ANALYSIS OF AMBIENT AIR QUALITY OF SHIMLA CITY

A PROJECT REPORT

Submitted by

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CERTIFICATE

This is to certify that the report entitled "**Analysis of Ambient Air Quality for Shimla City**" of the project is submitted by **Sabnam Thapa (111639),** in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering from Jaypee University of Information Technology, Waknaghat, Solan, and has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

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ABSTRACT

Air pollution is a matter of grave concern all over the world. The World Health Organization publication as of 16th September, 2014 reported that air pollution is responsible for the loss 7 million lives annually worldwide. A developing country like India has made its own contributions to the existing air pollution problems with its accelerating growth rate in the transportation sector, a booming construction industry, and a growing industrial sector.

In this context, numerous research papers and reports have been published about assessment of Ambient Air Quality in metro and tier I cities of India like Delhi, Mumbai, Kolkata, Pune and Bangalore. However for tier II cities like Chandigarh and Shimla, very little literature are available. Hence this project is an attempt to analyze the existing air quality of Shimla by assessing the change in ambient air quality in Shimla for over a decade (2004-2013) in the two monitoring locations, the Ridge and the Old ISBT of Shimla. The pollutants considered in this study are SO_2, NO_x and PM_{10} as only these three pollutants were monitored by the Himachal Pradesh Central Pollution Board (HPCPCB) in accordance to the National Air Quality Monitoring Program (NAMP) criteria for stations with minimal air pollution problems.

Shimla is not an industrialized city neither a place where mining and extensive agricultural practices prevail, however as would be discussed later, slightly higher than the permissible limits for RSPM still persists in this town. As transportation is a one of the predominant causes of air pollution, hence air pollution in Shimla could be attributed primarily due to vehicular exhausts. Thus, an initial modeling using a screening model called the DMRB screening model (*The Design Manual for Roads and Bridges)* was performed to predict the concentration of these pollutants-mainly NO_x and RSPM at the old ISBT. Test cases of model were done to check the accuracy of the model and inter comparisons of modeled and monitored data were done to check the reliability of the results obtained. It is worth mentioning that DMRB is just a basic screening model and yields quiet conservative results as it was designed to yield for the worst case scenario. But despite these drawbacks and all the assumptions that had to be made to run the model, the results that were obtained after running the DMRB modeling were fairly comparable to the monitored data. Hence no further detailed assessment were undertaken and instead prediction of the pollutant concentrations was done employing the screening model.

SUMMARY

The project titled "Ambient Air Quality Analysis of Shimla City" is targeted to present the analysis of monitored data, conclusions and recommendations when drafting air quality management plans for Shimla city. Numerous literature are available on existing air quality scenario in metro and tier I cities of India like Delhi, Mumbai, Kolkata, Pune, Bangalore etc but for tier II cities like Shimla and Chandigarh, very limited information are accessible. Hence this project with the aim of assessing the change in ambient air quality in Shimla over a decade (2004-2013), is an attempt to bridge this gap by providing information on air quality of Shimla by the analysis of the ten year long monitored data to understand the trend of air quality for the past one decade and after having acknowledged the unique air quality scenario then, make predictions of the future pollutant levels. Thus Annual, Seasonal and Monthly mean graphical analysis are first conducted with efforts to reason why typical graphical variations prevail. And then to predict future pollutant concentrations level, a simple Air Quality Modeling called the DMRB screening model have been employed. But before using the model, its validity and applicability have been tested by conducting two test samples followed by modeling the one decade long data and comparing these modeled and monitored data. Some basic statistical tools have also been employed to bring about an interrelation between the modeled and monitored data set. When these evaluations bore appreciable results, the DMRM model was finally used to predict pollutant concentration for Shimla city for the next five years. After predicting future pollutant levels, measures have been suggested to abate air pollution for Shimla city.

Introduction

India is one of the fastest growing economies in the world and with the new Government's "Make in India" initiative; the manufacturing industry would further take an uphill ride. But it is a well established fact that rapid urbanization and growth of motor vehicles are associated directly to the rapid rise in air pollution. Already, a WHO report released this year, ranked India with China as the worst air pollution affected countries of the world. Hence one cannot simply ignore the surging problem of air pollution irrespective of one's location or region.

According to a report, "Guidelines for Ambient Air Quality Monitoring" published by Dr. B. Sengupta, Member Secretary, Central Pollution Control Board, Delhi – 32, the major causes of air pollution in India are (i) Vehicles (ii) Industries and (iii) Domestic sources. The report also states that the reason why India had elevated levels of air pollution were because of (a) poor fuel quality (b) wrong sitting of industries (c) no pollution prevention measures taken during industrialization in India (d) Uncontrolled growth of vehicle population and (e) poor vehicle design. In order to ascertain the deteriorating air quality, to assess the existing and the anticipated pollutant concentration and to gauge how effective control measures were, monitoring of air pollutants are done. Modeling of pollutant concentration helps in the assessment of the air quality of a place and helps in making predictions of the future air pollutants with the help of relevant predicted input data sets. The type of assessment model chosen for a particular site depends upon the developmental features, input data available and the quality impacts.

Screening models are basic models which are quick to run and helps to determine if a further more detailed modeling is necessary. Hence these kinds of dispersion modeling are applied prior to any detailed modeling and especially if the predicted changes in the traffic are below 10%. Some of the examples of screening models are FRAME, ADAMS, RTDM3.2, AERMOD and DMRB screening model. In this study DMRB screening model is employed.

Detailed dispersion modeling requires detailed inputs to be able to efficiently provide reliable analyzing results. These types of modes are usually more complex but don't necessarily provide a more appropriate method of assessing air quality. Some of the examples of such detailed dispersion models are AERMOD, CALPUFF, BLP, CALIN3 and HOTMAC & RAPTAD.

In situations where traffic changes are less than 10%, screening models are just about adequate. It is pertinent to state that *"Modeled concentrations of airborne pollutants have an inherent level* *of uncertainty associated with them due to uncertainties in the model itself and the input parameters used (DEFRA, 2003).”* And while running models, a lot of assumptions have to be made. But the modeled outputs fairly comparable results to the monitored data. Thus to gain higher accuracy, utmost care should be taken while monitoring air quality and also while carrying out analyzing tasks and the modeled output should always be verified with the monitored data.

Literature review

Design Manual for Roads and Bridges (DMRB) is simple a screening model air quality tool used as an assessment tool that was developed by Department of Transport, DEFRA(Department of Environment, Food and Rular areas), UK.

According to the design manual for Roads and bridges, volume 11 section 3 in Annex 3 "*major difference between the Screening Method given and a more detailed study is that the latter should take into account special and unusual features of the scheme. That is not the case in the screening procedure, which is based largely on average statistics (concerning, for example, the composition of the traffic and the site dispersion characteristics) and is universally applicable. It is specifically the unusual aspects of a scheme that determine the size and nature of those differences between the air quality impacts it forecasts and those determined in a more accurate assessment.*"

It is of great significance that the right type of assessment model is chosen for a site under study so that comparable results are obtained and right conclusions are drawn. The selection of the type of assessment model from this study showed dependence on the type of assessment to be done: detailed or wholesome, available input data, the causes of pollutant concentrations and resources available. According to "Development Control: Planning for Air Quality" (NSCA, 2006) "*selection of the type of assessment method depends on the likely scale of the air quality impacts and the features of the development. Screening methods are quick to apply and can be used as an initial first step to identify whether further more detailed modeling is required. Where predicted changes in traffic or emissions are small (say <10%), a screening method will normally be adequate. In these situations screening models work well and more complex modeling is often unnecessary."* However a report on DMRB screening model clearly stated that irrespective of the type of situation, screening model should always be run first. And if the need be followed by a more detailed dispersing model.

The designers of this screening model built it so that it "errs at the side of caution" as stated in paragraph 12.11 chapter 12 of the air quality impact assessment by the Enviros Consulting Lt. The model always yields conservative results as found by many a studies. Some of the paper discussed below further strengthens this point.

A report submitted by Rajiv Ganguly et al involved the application of the DMRB screening to predict the concentration of CO, benzene, NOx and PM_{10} at the roundabout and motorway sites in Ireland. The inter-comparison of the two versions of DMRB models- 1999 and 2003, resulted in proving that the newer version of the screen DMRB model was more efficient than the old version at predicting reduced concentrations for NOx and PM_{10} and yielding other pollutant concentrations closer values to the monitored values for both the sites. The report also showed that the level of over prediction was seen to depend on assumed average vehicle speed and came to a conclusion that the DMRB model gives conservative estimates of traffic emission impact.

In chapter 12 of the air quality impact assessment, a study of road traffic emissions at existing sensitive receptors likely to be affected by development was carried out by Enviros Consulting Lt. The assessment carried out employing DMRB model showed that predicted concentrations of CO, Benzene and 1, 3-butadiene and NO_2 would not exceed the Air Quality Objectives in 2008 or 2021 at all of the sensitive receptors assessed. Whereas the PM_{10} limit values was exceeded for 2008 and 2021. The modeled results were not verified though no further assessment modeling gauged to be done.

In reference to the Response to comments from Wyre Borough Council (WBC) neighborhood services (Pollution control) carried out by the Westlake Scientific Consulting (WSC), despite assuming conservative parameters such as high the percentage of HDVs and low the speed of the traffic, the estimated concentrations of NO_2 on Vicarage Road came out to be lower (22 $\mu g/m^3$) than the objective (40 $\mu g/m^3$) and thus further more detailed analysis was not carried out.

The study carried out in the project also converges to the conclusion that the model does generates conservative modeled results as the modeled data differed by an average of 15.17% for NOx and 18.82% for RSPM. As this percentage difference was fairly comparable to the acceptance percentage limit of 15%, no further detailed dispersion modeling was carried out for Shimla city. Hence it is concluded that DMRB screening model is a fairly reliable model that yields conservative results and therefore need to be employed accordingly.

Chapter 1

Theory of Air pollution.

Air pollution is proliferating at an alarming rate worldwide. The consequences of which ranges from premature mortality due to aggravated morbidity effects such as respiratory illnesses; ecological impacts like loss of productivity and slower photosynthesis rate in plants; structural impacts such as corrosion of metal and bleaching of monuments; to aesthetic impacts including bad smell, reduced visibility and accumulation of soot and dust on buildings. Besides having such adverse impacts on human health and the environment, air pollution has multiple sources ranging from – vehicle exhaust, resuspended dust on the roads due to vehicle movements, industrial flumes, construction debris, garbage burning, domestic cooking and heating, and some seasonal sources such as agricultural field residue burning.

Characteristics, Causes and Effects of the major pollutants under study

Under N.A.M.P., four air pollutants *viz*., SO_2, NOX and SPM and Respirable Suspended RSPM/PM_{10}, have been identified for regular monitoring at all the locations. Since pollutants monitored by HPCPCB were RSPM, SO_2 and NOx, our study is limited to this.

1.1 Particulate matter

Re-suspended Particulate matter (also called RSPM) is a complex mixture of suspended dust, small liquid droplets and both organic and inorganic substances of such as fumes, smoke, dust, pollens and aerosols of varying size, composition and origin. PM_{10} represents the fraction of SP that is penetrable in the respiratory system of humans as its aerodynamic diameter is ≤ 10 µm. One of the broadest ways of categorizing PM is by distinguishing them into two size ranges:

a) Coarse **Particles:** particles with a size ranging from 2.5 to 10 µm (PM_{10} - $PM_{2.5}$).These particles are called PM_{10}, which stands for Particulate matter up to 10 micrometer in size.
b) Fine **Particles:** fraction contains the smaller ones with a size up to 2.5 µm ($PM_{2.5}$). The particles in the fine fraction which are smaller than 0.1 µm are called ultrafine particles.

According to this classification, PM_{10} and $PM_{2.5}$ have these properties:

Properties	PM_{10}	$PM_{2.5}$
Composition	Smoke, dust from road and factories, Mold, Spores and Pollens.	Toxic Organic compounds and Heavy Metals
Source	Crushing and grinding of rocks, Mining process, burning Fossils, dust from road, plant and insect parts and evaporation of sea spray.	Automobiles, burning plants, smelting and metal processing. Mostly formed from gases. Ultrafine particles formed by Nucleation.
Aerodynamic Properties	Heavier than $PM_{2.5}$ thus settles sooner. It travels slower. Gets stuck in the sideways and pathways of lungs. Thus lesser harmful.	Lighter than PM_{10} and remains suspended in the air. Travels faster. Can go farther into the lungs without being inhibited. Thus very hazardous.
Hazardous	Lesser hazardous than $PM_{2.5.}$	It's small size and the heavy-metal content makes it very hazardous to health of humans, animals and plants

Table 1.1: Distinctions between the Properties and sources of PM_{10} and $PM_{2.5}$

Some of the harmful environmental and health impacts of RSPM are:

1) Health problems:
   a) Breathing problems, respiratory infection
   b) Aggravates asthma, lung cancer.

c) Premature death of infants

d) Reduced visibility, irritation in the eyes, shortness of breath

e) Chronic bronchitis

f) Irregular Heartbeat, irritation in the airways and cancer.

2) Environmental effects

a) Increased Acidity of lakes and streams

b) Interferes with photosynthesis in plants by forming a film on the leaves and inhibits the growth of plants by disturbing the nutrient balance in the soil.

c) Damage the forest and crops

d) Reduce visibility

3) Structures

a) Reduces the useful life period and aesthetic appeal of edifices

b) Exacerbates the physical and chemical deterioration of materials

c) Suspended PM absorbs acidic gases like SO_2 and NO_2 forming acid-forming aerosols. These aerosols are capable of promoting the rate at which reinforcement corrodes.

d) Acid forming Aerosols reduce the life expectancy of paint- it causes discoloration, loss of paint thickness and its gloss.

e) Innervates the damage and soiling of materials.

Method for assessment of (RSPM/ PM10) in Ambient Air

Monitoring of RSPM is carried out for 24 hours with 8-hourly sampling. RSPM is measured gravimetrically with GFA/EPM 2000 filter paper using respirable dust sampler. In a gravimetric method, air is drawn through a size sensitive inlet at a flow rate of 1.1 m^3/min. Here the particulate matter is fractionated in two aerodynamic diameter size ranges, the 0-10 micro meter called RSPM of PM_{10} and above 10 micro meters called coarse fraction. The PM_{10} is collected on a 20.3 X 25.4 cm (8 X 10 in) filter. The mass of these particles is determined by the difference in filter weights prior to and after sampling. The concentration of PM_{10} is then calculated by dividing the weight gain of the filter by the volume of air sampled.

Fig 1.1 Respirable dust Sampler

1.2 Nitrogen dioxide (NOx):

It is a generic name given to a family of seven compounds

Formula	Name	Nitrogen Valence	Properties
N_2O	Nitrous oxide	1	Colorless, Water soluble, Short life, Ozone depleting nature. It is found in abundance.
NO N_2O_2	Nitric oxide Dinitrogen Dioxide	2	Both gases are colorless and slightly soluble in water. NO found in abundance while N_2O_2 found on small concentrations.
N_2O_3	Dinitrogen Trioxide	3	Black solid. Soluble in water and decomposes in it. Exists in small concentration.

NO_2 N_2O_4	Nitrogen Dioxide Dinitrogen Tetra-oxide	4	Red brownish gas. Highly soluble and decomposable in water. NO_2 is found in abundance but N_2O_4 is only found in small concentration in the atmosphere. NO_2 is a greenhouse gas.
N_2O_5	Dinitrogen Pent-oxide	5	White solid. Very soluble in water and decomposes too. Most highly ionized form of NOx and highly reactive. Found in small concentrations.

