VEHICULLAR POLLUTION ASSESSMENT AT STREET LEVEL UNDER DIFFERENT TRAFFIC LOAD CONDITIONS

Prof. Rabindra Nath Bhattarai[1] Bhola Thapa[2], Ph.D, Binod Aryal[3], Nawraj Bhattarai[4], Shubha Laxmi Shrestha[5]

[1]Director, Center for Pollution Studies, IOE

[2]Dean, School of Engineering, K.U.

[3]General Manager, Toyota Motors, Nepal, PhD Candidate

[4]Department of Mechanical Engineering, IOE

[5]Manager, Hilltake Industries (P) Ltd., Nepal

Abstract

Traffic congestions on the roads of Nepal especially metropolis like Kathmandu have been increasing at an alarming rate increasing both particulates and GHGs (Green House Gases). In the year 2006 alone the amount of particulates and green house gases (GHGs) from vehicles in Nepal were 642 tons and 10146 tons respectively. The pollutants cause air pollution and global warming. This study relates the emissions from vehicles in the present traffic jam and normal traffic flow conditions with special reference to the emission of particulate pollutants and CO. CLINE4 software was used to determine the pollution dispersion in three dimensions of the selected stretch of the road at selected traffic flow situations ranging from extremely slow moving traffic to normal. The study showed the dispersion of pollutants under different traffic flow conditions and clearly indicated the increase of fuel consumption, CO emission and particulates with the increase of traffic jam on the studied stretch. The energy consumption in one 1km stretch with approximately 800 cars during the extremely slow moving traffic condition (10 or less km/h) versus normal flowing (40km/h) traffic was calculated and found to be appreciable. The fuel consumption reduces to 30% to 50% thereby giving the less polluting tail pipe exhaust with proper traffic management. Appreciable difference was found in TSP as well as CO emission between the normal conditions and traffic jam with slow moving traffic. The study provides input to the reduction of particulate pollutants as well CO emission when the traffic flows in properly managed condition. It also suggests the traffic management systems in narrow Asian cities which can achieve substantial reduction in both pollutants and CO emissions and also enhances the quality of city life for drivers as well as pedestrians.

Keywords: Vehicular pollution, traffic management, GHGs

1.0 Introduction

Pollution, either of air, water, or noise, is the major problem, particularly in the developing countries. Achieving environmentally sustainable transport is a major challenge faced by the countries around the world, and particularly in developing countries which have to cope with transport related environmental problems stemming from the rapid economic growth. The rapid motorization, together with poor land use planning and traffic management condenses the available urban space and accelerates suburbanization thus leading to the development of an inefficient urban traffic system. A vicious circle of motorization and suburbanization has caused serious transport related environmental problems, including traffic congestion, inefficient energy use, as well as air, water and noise pollution. The main problems behind these are large increases in traffic demand, urbanization, motorization, poor control of vehicle emissions, the absence of effective inspection and maintenance systems, lack of adequate and appropriate infrastructures, and poor coordination of transport and land-use policies and road conditions as well

Motor vehicles are a major source of air pollutant emissions in Kathmandu valley, Nepal. In-use vehicle emission limits were first introduced in Nepal in 1998 and updated in 2000. The emission regulations for gasoline vehicles limit CO emissions to 3-4.5°A by volume and HC emissions to 1000 ppm for four-wheeled vehicles, and 7800ppm for two- and three- wheelers. Emission limits for LPG/CNG vehicles are 3% for CO and 1000 ppm for HC. For diesel vehicles, smoke density must not exceed 65-75 HSU depending on the age of the vehicle. The Government operates a rudimentary inspection and maintenance (I/M) program based on an idle engine test, utilizing an exhaust gas analyzer (for gasoline/ LPG/CNG vehicles) and an opacimeter for diesel vehicles. The I/M program is confined to four-wheeled vehicles and occasional three-wheelers. The inspections are required at least once a year and are conducted at designated vehicle testing stations. The I/M program is supplemented by roadside checks.

