Chapter 7

Air Pollution and Climate Change

Introduction

People can live without food and water for days, but cannot survive without air for even a few moments. An average person needs 13.5 kg of air every day. Dry air has concentrations of certain gases that are naturally present in the atmosphere. Any disturbance to the balance of the natural composition of air that has an adverse effect on people or the environment can be termed air pollution.

In pursuit of rapid economic development, many developing countries are confronted with environmental problems due to increasing air pollution resulting from industrialization, urbanization, and motorization. Worldwide, the World Health Organization (WHO) estimates that as many as 1.4 billion urban residents breathe air with pollutant concentrations exceeding the WHO air guideline values (WRI 1998). Although the causes and consequences of air pollution are often localized, transboundary movement of air pollutants has regional as well as global implications. Acid deposition, global climate change, and stratospheric ozone depletion are among the emerging issues that transcend political boundaries. Air pollution can be an ongoing feature, but can also present in acute, sometimes catastrophic, episodes. Table 7.1 shows some major air pollution disasters that have occurred during the last century.

Usually air pollution is differentiated into three broad categories: ambient, indoor, and transboundary. Ambient air refers to the air close to the ground that is in direct contact with the living world; indoor air pollution refers specifically to air within buildings, whether at the workplace or in the home; and transboundary air pollution is used to refer to pollutants that have entered the upper atmosphere and travel far from their source.

Air pollution of all three types is strongly affected by climate—precipitation, wind, temperature, radiation—and thus by changes in climate or "climate change". At the same time, air pollution is thought to be one of the major contributors to the present situation of "climate change"

This chapter deals with air pollution, its status, sources, and impacts, together with the context of the climate in Nepal and possible effects of climate change.

Status and Trends of Ambient Air Pollution in Nepal

Ambient air pollution may derive from both natural and anthropogenic sources. A typical natural process

Table 7.1: Catastrophic Air Pollution Episodes

Year	Location	Deaths and/or Injuries	Cause
1930	Meuse Valley, Belgium	63 deaths 600 sick	Pollutants released by coke ovens, steel mills, blast furnaces , zinc smelters, glass factories, and sulfuric acid plan ts were trapped in the valley.
1948	Donora, Pennsylvania	20 deaths 6,000 sick	Effluents from industries like a sulfuric acid plant, steel mill, and zinc production plant, became trapped in a valley by a temperature inversion and produced an unbreathable m ixture of fog and pollution (smog).
1952	London, England	4,000 deaths	"The London Fog" , daily temperatures below average, and industrial pollutants combined with condensation in the air to form a dense fog. Concentrations of pollutants reached very high levels causing suffocation and death.
1984	Bhopal, India	20,000 deaths 120,000 injured	Gas leakage from the Union Carbide pesticide plant caused a toxic cloud to drift over the city.

Source: Compiled from various sources by MENRIS staff is a seasonal dust storm. Anthropogenic activities have been largely responsible for changing the air quality in urban areas. The major sources of such pollution in Nepal are vehicle and industrial emissions, and combustion of biomass and fossil fuels. Anthropogenic activities have added large amounts of macro and micro-pollutants to the atmosphere, triggering an environmental problem.

Exposure to air pollution has become an inescapable part of urban life. Millions of people in urban centers are confronted with environmental and health problems owing to harmful emissions caused mainly by motor vehicles. Given the rate at which cities are growing and the paucity of pollution control measures, air quality will continue to deteriorate.

Many studies over the last decade (MOPE/UNEP/ICIMOD 2000; CBS 1994; MOPE 1998; Pokharel 1998; Kunwar 1999; NESS 1999) have shown that ambient air in the Kathmandu Valley is heavily polluted and not in accordance with international standards, and that the air quality is deteriorating. This development has mainly been due to a rapid rise in the number of petrol and diesel vehicles plying the streets. At the same time, continued emissions from the many brick kilns, the dyeing industry, and other industries are also important contributors.

Until recently, monitoring in Kathmandu Valley was sporadic, and it was rare to have continuous series of 24 hour per day measurements. Realizing the need for continuous air quality monitoring, the Government and the Danish International Development Agency (DANIDA) agreed in March 2001 to formally initiate air quality management of Kathmandu Valley as the fifth component of the Environment Sector Programme Support (ESPS). Monitoring stations are strategically located at six places in the Valley (Figure 7.1). The pollutants measured are total suspended particles (TSP) and particulate matter of 10 micrometers (μm) or less in diameter (PM10). Currently, PM2.5 (at some stations only), nitrogen dioxide (NO_2), and benzene are also monitored on a regular basis. Analysis of the ESPS data (MOPE 2004) indicates that the major problem is a high level of suspended particulate matter together with increasing levels of NO_2 and sulfur dioxide (SO_2).

Figure 7.1: Environment Sector Program Support (ESPS) Monitoring Stations

1. Putalisadak (Urban Traffic); 2. Thamel (Urban Traffic, Residential); 3. Patan (Urban Traffic); 4. Bhaktapur (Urban Background); 5. Kirtipur (Urban Background); 6. Matsyagoan (Valley Background)

Source: MOEST (undated)

Particulate Matter

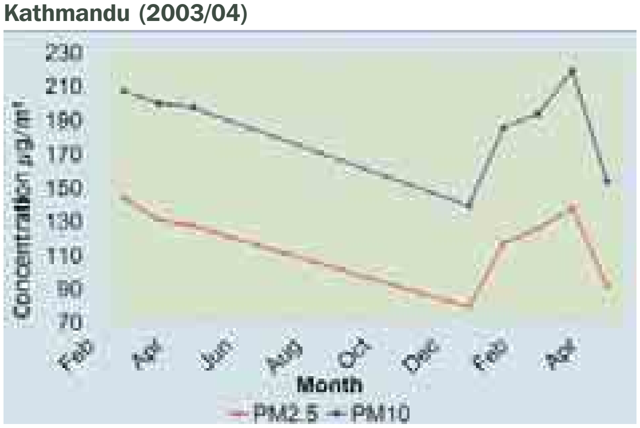
Particulate matter is the general term used for the mixture of solid particles and liquid droplets suspended in the air. These particles originate from stationary and mobile anthropogenic sources as well as from natural sources. Particulate matter is divided into two classes, primary and secondary. Primary particles are released directly into the atmosphere. Secondary particles are formed in the atmosphere as a result of reactions that involve gases.

Particulate matter is a serious problem in Kathmandu Valley. From a diesel vehicle's black puff of smoke to the haze that obscures the view of the beautiful Himalayas, particle pollution affects all residents. The complex pollution is present year round, causing health problems to the city dwellers. These particles come in many shapes and sizes and can be made up of hundreds of different chemicals. Some particles such as dust, dirt, and soot are large enough to be seen with the naked eye.

Particulate matter is generally classified according to size. Inhalable PM10 is the portion of the total air particulate matter that is 10 μm or less in diameter. Most particles with diameters greater than 10 μm will be caught in the nose and throat, never reaching the lungs. Particles between 2.5 and 10 μm will be caught by cilia lining the walls of the bronchial tubes; the cilia move the particles up and out of the lungs. Respirable particles (PM2.5) are 2.5 μm or smaller in diameter and can penetrate deeper into the air sacs.

According to the measurements done by ESPS (MOPE 2003), the average PM10 value lies between 30 and 295 micrograms per cubic meter ($\mu g/m^3$) in the core areas and 23 and 130 $\mu g/m^3$ in the sub-core and outskirts of the valley. During the dry winter periods, the PM10 values shoot up, while in the rainy season pollutants are washed from the air thus tending to lower airborne pollution (Figures 7.2 and 7.3). Apart from this seasonal variation, pollution levels peak at places where traffic density is high. Measurements for PM2.5 in Bhaktapur showed that more than 60% of PM10 is PM2.5 (Figure 7.2). This further indicates the health threat.

Figure 7.2: Concentration of PM2.5 and PM10 in Kathmandu (2003/04)



PM2.5 = particulate matter of diameter 2.5 microns or less
PM10 = particulate matter of diameter 10 microns or less
Data source: MOPE (2004)

Nitrogen Dioxide and Sulfur Dioxide

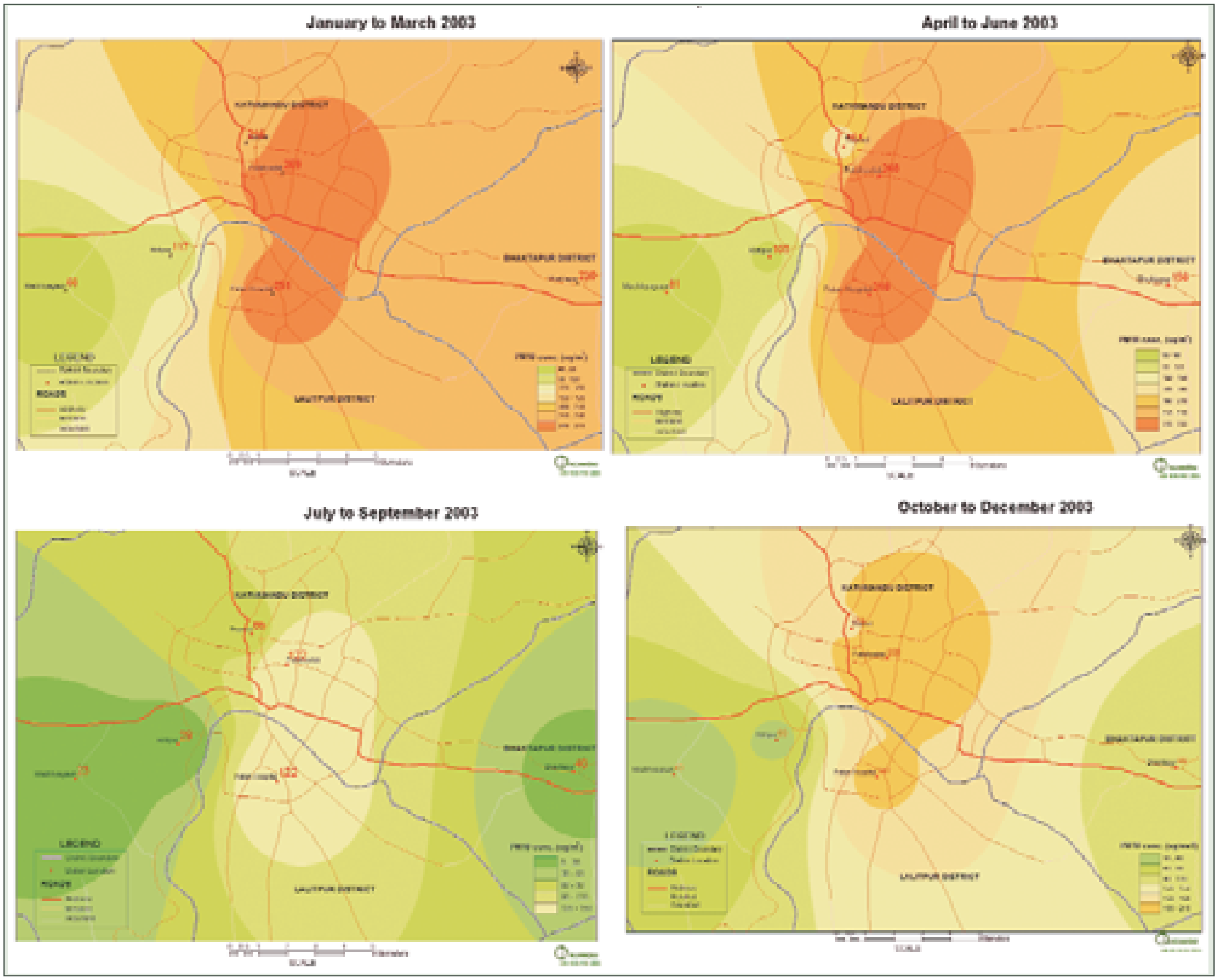
Nitrogen oxides (NO_x) form when fuel is burned at high temperatures, as in a combustion process. The primary man-made sources of NO_x are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels. Sulfur gases can be formed when fuel containing sulfur, such as coal and oil, is burned; when gasoline is refined from oil; or metals are extracted from ore. SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can harm people and the environment. The pollutants formed from SO_2 and NO_2 can be transported over long distances and deposited far from their point of origin.

