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URBAN AIR QUALITY MANAGEMENT IN INDIA (WITH SPECIFIC EMPHASIS ON PARTICULATE MATTER)

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ABSTRACT

Urban air quality is an issue of major concern across many cities and towns in the developing countries, including India. In particular, high levels of particulate matter (both SPM and RSPM) are responsible for non-compliance against air quality standards. This paper suggests various air quality management options that can be applicable to major urban centers which are at present most affected by the deteriorating air quality. As an example, Pune city is chosen, which is a top-ten urban agglomerate in India (based on population). Analysis of ambient air quality is carried out and the causal factors for poor air quality are determined. In order to highlight the gravity of the problem, the health impacts due to exposure to particulate matter emissions in Pune city are estimated, and economic evaluation of health damage is done. Sectoral emission loads are estimated for transport, industrial, and domestic sectors, which provide an estimate of the major contributors to air pollution with specific reference to particulate matter, which is a major pollutant of concern. A detailed scenario analysis is carried out to estimate the changes in emissions that would take place due to various interventions. On the basis of the above exercise, an air quality management plan is developed that specifically accounts for factors contributing to deterioration of air quality in Pune. This overall assessment of the air quality issues for Pune can provide useful insights for the development of the air quality management plan for other cities as well.

Key Words: Urban Air Quality Management, Particulate matter, Emission Loads, Health impacts, Scenario analysis

1. INTRODUCTION

Environmental quality is rapidly becoming a major issue in urban India. Indian cities suffer from some of the worst air quality problems in the world, which continue to be a major public health issue. Urban air pollution is largely a result of combustion of fossil fuels for transportation, power generation, industrial and other economic activities. Major contributing factors for urban air pollution are: 1) Increased migration of population towards urban areas, 2) Industrial development & higher levels of energy consumption, 3) Increasing traffic & related issues such as poor inspection & maintenance, congestion and outdated vehicular technology, and 4) poor quality fuels.

Highly Polluted Indian Cities

Delhi, the capital of India, itself is one of the most polluted city in the country. The trends of air pollutants: sulphur dioxide (SO_2), nitrogen oxides (NO_x), suspended particulate matter (SPM), and respirable suspended particulate matter (RSPM) are shown in Figure 1 for the years 1995 to 2004. With the intervention of Honourable Supreme Court, various strategies have been implemented to abate air pollution levels in the city. Though, SO_2 concentrations have come down significantly, but no substantial decrease is observed in the particulate matter concentrations. On a positive note, the SPM and RSPM concentrations have not increased despite the increased activity levels in the city. While SO_2 and NO_X are within the permissible limits, the SPM and RSPM concentrations have violated the ambient air quality standards in most of the years.

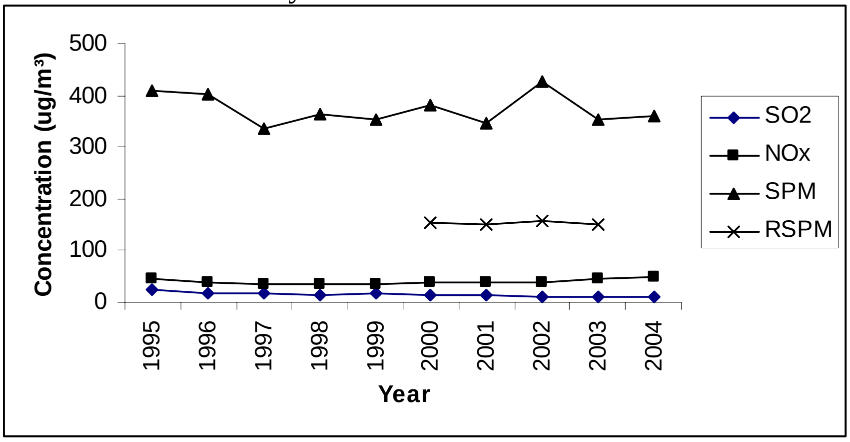

Figure 1: Trends of annual average SO_2, NO_x, SPM, and RSPM concentrations (average for all the stations) in Delhi for the years 1995 to 2004

Source : CPCB, 1997, 1998, 1999, 2000, 2001, 2002, 2004a, 2004b, 2005

The Honourable Supreme court of India ordered for preparation of scheme with regard to improvement of the air environment in 16 cities other than Delhi, which are equally, or more polluted. The cities are Agra, Ahmedabad, Kanpur, Solapur, Lucknow, Bangalore, Chennai, Hyderabad, Mumbai, Kolkata, Pune, Faridabad, Jharia, Jodhpur, Patna, and Varanasi. The brief status of ambient air quality in these cities for the period 1995 to 2003, is described in following sections.

