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NO_2 CONCENTRATION IN BANEPA VALLEY, NEPAL

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ABSTRACT
This study comprised of air quality monitoring during the day time at three municipalities of Banepa, Dhulikhel and Panauti(Known as Banepa Valley) in Kavre district of Nepal. The study was conducted in order to establish a baseline air quality data for those municipalities as the first time ever in the district. In each of those municipalities three air monitoring stations were established representing predominant industrial, commercial and residential areas. Nitrogen Dioxide (NO_2) had been estimated from air sampling programme which spanned 7 months and a total of 126 days reflecting winter, pre-monsoon and monsoon seasons. Low Volume Air (LVA) Sampler and Personal air sampler were used for sampling. UV spectrophotometer was used for estimation of the NO_2. The study found that during winter season the concentration of NO_2 was more and among the areas commercial area found to be highest level pollution. The over all mean, minimum and maximum level of NO_2 was found to be 24.62$\mu g/m^3$, 11.26$\mu g/m^3$, 91.20$\mu g/m^3$in the Banepa valley. The seasonal trend in pollution levels show that winter > pre-monsoon > monsoon. The pollution concentration trend noted among the areas was commercial > industrial > residential on almost all the occasions. This finding conclude that, most of the time NO_2 level are below the National Ambient Air Quality Standards (NAAQS) and World Health Organization (WHO) guideline representing little risk at present in Banepa Valley however commercial area of Banepa is more polluted and is associated with higher NO_2 concentration compared to other areas.

Keywords: NO_2, Nepal, Banepa, air quality, personal air sampler

INTRODUCTION
Nepal, a relatively small country with 1,47,181 sq km area inhabited by 22 million people, is known for exquisite environment. However, the real scenario is quite different because urban areas are environmentally degrading due to rapid unplanned urbanization and industrialization. Increasing numbers of human population, industries and automobiles, decreasing agricultural productivity, the frequent occurrence of floods in the lowlands, landslides in the midlands and forest fire are major environmental issues, and recent studies reveal that even the glorious mountain peaks of the high Himalayas have also undergone incipient pollution (Dokiya et al., 1992; Shrestha et al., 1997). Air pollution is considered to be one of the serious and prominent types of environmental pollution that is prevalent in most industrial towns and cosmopolitan cities of the world. It had been a

general impression in the past that air pollution is exclusively a problem of the industrially developed nations, however, recent studies have shown that air pollution is a growing problem in developing countries as well, and therefore, attention should be paid to this issue before it is too late. (Shrestha et al., 1997). Increased awareness of health problems related to air pollution arising from urbanization and industrialization has, especially during the last two centuries, gradually created a demand for more efficient emission controls, and thus there has been a notable decrease in both the emissions and ambient concentrations of many air pollutants. The health effect includes increased mortality and aggravation of existing respiratory and cardiovascular disease, as evidenced by increased hospitalization. Thapa (2001) concluded that the concentrations of pollutants (biological and non-biological) in the air have increased as the urbanization proceeded in Kathmandu. The level of these pollutants has exceeded the standards set by EPA and WHO. Operation of brick kilns has been considered as one of the major source of air pollution in the Kathmandu Valley. Brick manufacturing by Bull's Trench kilns was potentially a significant source of atmospheric emission in Nepal (Sharma et al., 1995).

Again meteorological conditions affect ambient air pollution in numerous ways. The most important role of meteorology is in the dispersion, transformation and removal of air pollutants from the atmosphere. There are numerous meteorological variables, often interrelated, that can affect ambient air pollution levels. Study of the relationship of air pollution and individual meteorological variables may be misleading as it does not account for the interrelation between the variables, while air pollutant levels normally respond to all of meteorological variables representing an air mass. Dry winter periods are the most vulnerable to air pollution while during the rainy season air pollutants are well below the average annual value as the rain flushes pollutants from the air.

From the above discussion it can be said that most of the air pollution studies conducted in Nepal were focused on Kathmandu Valley only. Very few air pollution study were done in semi urban areas of the country. The majority of the air pollution studies focused on traffic emissions, whereas industrial, domestic and other sources of air pollutants are not seriously undertaken in Nepal. There are several Non Governmental Organizations (NGOs), government offices and institutes working in the field of air pollution. However, their activities are scattered and limited within the city areas. At this point it is need to note that, so far there were no air quality monitoring programme conducted in Banepa, Dhulikhel or Panauti municipalities which can be considered as an semi-urban area..