Regular monitoring of NO_2 by passive samplers has been conducted by the ESPS project since 2004 (Figure 7.4). Prior to this, only sporadic measurements were done by various organizations. Devkota in 1993 measured a 24-hour NO_2 concentration of 18 $\mu g/m^3$ for a regional background site in Kirtipur with the highest concentration (38 $\mu g/m^3$) being recorded at the Himal Cement Company site (Devkota 1993). The Society for Legal and Environmental Analysis and Development Research (LEADERS Nepal) measured 24-hour average NO_2 concentrations in different locations within the Valley in June 1998 and found they varied from 0.02 parts per million (ppm) to 0.04 ppm with an average of 0.027 ppm (LEADERS 1999). The results from ESPS show that though the values are all below the WHO guidelines, there is an increasing trend for NO_2. The NO_2 also peaks during the dry season and where the traffic density is high. Monitoring of SO_2 was done for 3 months (November and December 2003 and January 2004). The highest value was recorded in Bhaktapur (70 $\mu g/m^3$), where most of the brick kilns are located (Figure 7.5). Appendix 7.1 summarizes the WHO guideline values.

Others

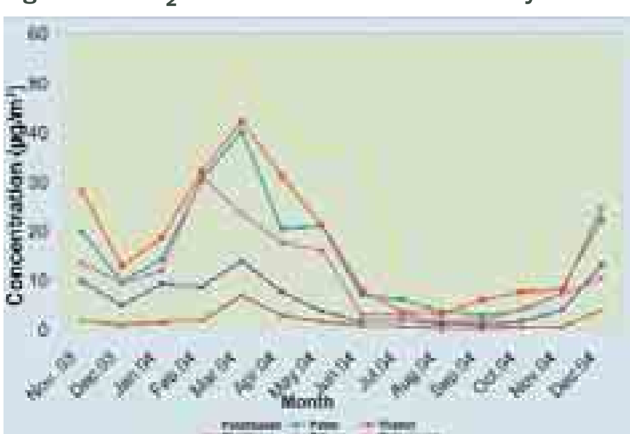
In 1993, the Environment and Public Health Organization (ENPHO) measured the average 24-hour lead concentration in the Valley and found an average value of 0.32 $\mu g/m^3$, with a range from 0.18 $\mu g/m^3$ to 0.53 $\mu g/m^3$ (ENPHO 1993). Due to the phase-out of leaded gasoline it was assumed that the lead concentration would decrease. Since 26 December 1999, only unleaded gasoline has been distributed in Nepal. However, a recent study (Chhetri et al.

Figure 7.3: Average Air Quality, January to December 2003



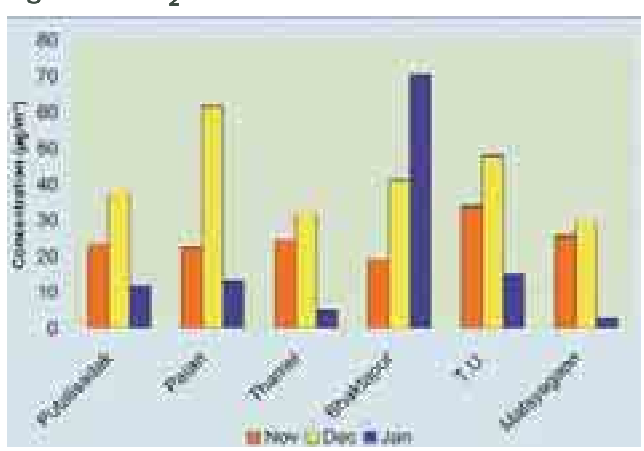
Source: Data MOPE (2003); basemap:ICIMOD (1996)

Figure 7.4: NO_2 values in the Kathmandu Valley



µg/m³ = microgram per cubic meter, NO_2 = nitrogen dioxide
Data source: MOPE (2004)

Figure 7.5: SO_2 values at different sites in Kathmandu



µg/m³ = microgram per cubic meter, SO_2 = Sulfur dioxide
Data source: MOPE (2004)

undated) revealed that lead is still present in Kathmandu's air despite the introduction of unleaded petrol. Lichens were transplanted to various places in Kathmandu to act as bioindicators. The highest concentrations of lead were found in dense traffic areas like Tripureshwor, Ratnapark, Bhadrakali, Gaushala, and Kalanki. The concentration of lead in transplanted lichen species ranged from 20 to 27 mg/kg.

The threat of benzene is now of concern also since the replacement of leaded petrol. Benzene is used in gasoline instead of lead to boost the octane. The octane number, which measures the anti-knock characteristics of fuel, is an important performance criterion for fuel. Internationally, most countries have ensured that there should be minimum levels of benzene in gasoline, generally less than 1%. However, fuel quality data from Nepal Oil Corporation show levels as high as 3–5% benzene found in gasoline samples in Nepal.

A three-week study conducted by the ESPS and the then Ministry of Population and Environment (MOPE) during January and February 2002 at seven locations in Kathmandu found weekly averages of ambient benzene concentrations as high as 77 $\mu g/m^3$ in Putalisadak, known as a high traffic area, but very low concentrations at Matsyagaon, a village located at the edge of the south-eastern part of Kathmandu Valley, about 150m above the valley floor (Figure 7.6). Other high traffic zones at Chabahil, Paknajol, and Patan had values of 44 $\mu g/m^3$, 30.3 $\mu g/m^3$, and 23.3 $\mu g/m^3$, respectively.

In November 2003, Bossi collected two samples of total PAH (polyaromatic hydrocarbons) from five different monitoring stations in Kathmandu and analyzed them in Denmark. Total PAH is the sum of all PAHs analyzed, which in this case included acenaphthene, fluorine, phenanthrene, fluoranthene, anthracene, 2-methylphenathrene, chrysene, benz(a)anthracene, benzo(a)fluoranthene, pyrene, benzo(a)pyrene, benzo(e) pyrene, pyrylene, indeno(1,2,3-cd) pyrene, benzo(ghi)perylene and dibenzo(a,h)anthracene). The samples taken from sites at Patan Hospital, Putalisadak, Thamel, and Bhaktapur had PAH concentrations of 2.32, 3.16, 3.23, and 4.30 $\mu g/m^3$ respectively—three times higher than the European Union recommended level (1 $\mu g/m^3$). The only place where the concentration was below this level was in Matsyagaon.

Bossi also measured PAH levels on September 18, 2003, which was a Nepal Bandh (enforced closure or "strike") day when there were very few vehicles on the streets. The level of PAH was about one-fifth of the level recorded during a normal weekday in November (Figure 7.7). This indicates clearly that vehicles are the main source of the pollution.

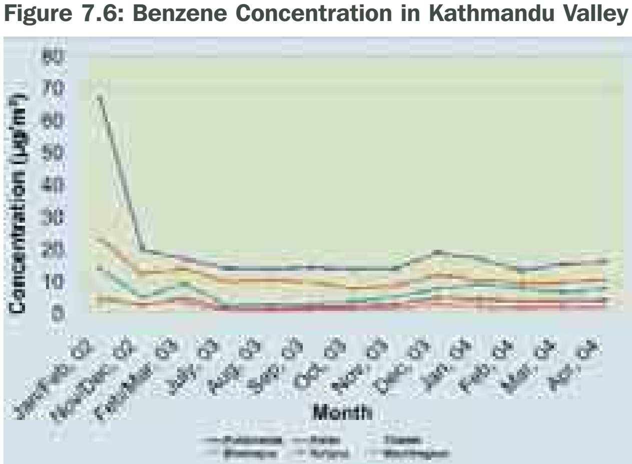
As a result of the high concentration of benzene in petrol, the ambient concentration of benzene in Kathmandu's air is at dangerous levels. Benzene, a known carcinogen, causes leukemia among others. Therefore in the interest of the health of Kathmandu's residents it has become urgent to address the problem of benzene in air.

Indoor Air Quality

The use of biomass fuels such as wood, dung, agricultural waste, and charcoal as cooking and heating fuel is the principle cause of indoor air pollution in the rural areas of Nepal. Poverty is one of the main barriers to the adoption of cleaner fuels, and the slow pace of development implies that biofuels will continue to be used by the poor. Limited ventilation increases exposure in poor households, particularly for women and young children as they spend long periods of time indoors.

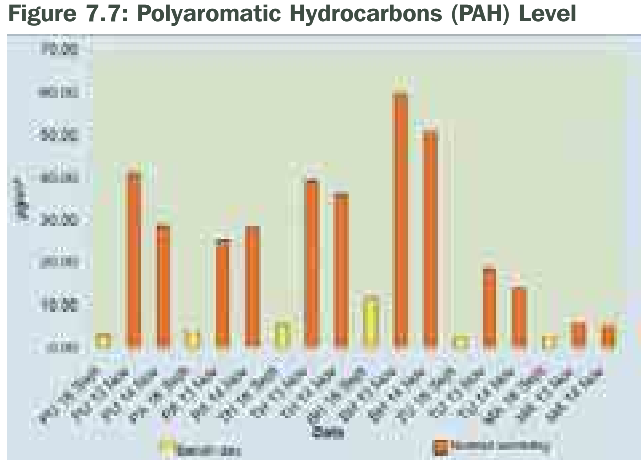
The smoke from biomass fuels is a complex mixture of aerosols containing significant amounts of carbon monoxide (CO), suspended particulate

Figure 7.6: Benzene Concentration in Kathmandu Valley



$\mu g/m^3$ = microgram per cubic meter
Source: MOPE (2004)

Figure 7.7: Polyaromatic Hydrocarbons (PAH) Level



$\mu g/m^3$ = microgram per cubic meter
Source: MOEST (undated)

matter, hydrocarbons, and NO_x (Naeher et al. 2005). Exposure to indoor air pollution carries severe health threats. Exposure to the smoke from a day's cooking is equivalent to smoking two packets of cigarettes (Warwick et al. 2004), directly affecting lungs and chest and posing risks for chronic respiratory disorders, acute respiratory infections (ARI), including pneumonia and bronchitis, chronic obstructive pulmonary disease (COPD), lung cancer, and other problems.

Pandey et al. (1987) identified the highest rates of chronic bronchitis in Jumla. After many years of study, the Nepal Health Research Council (NHRC 2004) found that the prevalence of ARI among children aged below 5 was 38% (11 of 29 examined). Comparing ARI by binary fuel types, children with unprocessed fuel in the kitchen had a higher prevalence (59%, 10 of 17) as compared with children with processed fuel in the kitchen (33%, 1 of 3). Bates et al. (2005) confirmed that the use of solid fuel in unflued indoor stoves is associated with an increased risk of cataracts in women, who do the cooking. According to a comparative study conducted by Reid et al. (1986) also cited by Raut (undated), the mean personal exposure to TSP in traditional (*agena*) cooking stoves and improved stoves is 3.92 and 1.13 mg/m^3, respectively. Similarly, mean personal exposure to CO in traditional stoves and improved stoves was found to be 380 and 67 ppm, respectively. This implies that improved cooking stoves reduce indoor TSP concentration by around 70% and CO concentration by 80% compared with traditional stoves. Lack of awareness, willingness to invest, and ability to pay for the new technology are issues preventing a switch to this cleaner technology.

The World Summit on Sustainable Development in Johannesburg acknowledged that the vicious cycle of energy and poverty needs to be broken to achieve the Millennium Development Goals for reducing world poverty. A lack of access to clean and affordable energy can, and should, be considered a core dimension of poverty.

Improvements in stoves and fuels, along with better-ventilated rooms, are the main tools for controlling the problem of indoor air pollution.

R. Shrestha

Woman with Baby Cooking

Transboundary Air Pollution

Transboundary air pollution refers to cross-boundary pollutants generated in one country and felt in others. Such pollution can survive for days or even years and can be transported hundreds or thousands of miles before affecting the air, soils, rivers, lakes, and food at the distant site. Transboundary air pollutants cause a number of different problems, e.g., formation of ground level ozone that is hazardous to health, formation of acid rain that can damage buildings and sensitive ecosystems, and other effects that are toxic to human health and the environment.

