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Comparison of vehicular fuel consumption and CO_2 emission before and during the covid-19 pandemic in Kathmandu valley

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Abstract

In the past few decades, the change in emission and fuel consumption pattern of Kathmandu valley (KV) has been increasing rapidly. But due to the COVID-19 pandemic, it was disrupted for a certain time. The main aim of this study is to compare the carbon dioxide (CO_2) emission before and during the COVID-19 pandemic for KV based on the motor-spirit (MS) & high-speed-diesel (HSD) fuel consumed by the vehicles. From the fuel sales data provided by Nepal Oil Corporation (NOC), CO_2 emission was calculated as per the Tier 1 approach given in the guidelines provided by the Intergovernmental Panel on Climate Change (IPCC). 14.9% of total fuel sales of Nepal was consumed in KV alone by road transport for fiscal year (FY) 2019/20. KV area produced 9, 14, 352 tonnes of CO_2 emissions from the transportation sector in the FY 2019/20 from the corresponding 2, 92, 260 kiloliters of fuels. CO_2 emission had declined by 80.11% after the lockdown was implemented in the valley but later on, till Asar (Mid June – Mid July) it again rose to 65

1. Introduction

Air pollution due to the various human activities has been a crucial issue at present [1] and the transportation sector is one of the major energy consuming sector and also a major global greenhouse gas emitting sector [2]. Fuel consumption has been increasing in the past few decades in Nepal and especially in Kathmandu Valley due to the rapid modernization and increasing populations that have been causing various emissions to our surroundings creating various environmental problems.

Outbreak of coronavirus (COVID-19) largely affected every aspects of life on Earth which also forced government authorities of Nepal to impose lockdown from 24, March 2019. This greatly reduce all the services including the transportation sector which reduced air pollution drastically. This directly affected the sales of petroleum related products as only a few essential vehicles were running on the road. So, it is obvious that the amount of fuel consumption was unexpectedly reduced.

This information can be directly linked with the amount of emissions emitted from the vehicles. In the transport related greenhouse gas emission, road transport contributes the highest share which is 79.5% [2]. The emissions from these vehicles are generally calculated in terms of carbon dioxide (CO_2) emissions. CO_2 emissions from vehicles are a major threat to the environment and is directly associated with the amount of fuel consumed. CO_2 is one of the major greenhouse gases (GHGs) that has the potential hazards on both climate and human health. It has been a potential threat for causing various environmental problems such as increasing global temperature resulting in severe weather conditions.

The sources that cause environmental pollutants can roughly be divided into stationary and mobile sources. Stationary sources include installations for the industrial processes. Mobile sources include various means of transport such as aircraft, heavy-duty trucks, passenger

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cars, motorbikes, etc [3]. This project will focus on the CO_2 emissions by road transportation in Kathmandu Valley.

The principal emissions from vehicles are greenhouse gas i.e. CO_2, N_2O and CH_4. The main gas emitted is carbon dioxide which is directly associated with the volume of fuel consumed and the type of fuel used (Petrol & Diesel). This pandemic has limited the movement of vehicles and therefore reduced the atmospheric levels of CO_2. Its effect on Kathmandu Valley was studied.

This clearly shows that the reduction in the vehicle movement reduced the fuel consumption which further reduced the emissions coming from those vehicles

2. Literature Review

2.1. COVID-19

On 23 March 2020, GoN, taking cognizance of the evolving global situation and using the 2020 Infectious Disease Act, decided for the first time to lock down the country from 24 March to which was extended multiple times until 21 July 2020. On 22 July 2020, most of the lockdown restrictions were lifted, with a few exceptions.

2.2. Fuel consumption

In Nepal, an increasing number of vehicles have tremendously increased the fuel consumption amount about 80% of imports of petroleum imported are consumed in the transport sector [4]. Similarly, between 2007 and 2013, gasoline and diesel import combined increased by 137%, while the import value of these fuels almost quadrupled [5]. The Kathmandu valley consumed 51 PJ of energy in 2016, which is 1.7 higher than 2011, with a rise in energy use mainly from the industrial and transport sector. This increase in fuel can be attributed to a continuous increase in the total number of fleets over the study period from 0.27 million to 2.23 million [6], which is estimated for each vehicle category using vehicle registration data and the survival function [7].

