STUDY OF ENVIRONMENTAL EMISSIONS FROM ROAD TRANSPORTATION
A CASE OF BHAKTAPUR MUNICIPALITY, NEPAL

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INTRODUCTION

- Several study has been carried out in a field of air pollution at Bhaktapur but none in vehicular emission sector.
- WHO defined air pollution as the contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere (WHO, 2016).
- In most of the developing countries, the main sources of air pollution are road vehicles (Bajracharya and Bhattarai, 2016).
- Air pollution plays significant role in the development of respiratory diseases (WHO, 2018).
- In children and adults, PM_{10} is highly associated in mortality and respiratory illness (Gautam, 2010) whereas particles of 2.5 microns or less than that has a high tendency to penetrate deep into lungs or even dissolve in blood stream (Xing et al., 2016), (WHO, 2016).
- In 2016, an estimated 16,302 people died from COPD in Nepal of which death rate due to COPD in female was 119.7 per 100,000 people compared to male comprising death rate of 102.6 per 100,000 people (Adhikari et al., 2018).
- The mortality rate due to COPD between year of 1990 and 2016 decreases both in gender but the declination was higher in male compared to female (Adhikari et al., 2018)
- In 2017, COPD occupy second position while ranking most causative factors to trigger deaths in Nepal accounting by 44.5%, in premature death at a rate of 1,584.2 per 100,000 people and death/disability at rate of 2,280.5 per 100,000 people (IHME, 2018).
- In Nepal, COPD was the common cause of mortality between year of 2013 to 2014 (DOH, 2014).

OBJECTIVES

General objectives
- Study of environmental emissions from road transportation.

Specific Objectives
- To estimate average annual energy demand in Giga joule (Gj)
- To estimate vehicular emission load in tons/year.

LIMITATIONS

- No instruments were used for the measurement of Vehicular emission.