Table 1.2: Properties of various NOx constituents.

Some of the sources of NOx are as follows

1) Biogenic sources:
   a) Lightening, b) forest fires, c) Agricultural fertilizers, d) Natural Nitrogen fixation by denitrifying bacterial action.
2) Anthropogenic Activities
   a) Mobile sources- 50%
   b) Electric Power Plant-20%
   c) Everything else-30

The adverse effects of NOx are:

1) Health effects:
   a) Inflammation of airways and increased respiratory symptoms in Healthy Individuals.
   b) Reduction in lung function
   c) Aggravate Heart diseases, asthma and bronchitis
   d) Premature deaths

2) Environmental impact

a) In presence of ammonia, moisture and other compounds form acid rain. Acidifies water-bodies bringing chemical imbalance.
b) Contributes Eutrophication and killing of aquatic life.
c) NO_2 in particular is a Greenhouse gas as stated in the table above. Increased NOx concentration in the atmosphere leads to global warming causing i) gradual rise in temperature of earth ii) rise in sea level iii) various human health problems iv) extinction of certain flora and fauna.
d) Damage to forest and crops due to acidification of leaves and promoting nutrient deficiency in the soil.
e) Contributes to reduced visibility especially in the urban areas.
f) Accelerates the weathering of structures.
g) Formation of toxic compounds which leads to biological mutation when NOx combines with organic chemicals like nitrate radical, nitroarenes, and nitrosamines and even ozone.

Method for assessment of NOx in the Ambient Air

In the assessment of the NOx from ambient air, it is absorbed in a solution of sodium hydroxide interference of sulphur dioxide is eliminated by converting it to sulphuric acid by addition of hydrogen peroxide. The absorbed nitrogen dioxide is then reacted with sulphanilamide in the presence of phosphoric acid at a pH of less than 2 and then coupling it with N-(1Nepthyl) ethylenediamine dihydrochloride. The absorbance of the highly coloured azo dye is measured on spectrophotometer at a wavelength of 540 nm. The detection range of the NO_2 concentration is 9 – 750 μg/m^3. The concentration of nitrite ion (NO_{-2}) produced during sampling is determined colorimetrically by reacting the nitrite ion with phosphoric acid, sulfanilamide, and N-(1-naphthyl)-ethylenediamine di-hydrochloride (NEDA) and measuring the absorbance of the Colored azo-dye at 540 nm.

a) The nominal range of the method is 9 to 750 μg NO2/m^3 (0.005 to 0.4 ppm)3. The range of the analysis is 0.04 to 2.0 μg NO_2/ml, following Beer's Law throughout this range (0 to 1.0 absorbance units). Under the specified conditions of 50 ml of absorbing reagent, a sampling rate of 200 cm^3 /min for 24 hours, and a sampling efficiency of 0.82, the range of the method is, therefore, 9 to 420 μg/NO_2/m^3 (0.005 to 0.22 ppm).Nitrogen dioxide concentrations in the range of 420 to 750 μg/m^3 (0.22 to 0.4 ppm) are accurately measured by 1:1 dilution of the collected sample.

b) Based on results from a collaborative study, the within laboratory standard deviation is 8 μg/m3 (0.004 ppm) and the between laboratory standard deviation is 11 μg/m3 (0.006 ppm) over the range of 50 to 300 μg NO_2/m^3 (0.027 to 1.16 ppm).

c) Based on results from a collaborative study, the method has an average bias of -3% over the range of 50 to300 μg NO_2/m^3 (0.027 to 0.16 ppm.

1.3 Sulphur dioxides (SO_2)

Sulphur dioxide is a very reactive and colorless gas with distinguished pungent- choking odor. It readily dissolves in water forming Sulphuric acid which is a major component of acid rain. It is good oxidizing and reducing agent.

Causes of SO_2 emissions

1) Fossil fuel consumption for generation of electricity (73%)
2) Industrial activities (20%)
3) Smelting of Mineral ores, petroleum refineries, cement manufacture, paper pulp manufacture, metal smelting and production facilities, volcanic eruption, tobacco smoking and vehicle exhausts

Some of the effects of SO_2 are

1) Health Effects
   a) Irritation to nose, lungs and airways
   b) Chest pain, shortness of breath, coughing and wheezing
   c) Cause of death and severe respiratory illnesses like asthma, bronchitis
   d) Premature death and cardiovascular diseases

2) Environmental impact
   a) SO_2 and NOx make up the major content of Acid rain.
   b) Acidification of water-bodies killing the aquatic life.

c) Damage the crops and forest directly upon falling on the leaves, acidification of soil and nutrient depletion
d) Corrodes the reinforcements and accelerates the weathering of buildings.

Method for assessment of SO_2 in the Ambient Air

Sulphur dioxide content in the ambient air is measured by the modified **West and Gaeke method**. Sulphur dioxide in ambient air is absorbed in a solution of 0.04M sodium tetrachloromercurate at an average flow rate of 1 liter per minute (LPM), resulting in the formation of dischlorosulphitomercurate complex. The main interference is due to the oxides of nitrogen, ozone and trace metals. Interference from oxides of nitrogen can be prevented by adding sulphamic acid, which acts as a reducing agent and converts some of the oxygenated nitrogen species to nitrogen gas. Interference from ozone can be eliminated by aging the sample prior to analysis. Interference from trace metals can be prevented by adding EDTA (disodium salt) to the unexposed absorbing solution. For analysis, the exposed sample is treated with sulphamic acid, formaldehyde and acid bleached pararosaniline containing hydrochloric acid. Pararosaniline, formaldehyde and bisulfite anion react to form violet red colored pararosaniline methyl sulphonic acid. The intensity of the color is measured on a spectrophotometer at 560 nm wavelength. The detection range of the SO_2 concentration is 4 – 1050 $\mu g/m^3$.

Concentration of sulphur dioxide in the range of 25-1050 $\mu g/m^3$ can be measured under the conditions given one can measure concentration below 25 $\mu g/m^3$ by sampling larger volumes of air, but only if, the absorber efficiency of the particular system is first determined and found to be satisfactory. Higher concentration can be analyzed by using smaller gas samples of a suitable aliquot of the collected sampler. Beer's law is followed through the working range from 0.03 to 1.0 absorbance unit. This corresponds to 0.8-27 μg of sulfite ion in 25 ml of final solution calculated as sulphur dioxide. The lower limit of detection of sulphur dioxide in 10 ml absorbing reagent is 0.75 μg based on twice the standard deviation, which represents a concentration of 25 $\mu g/m^3$ in an air sample of 30 liters.

Pollutant	Time weighted Average	Concentration In ambient Air		
		Residential, Rular and other areas in µg/m^3	Industrial Areas in µg/m^3	Sensitive Areas in µg/m^3
RSPM	Annual	60	120	50
	24 Hours	80	150	75
SO_2	Annual	50	80	15
	24 Hours	80	120	30
NOx	Annual	40	80	15
	24 Hours	70	12	30

Table 1.3 Summarized Permissible Concentration Limits for Different Air Pollutants

Chapter 2

Air Quality monitoring stations for Shimla.

Fig 2.1 Monitoring Station I for Shimla, Tekka Bench

Tekka bench or more popularly **the Ridge** is situated in the heart of Shimla city. It is the main attraction of the city, famous for its Neo Gothic Christ church, Town hall and Gaiety Theater. It is always bustling with people and so only few licensed vehicles are permitted to be driven around here. The Ridge hosts various government events and fairs during festive seasons or important dates. Besides this, it houses the water reservoir that supplies water to the entire city. This location was chosen to be **Station I** (**the Background site)** for air quality monitoring by HPCPCB as conversed to me by Junior Scientist ,Mr. Parveen Sharma from the HPCPCB for following reasons:

1) It exemplifies a place with the least possibility of traffic pollution**.**
2) Easy access to the site and convenient to travel.
3) Availability of site sheltering and facilities such as electricity of sufficient rating, water, telephone connection etc.
4) Vandal proof and protected from extreme weather

2.2 Station II - Old ISBT

Fig 2.2 Monitoring Station II for Shimla, Old ISBT

The State bus terminal houses the HRTC, HPTDC and other private buses besides harboring parking area for dozens of taxies. Despite having these important services to suffice, the bus terminal is **severely congested** with heavy traffic flows during peak hours, with no pedestrian pathways and vehicles moving in an unregulated pattern. Other than this problem, the old ISBT is has poor drainage system and there are litters all around. The garbage containers are emptied irregularly and the road is also unkempt and congested. This location was thus chosen as station II as it exemplifies the Traffic pollution at its best form.

However after the new ISBT started functioning since August 30th 2011, the burden of shouldering vehicular operations was shared with the new bus station. However, the old ISBT still operates as the most under- maintained of all places in Shimla city.

Chapter 3

Analyzing the Monitored Data

Ambient air Quality analysis was done for the two stations: **Tekka Bench and the old ISBT** called Station 1 and Station 2 respectively throughout the study. These two stations were chosen, because monitoring works had been done for just the two of these stations for Shimla city. The monitoring works on pollutant concentrations are carried out by the HPCPCB for 24 hours (4 hourly sampling for gaseous pollutants and 8hourly sampling for PM) twice a week- 104 observations in a year and so all the monitored data acquired for the study was provided by them in their site. Annual, seasonal and monthly analysis of monitored data have been done to study the trends shown by the pollutants in the past one decade, to discuss and reason why certain trends prevailed and finally to estimate future pollutant concentration using the DMRB model after the fully comprehending the behavior shown by the pollutants.

3.1 Annual Graphs

Using the Annual Air Quality Monitoring Report from 2004-2013 (a decade long), produced by the HPCPCB (Himachal Pradesh Central Pollution Control Board), Annual and Seasonal graphs were plotted for the two monitoring stations to analyze the behavior of the three major pollutants - NOx, SO2 and RSPM in the two stations. In this section, annual graphs are analyzed and evaluated to examine the trends projected by these pollutants and to compare annual values to the permissible limits as set by NAMP so as to determine the air quality of the Shimla city. The graphs are as follows:

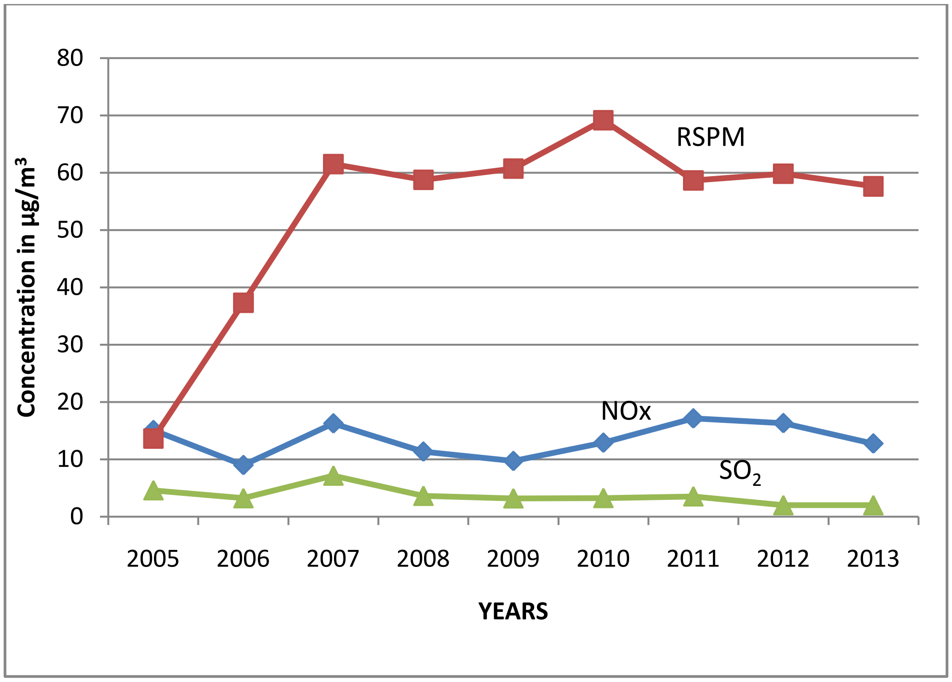

Fig 3.1 Graphical Representation of the annual pollutant concentration over a decade in station I

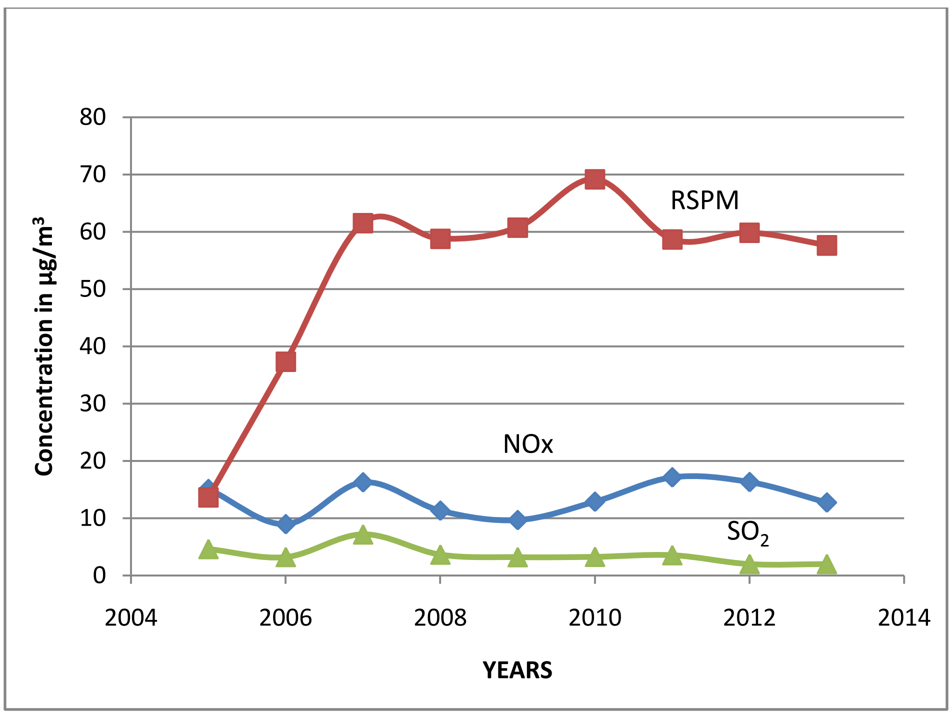

Fig 3.2 Graphical Representation of the annual pollutant concentration over a decade in station II.

Categorization of the Air Quality;

The air quality could be categorized into four broad categories based on an Exceedence Factor (the ratio of annual mean concentration of a pollutant with that of a respective standard) as followed by NAMP. The Exceedence Factor (EF) is calculated as follows:

$$\text{Exceedence Factor} = \frac{\text{Observed annual mean concentration of criteria pollutant}}{\text{Annual standard for the respective pollutant and area class}}$$

The four air quality categories are

- Critical pollution (C) : when EF is > 1.5;
- High pollution (H) : when the EF is between 1.0 - <1.5;
- Moderate pollution (M) : when the EF between 0.5 - <1.0; and
- Low pollution (L): when the EF is < 0.5.

It is obvious from the categorization above that the locations in either of the first two categories are actually not meeting the standards, although, with varying magnitude. Those, falling in the third category are meeting the NAMP standards as of now but likely to exceed the standards in future if pollution continues to increase and is not controlled. However, the locations in Low pollution category have a rather clean air quality and such areas are to be maintained at low pollution level by way of adopting preventive and control measures of air pollution.

