CHAPTER II

Air Pollution in Kathmandu Valley: Its Causes, Consequences and Abatement

2.1 Introduction

As a result of rapid urbanization, motorization and economic growth, cities in developing countries are increasingly becoming an unhealthy place to live. Absence of proper land-use planning, lack of government capacity to collect and dispose of municipal sewage, or to control emissions from transport and industry are causing environmental problems in urban areas in the developing countries. Air pollution, being a major environmental problem in the urban cities, causes a wide variety of damages ranging from a minor damage to buildings to major problems such as the green house effect. However, of all the cost of air pollution, damage to human health is by far the highest (Brandon, 1999,/www.worldbank.org).

Comparative risk assessment and health studies, carried out in a number of cities (eg. Bangkok, Cairo and Mexico city) have indicated that typically fine suspended particles (PM_{10} and smaller) and exposure to lead (urban air quality management /www.worldbank.org/html/fpd//urban/ air-poll/ air-poll) cause the greatest damage to human health. While ozone, sulfur dioxide and nitrogen dioxide also cause sickness and occasional death, their impact is generally less severe than those associated with particles.

The two largest health impacts of air pollution are: (I) premature mortality, primarily from exposure to high levels of fine particulate matter: and (II) excess cases of chronic bronchitis and other respiratory infections, again associated with fine particles (Brandon, 1999,/www.worldbank.org).In China alone , there are more than 10,000 deaths a year in Beijing, and 3,000-6,000 deaths in each of ten other Chinese cities. Jakarta experiences 6,000 deaths a year, whereas, there are 2,000-4,000 a year each in Bangkok, Seoul, and Manila (Brandon, 1999,/www.worldbank.org).

Further, there are tens of thousands of cases a year of severe chronic bronchitis and other respiratory diseases associated with air pollution (Brandon, 1999/www.worldbank.org). It has been estimated that the economic value of this health damage represents 4- 30 percent of urban income.

Particulate matter is also causing health damages in Kathmandu, the capital of Nepal. There are 85 deaths in one million population due to PM_{10}.The economic value of health damage is 4 million US$ while gross domestic product (GDP) per capita in the country is 210 US$ (World Bank, 1999)

2.2 The Air Pollution Problem in Kathmandu

Kathmandu has experienced unprecedented population, industrial and vehicle growth over the past 20 years. The urban population has been growing very rapidly;

70 percent within the 20 years from 1970 to 1990.Population growth took place at the remarkable rate of 46 percent between 1981 to 1991.This huge growth was mainly due to population shift from the rural areas.

Similarly the number of industries grew by 30% to approximately 2,200 factories. Especially there was three-fold growth in Bull's trench kiln within a period of 9 years. The number of Bull's trench kilns in 1984 was 102, but grew to 305 in 1993.

At the same time, the number of the vehicles plying the city also approximately doubled in the six years from 1993 to 1999.With the increase in the number of vehicles as well as of industries, the consumption of fuel also has increased at an alarming rate of not less than 150 percent over the period of 1990-93. (Larssen et al.,1996)

Although, all this growth resulted in the strengthening of the city's economy, the growth has come at the cost of increasing degradation of the environment. Air pollution has emerged as the most visible component of environmental degradation in Kathmandu Valley. Air pollution in Kathmandu Valley is damaging many historical buildings in the valley, threatening the glorious pride of past architects. More importantly, deterioration of public health resulting from air pollution, especially the increase in respiratory and skin diseases, has become a serious concern in Kathmandu Valley (Adhikari, 1998).

2.3 Magnitude of the problem

In order to assess the magnitude of problem it is necessary to analyze air quality status of the valley from the past as it helps identify the trends. As comprehensive studies are still lacking, to attempt to get a complete picture of the problem one has to combine pieces of information from the past. So the following section attempts to analyze the problem from previous studies.

Before exploring the problem of air pollution it should be noted that although there has been changes in the air quality guidelines of World Health Organization in recent times, but to make data more timely relevant, World Health Organization air quality guideline of 1992 is adopted for this chapter.

Actually, measurements of ambient air pollution concentrations have been carried out from 1980, but prior to 1993, only scattered measurements have been recorded. The KVVECP (Kathmandu Valley Vehicle Exhaust Control Program) (Mathur, 1993) identified 7 studies done prior to1993. The findings of these seven studies are shown in Table 2.1. Of these seven studies, only two studies reported lead concentrations. Bhattarai and Shrestha (1980) reported that dust lead concentration in two different spots of Kathmandu Valley were far in excess of the acceptable level of 0.6 parts per million (ppm). Davidson and Pandey made a similar finding and concluded that the lead levels of busy street were as high as of those in urban areas in industrialized countries.

As indicated by the Table 2.1, the remaining five studies were mainly concentrated on particulate pollution. The Ministry of Housing and Physical Planning, (MHPP) study on particulate loading (extent of dust present in the air) , during the month of September 1987(Larssen et al.,1996) was carried out in three spots of Kathmandu Valley , and found that the amount of dust particles per cubic meter of air were between 6 and 11 times the US Standard. The Center for Economic Development Activities (CEDA) (1990) reported that Suspended Particulate Matter (SPM) in the Kathmandu roadside was higher than WHO guideline. In 1992, U. Sharma et al, measured Total Suspended Particle (TSP) in 16 different locations and found that particle concentrations were in the range 194-524 micrograms / cubic meter, averaging 304 micrograms / cubic meter far in excess of World Health Organization (WHO) Air Quality Guideline (AQG) – (150-230) micrograms / cubic meter. The Norwegian Institute of Air Research (NILU) 1993, found low visibility and haze and high Suspended Particulate Matter (SPM). While Royal Nepal Academy of Science and Technology (RONAST, 1993) concluded that Kathmandu SPM was higher than international standards.

Beside these seven studies identified by KVVECP, there have been four other studies between 1993 and 1994.The findings of the studies are shown in Table 2.2. The Environment and Public Health Organization (ENPHO) (Karmachayra, and Shreshtha 1993) carried out TSP, PM_{10} NO_x CO, SO_2 and lead measurement in November 1992 at nine sites to get a picture of 24-hour averages and the results of this measurement indicated that TSP averaged (24 hour) 308 micrograms/ cubic meter while the corresponding range for WHO AQG (World Health Organization Air

TABLE: 2.1 Air Quality Related Studies in Kathmandu Valley prior to 1993

Reference of Study	Year	Conclusions
1.Bhattarai and Shrestha	1980	Kathmandu: dust Pb higher than the acceptable level of 0.6ppm at two locations
2. MHPP Pollution Study	1987	Kathmandu Roadside dust; Roadside dust: 6 to11 times that of U.S. std.
3.CEDA Study	1989/90	Kathmandu: Roadside dust (SPM)higher than WHO std.
4.Davidson and Pandey	1986	So_2, NO_x and Pb higher than WHO Std.
5. Sharma and Pradhananga	1992	SPM range: 197-524$\mu g/m^3$
6.NILU Study		Low visibility and haze, road side SPM high
7.RONAST	1993	Roadside high SPM 197-775 $\mu g/m^3$ higher than International standards.

(Source: Mathur (1993))

Quality Guideline) is150 –230 micrograms / cubic meter and the average PM_{10} level was 89 micrograms / cubic meter. In contrast, the SO_2, NO_x and CO were in low concentration. Similarly, lead concentration with a maximum 24- hour value of 0.53 micrograms / cubic meter was within the range of WHO guidelines 0.5-1 micrograms / cubic meter.