METHODOLOGY

Study Area

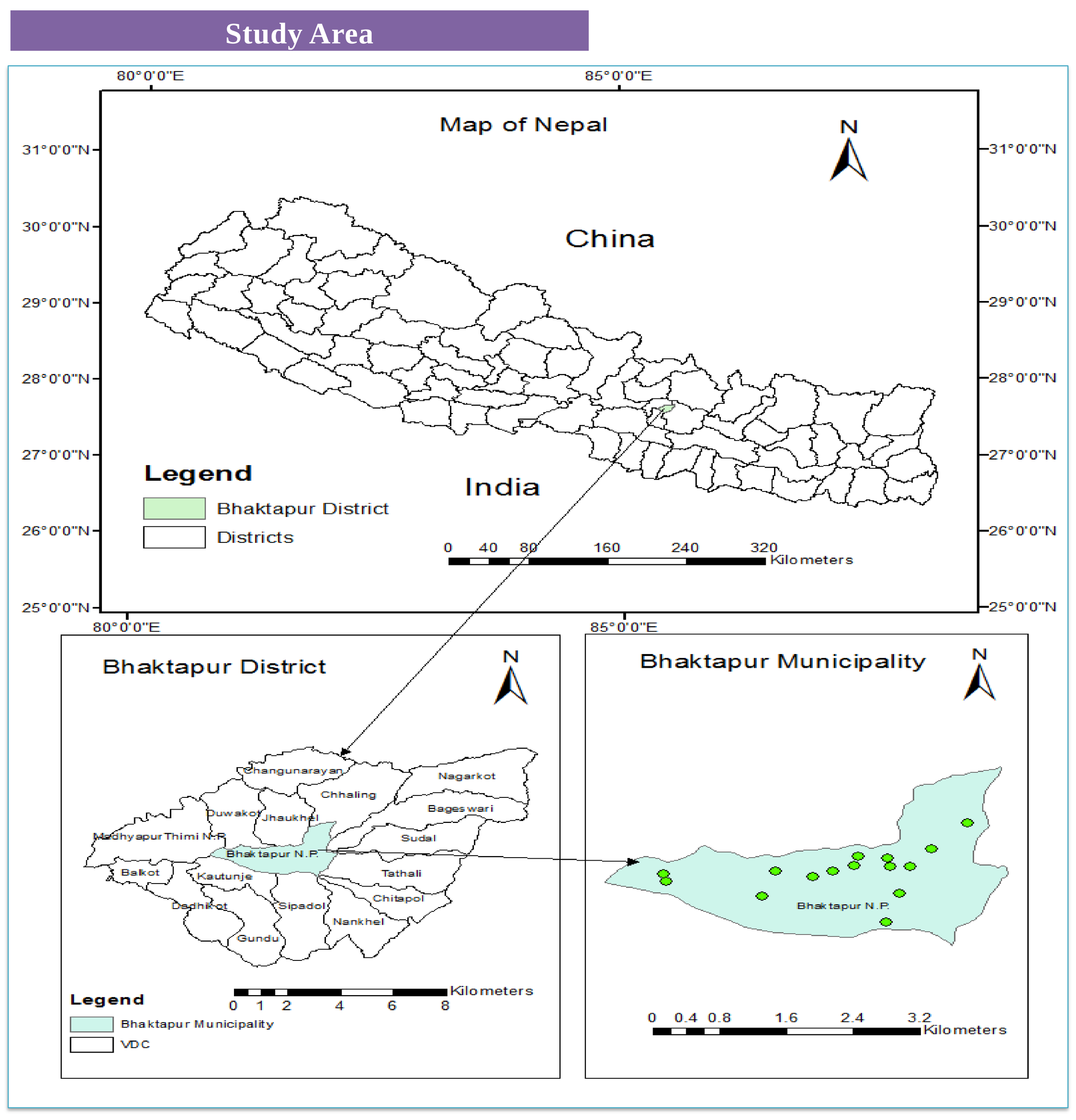

Figure 1: Map of Study area

- Bhaktapur municipality lies in the east corner of Kathmandu valley, about 13 km from the capital city having 10 administrative wards.
- The municipality occupies area of 6.89 sq. km with population 83,658 (Census, 2011).

Methods

- GPS coordinates were generated from earth explorer in a stratified random manner considering the road junction and traffic movement for sampling.
- Data were collected from 15 coordinates located in the map of Bhaktapur Municipality as shown in figure 1.
- Selecting different peak and non-peak hour, vehicular emission was estimated with the help of emission factors, derived equations, field visit and literature review.

Table 1: Total number of Vehicles plying on road with its average annual kilometre and fuel economy

Vehicle Types	Fuel Types	Total Number of Vehicles (Ni,t)	Average Annual Vehicle Kilometre (VKT i,t) in Km	Fuel Economy (F_i) in l/km
Mega Bus	Diesel	20	2016.26	0.28
Mini Bus	Diesel	201	2923.58	0.25
Car/Van	Gasoline	448	2243.09	0.07
Pickup Van	Diesel	212	4738.21	0.15
Mini Truck	Diesel	135	8417.89	0.25
Motor Bike	Gasoline	2212	2893.33	0.02
Others (Tractors/ Micro bus)	Diesel	55	6502.44	0.16

- Gaseous pollutants like CO_2, CO, NOx, HC and PM_{10} were taken in our study as emission factors of those pollutants was available in published article (Dhakal, 2006) tabulated in table 2 below.

Table 2: Emission Factors in g/l

Vehicle types	Fuel Types	CO_2	CO	NOx	HC	PM_{10}
Mega Bus	Diesel	3440	24	35.61	11.1	11.7
Mini Bus	Diesel	3440	24.8	11.2	10.4	8.1
Car/Van	Gasoline	3985	261.9	29.6	87.9	2.27
Pickup Van	Diesel	3440	24.8	11.2	10.4	7.2
Mini Truck	Diesel	3440	24.8	11.2	10.4	8.1
Motor Bike	Gasoline	3766	726.3	11.3	69.9	4.3
Others(Tractors /Micro Bus)	Diesel	3440	24.8	11.2	10.4	7.2

- Derived mathematical equations from published article was adopted for the estimation of vehicular energy demand and emission load (Bajracharya & Bhattarai, 2016) as given below.

Equation 1: Equation for Energy demand estimation

$$EDi,t = Ni,t * VKTi,t * Fi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

Where EDi,t is total annual energy demand in liters by each vehicle type i in a year t.

Ni,t is total number of existing vehicles in year t.

VKTi,t is average annual mileage in kilometer

Fi is average fuel economy in liters per kilometer

Equation 2: Equation for Emission load estimation

$$Ej,i,t = EDi,t * EFj,i,t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

Where Ej,i,t is total emission of emission type j by vehicle type i in year t.

