Improvement of Air Quality During Lockdown Period of COVID-19 Pandemic in Kathmandu Valley, Nepal

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Abstract: The Kathmandu Valley is currently Nepal's most hazardous region for human health and environmental sustainability because of increased air pollution and high particulate matter levels. According to multiple studies and observations, Nepal's urban districts saw an improvement in air quality during the COVID-19 lockdown. The Air Quality Index (AQI) is a standard method of informing the public about air pollution levels. The AQI is based on the quantitative value of pollutants' constituent parts, such as particulate matter (PM). Thus, the focus of this study was on how the AQI values change in the Ratna Park suburb of the Kathmandu district in the Kathmandu Valley and how those fluctuations are related to lockdown and non-lockdown times during the COVID-19 pandemic and comparing them to identify crucial information's. This study shows that during the lockdown, the air quality in the Kathmandu Valley dramatically improved, with average AQI values for PM2.5 and PM10 rising to 21.34 and 64.42 from 50.74 and 106.51, respectively. Furthermore, we investigate the positive correlation between relative humidity, a meteorological component, and air quality.

Keywords: Air Quality Index, Particulate Matter, Air pollution, Relative Humidity

1. Introduction

Kathmandu is the capital city of Nepal and it is the largest densely populated city in Nepal. The total population in Kathmandu district is 2017532 in 2021 (CBS, 2022; Timsina et al., 2020). Ratna Park area situated at the center of Kathmandu district, is the commercial and governmental administration center of the whole nation, it has been the hub of people's activities. Due to the poor pollution management from the government sector, air pollution has grown into one of the most hazardous factors in all of Kathmandu Valley. Air pollution is a huge headache for the government regarding how many of its resources are being allocated for its supervision and possible counters as well as controlling its health hazard risks(Saud & Paudel, 2018). Policy-making must include both the supply and demand sides of healthcare services because the mortality-risk classification has a substantial impact on various healthcare costs (Li, Du, & Zhang, 2020). Toxic or hazardous compounds are more prevalent in the air when there is high humidity. Additionally, it brings in dust mites, which lowers the air quality in our houses. According to several researches, reduced humidity can also result in dryness and discomfort (Nagda & Hodgson, 2001). This study also looks at air quality, which is greatly impacted by changes in humidity.

The Air Quality Index (AQI) (Leeuw & Mol, 2005) is the standard system that state and local governments use to notify the public about levels of air pollution. Unlike many other components of pollutants, PM2.5, and PM10 are highly dangerous and can fluctuate by a large margin within a short time(Gupta et al., 2023). So, our study used PM2.5 and PM10 as a base for AQI value. The pollutant of air particles which is smaller than 2.5 μm (PM2.5) has been estimated in terms of density to be 3-5μg/m³ both short and long exposure to particulate matter (PM), harms human health. Both PM2.5 and PM10 exposures for the short and long term harm human health in the long and short term PM10 range of particles is generated from the burning of biomass, soil and road dust, vehicular emission, coal, and so on. Some secondary sources of PM10 are gases such as SO2 and PM2.5: The secondary particles for PM2.5 also include vehicular emissions, biomass burning, soil and road dust, solid waste burning, coal, road dust and soil, and so on. Industrial pollution also contributes to 1 – 2% at all locations.

The purpose of the AQI is to assist people to know how the local air quality impacts their health (Muruna, 2004). The EPA (Environmental Protection Agency) calculates the AQI for five major air pollutants, for which national air quality standards have been established to safeguard public health. One can use the following equation for the calculation of AQI from the concentration (µg/m^3m of pollutants. The AQI tells, clean or unhealthy, focusing on health effects experienced within a few hours or days after breathing unhealthy air. The major air pollutants are ground-level ozone, particle pollution, carbon monoxide, and sulfur dioxide (EPA, 2009). AQI values for different levels determine the risk level for the health of the people, which has been categorized into six levels from good to hazardous (Rayamajhee et al., 2021)varying values range from 0 to over 300, as the AQI value increases health hazard also increases accordingly.

The recent worldwide spread of COVID-19 which has been ongoing for a long time, in response to it lockdowns were conducted in many highly infected parts of countries multiple times to prevent and try to control this pandemic. Many vaccines were also programmed in response to controlling the virus and many controlling steps were taken by the government. Nepal also made many situational attempts and their roles were studied mainly about essential supplies, media, quarantine management, revitalization of health care delivery, and COVID-19 vaccine strategy (Slezakova & Pereira, 2021). Nepal the first lockdown was also followed by a severe increase in infection and death rate on 24 March 2020, factories, industries, offices, and educational institutions closed and transportation was reduced results a decrease in human movements and their activities and their possible impacts (Tao, et al., 2022). During the lockdown, Kathmandu Valley was the most affected urban area in Nepal so record changes in AQI value were recorded. However, very few studies are available about the trend analysis of air quality during the period. Thus, this study aims to focus on trend analysis of AQI value to understand the air quality situation in the Ratna Park area of Kathmandu Valley. Ratna Park is at the heart of Kathmandu Valley and has a unique location in the heart of the mountains which results in unique atmospheric and weather conditions. So, this study focuses on two pollutant components, PM2.5 and PM10, in the Ratna Park area of Kathmandu which lies at the heart of Kathmandu Valley. This area has the most traffic, which directly reflects the AQI of the area. Thus, this study is concerned with the effect of lockdown on air quality during the COVID-19 pandemic in Kathmandu analyzing the trend of AQI values during lockdown and non-lockdown for the particular matter of PM2.5 and PM10 and their relationship with relative humidity.