SO_2 : SO_2 levels in all the selected cities are under permissible standards except in Jharia where SO_2 concentrations violated the standards in 1998/99. In 2003, the SO_2 concentrations in the cities were even less than 20 $\mu g/m^3$, which is one third of the conservative residential area standards. Among all the 16 cities, SO_2 levels were highest in Jharia, Faridabad, Kolkata, and Lucknow.

NO_x : NO_x levels in most the selected cities are under permissible standards. However, Kolkata, Pune, and Jharia have registered NO_x levels exceeding the annual average standards. On a positive side, the NO_x concentrations in all the other cities were less than the conservative residential area standards. Trends of NO_x concentrations are increasing in Pune, Kolkata and Jharia.

SPM : SPM emerges out as the pollutant of concern for our urban centers. Almost all the cities violated the residential area standards and cities like Kanpur, Agra, Lucknow, Patna, Jharia, and Jodhpur have even violated the less stringent industrial area standards many times. Chennai stands out with hardly violating even the residential area standards. On a positive note, trends are decreasing in Kolkata, Ahmedabad, Patna, Pune, and Jharia while they are increasing in Kanpur, Solapur and Jodhpur.

Case- Pune City

To simplify and to arrive at problem specific unique air quality management plan we chose Pune as the representative city among all the urban agglomerates. Pune, the second largest city in Maharashtra, has a population of 3.75 million people (PMC, 2003). Few important transformations of the post independence period in Pune are marked by: 1) Rapid growth of large industries in all peripheral areas, 2) Growth of new National level institutions, 3) Spilling over of residential development across the Municipal Corporation limits in all directions. Some of this spill bears a resemblance to planned development and a large part being in the form of unauthorized development.

- **Air Quality in Pune**

Annual average SO_2 concentrations across the Pune city have varied from 22-54 µg/m³ during 1995 to 2003, but remained under the prescribed residential area standards. While annual average NOx concentrations have varied from 23-78 µg/m³ and violated the residential area standard few times. Annual average SPM concentrations have violated the residential area standards in all the years and have shown increasing trend during the years 2000 to 2003. RSPM monitoring started in the year 2000 and the annual average RSPM concentrations have followed an increasing trend thereafter and also violated the industrial area standard during the years 2002-03. (Figure 2)

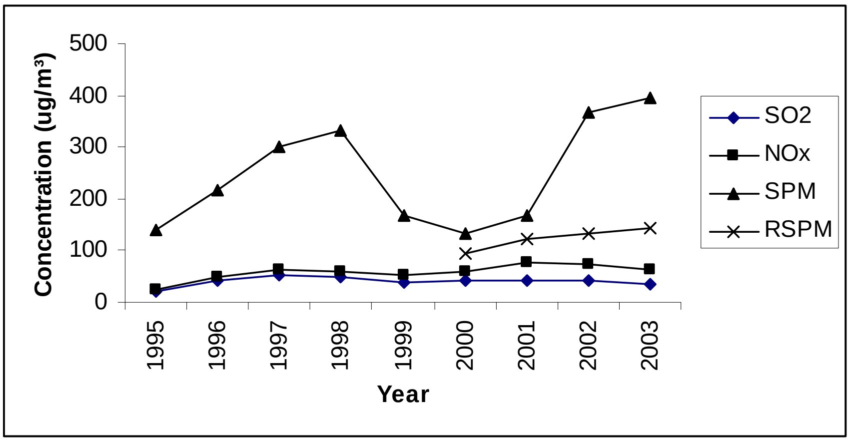

Figure 2: Trends of annual average SO_2, NO_x, SPM, and RSPM concentrations (average for all the stations) in Pune for the years 1995 to 2003
Source : CPCB, 1997, 1998, 1999, 2000, 2001, 2002, 2004a, 2004b, 2005