The Kathmandu Valley Vehicle Exhaust Control Program (KVVECP), took measurements of TSP, PM_{10}, CO and NO_2, from September to December, 1993 (Devkota, 1993). The results showed that TSP and PM_{10} concentration were twice the WHO guidelines, as shown in Table 2.2. For TSP about 70 percent of all the measurement days were above the lower guideline value (150 micrograms / cubic meter) and about 50 percent of the days were above the higher guideline value (230 micrograms / cubic meter). About 50 percent of the measurement days had PM_{10} above the guideline of 70 micrograms / cubic meter. The result, compared to other results, showed that SO_2, NO_2 and CO were at low concentration.

TSP measurement performed on the roof of the building at Babar Mahal, for a period of four months, January to August (Shrestha, 1994) showed that WHO guidelines were exceeded for the majority of this period. Further, findings showed an 8-month average concentration of 200 micrograms / cubic meter which was more than twice of WHO guidelines. NESS (Pvt.) LTD analyzed the lead concentration of dust particulate in the street dust and air particulate matter, PM_{10}, in Kathmandu. The measurements were reported for the months of September and October, 1993 (Otaki, Sharma, and Upadhyaya, 1995). As mentioned in Table 2.2, lead concentration was in

Table 2.2: Air Quality Related Studies in Kathmandu Valley

Reference of study	year	Conclusions
8.ENPHO study	1993	PM_{10} 89μg/m^3 at general site. TSP:24hr avg. 308 μg/m^3 Pb,CO,NO_2 and SO_2 within WHO AQG.
9.KVVECP study	1993	TSP and PM_{10} twice the WHO AQG.
10.NESS study	1993	Dust Pb: average 140ppm Air Pb: 24hr avg. 1.1 μ g/m^3 PM_{10}: 24hr average 800 μg/m^3
11.DHM study	1994	8-month TSP average: 2001μg/m^3
12.DHM study	1996/97	TSP-24hr average exceeded WHO AQG 12 months out of 15 months of measurement
13. NESS Study	1998	TSP 24hr average 6 times higher than WHO AQG

excess of an acceptable level of 0.5- 1 PPM. The values obtained for lead concentration in the respirable PM_{10} are marginal to above the WHO guidelines (0.5-1. micrograms / cubic meter) although this represents a short time during the traffic hours. Ness also conducted a rapid air survey on the PM_{10} during the months of October/November, 1993 in over 60 spots. The survey showed that PM_{10} concentrations in the busy streets and in the core areas of Kathmandu may be 2 to 6 fold higher than WHO guidelines.

The Department of Hydrology and Metrology (DHM) has been monitoring TSP from 1994. Data, as illustrated in Table 2.2, from January 1996 to April 1997 showed that TSP (24 hour) average concentration remained within lower limit (150μ g/m^3) of WHO guideline only for three months i.e. June, July and August (rainy season) of 1996(MoPE, 1998). The data further showed TSP concentration at the highest level in the driest months , February, March and April. Whereas rainy season which extends from April to August TSP concentration was expected to drop (MoPE, 1998). It can be concluded from the results of the above-mentioned studies, Kathmandu has been undoubtedly plagued by particulate air pollution and lead pollution. According to Table 2.2, studies conducted by ENPHO and KVVEP showed both SO_2 and NO_2 were well within the limit. Thus it can be believed, at least for the present, there is no problem where as SO_2 and NO_2 are concerned.

2.4 Cause and Consequences of Air Pollution

In the previous section, the air concentration of different pollutants was discussed. Monitoring of ambient air quality provides useful information with regards to how much of the air pollutants the population is being exposed. It is essential to assess the exposure of pollutants but in many cases the ambient air quality on their own is not enough to measure the gravity of the problem caused by air pollution. More often, it is further essential to explore the damage due to different pollutants to measure the severity of the problem. In addition to consequences, in order to design appropriate intervention, it is essential to know the causes of air pollution. In the following section, the cause and consequences of both lead and PM_{10} are discussed.

2.4.1 Consequences of Lead

Presently, as there are no studies that examine the extent of lead pollution and the consequences of lead in Nepal. Both the prevalnce of lead poisoning in the population and its health effects are unknown. Therefore, it is necessary to estimate the average blood lead level on the basis of average air lead concentration and using that average blood lead level, one can estimate the consequences of the lead pollution. The following part of this section will first find out average blood lead level of Kathmandudites from the air lead concentration and specific consequences of lead pollution for the average blood level of Kathmandudites.

As mentioned earlier, there is a discrepancy in air lead level readings in Kathmandu because the ENPHO study showed the average air lead levels of Kathmandu as 0.53 micrograms / cubic meter, whereas the NESS study showed 1.1 micrograms / cubic meter which makes it difficult to know what damage lead is presently inflicting on the health of Kathmanduites (Larssen et al.,1996). Thus it is desirable to find out the range of blood lead level using values from both these studies. Once the estimated average blood lead level is known, then the consequences of lead can be gauged.

There are two pieces of work that relate average ambient air lead levels to blood lead level. Azar and coworkers in 1975 determined individuals blood lead level experimentally, using personal respirators to quantify air lead exposure. According to Azar et. al., the relationship is as follows:

$$[\log \text{blood Pb}(\mu g/dl)] = 1.2257 + 0.153 \log \text{air Pb}(\mu g/m^3),$$

using air Pb=1.1 $\mu g/m^3$ from NESS(Pvt),1995, then log [blood Pb($\mu g/dl$)]=1.2257+ 0.153 log 1.1 $\mu g/m^3$, thus the value of blood Pb is 17.06 $\mu g/dl$ obtained. Alternatively, Gold Smith and Hexter established the relationship on the basis of their epidemiological and experimental studies. As per Gold Smith and Hexter:

$$\log \text{blood Pb}(\mu g/dl) = 1.265 + 0.2433 \log \text{air Pb}(\mu g/m^3),$$

using air Pb=1.1 $\mu g/m^3$ from NESS(Pvt),1995 then,

Blood Pb 18.83 $\mu g/dl$, is obtained for the population according to this relationship. The combination of the values obtained from both relationships will give the range of blood lead between 17-19 $\mu g/dl$.

If average air lead concentration is taken 0.53 $\mu g/m^{3,}$ as reported by the ENPHO study, then the average blood lead level (obtained from applying both Azar et al. relationship and Gold Smith-Hextre relationship) will be around 15 $\mu g/dl$. Considering all the values, it is reasonable to believe the range of average blood level lead of Kathmandu's population is between 15 to 19 $\mu g/dl$. After finding out the average blood lead level, now it is time to discuss the general overall consequences of lead.

Lead is a highly toxic heavy metal without any function in human body. It contaminates all of the environment but especially the urban areas. A primary route of human absorption of lead is through the respiratory tract. Children inhale more airborne lead than adults for two reasons: a) because of their low heights children inhale more airborne, as lead is a heavy metal that tends to concentrate at low heights b) children have a higher respiratory rate per unit of body weight. Although 5-10% of ingested lead compounds are absorbed from the gastrointestinal tract this percentage can increase with deficiencies of calcium and iron and high –fat diets which facilitate gastrointestinal absorption of lead. The gastrointestinal absorption of lead is more in children and infants than in adults (Lewis, 1997).