Table 3.1 NAMP

Pollutant levels	Annual Mean Concentration In ambient Air					
	Industrial, Residential, Rural and other areas in µg/m^3			Sensitive Areas in µg/m^3		
	SO2	NOx	RSPM	SO2	NOx	RSPM
Low (L)	0-25	0-20	0-30	0-10	0-15	0-30
Moderate(M)	26-50	21-40	31-60	11-20	16-30	31-60
High(H)	51-75	41-60	61-90	21-30	31-45	61-90
Critical©	>75	>60	>90	>30	>45	>90

classification criteria according to pollutant concentration.

Discussion

i. The concentrations of all the three pollutants were conspicuously higher in the old ISBT as compared to the Ridge owing to high volume of vehicular traffic there.

ii. NOx and SO_2 concentrations values over a period of a decade did not exceed the standard concentration of 50µg/m^3 and 40µg/m^3 as set by NAAQS. Decreasing trend of SO_2 could be attributed to various interventions that have taken place in recent years such as reduction in sulphur content in diesel, change in domestic fuel from coal to LPG, CNG etc globally. Other than these reasons, low SO_2 levels in Shimla due to the fact that only few small scale industries are there within the Municipal boundary of the city. NO_2 concentration has remained more or less fluctuating over the years despite due to intervention measures that have taken place such as improvement in vehicle technology and other vehicular pollution control measures like alternate fuel etc.

iii. RSPM values in both the air stations in Shimla come under moderate category i.e. it slightly exceeds the standard RSPM concentration of 60µg/m^3. The moderate values of RSPM in the both stations could be because of:

   a) Congested road but ever increasing numbers of vehicles on road. Vehicles operate most efficiently and produce least pollution when they are driven in free flowing traffic at moderate speeds.
   b) Poor drainage systems- dust re-suspension by wind and moving vehicle
   c) Running of old vehicles- especially Heavy Duty Vehicles like busses-older the vehicle lowers its engine's efficiency and higher exhausts emission.
   d) Higher concentration of RSPM pollutant due to higher number of Diesel-run vehicles.
   e) Poor road maintenance leading to greater rate of abrasion between road and tyre resulting in higher dust production.
   f) Commercial and domestic use of fuel etc.

iv. There is a noticeable decrease in RSPM concentration values from 2010 onwards. Noticeable decrease in RSPM concentration values from 2010 onwards in station II is due to the full functioning of the new ISBT of Shimla.

3.2 Seasonal Graphs

Since the annual average concentrations of SO_2 showed a steady decreasing rate for the past one decade and moreover as the concentration of SO_2 values was way below the standard SO_2 concentration of 50µg/m^3, further analysis of this pollutant was altogether avoided as it wouldn't have any significant effect on air quality analysis. As stated in the above, these ebbing values of SO_2 with the passing time is due to stringent rules to reduce sulphur content in fuels ass set by responsible authorities of the world with the ultimate motive of decreasing pollutant emissions from vehicle fuel. In this section, the seasonal analysis done for the study is being surveyed to comprehend seasonal patterns demonstrated by NOx and RSPM.