2. Methods and Materials

2.1 Study Area

Kathmandu is one of the fastest-growing capital cities of Nepal and sometimes this city is listed as the top ten most polluting city in the world and currently ranked as the third most polluted city globally by IQ Air Visual Ranking, based on its air pollution levels. Unplanned urbanization in the valley floor surrounded by steep hills, congested roads, poorly managed traffic system, lack of initiation to grow trees, problems of solid waste management, and rapid urbanization are the general characteristics of Kathmandu city now (Singh and Dhakal, 2024). Ratna Park is located at the heart of the urban city and vehicle frequency is the highest at this location, where the air quality measurement instrument has been installed. Thus, our study selected the data from the Ratna Park location for the values of PM2.5 and PM10 for air quality analysis. The geographic coordinates of Ratna Park are 27°42'23.66"N latitude and 85°18'54.81"E longitude.

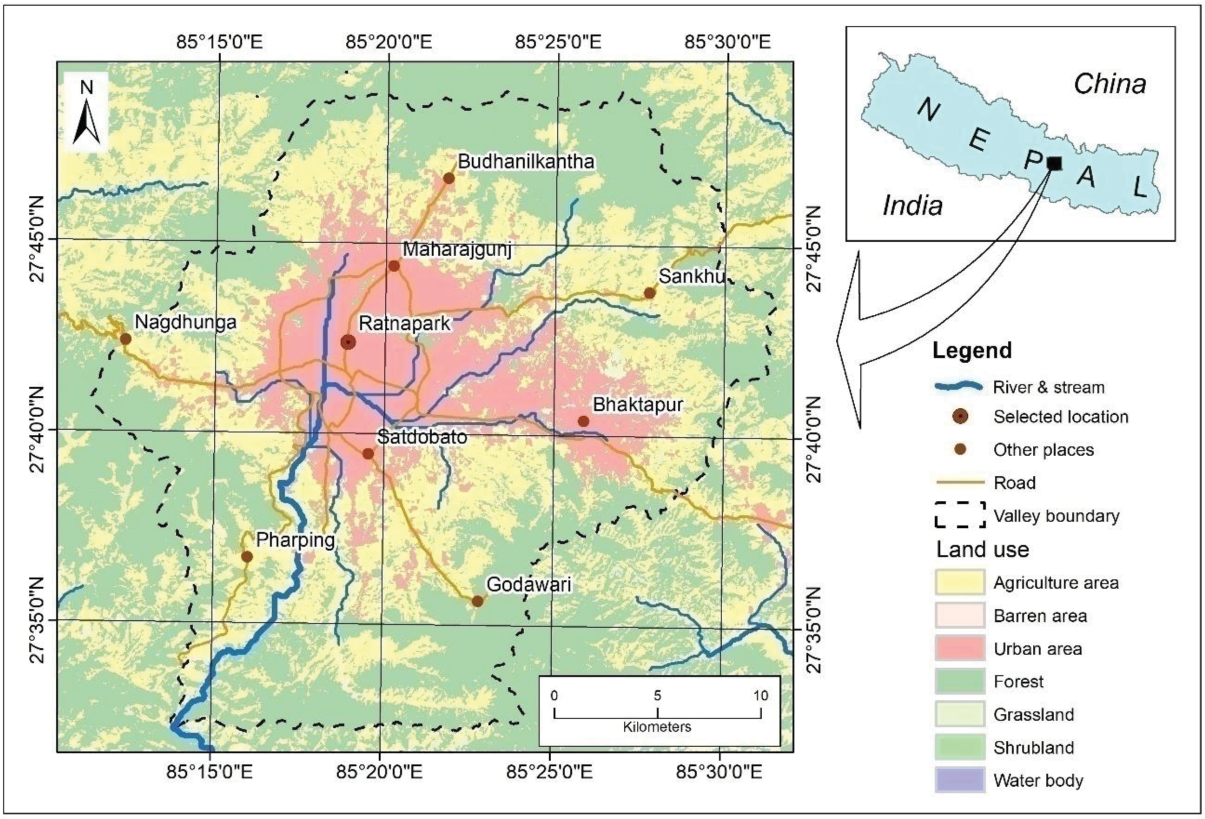

Figure 1. Map showing Ratna Park area located at the central part of the Kathmandu Valley

Due to the COVID-19 pandemic, Nepal also conducted its 1st lockdown from24th March 2020 to 14th June 2020 which spans a long period of 3 months and 2nd lockdown also took place on April 28, 2021, and many partial lockdowns were imposed between the two lockdowns and after 2nd lockdown. Kathmandu was also isolated and was completely locked. No vehicles were allowed except emergency work so people were confined to their homes. During this period, Kathmandu Valley was the most severely affected by COVID-19 restricting nearly 1.7 million vehicles' daily commutes and also isolating it from the rest of the part of the nation. Its impact was visible in a major part of the valley and Ratna Park being the major center of the valley and Kathmandu district, changes in the quality of air could be felt daily. Thus, this study selected the Ratna Park AQI data for the analysis of the Lockdown impact on the quality of the air as a result, which can be seen as positive in difficult times.

2.2 Data Base

This study is mainly based on Air Quality Index (AQI) values of PM 2.5 and PM 10, of Ratna Park station in Kathmandu, which is freely available on the webpage (http://aqicn.org/historical). This data is developed by the World Air Quality Index Project, a non-profit making organization based in Beijing, China, started in 2007. The mission of this project is to promote air pollution awareness for citizens and provide unified and worldwide air quality information. It provides air quality information in more than 130 countries establishing more than 30000 stations in 2000 major cities in the world. Daily data of AQI values of PM 2.5 and PM 10 of the Ratna Park area taken from October 2019 to March 2020 were downloaded. The data provided in Excel format consists of daily AQI values of PM2.5 and PM10 every month with few exceptions. We avoided those data as much as possible to maximize the accuracy of the study. This is the period Covid19 pandemic in Kathmandu, Nepal. This period covers all lockdown, partial lockdown, and non-lockdown periods in the Kathmandu Valley. Another important data for this study was the humidity. There is no meteorological station in Ratna Park. The nearest meteorological station is

Tribhuvan International Airport. Thus, the humidity data of this nearest station was purchased from the Department of Hydrology and Meteorology of Nepal.