EDt,i is total energy demand by vehicle type i in year t.

EFj,i,t is emission factor of type j expressed in gram per liters of vehicle type i in year t.

RESULTS

Annual Energy demand estimated for each vehicle types is tabulated below in table 3.

Table 3: Energy Demand in Giga Joule

Vehicle types	Energy Demand $Ed_{i,t}$ (Gj)	Energy Demand $Ed_{i,t}$ (Gj) in percentages
Mega Bus	445	1 %
Mini Bus	5671	17 %
Car/Van	2546	8 %
Pickup Van	5965	18 %
Mini Truck	10966	33 %
Motor Bike	5150	16 %
Others(Tractors/Micro Bus)	2301	7 %
Total	33044	100 %

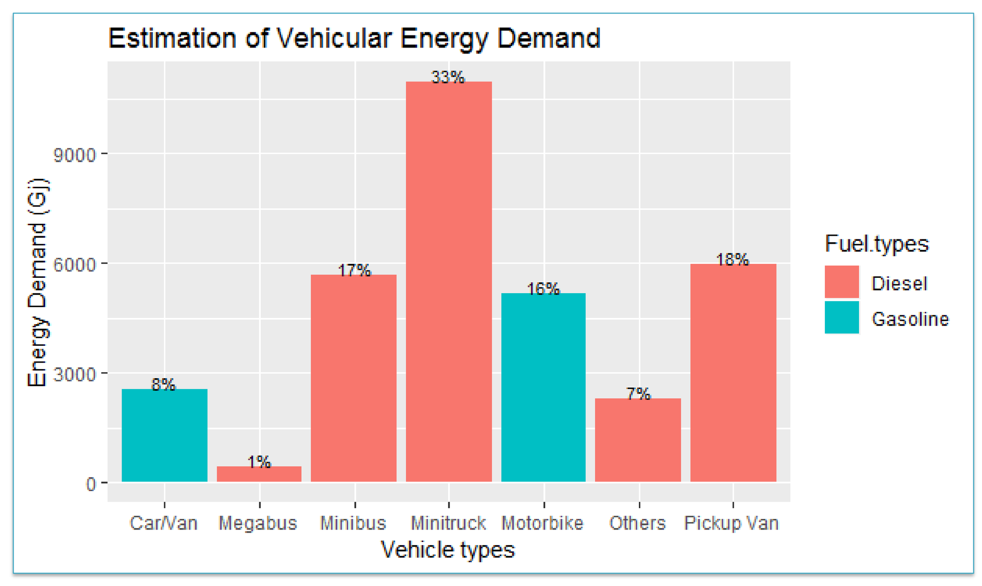

Figure 2: Estimation of Vehicular Energy Demand

- From table 3, total annual energy demand was found to be 33044 Gj of which Mini Truck found to account for highest energy demand by 33% followed by Pickup Van (18%), Mini Bus (17%), Motorbike (16%), Car/Van (8%), others (7%) and Mega Bus (1%) respectively.
- Emission load from each vehicle types are tabulated in table 4 below.

Table 4: Emission load in tons/year

Vehicle types	Fuel Types	CO_2	CO	NOx	HC	PM_{10}	Total	Total %
Mega Bus	Diesel	39.63	0.28	0.41	0.13	0.13	40.58	1 %
Mini Bus	Diesel	505.37	3.64	1.65	1.53	1.19	513.38	16 %
Car/Van	Gasoline	296.63	19.50	2.20	6.54	0.17	325.04	10 %
Pickup Van	Diesel	531.61	3.83	1.73	1.61	1.11	539.90	16 %
Mini Truck	Diesel	977.32	7.05	3.18	2.95	2.30	992.80	30 %
Motor Bike	Gasoline	567.12	109.37	1.70	10.53	0.65	689.37	21 %
Others	Diesel	205.04	1.48	0.67	0.62	0.43	208.24	6 %
Total		3122.73	145.14	11.54	23.91	5.98	3310	100%
Total %		94.36 %	4.39%	0.35%	0.72 %	0.18%	100%	

- From above table 4, total emission load was found to be 3310 tons/year of which CO_2 found to account 94.36% in total emission followed by CO (4.39%), HC (0.72%), NOx (0.35%) and PM_{10} (0.18%) respectively.
- Regarding vehicle types, Mini Truck found to account for highest emission by 30% and Mega Bus found to account for lowest emission by 1%.
- Similarly Motorbike found to account for 21% of total emission followed by Pickup Van (16%), Minibus (16%), Car/Van (10%) and others (6%) respectively.

