ENVIRONMENTAL POLLUTION IN NEPAL

A REVIEW OF STUDIES

NEPAL NATIONAL CONSERVATION STRATEGY IMPLEMENTATION PRGRAMME
NATIONAL PLANNING COMMISSION, HMG NEPAL, IN COLLABORATION WITH
IUCN-THE WORLD CONSERVATION UNION

Narayan Belbase

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CONTENTS

TABLES

LIST OF SELECTED ACRONYMS

INSTITUTIONS

ACAP	Annapurna Conservation Area Project
ADB	Asian Development Bank
BID	Balaju Industrial District
CBS	Central Bureau of Statistics
CEDA	Centre for Economic Development and Administration
DISVI	Disarmo e Sviluppo (Italian International Cooperation)
EEC	European Economic Community
EISP	Environmental Impact Study Project
ENPHO	Environment and Public Health Organisation
FAO	Food and Agricultural Organisation
GTZ	Deutsche Gessellschaft für Technische Zusammenarbeit (German Technical Cooperation)
HMG	His Majesty's Government
ICIMOD	International Centre for Integrated Mountain Development
ISC	Industrial Services Centre (now, Economic Services Centre, ESEC)
IUCN	International Union for the Conservation of Nature and Natural Resources (now, IUCN - The World Conservation Union)
NBSM	Nepal Bureau of Standards and Metrology
NPC	National Planning Commission
PID	Patan Industrial District
RONAST	Royal Nepal Academy of Science and Technology
SWMRMC	Solid Waste Management and Resource Mobilisation Centre
UNCRD	United Nations Centre for Regional Development
UNEP	United Nations Environment Programme

UNICEF	United Nations Children's Fund
WHO	World Health Organisation
WRI	World Resources Institute

TECHNICAL TERMS

ARI	Acute Respiratory Infection
BHC	Benzene Hexa-Chloride
BOD	Biochemical Oxygen Demand
CFCs	Chlorofluorocarbons
COD	Chemical Oxygen Demand
DDT	Dichloro-Diphenyl-Trichloro Ethane
DO	Dissolved Oxygen
EBI	Extended Biotic Index
ESP	Electrostatic Precipitator
GNP	Gross National Product
pH	Potential of Hydrogen (expressed in terms of hydrogen ion concentration)
PAN	Peroxyacetyl Nitrate
SPM	Suspended Particulate Matter
TDS	Total Dissolved Solids
TSP	Total Suspended Particulates

CHEMICAL FORMULAE

Ag	silver
As	arsenic
Ca	calcium
$CaCO_3$	calcium carbonate
Cd	cadmium
CH_4	methane
Cl	chlroide
Cl_2	chlorine
CO	carbon monoxide

CO_2	carbon dioxide
Cr	chromium
Cu	copper
Fe	iron
Fl	fluoride
Hg	mercury
HNO_3	nitric acid
H_2S	hydrogen sulphide
H_2SO_3	sulphurous acid
H_2SO_4	sulphuric acid
K	potassium
Mg	magnesium
Mn	manganese
N	nitrogen
N_2	nitrogen gas
Na	sodium
NH_3	ammonia
NH_3-N	ammonia nitrogen
NO	nitric oxide
NO_2	nitrite or nitrogen dioxide
NO_2-N	nitrite nitrogen
NO_3	nitrate or nitrogen trioxide
NO_3-N	nitrate nitrogen
NO_x	nitrogen oxides
N_2O	nitrous oxide
O_2	oxygen gas
O_3	ozone
P	phosphorus
Pb	lead
PO_4	phosphate
SiO_2	silicon dioxide
SO_2	sulphur dioxide
SO_3	sulphur trioxide

SO_x	sulphur oxides
Zn	zinc

UNITS AND SYMBOLS

cm	centimetre
dBA	decibel ("A" - weighted)
ft	foot/feet
g	gram
h	hour
kg	kilogram
kl	kilolitre
km	kilometre
l	litre
m	metre
m^3	cubic metre
m^3/s	cubic metre per second
mg	milligram
mg/l	milligram per litre
$mg/(m^2.h)$	milligram per cubic metre per hour
mg N/l	milligram of nitrogen per litre
mg P/l	milligram of phosphorus per litre
min	minute
ml	millilitre
mm	millimetre
mph	miles per hour
ppb	parts per billion
ppm	parts per million
s	second
t	metric tonnes
g/l	microgram per litre
$>$	greater than
$<$	less than

NATIONAL CONSERVATION STRATEGY IMPLEMENTATION PROGRAMME

The National Conservation Strategy (NCS) for Nepal was completed in 1987 and endorsed as policy in 1988. Nepal's NCS is being implemented through a series of programmes in the key areas of environmental planning and assessment, education and public information. Coordinated by the National Planning Commission (NPC), the implementation programme involves representatives of all the major ministries and government departments concerned with environmental issues, as well as an increasing number of local non-governmental organisations (NGOs).

The NCS was prepared and is being implemented with technical assistance from IUCN - The World Conservation Union. Nepal is one of over 700 members of IUCN, and is among more than 40 governments that have been assisted by IUCN in developing National Conservation Strategies.

Founded in 1948, IUCN is the largest professional world body working to conserve the earth's soil, land, water, air and life systems. IUCN is active in over 120 countries, and is a unique international agency whose membership includes both governments and non-governmental organisations, providing them equal opportunity to work together to achieve effective conservation action. IUCN's aim is to establish a tangible link between development and the environment that will result in a lasting improvement in the quality of life of people all over the world.

EDUCATION

Under the NCS for Nepal, a series of education and training projects are being designed and implemented within the NCS Environmental Education Programme. These projects aim to enhance the coverage of existing environmental management and resource conservation subjects in formal and non-formal education programmes in Nepal. A National Environmental Education Conference will provide a forum at which consensus can be reached on Nepal's environmental education needs.

Primary school curriculum is a priority concern of the programme. The Environmental Education in Primary Schools pilot project includes the preparation of model environmental curricula, revision and expansion of current textbooks and the development of associated resource materials. Teachers and students are being involved in a series of trial and evaluation workshops to refine the lessons and teacher's guides. This package will be comprehensively tested in selected schools, accompanied by teacher training and evaluation. Ultimately, the project aims to have the tested environmental education materials integrated into the national level primary school curriculum.

The Environmental Education Programme further emphasises pre-service and in-service training of extension workers and government officers. Environment courses have already been introduced on a trial basis within three governmental training centres, and this work will continue to be expanded to produce and test training packages for a number of sectors.

PUBLIC INFORMATION

The NCS Public Information Programme focusses on two main elements: publications support to other components of Strategy implementation and public environmental awareness activities. An NCS Newsletter provides information and updates on the status of the NCS implementation programme and on agencies and programmes working in environment-related fields. Public awareness activities are implemented through local NGOs and include a strong training element aimed at orienting members of the media and professionals of various disciplines towards consideration and coverage of environmental issues.