The main sources of this pollution are emissions of SO_2, NO_x, volatile organic compounds, and various toxic materials such as heavy metals and persistent organic pollutants from transport and energy usage. The main effects are acidification of water and soil, summer smog caused by tropospheric ozone, and eutrophication of soils and waters. SO_2, NO_x, and NH_3 cause acidification and eutrophication. Volatile organic compounds and NO_x deplete ozone, and heavy metals and persistent organic pollutants contribute to bioaccumulation of toxic substances.

The major weather patterns in Asia are conducive to transboundary transport of air

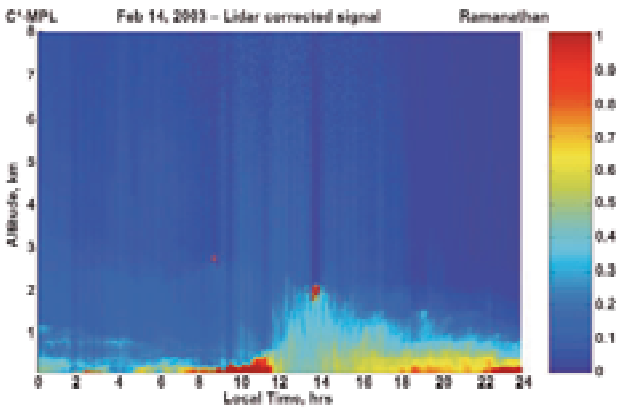
V. Ramanathan

Haze – *Haze over Phaplu: both photographs taken from the same location, one viewing north (top) and the other south (bottom), from a flight altitude of about 3 km above the ground in March 2001. During the dry season, the brown sky seen over Nepal is typical of many areas of South Asia.*

pollutants from land to sea and the reverse in summer (UNEP 2002) Pollutants can thus be carried from country to country in the region and collective cooperation and effort are required. The Malé Declaration on Control and Prevention of Air Pollution and its likely Transboundary Effects for South Asia, and the Atmospheric Brown Cloud Project are examples of regional cooperation in addressing these problems.

Studies carried out in Nepal are at too early a stage for any conclusive results. However, a light detection and ranging (LIDAR) observation from February 2003 showed long-range transport of pollution (Figure 7.8). The layer at 2600 meters above ground level is most likely due to dry convective lifting of pollutants at distant sources and subsequent horizontal upper air long-range transport (Ramana et al. 2004).

Figure 7.8: LIDAR Observation



Source: Ramana et al. (2004)

Sources of Emissions

Transportation

Nepal's transport sector is dominated by road transportation due to the country's land-locked geographical position. Apart from roads, air transport is the only modern form of transportation. Airplanes reach many remote destinations in the kingdom where roads do not or only barely exist. High currents and high slopes make water transportation impossible along the rivers. The only train track is a 52 km stretch from the border with India.

Much of the urban air pollution in Nepal, particularly in Kathmandu Valley, is caused by vehicular emissions. The problem is magnified by the narrow streets, poor traffic management, poor vehicle maintenance, and the use of adulterated, substandard fuel (Joshi 1993).

There were 418,910 transport vehicles registered in Nepal in March 2004 (Figure 7.9), an increase of 6.7% within the preceding eight-month period. Of these, 249,282 vehicles were registered in the Bagmati zone, an 11.2% increase from the previous year. The total road length in March 2004 was 16,042 km, giving an average of 26 vehicles per

Success of Safa Tempos

Kathmandu suffers from severe air pollution due to vehicle emissions and is ideal for the introduction of zero emission electrical vehicles. With a population of approximately 1.5 million people, the city occupies an area roughly 12 km wide. Thus, distances traveled are quite short. Speeds seldom exceed 40 km per hour and are generally below 30 km.

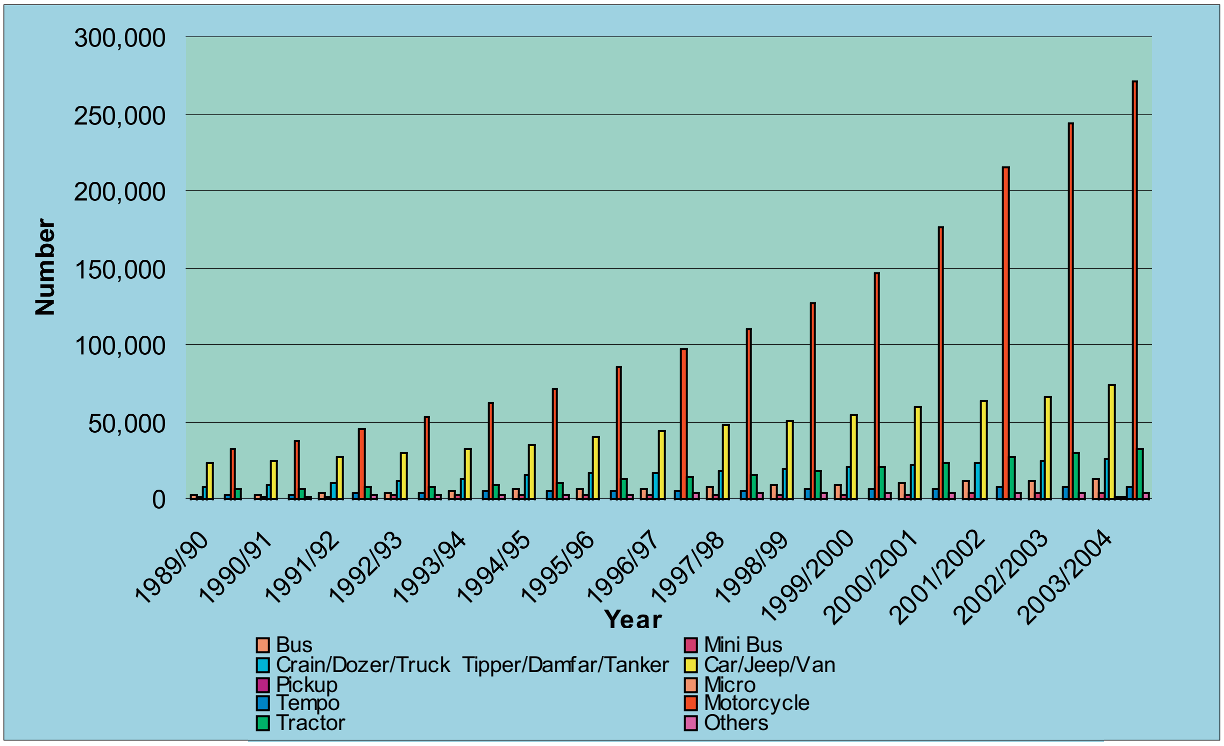
The Global Resources Institute initiated the first phase of an electric vehicle program for Kathmandu in September 1993 with the conversion of a diesel three-wheeler to electric power. Following extensive tests on the initial vehicle to optimize the drive system, seven new three-wheelers were built and the first converted vehicle was retrofitted with the new drive system. In August 1995, these eight vehicles were placed into service as a six-month demonstration project with a company providing public transportation. On February 20, 1996, these electric "tempos" — Safa tempos—were passed from the Institute to the owners of the Nepal Electric Vehicle Industry. Two other private companies have also been registered to operate electric public transportation networks.

Since mid-September 1999, 3-wheeler diesel tempos, popularly known as Vikram tempos, have been banned in the Valley. In their place, the Government made provisions to import petrol microbuses that meet Euro-1 standards. New registration of 3-wheeler diesel tempos was also banned. This decision dramatically increased the fleet of battery charged and liquefied petroleum gas (LPG) 3-wheelers to fill the gap in meeting the public transport demand. Further, the Government reduced import duties on components for local assembly of electric three-wheelers from 60% to 5% and on fully assembled electric vehicles of all types from 150% to 10%.

At present (early 2005) there are 450 Safa tempos in operation. Public response has been overwhelmingly favorable, the only criticism being the rise in the electricity tariff, which will eventually add to the cost of the battery recharge.

Source: Roy et al. (2001) and DOTM (2005)

Figure: 7.9: Vehicle Registered in Nepal



Source: DOTM (2005)

km of road in the country as a whole and 96 vehicles per km of road in the Bagmati zone. Consumption of petrol has risen continuously since 1998 with the vehicle fleet increase, but the consumption of diesel has fluctuated (Table 7.2). The estimated consumption figures for the Valley were 80% petrol and 27% diesel. Shrestha and Malla (1996) showed the total annual emission load from the transportation sector at 12,422 tons—an updated study would be extremely useful. The Valley is especially vulnerable to air pollution due to its bowl-shaped topography.

Industry

The manufacturing sector is relatively small in Nepal. Its share in national gross domestic product (GDP) is only 9.5% (CBS 2003). In the 2001/02 census (CBS 2002), Nepal had 3,230 industries, of which 1,498 were in the central development region and 846 in Kathmandu Valley. An emission inventory was conducted in the Kathmandu Valley in 1993 (Shrestha and Malla 1996). At that time the industrial sector in the Valley emitted 3,574 tons of TSP, 5,220 tons of CO, 1,492 tons of hydrocarbon, 628 tons of NO_x, and 1,349 tons of SO_2 per year.

After closure of the Himal Cement Factory, a major polluter, the brick industries located south of the Valley center are assumed to be the major air polluting industries, particularly with respect to dust emission. There are about 125 brick kilns operating in Kathmandu Valley, of which 113 are bull's trench type, 9 are clamp kiln type, and 3 Hoffmann kilns. As the manufacturing process in bull's trench and clamp kilns is very poor and inefficient, the amount of smoke emitted from these kilns is very high. A study carried out by Tuladhar and Raut (2002) near the vicinity of brick kilns (Tikathali village development committee (VDC), Lalitpur) showed that during the operation of the kilns the level of pollution was three times higher than on other days (Figure 7.10). Thanks to a cleaner technology initiative from an ESPS project initiating use of a new technology, suspended particulate matter was reduced to about 950 $\mu g/m^3$ from 2,000 $\mu g/m^3$ from the kiln. Brick production using the new technology is costlier, as it requires a large initial investment. However, it is environmentally friendly. The main advantages in the new technology are energy cost savings and quality production, which eventually pays for the initial investment by increasing production of grade "A" bricks to over 90% from around 40% with the older technology.