Objectives

The main objective of this study was to observe the variation of NO_2 concentration in sub-urban areas of Banepa valley. It also aimed to assess the variation of NO_2 concentrations at different seasons in different predominant land use areas like industrial, commercial and residential areas.

MATERIALS AND METHODS

Site Description

Banepa, Dhulikhel and Panauti are geographically located in the same valley region known as the Banepa valley (Figure 1) with distances of no more than 7 to 8 km in between them (Table 1). Banepa and Dhulikhel are both situated on the Arniko Highway. This highway is Nepal's only road to the Tibetan border and was constructed in the 1960s by the Chinese. It is an important trade route for goods coming from China into Nepal.

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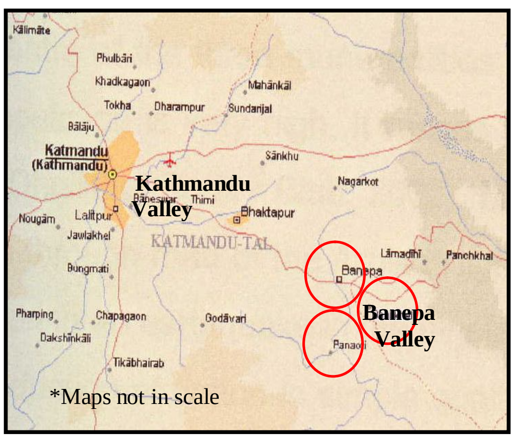
Panauti is attainable from the Arniko Highway in Banepa over a seven kilometer long side street. The study comprised of air monitoring during the day time at three municipalities of Banepa, Dhulikhel and Panauti. In each of the Municipalities three air monitoring stations were established representing predominant Industrial, Commercial and Residential areas. So there were altogether 9 air sampling stations selected in Banepa Valley, they were given below:

Table 1. General information about study area

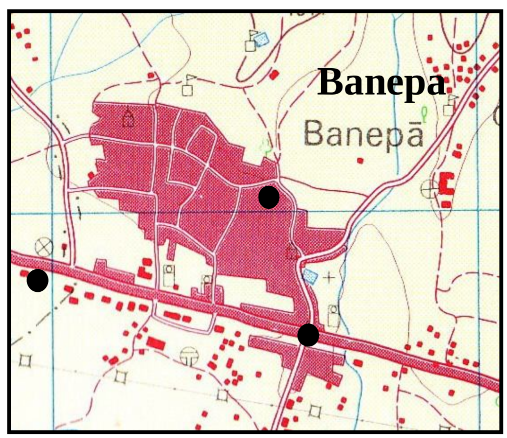
Municipalities	Distance from Banepa	Number of monitoring sites	Area (sq. km)
Banepa	0 km	3	5.56
Dhulikhal	4 km	3	8.22
Panauti	5.5 km	3	19.71
Total	-	9	33.49

Sampling Time and Frequency

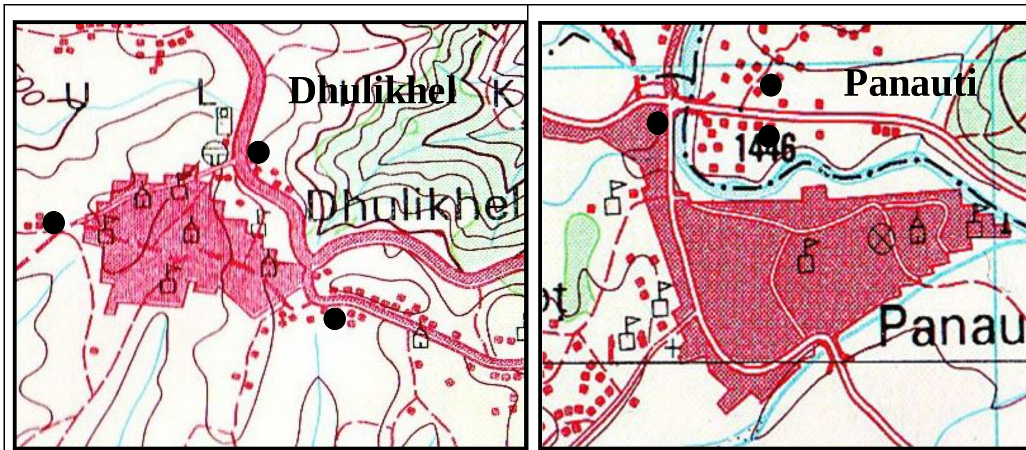
NO_2 has been estimated from air sampling programme which spanned 7 months and a total of 63 days from a height of one meter from the ground. The samples were collected twice in a month for each of the nine sites. Every day two samples were collected in the morning and evening. So the total number of sample was 126. The total sampling time was 8 hours in a day. These 8 hours in a day were divided into 4 hours each covering pick hours of day 9am to 5pm. So actual period of high traffic concentration of pollutants was measured.



