An Air Pollution Emission Forecast for Kathmandu Valley, Nepal

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Abstract

This paper describes the results of a study aimed at forecasting air pollution (total suspended particulates, or TSP) emissions for Kathmandu Valley as part of the "Air Pollution in Nepal Project" at Southern Illinois University in Edwardsville. Predictions of TSP emissions were performed for three possible future scenarios. The first possible scenario forecasts TSP levels if no control measures are implemented by the government. The second scenario forecasts what would happen if the government decides to ban vehicles more than 20 years old by 2002/3. The third scenario tested assumes that the government will implement a reduction of tailpipe emissions by 25% and introduce measures to counter the re-suspension of particles by 50% by the fiscal year 2004/5. The results predict that there will be a 37% decrease in TSP in the year 2011/12 compared to projected values for the same year if no action is taken. Such control measures in this third scenario include a rolling ban on vehicles more than 20 years old in addition to programs aimed at reducing tail pipe emissions and controlling the re-suspension of roadside dust.

1. Introduction

Air pollution is one of the immediate environmental problems of utmost concern in Kathmandu, the capital city of Nepal. In order to combat this problem, the Ministry of Population and Environment (MOPE) is looking into different policy options. One of the major actions considered is to control vehicular emission. In November 2000, the Nepal government published a notice stating that all commercially operated two-stroke engine vehicles as well as all vehicles older than 20 years old will be evicted from the Kathmandu Valley. This decision would have banished 4635 heavy vehicles (trucks, busses, and minibuses) and 1120 light vehicles (jeeps, cars, and vans) in the first year alone, and each subsequent year vehicles greater than 20 years old would also be phased out. The decision to evict all 20-year-old and two-stroke engine vehicles (except those vehicles used for private purpose) from Kathmandu Valley created pandemonium in the public transportation sector. When the decision became public, transportation entrepreneurs organized various protests, including a strike of the entire public transportation system throughout Kathmandu Valley. Recently, under tremendous pressure from drivers and the public transportation sector, the government formed a commission to analyze the benefits and shortcomings of the decision. This study contributes to the analysis by presenting possible outcomes of three different scenarios.

According to the Department of Transportation Management, the number of vehicles in the Bagmati area of Kathmandu has increased from 100,831 to 171,678 over the last five years (Table 1). During the last fiscal year alone, 23,143 additional vehicles have come into operation in the streets of Kathmandu. Listed in Table 1 is the total number of vehicles registered in the Bagmati zone over the last five years (CEN, 2001).

Table 1: Vehicle registration data, Bagmati zone

Vehicle Type	1996/97	1997/98	1998/99	1999/00	2000/01
Bus	1163	1298	1403	1632	1744
Mini bus	1468	1500	1527	1610	1804
Truck/Tanker	4483	4759	4811	5295	5484
Car/Jeep/Van	27153	28915	30919	35993	40674
3-Wheeler	3844	3925	4262	4778	4949
2-wheeler	58029	64142	71612	94217	112000
Tractors	1672	1672	1672	1672	1673
Other	3020	3278	3311	3338	3350
Total	100831	109489	117836	148535	171678

Another important source of TSP emission in Kathmandu is industry. Industrial growth has been strong in Kathmandu over the last decade. Kathmandu Valley shares 25% of the total units of industry in the country (UNEP, 2001), with brick and cement industries being the significantly polluting ones. (Pokhrel et al., 1998; URBAIR, 1997). Scenarios of pollutant decrease have targeted both motor vehicle emissions and industrial output. This study focuses on vehicle emissions in the description of three different scenarios.

This project was carried out using an air pollution model to forecast amounts of TSP after implementation of the decision to ban vehicles more than 20 years old. This model incorporated major sources of airborne TSP in Kathmandu Valley. The model simulates the dynamic systems of TSP pollution in Kathmandu, and thus helps us to understand how it may change over time. These forecasts may help to define management plans and policy options.

Problem Definition

Purpose statement:

This model intends to understand the TSP dynamics over various time periods. This model forecasts TSP emissions in Kathmandu up to the fiscal year 2011/12 under various scenarios. The first scenario forecasts TSP emissions if no control measures are implemented by the government. The second test forecasts what will happen if the government decides to ban vehicles more than 20 years old by 2002/3. The third scenario tested assumes that the government will implement a reduction of tailpipe emissions by 25% and introduce measures to counter the re-suspension of particles by 50% by the fiscal year 2004/5. Different control measures may include strict tailpipe emission standards, substituting old vehicles with new ones, better vehicle fuel quality, regular maintenance of road conditions, and the greening of roadsides with plants, among other possibilities.

2. Methodology

A system analysis approach was taken (using a Stella model) for this study. In this model, reservoirs are used to respond to the change in vehicle population over various periods of time. Different reservoirs were input to represent different classes of vehicles namely (1) truck/buses/minibuses, (2) jeeps/ cars/ vans, (3) 3-wheelers, and (4) 2-wheelers. The inflow and outflow factors were calculated referring to data obtained from the Department of Transportation Management for the years 1996/97-2000/01. The product of the number of vehicles, average distance (km) traveled per vehicle, emission factors (g/km), and re-suspension factors (g/km) gives the total amount of TSP produced by vehicles. Clearly, the change in vehicle population will also change the amount of TSP.