Household

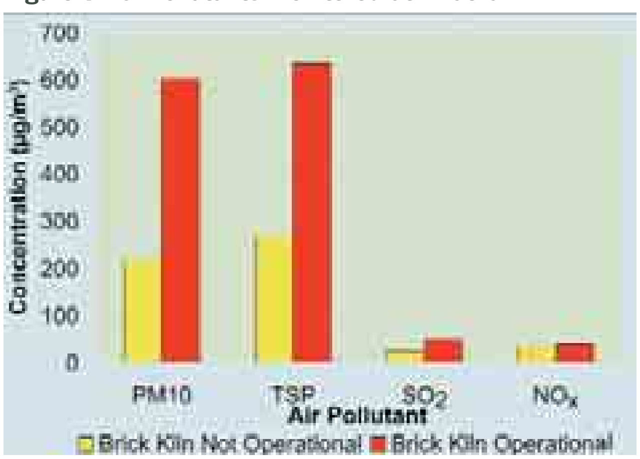
Biomass energy accounts for about 15% of the world's primary energy consumption, about 38% of the primary energy consumption in developing countries, and more than 90% of the total rural energy supplies in developing countries where large quantities of biomass fuels are used for cooking

Table 7.2: Consumption of Petroleum Products

Main Item of Petroleum	Unit	1988/89	1989/90	1990/91	1991/91	1992/93	1993/94	1994/95	1995/96
Petrol	'000 liters	17,340	14,708	17,241	26,780	29,910	31,056	34,942	41,191
Diesel	'000 liters	75,356	103,273	106,438	166,552	179,900	196,047	227,226	250,504
Kerosene	'000 liters	63,246	92,672	75,939	122,458	149,237	162,077	180,536	208,720
Light Diesel Oil	'000 liters		9,327	16,541	2,542	1,530	–	4,191	4,375
Furnace Oil	'000 liters	–	–	–	11,062	20,222	27,319	31,567	18,449
Air Fuel	'000 liters	–	–	–	24,836	29,210	30,250	37,536	40,621
LPG	million tons	–	–	–	–	–	–	–	18,400
Main Item of Petroleum	**Unit**	**1996/97**	**1997/98**	**1998/99**	**1999/00**	**2000/01**	**2001/02**	**2002/03**	**2003/04[a]**
Petrol	'000 liters	44,889	46,939	49,994	55,589	59,245	63,578	68,482	46,058
Diesel	'000 liters	257,235	300,604	315,780	310,561	326,060	287,657	301,672	181,818
Kerosene	'000 liters	243,005	282,026	294,982	331,120	316,381	390,113	351,696	208,033
Light Diesel Oil	'000 liters	2,017	967	547	4,005	3,418	2,413	610	556
Furnace Oil	'000 liters	16,858	27,776	33,860	26,876	20,999	18,255	14,502	6,405
Air Fuel	'000 liters	47,688	51,412	55,549	56,849	63,130	47,274	53,546	44,653
LPG	million tons	21,824	22,361	25,019	30,627	40,102	48,757	56,079	43,871

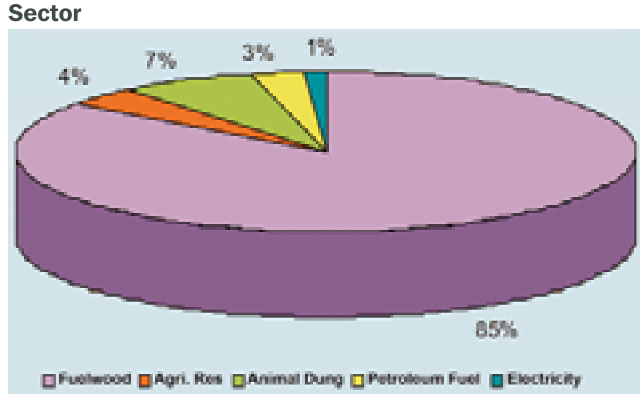
– = not available, LPG = liquefied petroleum gas
[a] First 9 months of the Nepali year, approximately April –December 2003 .
Source: MOF (2004)

Figure 7.10: Pollutants Monitored at Tikathali



µg/m³ = microgram per cubic meter
Source: Tuladhar and Raut (2002)

Figure: 7.11: Total Energy Consumption by Residential Sector



Source: WECS (1999)

(Bhattacharya undated). Deforestation and desertification are the most serious consequences of reliance on biomass fuels. Use of crop and animal residues for fuel deprives the soil of recycled nutrients and reduces crop yields along with the land's capacity to support livestock. Biomass fuels are the most common fuels used in rural areas of the Terai and the Hills. Use of coal and kerosene in rural areas is limited to relatively well-to-do families. In cities, liquefied petroleum gas is also used extensively. Figure 7.11 shows the amount of energy consumption by the residential sector by fuel type.

There are no estimates of emissions from domestic fuel use available for the entire country, although a few research studies have been conducted in Kathmandu Valley. Shrestha and Malla (1996) estimated that in 1993 14,246 tons of air pollutants were emitted each year from domestic sector energy use in Kathmandu Valley.

Household equipment is also a source of a particular group of "ozone depleting substances," chemicals that enter the air, travel to the upper atmosphere, and are instrumental in destroying the upper level ozone layer that shields the earth from harmful radiation. The people living in Nepal's urban areas are more used to modern amenities than those in rural areas. More and more urban inhabitants are able to enjoy a comfortable life with modern amenities such as refrigerators and air conditioning. A survey carried out by the Nepal Bureau of Standards and Metrology (NBSM 1999) identified chlorofluorocarbons (CFC-12) and hydro-

Brick Kiln

chlorofluorocarbons (HCFC–22) as ozone depleting substances (ODS). The consumption of these two substances was 30 tons and 23 tons, respectively (NBSM and UNEP undated). The country does not produce any ODS itself—all these substances are imported. The annual per capita ODS consumption in Nepal in 1999 was 0.0013 kg. The regulatory measures developed to address the problem are described in a later section.

Natural Sources of Air Pollution

Natural sources of air pollution include such things as volcanic eruption, forest fires, pollens from vegetation, and salt particles from sea spray. Forest fires occur annually in all the major physiographic and climatic regions of Nepal, including the Terai and Bhabar, the Siwaliks or the inner Terai, the Middle Mountains, and the High Mountains, although reliable statistics are not available. Pollen grains are another natural contaminant associated with health problems such as allergies. Many people suffer from asthma or hay fever although the symptoms disappear at the end of the pollen season—some even develop bronchitis, bronchial asthma, and dermatitis. Suspended dust from roads is also highly visible in Nepal, adding to the suspended particle load in the air.

Impact of Air Pollution

Although air pollution has become a visible environmental problem in the last decade, only limited data are available to evaluate its magnitude and impact.

The health impact of indoor and outdoor air pollution can be assessed by the increase in the number of patients suffering from diseases related to air pollution. Health effects range from minor irritation of eyes and the upper respiratory system to chronic respiratory disease, heart disease, lung cancer, and death. Air pollution has been shown to cause acute respiratory infections in children and chronic bronchitis in adults. It has also been shown to worsen the condition of people with pre-existing heart or lung disease. Among asthmatics, air pollution has been shown to aggravate the frequency and severity of attacks. Both short-term and long-term exposures have also been linked to premature mortality and reduced life expectancy (Mishra 2003).

The health impact of air pollution depends on the pollutant type, its concentration in the air, length of exposure, other pollutants in the air, and individual susceptibility. Different people are affected by air pollution in different ways. Poor people, undernourished people, the very young and very old, and people with pre-existing respiratory disease and other ill health are more at risk (Mishra 2003).

Exposure to particles can lead to a variety of serious health problems. Fine particles pose the greatest problems because they can get deep into the lungs and some fine particles into the bloodstream. Long-term exposure to particulate matter shows decreased lung function, chronic bronchitis, premature deaths, and heart attacks. No long-term epidemiological studies have been conducted in Nepal, but a few studies have conducted preliminary medical examinations of a group of exposed people or used dose-response relationships developed elsewhere.

According to the data published by the then Ministry of Health (now Ministry of Health and Population), among patients visiting the major hospital (DOHS 2003), ARI ranks as the third-highest cause of morbidity in Nepal after diarrhea, affecting 3.13% of the total population (this document, Chapter 2, Table 2.18). Chronic bronchitis falls at the eighth position.

Pandey et al. (1987) examined 240 rural children under 2 years of age for 6 months and found a significant relationship between the number of hours spent near the fire (as reported by the mother) and the incidence of moderate and severe cases of ARI. The study suggested that indoor air pollution is an important risk factor for ARI. A 1971 review of the cases of discharges from ten hospitals with a combined capacity of 265 beds revealed that ARI accounted for 32% of mortality for infants less than 1 year and 11% for children aged 1–4 (WINROCK 2004).

COPD is another major risk, especially among women, and has been strongly associated with smoke exposure from cooking on open biomass stoves. In rural Nepal, nearly 15% of non-smoking women 20 years and older had chronic bronchitis (WINROCK 2004), a high rate for non-smokers.

Similar cases are observed in the urban centers where outdoor air pollution is soaring. A study by the

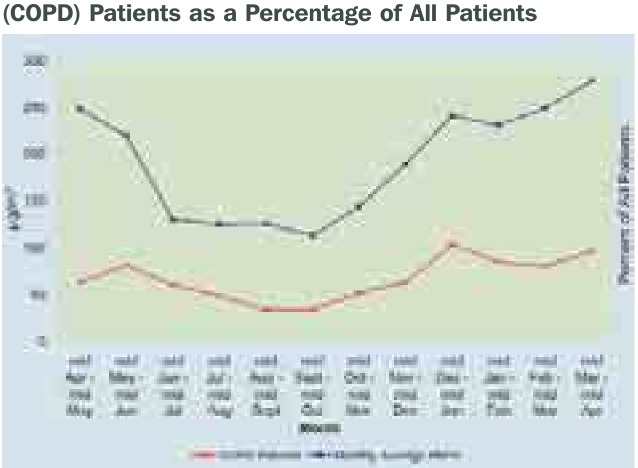
World Bank in 1990 estimated impacts on mortality and morbidity due to PM10 levels. The study estimated that Kathmandu's PM10 levels resulted in 84 cases of excess mortality, 506 cases of chronic bronchitis, 4,847 cases of bronchitis in children, and 18,863 asthma attacks per year. Overall, Kathmandu's residents experienced over 1.5 million respiratory symptom days per year (Shah and Nagpal 1997).

An analysis of the records of 369 COPD patients and 315 control patients admitted to Patan Hospital from April 1992 to April 1994 showed that the odds of having COPD are 1.96 times higher for Kathmandu Valley residents compared with outside residents. The study also stated that over the past decade the proportion of COPD patients had increased more than fourfold and that COPD was the number one killer of adult patients in the hospital (CEN and ENPHO 2003).

The records from three major hospitals in Kathmandu indicate that the number of COPD patients admitted to hospitals, as well as the number of COPD patients as a percentage of all patients, has increased significantly in the last ten years. Hospital records also indicate that the number of COPD patients is highest in the dry winter months, when air pollution in Kathmandu is at its peak (Figure 7.12). Vehicular pollution and suspended dust from poorly maintained roads are the major causes for the poor air quality in urban centers.

Another observable impact is on visibility. Atmospheric data obtained from Kathmandu airport from 1970 onwards shows a substantial decrease in visibility in the Valley since 1980. The trend towards reduced visibility in the Valley has been quite dramatic for the months November–March, and particularly for December–February. The number of days with good visibility (>8,000 m) at 11:45 am decreased in the winter months from more than 25 days/month in 1970 to 5 days/month in 1992. By 1997, the number of days per month in December–February with good visibility at noon approached zero (Sapkota et al. 1997).

Figure 7.12: Air Pollution Level in Kathmandu and Incidence of Chronic Destructive Pulmonary Disease (COPD) Patients as a Percentage of All Patients



Data Source: Limbu (2005)

The impacts of air pollution are felt not only on health but also on vegetation and in corrosion damage to buildings and monuments. Air pollution can inflict significant damage on local vegetation. The information collated by Regional Air Pollution in Developing Countries during the initial phase of the Crops and Forests Project has clearly shown that in many developing countries, and particularly in parts of Asia, crop yields and forest productivity are being severely affected by local ambient air pollutant concentrations. In the context of South Asia, there is a strong linkage between monsoon activity and agricultural productivity. In the last decade, Nepal and the Indo-Gangetic plains of India experienced severe sky overcast during winter, affecting major winter crops like potato, oilseeds, pulses, and onion. Yield reduction in 1997/98 ranged from 11% to 38% compared with the average of the preceeding 10 years. The precise reasons for this, however, are not yet clear. Frequent occurrence of cold waves and fog mixed with dust particles in the atmosphere could be the cause. Likewise, reduction of solar radiation could be the explanation. Aerosols can directly alter the hydrological cycle by suppressing evaporation and rainfall. With respect to agricultural changes, it can directly impact productivity by shading vegetation from solar radiation; and indirectly through induced changes in temperatures and the hydrological cycle (UNEP and C4 2002).

Climate and Climate Change

Nepal's Climate

The climate in Nepal varies from tropical to arctic within the 200 km span from south to north. Much of Nepal falls within the monsoon region, with regional climate variations largely being a function of elevation. National mean temperatures hover around 15°C, and increase from north to south with the exception of the mountain valleys. Average rainfall is 1,500 mm, with rainfall increasing from west to east. The northwest corner has the least rainfall, situated as it is in the rain shadow of the Himalayas. Rainfall also varies by altitude—areas over 3,000 m experience a lot of drizzle, while heavy downpours are common below 2,000 m. Although annual rainfall is abundant, its distribution is of great concern. Flooding is frequent in the monsoon season during summer, while droughts are not uncommon in certain regions in other parts of the year.