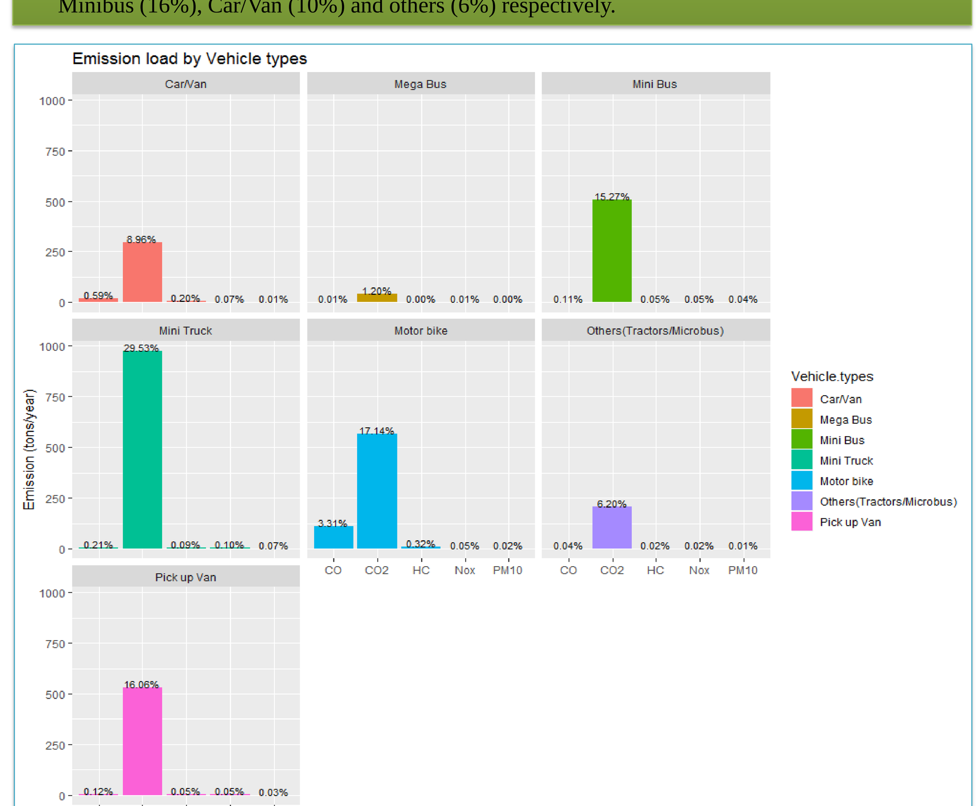

Figure 3: Emission load by Vehicle types

- From above figure, Mini Truck found to have highest CO_2 emission accounting by 29.53% followed by Motorbike (17.14%), Pickup Van (16.06%), Mini bus (15.27%), Car/Van (8.96%), Others (6.20%) and Mega Bus (1.20%) respectively.
- Mega Bus found to have small contribution towards CO_2 emission despite of fact that these vehicles are larger in both size and engine.
- Motorbike on other hand found to account for highest CO and HC emission by 3.31% and 0.32% followed by Car/Van emitting CO by 0.59% and HC by 0.20%.
- Other pollutants like NOx and PM_{10} were found in a very trace amount as shown in figure 3 above.

Table 5: Share of pollutants by fuel types in tons/year

Fuel types	CO_2	CO	NOx	HC	PM_{10}	Total
Diesel	2258.98	16.28	7.64	6.84	5.17	2294.89
Gasoline	863.75	128.87	3.91	17.07	0.82	1014.41
Total	3122.73	145.14	11.54	23.91	5.98	3309.31

- From above table 5, total emission from Diesel fuel found to be 2295 tons/year whereas total emission from Gasoline fuel found to be 1015 tons/year.