The present condition of the country, Nepal is getting worse day by day due to various causes like the unsystematic road condition, lack of proper placement of the over road bridges, lack of discipline among people and so on. The day by day life of the people in the valley is getting much problematic. The uncontrolled flow of the vehicles in the valley has resulted to long traffic jam resulting to concentrated noise pollution and the air pollution. Better traffic management is needed at present by imposing rules and regulations to make the environment condition better. Event the road condition has led to inability to run vehicles in the design condition which has increased the emission and needs very careful management to minimize it.

2.0 Problem Description

Kathmandu valley, the capital of Nepal has three major sub-cities called Kathmandu, Lalitpur, and Bhaktapur. Except extremely low length of the road in some selected areas of the city, most of the roads are two lane roads. The length three types of roads, namely Black topped, Graveled Road, and earthen road in Kathmandu is 566.9, 171.9, and 176 km respectively (Department of Roads, Government of Nepal's web). Similarly, it is 162.8, 90.2, and 95.4 Km in Lalitpur and 103.8, 40.1, and 38.2 Km in Bhaktapur. There is not a single flyover even in capital city of Kathmandu, most of the traffic signal lights in the city are either not operated in automatic mode most of the time or they are not in well maintained condition. There is lack of traffic etiquette both among the vehicle operators as well as amongst the pedestrians. The roads are not in well maintained conditions and the city is crowded. On top of that the number of vehicles plying in the three cities were 1163 buses, 1468 minibuses, 4483 trucks/tankers, 27153 Car/van/jeep, 3844 3-wheelers, 58029 2-wheelers, 1672 tractors and, 3020 others in 1996/97 resulting to a total of 100831 which increased to 10063 buses, 4850 minibuses, 13400 trucks/tankers, 85218 Car/van/jeep, 12064 3-wheelers, 165563 2-wheelers, 4770 tractors and, 9478 others in 2006/07. All put together, the traffic is often chaotic and difficult to drive. This is not only a serious threat to the pedestrian's safety but also very conducive to increased pollution due to inefficient and low speed driving often inter-spaced with frequent stop and drive cycle.

Automotive pollution can be controlled not only by tuning the engines but also by providing road environment to drive the vehicles in their optimum speed and load. Automobile pollution aggravated due to bad road and driving conditions and traffic jams, now a regular feature in a number of congestion hot-spots around the city is a major problem.

It is imperative to illustrate the additional pollution loading due to inadequate traffic management both for taking corrective actions and as help for integrated policy planning encompassing road construction, traffic management and pollution reduction.

3.0 Trends in Nepal

The vehicular emissions are composed of the emissions like CO, NOx, SOx, HC, etc. According to "Urban and Environmental Planning in Nepal, the CO emission is the highest in trend and is more by around 5.5:1 and the harmfulness of it is much higher. Table 1 shows the quantitative value of some emission elements for the year 1983 and 1995. (Ambika, 1998)

Table 1 Air Pollution in Kathmandu Valley
* Reported by Reuters

Pollutant	Tonnes emitted	Year
CO	22,000	1983
	56,000	1995*
NOx	4,000	1983
	4,000	1995*
SOx	333	1983
HC	1,000	1995*
Sulfur dioxide	840	1995*

4.0 Environmental Policy of the Country in Relation to Emissions

Activities for monitoring of exhaust emissions in the valley started with a UN project on "Vehicle emission Control in Kathmandu Valley" in 1993.The project aimed at establishing emission standards for the country.

With the establishment of the Ministry of Population and Environment, a number of regulations including standards have been drafted and endorsed in order to be implemented in the context of vehicle emission control.

With a strong backup from the 5-year national plans of the country (mainly the 8th and the 9th 5 year plans), the cases of prevention and control of pollution have been strongly reflected in the Environment Protection Act and the Environment Protection Regulation of the country came into its effect from 1997.