1a. Banepa Valley along with Kathmandu Valley



1b. Banepa Municipality



1c. Dhulikhel Municipality | 1d. Panauti Municipality

Figure 1. Showing the study area (Black dots indicate monitoring sites)

Sampling Methods

Personnel air sampling method, which represents subjective exposures to ambient air pollutants, was followed using standard Personal Monitors. The equipment, known as personnel air sampler used for NO_2 monitoring was standard dust/gas sampler (M/s. SKC, U.S.A.). It was designed for the measurement of dust and gaseous pollutant in the work environment. A low volume air sampling assembly was also employed to carryout the NO_2 sampling. Sodium hydroxide is used for NO_2 as absorbent medias. UV spectrophotometer was used for estimation of the NO_2.

Estimation of NO_2

Nitrogen dioxide is absorbed in sodium hydroxide absorbing medium to form a stable solution sodium nitrate. The diazonium salt formed on the addition of sulphanilic acid is coupled with N-(1-napthyl) ethylenediamine to form a colored azo dye. For the estimation of NO_2 Jacob and Hochheiser (Modified) Method was used. All the solutions forming pink colored azo dye of different concentration gives different color and from the colorimetric method which is built on the Beer- Lambert's law states that high color indicates higher concentration. These solutions giving different color were put in the spectrophotometer (UV-Visible Spectrophotometer-1601) with the wavelength of 540 nm and the absorbance is noted. On the basis of concentration and absorbance data the calibration curve was made. With the help of this calibration curve the concentration of NO_2 in air was collected.

RESULTS AND DISCUSSION

Mean concentration of NO_2 in Banepa Municipality

The seasonal mean values according to commercial, industrial and residential areas of Banepa Municipality are presented in Figure 2. The findings suggest that during winter season the NO_2 was more. Among the areas commercial area in Banepa noted highest NO_2 level. In fact, at commercial area a the mean concentration was found to be 62.90 $\mu g/m^3$ in the winter and a maximal level of 91.20$\mu g/m^3$ has been recorded on one occasion in winter which was not very much deviant to the mean level indicating persistently higher levels of NO_2 in this area. The over all mean, standard deviation, minimum and maximum level of NO_2 in Banepa was respectively 29.88µg/m^3, 14.25µg/m^3, 13.37µg/m^3 and 91.20µg/m^3.