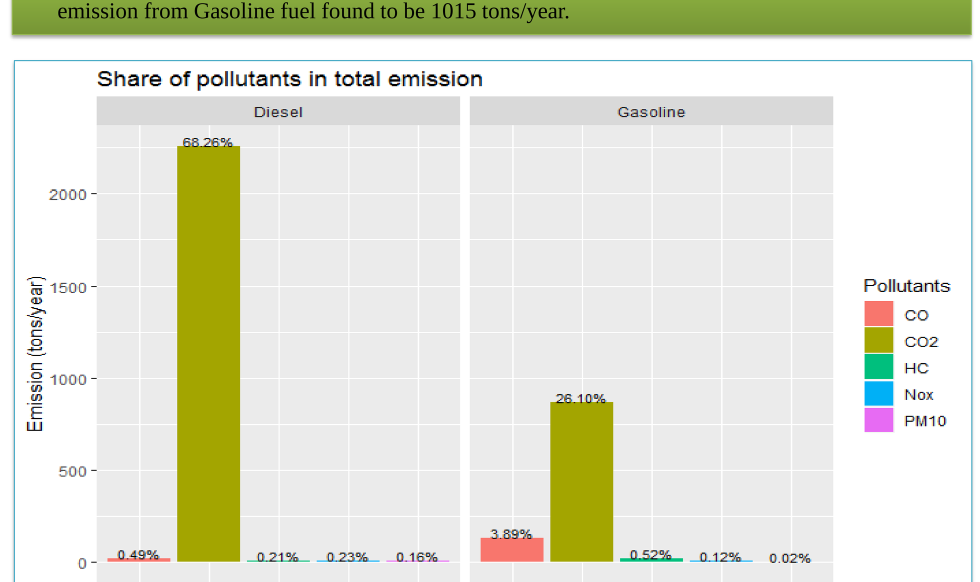

Figure 4: Share of pollutants by fuel types

- From figure 4, Diesel fuel found to have maximum share of CO_2 emission accounting 68.26% in total emission followed by CO (0.49%), NOx (0.23%), HC (0.21%) and PM_{10} (0.16%) respectively.
- On other hand Gasoline fuel found to have maximum share of CO_2 emission accounting 26.10% in total emission followed by CO (3.89%), HC (0.52%), NOx (0.12%) and PM_{10} (0.02%) respectively.
- It represents that Diesel fuel play a crucial role in emitting high amount of greenhouse gas like carbon dioxide and deteriorate air quality.
- Vehicular emission of Bhaktapur Municipality was obtained in a small amount but has a potential to play a significant role in deteriorating air quality due to small area size.
- Changes in amount of emissions was analysed by assuming an introducing of electric vehicles like Car, Motorbikes and Buses in different rate within Municipality which is calculated and tabulated in table 6 below.

Table 6: Changes in emission due to electric vehicles

Introducing electric Vehicles(Car, Motorbike and Buses)	Emission estimated in our study (tons/year)	Emission after launch of electric vehicles (tons/year)	Difference (tons/year)
10%	3309.31	3152.47	156.84
20%		2995.63	313.68
30%		2838.79	470.52

- From above table 6, if electric vehicles like Car and Motorbike is introduced by 10%, 20% and 30%; significant amount of emission can be reduced annually.
- Introducing 10% of electric vehicles can reduce 156.84 tons of emissions in a year. Whereas launching by 20% and 30% can reduce 313.68 tons and 470.52 tons of emissions in a year.