The Act in clause 7 describes, Prevention and Control of Pollution as: Nobody shall create pollution in such manner as to cause significant adverse impacts on the environment or likely to be hazardous to public life and people's health, or dispose or cause to be disposed sound, heat, radioactive rays and the wastes from any mechanical devices, industrial enterprises, or other places contrary to the prescribed standards. The Act of pollution control has been complemented by article 15 of the Environment Protection Rules of 1997 that is described as "Prohibition to emit waste in contravention of the prescribed standards: No person shall emit or cause the emission of noise, heat, radioactive material and waste from any mechanical means, industrial or any other place in contravention of the standards prescribed by the ministry by notification published in the Gazette.

4.1 Nepalese Standard for inspection of used vehicles is as follows:

CO = 3% by volume for all except 4.5% for 2-stroke engines – 1995. HC for gasoline vehicles = 1000 ppm for all except 7500 ppm for 2-stroke engines – 2000. Opacity test for diesel exhaust =65 HSU -1995. Opacity test for old diesel vehicles (revised) =75 HSU -1988

Standard for import of vehicles

- Nepal Standard for Mass Emission (EURO 1 based) – 1999
- The vehicles entering into Nepal should not be more than 5 years old

Compliance plans

- One and half years' of notice given for banning the use of commercial vehicles older than 20 years in Kathmandu valley by December 2001
- One and half years of compliance period given for changing 2-stroke gasoline vehicles to run on LPG
- 3 months period given for repair and maintenance of vehicles that fail the emission test before re-testing

Enforcement plans

- Restriction of areas for the emission test failing vehicles from 1995
- Banning of diesel 3-wheelers in Kathmandu valley since September 1999
- Restriction of import of 2^{nd} hand/reconditioned vehicle since December 1999
- Import of unleaded fuel in Nepal since January 2000
- 10% annual tax raise for vehicles older than 20 years from Kathmandu valley from December 2001
- Banning of 2-stroke 3-wheelers from Kathmandu valley from December 2001

Compensation Plans

- 99% custom rebate for import of public vehicles in Kathmandu against each banned diesel 3-wheelers that abandoned the valley
- Up-to 99% tax rebate for the import of parts that complement the transformation of 2-stroke gasoline engine to run LPG
- Only 1% import tax on parts of electric vehicles to be assembled in Nepal
- 100% tax rebate for the import of pollution control aids and devices
- Lesser import tax for mass transport and goods carrier vehicles

Vehicle Inspection Strategy of the Country: Regular Inspection of the Vehicles

In case of private vehicles, the frequency of inspection is once a year to see whether the vehicle is road worthy or not. The same inspection routine for the commercial vehicles is twice a year. The process of inspection of all the vehicles in the country is under the authority of Department of Roads and Transport Management, under Government of Nepal.

The process of renewing the registration of vehicles is done only after the regular inspection for road worthiness and the emission check. However, the emission check for the used vehicles is done by the Traffic Police Department.

Vehicles failing to meet the national roadworthiness standards are automatically subjected to repair and maintenance. They are not allowed to run from the very day, as their registration is invalid. The vehicles can be taken to any repair and maintenance shop and brought back for re-check

Inspection at the time of Import of Vehicles

Vehicles entering into Nepal have to be within prescribed 1999-Mass Vehicle Emission (EURO 1 based) standard. This check is performed through the certificate of mass emission norms issued by the exporting country's authorized institution for the manufacturer of that particular unit submitted at the Nepalese custom office. Vehicles older than 5 years are not permitted to enter into Nepal.

5.0 Global Tend of Vehicular emission

Nepal is still in EURO I standard although most of the imported cars are of higher standard. It indicates that somewhere in the decision making process, or follow up process, or the implementing process there is something which is/are discouraging moving up to progressively higher emission standard although some concrete and 'bold' decisions like banning of 2 stroke 3 wheelers have been taken in the past by the Government. While the country is still on EURO I, other countries in the region have already moved to higher standards which are quite stringent; Table 2.