Information is being disseminated at the community level through a wall newspaper, with the objective of expanding the currently limited information on conservation issues available to rural communities. Two weekly radio programmes, investigative reports and an interdisciplinary seminar series also form part of the Public Information Programme.

PLANNING AND ASSESSMENT

An Environment Core Group has a key role in developing new environmental policies and procedures best suited to Nepal. The Group comprises of some forty senior government officials from the fifteen ministries and departments and all NPC divisions. Over several years, this Core Group is participating in a series of practical, field-oriented professional interactions, as well as in intensive policy development workshops and secondments to the NPC and relevant ministries.

While the Environment Core Group programme for developing environmental planning policies is continuing at the national level, the NPC/IUCN NCS Implementation Programme has initiated local environmental planning activities through local NGOs. Communities are being assisted in the preparation of model environmental plans in eight villages and two districts, Lamjung and Arghakhanchi, to test field planning methods, including community involvement processes. This local planning effort will be used by the Core Group as a practical model for the formulation of national environmental planning guidelines and procedures.

The Environment Core Group is also engaged in preparing national and sectoral guidelines for environmental impact assessment (EIA) of development projects. Linkages, through the Core Group, with the NCS Environmental Planning Programme, will ensure that the procedures and methods defined for the appraisal of projects will be appropriate to the land use planning framework and field methods tested and developed under that Programme.

HERITAGE CONSERVATION

Another component of the NCS Implementation Programme is concerned with conserving cultural and natural heritage of national significance. Under the NPC's leadership, the NPC/IUCN NCS Implementation Programme is working closely with the Nepal Heritage Society, other local NGOs and relevant government ministries to compile a register of national heritage sites, their condition and current management. The programme will involve establishing criteria for national significance, critical review of existing inventories and comprehensive field survey, particularly for natural sites of importance outside existing protected areas. The preparation and implementation of management plans for selected demonstration sites that combine natural and cultural attributes of outstanding value is also a key element of the programme.

POLLUTION CONTROL

The first stage of the Pollution Control programme was completed in December 1990 and resulted in a comprehensive inventory of industrial sources of air, water, soil and noise pollution in the country. This national survey, undertaken in collaboration with the Nepal Environmental Conservation Group (NECG), identified industrial pollution problems requiring immediate attention.

The second stage of the pollution control programme is a demonstration project for industrial pollution assessment and control in the Balaju Industrial District, Kathmandu. The project commenced in January 1991 and will result in a pollution control management plan for the district. This stage also includes a comprehensive survey of laboratory facilities in Nepal.

Stage three of this programme will extend the implementation of management plans to industrial complexes which were identified in the national survey as requiring urgent pollution control attention. Management plans will be implemented in collaboration with relevant ministries and related public and private sectors. Draft standards will be prepared to cover all pollution-prone categories of industries operating in Nepal.

The wider ranging objective of this project is a detailed and comprehensive understanding of Nepal's pollution situation, with enough quantified data to establish practical pollution standards and technical capability to apply them.

As a preliminary exercise, the programme undertook a review of pollution studies conducted to date in Nepal, examining levels of water, air, land and noise pollution at sample sites in selected districts. This review provided the necessary background information for the design and implementation of the national survey of industrial pollution sources.

SUMMARY

Reliable pollution studies are very recent to Nepal and limited in the areas they cover. The quality of drinking water supplied to Kathmandu and a few places outside the valley has received the most attention. The number of studies is increasing, however, due to growing public concern about pollution and its impact on human health and the environment.

Although the reporting varies in quality, surveys between 1977 and 1990 show that pollution is increasing both in terms of area contaminated and in the levels of pollution. Already many of the most common contaminants are found at levels that far exceed internationally acceptable standards. These contaminants pose a serious threat to human health and the environment.

Pollution is causing a deterioration of Nepal's environment, even though the industrial development of Nepal is occurring at a relatively slow rate and the average consumption of energy is very low when compared with usage patterns of most other countries in Asia.

Pollution regulation and management is non-existent in Nepal. For example, there is no reliable treatment of sewerage; no controls on vehicular exhaust levels or pollution-prone industries; no effective regulation of pesticide use; no systematic monitoring of water quality; and very limited laboratory facilities. Baseline data on industrial production and practices in Nepal is inadequate, hindering efforts to develop legislation, pollution control standards and appropriate anti-pollution measures.

WATER POLLUTION

The quality of drinking water in the urban centres of Kathmandu, Pokhara and Biratnagar has been studied. Almost all the samples taken showed levels of coliform bacteria that exceeded the World Health Organisation (WHO) safe drinking water standard of less than 1 coliform bacteria cell per 100 ml of water. Virtually all drinking water in Nepal was found to be unsafe throughout the year, especially during the rainy season when contamination levels reached 4,800 coliform per 100 ml.

The drinking water supply is chlorinated before it enters the water delivery system, yet some researchers found that the drinking water system was being contaminated by sewage lines that run parallel to the water pipes in many places. Water delivery pipes were cracked and perforated, and the supply of water was not constant, so that outside matter was being sucked into the water pipes during the frequent periods of low water pressure.

In contrast with the bacteriological contamination levels, the chemical composition of reticulated drinking water was found to be within acceptable international standards.

Higher bacteriological and chemical contamination was found in water from wells, tubewells and stone spouts; almost all the chemical parameters tested from these sources exceeded international standards. Industrial discharge, sewage seepage and poor hygiene practices around the wells were the major factors found to be contributing to the poor state of Kathmandu's groundwater. This is a particularly disturbing phenomenon, as groundwater pollution tends to persist and concentrate over time and clean-up measures are difficult and expensive. Thus, Kathmandu's groundwater cannot be relied upon as an alternate source of water for the increasing population of the Valley.

The condition of the Bagmati river and two of its tributaries, Dobhi Khola and Tukucha, has been studied. The capacity of these rivers to sustain aquatic life approached zero at points adjacent to and downstream of urban Kathmandu. At times, the adverse effects of direct discharge of sewage and untreated industrial effluents to the Bagmati river could be seen up to 10 km downstream of Kathmandu.

The untreated discharge from the Bhrikuti paper mill into the Narayani river and from the Everest paper mill into the Orahi river has also been studied. As the Narayani is a large, swiftly flowing river, its recovery zone began quite near the discharge zone. The smaller size of the Orahi river resulted in more extensive damage and slower recovery.

AIR POLLUTION

In contrast with the wealth of data available in developed countries, virtually no quantitative studies have been undertaken to examine the status of air pollution in Nepal. Sources of air pollution in Nepal are varied and include combustion of fossil fuels, vehicular exhausts, industrial emissions and effluents, unmanaged solid wastes, and smoke emission from combustion of biomass.