2.3 Data Processing

As our study is mainly focused on the impact of COVID-19 on air quality, the year study period data of PM2.5, PM10, and relative humidity is from 23rd October 2019 to 30th September 2020, which includes normal period (1st six months) and the period during the impact of covid-19 (last six month). Change in AQI value of PM2.5 and PM10 and their comparison is to be able to carefully study by the bar diagram of a monthly average, based on daily records, taken over our study period. Monthly average data will be used for a simple graphical representation of the relation of PM2.5, PM10, and relative humidity.

Going into our main topic, this study separated the data into two categories of times, before COVID-19 or normal time from 23rd October 2019 to 23rd February 2020 and during COVID-19 from 23rd February 2020 to 30th September 2020. Finally, our data is also categorized into two parts lockdown and non-lockdown or a more detailed study. As our study period included only 1st lockdown, one category will include data from both PM2.5 and PM10 from the period of 24th March 2020 to 21st July 2020 whereas all other periods include the next.

2.4 Data Analysis

2.4.1 Air Quality Index (AQI)

AQI index is an index used for reporting the quality level of air in terms of how air pollution affects our health in a short period. Several methods were developed by researchers and institutions which mainly depend on the number of pollutants and types but there is no universally accepted method (Kanchan, Gorai & Goyal, 2015). It helps people, government, etc. to understand the quality of air and its impact on animals, human health, and surrounding environments (Tao et al., 2022).

AQI values were categorized into two parts, each of a period of six months. The change in AQI values before and after the lockdown was analyzed and compared monthly data with scale as per US-EPA standards. In Nepal, 1st lockdown started on 24th March 2020 and ended on 14th June 2020 and the second lockdown started on 29th April to May 13. Thus, based on the period of COVID-19 impact, the relationship between the AQI value of PM2.5 and PM10 is separated into two time periods. The first period was from 1st October 2019 to 30th March 2020 which is before COVID-19 and the second was from 1st April 2020 to 30th October 2020 after COVID-19. Finally, data is analyzed on the indicated scale of the AQI value of our study area in different situations defined by the US-EPA standard. The comparison of obtained data with the US EPA PM2.5 and PM10 standards is given below (Table 1).

Table 1. AQI category for PM2.5 and PM10 based on AQI value

AQI category	AQI value(PM2.5)	AQI value(PM10)
Good	0-50	0-50
Moderate	51-100	51-100
USG	101-150	101-150
Unhealthy	151-200	151-200
Very Unhealthy	201-300	201-300
Hazardous	301-500	301-500

Relative humidity data were obtained from the Department of Hydrology and Meteorology, Babarmahal Kathmandu. The day-to-day data was taken from Kathmandu International Airport at time noon exactly for two years 2019/2020. The monthly average of humidity was calculated.

2.4.2 Statistical Analysis

To obtain the correlation between the AQI value of PM2.5, PM10, and relative humidity during lockdown and non-lockdown, this study used Spearman rank-order correlation. First, the daily air pollutant concentrations PM, and relative humidity were aggregated into two parts lockdown and non-lockdown removing the missing data to smooth the data. The statistical distributions of the changes in concentrations of pollutants are not assumed to be normally distributed. Thus, parametric tests—where the parameters refer to the population of normal distributions—are not suitable, hence the use of non-parametric tests (distribution-free) tests we use Spearman rank correlation. Spearman rank correlation coefficient can be found by the formula given below (Zar, 2005).

$$\rho = 1- \frac{6\sum d_i^2}{n(n^2-1)}$$

whereas,

ρ is the Spearman Rank correlation coefficient

d is the difference between the two ranks of each observable

n is no. of observation

To understand the significant difference in PM value changes during two different situations (lockdown and non-lockdown) chi-square is used. For this process, we use two sets of AQI values PM2.5 and PM10 during the lockdown and non-lockdown for this operation (Tallarida, & Murray, 1987). Its formula is,

$$\chi^2 = \frac{(O_i - E_i)^2}{E_i}$$

where,

$O$is the observed value and $E$is the expected value

The frequency table of categories of AQI values of both 2.5 and 10 PM was prepared according to the categories of table no 1.

3. Results and Discussion

3.1 Study of AQI Value Indifferent Months

Figure 2 helps us with the comparative study of monthly average statistical data of PM2.5 and PM10 for 1 year from October 2019 to September 2020. It shows us the scale of AQI value for different months for both PM2.5 and PM10 and also to understand the trend of the impact of COVID-19 on the quality of the air (PM value) of Ratna Park.

From the comparison of PM2.5 and PM10 as well as the study of their respective changes in AQI value, we found AQI value is very high in 1st seven months duringPM2.5 similarly 1st six months for PM10 which indicates normal air quality value (relatively unhealthy as per our standard). But the period of the last 7th month shows average AQI value is rapidly decreasing and ends up fluctuating at a very low (healthy standard) i.e. 25 to 70 which is assumed to be due to subsequent decline in the flow of vehicles, the closing of commercial activities and also the flow of people due to the pandemic. We found 1stthemonth's monthly average is very high, fluctuating around 120 and is the normal function every very healthy day (USG) but the last five-month average is around 37 which is very low in comparison to normal time and also the moderate range according to US EPA standard (Mohajeri et al., 2021) which is relatable to much other research done which indicates the major decrease in particulate matter impact to a lesser degree as air quality improves (Leeuw & Mol, 2005). Its detailed analysis for each month is given below.