However, the amount of TSP in the air is also dependent upon sources other than vehicles. Industries are also large emitters of TSP. Major sources of industrial air pollution in Kathmandu are brick kilns and the Himal cement factory. However, for this study, emissions from non-vehicular sources are held constant through time. Thus, changes in TSP emissions reflect only vehicular activity.

Values for emission factors were provided by URBAIR (1997) and Adhikari (1999)(see APPENDIX). The URBAIR study selected emission factors based on:

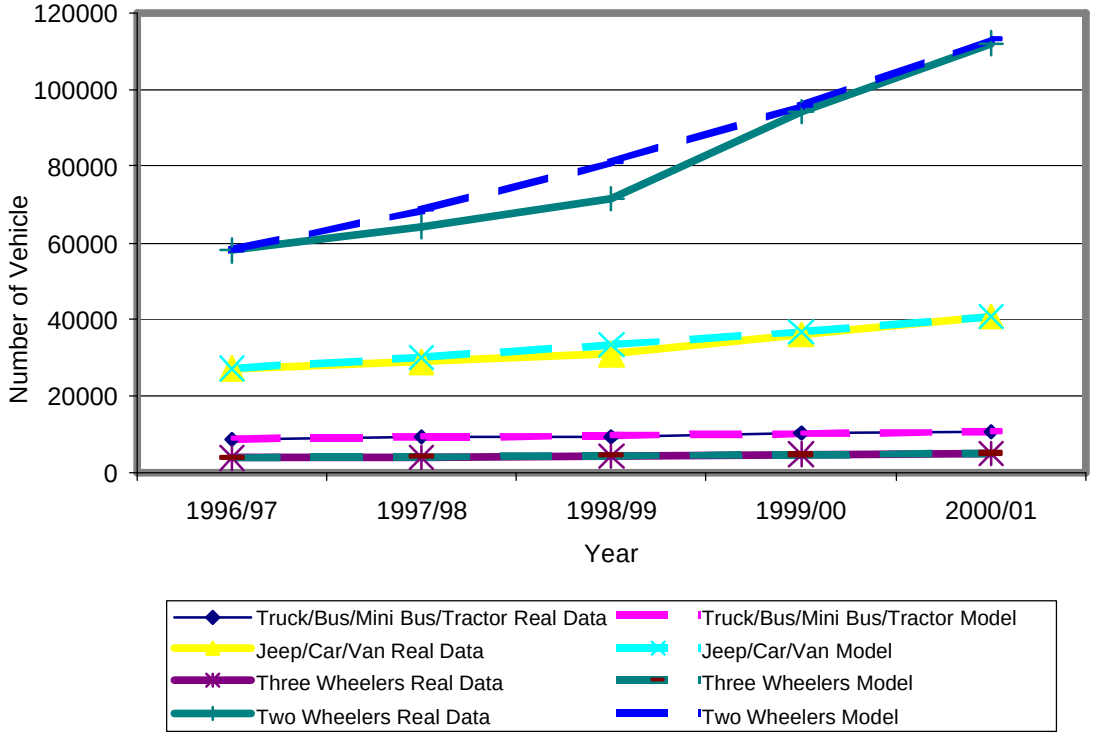
- United States Environmental Protection Agency (EPA) emission factors of the AP42 publication;
- Emission factors of from the World Health Organization's (1993) *Assessment of Source of Air, Water, and Land Pollution", Part I: Rapid inventory technique in Environmental Pollution*;
- Particle emission factors for road vehicles, as deduced from smoke meter measurements in the Kathmandu Valley Vehicular Emission Control Project (KVVECP)(Mathur, 1993)
- Study done by Devkota (1992), Bhattrai (1993), Shrestha and Malla (1993).

In order to be consistent with the URBAIR report, the re-suspension of dust was assumed to be 2 g/km. Likewise, traffic activity calculated in the URBAIR report was used for this study. In addition, traffic activity was calculated based upon data reported by Shrestha (1993) on average fuel consumption and average kilometers traveled annually per vehicle class. TSP emissions were first tested using factors that fit the present unchanging condition. Then the other scenarios were tested.

Model Validity

A model is valid if its prediction of system performance adequately mimics how the system behaves. Models require structural validity and predictive validity. Structural validity was verified reviewing each component of the system diagram. The equations and units were rechecked. The vehicle trend obtained from the model for the years 1996/97-2000/01 was compared to vehicle population data obtained from the Department of Transportation (Figure 1). The model was capable of reproducing past behaviors. However it should be noted that trend of vehicle increase is slightly exponential in nature, where the model generated a linear curve. Thus, the projected number of vehicles and TSP emission is likely to be less than that of actual values.