Suspended particulate matter and gaseous chemicals are leading air pollutants and are potential health and ecological hazards.

There is a serious lack of information on pollutants emitted from combustion of biomass fuels used for cooking and heating purposes in rural Nepal. Poorly ventilated houses compound the effects of these emissions. A number of lung and eye diseases prevalent among Nepalese women are ascribed to indoor pollution. One study demonstrated the correlation between the use of new, improved cookstoves and a dramatic reduction in the levels of particulate exposure.

Air pollution in the urban areas of Nepal includes vehicular emissions and industrial discharges, the most serious of which are sulfur dioxide, nitrogen trioxide and carbon. The levels discovered were comparable to urban areas in industrialised countries. Of particular concern is the high lead concentration which in other countries has caused acute and irreversible health problems, particularly in children. The main contributor to lead pollution in urban areas is the use of leaded gasoline. Poor vehicle maintenance and the low octane level of leaded gasoline exacerbate the problem.

Little reliable data exists on the nature and extent of industrial air pollution. Very high levels of dust are emitted by cement, brick and tile factories and textile mills. Offensive odours and health hazards are also associated with the open land dumping practices of leather tanneries.

LAND POLLUTION

Figures on the volume and types of solid waste in Nepal are unreliable for comparison of changes in patterns over time and from place to place. The Solid Waste Management and Resource Mobilisation Centre estimates that solid waste generated in Nepal will increase by almost 50 percent over the 5 years to 1995 with serious implications for the spread of diseases, contamination of ground and surface water, and for air pollution. Solid waste is primarily an urban problem, limited in rural areas to localised dumping in village and along trekking routes.

A centralised solid waste collection and landfill system has been operating in Kathmandu, Patan, Bhaktapur for seven years. In 1988, the Centre reported that about 168 tonnes per day or 400 grams per head per day of solid waste was generated in the valley. According to the Centre, just over 50 percent of this waste was being collected, of which 22 percent was non-biodegradable.

The Gokarna dump site has been studied in some detail. Several mitigation measures have been implemented at the site. Drainage ditches have been constructed, leachate ponds dug, and the dump site has a gradient for rain runoff. Despite these precautions.

monitoring wells installed show that leachate from the site has seeped into, and is contaminating, the groundwater supply.

The area around the Everest base camp was also studied. An increase in the number of trekkers visiting the base camp has created a waste disposal problem. The site itself presents very few alternatives for disposal of wastes. One clean-up operation has been undertaken and policies and regulations now require trekkers to carry wastes out of the area.

The environmental impact of farm pesticide and fertiliser use has not been quantitively studied. The use of such chemicals by farmers is limited by availability and high costs. However, as the productivity of the land declines, fertiliser use and, in some areas, the application of pesticides is increasing with uncertain consequences. Serious incidences have been documented of mishandling and poor management and storage of pesticides. The use of banned pesticides such as BHC continues, and the heavy use of DDT with long-term residual effects has only recently been discontinued. One study reported that pesticide consumption by residents of Kathmandu valley was likely to be high due to the wide availability and heavy use of pesticides in the valley.

NOISE POLLUTION

Noise pollution is a relatively new concern. Scientific studies show that long exposure to loud noise has both physiological and psychological effects. Study of the noise levels in various built-up sections of Kathmandu found average decibel (dBA) levels to be 80-100. These levels exceed international safety standards.

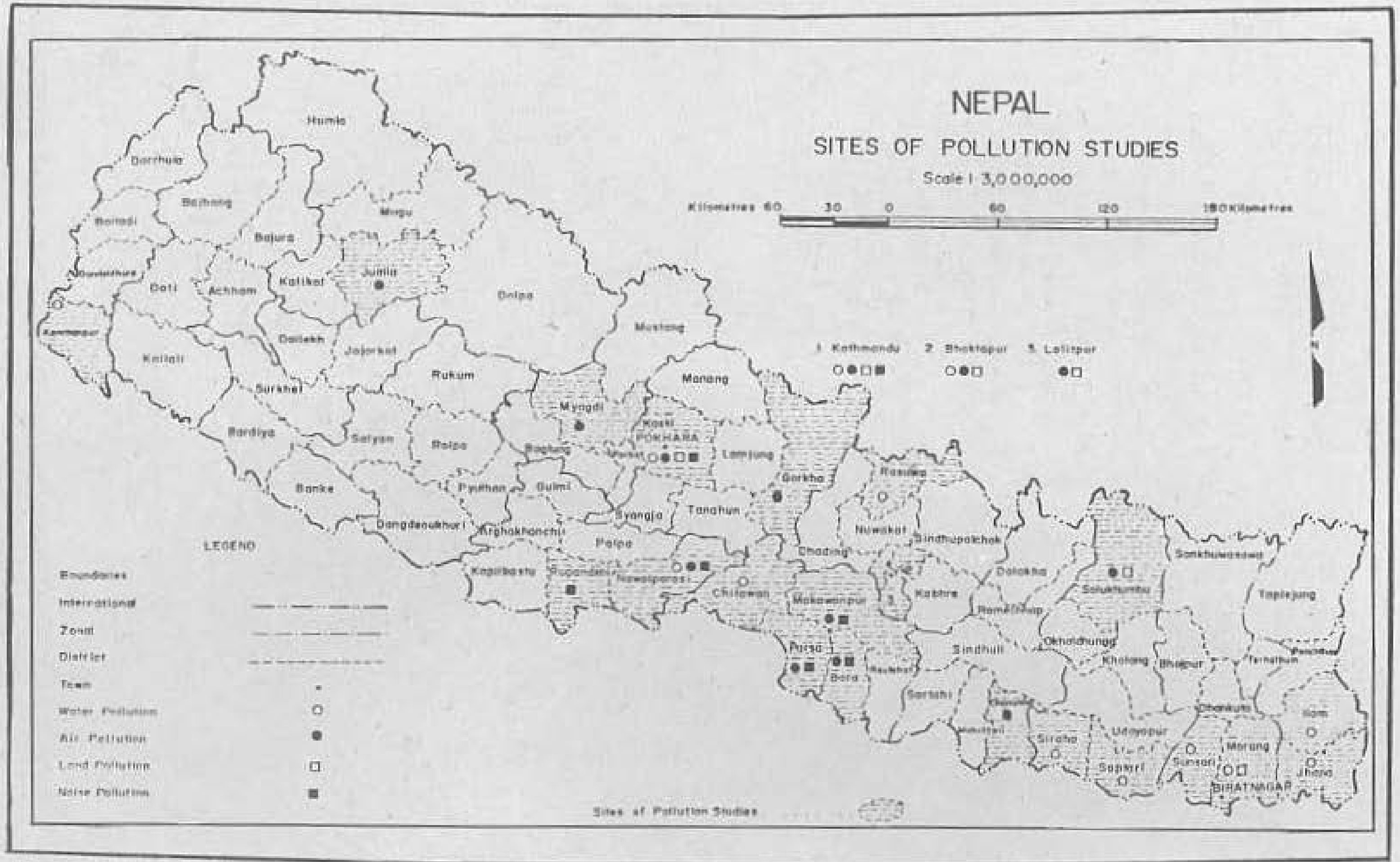
CONCLUSION

Much quantitative work is still required to improve our understanding of pollution in Nepal. Environmental baseline data is not available for most areas and very few areas have monitoring stations. However, from this review of studies conducted over the past 13 years, it is clear that Nepal suffers from pollution problems associated with development (for example, air pollution from vehicles) and under development (for example, bacteriological contamination of drinking water). Inadequate management structure, technical capacity and coordination impedes the study of, and responses to, pollution problems in Nepal.