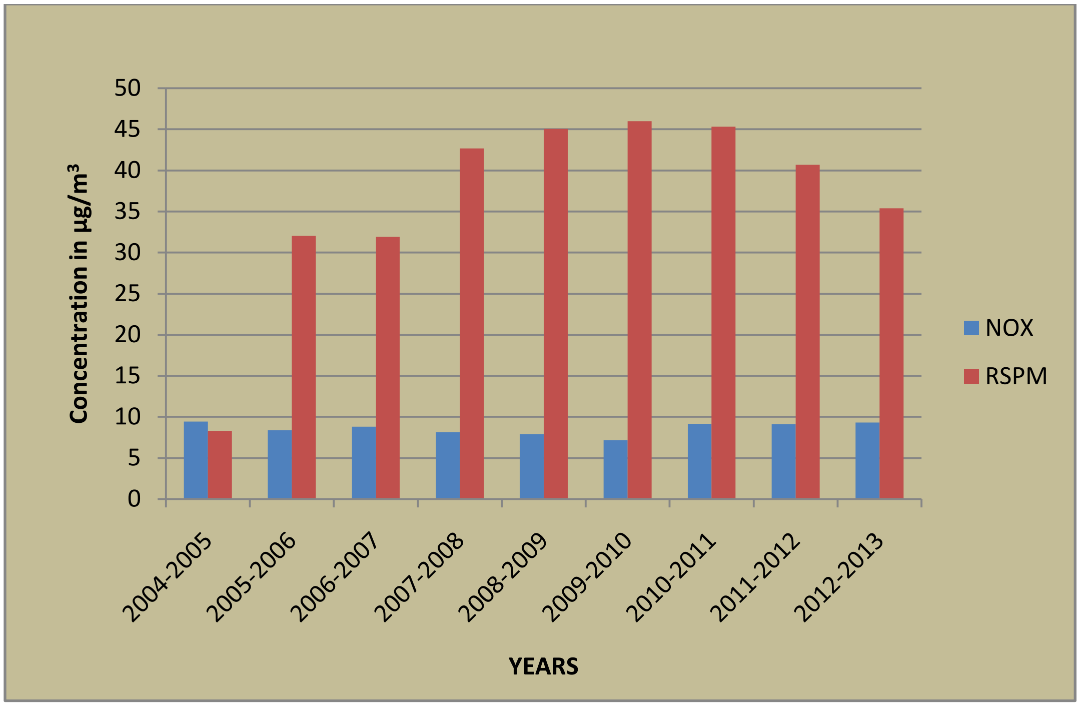

Fig 3.3Analysis of Spring season for station I

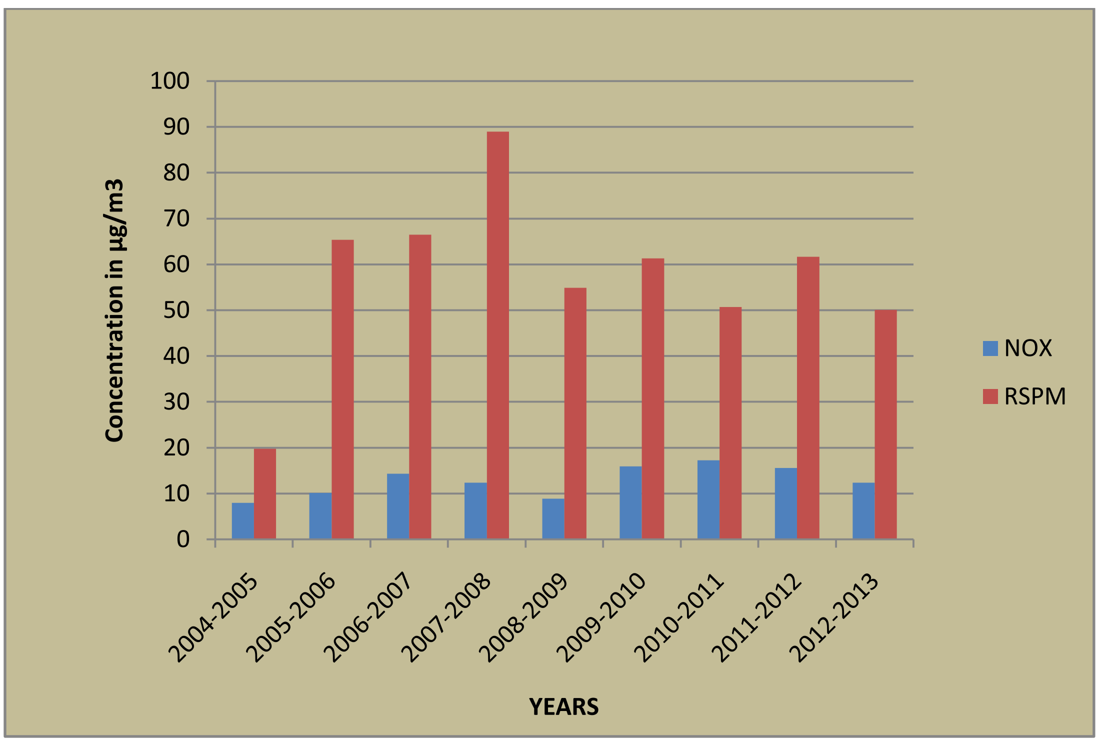

Fig 3.4Analysis of Spring season for station II

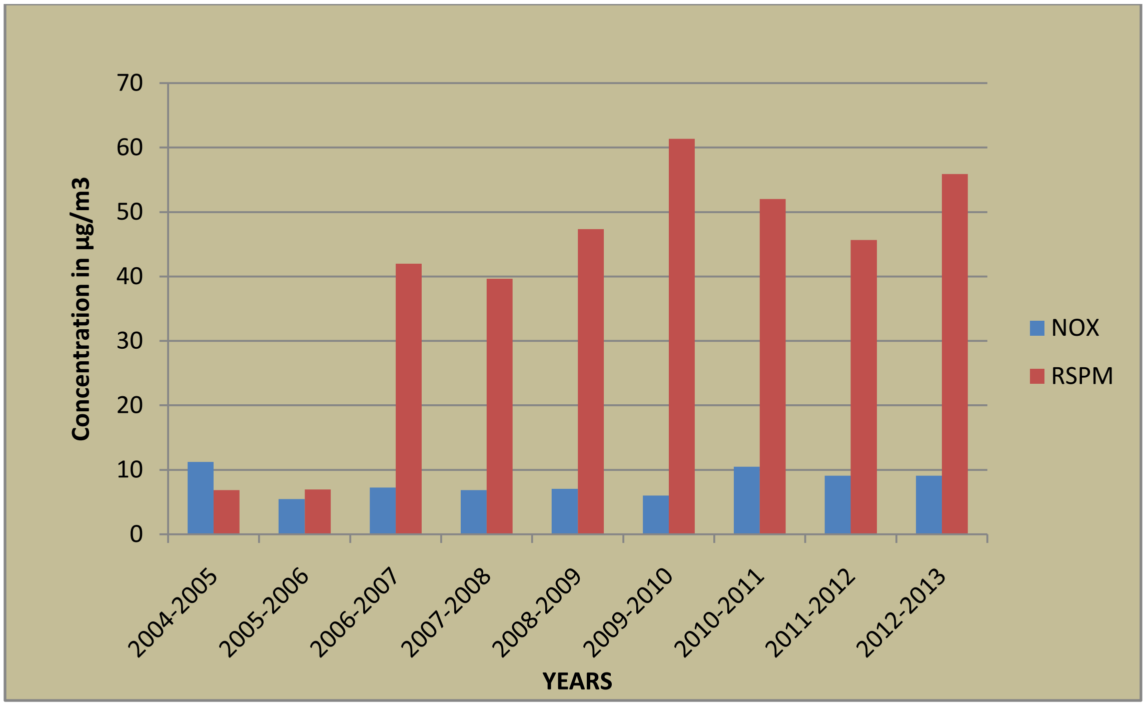

Fig 3.5 Analysis of Summer season for station I

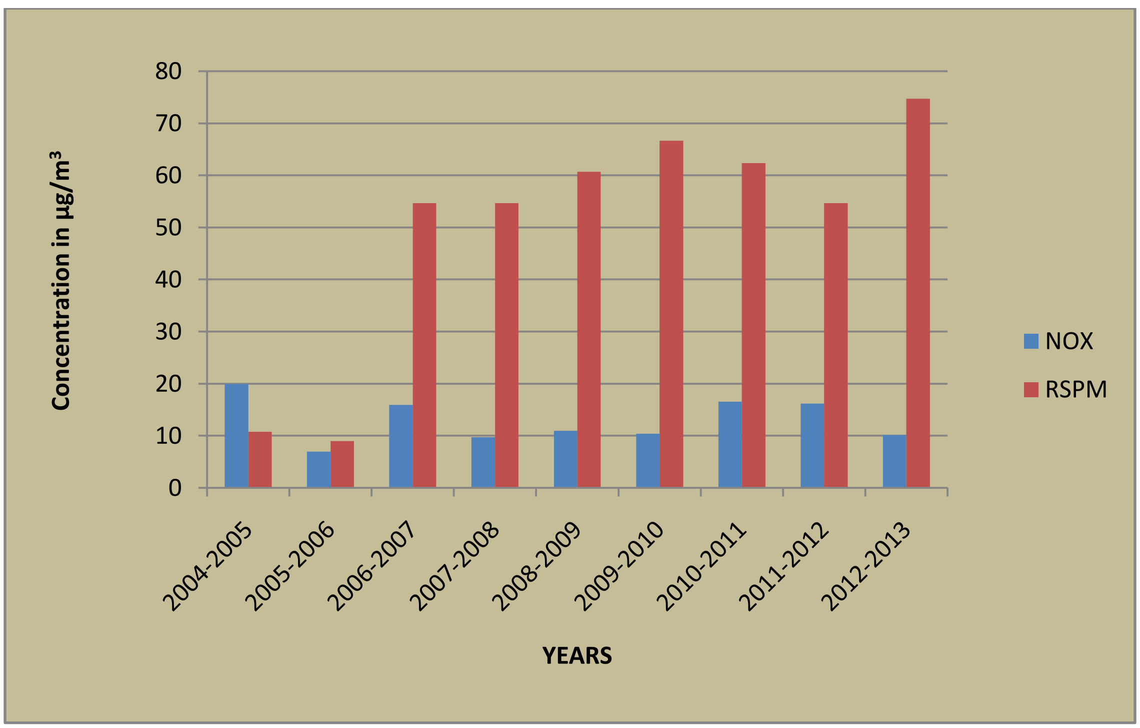

Fig 3.6 Analysis of Summer season for station II

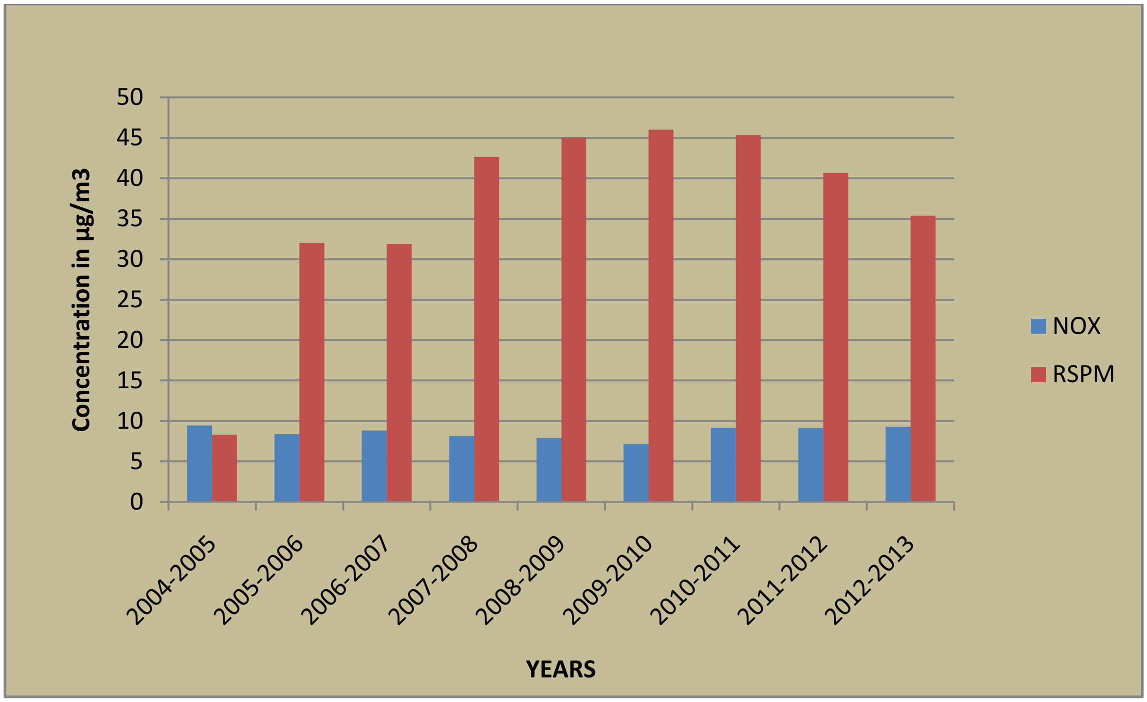

Fig 3.7 Analysis Autumn season for station I

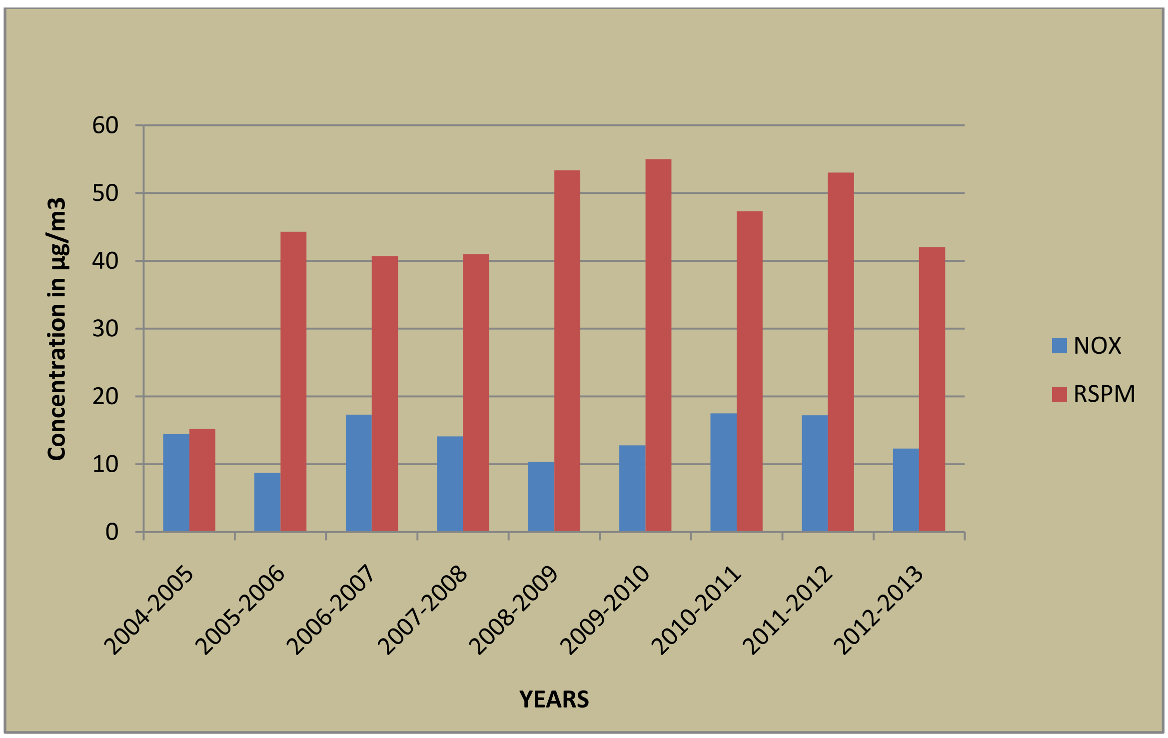

Fig 3.8 Analysis Autumn season for station II

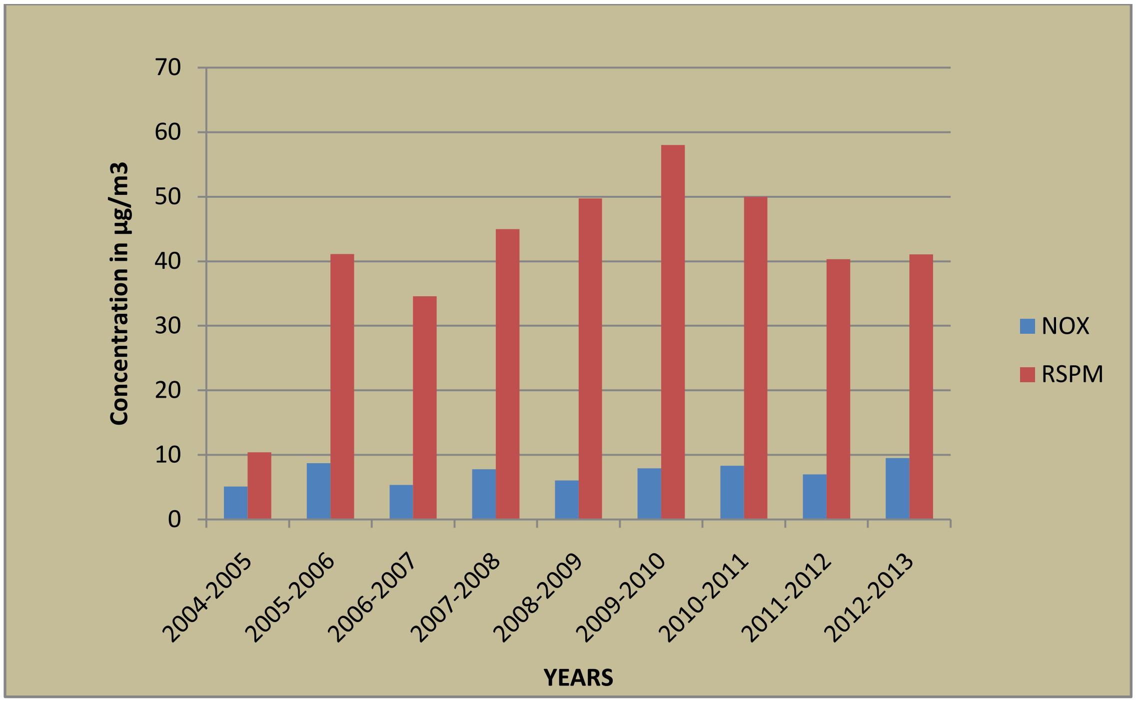

Fig 3.9 Analysis Winter season for station I

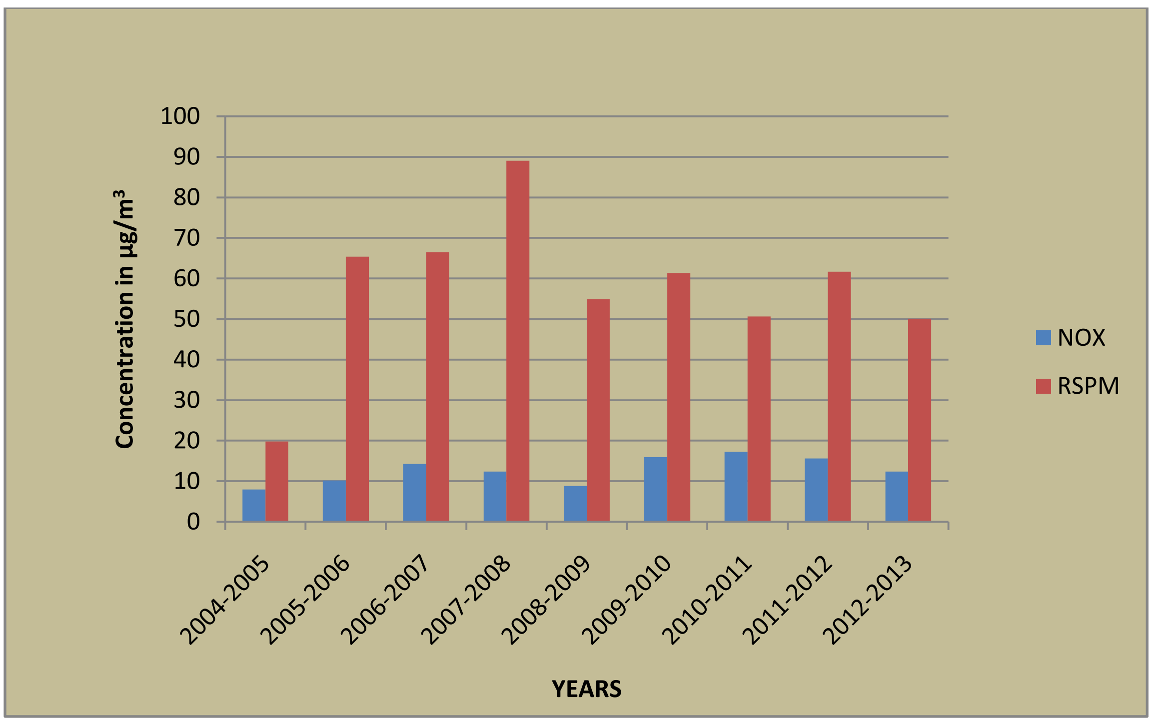

Fig 3.10 Analysis Winter season for station II

Discussion

i. Concentrations of all the three pollutants viz RSPM, NOx and SO2 are comparatively higher in station II than in station due to –
   a) High volume of flow of Traffic in station II as it is the state bus terminal.
   b) Only licensed vehicles allowed in station I.

ii. Higher concentration of RSPM is noted in the Spring Season for both the stations. While in Autumn Season the concentrations were found to be the lowest. NOx showed a fluctuating concentration owing to improvement in vehicular technology and switching to electric heaters and other electrical appliances rather than using coal. Whereas the rationale behind elevated levels of RSPM are:

a) Spring season is the Peak Tourist season in Shimla as shown in fig 3.11. The population of Shimla city almost doubles at this time of the year according to the Tourism Department of Shimla city.
b) Busiest roads network. Many of the pollutants emitted from road vehicles react together and with pollutants from other sources to form secondary pollutants which can also have significant effects.
c) Least precipitation anticipated at this time of the year as shown in fig 3.12.
d) Period of dispersion of Pollen grains from pine trees, flowers.

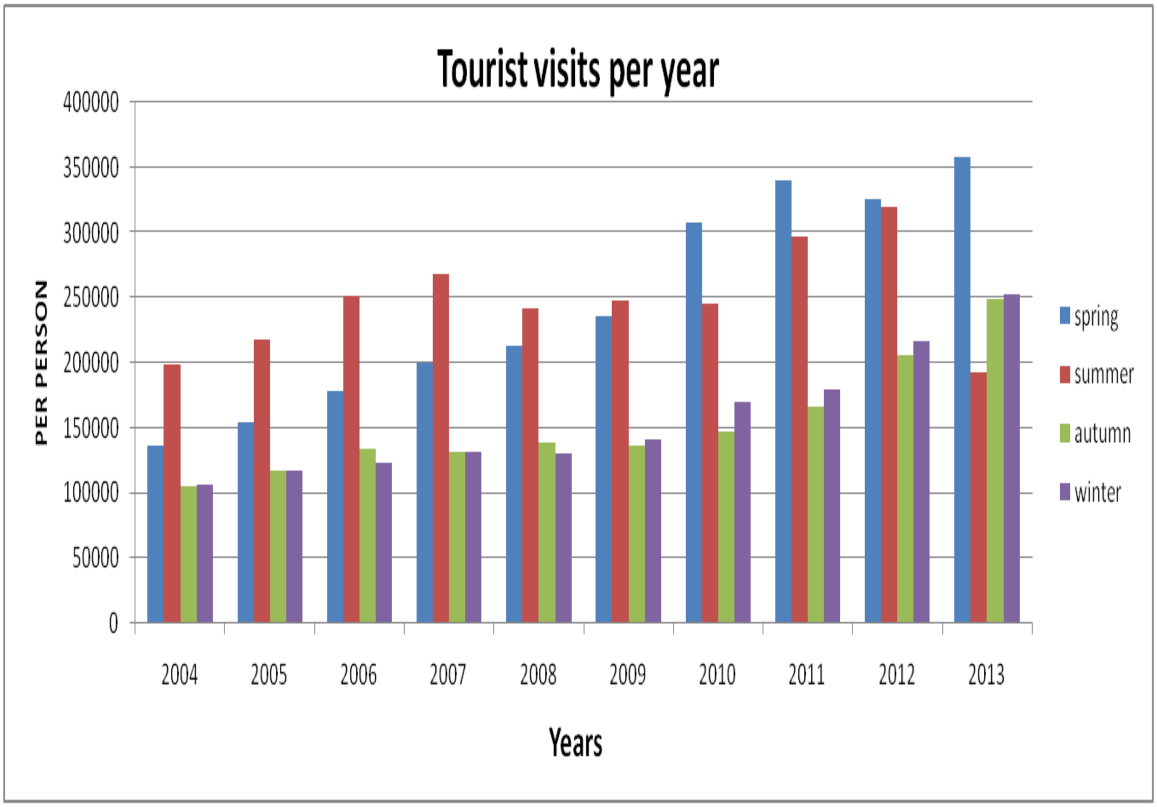

Fig 3.11 Variation in tourist volume for different seasons during the study period.

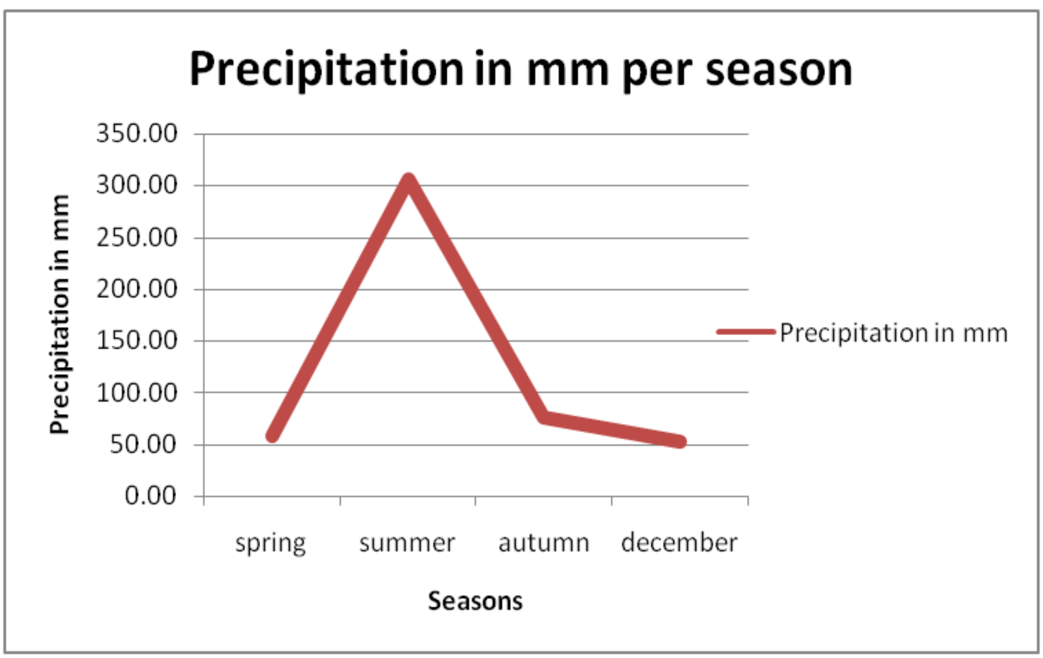

Fig 3.12 Variation in precipitation seasonally.

