average for AQI (PM2.5) in January for Phora Durbar, US Embassy, and Ratnapark station was more than 150 and lies in the “Unhealthy” zone whereas, at Bhaisipati station, it was less than 150 and lies in “USG” zone. In February, monthly average AQI (PM2.5) was still found more than 150 (Unhealthy). But in other stations, it went down to the “USG” category. In March and April, the monthly average AQIs at all the stations were found to be decreased. Monthly average AQI (PM10) at all the stations was found to be in the “Moderate” and “Good” zone. Interestingly, AQI decreased to below 50 inApril at all the stations, indicating safe from PM10. Very high pollution is recorded in Kathmandu in the past. It was also ranked as one of the most polluted cities in Asia. Our study from Jan 2020 to April 2020 shows that pollution in Kathmandu is remarkably reduced inMarch and April.

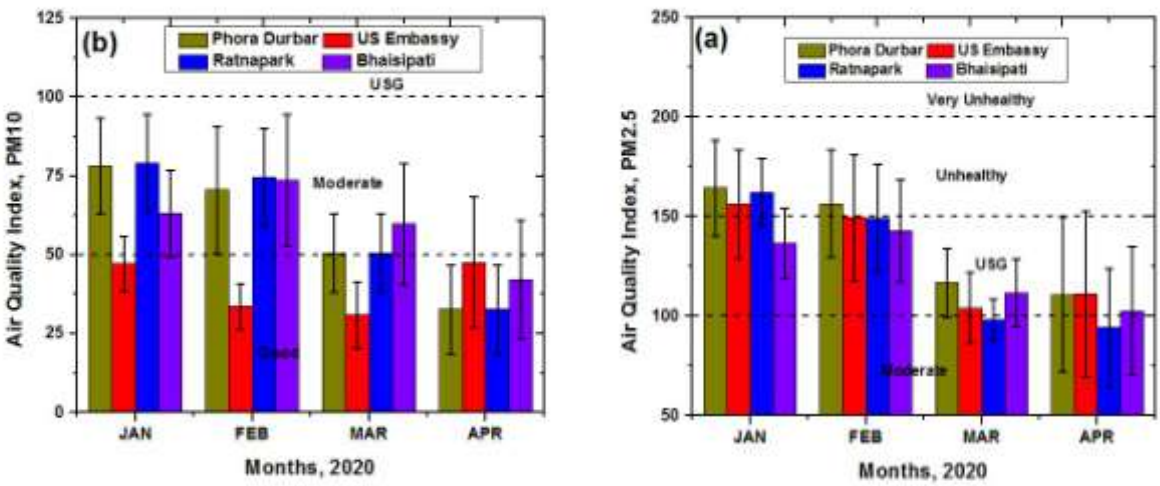

Figure 9: (a) Monthly average AQI (PM2.5) in different months at different stations of Kathmandu. (b) Monthly average AQI (PM10) in different months at different stations of Kathmandu.

IV. Conclusion

Due to rapid urbanization and various infrastructure development projects, the level of air pollution ofKathmandu city is increasing day by day, threatening the lives of thousands of people every year. Kathmandu was ranked as one of the most polluted cities in Asia. We were interested to study the pollution of Kathmandu before and after the lockdown due to the Covid-19 pandemic. Ambient AQI in different four stations viz. Phora Durbar, US Embassy, Ratnapark and Bhaisipati from January 2020 to April 2020 was studied. Daily, weekly and monthly variations on AQIs of all the stations were plotted. AQIs were found to lie within the “Unhealthy” and “Good” zone. AQI in January and February was found to be greater than in March and April. Due to COVID-19, the city was locked downfrom March 24, 2020.Tackling this global pandemic may be matched behind the interesting decrease in the air pollution of KathmanduinMarch and April as lockdowns have shut down factories and kept cars off the roads. Large numbers of non-permanent residents left the cityand traveled to their own homes. Roads and bazaars were almost empty. But it is just a short-term result and that air quality is likely to worsen again as soon as the pandemic is over.It is of utmost urgency to teach the people of Kathmandu city on harmful aspects of air pollution and therefore the necessary precautions to stop its deadly consequences.The permanent solutionfor controlling the air pollution of Kathmandu city can be achieved only when thegovernment takes the leading role in addressing the situation. We believe that this study would serve as a reference for future studies and pollution control policies.

Acknowledgment

Data for this study is obtained from the World Air Quality Index project (https://aqicn.org/). We would like to thank the project team for generating and sending data. We aknowledge to Government of Nepal, Ministry of Population and Environment, Department of Environment Air Quality Monitoring (pollution.gov.np) for operating air quality monitoring stations and continuously providing data and information to the public. This work is done using the tools Python3 and ORIGIN9.

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