The maximum upper limit value of sulfur is 350 mg/kg of diesel (BS III) for Nepal [8]. Fuel consumption of vehicles generally increases with their gross vehicle weight and engine displacements [9]. Nepal's Transportation sector does not use traditional energy at all but entirely relies on imported petroleum fuels. In 2012, the valley consumed 46% of the total petrol and 16% of the total diesel sales in Nepal [10].

In the Bagmati Zone, which encompasses three districts in the Kathmandu Valley, around 30% of domestic vehicles are registered. This represents 50% of the national consumption of gasoline and 27% of national diesel consumption in the valley [7].

Table 1: Average fuel economy of vehicles during urban drive in the Kathmandu valley [10]

Vehicle Type	Fuel Type	Fuel Consupmtion (km/l)
Bus	Diesel	3.5
Minibus	Diesel	4
Microbus	Diesel	6.2
Car	Gasoline	13.5
Jeep	Diesel	8.5
Pick-up	Diesel	6.5
Motorcycle	Gasoline	42.5
HDV	Diesel	3.5
Mini Truck	Diesel	3.5

2.3. Emission

One of the most important contributors of greenhouse gases (GHGs) is the transportation sector [11]. Emission of air pollutants in the transport sector is the product of the level of activity (passenger and freight travel), structure (share by mode and vehicle type), fuel intensity (fuel efficiency), and emission factor.

However, the emission largely depends on other factors like the engine standard i.e. Euro VI emits less than Euro I [3].

CO_2 from transport is one of the major emissions from road vehicles. The average emission is 130 g CO_2/km for passenger cars. In general, the lower this figure, the less fuel that a vehicle uses: a car with 100g/km CO_2, should have a good fuel economy. One with 180g/km CO_2 or more will use a lot of fuel [1].

As far as CO_2 emission is concerned in Nepal, the transport sector is responsible for more than half of the country's total energy-related CO_2 emissions which was 2190 Kt alone in 2013 [5]. Similarly, the rise in production by the point-source and vehicle registration industries led to an increase in sectoral energy in these two sectors by a factor of 3 and 2, respectively [7]. As a sector, 15% of combustion-based CO_2 emissions came from the transport sector. According to the Google mobility report during the lockdown imposed mobility trends for places that are public transport hubs in Nepal decreased by 58% compared to baseline which is the median value, for the corresponding day of the week, during the five-week period 3 Jan – 6 Feb 2020.

2.4. Emission Factor(EF)

EF are usually calculated by dividing the weight of a pollutant by a unit weight, volume, distance, or interval of the activity emitting the pollutant. These factors are used to calculate emissions from different sources of air pollution [12].

Likewise, EF is a representative or characteristic value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutants. It is given by:

$$\begin{aligned} E &= A \times EF \\ EF &= \frac{E}{A} \end{aligned} \tag{1}$$

Where,

E : Emission in units of pollutant per unit of time

A : Activity rate in units of volume, weight, distance, or duration per unit of time

EF : Emission factor in units of pollutant per unit of weight, volume, distance, or duration

2.5. Factors affecting emission

Several parameters impact the emissions from the vehicles. Some of them are age, number of vehicles, fuel quality, and efficiency, the weight of the vehicle, etc. At present vehicles are one of the major sources of air pollution in the Kathmandu valley as 8, 18, 484 (42% of total vehicles registered in Nepal until April 2015) vehicles were registered in the Bagmati zone [8]. Similarly, in 2016, 78% of the total registered vehicle were motorcycle, 8% car/jeep/van, 3% tractors and trucks, 2% pickup, 1% Bus, and remaining others (tempo, rickshaw, heavy equipment, mini bus, and micro bus). Out of total registered vehicles, 93% are passenger vehicles (private and public), and the remaining 7% are freight vehicles. There was registration of only 4% of the public vehicle (bus, mini bus, micro bus, and taxi) whereas the remaining 96% are private vehicles [4]. More than 90% of the total registered vehicles in the valley are personal vehicles, mostly motorbikes (80%) and light duty

vehicles (12.5%) such as car, jeep, van, and taxi. Over the last 10 years, the annual average growth rate of registered vehicles in the valley has been 17% [10].

CO_2 emissions in Nepal increased from 5,057 kilotons in 2010 to 8,033 kilotons in 2014. The general public perception is that air quality has declined in most of Nepal's cities over the past 10 years [13].