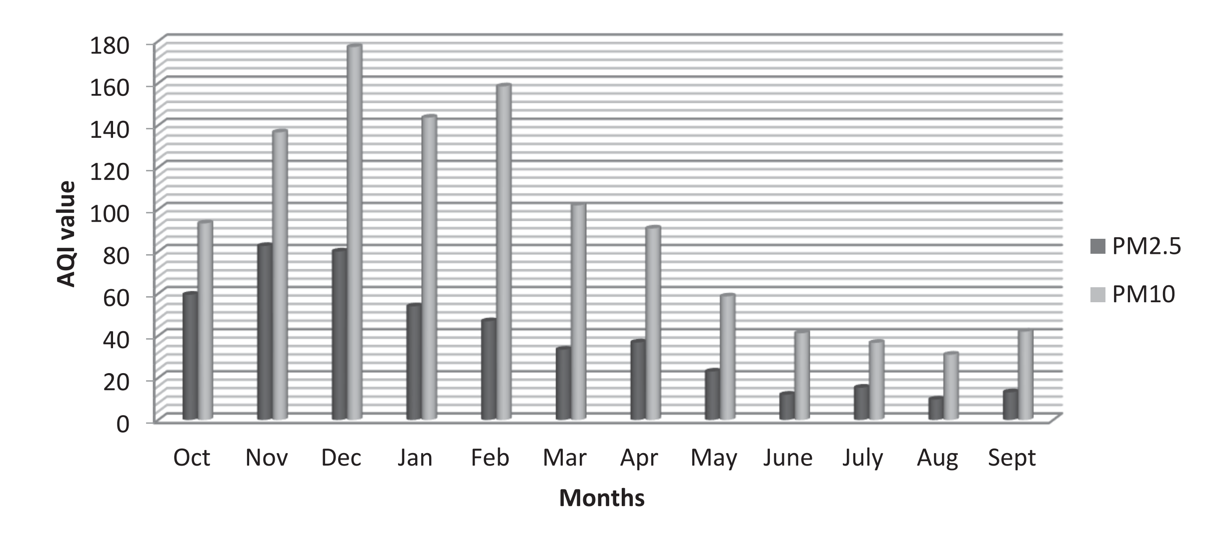

Figure 2. Bar Diagram of PM2.5 and PM10 monthly Average vs AQI value

Figure 3 shows a clear indication of the number of days in particular AQI value scale region for PM10, with brown and green color showing AQI values greater than 100(unhealthy) and below 50 (Healthy) with the total no of days (blue)in a month respectively. The first five months have the 2nd bar which shows several days with an AQI value greater than 100 indicating the unhealthy quality of air compared with the total no of days it is rapidly decreasing and finally reached 0 in April which shows the AQI value is rapidly decreasing to reach below 100 as the quality of air continues to improve.

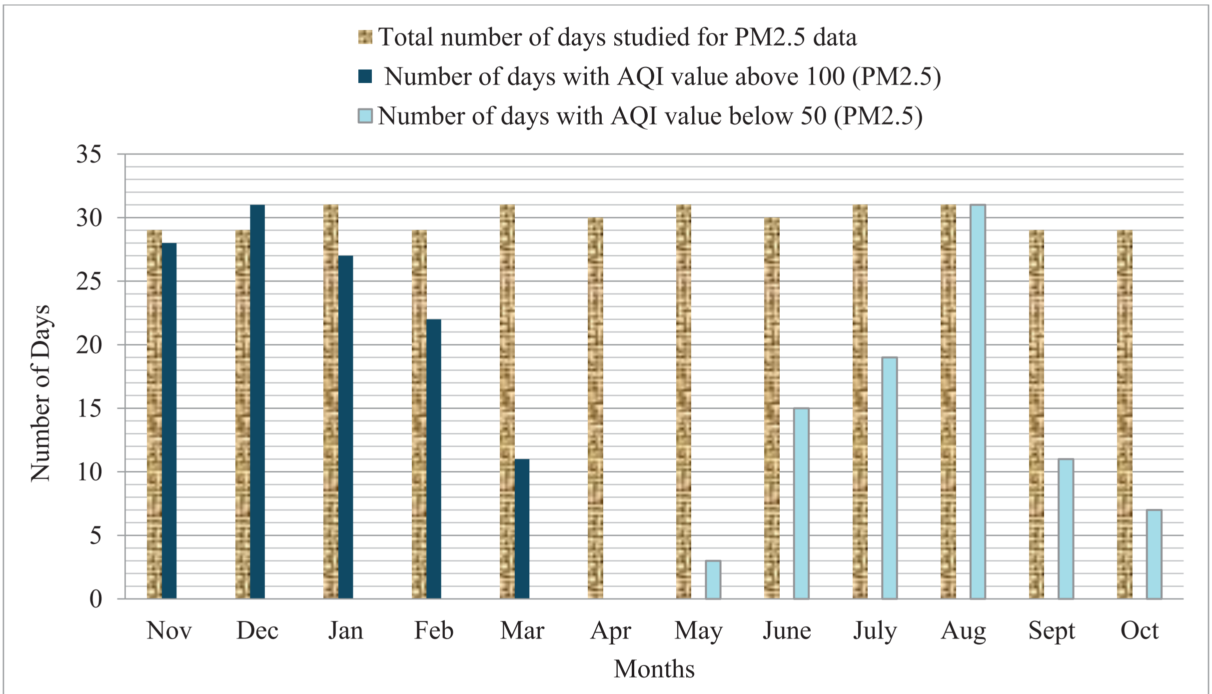

Figure 3. Monthly Analysis of Daily AQI value for PM2.5 as per US EPA Standard

Similarly, we found a 3rd bar (AQI value <50) –healthy reason- in the last six months as it continues to grow to reach a peak in August and slowly decrease which is during the pandemic nationwide lockdown and its positive effects on air quality.