Lead affects all the systems of the body. In the bloodstream, the majority of the absorbed lead is bound to erythrocytes and is also responsible for number of hematological disorders. The free diffusible plasma fraction is distributed to the brain, kidney, liver, skin and skeletal muscle. Lead even crosses the placenta thus may increase blood lead level of the fetus (Lewis, 1997). Likewise, lead affects development of the fetus if prenatal blood lead level is increased. Lead, when reaching the brain affects the central nervous system and shows neurological effects. Similarly, lead affects various functions of the kidney and is responsible for number of nephrological disorders.

Bone constitutes a major site of storage of absorbed lead where it is incorporated into bony matrix similar to calcium. As a result, lead remains in the body a long time. Lead also binds to proteins, and modifies their tertiary structure, and consequently interferes with numerous cellular enzymes (Lewis, 1997). As lead modifies the tertiary structure of protein, it produces disorder in the hormone system.

Excretion of lead is slow over time, primarily through the kidney, although fecal excretion and sweat are other routes. The half -life of lead is long, estimated to be from 5 to 10 years. However this varies with the intensity and duration of exposure (Lewis, 1997). The physiologic effects of lead are as follows: neurologic effects; hematologic effects; endocrine effects; nephrologic effects; growth and developmental effects on fetus; carcinogenic effects. The diagrammatic representation of the lead effect is shown in the Table 2.3. The most sensitive target of lead poisoning is the nervous system. Lead primarily affects the peripheral and central nervous systems.

As referred to in Table 2.3, in children, neurological deficits have been documented at lead blood levels as low as 10μg/dl, as shown in Table 2.3. ATSDR (1989) considers that a child may suffer from IQ loss, cognitive loss, hearing deficit and reduced growth at the blood lead level of 10μg/dl. In the past, this level was considered to be safe. But, Mary Fulton's research showed dose –response relation between blood lead and its affect on cognitive and educational attainment, with no evidence of threshold (Fulton, Thomson, Hunter, & Raab, 1987). Hawk's research further revealed a highly significant negative relationship between blood lead levels with IQ; that is, IQ decreases linearly as blood lead increases (Hawk et al.,1986).Likewise, decrease in blood lead levels cause cognitive improvements in moderately lead-poisoned children (Ruff, Bijur, Markowitz, Ma, & Rosen , 1993) .

Further, David Bellinger and his team found inverse association between high prenatal blood lead levels and the mental development of infants (Bellinger, Leviton, Waternaux; Needleman & Rabiowitz, 1987). These early lead –related deficits are partly mediated through birth weight and gestation (Dietrich, K. et. al,1987) since higher prenatal blood –levels were associated with reduced gestational age and reduced birth weight (Davis and Svendsgaard ,1987) . Beside this, the exposure of lead in childhood has a long-term effect. An 11 –year follow up study by Needleman's team revealed that exposure to lead in childhood is associated with deficits in central nervous system functioning that persist into young adulthood. The study evidently found higher lead levels in childhood were also significantly associated with lower class standing in high school, increased absenteeism, lower vocabulary and grammatical- reasoning scores, longer reaction times and poorer – hand eye coordination. This study revealed that the children with dentin lead levels > 20 ppm had a markedly higher risk of dropping out of high school and of having a reading disability as compared with those with dentin lead levels <10ppm (Needleman, Schell, Bellinger, Leviton, & Allered, 1990). Further, blood lead levels at 2 years age independently can effect IQ at 10 years

Hematologic effects of lead are increased erythrocyte protopophyrin in red blood cells and consequently anemia. Although anemia appears at high lead blood levels the increase in erythrocyte protopophyrin takes place at the level of 20µg/dl. As a result of lead in the body, the endocrine system of body is also affected and consequently it hampers the metabolism of Vitamin D (ASTDR, U.S Department of Health & Human Services, 1992)

Increasing evidence indicates that lead not only affects the viability of the fetus but development as well. The consequences of prenatal exposure to low lead levels includes reduced birth weight and premature birth. Although the carcinogenic effect of lead is also reported, the association between cancer and lead remains uncertain (ASTDR,U.S Department of Health & Human Services,1992).

From the above calculation, in case of Nepal the average blood lead level of total 1 million population of Kathmandu is within in the range of 15-19µg/dl. As referred in Table 2.3, the consequences of this range of blood lead level are loss of IQ, hearing acuity and reduced growth in children. Further, Table 2.3 shows that children and adult women may have erythrocyte protophyrin increased in blood when they have blood lead level between 15-19 µg/dl. Children may suffer from vitamin-D deficiency. Adults can suffer from hypertension even at 10µg/dl of lead in their blood

Table 2.3: Effects of inorganic lead on children and adults-lowest observable adverse effect levels

Children	Blood µg Pb/dl	Adults
Death →	150	
		← Encephalopathy
Encephalopathy →	100	← Frank Anemia
Nephropathy →		
Anemia →		
		← Decreased Longevity
Colic →		
	50	← Hemoglobin Synthesis
Hemoglobin Synthesis ↓ →	40	← Peripheral Neuropathies Infertility (Men) Nephropathy
		← Systolic Blood Pressure (Men) ↑
Vitamin D Metabolism ↓ →	30	Hearing Acuity ↓
		← Erythrocyte Protopophyrin ↑ (Men)
Nerve Conduction Velocity ↓ →	20	
Erythrocyte Protopophyrin ↑ Vitamin D Metabolism ↓ →		← Erythrocyte Protopophyrin ↑ (Women)
Developmental Toxicity →		
IQ ↓ Hearing ↓ Growth ↓ →	10	← Hypertension (?) ↑
Transplacental Tranfer →		

↑ Increased function ↓ Decreased function

Adapted from ATSDR, Toxicological Profile for lead (1989)

2.4.2 Causes of lead pollution

The major cause of air lead pollution in Kathmandu valley is leaded gasoline. 87-octane gasoline is used by vehicle (Sharma and Upadhaya, 1995) which contains about 0.58 gram of lead per liter. This gasoline lead content for vehicles is among the highest in the world (Adhiakry, 1998).The organic lead (Tetraethyl Lead) is used as an anti-knocking additive in gasoline. Since it is not used in the combustion process, it is released into the atmosphere as airborne lead particulate through the exhaust, generally as lead oxide or lead chloride. NESS, in 1995, estimated that nearly 10 tons of Pb dust is released into the atmosphere of the Valley (Sharma and Upadhaya, 1995).

2.4.3 Consequences of Particulate Pollution

Before discussing the particulate pollution in Kathmandu Valley it is essential to discuss overall health impacts of particulate pollution as it will give a clear picture of damages due to particulate. There have been number of studies on the health impacts of particulate pollution. But many of these are done in the developed world where there are good regulations of air quality unlike a developing country like Nepal. The following section discusses results of the studies on PM_{10} pollution and this section also contains consequences of PM_{10} in the Kathmandu Valley.