Similarly, the average peak vehicle running speed dropped from 20.8 km per hour in 2012 to 15.2 km per hour in 2019 [13] which shows that the traffic congestion in the valley have not improved yet. Traffic congestion and road conditions are also the factors for causing a higher number of full-size super-emitter buses to generate higher emissions. It is worth mentioning that in Kathmandu the super-emitter fraction is much higher (i.e. 35%) than in other countries [14].

This has led to higher emissions from these old vehicle types. Tippers, indeed, are the recently introduced heavy vehicles for the Kathmandu valley fleet [6] that comply with Euro III requirements and have more sophisticated engine modifications than older vehicles. These vehicles were also found to emit less.

3. Materials and methods

3.1. Study area

Kathmandu Valley is the main interest of study for this research. Kathmandu Valley is comprised of three districts of Nepal: Bhaktapur, Lalitpur, and Kathmandu. It lies at the average elevation of 1,400 masl and covers an area of around 665 sq. km. Valley is the political, cultural, and economic hub of Nepal with a population of almost 3 million. The temperature in the valley is around 2035°C to 35°C in summer and 235°C to 1235°C in winter. Valley experiences an average rainfall of 1400 mm during monsoon which starts from June.

The time period for the study was months of April to July of 2020 as lockdown due to the COVID-19 pandemic was imposed during this period. However, the fuel sales data of FY 2019/20 before lockdown was taken into account for the comparison.

3.2. Method description

The general methodology of the study is as shown in Fig. 1.

The statistics of the vehicle data provided by the Department of Transport Management [6], Nepal is only the cumulative number of vehicles since their first registration and therefore, do not represent the actual vehicle fleet existing and plying on the road each year. Every year, a large number of vehicles are scrapped. The actual vehicle fleet plying on the road can be estimated by subtracting the scrapped vehicles from the annually registered vehicle numbers. However, data for annual scrapping rate do not exist in Nepal. So, the public vehicles older than 20 years are not included which are not allowed to run in the Kathmandu valley.

Another significant factor in road transport energy demand and emissions is the average distance traveled by a vehicle in kilometer in a year, also called 'Annual Vehicle Kilometer Traveled (VKT)'. According to [10], the average annual urban drive VKT for different types of vehicles based on survey data was estimated. The annual VKT declines as the vehicles age over a period

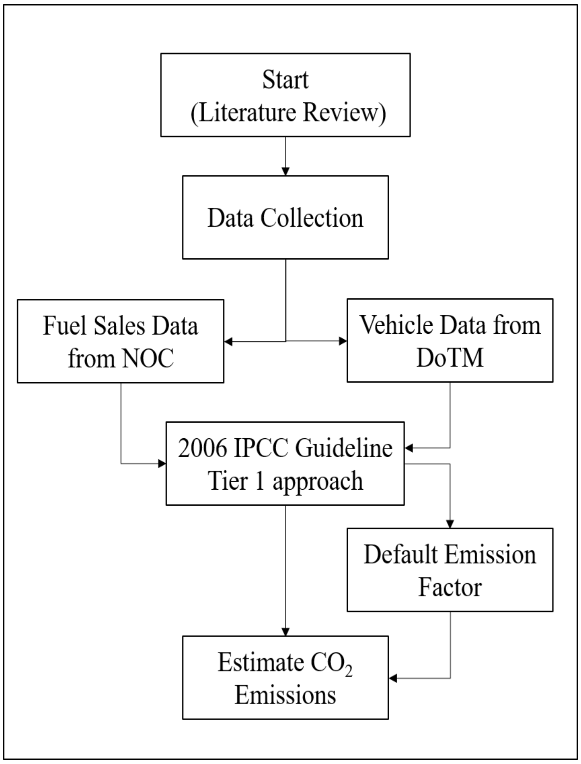

Figure 1: Methodological framework of the study

Table 2: Average annual vehicle kilometer travel(VKT) in the Kathmandu Valley [10]

Vehicle Type	VKT
Bus	44,105
Minibus	43,307
LDV	-
Private(Car/Jeep/Vans)	12,310
Public (Taxi)	25,356
Microbus	38,520
Motorbike	8,952
HDV	37,800
Mini truck	37,415

of time. Therefore, this aging factor has to be considered.

The choice of methods depends on various factors such as the availability of data and the importance of the source category. Since there are no country-specific emission factors for emission assessment in Nepal, the default values provided by the IPCC guidelines are used either in the calculation of the net calorific value or in the CO_2 emission studies or in the carbon oxidation fractions.