Climate Change

A region's climate is a summary of the past weather events that have occurred at that location. Climate is typically described by the statistics of a set of atmospheric and surface variables, such as temperature, precipitation, wind, humidity, cloudiness, soil moisture, sea surface temperature, and the concentration and thickness of sea ice. Statistics may be in terms of the long-term averages or other measures such as daily minimum temperature, length of the growing season, or frequency of floods. Weather, on the other hand, refers to the temperature, precipitation (rain and snow), humidity, sunshine, and wind that occur at a particular time at a specific location.

Climatologists say that our planet is getting warmer overall and that this is leading to climate change (IPCC 2001). The mean global surface temperature has increased by about 0.3 to 0.6°C since the late 19th century and by about 0.2 to 0.3°C over the last 40 years, which is the period with the most reliable data (UNEP undated). This build-up is attributed to the result of human activities, especially our use of fossil fuels in, for example, automobiles and power plants. In other words, air pollutants in the broadest sense are considered to be the main cause of climate change. The impacts of this unprecedented warming—increased floods and drought, rising sea levels, spread of deadly diseases such as malaria and dengue fever, increasing numbers of violent storms—threaten to be more severe and imminent than previously believed.

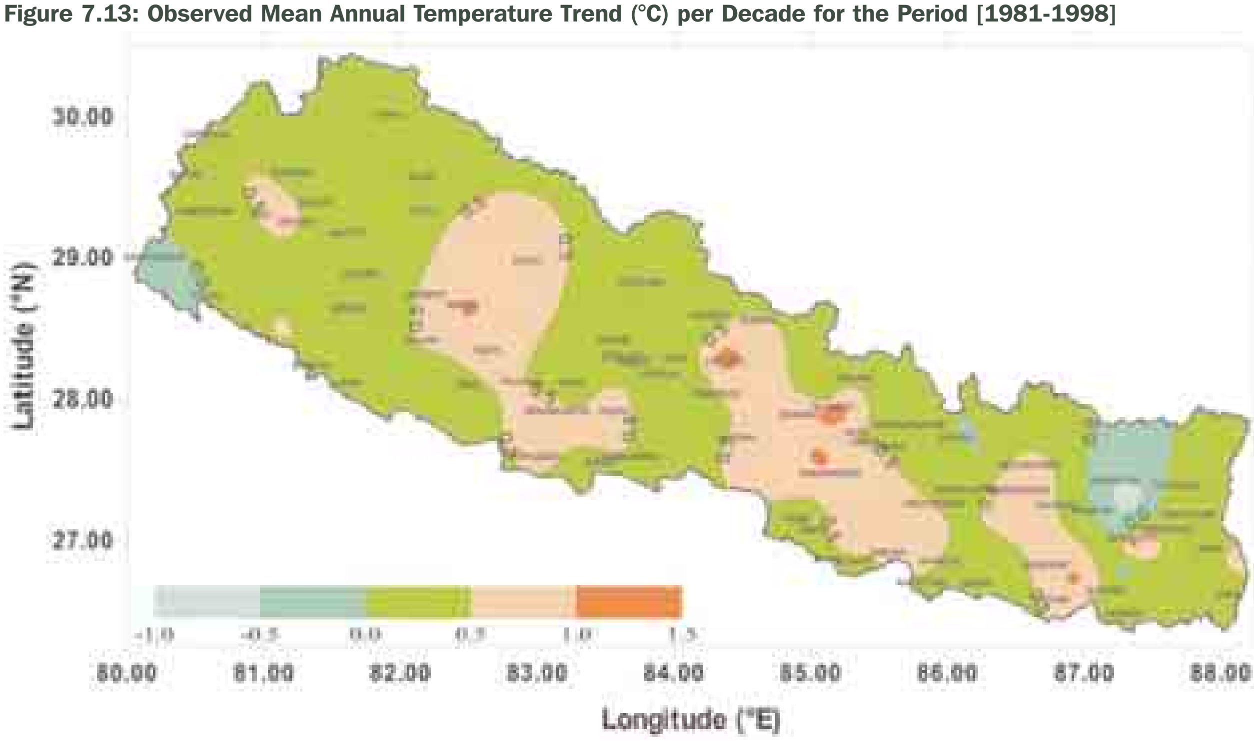
Impacts are already being felt in the Arctic, where the average annual temperature has increased approximately four times as much as average annual temperatures around the rest of the globe (CIEL 2004). Rising temperatures have caused outbreaks of insect pests such as the spruce bark beetle, which is reproducing at twice its normal rate in today's warmer climate (Anchorage Daily News 2005). Similarly, observable changes have also been felt in Nepal. Some particular aspects of climate change as they relate to Nepal are discussed below.

Climate Change in Nepal

Temperature Change

In Nepal, the elevation generally increases from south to north and is accompanied by decreasing temperatures. Temperature observations in Nepal from 1977–1994 showed a general warming trend (Shrestha et al. 1999) with significantly greater warming at higher elevations in the northern part of the country than at lower elevations in the south. This finding is reinforced by observations by Liu and Chen in 2000 on the other side of the Himalayas on the Tibetan Plateau. Significant glacier retreat as well as significant expansion of several glacial lakes has also been documented in recent decades, with an extremely high likelihood that such impacts are linked to rising temperatures. The results of a temperature trend analysis for the period 1981 to 1998 based upon data from 80 stations are shown in Figure 7.13. Except for small pockets in the eastern

Figure 7.13: Observed Mean Annual Temperature Trend (°C) per Decade for the Period [1981-1998]



Source: MOPE and UNEP (2004)

region and far western Terai, most of Nepal showed a positive trend of between 0°C and 0.5°C per decade. Agrawal et al. (2003) pointed out that the temperature differences are most pronounced during the dry winter season, and least during the height of the monsoon.

A study carried out by MOPE and the United Nations Environment Programme (UNEP) for the Initial National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change using models (Canadian Climate Change Model ["CCCM"], Geophysical Fluid Dynamics Model ["GFD3]", and Regional Climate Model) and their projections showed a projected 2 to 4°C rise in average annual temperature over Nepal when CO_2 is doubled. The magnitude of temperature rise would be greater in western Nepal than in other regions. According to the CCCM model, winter showed the greatest increase of any season with the highest value in the far-western region (2.4°C to 5.4°C), and for all seasons, the rising gradient was from east to west, whereas in the GFD3 model it was from west to east during pre-monsoon and winter.

Precipitation Change

In Nepal, altitude affects annual rainfall and precipitation patterns. Up to about 3,000 m, annual rainfall totals increase with altitude; thereafter, annual totals decrease with increasing altitude and latitude. Eastern Nepal receives approximately 2,500 mm of rain annually, the Kathmandu area about 1,420 mm, and western Nepal about 1,000 mm (Figure 7.14).

In the prediction study conducted by MOPE and UNEP (MOPE and UNEP 2004) precipitation was found to increase for all seasons in general, with a rising gradient from west to east using the GFD3 model. The CCCM model predicted a negative gradient of precipitation from west to east during winter but followed the trend of the GFD3 model in other seasons. Trend analysis of observed precipitation between 1981 and 1998 (Figure 7.15) showed a negative trend in the monsoon, post monsoon, and annual scenarios which was more pronounced in western Nepal than in eastern Nepal. Most of the Terai belt, except in the eastern region, had a negative trend for all seasons.

Impact of Climate Change in Nepal

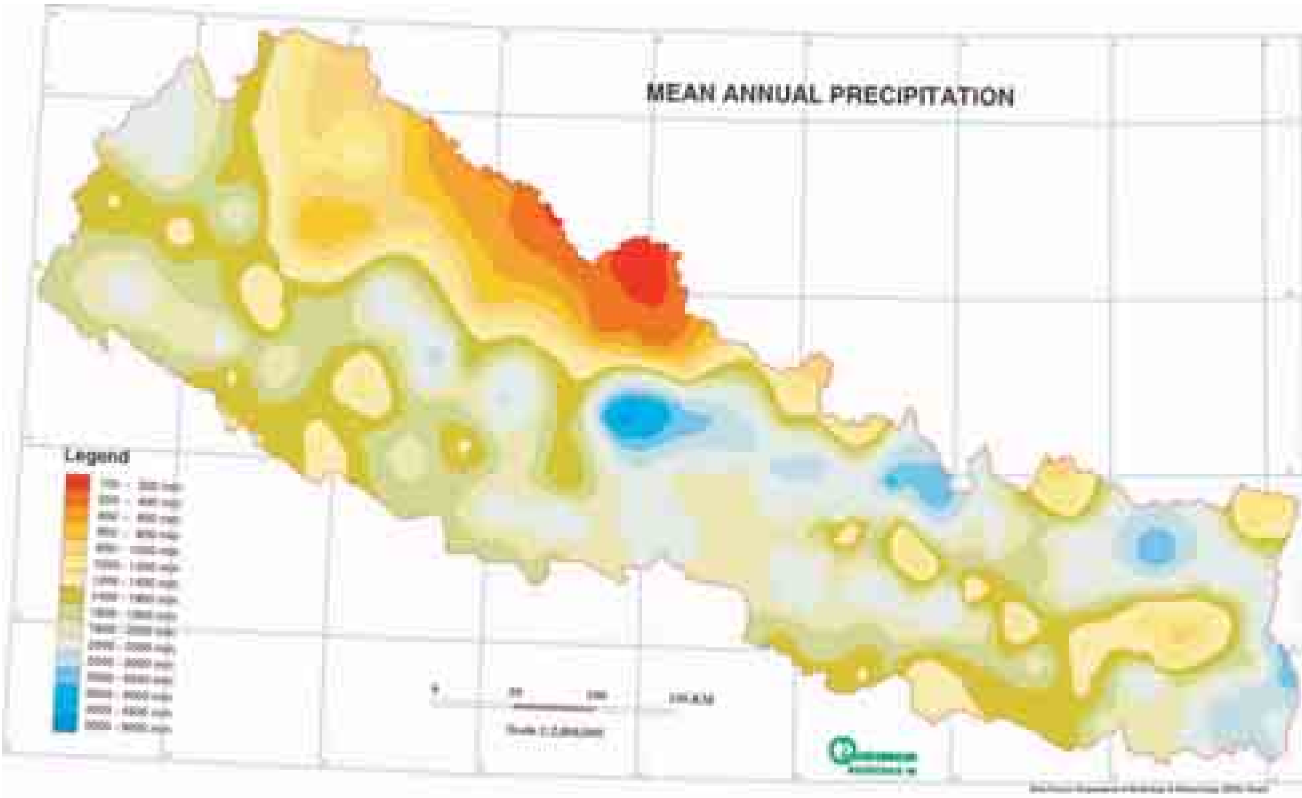
There are a number of anecdotal perceptions about Nepal's changing climate. However, further research is needed before drawing firm conclusions as to whether and how the climate is already changing.

In the Terai belt during the winter, news reports indicate that fog persists until late morning, and winter mornings are thus much colder than previous years. Winter days in Kathmandu Valley are less cold, frost is becoming rare, and the summers are warmer. The beginning of spring has become a persistent cold rain. Rain has become less predictable and dependable, both in distribution and amount. There has been more ice and less snow. These changes can have a direct influence on surface runoff, agriculture, vegetation, and people's daily lives.

One of the few measured changes is that of glacier retreat. The increase in temperature in the Himalaya and the vicinity appears to have been higher in the uplands than in the lowlands (Shrestha et al. 1999). The warming has resulted in marked retreat of the glaciers with a reduction in both area and ice volume (Agrawal et al. 2003). The glacier from which Sir Edmund Hillary and Tenzing Norgay set out to conquer Mount Everest nearly 50 years ago has retreated three miles up the mountain—presumed to be a result of climate change—as reported by a team of climbers backed by UNEP (UNEP 2002). The Himalayan glaciers are a renewable storehouse of fresh water that benefits hundreds of millions of people downstream, thus glacier retreat has long-term implications for water storage and availability. Glacier retreat can also lead to more immediate problems. As glaciers retreat, lakes can form behind the newly exposed terminal moraine. The unstable "dam" formed by the moraine can breach rapidly, leading to a sudden discharge of huge amounts of water and debris—a glacial lake outburst flood—often with catastrophic effects in terms of damage to roads, bridges, trekking trails, villages, and agricultural lands, as well as loss of human life and other infrastructure. Over the past 50 years, there have been at least 21 recorded outburst flood events that have affected Nepal. In 2001, ICIMOD and UNEP documented 27 potentially dangerous glacial lakes in Nepal (Mool et al. 2001).