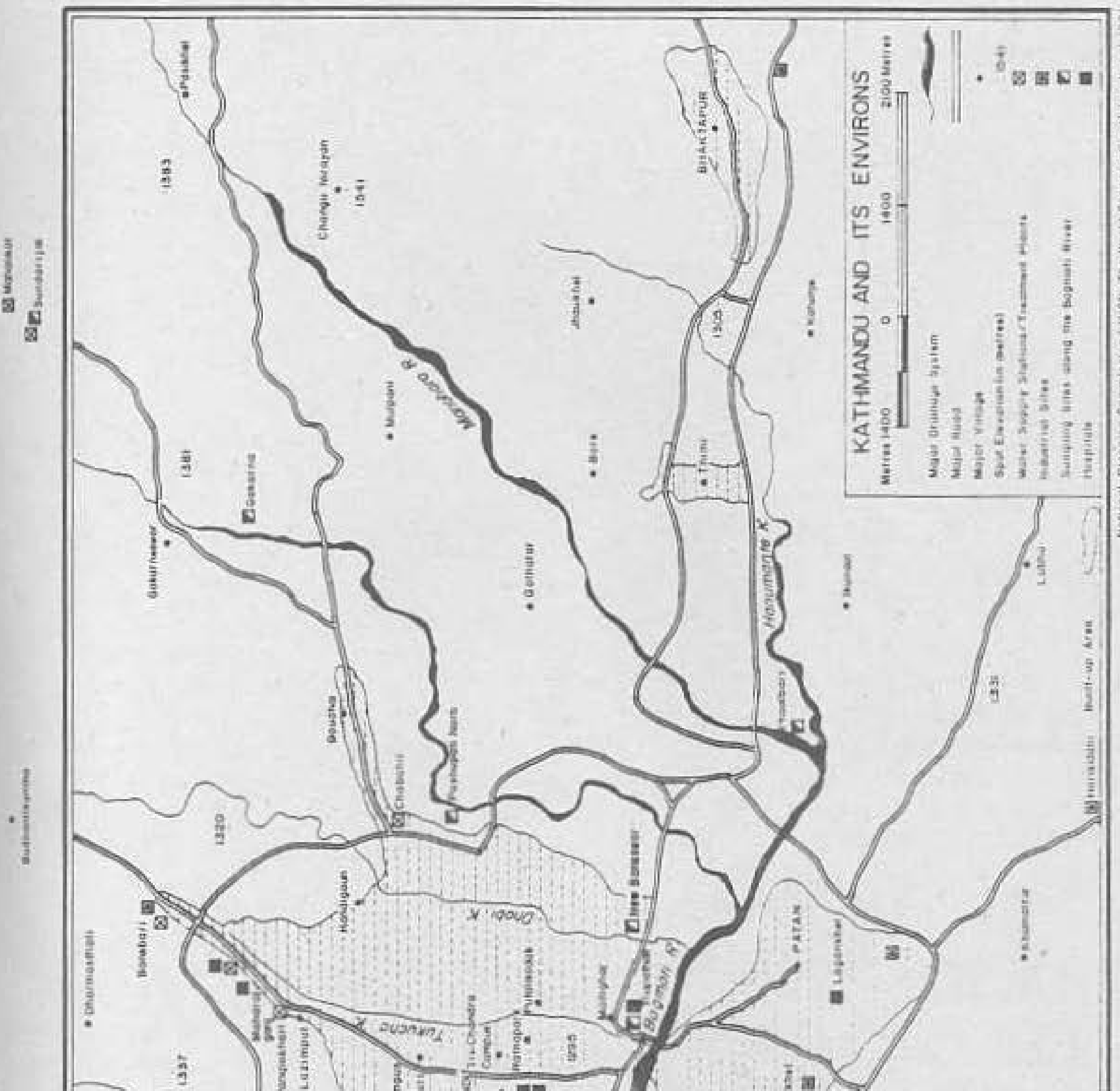
While these technical and infrastructural problems are being addressed, scope exists for further improvement in governmental and private sector investment in this field. Since most development initiatives in Nepal are project-led, good environmental impact assessment procedures would go a long way towards minimising future problems. Many multi and bilateral aid agencies now require environmental impact assessments of their aid projects, but much greater collaboration of effort is needed to integrate these activities with government decision-making procedures. Systematic environmental planning at both national and local levels, incorporation of practical standards and guidelines based on studies and monitoring of existing industries are also essential to minimising the pollution that is causing degradation of Nepal's resource base.

Currently, the Government does not make it mandatory to conduct environmental impact assessments prior to approving projects and industrial development activity. This situation is under review, and the National Planning Commission with assistance from IUCN - The World Conservation Union is formulating environmental impact assessment policies and procedures. This work complements other initiatives under the National Conservation Strategy Implementation Programme to set up structures for environmental planning and management in Nepal.

MAP I



National Planning Commission / IUCN - The World Conservation Union, Nepal, 1991



National Planning Commission / IUCN - The World Conservation Union, Nepal, 1991

WATER POLLUTION

Water pollution is the most serious environmental quality issue in Nepal. It is caused by the disposal of solid and liquid wastes on land or into surface waters. The most significant wastes are sewage, industrial effluent and agricultural residues and chemicals. Sewage originates primarily from domestic premises. Along with industrial effluents it is discharged untreated into streams and rivers, indirectly through runoff and open drains and directly via the public sewerage system. Pesticides, fertilisers, and livestock are the main agricultural sources of ground and surface water pollution.

Reticulated sewerage and treatment plants have been established only in the cities of Kathmandu valley but have a poor performance record. The Kathmandu system is old and fragmented and a lack of maintenance has led to frequent malfunction (ADB, 1985). The oxidation pond and treatment plant at Kirtipur has ceased to operate for the same reason. Sewage from septic tanks is dumped into the Bagmati river or public drains. Drinking water supplies are polluted through runoff into storage sites or cross-leakages between overloaded sewer lines and water pipes. Sewage is the primary cause of drinking water pollution, and industrial effluent and sewage combined are the main causes of river pollution.