Methodologies for estimating national inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases are given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The Tier 1 approach as per IPCC Guidelines for National Greenhouse Gas Inventories, 2006 was used for calculating CO_2 emissions. Represented by the Eq. 2,

Table 3: Emission Factor by Vehicle Type [10]

Vehicle Type	CO_2 (kg/GJ)	CO (g/Km)	NO_x (g/Km)	HC (g/Km)	PM_{10} (g/Km)
Bus	79.7	4.9	6.8	0.87	1.075
Minibus	79.7	4.9	6.8	0.87	1.075
LDV	-	-	-	-	-
Gasoline car	70.54	3.16	0.21	0.19	0.06
Diesel car	54.82	3.16	0.26	0.14	0.18
Jeep /Van	75.66	3.16	0.28	0.32	0.48
Motor-bike	34.71	2.4	0.19	0.52	0.06
HDV	82.61	4.9	9.3	0.87	1.24
Hybrid Car	58.85	0.18	0.019	0.013	0.01

CO_2 from Road Transport

$$E = \sum_a \text{Fuel}_a \times \text{EF}_a \tag{2}$$

Where,

E : Emission of CO_2 (kg)

Fuel_a : Fuel Sold (TJ)

EF_a : Emission factor (kg/TJ). This is equal to the carbon content of the fuel multiplied by 44/12.

a : Type of fuel (eg: petrol, diesel)

Similarly, from [10], for energy demand and emission per mode of transports can be calculated using the Eq. 3

$$ED = N \times VKT \times F \tag{3}$$

Where,

ED : Energy Demand

N : Number of Existing Vehicles

VKT : Average annual mileage in kilometer

F : Average fuel economy in liters per kilometer

Emission from a vehicle is a function of energy consumed by it, therefore given by Eq. 4

$$E = ED \times EF \tag{4}$$

Where,

E : Emission

EF : Energy Factor

ED : Energy Demand

4. Results

4.1. Vehicle registered

From the data obtained from the Department of Transport Management (DoTM) following composition Fig. 2 of vehicle type was obtained till of 2017 AD.

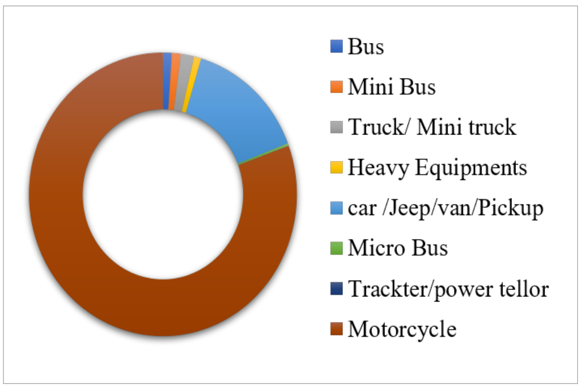

Figure 2: Vehicle types composition in KV

As shown in Fig. 2 Motorcycle/Scooter (2 wheeler) comprised the highest share among the other vehicles at 81% followed by Car/Jeep/Van/Pickup at 14%.

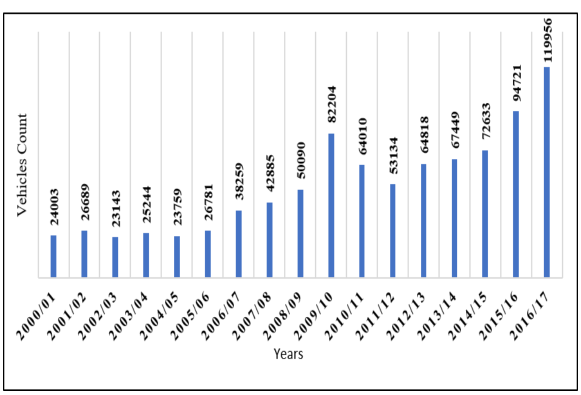

Figure 3: Number of Registered Vehicles in Kathmandu Valley

4.2. Age of vehicles

Considering age as one of the factors for differing emissions from various vehicle types based on the data obtained from DoTM, the number of existing vehicles were categorized as shown in the Fig. 4.