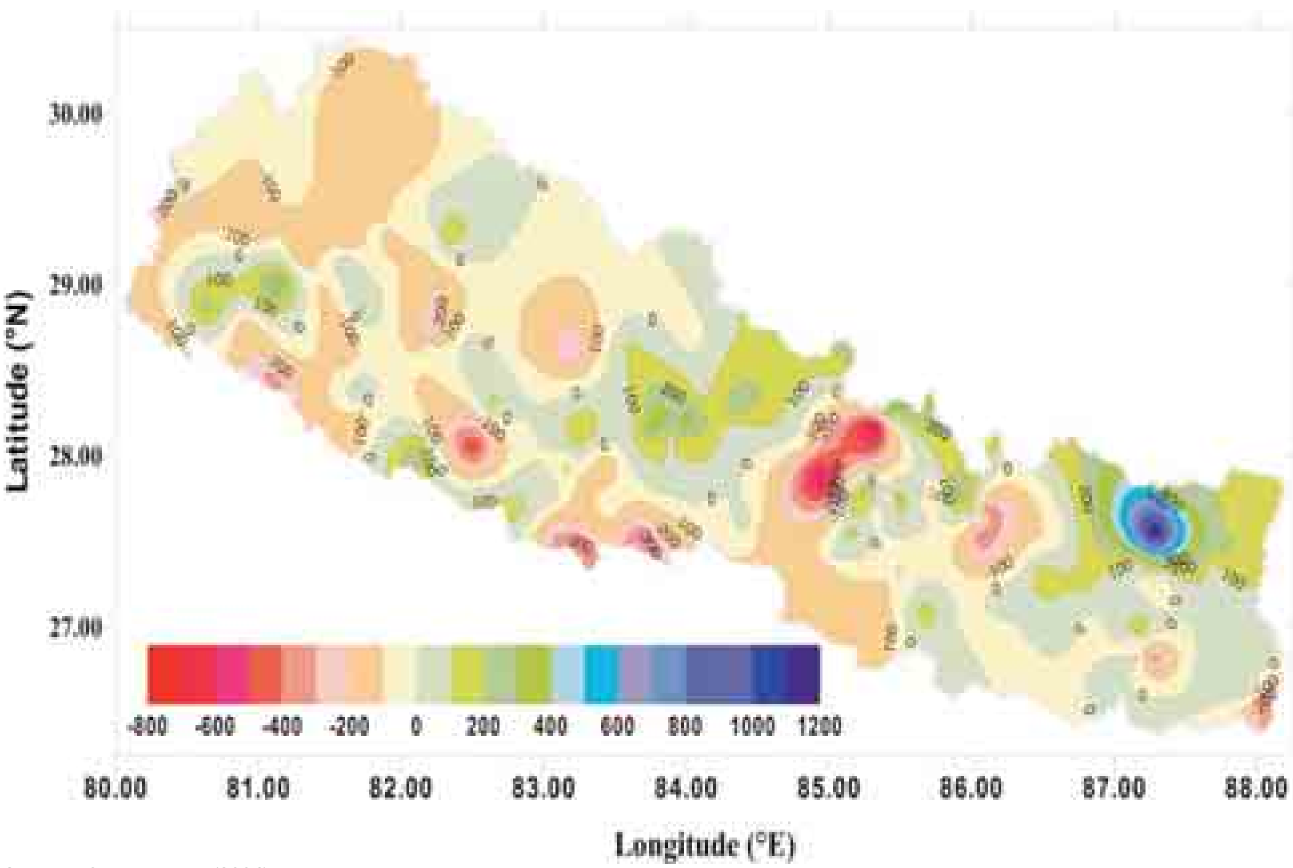
Climate change will inevitably have an impact on air pollution in the country. Rainfall markedly reduces the levels of certain pollutants in ambient air, especially particulate matter. Increased frequency of rain will reduce urban air pollution and vice versa. Equally, precipitation could set chemical processes in motion that have a negative impact. Increased wind and storms may increase the levels of transboundary pollutants, and/or increase dust levels. Raised or lowered temperatures and precipitation may impact on human activity and thus on levels of air pollutants. There are a myriad different possibilities, but as yet prediction and measurement of possible climate change in Nepal is in its infancy, and thus the possible impacts can only be guessed at.

Figure 7.14: Mean Annual Precipitation



Data Source: DHM (2003); Base map: ICIMOD (1996)

Figure 7.15: Trend of Annual Precipitation (mm) per Decade for the Period (1981-1998)



Source: MOPE and UNEP (2004)

Policy Response

Recent years have witnessed the emergence of a number of national and local responses to environmental problems in Nepal. These initiatives are described below.

Regulatory Measures

Air pollution is increasingly recognized as a serious problem in urban and peri-urban settlements. Accordingly, ambient air quality standards have been formulated (Table 7.3). Public awareness and judicial actions have also prompted policy initiatives. However, enforcement of the standards still needs to be strengthened.

The transportation sector is one of the main contributors to air pollution in urban areas. The Government has taken several measures to reduce vehicular emissions, which are described below.

Nepal introduced vehicle exhaust emission tests in 1994 following the tail-pipe standards of 65 hartridge smoke units (HSU) for diesel-operated vehicles and 3% CO for petrol-operated ones. A vehicular color rating system with respect to the exhaust emission standards was introduced. This system provides green stickers to vehicles meeting the emission standard and red stickers to vehicles failing the test. See Table 7.4 for details.

Nepal Vehicle Mass Emission Standard 2056 (2000) is the Government's major step towards reducing emissions per kilometer of travel. This standard is similar to the European Union standard, popularly known as the EURO-1 standard.

Actions undertaken include the following. Since mid-September 1999, 3-wheel diesel tempos have been banned in Kathmandu Valley, Pokhara, and Lumbini. Electric vehicles and LPG 3-wheelers have been introduced to meet the public transport demand. Lead free gasoline was introduced in Kathmandu Valley in July 1997, and since December 26, 1999 only unleaded gasoline has been distributed in Nepal. The Government resolved on November 10, 1999 to ban movement of vehicles older than 20 years and all three wheelers and two-stroke engines from the Valley beginning middle of November 2001. But this decision was not implemented by the Government due to protest by many vehicle owners. The Government has already banned the registration of new two-stroke engine vehicles in Kathmandu.

Measures have been taken to ban the polluting bull's trench kilns from Kathmandu Valley, and registration of these kilns has stopped. The Government closed the Himal Cement Factory following local public complaints. Pollution-prone industries must now obtain licenses prior to establishment or expansion. Licenses for such industries will be given only after ensuring that they have no adverse impact on the environment. Industrial pollution control regulations have been drafted and environmental impact assessment (EIA) guidelines have been prepared for each industrial sector.

Regulatory measures have also been introduced to address the problem of ozone depleting substances (ODS). Nepal is a signatory to the Montreal Protocol, and the Nepal Bureau of Standards and Metrology has been designated to implement it. The Gazette Notification issued on September 2000 determines the annual consumption quotas and established an annual phase out of chlofluorocarbons, hydrochloro-fluorocarbons, halons, and other ODS. Similarly, the ODS Consumption (Control) Regulations 2001, requires all ODS importers to obtain licenses and forbids re-export of imported substances to other countries. The joint phase-out rate of CFC 11/12 will be 10% a year, to reach zero by 2010. Because all these substances are imported from other countries, it is feasible to keep track of the amount of ODS being consumed and to achieve this goal by 2010.

Economic Instruments

Financial incentives in the form of tax concessions and subsidies are common practices as economic instruments. The Department of Transport Management charges tax according to the date of vehicle manufacture, with a higher tax levied on vehicles older than 20 years.

Similarly, a levy of NRs 0.50 per liter was introduced on the sale of petrol and diesel. The amount collected goes to the Kathmandu Valley Development Fund for pollution control, environment protection, and improvement of roads, sewerage system, and water supply. However, this still needs to be implemented (personal communication, Ministry of Environment, Science and Technology [MOEST]).

Other initiatives include a subsidy on alternative energy, as follows: solar photovoltaic—50% subsidy; PV pumping system—75% subsidy; solar dryer—50% subsidy (1998).

Technological Improvements

Environmental considerations have started to influence industrial establishments, requiring them to limit their emissions and wastes. Due to public pressure from nearby residential areas and from consumers, industries are gradually being required to utilize environmentally friendly processes (ESPS undated). ESPS has started one such activity in Hetauda Industrial District.

Table 7.3: National Ambient Air Quality Standards for Nepal

Parameter	Units	Averaging Time	Concentration in Ambient Air, maximum	Test Methods
TSP (total suspended particulates)	µg/m^3	Annual		
		24-hours[a]	230	High volume sampling
PM10	µg/m^3	Annual		
		24-hours[a]	120	Low volume sampling
Sulfur Dioxide	µg/m^3	Annual	50	Diffusive sampling based on weekly averages
		24-hours[b]	70	To be determined before 2005.
Nitrogen Dioxide	µg/m^3	Annual	40	Diffusive sampling based on weekly averages
		24-hours[b]	80	To be determined before 2005.
Carbon Monoxide	µg/m^3	8 hours[b]	10,000	To be determined before 2005.
		15 minute	100,000	Indicative samplers [c]
Lead	µg/m^3	Annual	0.5	Atomic Absorption Spectrometry, analysis of PM10 samples [d]
		24-hours		
Benzene	µg/m^3	Annual	20[e]	Diffusive sampling based on weekly averages
		24-hours		

µg/m^3 = micro gram per cubic meter, PM 10 = particulate matter of diameter 10 micron or less

[a] 24 hourly values shall be met 95% of the time in a year. The standard may be exceeded on 18 days per calendar year, but not on two consecutive days.

[b] 24 hourly standards for NO_2 and SO_2 and 8 hours standard for CO are not to be controlled before MoPE has recommended appropriate test methodologies. This will be done before 2005.

[c] Control by spot sampling at roadside locations: minimum one sample per week taken over 15 minutes during peak traffic hours, i.e., in the period 8 am–10 am or 3 pm–6 pm on a workday. This test method will be re-evaluated by 2005.

[d] If representativeness can be proven, yearly averages can be calculated from PM10 samples from selected weekdays from each month of the year.

[e] To be reevaluated by 2005.

Source: MOPE (2003)

Table 7.4: Vehicle Emission Standards for Green Stickers

Type of Vehicle	CO% by Volume	HC (ppm)
Petrol-Operated Vehicles		
Four-wheelers 1980 or older	4.5	1,000
Four-wheelers 1981 onwards	3.0	1,000
Two-wheelers (two-stroke)	4.5	7,800
Two-wheelers (four-stroke)	4.5	7,800
Three-wheelers	4.5	7,800
Gas-Operated Vehicles		
Four-wheelers	3.0	1,000
Three-wheelers	3.0	7,800
Diesel-Operated Vehicles		
Older than 1994	75.0	
1995 onwards	65.0	

ppm = parts per million, CO = carbon monooxide, HC = hydro carbon

Source: MOPE (2003)

The introduction of improved cooking stoves commenced in 1950 to reduce indoor air pollution. The national ICS Programme has disseminated about 125,000 ICS in 33 mid-hill districts. Similarly, the Biogas Sector Program has built 137,000 family-size biogas plants in 66 of Nepal's 75 districts, saving 400,000 tons of firewood and 800,000 liters of kerosene, and preventing 600,000 tons of greenhouse gases from escaping into the atmosphere (Nepali Times 2005). Likewise, estimates in 1998 indicate that almost 1,000 micro-hydropower plants are in operation (SHTF undated) and 1,100 kW of photovoltaic power is used in various public and private sectors of Nepal (EnvironmentNEPAL 2003).