STATISTICAL ANALYSIS

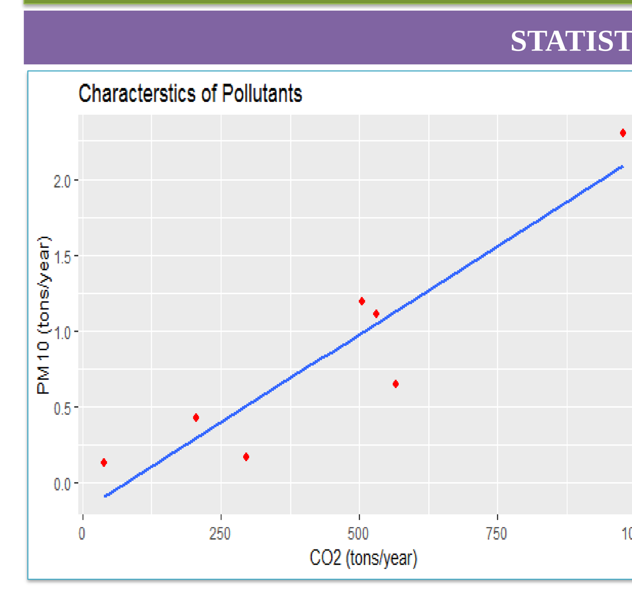

Figure 5: Scattered plot showing relationship between pollutants

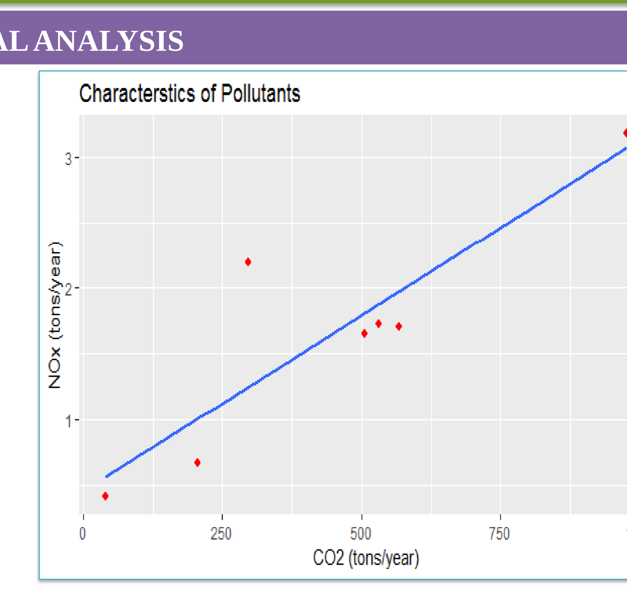

Figure 6: Scattered plot showing relationship between pollutants

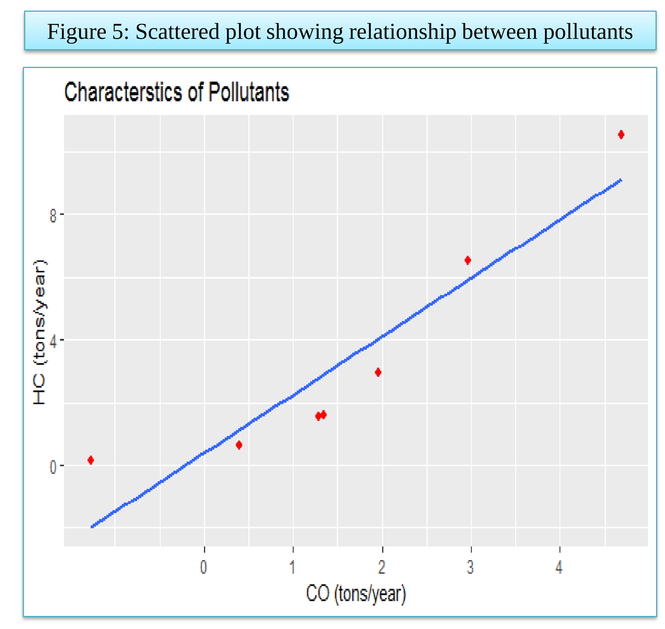

Figure 7: Scattered plot showing relationship between pollutants

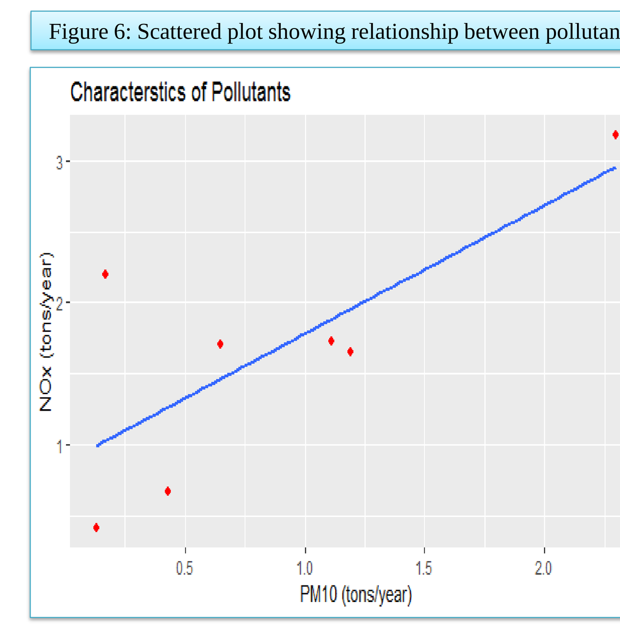

Figure 8: Scattered plot showing relationship between pollutants

- Pearson product-moment correlation analysis between CO_2 and PM_{10} (r = 0.92, p = 0.002), CO_2 and NOx (r = 0.87, p = 0.009), CO and HC (r = 0.90, p = 0.004) and NOx and PM_{10} (r = 0.74, p = 0.05) were found having positive uphill linear correlation and statistically significant at 5% level of significance as shown in figure 5,6,7 and 8 respectively.