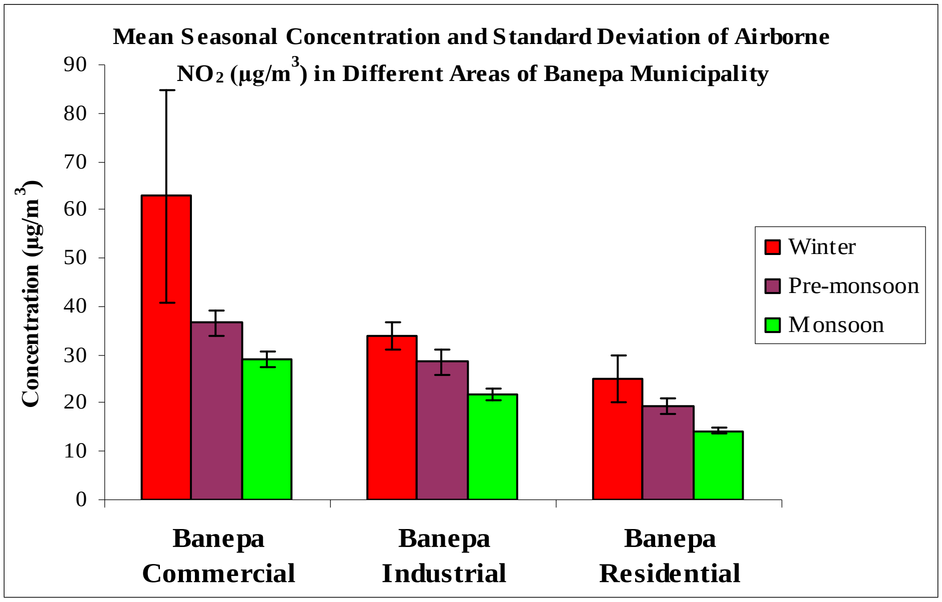


Figure 2. Mean seasonal concentration and standard deviation of airborne NO_2 in different areas of Banepa municipality.

The National Ambient Air Quality Standards (NAAQS) in Nepal for NO_2 had been set as 80 µg/m^3 which is 24 hourly values, 40µg/m^3 for annual averaging. From the Figure 2 it was seen that only the concentration of mean NO_2 pollution in Banepa Industrial area had crossed the NAAQS level in winter season, all other sites are with in the permissible limit. But, it should be note that the present study represented 8 hourly mean values which were reflected only the pick hours concentration of NO_2 in the studied areas. The seasonal trend in NO_2 levels show that winter>pre-monsoon > monsoon. The trend noted among the areas was commercial>industrial>residential on all the occasions. This finding suggests that commercial area of Banepa is more defined and is associated with higher NO_2 concentration compared to industrial area.

Mean concentration of NO_2 in Dhulikhel Municipality

The seasonal mean values according to commercial, industrial and residential areas of Dhulikhel Municipality are presented in Figure 3. From the study it is found that during winter season the NO_2 was more and among the areas Dhulikhel commercial area noted highest mean NO_2 concentration with a mean concentration of 24.09µg/m^3. But at industrial area a maximal level of 35.25µg/m^3 has been recorded on one occasion, which was highest within the areas. The over all mean, standard deviation, minimum and maximum level of NO_2 in Dhulikhel municipality was respectively 21.32µg/m^3, 5.81µg/m^3, 11.26µg/m^3 and 35.25µg/m^3. From the study it was also seen that the concentration of mean NO_2 pollution in all three season in all the three land-use areas of Dhulikhel Municipality are with in the permissible limit of NAAQS level of 80µg/m^3 of 24 hours standards. The seasonal trend in NO_2 levels show that Winter > Pre-monsoon >

Monsoon. The trend noted among the areas was Commercial >Industrial > Residential on all the occasions.

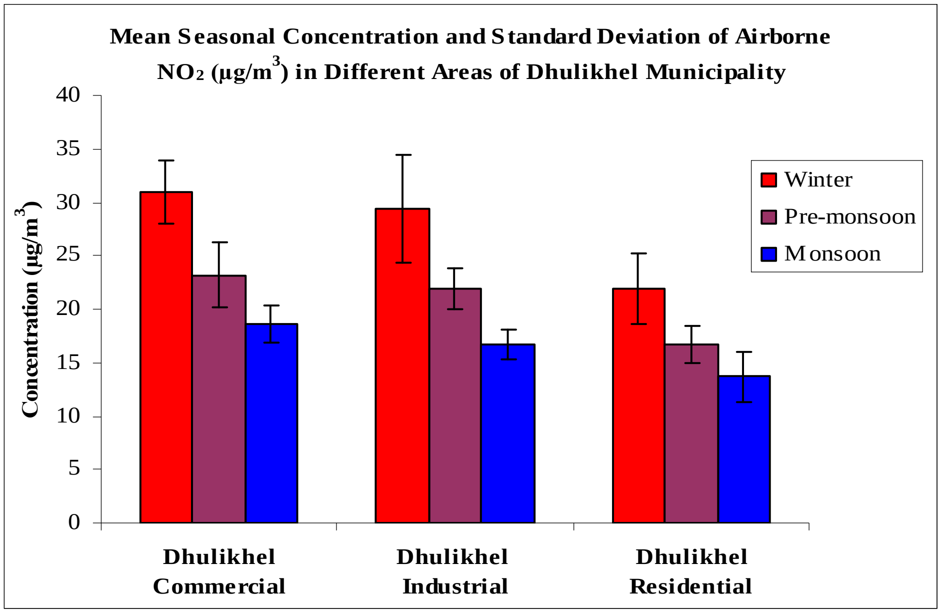


Figure 3. Mean seasonal concentration and standard deviation of airborne NO_2 in different areas of Dhulikhel municipality

These findings conclude that, commercial area of Dhulikhel is more defined and is associated with higher NO_2 concentration compared to industrial area.