- **Health Impacts And Economic Damage**

To highlight the enormity of problem, the health impacts due to exposure to respirable particulate matter emissions in Pune are estimated. The estimation exercise started off with the estimation of the population exposed to the pollution. The figures for the population of Pune city are collected from Census India 2001 with categorizations of slum and non-slum, by gender and age groups. Health impact coefficients (Ostro B.,1994) are used to arrive at health effects due to change in concentration of the particulate matter. These effects are then monetized using the monetary cost attached with unit health state (Brandon and Hommann (1995). The results are presented in Table 1, which reveals that due to the annual average RSPM concentration of 141 µg/m³ in the year 2003-04, which is well above the earlier suggested WHO guideline value of 40µg/m³, nearly 6633 mortalities are expected to occur which amounts to an economic damage of nearly 977 millions. Also, economic damage of nearly 966 millions is expected to occur due to restricted activity days.

Table 1: Health impacts and economic damage due to RSPM concentration in Pune in 2003-04

Outcome	**Number**	**Economic damage (Million Rs)**
Mortality	6633	977
Hospital admissions	5362	17
Emergency room visits	105186	23
Restricted activity days	14210532	966
Lower respiratory illness in children	337493	1
Asthma Attacks	1019688	14
Symptoms of respiratory disorder	81771618	164
Chronic Bronchitis	27347	7
Total (Millions)		2169

- **Causal Factors**

Population growth: Pune city has grown at moderate rates in the post independence period with decadal growth rates ranging from 7 to 102 percent over the last eight decades. Pune urban population has grown from 17.35 lakhs to about 26.97 lakhs between 1991 and 2001 (Census of India, 2001). Continuously growing population exerts tremendous pressure on the limited resources and thus affects the environment significantly.

Vehicular growth: Due to increase in personal vehicles and less dependency on public transport, Pune is facing major problems of congestion and air pollution. The total numbers of on-road vehicles in 2002-03 were about 7 lakhs, which are projected to double by 2014-15, and the use of liquid fuels like petrol and diesel can only make the situation worse.

Industrial growth: There are about 30000 small-scale industries in Pune district. The major types of industries are paper and wood, foundry, metal, forging, automobile, engineering, textile, dairy, steel mills, refractory and ceramic, galvanizing units.

Domestic & Commercial: Though, cleaner fuel like LPG has taken over in urban areas, but people living in slums continue to use polluting fuels like firewood, biomass, etc. With ever-rising population, the emissions from domestic sectors are always increasing.

EMISSION INVENTORISATION

The approach towards emission inventorisation used in this paper is based on the activity data/ fuel consumption estimates and use of appropriate emission factors. The base year for the calculations was assumed as 2004-05 and projections were made for a decade i.e., up to 2014-15. Different scenarios, which are developed to study the impact of various interventions on the SPM emission loads, are:

a) *Business As Usual (BAU):* This scenario simulates the SPM emission loadings, if no interventions are taken in any of the sectors.

b) *CNG scenario:* This scenario simulates the SPM emission loadings,

- if CNG is replaced with traditional fuels like petrol and diesel with city specific switch over percentages in the vehicular sector, and
- if natural gas is replaced with traditional fuels like petrol, diesel, furnace oil, biomass etc with city specific switch over percentages in the industrial sector.

c) *PCV Scenario (Phase-out 10 yr. old commercial vehicles):* This scenario simulates the SPM emission loadings, if all the commercial vehicles (auto-rickshaw, taxi and buses) older than 10 years are phased out.

d) *PAV Scenario (Phase-out all 10 yr. old vehicles):* This scenario simulates the SPM emission loadings, if all the vehicles older than 10 years are phased out.

e) *IS Scenario (Industrial scenario):* This scenario simulates the SPM emission loadings, if 10 % of the emissions coming out of industrial sources can be avoided due to technology change, shifting, less fuel usage or modified production processes.

f) *PTS Scenario (Public transport system scenario):* This scenario estimates the emission loadings, if the existing private vehicles (2-wheeler & cars) fleet is replaced by an efficient public transport system (bus based). Estimations are also made for public transport system based on fuel usage (diesel as well CNG) (PTS-d & PTS-c). The emission estimates were made for three major sectors (transport, industrial, and domestic) and the same are dealt below in detail.