Traffic problems leading to Air pollution in Shimla city:

a) Inadequate space for movement of buses. Narrow roads, hilly area.
b) High Traffic congestion. It is the most significant issue that Shimla is facing today. The coverage of road network for vehicular movement is low and existing roads are operating more than its desired capacity. The width of roads have become narrow for ever increasing traffic volume and increase in activity centers along the roads impairing traffic movement and creating bottlenecks.
c) Absence of dedicated bus bays causes buses to stop on Cart Road for boarding and alighting of passengers thereby causing traffic congestion on Cart Road.
d) Unregulated stopping of buses at any location other than designated bus stops.
e) Multiple organizations involved in development and management of Traffic & Transportation facilities in Shimla City. Confusion in minds of the working people about their specific responsibilities regarding transportation.

<u>Probable reasons for moderate conc. of RSPM values in Shimla city</u>

i. Poor road conditions in Shimla: this leads to higher dust production due to attrition between the tyres of the vehicle and the road that result in higher dust re-suspension and hence higher RSPM concentration.

ii. Improper drainage system: drains by the Old ISBT roadside are in deplorable conditions. They are clogged, very dirty and non-functional. Due to this poor drainage condition,

iii. Congested roads (Narrow roads): studies have proved that the highest rates of emission occur in congested, slow moving traffic.

iv. High density of vehicle- proliferating vehicle count each year.

v. Usage of old vehicles. Older the vehicle, lower the efficiency and higher the production of pollutants due to incomplete combustion of fuels.

vi. High numbers of diesel run vehicles. Studies have proved that diesel run vehicles emit higher pollutant concentration. "*Diesel exhaust contains much higher particle concentrations (in terms of mass) than petrol exhaust"*- Design Manual for Roads and Bridges, Volume 11 Environmental Assessment, Section 3 Environmental Assessment techniques, Part 1, page 14.

vii. No CNG run vehicle in Shimla City until this year.

3.3 Monthly mean Graphs

To actually pin down which months had the highest or the lowest recorded pollutant concentrations, average of the ten year data were tabulated and put into a graphical form.

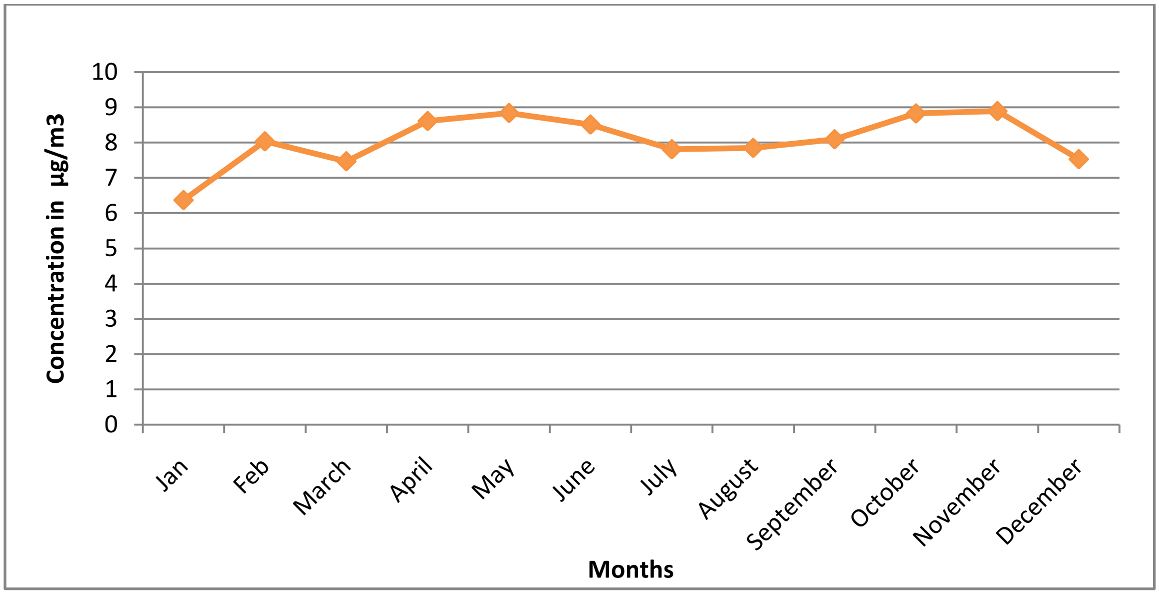

Fig 3.13 Monthly NOx concentration variations for station I

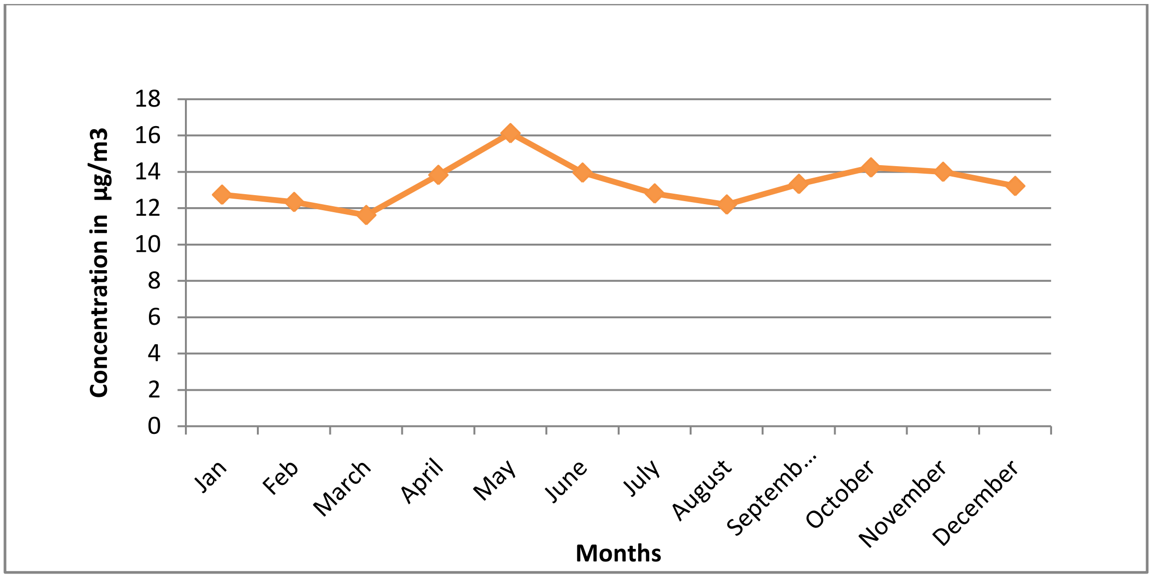

Fig 3.14 Monthly NOx concentration variations for station II

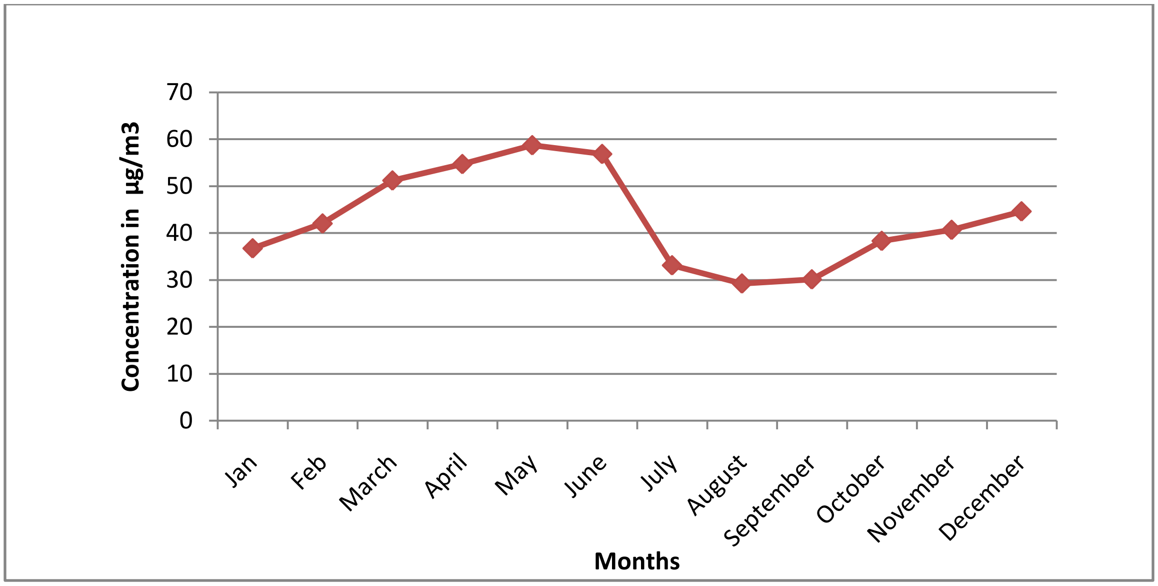

Fig 3.15Monthly RSPM concentration variations for station I

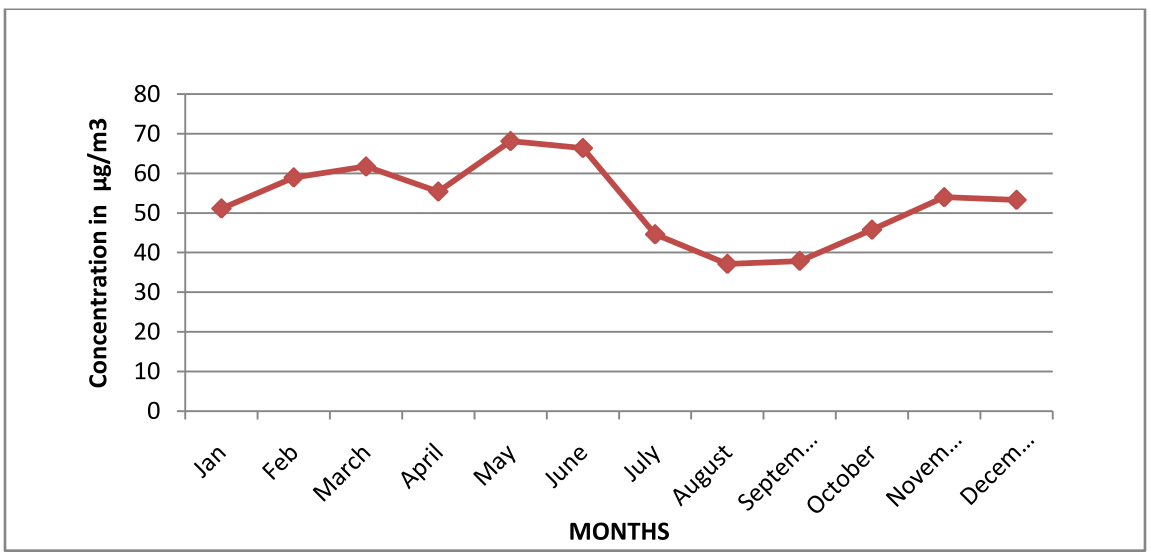

Fig 3.16 ***Monthly NOx concentration variations for station II***

Discussion

This process of analyzing monthly variations brought about the following graphs for RSPM and NOx. All the graphs clearly portrays that during the Month of May, both NOx and RSPM concentrations are marked to be the highest. This could be attributed to the same reasons as to why in spring season pollutant concentration is the highest as discussed in section 3.2.

Chapter 4

DMRB modeling

4.1 Introduction to DMRB modeling

From the graphical analysis of monitored data, it is evident that NOx and SO_2 concentration are way below the standards concentration as set by NAAMP, whereas RSPM values slightly exceed the standards. Since Shimla there are no industries or factories in the vicinity of the city, this noticeable trend of elevated RSPM values could be attributed entirely to Vehicular exhausts. For the assessment of pollution due to traffic various models like ADMS-Roads, ADMS-Urban, the DMRB spreadsheet, Caline4 and Breeze-Roads are employed. However where air quality standards are unlikely to be exceeded and the expected changes in the traffic are small, then a basic screening approach such as the DMRB spreadsheet is appropriate. DMRB modeling is an assessment tool programmed to err at the side of caution. It is a spreadsheet based model developed by UK Highway Agency that is very simple to use and doesn't require advanced data for running it.

4.2 Unique Features of the DMRB modeling

a) This basic screening model exploits average statics like composition of Traffic, AADT values and average vehicular speeds to assist the assessment of air quality due to vehicular pollution in close proximity to roads.

b) The screening model demands least number of input data to run and predict appreciable pollutant concentrations.

c) It is very easy to use as it doesn't require any specific skill sets and applicable to all road schemes and is cost effective too.

d) It presents in itself a very conservative approach developed this way primarily for the assessment of major new road schemes in relatively rural areas and so it purposefully overestimated pollutant concentrations.

e) The main objective of running this modeling is to provide a guideline prediction concentration and indicates if further detailed air quality study is needed or not.

f) DMRB approach makes annual average concentrations of concentrations of carbon moNOxide (CO), nitrogen dioxide (NO_2), non–methane hydrocarbons (benzene and 1, 3–butadiene) and particulate matter (PM_{10}).

DMRB model employed for this project is the 2007 version of DMRB. As stated in the background there were no proper maintenance of the proper records of vehicle count, vehicle speed, ADT values, AADT values, proportion of heavy and light vehicles etc. hence some assumptions had to be made.

The screening model was developed to assist with the assessments associated with the two elements- a) Local Impacts b) Regional Impacts. The first of these is the estimation of roadside air pollution concentrations, referred to as local impacts, associated with new or modified road schemes. The second is an estimation of total annual emissions arising from a road scheme, referred to as regional impacts.

The pollutants considered in the local assessment by DMRB Screening Model are nitrogen dioxide, particles, carbon moNOxide, benzene, and 1,3-butadiene. The rationale supporting the selection of these pollutants was based primarily on the air quality criteria reviewed in the context of road transport emissions and their contribution to air pollution levels. The pollutants considered in the regional assessment are nitrogen oxides, particles, carbon moNOxide, carbon dioxide and hydrocarbons (expressed as equivalent to the empirical formula CH1.85.). However in this project, modeling has been done for concentration of RSPM and NOX only.

4.3 The required data input are:

a) AADT values

b) Proportion of light and heavy good vehicles.

c) Average Vehicular speed

d) Year

e) Distance to receptor

f) Background Concentrations.

g) The receptor name and number.

4.4 Method for assessment of local air quality

The procedure in the DMRB Screening Method involves seven steps. These steps are highlighted as follows:

Step 1 Enter the receptor name and number (1 for first receptor, 2 for second, and so on). Up to 20 different receptors can be assessed, with each one requiring a unique identification number. If the results for a specified receptor number are already present on the Local output sheet, the program will ask for a different receptor number.

Step 2 Enter the assessment year (1996 to 2025).

Step 3 Enter the number of links to be assessed for the current receptor. Up to 15 different links can be assessed. Carriageways on the same road must not be entered separately.

Step 4 Enter the background concentrations which are relevant to the locality of the assessment for the assessment year. If there is no requirement to assess a particular pollutant, a zero can be entered as the background value. A result will still be presented for the pollutant on the Local output sheet, but this can be ignored.