Mean concentration of NO_2 in Panauti Municipality

The seasonal mean values according to commercial, industrial and residential areas of Panauti Municipality are presented in Figure 4. The study found that during winter season the NO_2 concentration was more and among the areas Commercial area in Panauti noted highest mean NO_2 concentration. The over all mean, standard deviation, minimum and maximum level of NO_2 in Panauti was respectively 22.65µg/m^3, 7.33µg/m^3, 12.21µg/m^3 and 39.55µg/m^3. From the table 4 it was also shown that the concentration of mean NO_2 pollution in all three season in all the three land-use areas of Panauti municipality are within the permissible limit of NAAQS level of 80µg/m^3 for 24 hours standards.

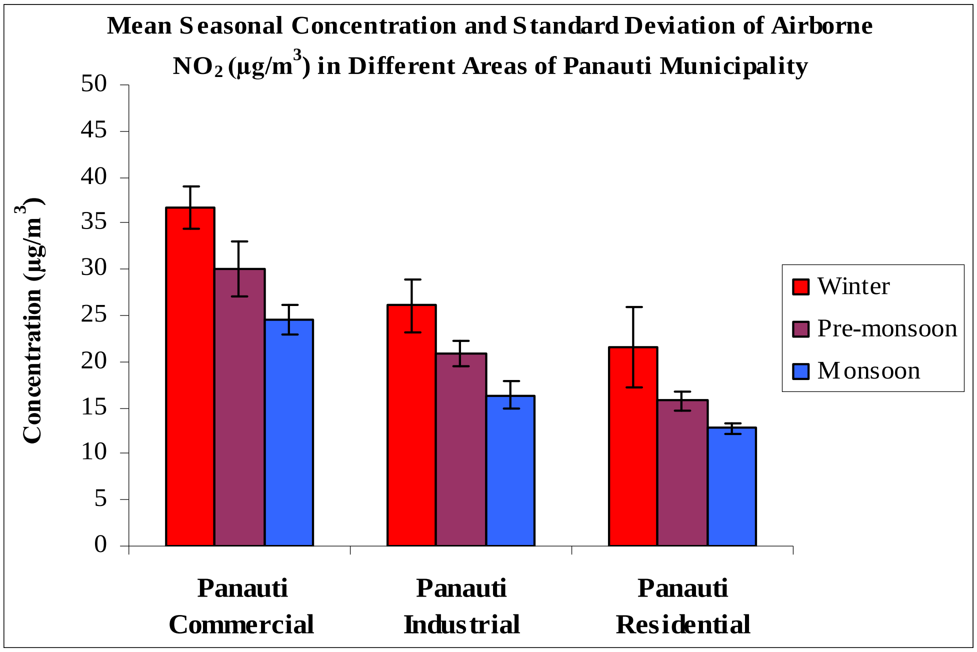


Figure 4. Mean seasonal concentration and standard deviation of airborne NO_2 in different areas of Panauti municipality

The seasonal trend in NO_2 levels show that Winter > Pre-monsoon > Monsoon. The trend noted among the areas was Commercial > Industrial > Residential on almost all the occasions. This finding suggests that commercial area of Panauti is more defined and is associated with higher NO_2 concentration compared to industrial and residential areas.

NO_2 concentration in Sites in respect to Seasons

From the Table 2., it is shown that Banepa commercial area has the highest seasonal mean NO_2 concentration with mean concentration of 41.94µg/m^3 among all the 9 sites of 3 municipalities. It recorded highest level of concentration all three seasons i.e. winter, pre-monsoon and monsoon. Panauti Residential area has lowest concentration with a mean concentration of 16.55µg/m^3.