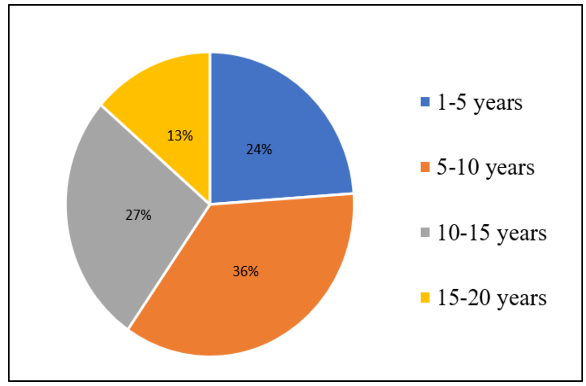

Figure 4: Vehicle Fleet at KV based on age

4.3. Fuel consumption

Fuel sales data obtained from the NOC represents the fuel consumption data.

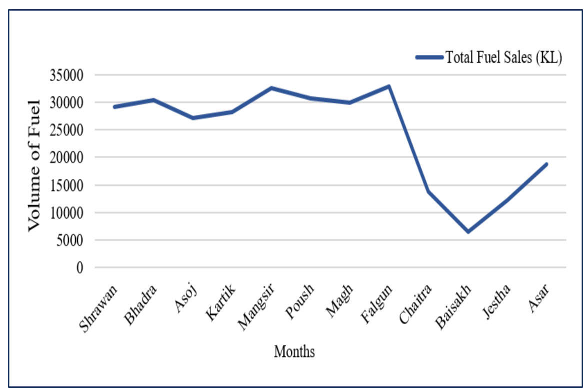

Figure 5: Total fuel sales of KV

Fig. 5 shows the overall fuel sales data of KV for the fiscal year 2076/77 BS (2019/20 AD) where certain drop of the fuel sales can be observed after the month of Falgun till the Baisakh with lowest fuel sales i.e. 6,522 KL during the lockdown period imposed due to the COVID-19 pandemic which shows that the fuel consumption was decreased by 80.11% compared to that of Falgun.

Among the three districts of the valley, Kathmandu had the highest volume of total fuel consumed at 1,04,530 KL MS followed by Lalitpur & Bhaktapur at 25,246 KL & 15,332 KL respectively and 99,306 KL HSD followed by Bhaktapur at 25,803 KL and Lalitpur at 22,016 KL.

In case of Nepal, the diesel sale dominates the MS value by 9,45,806 KL. Whereas the fuel consumption in KV is fluctuating, from Fig. 6, 7 it can be observed that amount of diesel & petrol consumed by road transportation in the KV was 10.12% & 28.57% respectively of

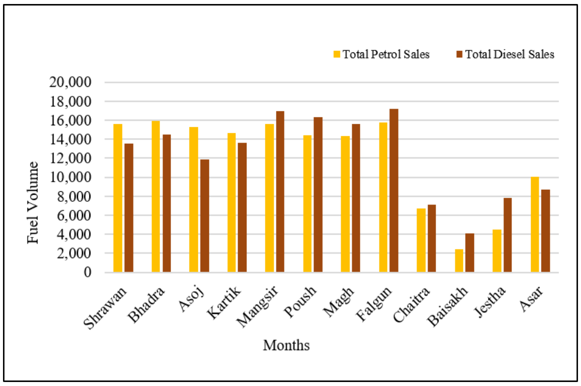

Figure 6: Total Petrol and Diesel Sales of Kathmandu Valley

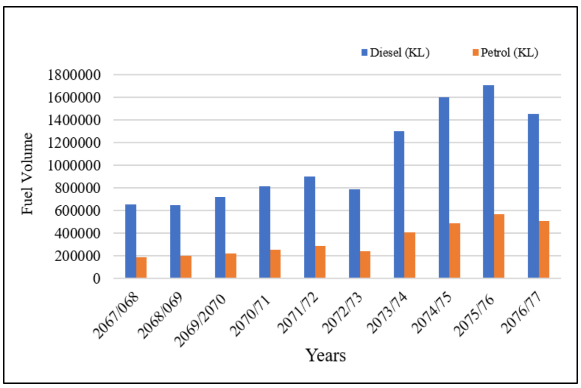

Figure 7: Total Petrol and Diesel Sales of Nepal

total fuel consumed in Nepal for FY 2076/77 BS. 14.9% of total fuel sales of Nepal was consumed in KV alone by road transport for FY 2019/20 AD. In the context of nationwide fuel consumption, diesel is in more amount however in the case of KV, the diesel sales exceed petrol sales only during winter seasons.

4.4. Carbon dioxide emission

Using the Tier 1 approach provided by the 2006 IPCC guidelines the following results were estimated for CO_2 emission.