Figure 4 shows a clear indication of the number of days in particular AQI value scale region for PM10, with the 2nd and 3rd bar showing AQI values greater than 100(unhealthy) and below 50 (healthy) with a total no of days (1st bar) in a month respectively.

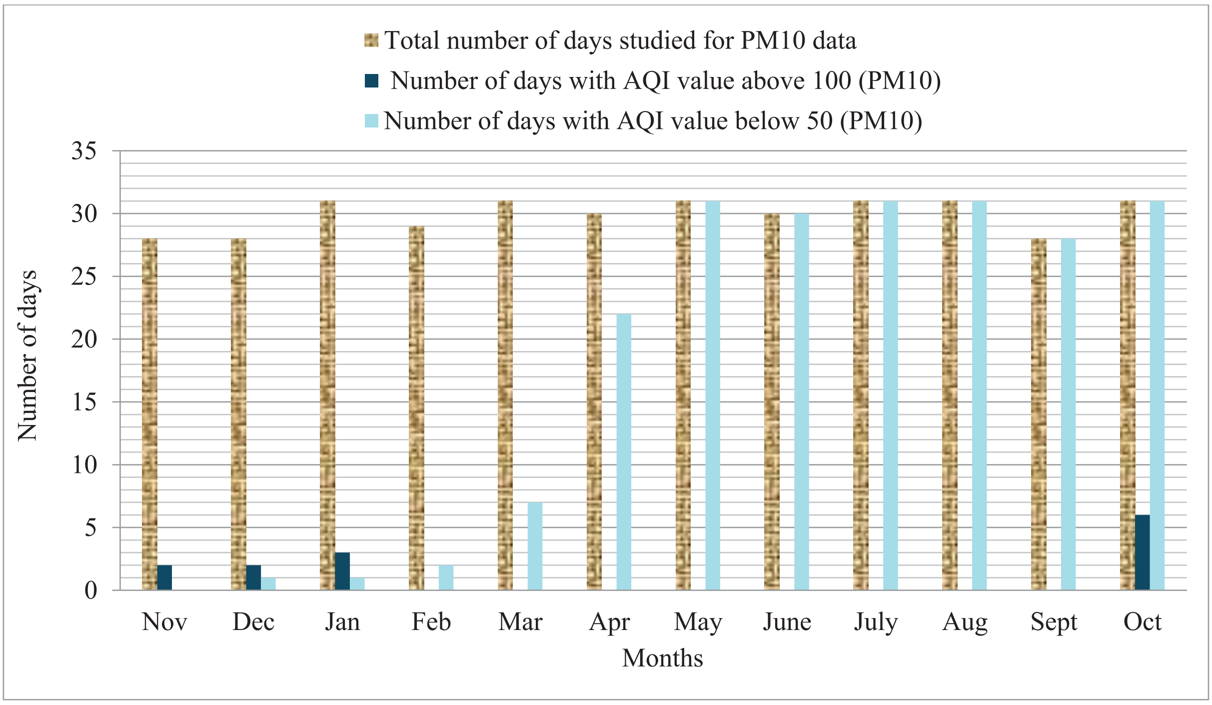

Figure 4. Monthly Analysis of Daily AQI Value for PM10 as per US EPA Standard

Figure 4 illustrates the daily AQI data available, and analysis of data for PM10 where data above 100 is indicated by the 2st bar (indicating days which are in the unhealthy index as per US EPA standard), below 50 by 3rd (healthy). From the beginning of PM10 AQI value below 50 is almost zero and above 100 is a few more than 1 or 2 days in 1st three months which shows average air quality is ok (AQI value is between 50 to 100) and 6 days in the last month October. But in the middle eight months from February to September, we can see the number of days above an AQI value of 100 is zero, and days with an AQI value less than 50 are rapidly increasing with most days with an AQI value below 50. This was during 1st lockdown and zero no of days were with AQI value from May to October.

The graph in Figure 5 shows the trend of AQI values of PM10, PM2.5, and average relative humidity (%) for 12 months from October 2019 to September 2020.

Figure 5 shows the relationship between the AQI value of particulate matter PM2.5, PM10, and relative humidity during various periods of our study. We can see that the AQI values of both PM2.5 and PM10 are positively related through their very similar trend line despite the gap in AQI value whereas the humidity trend line does not show a clear distinct relationship but at the end some inverse relation which is seen and could be analyzed by using various statistical tools.