Table 2. Mean Seasonal Concentration of Airborne NO_2 µg/m^3) in all the Study Areas

Sites	Winter	Pre-monsoon	Monsoon	Seasonal Mean
Banepa Commercial	62.90	36.56	29.05	41.94
Banepa Industrial	33.90	28.54	21.70	28.12
Banepa Residential	24.96	19.55	14.27	19.59
Dhulikhel Commercial	30.98	23.18	18.56	24.09
Dhulikhel Industrial	29.39	21.95	16.66	22.56
Dhulikhel Residential	21.86	16.72	13.66	17.31
Panauti Commercial	36.69	29.97	24.49	30.32
Panauti Industrial	26.07	20.89	16.37	21.08
Panauti Residential	21.52	15.76	12.77	16.55
Over all mean	32.03	23.68	18.61	24.61

The chronology of the highest to lowest pollutant area in all three municipalities are as Banepa Commercial > Panauti Commercial > Banepa Industrial > Dhulikhel Commercial

> Dhulikhel Industrial > Panauti Industrial > Banepa Residential > Dhulikhel Residential > Panauti Residential

NO_2 concentration in Sites vs Months

Within seven months among all the nine sites Banepa commercial site recorded the highest concentration of NO_2 with a mean level of 41.94µg/m^3. Among the seven months all the months it recorded highest NO_2 concentration. On the other hand Panauti Residential areas recorded lowest concentration of NO_2 pollution with a mean level 16.55µg/m^3. Among the seven months all the months it recorded lowest NO_2 concentration.

Table 3. Mean Concentration of Airborne NO_2 (µg/m^3) in all the Study Areas According to Months

Sites	January	February	March	April	May	June	July	Average
Banepa Commercial	80.05	45.75	38.08	37.69	33.90	29.33	28.77	41.94
Banepa Industrial	36.28	31.53	31.47	28.24	25.90	22.46	20.94	28.12
Banepa Residential	28.32	21.61	21.02	19.93	17.71	14.47	14.08	19.59
Dhulikhel Commercial	33.36	28.60	22.63	24.70	22.23	19.74	17.37	24.09
Dhulikhel Industrial	33.52	25.26	23.86	21.96	20.02	17.53	15.79	22.56
Dhulikhel Residential	24.59	19.14	18.32	16.52	15.33	14.40	12.91	17.31
Panauti Commercial	37.14	36.24	32.40	29.57	27.96	25.30	23.68	30.32
Panauti Industrial	28.56	23.59	21.88	21.36	19.44	15.83	16.90	21.08
Panauti Residential	24.42	18.63	16.88	15.26	15.14	12.75	12.79	16.55
Total Average	36.25	27.81	25.17	23.91	21.96	19.09	18.13	24.62

Influence of Meteorological Parameters on NO_2

Season VS Meteorological Parameters

To check the influence of meteorological parameter on NO_2 concentration we have selected some meteorological parameter such as Temperature in (^{O}F) Fahrenheit, Humidity in Percentage (%), Dew point in (^{O}F) Fahrenheit, Wind speed in MPH, Barometric Pressure in inches, Rainfall in inches and solar radiation in W/m^2, The Table 4 represents the influence of meteorological parameter on NO_2 concentration in Banepa Valley.

Table 4. Seasonal NO_2 concentration in relation with metrological parameter

Season	NO_2	Temp	Humidity	Dew point	Wind Speed	Barometric Pressure	Rainfall	Solar Radiation
Winter	33.40±14.32	52.68±5.61	76.93±10.99	45.19±3.90	1.06±0.41	30.33±0.08	0.00±0.01	286.49±157.39
Pre-monsoon	21.98±6.10	74.42±5.60	64.98±16.47	60.62±4.33	1.64±0.75	29.94±0.12	0.00±0.00	489.45±159.61
Monsoon	18.41±5.58	73.62±4.53	84.53±14.39	68.06±3.19	0.74±0.60	29.76±0.09	0.00±0.01	306.35±150.65
Total	26.05±12.23	64.82±11.92	74.90±15.56	55.76±10.43	1.17±0.68	30.06±0.26	0.00±0.01	357.14±180.04

From the table 4. it is observed that when the ambient temperature increases the NO_2 concentration decreases. The concentration of NO_2 33.40µg/m^3 was observed in average temperature of 52.68 ^{O}F and as the average temperature increases to 74.42^{O}F the NO_2 decreases to 21.98µg/m^3.