Figure 1: Vehicle registration data versus projected number of vehicle population using the Stella model



Based on data collected in 1993, URBAIR (1997) estimated the amount of TSP emissions from vehicles to be 2104 tons. The amount of TSP from vehicles estimated by the model for the year 1996/97 was 3274 tons. It should is to be noted that 67,000 vehicles were registered in Kathmandu Valley in the year 1993 (URBAIR, 1997), where 100,831 vehicles operated in Kathmandu in the year 1996/97 (CEN, 2000). Thus, the increase in vehicular TSP emissions 55.6% corresponds nicely with the 50.5% increase in the number of vehicles for the same three-year time period.

3. Results

The fiscal year 1996/97 was taken as the base year for this study. It has been observed that emission of TSP from the vehicles contributes to18% of total emission for this base year. The model was used to make forecasts for a fifteen-year period, from fiscal year 1996/97 through 2011/12. It was assumed that the ban on 20-year-old vehicles would be

implemented on the sixth year (fiscal year 2002/03). It was also assumed that the enforcement of control measures to reduce vehicular emissions and the re-suspension of roadside dust would be implemented for eight years after the base year (i.e. 2004/05).

The model predicted that at the present rate of vehicle increment with no ban, the amounts of TSP would increase by 82% in 15 years time (by 2011/12). If the decision to impose a rolling ban on vehicles more than 20 years old is first enforced in fiscal year 2002/03, then TSP emissions will instead increase by 72%. On the other hand, if all proposed measures are enforced by 2004/05, then TSP levels will increase by only 15% above base year levels. Thus, if the proposed measures are enforced, TSP levels in 2011/12 will be roughly the same to levels in 2002/03 (Table 2).

Table 2: Results showing estimated TSP emission for different scenario at different period of time

Amount of TSP for no action taken (2002/03) (tons)	Amount of TSP with ban of vehicle (2002/03 (tons)	% decrease in TSP
20506	**20218**	**1.4%**

Amount of TSP for no action taken (year 2011/12) (tons)	Amount of TSP with ban of vehicle (year 2011/12) (tons)	% decrease in TSP
32395	**30561**	**5.6%**

Amount of TSP for no action taken (year 2004/05) (tons)	Amount of TSP with ban of vehicle and control measures (year 2004/05) (tons)	% decrease in TSP
22024	**21336**	**3.1%**

Amount of TSP for no action taken (2011/12) (tons)	Amount of TSP with ban of vehicle and control measures (year 2011/12) (tons)	% decrease in TSP
32395	**20505**	**36.70%**

The model projected that the decrease in TSP during the first year of an enforced rolling ban on vehicles more than 20 years old would be rather insignificant at 1.4% (Table 2). However, the cumulative effect would be a 36.7% decrease in TSP in the 15th year

(2011/12; 20,505 tons) in comparison to projected emissions for 2011/12 (32,395 tons) if no control measures are implemented. In brief, TSP emissions in 2011/12 (20,505 tons) would remain at projected 2002/03 levels (20,506 tons) if: a rolling ban on 20-year old vehicles is enforced, if tailpipe emissions are reduced by 25%, and if re-suspended particulates are reduced by 50%.

4. Conclusion

The levels of particulate matters being emitted in the atmosphere of Kathmandu are increasing at an alarming rate. If no environmental measures are implemented to account for the increasing number of vehicles in Kathmandu Valley, it is estimated that emissions of TSP will increase by 82% by the year 2011/12. At the present rate of vehicular increase, it appears that the present control measure being considered (a rolling ban on vehicles more than 20 years old) alone will not be sufficient to improve air quality in Kathmandu. It is also important to control the number of vehicles introduced each year. However, consideration must be given so that such decisions do not compromise the needs of commuters. 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. Since such new technologies are available, we support the decision to ban vehicles that are more than 20 years old. Implementation of such a policy would be advantageous in the long run, as it would help to slow down the growth rate of pollution. Based on the results of forecasts from Stella, we also recommend enforcing standards to lower tailpipe emissions, as well as the implementation of other programs to control the re-suspension of roadside dust.

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APPENDIX: Factors used in Model

	Truck/ Bus/ Mini bus/ Tractor	Car/ Jeep/ Van	3- wheelers	2-wheelers
Inflow rate	0.050	0.107	0.065	0.182
Outflow rate* (for first year after implementation of decision)	0.104	0.086		
Outflow rate (from second years onwards after implementation of decision)	0.002	0.040		
Annual Average km traveled per vehicle	31317	17750	27007	15515
Emission factor (g/km)	2.49	0.772	1.25	0.5
Present Re-suspension factor (g/km)	2	2	2	2
Present control factor	1	1	1	1

Note: Factors were calculated from the data referred to URBAIR (1996) and Adhikari (1999).

* Outflow rate for present is considered zero because there is no record on scarpage rate of vehicles. It is assumed all vehicles registered are plying on road.

Emission Inventory used in model besides vehicles

Source	TSP emission per annum (tons)
Himal Cement	6000
Brick Klins	5182
Fuel Combustion	2907
Miscellaneous	384

Source: URBAIR 1997