The ability of the human respiratory system to defend itself against particulate matter is, to a large extent, determined, by the size of the particles. Larger particles that enter the respiratory system can be trapped by the hairs lining of the nose. Smaller particles that make it into the tracheobronchial system can be captured by mucus, work back to the throat by tiny hair likes cilia, and removed by swallowing or spitting. Particles, larger than 10 micron, are quite effectively removed in the respiratory system by this defense mechanisms. Smaller particles, however, are often able to traverse many turns and bends in the upper respiratory system without being captured on the mucus lining. Particle roughly between 0.5 and 10 micron may be small enough to be deposited there by sedimentation. Most inhaled particles of greater than 5 micron aerodynamic diameter deposit in the upper airways to larger airways. Particles smaller than 5 micron are likely to deposit in the smaller, e.g. the bronchioles and the alveoli (Dockery and Pope III, 1994). Pope III, Bates and Raizenne, 1995, reviewed the studies conducted by of PopeBraun- Farlander et al., 1992, Dassen et al., 1986, Dockery et al., 1982, Johnson et. al., 1990, Johnson et. al.,1990, Hoek and Brunekreef , 1993, Koeining et. al., 1993,Krupnick et al. 1990., Ostro et al.,1991 , Pope et al.,1991 , Pope and Kanner , 1993, Raizenne et al., 1989, Schwartz et al., 1994, Whittemore and Korn, 1980.These studies evaluated the acute morbidity effects of particulate pollution by examining short term – effect temporal associations between lung function measures and/or respiratory symptoms and pollution. Negative associations with particulate pollution and lung function measures were often observed. The particulate pollution effect on lung function was generally physiologically, small but statistically significant. Results of most of these studies suggest, however, that a 10 $\mu g/m^3$ in PM_{10}. resulted in less than a 1% decline in lung function (Pope III, Bates and Raizenne,1995) (Dockery and Pope III, 1994,). Nevertheless, in several studies, when 24-hr PM_{10} concentrations occasionally exceed 150 $\mu g/m_3$ lung function declined by as much as 7 % during those episodes. In addition to declines in lung function, many of these studies observed increases in respiratory function symptoms (Pope III, Bates and Raizenne, 1995). A 10 μg/m_3 increase in PM_{10} is typically associated with 1 –10% increase in symptoms such as cough, combined lower respiratory symptoms, and asthma attacks (Pope III, Bates and Raizenne, 1995). These effects were also observed at comparable PM_{10} levels near or even below 150 μg/m_3. The major concern of these studies, however, was that these pollution effects may be due to other confounding factors like weather and so forth which were not adequately accounted for the analyses (Pope III, Bates and Raizenne, 1995).

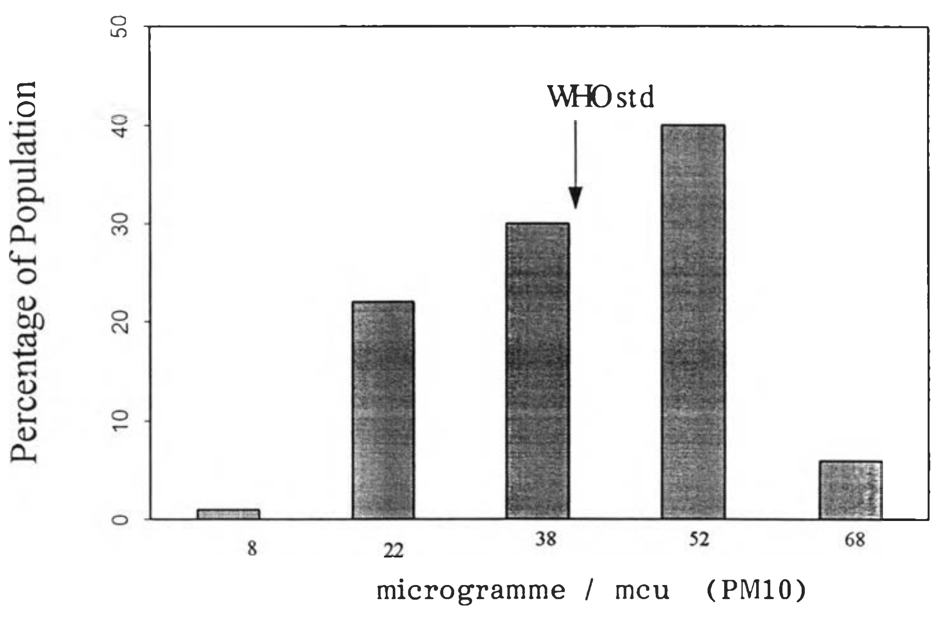
Pope III, Bates and Raizenne, 1995, reviewed studies conducted by Chestnut et al., 1991, Schwartz, 1989, Vedal et al., 1991, Dockery et. al., 1989, Ware et al., 1986,: Speizer, 1989, Euler et al., 1987, Porney and Mullahy,1990 and Schwartz, 1993, summaerized that respiratory disease , including emphysema and chronic bronchitis, and the incidence of respiratory symptoms were also associated with particulate pollution. The results suggest that a 10 μg/m^3 increase in PM_{10} was typically associated with 10-25% increase in bronchitis or chronic cough(Pope III, Bates and Raizenne,1995).

Pope III., Dockery and Schwartz,. 1995 reviewed many studies (i.e. Bates and Sitzto, 1987,1989, Lipfert and Hammerstrom 1992, Bates et al., 1990, Burnett et al., 1995, Schwartz et al. 1993, Thurston et al., 1992, Lutz, 1993, Ponka, 1991, Pope, 1989,1991 , Samet et al., 1981, Schwartz 1994, Sunyer et al., 1991, Ostro,1983, 1987, 1990, Ostro and Rothschild, 1989, Ransom and Pope, 1992).These studies evaluated acute morbidity effects of particulate pollution by examining short-term temporal association between particulate air pollution and hospital admissions, health care visits, or other measures of restricted activity due to illness. Most of these studies suggested that a 10 μg/m_3 increase in PM_{10} was typically associated with a 1-4% increase in hospital visits (Pope III., Dockery and Schwartz,. 1995). These studies also revealed an association between respiratory morbidity and observed long lead-lag times. Ransom and Pope found association between particulate pollution in Utah valley and absences of elementary schoolchildren with lead-lag relationships up to 4 weeks. Similarly Ostro observed that the association between particulate air pollution and days of respiratory morbidity serious enough to restrict activity (including loss of work, confinement to bed, or other restrictions) with a lead-lag time of 2 or more weeks (Pope III, Bates and Raizenne, 1995).

Ostro, 1984, Schwartz and Marcus, 1990; Iot et al., 1993,Schwartz 1993, Ozkaynak and Spengler, 1985, Wyzga, 1978, Schwartz and Dockery, 1992, Shumway et al. 1988, Kinney and Ozkaynak 1991, Mazumdar and Sussman, 1983, Dockery et al. 1992, Schwartz 1991, Fairley 1990, Pope et al., 1992, Schwartz and Dockery, 1992, Saldiva et al. 1995 and Wichmann ey al., 1989 conducted various time-series studies on acute effects of particulate pollution on mortality. Pope III, Bates and Raizenne, 1995 reported the findings of these studies. Findings of these studies showed that a 10 μg/m_3 increase in PM_{10} was associated with an increase in daily mortality by 0.5-1.5% (Pope III, Bates and Raizenne,1995) (Ostro, Sanchez, Aranda, and Eskeland., 1996) . Some studies also observed lagged pollution effects up to even five days. In case of mortality by cause of death, these studies suggested that respiratory disease deaths were strongly associated with particulate levels. Strong associations were observed with both respiratory (3.4% per 10 $\mu g/m^3$ PM_{10}) and cardiovascular disease (1.4%per 10 $\mu g/m^3$ PM_{10}) (Dockery and Pope III, 1994). These studies suggested that association between particulate pollution and mortality were not confounded by weather, SO_2 or ozone; indicating that the relationship between mortality and particulate pollution was independent of SO_2, ozone and weather (Dockery and Pope, 1994,).