- **Transportation Sector**

For each year, estimates of breakup of different types of vehicles (old and new) and vehicle kilometer travelled were made along with the switchover percentage to CNG. The emission factors for different reference years are based on the type of vehicle and fuel used (TERI, 2002). Besides this, the emission factors for the period 2010-11 to 2014-15 for LCV and passenger cars were taken as per the norms specified for Euro IV vehicles under the auto fuel policy of the Government of India. However, in the case of diesel heavy-duty vehicles, the emission norms were adopted from a study that evaluated the alternative fuels and technologies for buses in Mumbai (TERI, 2001). Emission loads are calculated as:

Emissions Load/Day = No. of vehicle x Kilometers travelled per day (Km/d) x Emission factor (g/km)

The emission inventory of SPM for the transport sector for years 2004-05 and 2014-15 under different scenarios is shown in Figure 3.

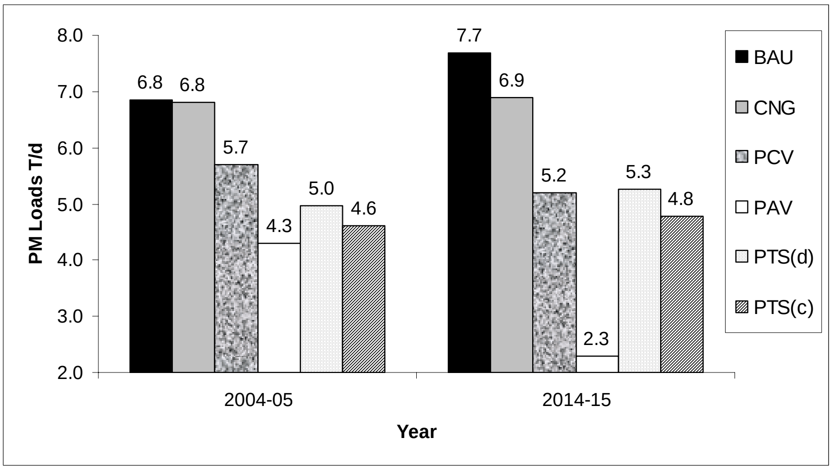

Figure 3: Vehicular SPM loads for Pune under different scenarios

Figure 3 clearly compares the vehicular emission loads of Pune under different scenarios and clearly exhibits the fact that the vehicular pollution load will increase to its maximum if activity levels go with the same pace as they are going presently.

- *BAU scenario:* Figure 3 reveals the increase in emission loads during 2004-05 to 2014-15 due to increase in number of vehicles. As per the present rate, the total SPM emission loads from vehicular sector will increase from 6.8 T/D in 2004-05 to 7.7 T/D in 2014-15.
- *CNG scenario:* Figure 3 reveals the decrease in emission loads due to intervention of CNG in the automobile sector. Therefore, it is estimated that SPM emission loads will be reduced by nearly 10% in 2014-15 when compared to BAU scenario.
- *PCV scenario:* Phasing out commercial vehicles older than 10 years can have a significant impact on the SPM emission loads generated by vehicular sector. Immediate phase out of 10 year older commercial vehicles results in a decrease of 16 % SPM emissions loads in Pune. However, continuation of this phasing out programme, leads to a decrease of 33% of SPM emissions in 2014-15, in comparison to BAU scenario, in Pune.
- *PAV scenario:* This emerges out to be the most effective scenario. Phasing out all vehicles older than 10 years can have a tremendous impact on the SPM emission loads generated by vehicular sector. Immediate phase out of 10 year older vehicles results in a decrease of 37 % SPM emissions loads, in Pune. However, continuation of this phasing out programme, leads to a decrease of 70% of SPM emissions in 2014-15, in comparison to BAU scenario, in Pune.
- *PTS scenario:* PTS(d) scenario replaces all the 2-w, cars and existing buses with an equivalent efficient public transport system of new diesel buses. Immediate action can result in reduction of 26% SPM emission loads when compared to BAU scenario and continuation of program till 2014-15 may result in a decrease of 31% SPM emission loads when compared to BAU scenario. PTS(c) scenario replaces all the 2-w, cars and existing buses with an equivalent efficient public transport system of new CNG buses. Immediate action can result in reduction of

32% SPM emission loads when compared to BAU scenario and continuation of program till 2014-15 may result in a decrease of 38% SPM emission loads when compared to BAU scenario.