The total CO_2 emission on Falgun and Mangsir were higher and the lowest was on Baisakh followed by Jestha. This is because of low fuel consumption during these periods than that of normal times. The all-time highest CO_2 emission of the year was 103090 Tonnes and the lowest was 20500 Tonnes. Overall, Diesel accounts for more CO_2 emissions in KV than compared with the emissions from petrol.

From Fig. 8, CO_2 emission had declined by 80.11% after the lockdown was implemented in the valley but later on till Asar it again rose by 65%.

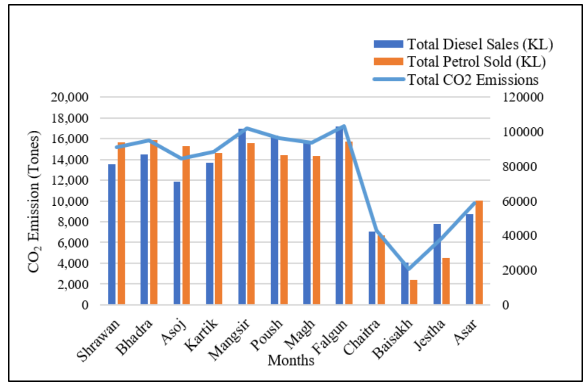

Figure 8: Total Vehicular Emissions

From the Fig. 9, 10, & 11 it can be observed that the drop in the emissions of CO_2 after the month of Falgun till Baisakh. Among the three districts of the valley, Bhaktapur had a decline in CO_2 emission by 75.79%, Lalitpur by 79.96%, and with the highest decline of 81.07% at Kathmandu.

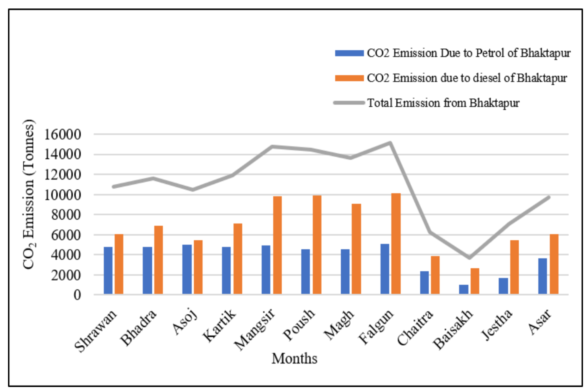

Figure 9: CO_2 Emissions of Bhaktapur

Bhaktapur had CO_2 emission more dominated by the consumption of diesel.

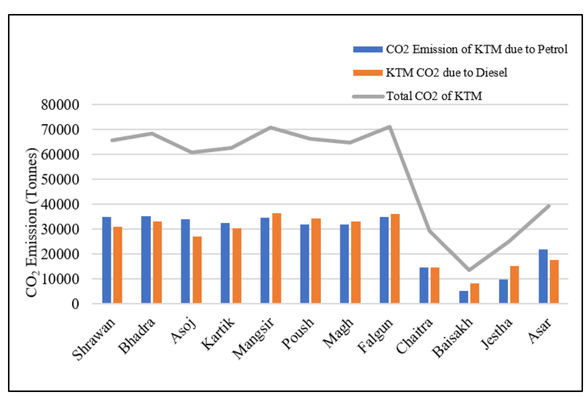

Figure 10: CO_2 Emissions of Kathmandu

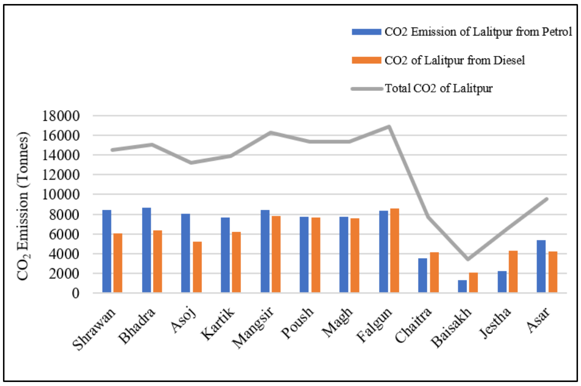

Figure 11: CO_2 Emissions of Lalitpur

Kathmandu and Lalitpur had CO_2 emission more dominated by the consumption of petrol. Among three districts of the valley, Bhaktapur had seen a growth of CO_2 emission by 165.06%, Lalitpur by 181.58% and with highest growth of 192.43% at Kathmandu. This was mainly due to lift down of lockdown.