Table 4 also shows, the mean NO_2 was found to be lower with increase of relative humidity. The NO_2 concentration of 33.40µg/m^3 was found in relative humidity of 76.93% and as this to 84.53% the NO_2 decreases to 18.41µg/m^3. This may be due to increase in relative humidity means increase in amount of water vapors in the atmosphere and therefore it can be implied that increase in humidity implies increase in rainfall and which directly decrease the NO_2. Table 4 also showed, as the dew point increased the NO_2 concentration decreased. The NO_2 concentration of 33.40µg/m^3 was found when the dew point was 45.19 ^{O}F and as the dew point increased in 68.06 ^{O}F the NO_2 concentration decreased to 18.41µg/m^3.

The trend shows that, as the wind speed increases the NO_2 decreases. As there is no such clear difference in increased wind speed but the NO_2 decreases. The NO_2 concentration of 33.40µg/m^3 was found in wind speed of 1.06 MPH and as this increase to 1.64 MPH the NO_2 decreases to 21.98µg/m^3. This means that the wind speed help in decreasing the NO_2.

From the Table 4 it is also found that, there is a positive relation with barometric pressure and NO_2 concentration. It shows that, in the winter when the barometric pressure was higher (30.33) the NO_2 concentration was also higher (33.40µg/m^3) and in the monsoon with the decreases of barometric pressure decreased (29.76) there is a decreases trend of 18.41µg/m^3 NO_2 concentration also observed.

The trend shows that as the rainfall increases the NO_2 decreases. From the table 4, it is seen that NO_2 concentration decreases with the increases of rainfall. It is observed that in winter when the mean rainfall was 0.02 inches the mean NO_2 was 33.40µg/m^3 whereas in monsoon the NO_2 comes down in 18.41µg/m^3 with the increases of 0.06 inches this may be due the washing effect of the rainfall.

From the table 4 it is observed that, when the solar radiation increases the NO_2 concentration decreases. The maximum NO_2 concentration 33.40µg/m^3 was observed in radiation increases of 286.49W/m^2. And as the solar radiation increases to 306.35W/m^2 the NO_2 decreases to 18.41µg/m^3. This may be due to the increase in temperature as the solar radiation increases.

Time VS Meteorological Parameters

Table 5. Diurnal NO_2concentration in relation with metrological parameters

Time	NO_2	Temp	Humidity	Dew point	Wind Speed	Barometric Pressure	Solar Radiation
Morning	26.41±11.26	63.28±11.27	79.93±12.70	56.35±10.07	1.12±0.64	30.11±0.26	422.87±181.67
Evening	25.68±13.27	66.37±12.49	69.87±16.66	55.16±10.88	1.22±0.72	30.02±0.25	291.42±154.41
Total	26.05±12.23	64.82±11.92	74.90±15.56	55.76±10.43	1.17±0.68	30.06±0.26	357.14±180.04

The above table represents the diurnal NO_2 concentration in relation with metrological parameters. From the table 5, it is observed that in the morning the NO_2 concentration is higher then in the evening. And in the evening when the maximum temperature increases the NO_2 concentration also decreases. The mean NO_2 was found to be lower with the decrease of relative humidity. The NO_2 concentration of 26.41µg/m^3 was found in relative humidity of 79.93% in the morning and 25.68µg/m^3 as this to the decreases of relative humidity to 69.87%.

CONCLUSIONS

The study provided base line data on air quality in terms of NO_2 concentration that provided in representative semi urban areas of Nepal. It represent the mean concentration, standard deviation, maximum and minimum concentration of all nine sites. Influences of meteorological parameters on NO_2 were discussed briefly using appropriate table and graphs. Commercial areas in semi urban areas observed with high NO_2 levels. NO_2 levels had definitive trend at all the three sub-urban areas, like commercial> industrial> residential. Monsoon season was observed less concentration of NO_2 in all the areas. A few metrological parameters had inverse relationship with NO_2 while few others had direct relationship. It was concluded from the findings of the present study that the NO_2 concentration is within the permissible level in Banepa Valley.

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