There are a number of studies on particulate pollution, and its consequences are well documented in Nepal. A study conducted on the initiation of the World Bank presented a good and complete picture of impacts on health due to particulate matter.

Figure2 1: Frequency Distribution of PM10 exposure (annual average) Kathmandu, 1992/93



Reports of this study were published in Urbair, Kathmandu Valley Report, 1996. The health impacts due to suspended particulate matter were evaluated in terms of PM_{10}.To evaluate the impacts, the Ostro's dose –effect relationship (1994) was applied in the study. Ostro's relationship assumed a bench mark value, and it was assumed that excess death occurs when the PM_{10} concentration exceeds that benchmark value. But, WHO air quality guidelines 1999, also indicate there is no threshold limit for PM_{10}. Despite this weakness, Ostro's relationship succeeded in giving a reasonably good account of consequences of PM_{10}. These consequences are shown in Table 2.4.

As shown in Figure 2.1,one of the consequences of particulate problem is that 45 -46 percent of the 1 million population of Kathmandu Valley is exposed to PM_{10} concentrations above WHO air quality guidelines of 1992. Table 2.4 shows that the PM_{10} is, undoubtedly, a serious problem as it drains a huge amount of money, increases mortality rates and causes many diseases. In addition to these health damages, tourism industries are blaming air pollution for a decrease in the number of tourists. Although, there are no studies to assess the damage by air pollution to tourism industries, the particulate pollution may have some effects on the tourism industry. The loss of revenue due to less tourism is very crucial to Nepal as tourism is one of the main sources of foreign currency.

Table 2.4: Impact of PM_{10} in Kathmandu Valley: on Mortality, Morbidity and Economic Valuation of Impacts

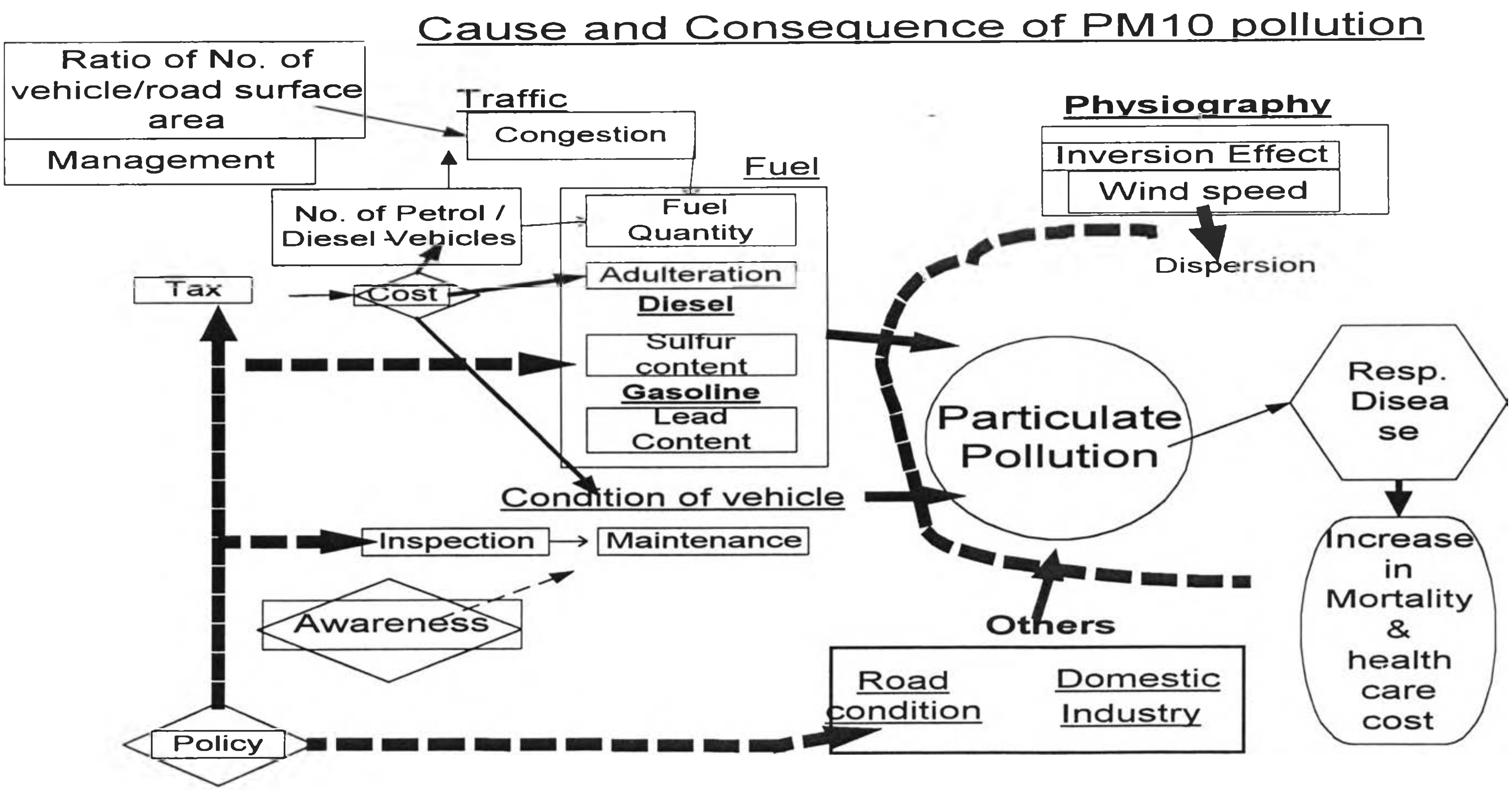
Type of health impact	No. of cases	Total lost (NRs)
Excess mortality	84	28,644,000
Chronic bronchitis	506	41,988,000
Restricted activity days	475,298	26,617,000
Emergency room visits	1,945	1,167,000
Bronchitis in children	4,847	1,697,000
Asthma	18,863	11,318,000
Respiratory symptom days	1,512,689	75,634,000
Resp. hospital admissions	99	415,000
Total	209,051,000 NRs (U.S.$ 4,181,020)	

Source: Larssen et al.,1996

2.4.4 Sources of Particulate Pollution

As shown in the Figure 2.2,Vehicles, industries, households and resuspension of road dust are the main sources of particulate pollution in Kathmandu Valley. As shown in Figure 2.2, physiography (i.e. inversion effect, wind speed), though, is not a source of particulate pollution but influences either to aggravate or reduce particulate pollution as it is responsible for dispersion of particulate matter in the atmosphere. A detail description of all these sources is given on the following section.

Figure 2.2


Cause and Consequence of PM10 pollution
Ratio of No. of vehicle/road surface area
Management
Traffic
Congestion
Physiography
Inversion Effect
Wind speed
Fuel
No. of Petrol / Diesel Vehicles
Fuel Quantity
Adulteration
Diesel
Sulfur content
Gasoline
Lead Content
Tax
Cost
Dispersion
Resp. Disease
Particulate Pollution
Condition of vehicle
Inspection
Maintenance
Increase in Mortality & health care cost
Awareness
Others
Road condition
Domestic Industry
Policy

A total of 165,000 tons of TSP and 4,700 PM_{10} were emitted by these sources in 1993 in Kathmandu Valley (Larssen et al., 1996). As shown in Table 2.5, although domestic fuel combustion and vehicle exhaust emit low TSP, but high PM_{10}, this is because both of these emissions have high PM_{10}/ TSP ratio. As a result the vehicle exhaust, though, emitted 3.5 % of total emission of TSP but it was responsible for 12% of total PM_{10} emission.