Table 2. European emission limits (in g/kwh) Heavy duty engines: European 13-mode test

Gases	Euro I 1992	Euro II 1995	Euro III 2000	Euro IV 2004
NOx	8	7	<5	<3
CO	4.5	4	2.5	1
HC	1.1	1.1	0.7	0.5
PM	0.36	0.15	<0.10	<0.10

The global trend shows the difference in the developed and the developing countries. The emission has been decreasing in the developed countries while the emissions have been increased in the developing countries. The developing countries have to be more concerned in preserving the world by fulfilling its duty as a true citizen of this world.

6.0 Economic costs of air pollution

It is estimated that air pollution costs about US$4 million per year in medical costs for Kathmandu residents. Kathmandu Valley's bowl-like topography and low wind speeds during winter create poor dispersion conditions, which predisposes the area to serious air pollution problems.

The World Bank's Urban Air Quality Management Strategy (URBAIR) Kathmandu Valley Report (1997) estimated that air pollution is the cause of about 85 pollution-related premature deaths, with estimated health damage costs of Rs. 210 (US$4.4) million a year. (World Bank)

7.0 Methodology Adopted

A survey of the pollution hot spots due to traffic jam in Kathmandu valley was made. Finally after many areas, a stretch of the road close to Kalanki, which is the main way for the vehicular traffic to enter and exit Kathmandu valley was selected. A detailed survey of the selected stretch was carried out .Traffic flow data was collected from the traffic police post at Nagdhunga, (Police Post, Nagdhunga) the entry and exit point for vehicular traffic coming in and going out of the valley. Accordingly an average of 2400 'vehicles' meaning a mix of cars, light vehicles, mini buses, buses, trucks and two wheelers go out and enter and leave Kathmandu valley every normal day making the total number of vehicles 4800. The precise number of fleet mix was not available so no attempt has been made to classify the segregation of the fleet mix.

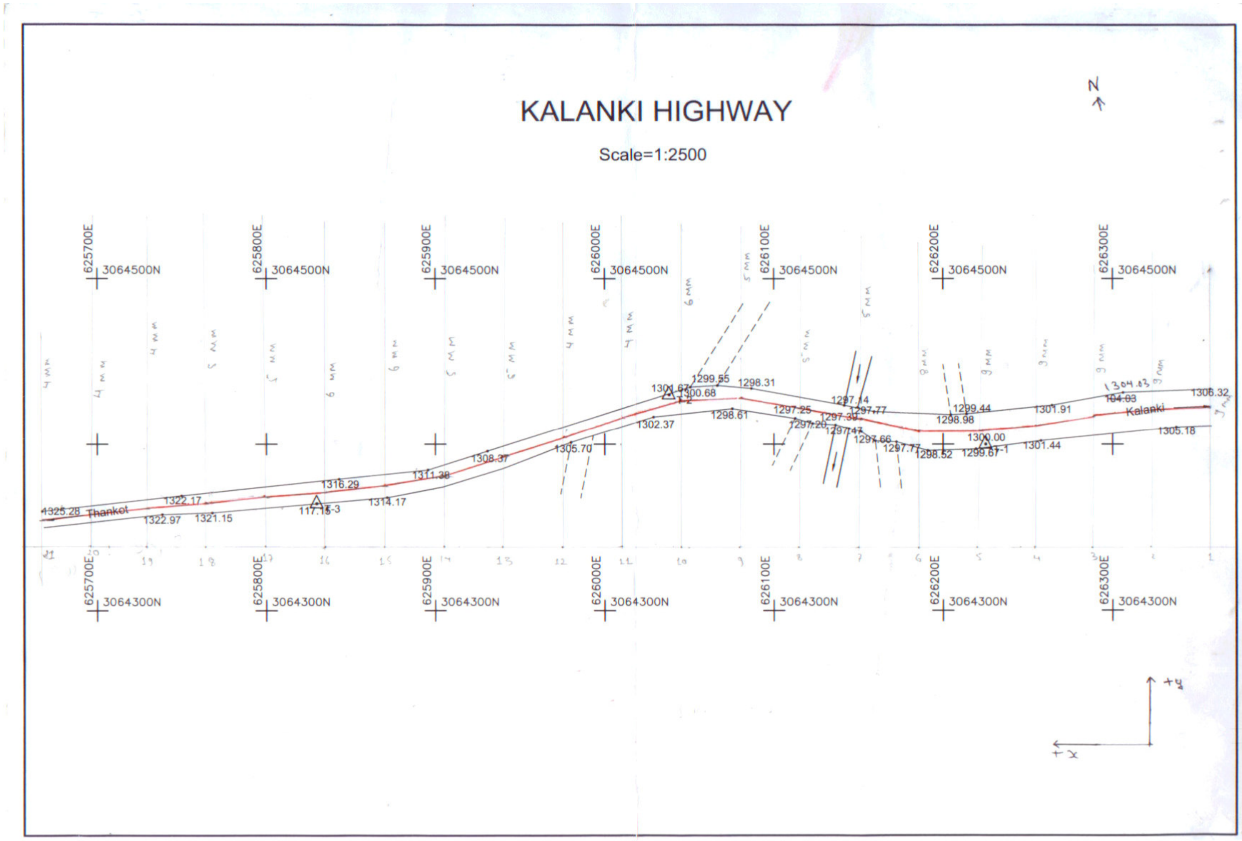
The 4800 number for 24 hours had to be converted to per hour traffic flow for input into the model. The traffic flow pattern in and out of the valley was studied to derive the most appropriate per hour flow. Due to the terrain of the valley and the traffic pattern it was observed that the peak hours of the traffic lied generally between 6 am in the morning to 10 am and 5 pm to 9 pm.