DRINKING WATER POLLUTION

Pollution of drinking water is the most serious public health issue in Nepal. Yet the vital connection between water and health is given little emphasis in government policy on water supply (UNICEF, 1987).

Till 1950, drinking water supply was limited to the urban areas of Kathmandu. Now most of the 33 urban centres in the country have piped water (CBS, 1989). However, many supply systems provide water for only a few hours each day (ADB, 1985) and, despite receiving varying levels of treatment, bacteriological contamination remains high.

Although some rural water supply schemes exist, most of the rural population uses traditional sources of water, irrespective of quality (ADB, 1985). In rural areas as well, coliform contamination of drinking water is a major concern.

Coliform bacteria inhabits the intestinal tract of humans and animals. Generally, its presence in drinking water indicates faecal contamination, although not all coliforms are of faecal origin. Coliforms include all aerobic and anaerobic nonspore-forming bacilli, such as *Escherichia coli*, *Citrobacter freundii*, *Enterobacter* *aerogens, Enterobacter cloacae and Klabsiella pneumoniae*. The presence of coliform micro-organisms in drinking water may indicate the presence of bacterial infections that cause waterborne diarrhoeal diseases. In 1985, over 50 percent of hospital patients in Nepal were found to be suffering from gastro-intestinal disorders normally caused by waterborne pathogens (ADB, 1985).

There is no water quality monitoring network in Nepal, and studies on drinking water quality do not cover all the urban areas served with piped water supply, much less rural areas where water treatment facilities are rare. Most water pollution studies have examined the quality of drinking water supplied to the Kathmandu valley, particularly to its urban areas. Very few places have been surveyed elsewhere in the country. However, the extent of drinking water contamination in the areas covered by pollution studies suggests that the problem is nationwide.

Kathmandu

Bacterial contamination

River water, groundwater, and natural ponds are the main sources of water supply for Kathmandu valley. The Nepal Water Supply Corporation is responsible for the distribution of water supply in urban communities. It operates water treatment facilities at the water reservoirs serving the valley. The water is treated with chlorine (Cl_2) for disinfection at Kathmandu's three water supply stations — Sundarijal, Balaju and Panipokhari. Some suburban communities, however, use untreated water from sources such as wells, ponds, and streams for domestic purposes. Additionally, people from some core urban localities still use untreated water drawn from local tubewells and dugwells.

The quality of drinking water in Kathmandu has been examined by several workers. All but one study indicate that the public water supply is far from satisfactory in almost all localities in terms of bacterial contamination.

A study was undertaken by Sharma (1978) to determine the quality of drinking water supplied to the households of the Kathmandu valley. Coliform tests were performed on water samples from 39 localities, and results showed that all the water samples had some degree of faecal contamination. The number of coliform cells per 100 ml of water ranged from 4 to 460. The most polluted water was found in Thamel, Maruhiti, Gyaneshwor and Chikanmugal areas of Kathmandu.

The levels of coliform organisms present in the drinking water far exceeded the maximum permissible value of less than one cell per 100 ml of water set by the World Health Organisation (WHO) (Annex I) and posed a clear threat to human health. As the drinking water supply is treated and chlorinated at the treatment plants, it was assumed that the coliform bacteria must have entered the drinking water supply through the delivery system. Drinking water and sewer pipelines are adjacent and parallel to each other in many sections of the city. The sporadic water supply, resulting in decreased water pressure in the pipelines, causes sewage to be sucked into the cracked water pipes. Since farmers illegally drill holes in the main pipelines to get water for irrigation, it is likely that sewage also enters the system through these holes during periods of low water pressure.

Another probable source of contamination stems from the unhygienic environment around public taps. At a number of areas faecal matter from baby diapers, kitchen wastes and animal excreta accumulate at the public tap during washing and cleaning activities. Such wastes also enter the water pipelines through leakage points.

In a followup study A. P. Sharma (1986) found that the levels of coliform contamination of drinking water in Kathmandu had significantly increased in nine years. In 1978 the maximum coliform count was 460 per 100 ml. In 1986, the contamination levels reached 4,800 coliform cells per 100 ml.

The 1986 study examined the relationship between the level of bacterial contamination of water and the seasonal variation. Water samples were taken in the dry summer season, the rainy season, and the winter season. Samples were also collected from the Lalitpur area. Additionally, this study tested the industrial effluent of selected industries.

The bacterial count was found to be much higher in the rainy season than in the summer and winter seasons. The coliform bacteria count ranged from 0 to 4,800 during the rainy season, 0 to 75 in winter and 0 to 460 per 100 ml in the summer months. It was concluded that sewage system contamination of the drinking water supply increased significantly in the rainy season, as water volume in the sewers increased, submerging the water supply pipelines.

The view that contamination is a result of cross-leakages between adjacent water pipes and sewage lines, and sucking in of sewage by water pipes during low pressure periods, is supported by the minimal levels of pollution found near the water treatment stations. For example, the bacterial count was zero in water samples from the Balaju Park during all three seasons. The level of bacterial contamination increased gradually as the water pipelines approached densely populated areas. Similarly, samples tested near the industrial drainage systems showed a high percentage of coliform bacteria.

The level of bacterial contamination varied greatly between samples. This variation may follow the variation in water pressure maintained in the drinking water supply system. When water pressure is low, as is often the case during the day, the vacuum created in the pipeline may be sufficient to suck in sewage.

In some areas, there was little difference in the coliform count between chlorinated water samples and water samples taken from non-chlorinated sources. DISVI, an Italian technical assistance organisation, in an examination carried out to determine the amount of free-residual chlorine in the public water supply taps in Kathmandu, confirmed that the chlorination of drinking water in treatment plants was not sufficient to render it potable. One of the easiest and quickest methods to assess the bacteriological quality of drinking water is to determine the concentration of free-residual chlorine in the public water supply system. A total of 207 water samples were tested for free-residual chlorine, and among them 34 percent had chlorine concentration less than 0.2 mg/l, the lower limit specified by WHO. DISVI (1990a) therefore, concluded that the city lacked a proper disinfection system.

Adhikari *et al* (1986) carried out coliform tests on 100 samples of drinking water collected from different areas in the Kathmandu valley, and from different sources — from water taps, natural springs and ponds. The samples were grouped into four categories on the basis of the number of coliform present per 100 ml of water as follows — excellent (no coliform), satisfactory (1-3 coliforms), suspicious (4-10 coliforms), and unsatisfactory (more than 10 coliforms). The study revealed that 88 percent of the samples were unsatisfactory, 2 percent suspicious, 6 percent satisfactory, and only 4 percent excellent for drinking purposes. Most of the unsatisfactory water samples had more than 1,800 coliform per 100 ml of water: 42 of the 48 tap water samples, 22 of the 27 spring water samples, and 24 of the 25 pond water samples were unsatisfactory.