2.4.4.1 Industries

Although the major industries in the Kathmandu Valley are carpet manufacturers, the food industry, brick manufacturers and metal products, the Himal Cement Factory and brick manufacturing kilns are the main sources of industrial particulate pollution. The Himal Cement Factory even now does not utilize any significant pollution prevention mechanisms and contributes 36% of the total TSP and 17% of total PM_{10} as shown in Table 2.5. Its emission level was reported to be significantly higher than in similar facilities in India (Adhikari, 1998).

Brick manufacturers are considered to be the major contributors of PM_{10} as these industries produce 28% of PM_{10} emissions (Table 2.5). There were about 150 brick kilns estimated to be in operation in 1998.These kilns are without electrostatic scrubbers, and consequently smoke, ash particles and brick dust are directly released into the atmosphere. Moreover, smoke emissions from these kilns are particularly high during the major brick production season from November to May, the driest months, when the effects of air pollution are heightened (Adhiakri,1998).Further, the fuels brick kilns use are low quality coal and "anything that burns"-like tires and plastics. They even emit banned gases like dioxin and furan in addition to carbon monoxide and sulfur dioxide (Phuyal, 16 Feb, 1999).

Table 2.5: Sources of PM_{10} Emission and TSP Emission in Kathmandu Valley in 1993

Source	TSP %	PM_{10} %
Brick industry	31	28
Domestic Fuel Combustion	14	25
Himal Cement	36	17
Vehicle exhaust	3.5	12
Resuspesion of road dust	9	9

Source: Larssen et al., 1996

2.4.4.2 Vehicles

Air pollution from vehicles is a complex function of fuel characteristics, extent of combustion, reaction with various other gases and atmospheric conditions. Although the number of vehicles is not large, 128,283, vehicles in Kathmandu Valley (DoTM, 1999), owing to the narrow width of roads (average 4.6m)(Otaki et al., 1995) and the very short length of motorable roads, there are more than 300 vehicles per kilometer which represents very congested traffic conditions (Adhikari, 1998).

As a result of the government's fuel pricing policy, there is a large gap between the prices of diesel fuel and gasoline, making the former much cheaper,

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which makes adulteration of gasoline , by adding diesel, a common practice in Nepal. Adulterated fuel used in gasoline increase vehicle emissions.

Fuel especially diesel, sold in Nepal is very poor quality, similar to that available in India and Pakistan. The cetane number of diesel fuel used for automobile purposes is not as good as other countries. The specified cetane number of diesel is 42 in Nepal, whereas, for USA, Japan and Europe, the corresponding cetane number requirements vary from 48 to 50. The cetane number of fuel determines emission of PM_{10} (Larssen et al., 1996), the lower the centane number the lower emission of PM_{10}. Further, the diesel fuel sold in Nepal contains 1.0 percent sulfur by weight which is also the highest in the world. Diesel fuel normally contains between 0.1 to 0.5 percent by weight (in the US, it is about 0.05)(Adhiakri, 1998). The high sulfur content does not only mean high emission of SO_2, but also high emission of PM_{10} because a part of the particles emitted consist of sulfates that originate from the sulfur in the fuel (Larssen et al, 1996).

2.4.4.3 Domestic Factors

Although a majority of urban households use kerosene and gas for their cooking, there are many households in Kathmandu, which still use biomass, particularly firewood for cooking and heating. As a result, households emit 25% of total PM_{10} (Table 2.5). Many of the households still use local, traditional stoves, which are highly energy-inefficient and problematic in public health, especially in the context of indoor pollution. The impact of indoor pollution is high in the rural areas yet it contributes to outdoor concentration of PM_{10} in Kathmandu. Pandey et. al., in1985, showed the prevalence of chronic bronchitis in 8% percent of valley's population due to indoor air pollution(Larssen et al.,1996). But domestic emissions will go down, especially in the urban areas, as the cost of fuel wood is getting expensive in comparison to other fuel like kerosene. Improved stoves, that are 20% energy efficient compared to the 12% of traditional stoves, are appearing even in the rural areas, by the efforts of both governmental and nongovernmental organizations.

2.4.4 .4 Resuspension

Only 60% of all roads are tarred in Kathmandu valley. The conditions of most of tarred roads is poor which contributes to atmospheric dust pollution due to resuspension of street dust by vehicular movement (Otaki et al.,1995). But there needs to be a lot of study done on the problem of resuspension.

2.5 Priority setting: Lead vs PM_{10}

There are two competing problems of air pollution in Kathmandu (in terms of their adverse health effects): one is lead, and the other is particulate. For PM_{10} there are clear evidences of its consequences. However, in case of lead, due to lack of information, its consequences can be assessed from the mathematical estimation of blood lead level based on the ambient air lead concentrations. Questions to be considered at this point are: (1) are both lead pollution and PM_{10} pollution serious enough to intervene (2) if both are serious problems which one takes priority in the event of scarce resources. The following part of this section will discuss this issue. The common criteria for priority setting for the intervention are as follows:

a) The burden of disease or ill health

b) Consideration of feasibility of the intervention

In terms of the burden of diseases or ill health; as mentioned earlier, no study has estimated the extent of the lead problem. There have been no reports concerning the extent of the health impacts from lead in Nepal. But, based on several known toxicological studies of lead, the valley's population of 1 million, calculated from the average air lead level of Kathmandu, having a blood lead level which is in the range of 15-19ug/dl, suffer from the toxicity of lead. The consequences of this range of blood lead level are the loss of IQ, hearing acuity and reduced growth in children. Further, at this level children and adult women may have increased erythrocyte protophyrin in the blood. Children may suffer from vitamin-D deficiency. Adults can suffer from hypertension. Although lead pollution is not evidently causing mortality in Kathmandu Valley, the burden of resulting diseases may be significant, as the most vulnerable victims of lead are children. In addition, the effects of lead are permanent in nature.

As far as PM_{10} is concerned, there are concrete evidences supporting PM_{10} as causing significant health damage in Nepal. Studies in Nepal show that it is not only inflicting 85 excess deaths in population of 1 million people and a number of diseases, but is also responsible for a loss of more than 4 million US.$ in terms of health damage costs. Furthermore, a 10 percent reduction in PM_{10} concentration from four main sources will reduce about mortality by 5 % (Larssen et al., 1996). Since there are evidence showing that PM_{10} is causing health problems and abatement of its concentration will reduce these health problems caused by PM_{10}, thus, it is beneficial to target our intervention to control PM_{10} pollution.

The second criterion for choosing the intervention can be judged by the feasibility of intervention. The most effective lead abatement strategy is at the policy level. Realizing the seriousness of the lead problem in Nepal, the government is dealing with the problem by considering the mandatory use of unleaded gasoline (The Kathmandu Post, September 12,1999). This has already started in Katmandu valley. This will, expectedly, help to control lead pollution. Since Nepal does not produce its own gasoline and does not have its own refinery to produce unleaded gasoline it has to rely on the Indian Oil Corporation for unleaded gasoline. Even India has recently introduced unleaded gasoline only in a few selected cities. Thus large-scale utilization of unleaded gasoline will not be successful in Nepal until unleaded fuels are more widely marketed in India. This suggests that the intervention of unleaded fuel is only feasible after unleaded fuel is easily available in India.