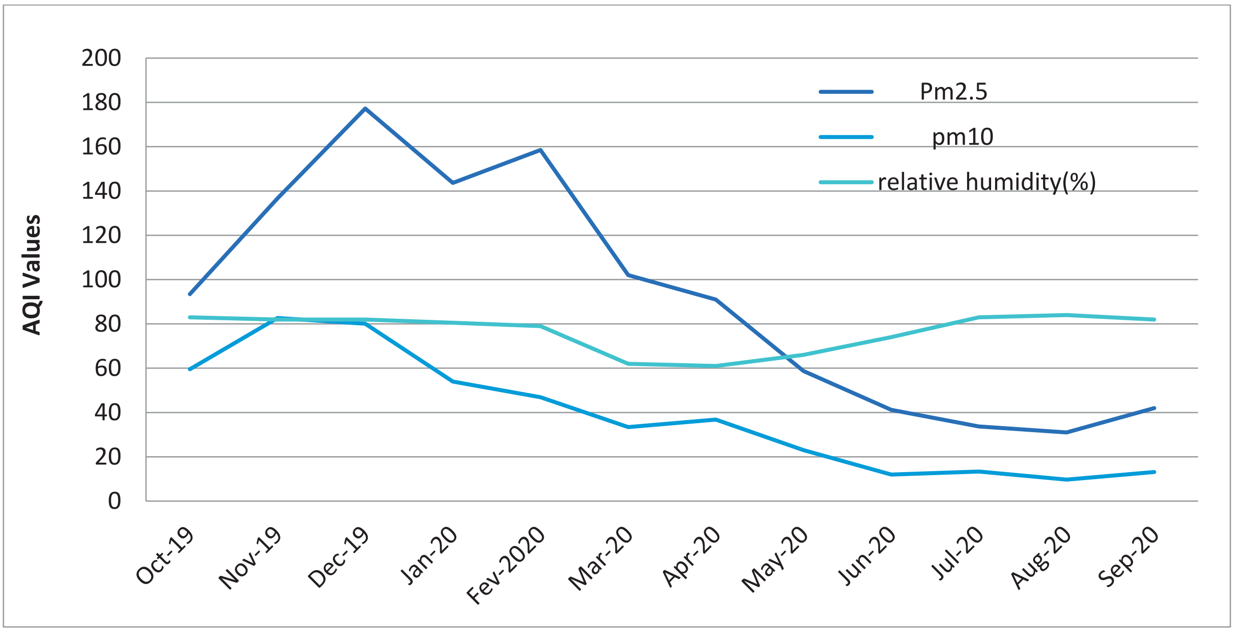

Figure 5. Relation between AQI value of Particulate Matters (PM2.5 &PM10) and Relative Humidity (%) over a year

3.2 Study of the Trend Line of PM2.5 and PM10

For a better reading of fluctuation in AQI value we use daily data for the 1stfive months (indicating the period before the pandemic or normally without the influence of the pandemic) from Oct 23, 2019, to February 31, 2020 statistics and try to evaluate some results or indications (Figure 6).

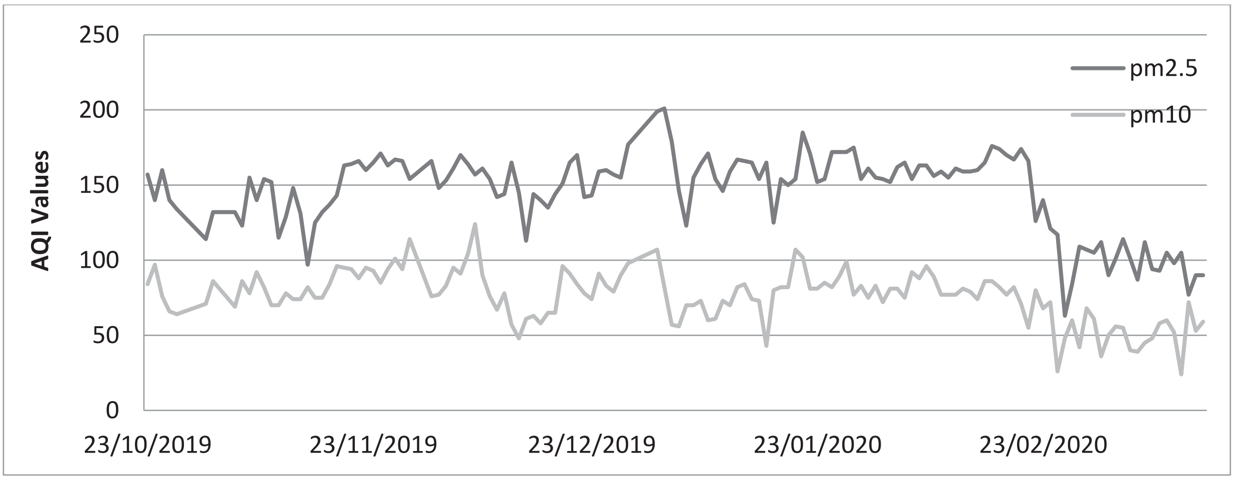

Figure 6. Comparison of Daily AQI Value of PM2.5 and PM10 Before the Pandemic

Figure 6, shows the AQI value trend of PM2.5 and PM10 for five months before lockdown, both are in an unhealthy category with an average of 106 and 50.74 as defined by the US-EPA 2016 standard. These indicate that the air quality of Kathmandu Valley during normal times is unhealthy, especially for old people, children, and people with respiratory problems. It is visible many fluctuations in AQI value before the lockdown but there is a huge decrease in AQI value for both at the same time at the end of the graph which is indicated with an arrow which may be due to the pandemic. Though Nepal's lockdown was on 24th March 2020, it already experienced improving air quality because of the direct impact on AQI value compared to before the lockdown period. The worldwide spread of COVID-19 slowly reaches the border of Nepal. Nepal's 1st case was recorded on Jan-23-2020 (a 31-year-old student returnee from Wuhan. So, there was the influence of COVID-19 in Nepal and people's fear was rapidly rising, resulting in the rapid closedown of factories, vehicles, etc which may have increased air quality can be seen directly in the graph above.