Emission due to the petrol fuel consumption during the period of lockdown decreased by 84.61% in KV. But there was a growth of 314.84% in CO_2 emission from the petrol consumption after the months of Baisakh.

76.14% decline in CO_2 emission due to the diesel usage was observed. Later on, the value rose up to 112.36% of CO_2 emission from diesel consumption till Asar.

5. Discussion

The atmospheric concentration of carbon dioxide has increased extensively since the industrial revolution due to human activities and has now reached dangerous levels not seen in the last 3 million years. This is because natural sinks remove from the atmosphere about the same amount of carbon dioxide as natural sources produce. This has kept the levels of carbon dioxide balanced and in a safe range. But human sources of emissions have disturbed the natural balance by adding extra carbon dioxide to the atmosphere without eliminating any extra carbon dioxide.

From petrol consumption pattern it can be observed that from Falgun (Mid February – Mid March) onwards there is a decrease in MS Consumption. The lowest recorded MS was 2419.839 KL (Kilo Liter) in Baisakh and it reached up to 10038.949 KL in Asar (Mid June – Mid July). It saw an increase of 314.83%. The MS consumption is high in Lalitpur, Kathmandu and Bhaktapur respectively by district wise.

And for the case of HSD (Diesel), the scenario is a little different. The graph dropped till Baisakh (Mid April – Mid May) month and then gradually started rising and also stable at the end of Asar (Mid June – Mid July) because of the slackness of lockdown. The lowest recorded HSD was 4102.435 KL in Baisakh and it reached up to 8712.200 KL in Asar. It saw an increase of 112.38%. The HSD consumption is high in Kathmandu, Bhaktapur, and Lalitpur respectively by district wise.

Looking at the results one can observe the regain of the sales values from Baisakh onwards. Generally, HSD is used in excessively higher volume as usual in comparison to MS. The graph's annual growth seems to be increasing but in 2015/16 and 2019/20 it is less due to obvious reasons of earthquake & economic blockade and COVID-19 pandemic respectively. However, in the absence of pandemic, there could have been a stable rise in the fuel consumption for the FY 2019/20 as well. The almost equivalent consumption of fuels in KV is due to a higher number of 2-Wheelers and other diesel vehicles.

Nepal had total CO_2 emission of 9.45 million tonnes in 2018 as per Global Carbon Project and the Carbon Dioxide Information Analysis Centre (CDIAC). Due to Nepal's low per capita vehicle ownership rates, the volume of CO_2 emissions from passenger transport in the Valley is lower than that in towns in developed regions of the world. In 2018 Nepal's per capita CO_2 emissions was 0.34 tonnes of CO_2. A key part of understanding global warming and climate change is greenhouse gases. Knowing the fundamentals of their origin and how they affect the planet provides us with tools to be critical of an increasingly politicized problem.

Controlling measures like a ban on vehicles more than 20 years old alone is not sufficient to improve air quality in Kathmandu. Control measures also require taking out of old vehicles from the road and substituting them with vehicles with better technology so that fewer pollutants are emitted, slow down the growth rate of pollution.

6. Conclusion

This report calculates from a mass balance point of view. Kathmandu Valley i.e. the capital city of Nepal produced 9,14,352 tonnes of CO_2 emissions from transportation in the FY 2019/20 from the 2,92,260 KL of fuels. As per the study aims, the fuel sales for KV before the pandemic is slightly fluctuating with simple high and lows whereas after lockdown started from the month of Chaitra (Mid March – Mid April) certain drop in the sales was observed which eventually reduced the CO_2 emission.

7. Recommendations

While rising CO_2 emissions have a clear negative environmental impact, reducing it is important to protect the living conditions for future generations. Based on the findings of the CO_2 emission level, it is recommended to find multiple ways to reduce the emissions. This will help ensure to keep the CO_2 emissions at an optimum level. Some of the ways to achieve lower emissions are: use of mass public transportation, bicycle-friendly infrastructures, periodic emission testing, implementing EURO-VI standards vehicles, EVs, and hybrid vehicles which emits very less CO_2.

Collecting various data about scrappage vehicles, vehicle kilometers, fuel economy and other related info in the national data inventory would further give accuracy to the research.

Other mitigating measures include planting trees, conserving existing forests and grasslands and various awareness program.

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