The concentration of Carbon monoxide (CO) was evaluated using CALINE 4 model for the selected stretch in different traffic flow conditions. CALINE 4 (Caltrans, 1989) is a dispersion model that predicts carbon monoxide impacts near roadways. It uses a simple line source Gaussian plume dispersion model. The input that has to be fed by the user includes the geometry of the roadways under study, traffic volume, worst-case metrological parameters, and the receptor positions. The carbon monoxide emission factor for the vehicles has to be provided as well.

The terrain, nearest destination from Kathmandu, culture etc. play an important role in deciding the preference of the people for in and out of valley transport. The nearest cities of commercial importance from Kathmandu are Narayangadh and Pokhara on not considering smaller villages and municipalities like Lekhnath municipality on the way to Pokhara as well as not considering the old Tribhuvan Rajpath. Narayangadh is at a distance of about 120 km from Kathmandu and Pokhara is at a distance of 200 Km. Other destinations are further down from Narayangadh and Pokhara. Gorkha is in between but there is considerably low traffic to and from Gorkha than the other two cities and destinations beyond that. The mountain terrain and the distance to nearest municipality has given rise to the morning-start evening reach or evening start-morning reach travel pattern for most of the vehicles that ply on that route not considering the local traffic which is small compared to the long distance traffic. The traffic was studied and to determine the peak hours so that an appropriate 'hourly traffic rate' could be determined. It was found that the traffic movement peaked during the early hours from 6 in the morning to 10 in the morning and 4 or 5 in the evening, depending on the season, to 8 or 9 in the evening. As such, for appropriate hourly distribution, the total traffic of 4800 was considered to have entered or left Kathmandu valley in 8 hours of a day. Accordingly, the traffic hourly rate was taken as 600/hr.

The selected stretch was divided into equal segments of 20 Links and 10 receptor positions were selected randomly on both sides of the road central line. Figure 1 shows the survey map of the selected stretch and Figure shows survey map of selected stretch.

Figure 1. Survey map of the selected stretch



The Wind angle was selected for ‘worst case’; aerodynamic roughness coefficient was selected for ‘suburban’ scenario, and altitude of 1000 meter has been considered. When the ambient Pollutant Concentration is forced to 0, then what CO (ppm) values the model predicts is done by traffic alone. In order to focus on the traffic induced CO concentration, the ambient Pollutant level was forced/assumed to be 0 ppm. Table 2 shows the run conditions selected.