- **Industrial Sources**

The consumption of various fuels (Petrol, Diesel, Furnace Oil, Coal, Firewood, LPG & Natural gas) in various categories of industries has been estimated. The emission factors (in Kg/Unit of fuel consumed) have been adopted from WHO(1993). Emission loads have been estimated for SPM for BAU, CNG, and IS scenarios.

Emissions Load/Day = Fuel Consumed x Emission Factor (Kg/Unit of fuel consumed)

The emission inventory of SPM for years 2004-05 and 2014-15 under BAU, CNG, and IS scenarios is shown in Figure 4.

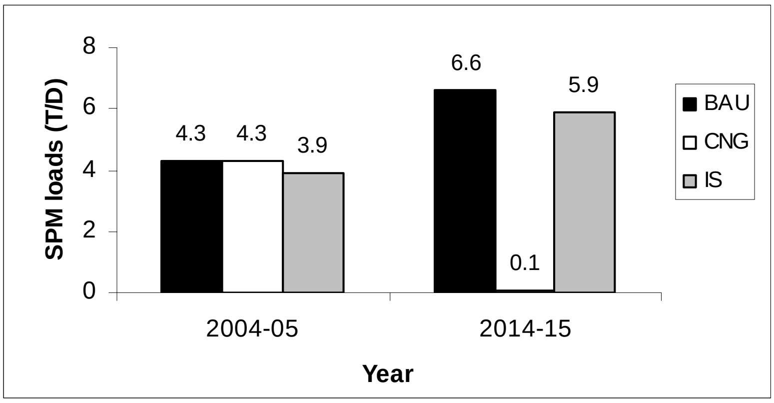

Figure 4: Industrial SPM loads for Pune under different scenarios

- *CNG scenario:* Figure 4 reveals the drastic decrease in emission loads due to intervention of natural gas in the industrial sector. This is with the assumption of very good percentage switch of industries towards natural gas due to economical or regulatory reasons.
- *IS scenario:* This scenario lowers down the emission levels by 10 % due to various factors like technology change, process modifications, energy conservation and cleaner production initiatives. Therefore, a marginal decrease can be observed under this scenario.

- **Domestic Sector**

The total fuel consumption has been estimated accounting for the population in Pune city and the per capita fuel consumption based on NSSO (2001). Emission factors for LPG, fuel-wood, and kerosene have been adopted from World Bank1997 and TERI 2003 in order to estimate emission loads.

Emissions Load/Day = Fuel Consumed x Emission Factor (Kg/Unit of fuel consumed)

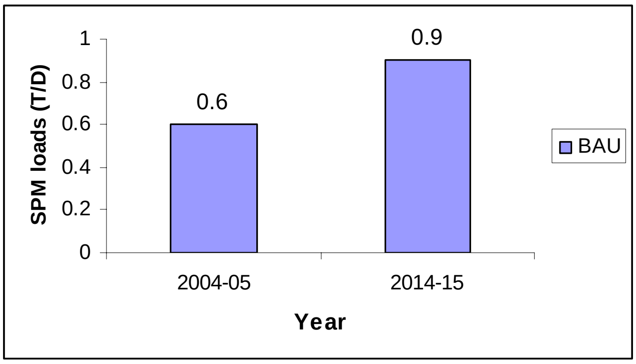

Figure 5: Domestic emission load in Pune in BAU scenario for 2004-05 and 2014-15

- **Aggregated SPM Emission Loads**

Aggregated SPM emission loads are calculated by adding the emission loads from all the three sectors. Analysing the results, CNG scenario emerges out to be the best, which targets all the sectors and expected to reduce the emissions by 48% by the end of 2014-15. PAV scenario reduces the total emissions by nearly 21% immediately and 36% after 10 years. However, if commercial vehicles are only phased out, then reduction is 9% immediate and 16% after 10 years. PTS scenarios (diesel & CNG) also show immediate reduction of 15-18% emission loads, and a reduction of 16-19% in the year 2014-15. (Figure 6)