Step 5 Enter the distance and traffic data for each link. The number of links specified here must match that defined in Step 3, and the following input data are required:

a. The distance in meters from the link centre to the receptor. The minimum distance allowed is 2 m.
b. The combined annual average total daily traffic flow (AADT). Carriageways must not be treated separately.
c. The annual average traffic speed in km/h. This must be between 5 km/h and 130 km/h.
d. The road type

Enter either A, B, C or D in upper case or lower case, but not a mixture of both. If information on the traffic composition on the link is not available, enter either ‘A’, ‘B’, or ‘C’, where

A = Motorways or A-roads

B = Urban roads which are not motorways or A-roads

C = All other roads

If either ‘A’, ‘B’, or ‘C’ is entered in a cell, the cell shading will change to light grey to indicate which type of traffic composition must be used. Where information on actual traffic composition is available from classified counts, this may be used in place of the preset traffic compositions by entering ‘D’ in the road type cell. If ‘D’ is entered in a cell, the cell shading will change to dark grey.

The traffic composition

If either ‘A’, ‘B’, or ‘C’ has been entered in the road type cell, then only the total percentages of heavy-duty vehicles (HDVs) and light-duty vehicles (LDVs) need to be entered in the appropriate light grey cells. The dark grey cells must be left blank.

If ‘D’ has been entered in the road type cell, the percentage of vehicles in each of the following five classes must then be entered:

i. Passenger cars

ii. Light goods vehicles

iii. Buses and coaches

iv. Rigid heavy goods vehicles (>3.5 tones gross vehicle weight)

v. Articulated heavy goods vehicles (>3.5 tones gross vehicle weight)

The appropriate values are entered in the corresponding dark grey cells. The light grey cells must be left blank.

Step 6- Place the cursor over the CALCULATE and click the button. The amount of time required for the calculation varies according to the number of links involved. During the calculation a message will appear on the screen to indicate the percentage of the calculation which has been completed. When the calculation has been completed, a ‘RUN COMPLETE’ message appears, and the results for the current receptor can then be viewed on the Local output sheet. If only one receptor is to be assessed, the procedure ends at this point. The Local output sheet displays the details of the current receptor (name, number, and assessment year), the predicted concentrations for the receptor.

Step 7 In some assessments, there may be a need to look at several receptors. If this is the case, the results for the current receptor can be stored on the Local output sheet by pressing the STORE RESULTS FOR THIS RECEPTOR button on the Local sheet. Enter data for the next receptor by overwriting the input data already present, or start from scratch by pressing the CLEAR INPUT DATA button.

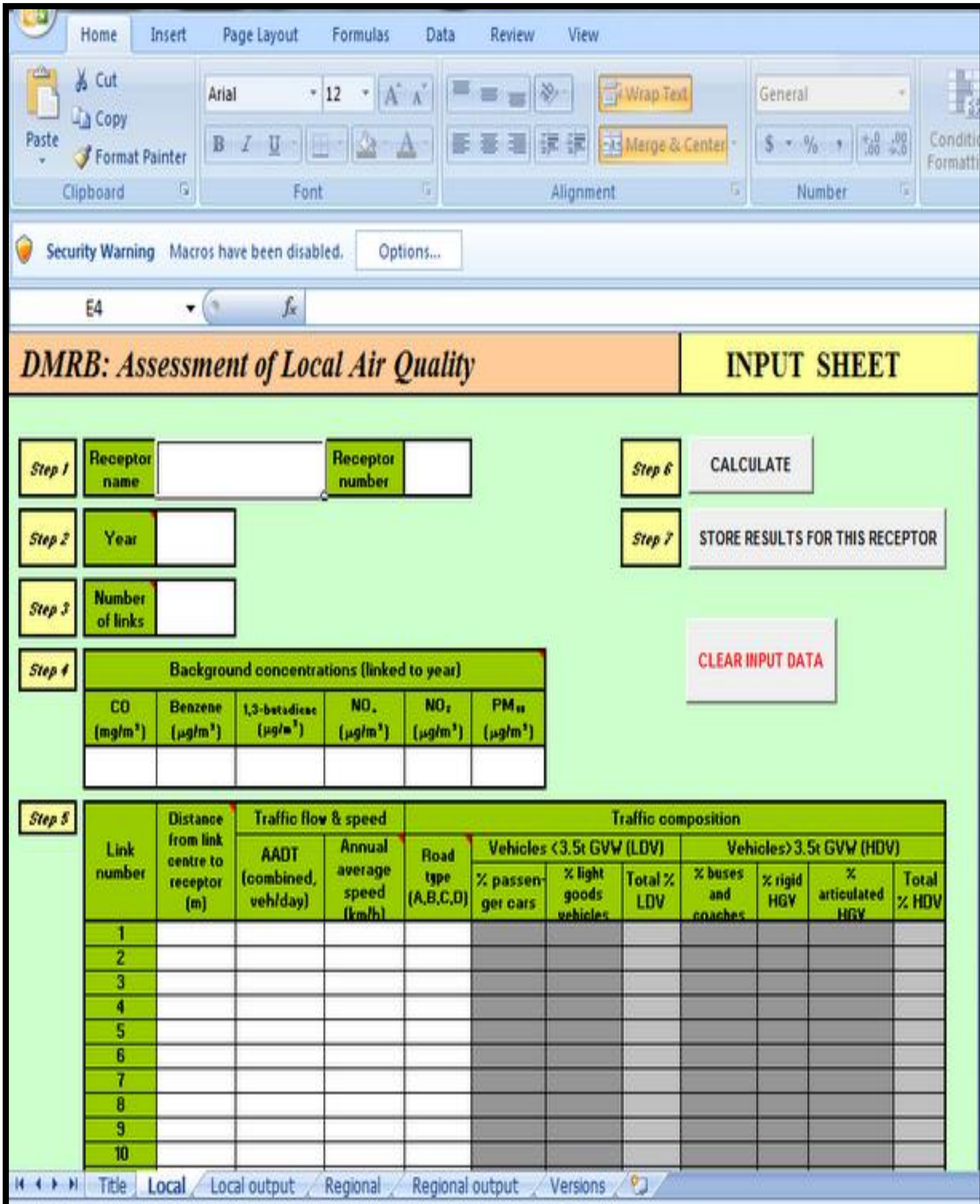

Fig.4.1 Screenshot of the DMRB local input spreadsheet

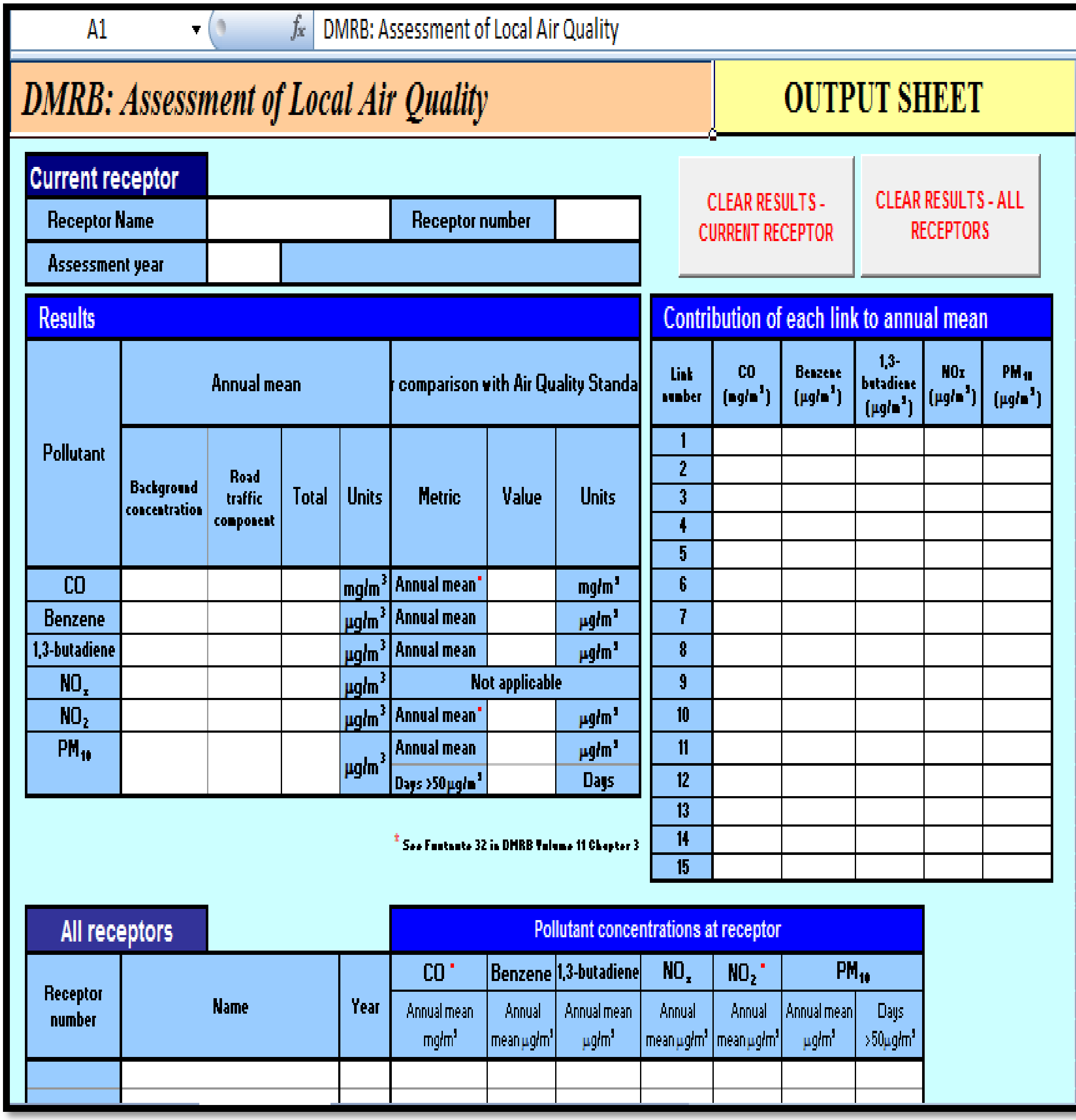

Fig 4.2 Screenshot of the DMRB local output spreadsheet.

4.5 Sample test cases of running the models

To validate the applicability of the DMRB Screening model, two sample tests were undertaken before actually employing it to perform modeling for monitoring station II. Both case studies were extracted from the paper titled “Applicability of a screening model at motorway and roundabout sites in Ireland”.

Test sample I

Distance of Receptor	30 m
AADT values	1400
%HDV	20 m
Average Speed	90 kmph
Background concentrations in µg/m^3	
CO	0.27
Benzene	0.4
NOx	11.73
RSPM	11.9

Table 4.1 DMRB input data for case I

DMRB RESULTS VS MEASURED VALUES

Pollutant	Actual measured concentration in µg/m^3	1999	2003	2007
CO in µg/m^3	**0.32**	**0.32**	**0.37**	**0.39**
Benzene in µg/m^3	**0.53**	**1.09**	**0.59**	**0.54**
NO_x in µg/m^3	**32.29**	**142.05**	**80.13**	**80.2**
NO_2 in µg/m^3	**17.09**	**58.27**	**15.86**	**15.7**
PM_{10} in µg/m^3	**15.5**	**15.83**	**17.99**	**17.99**

Table 4.2 DMRB RESULTS VS MEASURED VALUES

Observations made:

The observations made upon running the 2007 version DMRB model, gave similar results as the work done in the paper. In fact as shown in the table, a number of times the results obtained from the 2003 and 2007 version of DMRB were exactly the same.

Test Sample 2:

Link number	5
Distance of Receptor	15
	15
	35
	45
	45
AADT Values	2480
	1070
	2760
	1200
	1790
%HDV	7
Average Speed	15 kmph
Background concentrations in µg/m3	
CO	0.21
Benzene	0.4
NOx	11.73

Table 4.3 DMRB input data for case II

Pollutant	Actual measured concentration in µg/m³	1999- 5 link	2003		2007
			5-link	**3-link**	
CO in µg/m³	**0.54**	**2.09**	**2.25**	**1.36**	**2.25**
Benzene in µg/m³	**2.53**	**12.54**	**4.39**	**2.53**	**4.39**
NO_x in µg/m³	**39.42**	**774.95**	**283.2**	**165.04**	**283.2**
NO_2 in µg/m³	**19.79**	**193.95**	**39.65**	**31.84**	**39.1**
PM_{10} in µg/m³	**25.5**	**44.91**	**54.68**	**36.49**	**55.68**

Table 4.4 DMRB RESULTS VS MEASURED VALUES

Observations made from Test Sample 2:

When the results of the three different versions of DMRB models were compared, as shown in the table and as stated earlier, the 2003 and 2007 DMRB model versions showed considerable congruence. Hence the results I obtained are as was concluded in the paper.

Chapter 5

Air Pollution Modeling

5.1 Model Input data

Background concentrations used in the DMRB model for PM_{10} and NOx were the annual PM_{10} and NOx for Station I i.e. the Ridge as it is the background site. The distance from the link centre to the receptor was measured to be 20 m and so for all the years analyzed, it remains unaltered. AADT values had to be approximately calculated because the actual count of Annual Average Daily traffic for station II was not recorded daily. To take reasonable approximation of AADT values, I was helped by the General Manager of Transportation Department; Mr. Rughubir Choudhary. The approximations for 2013 are given in the table 5.2, while for the rest of the years, the AADT values were calculated assuming 10% increase every five years, applying the WEBTAG Technical Guidance Unit 3.3.3 specifications that states that traffic flows on all of the roads in the assessment which have been assessed will change by less than 10% as a result of the development.

The Annual Average Speed for the vehicles is input the same as the design speed for all vehicles. This data too was provided by the General Manager. From 2004-2010 Road type was inputted as A since Old ISBT operated as a National Highway Road then. However from 2010 onwards, the Road type was altered to B since the new ISBT came into full operation and the road running to Old ISBT was demoted to urban roads.

Since daily count of vehicles running around station II had no written records, LDV and HDV was calculated by assuming that the number of vehicles registered in the RTO was equivalent to the vehicles running in station II. The count of vehicle registered annually from 2013-2011 was provided by the Regional Transport Office of Shimla. Earthmoving vehicles were excluded from calculating HDV% as it is a fact that such vehicles wouldn't run every day in the old ISBT. Moreover, an assumption that every few years LDV% rises by 10% was made with respect to the WEBTAG Technical Guidance Unit 3.3.3 and with consent from the General Manager. A jest of the calculation tables for LDV% and HDV% calculations is as shown in table 5.1.