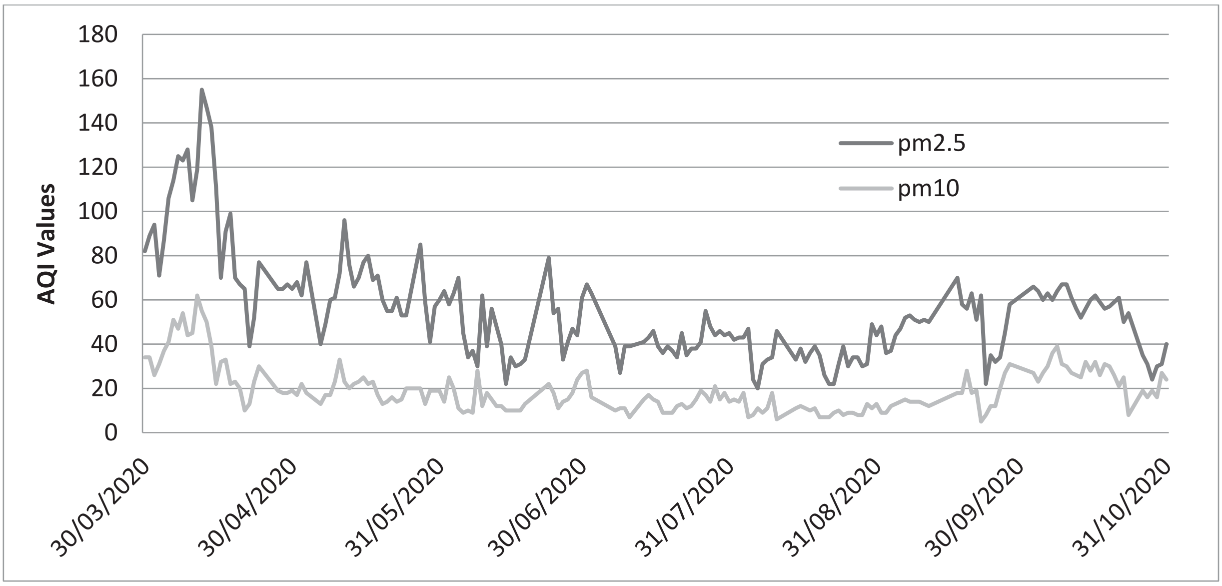

Figure 7. Comparison of Daily AQI value of PM2.5 and PM10 During a Pandemic

From Figure 7, we can observe the relationship between the AQI value of particulate matter PM10 and PM2.5 during COVID-19 influence with a few major lockdowns and a few partial lockdowns. Its impact on air quality is found with an average of around 52 and 19 which is in good region as defined by the US-EPA 2016 standard. Though the AQI value is constantly fluctuating it remains below 60 most of the time except at the beginning and ironically the impact on air quality is found to be positive for the quality of air.

Nepal's 1st lockdown from 24th March to 21st July 2020 is included within this period. AQI value can be seen in very huge fluctuation from non-lockdown to lockdown and the scale is rapidly decreasing. During this period, we can see the mean AQI values of 64.41 and 21.34 are within the healthy region as defined by the US-EPA 2016 standard for most of the period and slowly increase during the August month which indicates the impact of 1st lockdown in atmospheric pollution (Mohajeri et al., 2021). During lockdown mean, maximum, and minimum values are significantly lower compared to non-lockdown, standard deviation and overall ranges also decreases. This shows the mean AQI values of 64.41 and 21.34 are very good compared to 106 and 50.64 values during non-lockdown (Table 2).

Table 2. General Scenario of AQI Values and Statistics Results in Comparison Between the Lockdown and non-lockdown periods

Condition	PM 10				PM 2.5			
	Mean	ST DEV.	Min	Max	Mean	ST DEV.	Min	Max
Lockdown	21.34	11.705	7	62	64.41	27.60	22	155
None	50.74	11.71	5	99	106.51	54.385	20	201

The correlation coefficient values of relative humilities with AQI values are negatively correlated in both lock-down and non-lockdown periods having similar levels of correlations. However, the significance level is not sufficient to be confident about this correlation coefficient at a 1% significance level because of the irregularities of lockdown. However, it can be concluded that relative humidity and AQI had negative correlations during the study periods (Table 3).

Table 3. Correlation Between Humidity and AQI Value

Condition	PM10		PM2.5	
	Correlation 'R"	*p*	Correlation 'R"	*P*
Lockdown	-0.64	0.01	-0.66	0.01
Non-lockdown	-0.53	0.01	-0.54	0.01

In general, the statistical result shows that there is a significant fluctuation of AQI values of both PM2.5 and PM10 because of the heavy impact of the lockdown improving air quality in Kathmandu Valley i.e. Ratna Park. The chi-square test result also proved that there was a significant reduction in AQI values (in both PM2.5 and 10) during the lockdown period at a 95% confidence level. It has proved that human activities like vehicle movement and industrial activities in Kathmandu Valley have significant contributions to air pollution. Although the general trend of AQI values during the lockdown and non-lockdown periods was sharply different, there were higher functions of AQI values during the lockdown period because of the not-so-clear-cut implications of the rules and regulations of lockdown. The first stage of lockdown was just a partial lockdown then after the rapid spreading of COVID-19, the full lockdown was implemented. Even in between the lockdown periods, there was some period of partially closed periods. Thus, there are heavy fluctuations in AQI values during lockdown periods.

Similar results were also identified even in other cities of Nepal including Kathmandu Valley of Nepal according to the comparative study (Baral and Thapa, 2021), an in-depth analysis focusing on the Ratna Park area and study of its relationship with humidity further validated the study result Covid19 lockdown played an important role in reducing air pollution globally but at the initial phase of the lockdown in the industrial state there was no significant reduction in air pollution and later on, there was also a positive impact. However, there was a heterogeneous result near the equator because of the heterogeneous human mobility condition (Dang and Trinh, 2020).