For abatement of PM_{10}, there are a number of alternatives to control the sources i.e. one can reduce vehicle emissions or one can target factory to reduce PM_{10}. In dealing with even one source, there are a numbers of possible interventions. For example, common measures to control PM_{10} from traffic exhaust are a) implementing inspection and maintenance schemes, b) improving fuel quality i.e. checking adulteration. etc. Similarly one can reduce factory emissions of PM_{10} by adopting proper technology such as using electrostatic scrubbers etc.

In conclusion, although the burden of the disease for both, lead pollution and PM_{10} pollution are more or less equal but the problem of particulate pollution is chosen here. The approach to control PM_{10} proposed by the investigator is more feasible to implement with immediate favorable outcomes than the lead pollution control. An effective lead abatement strategy requires changes at policy level which lies outside the boundaries of the investigator's manageability and job responsibilities. Furthermore, the lead pollution problem will be lessen in years to come as the result of the introduction of unleaded gasoline.

2.6 Justification for intervention

After setting the priority, it is essential to explore whether an intervention is economically feasible and consider the cost effectiveness of the interventions. The following section discusses whether the proposed intervention is deserving or not.

Nepal still remains of the one of poorest country in the world. With more than 9 million of the 21 million people living below the poverty line, Nepal's social indicators remain well below the average for the South Asian region. Life expectancy at birth is 57 years, well below that of its neighbors, India, Pakistan and Sri Lanka; with infant mortality equaling 83, the highest in the region (World Bank,1999).

Furthermore, Nepal is fighting to overcome health problems like acute respiratory infection (ARI), which accounts for 30- 40% of total childhood deaths and diarrhea, which accounts 16-25 % of childhood deaths (UNDP/Nepal, 1998). In this context, Nepal with per capita income of US$ 210 and very low limited public expenditure in health, US $ 2 per capita (World Bank, 1999), cannot afford to lose more than 4 million US$ caused by particulate pollution. If pollution is not tackled in the right manner, the burden of the problem will consume more resources that will ultimately aggravate the other health problems that the country is facing. All these facts highlight the need for intervention.

After establishing the need for intervention, the point is to consider whether intervention is cost effective or not. If intervention is not cost effective, the rationale for implementing the intervention will be weak, however deserving the need. If the total emissions in Kathmandu valley are reduced by 10%, there will be a reduction of not only 5% of total mortality caused by particulate pollution but also a further saving of US$ 368,938 due to the reduction in adverse health effects (Larssen et al., 1996).

2.7 Rational for Choosing Traffic to Control PM_{10}

As mentioned earlier, there are four main sources of PM_{10} pollution in Kathmandu Valley. In the event of scarce resources, it's not practically possible to intervene in all areas. The situation, therefore, demands prioritization of interventions. All the sources of pollution can be ranked on the basis of the health damages they cause to the population. The health damages are generally measured either in terms of mortality and morbidity or in terms of monetary damage. The monetary damage is assessed by attaching monetary value to excessive mortality and excessive morbidity.

The second column of Table 2.6 indicates PM_{10} average total emission in a year for each source. The third column of the table indicates change in emission in terms of percentage. The fourth denotes change in percentage of mortality as a result of change in corresponding emissions. The last column presents the estimated marginal "damage costs" and " benefits" of changes in emissions.

Table 2.6: Marginal Benefits from Emissions Reduction in Different Sources

Sources	Emissions (tons)	% change in Emission	% change in Mortality	Marginal Cost/Benefits (US$/KG)
Traffic (exhaust)	440	-10	-6	11.52 / 6.82
Resuspension	400	-10	-2	11.42 / 2.44
Domestic emissions	1,160	-10	-9	5.4 / 3.7
Brick	1,250	-10	-3	5.06 / 1.24

(Source: Larssen et al.,1996)

It can be seen from the Table 2.6, in the last column, that changes in traffic emissions may have the largest impact on health. As an increase of 1 kg of emission in traffic exhaust will increase health damage by US $ 11.52. Similarly a decrease in 1 kg of emission of PM_{10} in traffic exhaust will reduce the health damage by US$ 6.82. In conclusion, it is clear from that from a purely a monetary point of view, reduction of vehicle exhaust achieves the maximum benefit when compared to other reductions.

Although, abatement of domestic emissions will help reduce more excess deaths than abatement of vehicular emissions .But domestic emissions is expected to decrease. Domestic emissions mainly due to the burning of fuelwood is decreasing in the Valley. It can be seen that fuelwood consumption is decreasing by a factor of 1.5 between 1983 and 1990. Although data are not available for evidence, the consumption of fuel wood must be decreasing at the same rate in recent time and will continue to decrease in the future because of the rising cost of fuelwood relative to other fuels gas and kerosene. As result, the problem of pollution due to domestic emission will decrease in the future.

Table2.7:Fuelwood Consumption, Kathmandu Valley

Year	10^3 t/yr.	Year	10^3 t/yr.
1983/84	35.9	1987/88	21.2
1984/85	40.0	1988/89	23.7
1985/86	23.7	1989/90	20.0
1986/87	29.0		

source: Devkota,1992

The number of vehicles in Nepal, especially in Kathmandu valley, is expected to grow substantially in the years to come because of increasing levels of personal income in the valley. Studies have shown that the level of motorization (vehicles per thousand population) is very closely related to income (Adhiakari, 1998). As the economy of Kathmandu is growing with increases in personal income, there will be an increased number of vehicles and consequently more vehicular pollution, unless appropriate measures are taken. In conclusion, the decreasing rate of fuelwood consumption, and the expected increase in vehicular pollution and remarkable difference in the marginal health damage cost favors the proposed intervention to curb the vehicular emissions of PM_{10}.

2.8 Alternatives of intervention

After prioritizing the target area for pollution control, it is now time to consider the alternative approaches to control pollution. Presently there are three approaches for control. These are:

1)Legal regulatory approaches,

2)Market based approaches, and

3)Information approaches

2.8.1 The Regulatory Aapproaches:

The first phase of pollution control involves applying traditional legal remedies such as emissions standards (Tietenberg & Wheeler, 1998). Over time, it becomes clear that the regulatory approaches are not only insufficient, but also excessively costly in some circumstances (Tietenberg, 1995). Failures have been especially common in developing countries, where legal and regulatory institutions are often weak (Afsah, and Lamplante, 1996).

Failure of regulatory approaches in many developing countries is mainly from causes like poor monitoring and bureaucratic inefficiency (Tietenberg & Wheeler, 1998). Monitoring is often so poor that compliance is difficult to assess. Nepal is equally ridden by poor monitoring when it comes to control of pollution. The editorial of The Kathmandu Post dated 29, April, 1999 complained about motoring in following manner.