New methods for prevention and early warning of glacial lake outburst floods are also being developed and installed, although so far only at one lake, the Tsho Rolpa (Mool et al. 2001). Prevention involves recognition of the potential problem and employment of modern engineering measures like controlled draining. Modern early warning systems provide alarms downstream that enable timely evacuation of people and animals and protective measures to be taken for property.

Another longer term possibility for more far reaching change—use of hydrogen as an energy source—is described in the box.

Conclusion

The energy, industry, and transportation sectors are the major contributors to air pollution. The use of low quality fuel, inefficient methods of energy production

Hydrogen Energy—A Brighter Option for Nepal

Energy is a vital input to the national economy and wellbeing of people. Normally, economic growth requires more use of energy. Current patterns of energy use result in emissions of pollutants. Local-level pollutants such as carbon monoxide, suspended particles, and hydrocarbons degrade air quality and damage health. Sulfur dioxides and nitrogen oxides are examples of regional level pollutants that contribute to acid deposition, which can damage vegetation such as forests and crops, and human-made structures. Large increases in emissions may occur during the next 20 to 50 years if current trends persist. Air pollution has become a priority issue in most countries in Asia.

At present sustainable energy is of increasing interest in the region. The rapid growth of atmospheric environmental issues along with the fear of energy shortages is creating a consensus about the potential benefits of hydrogen from renewable energy sources. These interesting perspectives are further supported by the development of key technologies, such as renewable energy sources, advanced production processes, and fuel cell vehicles. This provides an ideal opportunity to introduce a hydrogen economy in Nepal. Nepal is one of the top five countries in the world in terms of hydroelectric production potential. Nepal could provide the opportunity to introduce emission-free production of hydrogen energy not only to the country but for the whole region. In addition, Nepal has the added advantage of cheap labor which can support the production of hydrogen at an affordable price. The economic and environmental benefits of hydrogen energy could also help to reduce poverty by creating domestic jobs and providing electricity beyond the national power grid.

Source: A project proposal by UNEP RRC.AP.

and use, and poor condition of vehicles and traffic management are among the reasons for increasing emissions in Nepal. Biomass burning for cooking and space heating is a source of indoor air pollution and resultant health effects. Though long-term data on pollution are lacking, available information reveals that the nature and extent of air pollution is serious in major urban areas and in the hill regions of Nepal.

Air pollutants also contribute to the developing problem of climate change, although it is not possible to assess to what extent. At the same time, climate change will itself have an impact on the pattern and extent of air pollution.

As Nepal imports petrol, it should start demanding low benzene petrol. It should also emphasize zero-emission electric vehicles such as trolley busses and Safa tempo. In the long term, Nepal should opt for hydrogen energy which will benefit the country both economically and environmentally. Though the capital investment cost is higher at the beginning, this would be repaid in the long run.

Raising awareness is another fundamental measure to curb air pollution. This can be done through hands-on workshops, seminars, and site visits. However, the media should play a key role in the overall strategy. Media coverage of key messages that need to be delivered to primary stakeholders would reinforce the importance of those messages. At the same time, using the media ensures that these messages reach the general public as well, serving as information as well as reinforcing the importance of those messages.

Along with awareness raising, capacity building is equally important. Scientific information remains the basis for any pollution-control efforts, and capacity building of both institutions and individuals is vital. The contemporary view of capacity building goes beyond the conventional perception of training. The central concerns of air quality management to manage change, to resolve conflict, to manage institutional pluralism, to enhance coordination, to foster communication, to develop a strong credible database, and to ensure that data and information are shared—require a broad and holistic view of capacity development, which is still poor in Nepal and needs to be strengthened.

Bibliography

Adhikari, A.P. 1998. *Urban and Environmental Planning in Nepal: Analysis, Polices and Proposals*. Kathmandu: The World Conservation Union (IUCN).

Adhikari, D.P. 1997. "Energy and Environmental Implications of Alternative Transport Options: The Case of Kathmandu, Nepal." Unpublished M. Eng. Thesis, Asian Institute of Technology, Bangkok.

Agrawala, S., V. Raksakulthai, M. Aalst, P. Larsen, J. Smith, and J. Reynolds. 2003. *Development and Climate Change In Nepal: Focus On Water Resources and Hydropower*. Paris: Organisation for Economic Co-operation and Development. Available: http://www.oecd.org/ dataoecd/6/51/19742202.pdf

Anchorage Daily News. 2005. "Scientists Link Warmer Weather to Beetle Outbreak." September 11. Available: http://www.fire.uni-freiburg.de/media/2005/news_20050912_us2.htm

Asian Institute of Technology (AIT). undated. "Energy, Environment and Climate Change Issues: Nepal." A study by the Asian Regional Research Programme in Energy, Environment and Climate, Bangkok.

Basnyat, P., R.N. Bhattarai, and S.K. Mishra. 2004. "Use of Earth Air Tunnel HVAC System in Minimising Indoor Air Pollution." Paper presented at the *Workshop on Better Air Quality (BAQ) 2004*, 6–8 December, Agra, India. Available: http://www.cleanairnet.org/baq2004/1527/article-59311.html

Bastola, T.S. 1998. "Responses to Air Pollution Impacts." In *A Compendium on Environment Statistics 1998*. Kathmandu: His Majesty's Government of Nepal, Central Bureau of Statistics.

Bates M.N., A. Deuja, A. Khalakdina, A.K. Pokhrel, and K.R. Smith. 2005. "Case–Control Study of Indoor Cooking Smoke Exposure and Cataract in Nepal and India." *International Journal of Epidemiology* 34 (3): 702–708.

Bhattacarya, S. undated. "Cooking Options in Developing Countries." Asian Institute of Technology, Thailand. Available: http://www.serd.ait.ac.th/teenet/cooking.htm

Chalise, S.R., M.L. Shrestha, B.R. Shrestha, K.B. Thapa, and B. Bajracharya. 1996. *Climatic and Hydrological Atlas of Nepal*. Kathmandu: ICIMOD.

Clean Energy Nepal (CEN) and Environment and Public Health Organization (ENPHO). 2003. "Health Impacts of Kathmandu's Air Pollution." Unpublished report, Kathmandu.

Central Bureau of Statistics (CBS). 1994. A *Compendium on the Environmental Statistics of Nepal Issues and Facts*. Kathmandu.

———.1996. *Nepal Living Standards Survey Report 1996*. Kathmandu.

———.2002. *Census of Manufacturing Establishment Nepal 2001–2002*. Kathmandu.

———.2003. *Population Monograph of Nepal*, *Vol. I*, pp. 341–371. Kathmandu.

———.2004. *Handbook of Environment Statistics 2003*. Kathmandu.

Chettri, M.K. 2000. "Toxic Heavy Metals in Ambient Air of Kathmandu." In *10th Anniversary Souvenir*. Kathmandu: Environment and Public Health Organisation.

Chettri, M.K., K.B. Thapa, K. Poudyal, and B.D. Acharya. undated. "Biomonitoring of Toxic Heavy Metals in Kathmandu Valley Using Lichen." *Ecoprint* 8(1): 69–76. Available: http://www.cleanairnet.org/caiasia/1412/articles-60182_resource_1.pdf

CIEL (The Center for International Environmental Law). "Climate Change Program." Washington, DC. Available: http://www.ciel.org/Climate/programclimate.html

Davidson, C., S. Lin, and J.F. Osborn. 1986. "Indoor and Outdoor Air Pollution in the Himalayas." *Environmental Science and Technology* 20(6): 561–567.

Devkota, S.R. 1993. "Ambient Air Quality Monitoring in Kathmandu Valley." Report prepared by the Kathmandu Valley Vehicular Emission Control Programme, United Nations Development Programme, Kathmandu.

Devkota, S.R., B. Koirala, and C. Gautam. 1996. "Industrial Pollution Inventory and Management in Nepal." *UNEP Industry and Environment* 19(1): 37–42.

Devkota, S.R., and C.P. Neupane. 1994. "Industrial Pollution Inventory of the Kathmandu Valley and Nepal." Report prepared by the Industrial Pollution Control Management Project, Ministry of Industry, Kathmandu.

Dhakal, S. 1998. "Transportation and Environmental Issues: A Case Study of Nepal." Reprint of paper presented at *International Students' Seminar on Transport Research*, Chiba, Japan.

———.2001. "Financing the Adaptation to the Climate Change: Issues and Controversies." *Environment* 6(7): 23–33.

Department of Health Services (DOHS). 1997. *Annual Report 1995/1996*. Kathmandu.

———.2003. *Annual Report 2001/2002*. Kathmandu.

Department of Hydrology and Meteorology (DHM). 2003. Unpublished Information on Total Suspended Particulate Matter (TSP) Concentrations in the Kathmandu Valley, His Majesty's Government of Nepal, Department of Hydrology and Meteorology, Kathmandu.

Department of Roads (DOR). 1998. *Nepal Road Statistics 1998*. Kathmandu: Ministry of Works and Transport.

Department of Transport Management (DOTM). 2005. Unpublished data accessed from record files, Department of Transport Management, Kathmandu.

Dixit, K. 2005. "Cow Dung Takes the Cake: Nepal's biogas program bags coveted award. In *Nepali Times*, Issue No. 257. 22–28 July. Kathmandu.

Economopoulos, A.P. 1993. "Assessment of Sources of Air, Water, and Land Pollution, A Guide to Rapid Source Inventory Technique and Their Use in Formulating Environmental Control Strategies Part Two: Approach for Consideration In Formulating Environmental Control Strategies." World Health Organization, Geneva.

Environment and Public Health Organization (ENPHO). 1993. "Air Quality Assessment in Kathmandu City." Kathmandu.

———.1999. "A Report on Study on Reduction of Pollution and Waste in the Himal Cement Company Limited." Kathmandu.

Environment NEPAL. 2003. Energy-Solar Photovoltaic. Available: www.environmentnepal.com.np/energy_m.asp

Environment Sector Programme Support (ESPS). "Cleaner Production." Available: http://www.esps.org.np/brochures/clean.html

Environmental Protection Agency (EPA). "The Particle Pollution Report, Current Understanding of Air Quality and Emissions Through 2003." New York. Available: http://www.epa.gov/ airtrends/pmreport03/report_2405.pdf#page=1

Hildebrandt, M.L, an S. Pokhrel. 2002. “Climate and Air Quality: A Case Study of PM10 Pollution in Kathmandu, Nepal.” Department of Geography, Environmental Sciences Program, Southern Illinois University Edwardsville, Edwardsville.

Intergovernmental Panel on Climate Change (IPCC). 2001. *Climate Change 2001: The Scientific Basis*. Cambridge: Cambridge University Press/Intergovernmental Panel on Climate Change

IUCN (The World Conservation Union). 1991. *Sources of Industrial Pollution in Nepal: A National Survey*. Kathmandu: His Majesty’s Government of Nepal, National Planning Commission-National Conservation Strategy Implementation Project.

———.1992. *Environmental Pollution in Nepal: A Review of Studies*. Kathmandu: His Majesty’s Government of Nepal, National Planning Commission-National Conservation Strategy Implementation Project.

Iyngararasan, M., L. Tianchi, and S. Shrestha. 2002. “The Challenges of Mountain Environments: Water, Natural Resources, Hazards, Desertification and the Implications of Climate Change.” Draft background paper for review by the Mountain Forum, *Bishkek Global Mountain Summit*. United Nations Environment Programme, Regional Resource Center for Asia and Pacific. Available: http://www.mtnforum.org/resources/library/iyngx02a.htm

Joshi, K.M. 1993. “Report on the Works of Monitoring of Vehicular Emissions in Kathmandu Valley.” Kathmandu Valley Vehicular Emission Control Project, United Nations Development Programme/His Majesty’s Government of Nepal.

Kunwar, U.K. 1999. “Ambient Air, Surface Water and Ground Water Quality Standards for Kathmandu Valley.” Unpublished report submitted by Institutional Strengthening of Ministry of Population and Environment (TA No. 2847-NEP) to Ministry of Population and Environment.

LEADERS (Society for Legal and Environmental Analysis and Development Research).1999. “A Comparative Study of Air Pollution in Three Major Cities of Nepal.” Kathmandu.