Table 3 the run conditions for the model

Run	Hour
Wind speed (m/s)	1
Wind direction (degrees)	90
Wind direction Std. Dev. (degrees)	1
Atmospheric Stability (Class 1-7)	7
Mixing Height (meter)	750
Ambient Temperature (degrees C)	15
Ambient Pollutant Concentration (ppm)	0

Numbers of studies have shown that the emission factor depends on the vehicle speed. The engines of the vehicles are designed to operate effectively and efficiently at certain optimum speed. The efficiency decreased both below and above the optimum speed. There are a number of ‘hot spots’ in Kathmandu which frequently experience traffic jams. The jams not only increase the commuting time, driver’s and passenger's irritation, but they cause increase in the CO concentration on the sides of the road and also increase the particulate load in the vicinity. CO concentration is found to increase from 18 gm/mi to 58 gm/mi when the vehicle speed decreases from 30 mph to 2.5 mph, (Handbook of Transportation Engineering, 2004) typical of traffic jam scenario that happens in Kathmandu. The model run was thus made for CO emission factor of 58 gm/mi for traffic jam scenario and 18 gm/mi for non traffic jam scenario and the results are compared.

8.0 Data Analysis and Discussion

Figure The concentration of the predicted CO emission in two scenarios of traffic jam versus clear road on the 10 Receptor positions selected along the road stretch are as follows, Table 4:

Table 4 Predicted CO at different traffic conditions

Receptors	Predicted CO (ppm)	
	Traffic Jam	**Clear traffic**
1	7	2.2
2	6.3	2
3	5.9	1.8
4	5.2	1.6
5	5.9	1.8
6	4.6	1.4
7	2.7	0.8
8	5.4	1.7
9	6.4	2
10	6.6	2.1

Figure 2 shows the plot of CO at different receptors at different traffic conditions and the difference between the two values. The high values refer to traffic jam scenario and the low values represent the CO values when the same stretch of the road is clear and has no jam. The central plot is indicates the differences and the savings in CO when the road stretch is not obstructed. The effects of different links on the receptors are plotted in Figure 3.

Figure 2. CO emissions at different Receptors

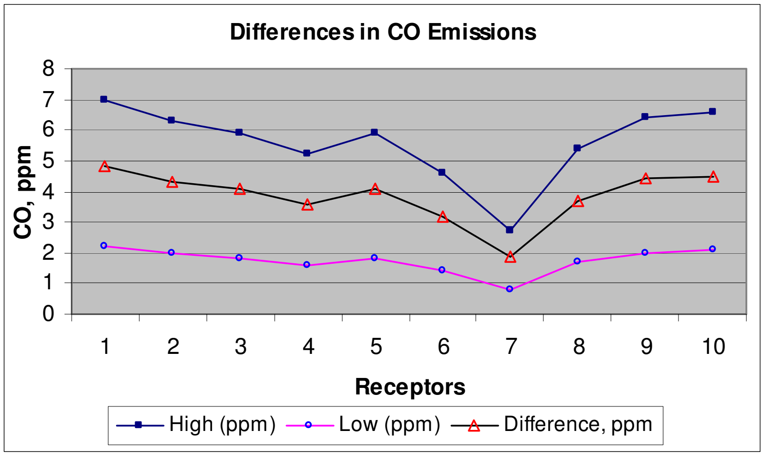
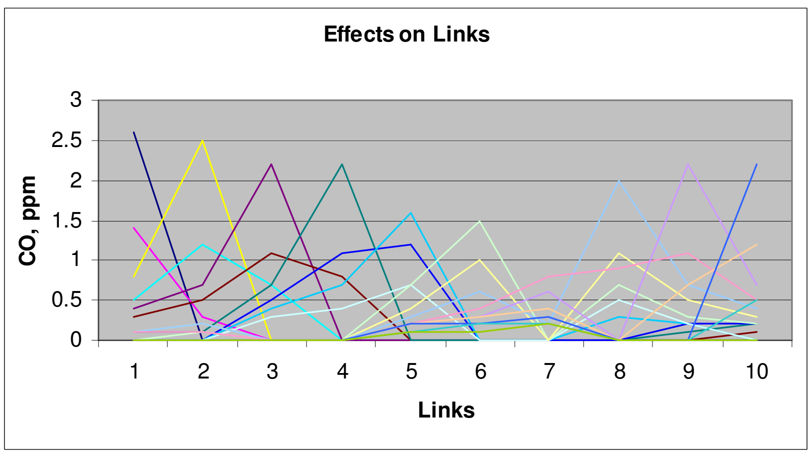