DISCUSSION

- There are 70,000 vehicles plying on the road of Kathmandu (Ghimire & Shrestha, 2014) which was 22 times higher than the vehicles on the road of Bhaktapur Municipality.
- Estimated total annual energy demand in our study i.e 33044 GJ is nearly 2.3 times higher than the energy estimated in Kathmandu valley by 14,209 GJ (Bajracharya & Bhattarai, 2016) despite of population density and area size differences.
- Our study showed that contribution of CO_2 was significantly highest by 94.36% compared to other pollutants.
- Amount of CO_2 level is often highest compared to other pollutants (Dhakal, 2006), (Bajracharya & Bhattarai, 2016), (Shrestha et al., 2013), (Shrestha & Malla, 1996), (Ghimire & Shrestha, 2014), (Tang et al., 2016), (Lang et al., 2014), (Cai & Xie, 2007) and (Wang et al., 2009).
- Total CO_2 emission in our study was estimated 3,123 tons/year which was much lesser than CO_2 estimated in a year of 2013 and 2014 at Kathmandu comprising a emission of 1,554,000 tons /year and 680,761.85 tons/year (Shrestha et al., 2013) and (Ghimire & Shrestha, 2014).
- Mini Truck found to emit highest level of CO_2 by 977.32 tons/year in Bhaktpur whereas Bus/Minibus found to emit highest level CO_2 by 1,551,387.91 tons/year in Kathmandu (Ghimire & Shrestha, 2014).
- Motorbike found to emit highest level of CO in Bhaktapur by 109.37 tons/year and Kathmandu by 233,364.06 tons/year (Ghimire & Shrestha, 2014).
- Vehicles like Mini Truck and Motorbike in Bhaktapur found to emit highest amount of NOx, PM_{10} and and HC by 3.18 tons/year, 2.30 tons/year and 10.53 tons/year whereas in Kathmandu, vehicles like Minibus, two wheeler and Bus/Minibus found to emit highest level of NOx, HC and PM_{10} by 17,538.71 tons/year, 22,459.24 tons/year and 5,764.13 tons/year respectively (Ghimire & Shrestha, 2014).
- In our study, Diesel fuel found to have maximum share of CO_2 by 68.26% and minimum share of PM_{10} by 0.16% whereas in other study Diesel fuel found to have a maximum share of PM_{10} by 38.2% and minimum share of HC by 3.0% (Dhakal, 2006).
- In our study, Gasoline fuel found to have maximum share of CO_2 by 26.10% and minimum share of PM_{10} by 0.02% whereas in other study Gasoline fuel found to have maximum share of CO_2 by 97.7% and minimum share of HC by 3% (Dhakal, 2006).

CONCLUSION

- Annual energy demand of Bhaktapur Municipality for a year of 2018 was estimated 33,044 GJ and vehicular emission load including pollutants CO_2, CO, NOx, HC and PM_{10} was estimated 3310 tons/year.
- Diesel fuel found to have maximum share in emission compared to Gasoline fuel.
- CO_2e was found 3123 tons that equals to 850.95 tons of carbon, CO_2 alone seems to deteriorate air quality in future.
- The numbers of vehicles are expected to increase dramatically in coming years, which would enhance in emission level.
- Alternative practices relying on clean energy if inaugurated in time can prevent worse future scenario.
- Introducing electric vehicles showed a significant reduction in emissions in an annual basis.
- Statistical analysis between CO_2 and PM_{10} (r = 0.92, p = 0.002), CO_2 and NOx (r = 0.87, p = 0.009), CO and HC (r = 0.90, p = 0.004) and NOx and PM_{10} (r = 0.74, p = 0.05) were found having positive uphill linear relationship and statistically significant at 5% level of significance.

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