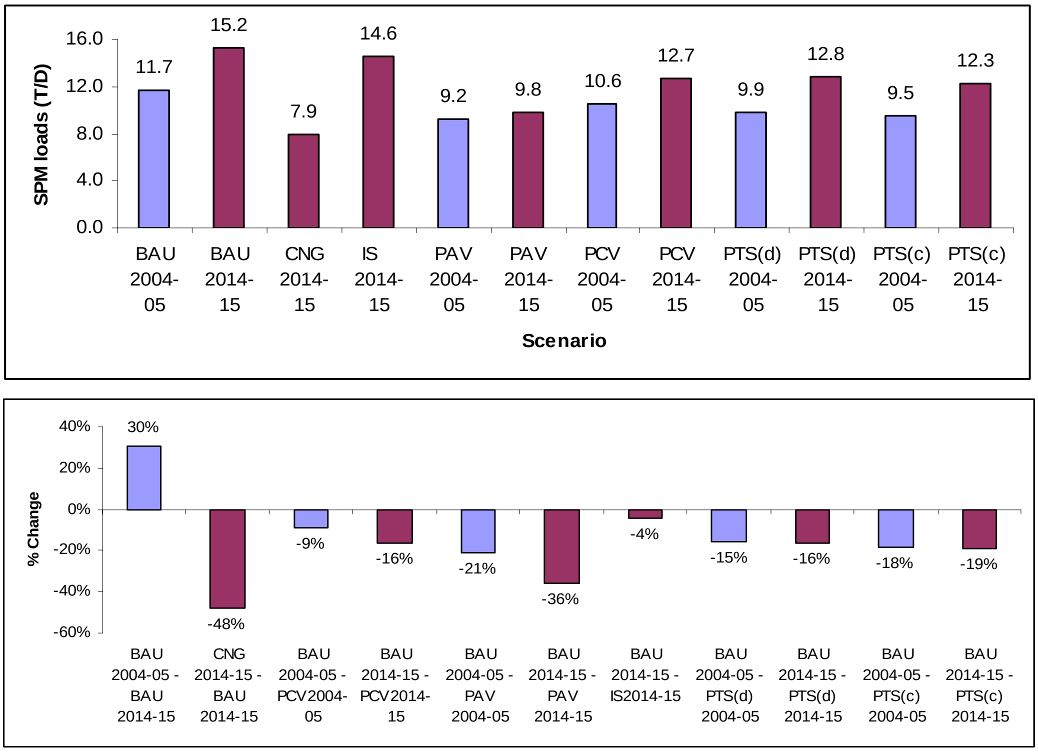

Figure 6: Total and percentage change in emission load in Pune under various scenario for 2004-05 and 2014-15

- **Percentage share of SPM loads from various sectors under different scenarios**

Figure 7 clearly explains the percentage share of SPM emission loads under different scenarios. CNG scenario targets the industrial sector and reduces its share drastically. However, PCV, PAV and PTS scenarios aim the transport sector and reduce their share from total SPM emission loads. In 2004-05, percentage share of vehicular emission load is maximum (58%) with other major contributors are the industries with 37% share. However, in the BAU scenario 2014-15, the percentage share of industries increases to 43%. Though, with the intervention of Natural gas in the CNG scenario, there has been a drastic decrease in industrial emissions and its share goes down to 1%. In PAV and PCV scenarios, percentage share of vehicular sector reduces to 24% and 41% respectively, in the year 2014-15, while under the PTS scenarios the share remains nearly 40% in the same year.