Figure 3. Effect of links on receptors



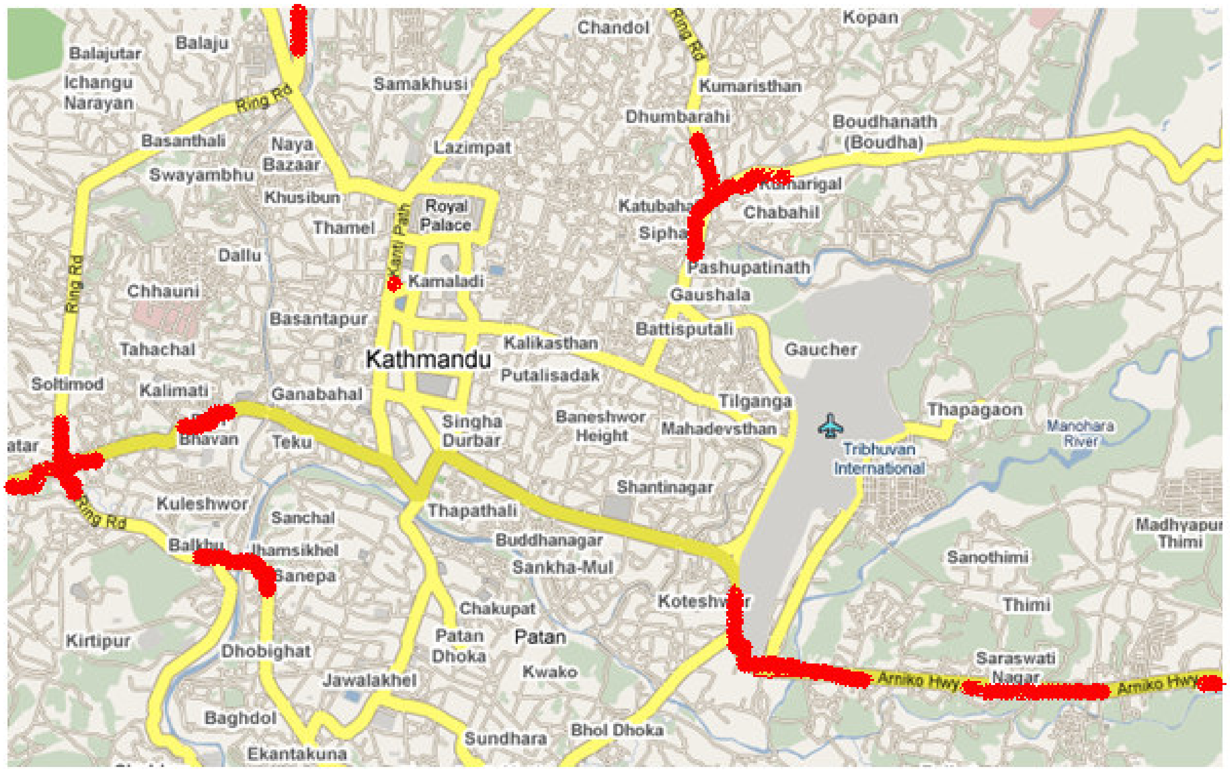
9.0 Traffic hot spots

The difference of CO emission between traffic jam and clear traffic for the 0.7 km stretch under study thus indicates a total of 0.018945 $gmm^{-3}Hr^{-1}$, amounting to 0.1556 gm for 8 hours. There are a number of traffic hot spots which suffer frequent traffic jam. They are Kalanki chowk, a stretch of about 3 kilometer towards Thankot and 1 km each towards Balkhu and New bus part. This amounts to a distance of about 5 km. Other hotspots are From Koteswor to Thimi, a distance of about 5 Km, around Ranipokhari, a total of about 1 km, and about 4 km in some other areas like Balkhu, Balaju, and Chabahil. Figure 4 indicates these hot spots on the map of Kathmandu. Based on these the total length of the hot-spots amounts to 15 km in the valley excluding the places which are not regarded as having regular jams.