" It is, however, an open secret that drivers whose vehicle fail to meet the criteria either bribe police officials or tamper with vehicle as to pass the test. Once the green sticker is pasted on the windscreen, the vehicles are free to belch as much as they please." (The Kathmandu Post,29 April,1999)

The other prominent problem in legal regulatory approaches is bureaucratic inefficiency. Because of bureaucratic inefficiency, enforcement of regulation faces hurdles and at times it renders the enforcement ineffective. These kinds of problems, due to bureaucratic inefficiency and corruption, are common in Nepal, as they are in other developing countries. The government of Nepal has earlier planned to ban old and polluting vehicles within the ring road of Kathmandu by 2000 in a phasewise manner; however, the plan virtually is not yet implemented due to rampant bureaucratic "red-tapism" in the concerned ministry (The Kathmandu Post, 17 June).

Conclusively, it can be said that the present problem of pollution in Kathmandu cannot be solved only by the enforcement of further legal regulations. Instead, it can be said that problem of pollution is increasing in Kathmandu Valley even though sufficient regulations (vehicle emission act) are already there .

2.8.2 Market -Based Approaches

The second phase evolves in response to the deficiencies of legal regulatory methods as mentioned earlier and tries to regulate pollution through market mechanisms. The market-based approaches involve tradable permits, emission charges, deposit -refunds and performance bonds to control pollution (Tietenberg, 1990). In some instances these approaches have worked successfully either by substituting or complementing traditional regulatory methods. Especially Eastern Europe, these approaches have added both flexibility and improved cost-effectiveness to pollution control policy (Tietenberg and Wheeler, 1998). Pollution charges have also contributed to improved environmental performance in developing Asia and Latin America, with particularly noteworthy examples in China (Wang and Wheeler, 1996), and Malaysia

Even the addition of market based approaches, however, has not fully solved the problem of pollution control. These approaches are too demanding in terms of staff and budgets for the task of regulating. In many developing countries, these difficulties are compounded by the problems associated with designing, implementing, monitoring and enforcing the market -based approaches (Tietenberg and Wheeler, 1998).

2.8.3 Information approaches

The third alternative to pollution control focuses on the dissemination of information. Information approaches emerge because the falling cost of information collection, aggregation and dissemination and the rising demand for environmental information from communities and markets (Tietenberg and Wheeler1998). The dissemination of information is basically for the two following purposes:

a) Information intensity: Effective pollution management by the state is impossible unless regulatory organizations have reliable data, integrated information systems, and the capacity to set priorities in terms of cost and benefit. Community needs information if it is to work as an active participant in the regulatory process.

b) Information leveraging: Activities by environmental agencies that influence polluters indirectly may be as important as direct enforcement. These involve influencing the polluters by carrying out those activities by environmental agencies. These activities include: educating the community about the environment; promoting voluntary, public agreements for pollution reduction; and conducting environmental training or educational program for polluters.

2.8.4 Conclusion

In the context of Nepal, where the legal remedies for good environmental management have not been sufficient on their own until now, further enforcement of law will not be successful because of poor monitoring and bureaucratic inefficiency and corruption. Market based approaches are yet to be introduced in Nepal. Furthermore, designing policy related to market –based approaches and implementing the policy need experts that Nepal is lacking.

Thus, air pollution of Kathmandu valley, most likely, can be improved by disseminating information to both polluters and the general public. This can be a very useful approach in the context of Nepal where access to environmental information is restricted to only a handful of academics. Information to polluters will help them to realize why it is necessary to change their existing polluting behaviors. Furthermore, information related to the advantage of practicing clean behaviors will encourage them to practice environmentally sound behaviors. Information to the general public will help them realize the risk of pollution and finally motivate them to play regulatory role in the pollution control.

2.9 Health Promotion, Mass Media and Behavior Change

Health promotion is the process of enabling people to increase control over, and to improve their health (WHO, 1984). Thus there are two aims of health promotion: the first aim is solely to improve health and the second is to empower people to have more control over aspects of their lives (i.e., social, economic, and environmental aspects) which affect their health (Ewles and Simnett, 1996). These aims of health promotion are achieved by seven health promotion activities. These activities are 1) health education programs 2) preventive health services 3) environmental health measures 4) healthy public policy 5) organizational development 6) economic and regulatory activities and 7) community based work. For example, health education programs provide opportunities for people to learn about health and to undertake voluntary changes in their behavior for prevention of diseases. Similarly, environmental health measures refer to all those effort to make physical environment conducive to health. Likewise, preventive health measures aim to prevent ill health such immunization etc.

Similarly, a radio program, which aims to control air pollution, is engaged in the environmental health measure. But as radio provides information to change attitudes, to make healthy decisions and to enable behavior change, it is providing a health education program at the same time. In other words, a radio program with aims to control air pollution by adopting information approach doing both health promotion activities; health education program and environmental health measure in a package.

In recent time, there has been an increase in the use of mass media for the health promotion particularly for health education. Health education is centered on mass media by virtue of its goal to educate individuals and the public. Throughout the world, media has been playing a significant role in the prevention of disease and in environmental movements (Nandy and Nandy, 1997).

As health education aims not only to increase awareness and knowledge, change attitude but also to enable behavior change, there is sufficient evidence that media are significantly successful in achieving the goal of increasing awareness and knowledge and changing behavior to some extent. For example, in Mali, Save The Children (SCF) -UK (United kingdom) implemented a radio program on prevention of HIV/AIDS (Human immune deficiency virus/ Acquired immune deficiency syndrome) which aired from 12 local radio stations. The outcome was that the main source of local population's knowledge about HIV/AIDS was radio. During the evaluation it was found that 47 percent of respondents had heard about AIDS through radio, 24% from neighbors and only 5.7 from the health services (Adam and Harford, 1998)

Similarly, BBC (British Broadcasting Corporation) Afghan Education Drama Project showed before the program that only one third of men and women correctly answered the question " at what age does a child need extra food in addition to mother's milk", whereas, two third of men and women gave correct answer to same question after the program. Likewise, this radio drama project was successful in increasing the understanding on other health issues like regular feeding of infants and immunization of children with minor illness. The number giving the correct answers after the broadcast rose to 80 percent while only 45 percent gave correct answers before the program(Adam and Harford,1998).

Beside increasing awareness and knowledge, radios are effective in changing the behavior of a target population. Evidence shows radio programs are successful enough to change behaviors. In 1993, 760 cases of guinea worn infestation were reported in Douentza, Mali, but by 1996 this had fallen to104 cases. During this period a radio program on prevention of guinea worm, developed by Save the Children - UK, was aired on local stations. Although numbers of other factors may have played important roles in lowering the cases, many people adopted a new behavior of filtering water learned from the radio (Adam and Harford, 1998).

Further, in Nepal, there is some evidence to show that radio cannot only increase knowledge and awareness but also can change behavior. A radio program ' Service Brings Reward,' developed in cooperation with John Hopkins University and aired by Radio Nepal, not only increased and upgraded contraceptive knowledge but also improved interpersonal communication and counseling skills among program participants (Karmacharya,1997)

Additionally, radio is also effective enough to change behavior in areas other than health. After the broadcast on tree plantations by Radio Douentza FM, of Mali, a high proportion respondent showed increased awareness of how to mark young trees. Moreover they were also putting the advice into practice as recommended by the program.

In conclusion, abatement of pollution is a health promotion program on its own. A pollution control program requires change in drivers knowledge, attitude and behavior and can be achieved through health education. There are ample evidences to show that radio is one of aspect of mass media which is effective in changing the behavior of target populations of both in Nepal and other countries with similar economics and lack of infrastructure and resources as of Nepal. Thus, the prime objective of changing behavior to control can be pollution can be achieved by radio.

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