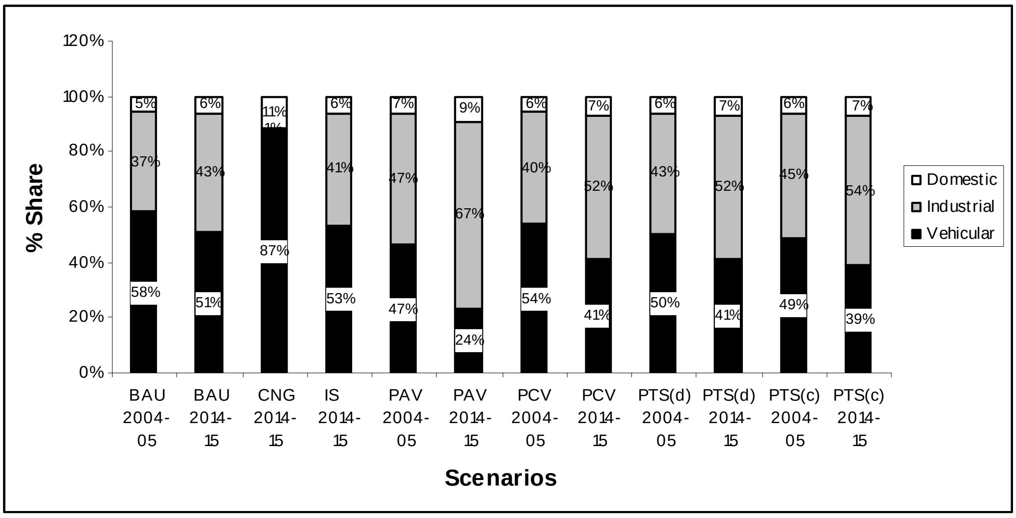

Figure : 7 Percentage share of each sector under different scenarios in Pune.

AIR QUALITY MANAGEMENT PLAN

Pune is a city in which vehicles and industries both contribute almost equally. Therefore management strategies should focus upon both the sectors. Some of the city specific key strategies can be:-

- Introduction of CNG in vehicular and natural gas in industrial sector can reduce the SPM emissions substantially.
- Notification of vehicles norms like Bharat-II, III, IV.
- Phasing out of 10-year old commercial or all the vehicles (if possible).
- Shifting of industries to the outskirts of the city.
- Checking fuel adulteration.
- In non-CNG scenario, supply of better quality of diesel and petrol.
- Proper inventorisation of industrial emission loads.
- Round the clock vigilance of industries.
- Major augmentation of public transport system is required. Mass Rapid Transport system may be considered for the fast expanding and major urban areas in the country.

- Strengthening of inspection and maintenance system is required for regulating pollution from the large fleet of in-use vehicles

Also, few general strategies can also be adopted as: -

- Development of comprehensive air quality management plans based on scientific studies that involve information related to urban planning, ambient air quality, emission inventory, and air quality models.
- Systematically planned emission load mapping studies should be undertaken at regular intervals. Development of emission factors for Indian conditions to be expedited.
- Review of air quality standards based on health studies
- Strengthening of air quality monitoring network (both in terms of number of stations as well as parameters monitored, including air toxics)
- Development, maintenance and continuous updating of a credible database on air quality, noise levels, emission inventory, source apportionment, health effects, etc
- Proper siting of projects to minimize the adverse impact on people and environment
- Urban planning with focus on environmental issues
- Non-point sources of pollution (such as generator sets, waste burning, etc) also need to be controlled
- Promoting use of cleaner fuels like LPG and kerosene for domestic consumption for reducing indoor air pollution
- Incentives for environmentally benign substitutes, technologies and energy conservation
- Use of fiscal measures for pollution prevention and control. Economic instruments need to be in place to encourage a shift from curative to preventive measures, internalization of the cost of environmental degradation, and conservation of resources.
- Promotion of appropriate research and development (R & D) studies in areas such as source apportionment, environmental health, exposure assessment, environmental modeling etc.
- Thrust to information dissemination & public awareness activities
- Capacity building (both in terms of infrastructure and human resources) for various pollution control boards/Department of Environment

3. CONCLUSION

The scenario analysis approach provides various options for air quality management under different circumstances. Analyzing the options, a priority list of actions can be framed. In the case of Pune, vehicular and industrial sectors contribute almost equally to the total SPM emission loads, which directs us to frame the strategies targeting both the sectors. Analysing the results of scenario analysis, intervention of CNG in vehicular and industrial sectors appears to be the most appropriate option to reduce the SPM emission loads most effectively. Alternatively, phasing out all the 10-year-old vehicles can also help in reducing the SPM loads significantly.

This overall assessment of the air quality issues for Pune provides useful inputs for framing the strategies for air quality management in other cities as well.

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