The quality of drinking water in Kathmandu was also examined by Manandhar *et al* (1987). Microbiological tests were carried out on tap water samples in Kathmandu city. In sharp contrast to the results of earlier studies (Sharma, 1978; Sharma, 1986; Adhikari *et al*, 1986), no coliform contamination was found. This study needs to be interpreted with caution because the sample size was small and taken from only three localities — Jhochhen, Lazimpat, and Baneshwor. Furthermore, the samples were taken in winter which Sharma (1986) noted as the season of least contamination.

A more detailed and comprehensive study was carried out by DISVI in 1989. The objective of the study was to assess the quality of Kathmandu's drinking water supply and identify weaknesses in the city's public water supply system. The quality of drinking water was monitored for a period of six months, from January to June. Drinking water samples were collected from 58 sampling points — 7 water treatment plants and reservoirs, 7 hospital storage tanks, and 44 water taps. A total of 472 samples were tested.

The study provided an opportunity for the first time to determine more clearly linkages between seasons and the level of coliform contamination, to compare the quality of drinking water at distributing and receiving ends, and to assess water quality in storage sites.

The study found that almost all the water samples had coliform counts far exceeding WHO standards (Table I). Samples from congested areas of the city had the highest levels of contamination. In these areas, both the water supply pipelines and sewerage network are old and in poor condition.

The study showed that bacteriological contamination increased as the water travels from the water treatment plants to the distribution system. WHO guidelines require that treated water entering a distribution system should contain less than one coliform organism per 100 ml.

As with the earlier studies, DISVI concluded that contamination of drinking water was due mainly to the infiltration of sewage into drinking water pipelines. The seasonal variation in total coliform in the distribution system showed least pollution during winter (January to March), with steadily increasing levels from April to June during the hot rainy season. It was speculated that polluted water seeped into the ground at an increased rate during April to June, increasing the pressure and temperature in the sewage lines, thus facilitating microbial growth.

The 44 sampling locations for tap water were divided into three sectors based on household density, Sector I being the most densely populated and congested section of the city, and Sector III the least. Within the distribution system, Sector I had the highest degree of contamination with 79 percent of the samples exceeding the WHO standard value and only 15 percent of the samples without coliform. Seventy percent of samples from all sectors had an average of 196 coliform cells with some samples having as many as 2,800 cells per 100 ml of water. All the sampling points in the distribution system, except those of Boudhanath and Sano Gaucharan, showed

Table I: Coliform Contamination in Kathmandu Drinking Water

	Treatment Plants	Distribution Systems	Hospital Storage
Number of samples	154	282	36
Minimum count/100 ml	0	0	0
Maximum count/100 ml	400	2,800	3,000
Average count/100 ml	10	196	639
% of samples with no coliforms	77	30	8
% of samples with coliforms	23	70	92

Source: DISVI (1989).

various degrees of bacteriological contamination, indicating that pollution was widespread in the city. There were no safe areas. Even samples from points located very close to the treatment plants and reservoirs such as Old Chabahil and Balaju were contaminated.

The seven water treatment plants were also found to be contaminated. The new and old reservoirs of Mahankalchour were the least polluted with only 4 percent and 8 percent of samples respectively above the WHO standard. The Balaju treatment plant was the most polluted with 52 percent of the samples above the WHO standard. Sundarighat and Sundarijal treatment plants and Maharajgunj and Bansbari reservoirs had between 23 to 35 percent of samples above the standard. Seventy-seven percent of all samples from the treatment plants and reservoirs were satisfactory and 23 percent unsatisfactory with an average of 10 coliform cells per 100 ml of water.

Water quality in reservoirs supplied by only one source, whether ground or surface water, was better than that of reservoirs supplied by more than one source. Mahankalchour Old and Bansbari reservoirs are supplied only by groundwater, and the Sundarijal and Maharajgunj treatment plants are exclusively supplied by unpolluted surface water. The situation is more critical for the Sundarighat treatment plant, supplied by highly polluted surface water, and for the Balaju treatment plant and Mahankalchour New reservoir, supplied by both surface and groundwater. The higher the number of sources supplying a reservoir, the greater the chance of pollution. DISVI also noted that a high degree of variability in the chemical composition of water entering the treatment plant from different sources made it more difficult to treat the water, resulting in higher levels of bacterial contamination.

All samples taken from water storage tanks of seven hospitals in Kathmandu were found to be more contaminated than those collected from public taps. Only 8 percent of the samples were free of coliform bacteria, and 92 percent of the samples had 639 coliform cells per 100 ml of water on average. In some samples a staggering 3,000 coliform cells were found in 100 ml of water. This is a particularly disturbing finding given the nature of the public facility.

CEDA (1989) also tested water from different localities in Kathmandu and demonstrated that almost all samples were contaminated with faecal material. None of the tap and groundwater sources tested were safe for drinking.

Chemical Composition

The improper disposal of ever-increasing quantities of organic and inorganic chemicals in the municipal sewage and industrial effluents can adversely affect the chemical quality of drinking water.

The drinking water supply in Kathmandu from surface sources is within safe limits in terms of chemical parameters, but groundwater sources are not satisfactory in this respect. This situation has been substantiated by a number of studies.

Sharma (1986) found that most tap water samples from 51 localities in Kathmandu were chemically suitable for drinking purposes, confirming his 1978 study. Little variation was observed in the chemical content of drinking water supplied to different localities in Kathmandu. The pH content ranged from 6.5 to 7.5, while the $CaCO_3$ content varied from 26 to 30 mg/l. Total hardness due to the presence of various metallic salts was also similar from one location to another. The chemical constituents tested were found to be within the standards prescribed by WHO.

CEDA confirmed these findings in a 1989 study of 13 sites, including three reservoirs — Balaju, Maharajgunj and Mahankalchour. The chemical parameters tested included pH, dissolved oxygen (DO), BOD, chemical oxygen demand (COD), ammonia (NH_3), NO_3, phosphate (PO_4), and Cl.

DISVI also undertook a detailed chemical analysis of drinking water in Kathmandu in 1989. The study examined chemicals which corrode water pipelines, affect the aesthetic quality of water, and indicate contamination by domestic sewage. As described in the previous section, the DISVI study covered treatment plants and reservoirs, hospital storage tanks, and taps in the public water supply system.

The water samples from treatment plants and reservoirs were tested for eight chemical parameters — conductivity, hardness, Cl, organic matter (oxygen consumed or BOD), iron (Fe), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), and nitrite nitrogen (NO_2-N).