4 Conclusions

Analyzing the AQI values of a place over some time is the best method to identify the air quality level of that place. From this study, the general AQI value during lockdown is significantly lower and more uniform in comparison to non-lockdown, which is a moderately healthy scale as per the AQI standard. If compared to the observed AQI value meaning a non-healthy scale during non-lockdown, we conclude the huge improvement in air quality of the Ratna Park area. In addition to that, a significant negative correlation between AQI value particulate matter and relative humidity which may be purely coincidental as compared to another study, and this demands more study on this topic. Studying during this period is very unique opportunity and effectiveness in understanding the impact of the lockdown in Kathmandu Valley. Similar and deeper future study results will give us more period and crucial information to us, working towards the solution for increasing air quality problems. It will provide us the chance to study human factors affecting the environment as well as impact level and provide us ideas on understanding many different components and different angles of air pollution control while minimizing negative effects on people's livelihood. A global issue regarding air quality in suburban and urban areas having detrimental effects on people's health, which has always been a major concern for the government, this study may have provided a key to implementing robust air quality management strategies. So, a further in-depth study is required in this regard. As the awareness of people and government rises, focus on this issue and these results may create many opportunities for more study.

References

Baral BD, Thapa K. (2021). Effect of the COVID-19 Lockdown on Ambient Air Quality in Major Cities of Nepal. *Health Pollute*, 11(29):210211. https://doi.org/10.5696/2156-9614-11.29.210211.

CBS (2022). Population Census 2021: Preliminary Result (Nepalese language). Kathmandu: Central Bureau of Statistics.

Dang, H. A. H. and Trinh, T. A. (2020). Does the COVID-19 Pandemic Improve Global Air Quality? New Cross-National Evidence on Its Unintended Consequences (Discussion paper series number 13480). Institute of Labor Economics, Bonn, Germany

EPA (2009). Air Quality Index: A Guide to Air Quality and Your Health. New York: United States Environmental Protection Agency.

Gupta, S. N., Mohta, Y., Heda, K., Armaan, R., Valarmathi, B., Arulkumaran, G. (2023) Prediction of air quality index using machine learning techniques: A comparative analysis. Journal of Environmental and Public Health, 2023, 4916267. https://doi.org/10.1155/2023/4916267

Kanchan, K., Gorai, A. K, and Goyal, P. (2015). A review on air quality indexing system. *Asian Journal of Atmospheric Environment*, 9(2):101-113.http://dx.doi.org/10.5572/ajae.2015.9.2.101

Leeuw, F. D., Mol, W. (2005). Air quality and air quality indices: a world apart? (ETC/ACC technical paper 2005/5). Bilthoven: European Topic Centre on Air and Climate Change.

Li, L., Du, L., Zhang, C. (2020). The impact of air pollution on healthcare expenditure for respiratory diseases: evidence from the People's Republic of China. *Risk Management Healthcare Policy*; 13:1723-1739. http://dx.doi.org/10.2147/RMHP.5270587

Mohajeri, N., Walch, A., Gudmundsson, A. Heaviside, C., Askari, S., Wilkinson, P., Walch, A., Gudmundsson, A. Heaviside, C.; Wilkinson, P., Davies, M. (2021). COVID-19 mobility restrictions: impacts on urban air quality and health. *Buildings and Cities*, 2: 759–778. http://dx.doi.org/10.5334/bc.124

Muruna, F. (2004). Measuring air quality in a large urban area: Development and application of an air pollution index at the urban area of Naples.*Atmospheric Environment*, 38 (36): 6195-6202.http://dx.doi.org/10.1016/j.atmosenv.2004.07.023

Nagda, N. L., and Hodgson, M. (2001). Low relative humidity and aircraft cabin air quality. *Indoor Air*, 11(3): 200-214. http://dx.doi.org/10.1034/j.1600-0668.2001.011003200.x

Rayamajhee, B., Pokhrel, A., Syangtan, G., Khadka, S., Lama, B., Rawal, L.B., Mehata, S., Mishra, S.K., Pokhrel, R., and Yadav, U.N. (2021). How well the government of Nepal is responding to COVID-19? An experience from a resource-limited country to confront an unprecedented pandemic. Frontiers in Public Health, 9. https://doi.org/10.3389/fpubh.2021.597808

Saud, B. and Paudel, G. (2018). The threat of ambient air pollution in Kathmandu, Nepal. Journal of Environmental and Public Health, 2018, 1504591. https://doi.org/10.1155/2018/1504591

Slezakova, K., Pereira, M. C. (2021). 2020 COVID-19 lockdown and the impacts on air quality with emphasis on urban, suburban, and rural zones. Scientific Reports, 11, 21336. https://doi.org/10.1038/s41598-021-99491-7

Singh, R. P. and Dhakal, J. (2024). Problems and prospects of urbanization in Kathmandu Valley. International Journal of Atharva (IJA), 2(1): 19-33 DOI: https://doi.org/10.3126/ija.v2i1.62821.

Tallarida, R. J. and Murray, R. B. (1987). Chi-square test. Manual of pharmacologic calculations: with computer programs, 140-142. Springer Verlage.

Tao, C., Liao, Z., Hu, M., Cheng, B., andDiao, G. (2022). Can industrial restructuring improve urban air quality? - A quasi-experiment in Beijing during the COVID-19 pandemic. Atmosphere, 13(1), 119. https://doi.org/10.3390/ atmos13010119

Timsina. N. P., Shrestha, A., Poudel, D. P., and Upadhyaya, R. (2020). The trend of urban growth in Nepal with a focus on Kathmandu Valley: A review of processes and drivers of change (Tomorrow's Cities Working Paper 001). http://dx.doi.org/10.7488/era/722

Zar, J. H. (2005). Spearman rank correlation. Encyclopedia of Biostatistics (Second Edition). John Wiley & Sons, Ltd. http://dx.doi.org/10.1002/0470011815.b2a15150