Limbu. S. 2005. “Ambient Air Quality of Kathmandu Valley.” Unpublished M.A. Thesis. Central Department of Geography, Tribhuvan University, Kathmandu.

Liu, X. and B. Chen. 2000. “Climatic Warming in the Tibetan Plateau during Recent Decades.” *International Journal of Climatology* (20): 1729–1742.

Malla, S. 1993. “Urban Energy Use and Environment Management: The Case of Kathmandu Valley.” Unpublished M. Eng. Thesis, Asian Institute of Technology, Energy Program, Bangkok.

Manandhar, A. 2000. “Status of Cleaner Production (CP) in Nepal.” Unpublished document, Kathmandu.

Ministry of Environment, Science and Technology (MOEST). undated. “Ambient Air Quality of Kathmandu Valley 2003–2004.” Kathmandu.

Ministry of Finance (MOF). 2004. *Economic Survey (FY2003/2004)*. Kathmandu.

Ministry of Population and Environment (MOPE). 1998. *State of the Environment Nepal*. Kathmandu.

———.2003. Data source: Air Quality Monitoring. Available: http://mope.gov.np/mopepollution/

———.2004. Data source: Air Quality Monitoring. Available: http://mope.gov.np/mopepollution/

Ministry of Population and Environment (MOPE) and United Nations Environment Programme (UNEP). 2004. “Initial National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change.” His Majesty’s Government of Nepal, Ministry of Population and Environment, Kathmandu.

Ministry of Population and Environment (MOPE)/United Nations Environment Programme (UNEP)/ International Centre for Integrated Mountain Development (ICIMOD). 2000. “Implementation of The Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia.” Unpublished Report, UNEP/ICIMOD/ MOPE/South Asia Cooperative Environment Programme (SACEP)/ Sustainable Ecosystems Institute (SEI), Kathmandu.

Mishra, V. 2003. “Health Effects of Air Pollution.” *Population-Environment Research Network (PERN) Cyberseminar*, December 1–15. Available: http://www.populationenvironmentresearch.org

Miyoshi, Y. 1987. *Pollution Control in Selected Industries*. Kathmandu: Industrial Service Centre, Balaju

Mool, P.K., S.R. Bajracharya, and S.P. Joshi. 2001. *Inventory of Glaciers, Glacial Lakes and Glacial Lake Outburst Floods, Monitoring and Early Warning System in the Hindu Kush-Himalayan Region*. Kathmandu: International Centre for Integrated Mountain Development.

Naeher, L.P., K.R. Smith, M. Brauer, Z. Chowdhury, C. Simpson, J.Q. Koenig, M. Lipsett, and J.T. Zelikoff. 2005. *Critical Review of the Health Effects of Woodsmoke*. Berkley: University of California. Available: http://ehs.sph.berkeley.edu/krsmith/publications/HC%20woodsmoke%20report%20Mar%2031%2005(rev).pdf

Nepal Bureau of Standards and Metrology (NBSM). 1999. *Nepal Country Program for the Phase out of Ozone Depleting Substances*. Kathmandu: His Majesty’s Government of Nepal, NBSM/United Nations Environment Programme.

Nepal Bureau of Standards and Metrology (NBSM) and United Nations Environment Programme (UNEP). undated. “Shield, South Asia’s Compliance with the Montreal Protocol.” His Majesty’s Government of Nepal, NBSM, Kathmandu:

Nepal Environmental and Scientific Services (NESS). 1995. “Research on Environmental Pollution and Management.” Kathmandu.

———.1999. "Ambient Air Quality Monitoring of Kathmandu Valley." Unpublished reported submitted to Ministry of Population and Environment by Asian Development Bank Project (TA 2847- NEP), Kathmandu.

Nepal Health Research Council (NHRC). 2004. *Situational Analysis of Indoor Air Pollution and Development Guidelines for Indoor Air Quality Assessment and House Building for Health*. Kathmandu.

Niraula, B.P. 1998. "Health." In *A Compendium of Environment Statistics 1998*. Kathmandu: His Majesty's Government of Nepal, Central Bureau of Statistics.

Pandey, M., and B. Basnet. 1987. "Chronic Bronchitis and Cor Pulmonale in Nepal: A Scientific Epidemiological Study." Monograph. Mrigendra Medical Trust, Kathmandu.

Pokharel, A.K.. 1998. "A Citizen Report on Air Pollution in Kathmandu Valley: Children's Health at Risk." LEADERS (Society for Legal and Environmental Analysis and Development Research), Kathmandu.

Pokhrel, S. 2002. "Climatology of Air Pollution in Kathmandu Valley, Nepal." Unpublished M.Sc. Thesis. Graduate School, Southern Illinois University Edwardsville, Edwardsville.

Ramana, M.V., B.B. Pradhan, V. Ramanathan, B. Shrestha, and I.A. Podgorny. 2004. "Direct Observations of Large Aerosol Radiative Forcing in the Himalayan Region." *Geophysics Research Letters,* 31, L05111, doi:10.1029/2003GL018824.

Raut, A.K. "Crisis Brewing in Nepal's Smoke-filled Kitchens." In One World South Asia. Available: http://southasia.oneworld.net/article/view/92090/1/

———.2003. "Health Impact Assessment of Brick Kilns." Paper presented at the *Workshop on Health Impact Assessment,* organized by Nepal Health Research Council in Kathmandu.

Reid, H.F., K.R. Smith, and B. Sherchand. 1986. "Indoor smoke exposures from traditional and improved cookstoves: Comparisons among rural women." *Mountain Research Development* 6(4): 293–304.

Roy, R., S. Gurung, and P. Bam. 2001. "A Social Dynamics on Launching Safa Tempos in Kathmandu Valley: A Campaign Against the Air Pollution." *Environment* 6(7): 89–95.

Sapkota, B.K., N.P. Sharma, K. Poudel, and B. Bhattarai. 1997. "Particulate Pollution Levels in Kathmandu Valley." *Environment* 3 (2).

Shah, J., and T. Nagpal, eds. 1997. "Urban Air Quality Management Strategies in Asia Kathmandu Valley Report." *World Bank Technical Paper No. 378*, Washington, DC: World Bank.

Shah, I. 2004. "An Effort to Reduce Indoor Air Pollution Through Paper and Power Project." Paper presented at the Workshop on *Better Air Quality (BAQ) 2004*, 6–8 December, Agra, India. Available: http://www.cleanairnet.org/baq2004/1527/article-59310.html

Shakya, K., M.K. Chettri, and T. Sawidis. undated. "Appraisal of Some Mosses for Biomonitoring Airborne Heavy Metals in Kathmandu Valley." *Ecoprint* 11(1) 35–49. Available: http://www.cleanairnet.org/caiasia/1412/articles-60183_resource_1.pdf

Shrestha, A.B., C.P. Wake, P.A. Mayewski, and J.F. Dibb. 1999. "Maximum Temperature Trends in the Himalaya and its Vicinity: An analysis based on temperature records from Nepal for the period 1971–1994." *Journal of Climate* (12): 2775–2789.

Shrestha, R.M., and S. Malla. 1996. "Air Pollution from Energy Uses in a Developing Country City: The Case of Kathmandu Valley Nepal." *Energy* 21: 785–794.

SHTF. undated. International Small-Hydro Atlas: Nepal. Published online by the Small-Scale Hydro Task Force under the IEA Hydropower Agreement. Available at www.small-hydro.com/index.cfm?Fuseaction=countries.country&Country_ID=54

Smith, K.R. 1987. Biofuels, Air Pollution, and Health: A Global Review. New York: Plenum Press.

Thapa, S., S.S. Shrestha, and D. Karki. 1993. *A Survey of Brick Industries in Kathmandu Valley*. Kathmandu: Environment and Public Health Organization (ENPHO).

Tuladhar, B., and A. Raut. 2002. *Environment and Health Impacts of Kathmandu's Brick Kilns*. Kathmandu: Clean Energy Nepal.

United Nations. 2001. Air Quality in Asia and the Pacific: An Analysis in Relation to National and International Standards. New York. United Nations

United Nations Development Programme (UNDP) and United Nations Environment Programme (UNEP) Regional Resource Center for Asia Pacific (RRCAP). 2002. "Malé Declaration on Control and Prevention of Air Pollution and Its Transboundary Effects for South Asia." UNEP RRCAP Newsletter, November 2002, Bangkok.

United Nations Environment Programme (UNEP). 2001. *Nepal: State of the Environment 2001*. Bangkok: United Nations Environment Programme, Regional Resource Center for Asia Pacific.

———.2002. "Impact of Global Warming on mountain areas confirmed by UNEP-backed mountaineers." UNEP Press Release. 10 June. Available: http://www.unep.org/Documents/Default.Print.asp?DocumentID=253&ArticleID=3080

———. "Trend in Global Average Surface Temperature." In Observed Climate Trends. Online resource from GRID–Arendal. Available: http://www.grida.no/climate/vital/17.htm

United Nations Environment Programme (UNEP) and Center for Clouds, Chemistry, and Climate (C4). 2002. "The Asian Brown Cloud: Climate and other Environmental Impact." Available: http://www.adb.org/vehicle-emissions/General/Environment-cloud.asp

US Environmental Protection Agency (EPA). 2004. "The Particle Pollution Report: Current Understanding of Air Quality and Emissions through 2003." Office of Air Quality Planning and Standards Emissions, Monitoring, and Analysis Division, North Carolina. Available: http://www.epa.gov/airtrends/pm.html

Warwick, H., and H. Doig. 2004. Smoke—the Killer in the Kitchen, Indoor Air Pollution in Developing Countries. London: ITDG Publishing.

Water and Energy Commission Secretariat (WECS). 1996. *Energy Synopsis Report: Nepal 1994/1995*. Kathmandu: His Majesty's Government of Nepal, Ministry of Water Resources.

———.1999. *WECS Bulletin* 10(1). Kathmandu.

Winrock International Nepal. 2004. "Household Energy, Indoor Air Pollution and Health Impacts: Status Report for Nepal." Submitted to United States Agency for International Development (USAID), Increase Use of Renewable Energy Resources Program, Kathmandu.

World Resources Institute (WRI). 1998. *World Resources 1998–99: Environmental Change and Human Health*. Joint publication of the World Resources Institute/ United Nations Environment Programme/United Nations Development Programme/World Bank.

Appendix 7.1: World Health Organization Guideline Values

Compound[a]	Guideline Value	Averaging Time
Ozone	120 micrograms/cubic meter (0.06 ppm)	8 hours
Nitrogen dioxide	200 micrograms/cubic meter (0.11 ppm)	1 hour
	40 to 50 micrograms/cubic meter (0.021 –0.026 ppm)	1 year
Sulfur dioxide	500 micrograms/cubic meter (0.175 ppm)	10 min
	125 micrograms/cubic meter (0.044 ppm)	24 hours
	50 micrograms per cubic meter (0.017 ppm)	1 year
Carbon monoxide[b]	100 mg/cubic meter (90 ppm)	15 min
	60 mg/cubic meter (50 ppm)	30 min
	30 mg/cubic meter (25 ppm)	1 hour
	10 mg/cubic meter (10 ppm)	8 hours
Lead[c]	0.5 to 1.0 micrograms/cubic meter	1 year

mg = milligram, p pm = parts per million

[a] Guideline value for particulate matter is no longer set because there is no evident threshold (lowest safe level) for effects on morbidity and mortality. (See below for previous guideline value for particulate matter).

[b] The guideline is to prevent carboxyhemoglobin levels in the blood from exceeding 2.5%. The values are mathematical estimates of some CO concentrations and averaging times over which this goal should be achieved.

[c] The guideline for lead was established by WHO in 1987.

Source: WHO Ambient Air Quality Guidelines, http://w3.whosea.org/techinfo/air.htm

Previous WHO Guideline Value for Particulate Matter

WHO Air Quality Guidelines (mg/m^3)

Duration	TSP	PM10
Long Term (annual average)	60–90	
Short Term (24 hour average)	150–230	70
Short Term (8 hour average)	120	70

Source: CBS (2004)