All the treatment plants and reservoirs had conductivity, hardness and Cl values within the WHO standards. These three parameters should remain constant, or should have only minimal variations which reflect the variability of the chemical composition of the source water used to supply the treatment plants and reservoirs studied. The Sundarighat treatment plant, Mahankalchour New reservoir and Balaju treatment plant varied more in these three parameters. The values of NO_3-N found in all treatment plants were within WHO standards.

Sundarighat treatment plant and Mahankalchour Old reservoir showed very high amounts of organic matter as indicated by their BOD level. High amounts of NH_3 were detected in these plants as well as at the Bansbari reservoir. The Sundarighat treatment plant also had a very high content of NO_2, with an average value of 0.917 mg N/l, and 55 percent of the samples exceeded the WHO standard of 0.10 mg N/l.

The WHO standard for iron in drinking water, at 1 mg/l, was exceeded in water samples from the Bansbari and the Mahankalchour Old reservoirs, averaging 1.68 mg/l and 3.30 mg/l respectively. Over 90 percent of the water samples from these reservoirs exceeded the WHO standard.

Two percent of samples from treatment plants contained less than the required level of 0.2 mg/l of free residual chlorine; in the distribution system, the percentage escalated to 40 percent.

Table II: Chemical Parameters of Taps and Groundwater in Kathmandu

	Unit	Tap Water	Ground Water
Chloride	mg/l	5 to 12	610* to 1100*
Nitrate	mg/l	18 to 48	27* to 58*
Sulphate	mg/l	1 to 3	61 to 92
BOD	mg/l	1.5 to 3	2 to 12*
pH		6 to 8.5	6 to 8.9
Hardness salts	mg/l	10 to 35	230 to 750

* Values exceeding the WHO international standard

Source: Sharma (1986).

The chemical quality of the water of the Mahankalchour and Balaju treatment plants was fairly acceptable. The percentage of samples exceeding the WHO standards for iron and NH_3 was comparatively higher than for Sundarijal and Maharajgunj. As Mahankalchour and Balaju are fed by groundwater sources, it is assumed that the groundwater contains high values of these elements.

The water of Mahankalchour Old reservoir and Bansbari reservoir also had very high amounts of NH_3 and iron. These two components are thought to be naturally present in groundwater. Although they do not pose a health hazard to people, they decrease the effectiveness of disinfection processes by consuming part of the chlorine through oxidation. Moreover, they promote microbial growth and corrosion in pipelines.

The average values of the chemical parameters did not show large variations between the treatment plants and the distribution system, except for NO_2 which increased ten times, and NO_3 which increased four times. The higher values of NO_2 and NO_3 are probably due to the oxidation of NH_3. Total inorganic N and Cl also increased, probably due to the infiltration of polluted water into the distribution system.

The extreme variability of the chemical composition of the water at most of the sampling points within the distribution system made it difficult to detect pollution using chemical quality as an indicator. Furthermore, the water supplied from the treatment plants mixed in the distribution system at varying rates. DISVI suggested that the distribution system should be streamlined so that the different areas of the city are supplied by water from one source only.

Pokhara

In 1989, CEDA conducted chemical and bacteriological tests of the drinking water supply to Pokhara. The tests were performed on water samples from reservoirs, the public supply system and domestic containers. The reservoirs sampled were Kalmuda, Bhotekhola, Mardhikhola and Bagdhara. The Seti Canal and Phewa lake, other water sources, were also sampled. Water samples were collected from six different sites.

Chemical and bacteriological tests of drinking water indicated that chemically, the water was suitable for drinking, but bacteriologically it was not.

While the faecal coliform bacteria count for water samples from reservoirs was 35 cells/100 ml of water, that of tap water samples and samples from domestic containers rose to more than 4,800 cells/100 ml of water. Water samples from Phewa lake and Seti Canal also showed very high levels of coliform bacteria. Amongst the tap water samples, the sample collected from K.I. Singh Pool area had a relatively lower count — 44 cells/100 ml water. All these figures exceed WHO standards.

Values for pH, COD, NH_3, NO_3, PO_4, and Cl were all within WHO standards. The value for DO was slightly lower than required, while the BOD value was slightly higher than the WHO standard.

It was noticed that water pipelines in Pokhara run side by side with city sewers at many sections. Water and sewerage pipes have deteriorated and may have developed leaks leading to cross contamination.

Biratnagar

Biratnagar's drinking water has also been tested for chemical and bacterial contamination. Chemical and bacteriological tests were conducted by CEDA (1989) on water samples collected from reservoirs, public supply systems and domestic containers at various locations. In Biratnagar, 45 percent of drinking water needs are met by the public supply systems, 47 percent from tubewells and the remainder from other sources including river water. The main water supply stations are at Tinpaini, Minalpath and Mills Area (near Jogbani, India).

Although the water is chlorinated, the water samples showed levels of bacterial contamination as high as 4,800 cells/100 ml. Even the samples tested from the reservoir showed 29 cells/100 ml of water. The water in Biratnagar, therefore, was found to be unsuitable for drinking purposes.

The chemical analysis showed all the parameters to be within the WHO standards except for BOD and iron content values. While the BOD value only slightly exceeded the WHO standard in all the samples, the iron content level was much higher than the WHO standard. The other chemical parameters examined were pH, DO, COD, NH_3, NO_3, PO_4, and Cl.

Rural Areas

The bulk of Nepal's rural population does not have access to piped drinking water supply and waste disposal facilities. In 1981, UNEP reported that only 6.6 percent of the rural population had access to reticulated drinking water. Pradhan and Pradhan (1972) observed that in rural hilly areas people used water from springs, rivers, and ponds, and in the Terai, water was extracted from rivers, ponds, wells, and shallow tubewells. Rural communities continue to use the most convenient sources of water irrespective of quality (ADB, 1985). Collected water is contaminated both outside and within the domestic environment through poor hygiene and sanitation practices. One third of child deaths under four years of age in rural Nepal are due to such waterborne diseases as cholera, typhoid, dysentery, and gastro-enteritis.

Quantitative information is limited on drinking water quality in rural areas. The few studies that have been conducted indicate that the water quality situation in rural areas requires continued urgent attention.

A drinking water quality assessment was carried out by DISVI (1990b) in seven rural areas of Illam in Eastern Nepal. The seven villages surveyed where water samples were collected were Phikal, Chhipitar, Pashupatinagar, Gurung Niwas, Karfok, Aitabare and Teenghare. Samples were collected from 36 households and 17 water sources including springs, spring wells, aquifers (*kuwa*), rivers, and river water reservoir. Bacteriological, physical and chemical parameters were tested. The main objective of the assessment was to generate baseline data on water quality at sources and households in order to evaluate the impact of a health and sanitation education programme run in the villages.

All but two sources, Chhipitar and Hity Kuwa in Phikal, had unacceptable levels of faecal coliform bacteria ranging from 2 to 2,400 cells/100 ml. Table III shows the maximum and minimum levels of faecal coliform contamination in the surveyed villages.