2013 vehicle registration

Sl.No	Category of vehicle	RTO SML	RLA SML®	RLA SML(U)	TOTAL
1	AIR CONDITIONED BUS		1	1	2
2	AMBULANCE	135	4	21	160
3	ARTICULATED VEHICLE			1	1
4	BREAK DOWN VAN			1	1
5	BUS	302	70	346	718
6	CAMPER VAN			1	1
7	CASH VAN				0
8	DELIVERY VAN	1	1	4	6
9	DELUXE BUS	10	1		11
10	FORK LIFTS				0
11	GOODS TRUCK CONTAINER	2	5	1	8
12	HEAVY GOODS VEHICLE	3403	843	1287	5533
13	HEERS CAR (H.M.V.)		11	92	103
14	HEERS CAR (L.M.V.)	2		10	12
15	INVALID CARRIAGE		2	4	6
16	JEEP TAXI	3	43	8	54
17	L.M.V. (CAR)	3703	9158	13617	26478
18	L.M.V. (IMP.)	1	21	20	42
19	L.M.V. (VAN)	44	132	297	473
20	L.M.V.(JEEP/GYPSY)	256	212	1046	1514
21	LIGHT GOODS VEHICLE	3124	665	972	4761
22	MAXI CAB	1812	12	5	1829
23	MEDIUM GOODS VEHICLE	1451	226	171	1848
24	MINI BUS	265	22	41	328
25	MOBILE CANTEEN		1		1
26	MOBILE CLINIC				0
27	MOBILE LAB VAN (H.M.V.)			1	1
28	MOBILE LAB VAN (L.M.V.)				0
29	MOBILE LIBRARY VAN				0
30	MOBILE SERVICE VAN				0
31	MOBILE WORKSHOP				0
32	MOPED	1	89	2	92
33	MOTOR CAB / CAR TAXI	2455	2	2	2459
34	MOTOR CYCLE	555	2981	2360	5896
35	MOTOR CYCLE (IMP.)		11	26	37
36	MOTOR CYCLE WITH SIDE CAR		1		1
37	MOTOR GRADER				0
38	MULTI AXLE GOODS VEHICLE	1		1	2
39	OMNI BUS	19	3	5	27
40	OMNI BUS(PVT)	3	1	2	6
41	PASSENGER AND GOODS VEHICLE		13	2	15
42	POSTAL VAN			1	1
43	PSV MOTOR CAB	10	31	42	83
44	RADIO TAXI			2	2
45	RECOVERY VAN(HEAVY)		9	5	14
46	RECOVERY VAN(LIGHT)	9	10	1	20
47	RECOVERY VAN(MEDIUM)	2	1	1	4
48	ROAD WATER SPRINKLERS		1		1
49	SCOOTER WITH SIDE CAR	1	215	3	219
50	SCOOTER/MOPED	52	782	3997	4831
51	SEMI DELUXE BUS	1		1	2
52	STATION WAGON			2	2
53	TANKER	12	3	17	32
54	THREE WHEELER (GOODS)	5	2		7
55	THREE WHEELER (PASSENGER)	261			261
56	THREE WHEELER PRIVATE				0
57	TOURIST BUS				0
58	TOURIST MAXI CAB	2			2
59	TOURIST MOTOR CAB / TAXI	9			9
60	TOW TRUCK		2	10	12
61	TOWER WEGONS			1	1
62	UTILITY VAN	3	4	9	16
63	X-RAY VAN		3	1	4
	Total	**17915**	**15594**	**24440**	57949

HDV	TOTAL
AIR CONDITIONED BUS	2
ARTICULATED VEHICLE	1
BREAK DOWN VAN	1
BUS	718
DELUXE BUS	11
EXPLOSIVE VAN	3
FORK LIFTS	0
GOODS TRUCK CONTAINER	8
HEAVY GOODS VEHICLE	5533
INVALID CARRIAGE	6
RECOVERY VAN(HEAVY)	14
ROAD WATER SPRINKLERS	1
SEMI DELUXE BUS	2
TOURIST BUS	0
TOW TRUCK	12
TOWER WEGONS	1
MINI BUS	328
OMNI BUS	27
OMNI BUS(PVT)	6
STATION WAGON	2
TANKER	32
TOTAL	**6708**

LDV	**51241**
	88%

EXCLUDED LIST OF VEHICLES

BULLDOZER
CRANE
DUMPER
SELF LOADER CONC MIXER
TRACTOR (AGRICULTURE)
TRACTOR (COMMERCIAL)
TRACTOR(PRIVATE)
TRAILER (PRIVATE)
TRAILER (AGRICULTURE)
VEHICLE FITTED WITH COMPRESSOR
EARTH MOVING EQUIPMENT
HAULAGE VEHICLE
EXCAVATOR
ROAD ROLLER

Table 5.1 HVD-LDV% calculations for the year 2013.

AADT Cal	
PVT buses	120
HRTC bus	965
taxis	1500
other veh	250
TOTAL	**2835**

Table 5.2 AADT calculation for 2013

Summarized Input Data										
Receoptor Name	Years	Background Data in µg/m^3		Number of links	Distance from Receptor	AADT	Annual Average Speed	Road Type	Total LDV in %	Total HDV in %
		NOx	RSPM							
SHIMLA 101	2005	9.39	8.78	1	20 m	2700	20 Kmph	A	83	17
SHIMLA 101	2006	7.41	24.34	1	20 m	2700	20 Kmph	A	83	17
SHIMLA 101	2007	7.72	41.09	1	20 m	2700	20 Kmph	A	83	17
SHIMLA 101	2008	7.38	47.67	1	20 m	2700	20 Kmph	A	83	17
SHIMLA 101	2009	6.58	53.70	1	20 m	2700	20 Kmph	A	83	17
SHIMLA 101	2010	7.33	60.00	1	20 m	3000	20 Kmph	B	93	7
SHIMLA 101	2011	9.08	55.25	1	20 m	3000	20 Kmph	B	93	7
SHIMLA 101	2012	8.38	49.08	1	20 m	3000	20 Kmph	B	93	7
SHIMLA 101	2013	9.35	47.39	1	20 m	3000	20 Kmph	B	88	12

Table 5.3 Summarized input data for all the years

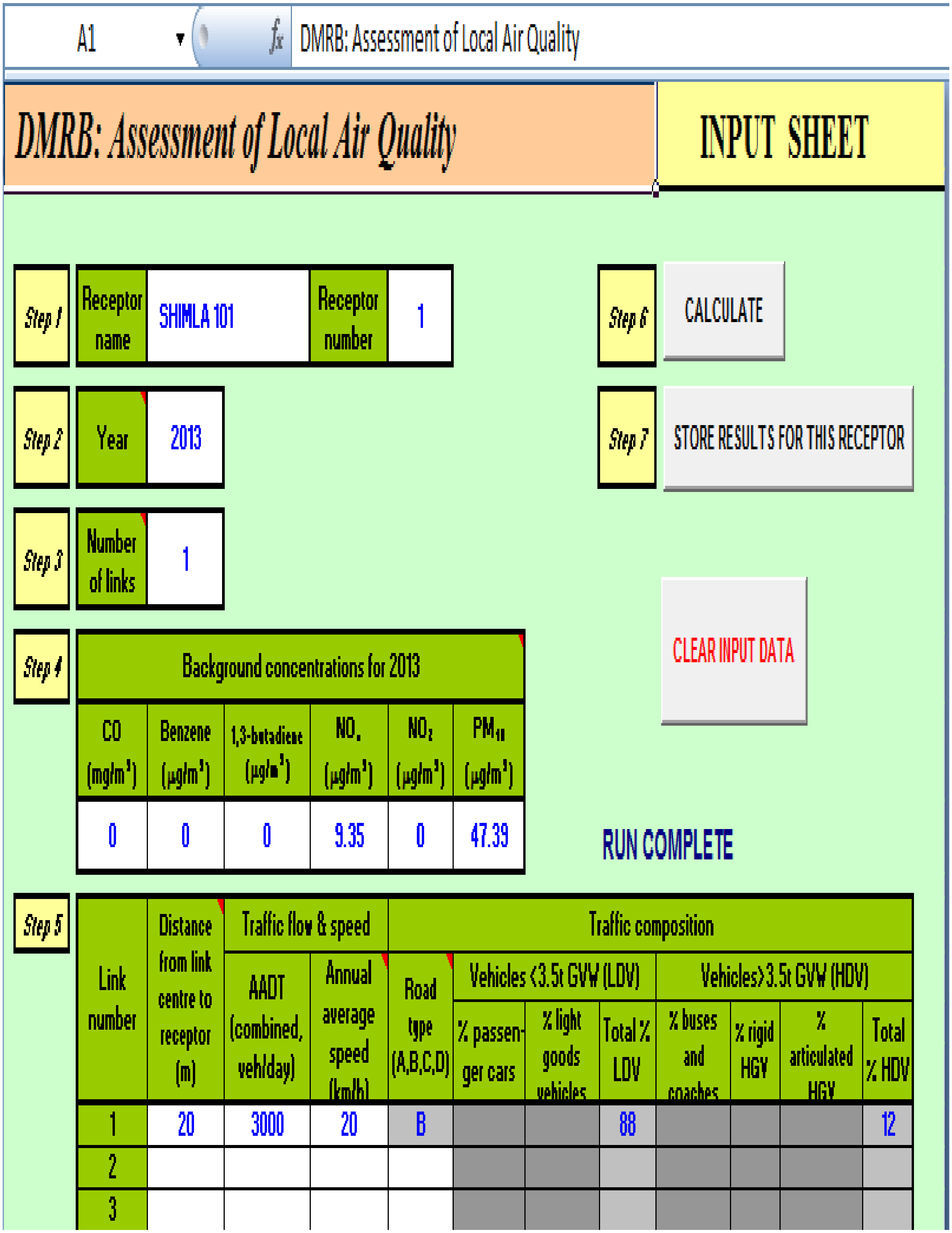

Fig 5.1 Screenshot of the Input model for 2013

5.2 Comparison of Actual measured values and DMRB Modeled values.

a) NO_x

Years	Monitored	Modeled	Difference%
2004-2005	**15.07**	**19.80**	**-31.42**
2005-2006	**8.96**	**16.50**	**-84.19**
2006-2007	**16.24**	**16.80**	**-3.46**
2007-2008	**11.31**	**15.80**	**-39.72**
2008-2009	**9.67**	**14.20**	**-46.90**
2009-2010	**12.87**	**11.20**	**12.95**
2010-2011	**17.11**	**12.70**	**25.77**
2011-2012	**16.28**	**11.10**	**31.83**
2012-2013	**12.73**	**12.90**	**-1.38**
Average			**-15.17**

Table 5.4 Monitored Vs Modeled data set

From the table it is evident that from 2004-2009, the modeled values overestimates the NO_x concentration in comparison to the monitored values by 41%. It is then noticed that from 2010 onwards up till 2012, the model under-estimates the NO_x concentration by 24%.And for 2012-2013, modeled values over-estimates the pollutant concentration by 1.41%. Overall the average concentration variation between the modeled and monitored comes out to be 15.17%. Hence we conclude that this method of assessment of pollutant concentration is fairly comparable to the modeled data set and within acceptable range thus requiring no further detailed analysis.

a) RSPM

Years	Monitored	Modeled	Difference %
2004-2005	**13.63**	**10.09**	**25.98**
2005-2006	**37.33**	**25.40**	**31.96**
2006-2007	**61.54**	**42.15**	**31.50**
2007-2008	**58.78**	**48.59**	**17.33**
2008-2009	**60.75**	**54.50**	**10.29**
2009-2010	**69.17**	**60.46**	**12.59**
2010-2011	**58.67**	**55.66**	**5.13**
2011-2012	**59.83**	**49.39**	**17.45**
2012-2013	**57.64**	**47.74**	**17.18**
Average			**18.82**

Table 5.5: ***Monitored Vs Modeled data set***

Upon meticulously examining the modeled and monitored data, the modeled data under-estimates the RSPM concentration values significantly throughout the study period. This could be due to discrepancies as a result of the many assumptions that had to be made since records on vehicle count running around the old ISBT were not maintained. However, the average variation of the actual monitored values to the modeled value was about 18.82% which is just slightly higher than the acceptable deviation percentage between the monitored and modeled values of 15%. Hence it is concluded that the screening model employed has resulted in acceptable pollutant estimation for Shimla city based on the assumptions made and so no further detailed assessment modeling for RSPM as well is not required. On the basis of this finding, it is therefore recommendable to use this model to find future pollutant concentration.

5.3 Relationship between Speed and pollutant concentration

Before we find future pollutant concentration for Shimla city, it is important that we understand the relationship between speed and pollutant concentration to be able to draw good conclusions.

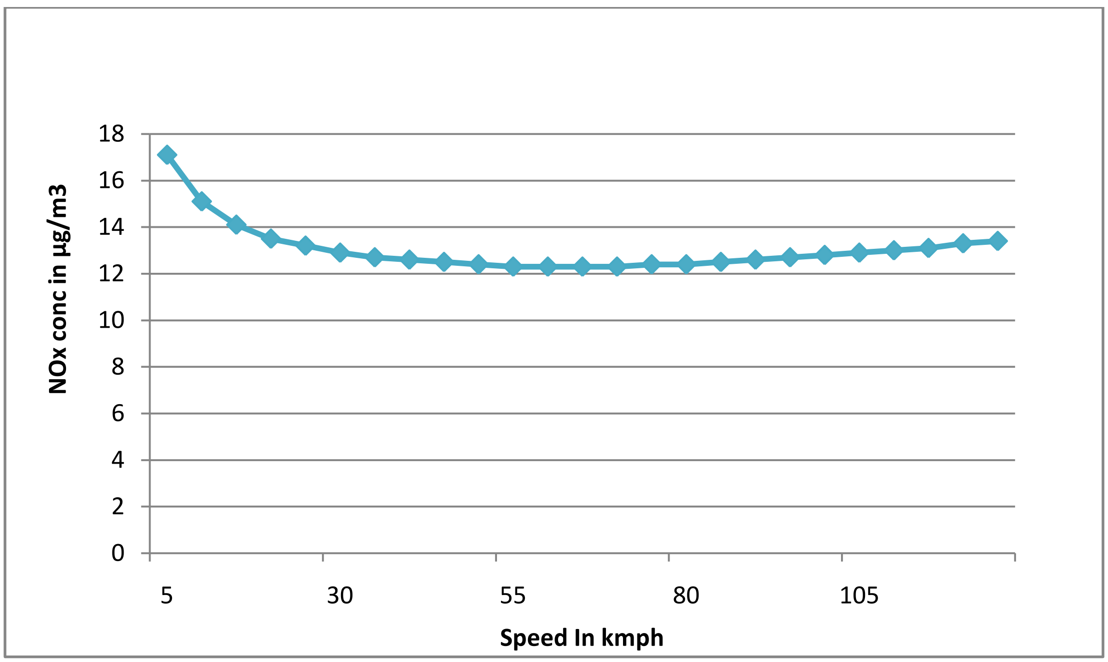

Fig 5.2 Variation of NOx concentration with speed.

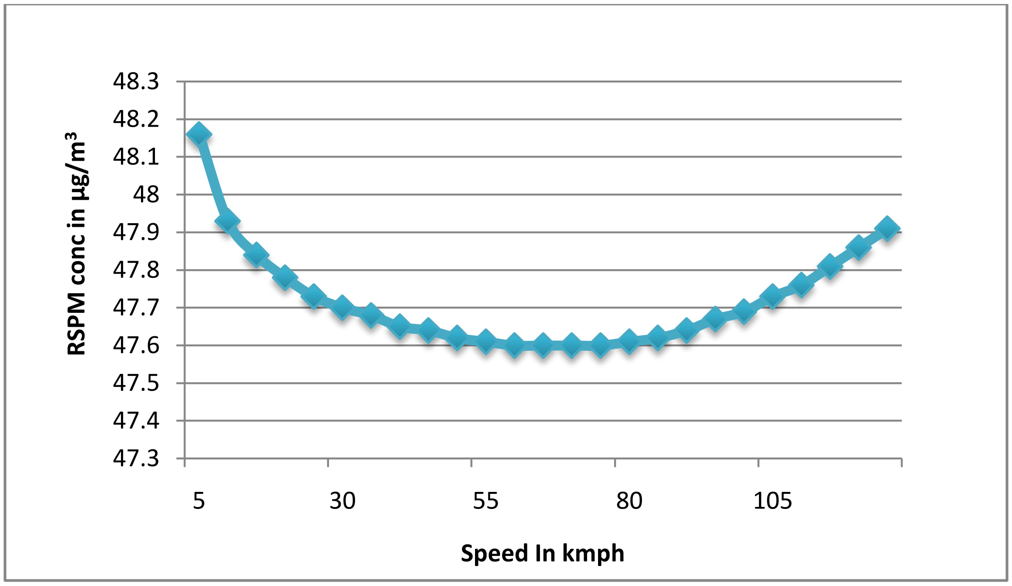

Fig 5.3 Variation of RSPM Concentration with Speed.