The total carbon monoxide loading due to traffic jams contribution adds up to the total of 1.18 Kg a year calculated for 8 hrs day.

The production of NO_X when the traffic is slow moving with velocity less than 10 km/hr and at a speed of about 35 Km/hr are 4.5 gms/mile and 2.4 gms/mile respectively (Handbook of Transportation Engineering) For 600 vehicles difference in the values of NO_X as a result of traffic jam in a similar situation for a total study distance of 0.7 km stretch, the resulting increase of NO_X release amounts to 551.25 gm, amounting to 7.5 tonnes for a year at 8 hrs/day consideration.

Figure 4. Traffic jams hot-spots in Kathmandu



Map of Kathmandu Valley (Courtesy: Google Maps, http://maps.google.com/maps?hl=en&tab=wl)

Energy consumption difference in the test strip was calculated and was found appreciable. However, it was felt that the findings, that the data collected during the study, on which it was based, were not felt to be large enough for generalizing. It was found that the energy consumption depended on the frequency of stop and drive cycle, type of vehicle, load on the vehicle, and so on. Additional inputs regarding the fleet mix was also deemed to be necessary. The generalizing was thus decided to require more extensive study than the scope of this study which is primarily focused on the effects of pollutants due to traffic jam.

10.0 Total Suspended Particulate (TSP)

The studies have shown the average TSP values between 61 and 572μgm^{-3} around Kathmandu Valley. Monthly average data of the urban areas, which have much higher concentrations than the rural areas, even exceeded the daily standard level of PM10 (WHO guidelines TSP: 120 μgm^{-3}).The highest monthly average concentration in urban area is observed at the end of winter and the lowest concentration during the monsoon period. The regular monitoring of TSP at the roadside automobile workshop by using hour. These suspended particles are mainly due to heavy traffic in the road.

11.0 Limitations

The study stretch was selected as the most representative one for Kathmandu city. The limitations inherent in this type of study are:

- Lack of control of study area as it has to be a public road.
- Lack of data on local emission values resulting on the need to use default values.
- Lack of information on fleet-mix
- Lack of detailed hourly vehicular movement

12.0 Conclusion

Traffic jam as a result of bad road condition and traffic management is a common problem in developing countries. It significantly aggravates the vehicular pollution problem. In developing countries, the vehicular pollution problem should be considered in totality with road side management and traffic education. The policy should encompass the proper road maintenance, alternate road construction, traffic education, and proper implementation of traffic rules to mitigate the problems of auto pollution.

13.0 Acknowledgement

The authors would like to express their gratitude to Nagdhunga Police Post for providing information on incoming and outgoing traffic volume.

14.0 References

Ambika Prasad Adhikari, 1998, IUCN "Urban and Environmental Planning In Nepal" Air Pollution in Kathmandu Valley

Air Pollution-Related Health Damage Costs Kathmandu Valley Millions Each Year: World Bank

http://www.dor.gov.np/road_statistic/pavment_category.php, web site of Department of Roads, Government of Nepal.

Danda Pani Pokhrel (2005), Assessment of Occupational Environment in a Few Sections of Mechanical Engineering Workshop of Heavy Equipment Division, Department of Roads, M. Sc. Thesis, Kathmandu University, Nepal

Myer Kutz, 2004. Handbook of Transportation Engineering. Mc. Graw Hill Professional 2004. ISBN 0071391223, 9780071391221

http://maps.google.com/maps?hl=en&tab=wl. Google Map of Kathmandu Valley