The two graphs for speed vs. concentration of both RSPM & NOx were plotted by obtaining pollutant concentration from DMRB model altering just the speed and keeping all other inputs constant. It clearly shows that at a certain speed, the generation of NOx and RSPM pollutant concentration from vehicle exhausts is the minimum. This optimum speed for producing minimum pollutant exhausts ranges from 60-75kmph for RSPM and 55-70kmph for NOx pollutant. These graphs further prove that at low speeds i.e. congested roads; the generation of pollutants is very high. When vehicles are driven in freely flowing traffic at moderate speeds, lowest overall pollution levels are produced. At speeds higher than this optimum speed, higher volume of fuel is required to support the requirement and also incomplete combustion of fuel leading to heightened pollutant creation

5.4 Analyzing the Inter-relationship between Monitored and Modeled data sets.

To analyze the interrelationship between the monitored and the modeled data set for study period, some basic statistical tools were applied. These statistical tools were Mean, Standard Deviation and Bias.

Statistical tools	NOx		RSPM	
	Monitored	Modeled	Monitored	Modeled
MEAN	13.36	14.56	53.04	43.78
STANDARD DEVIATION	2.99	2.90	17.04	16.12
Mean Fractional Bias	-1.20		9.26	
% deviation w.r.t mean monitored data	-15.17		18.82	

Table 5.6 Results of the Statistical analysis

The mean percentage deviation of the modeled values from the monitored is -15.17% for NOx and 18.82% for RSPM. The model overestimates NOx values from 2004-2009, while from 2010 onwards the predicted values are lower than the monitored data set. All of RSPM values have been underestimated by the model. This variation is within the standard acceptable percentage variation 15% for NOx and slightly above this permissible percentage for RSPM. Despite all the assumptions that had to be made and the inbuilt characteristic of DMRB model to make estimation for the worst case scenario, it is must be accepted that the model produces fairly reliable results.

The standard deviation of the modeled and monitored data set for both NOx and RSPM are close to other. The large values of the standard deviation show that the data set is scattered- i.e. it has a large variation about the mean.

The graphical representations of modeled and monitored RSPM concentrations as show in fig 5.5 show the same pattern for all the years and as analyzed, modeled data sets are smaller than the monitored data sets. Whereas the graphical representation of modeled and monitored NOx concentrations as shown in fig 5.4, show similar pattern and some variation as a result of over or underestimating results obtained from the model.

Hence from the analysis, it could be concluded that the modeled and monitored data set have good interrelations and that the screening model is reliable future pollutant predictor.

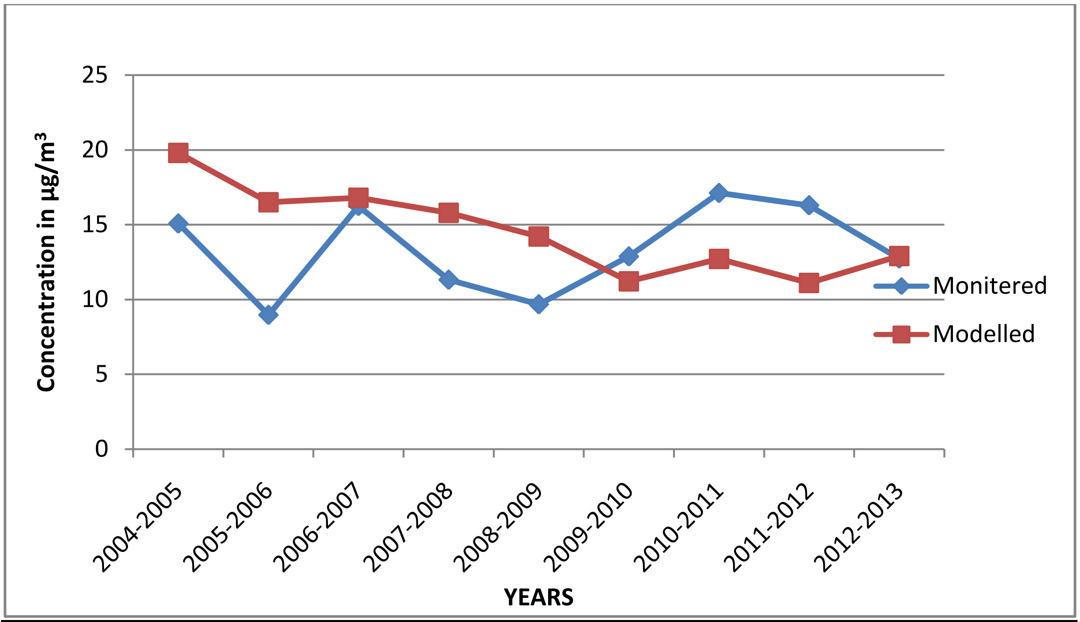

Fig 5.4 Monitored deled Vs Modeled for NOx concentration.

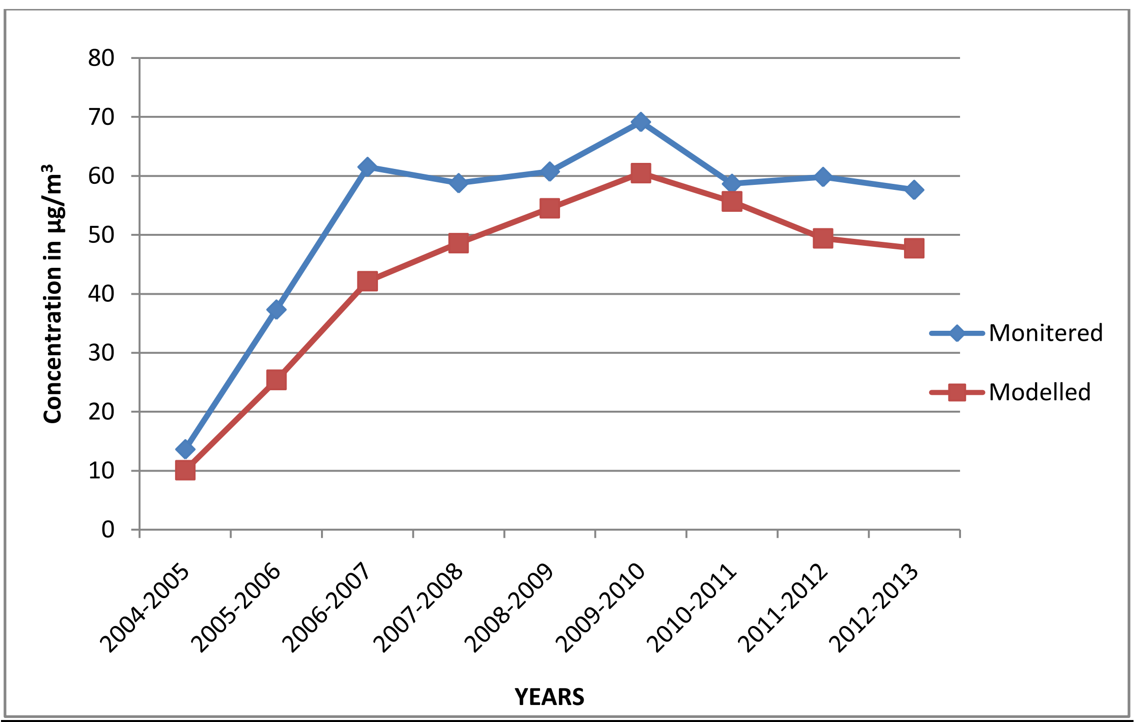

Fig 5.5 Monitored Vs Modeled for RSPM concentration

Chapter 6

Prediction of pollutant concentration

6.1 Input data for estimating pollutant values.

Predictions for the next five years from the study period were made employing the DMRB screening model. Background concentrations used for running the model for these five years were obtained by extrapolating the monitored data for previous years in excel. And since only three of pollutants - SO_2, PM_{10} and NOx pollutants were monitored; background concentration for other pollutants like NO_2, Benzene, B1, 3-butadiene and CO were input as zero. The distance from the link centre to the receptor and the Annual Average Speed for the vehicles were maintained as 20 m and 20Kmph respectively. The AADT values were increased by another 10% confirming to the thumb rule assuming a 10% increase in traffic data due to developmental activities.

The Road type was maintained as B while, LDV and HDV were maintained as same as that obtained for 2013 from the count of registered vehicles. The table presents a summarized version of the input and the final predicted NOx and RSPM values.

Years	AADT	LDV%	HDV%	Annual speed in Kmph.	Link distance in meters	Background in µg/m^3		Predicted in µg/m^3	
						NOx	RSPM	NOx	RSPM
2014	3300	88	12	20	20	10.32	45.7	14	46.06
2015	3300	88	12	20	20	11.28	44	14.8	44.34
2016	3300	88	12	20	20	12.25	42.32	15.7	42.66
2017	3300	88	12	20	20	13.22	40.63	16.4	40.94
2018	3300	88	12	20	20	14.18	38.93	17.4	39.24

Table 6.1 Summarized input data and Predicted Results

It is evident that the predicted values of RSPM and NOx, using the DMRB screening model, are below the Standard concentration of 60µg/m^3 and 50µg/m^3 respectively. However when the monitored and modeled values of RSPM were compared for the study period, the model mostly underestimated the RSPM concentrations.

Chapter 7

Measures to abate Air pollution

Both annual and seasonal analysis for a decade (2004–2013) of Shimla city demonstrated that NOx and SO_2 pollutant concentrations didn't exceed the permissible limits of 40µg/m^3 and 50µg/m^3 respectively. However annual average RSPM concentrations did exceed the permissible limits 60µg/m^3 slimly. Having said this, it doesn't mean that one ought to be ignorant of the ever proliferating issues of air pollution in other cities like Delhi, Patna, Kanpur and Pune to name a few. Instead, this calls for a stronger commitment to curtail air pollution at it's base level by taking immediate measures now.

Following these measures would be facilitating air pollution reduction for Shimla city:

7.1 Traffic Congestion is the most significant issue that Shimla is facing today. The roads in Shimla are carrying more vehicles than its desired capacity.

- Works on road enlargement should be done to support the ever increasing traffic volume.
- Road-infrastructure development, management and by-passing of inter - state vehicles, parking restrictions, etc. are some of the measures being adopted in the cities. Cities like Delhi, Mumbai, Kolkata, Pune etc. have constructed many flyovers and multi-lane roads to ease traffic congestion. This could be implemented for Shimla city too.
- Bus Rapid Transit System (BRTS) aims at segregation of traffic in various lanes according to type of vehicles. Through BRTS it is expected that the hindrance caused to speed of fast moving vehicles by speed of slow moving vehicles will overcome and mass transit vehicles i.e. buses will move in optimal way.
- Dedicated bus bays should be made to prevent buses to stop on cart road for boarding and alighting of passengers. Stopping of buses at any location other than designated bus stops should be regulated.

7.2 In-use vehicle

- All vehicles running in the roads should conform to the mass emission standards of India the **Bharat stage emission standards**.
- Vehicles older than fifteen years should be banned from roads.

- Regular air quality monitoring/ stack emission of industries is should be carried out.

7.3 Alternate Fuels – Initiatives

- Just like Delhi, Mumbai, Ankleshwar, Vadodra & Surat in Gujarat and Kanpur, Bareli, Agra & Lucknow, CNG as automotive fuel should be implemented in Shimla too.
- Work is to introduce bio-diesel in the form of B20 as an automotive fuel in India. Several research studies and field trials have been initiated by Organizations like – IITs, IOC, Mercedes, Railways, etc. Already "Jatropha Carcus" has been identified and earmarked to be the prominent source of biodiesel in the country. Efforts for developing and popularizing electric vehicles also gained momentum during this year. Already "Reva Motors" have commercialized a small electric/battery car. Many three-wheeler manufacturers are also contemplating electric driven OEM for Indian markets.

7.4 Proper maintenance of existing roads and Introduction of new system

- Existing roads should be regularly checked against cracks, wear and tear and seasonal weathering. Inspection of road condition at regular time intervals and facilities and manpower to fixes damaged portion of the roads should made available.
- Modes of transportation which could cater to vertical and horizontal mobility like ropeways, escalators, BRTS (Bus Rapid Transport System), MRTS (Mass Rapid Transport System) could be made an option for mobility in Shimla. More lifts/escalators at appropriate locations should be made available.

7.5 Others

- Car-pooling could be encouraged. Use of public transport for transportation could be bolstered by making it easily accessible and cheaper.
- Subsidiaries on Diesel fuel should be scrapped.
- The HP Government should invest in Source Apportionment studies so that exact culprit of air pollution could be caught and according managed.

- Proper maintenance and management of wastes should be practiced. Open burning of litter in any form must to be discouraged.
- Forest fire is required to be prevented.
- Regular air quality monitoring/ stack emission of industries is required to be carried out.
- All vehicles carrying potentially dusty materials to or from the construction site should be fully sheeted on the public highways to decrease dust generation on roads.

Conclusion

The project titled "Ambient Air Quality analysis of Shimla city" was set out to assess the change in ambient air quality of Shimla city for over a decade. Upon analyzing the monitored data by graphical means-seasonal graphs, annual graphs and monthly average graphs, the annual graphical analysis ascertained that NOx and SO_2 concentration limits were well below the annual permissible limits of 40µg/m^3 and 50µg/m^3 respectively, while RSPM values slightly exceeded the permissible limits of 60µg/m^3 as for Industrial, Residential, Rural and other Areas in accordance to the Revised National Ambient Air Quality Standards (NAAQS). The reason for these elevated values of RSPM was concluded to be as a result of congested and under-maintained roads that caused higher road dust suspension in the atmosphere, running old vehicles that emitted higher rate of pollutants, use of diesels to run vehicles and poor maintenance of drains and litter. Whereas the cause of reduced concentration levels of SO_2 was ruled out to be as a result of only few small scale industries within the Municipal boundary of the city supplemented by the growing stringent rules to reduce sulphur contents in vehicle fuels.

From the seasonal graphs evaluation it was found that all of the three pollutants RSPM, NOx and SO_2 had the highest concentration levels during spring seasons. The reason for this peculiar behavior when examined was found to be as a result of Spring being the peak tourist season, the season with minimal precipitation and the season with the highest rate of dispersion of pollen grain from Pine trees and flowers across Shimla city.

The 2007 version of DMRB screening model was employed to make future predictions of absolute annual mean pollutants concentration for Shimla city. To determine the model's reliability and validity for the study, firstly test samples were run in the model and then the modeled results obtained where compared with the monitored data and older DMRB versions. This comparison between modeled and monitored evidently showed that the model did yield results that were comparable with the monitored data however at the price of over or under estimation of some pollutants. The second test conducted to reaffirm its applicability was, modeling the data for the past one decade and comparing it with the monitored data. The model did over-estimate and under-estimate pollutant concentration at different times, nonetheless these errors were within the acceptable limits of the acceptability range of this model. Thus it was adjudicated that the model was applicable to the case study and that no further detailed analysis was required.

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