Fifty five percent of the samples from households drawing water from these sources had increased contamination, 8 percent remained unchanged, and 36 percent had decreased contamination. Coliform contamination seemed to decrease in water collected and stored in traditional copper and brass containers (*gagri*), a correlation that warrants further investigation.

In terms of chemical quality, water samples from six sources were found to be acidic with pH values outside the acceptable limits set by WHO. Total hardness and Cl were also not within the desirable level. Other parameters such as conductivity, NH_3-N, NO_3-N, Manganese (Mn), Fe, and PO_4 were found to be within the WHO standards. In general the physico-chemical quality of the drinking water was found to be acceptable.

Bacteriological quality of drinking water in rural areas nearer to the capital were similar. Joshi (1987) carried out bacteriological tests of drinking water sources of two villages of central Nepal: Chaubas (Shivapuri Watershed and Wildlife Reserve) and Syabru (Langtang National Park). He reported that pollution of drinking water was a problem in these villages. The coliform count ranged from 5 - 100 cells per 100 ml of water. Covered springs were less contaminated than uncovered springs. In Chaubas, water from covered springs showed

Table III: Bacteriological Quality of Drinking Water in Ilam

Location	Faecal Coliform (Cells/100 ml) Minimum	maximum
Phikal	0	1,400
Chhipitar	-	0
Pashupatinagar	20	114
Gurung Niwas	-	1,800
Karfok	-	50
Aitabare	77	2,400
Teenghare	-	1,100

Source: DISVI (1990b)

coliform contamination within the range of 5-10 cells/100 ml, whereas in Syabru water from uncovered springs showed contamination within the range of 20-100 cells/ml (Table IV).

GROUNDWATER POLLUTION

Groundwater quality has not been extensively studied in Nepal. Many village communities supplement their water demand with groundwater; others depend solely on this

Table IV: Total Coliform Contamination of Village Water Source

Village	Water Sources	Total Coliform/100 ml
Chaubas	Covered spring	5 - 10
	Surface pool	5 - 10
	Village tap	10 - 20
Syabru	Village tap	10 - 20
	Spring 1	20 - 30
	Spring 2	-100
	River	-100

Source: Joshi (1987).

source. Groundwater is extracted through bore holes and wells. In the Terai use of tubewells and dugwells is widespread in areas where there is no easy access to surface water.

Kathmandu

People in many areas of Kathmandu and Lalitpur use groundwater from open dugwells, tubewells, and stone spouts (*dhunge dhara*) for washing, drinking and ceremonial purposes. CEDA (1989) reported that 5 percent of Kathmandu's population regularly used water from dugwells and stone spouts. A. P. Sharma (1986) found that water from these sources was highly polluted with coliform bacteria counts from 0 to 460 per 100 ml during summer. Water from tubewells was more contaminated than that from open dugwells and water spouts.

The most polluted spout water was found at Dhobighat in Jawalakhel, Lalitpur. Groundwater in this area was found to be contaminated by the effluent discharge of the Jawalakhel Distillery. The coliform count in the distillery effluent and spout water was 4,800 per 100 ml. The open dugwell with the highest levels of pollution was at Hyumat in Kathmandu. It was noticed that the sewerage system in this locality was seriously overloaded, leading to groundwater contamination. Overall, no groundwater that supplied open dugwells, tubewells and water spouts was found to be suitable for drinking, a conclusion substantiated by Vaidya and Karmacharya (1986).

Bacteriological quality of groundwater in Kathmandu was also investigated by ENPHO/DISVI (1990). Samples were collected from stone spouts in 21 localities. Water from all the spouts was found to be faecally contaminated. The lowest average faecal coliform densities were observed in the samples from Bhatbhateni (8 cells/100 ml), Balajutar (1 cell/100 ml) and Sundhara (19 cell/100 ml). The highest densities were observed in the samples from Bhimsenthan (37,602 cells/100 ml) and Narayanhity (15,198 cells/100 ml). In all, 81 percent of the samples contained an average density of more than 100 cells/100 ml. In general, contamination was found to be higher in the rainy season (June - September) than in the dry season. This study confirmes that the groundwater from stone spouts in Kathmandu is not safe for drinking.

Terai Areas

Groundwater quality was assessed by DISVI (1990c) in seven rural areas of Morang, Sunsari, Jhapa, Siraha, and Saptari in the Eastern Development Region of Nepal. The study was conducted for UNICEF, and covered villages served by the Terai Tubewell Project: Baijnathpur, Takuwa and Bayarban in Morang, Shreepur Jabdi in Sunsari, Panchagaachhi in Jhapa, Bandipur in Siraha, and Naktiarpur in Saptari. A total of 164 samples were tested for chemical and bacteriological properties, 70 from iron removal plants of the project, 20 from non-project tubewells, 12 from non-project dugwells, and 39 from households.

The bacteriological quality of water from tubewells was found to be far better than that of water from dugwells. About 90 percent of the samples from project tubewells had less than 10 faecal coliform cells per 100 ml, 8 percent had 10-100 cells/100 ml, and only 2 percent had more than 100 cells/100 ml. Similar and comparatively low levels of water pollution were found in non-project tubewells.

Samples from dugwells were highly polluted. None of the samples collected from project dugwells had less than 10 faecal coliform cells per 100 ml, and about seven percent of samples had 10-100 cells/100 ml, while 93 percent had more than 100 cells/100 ml. All samples from non-project dugwells had more than 100 cells/100 ml. Water from households was generally more contaminated than at its source.

Several parameters were tested to determine the physico-chemical quality of water and most were within WHO standards for drinking water quality, except Fe, Mn, NO_3, and hardness. Fe and Mn are classified by WHO as constituents that may affect the aesthetic quality of drinking water, but are not of particular importance in terms of health. About 82 percent of Fe and Mn present in the water was removed by iron removal plants installed by the project. NO_3 can pose a threat to health, but only 3 percent of the samples collected from project tubewells and none of the samples collected from the other sources were above WHO guidelines.

SURFACE WATER POLLUTION

Drinking water comes mainly from streams, rivers, lakes and reservoirs. In addition rivers and other surface water bodies are important for recreation, irrigation, hydropower generation and fisheries. They play a fundamental role in the economic development of Nepal. Yet they are also the main repository for the nation's untreated sewage, solid waste and industrial effluent. As the population increases and human use of surface water courses and bodies intensifies, many of these uses become incompatible.

There are over 6,000 rivers in Nepal with an estimated total length of some 45,000 km (CBS, 1989). Economically, the most important rivers are the Koshi, Gandaki and Karnali. Other major rivers include the Kankai, Kamala, Bagmati, Tinau, West Rapti and Babai. Nepal has only a few small lakes; the best known and most intensively used is the man-made Phewa lake in Pokhara. The turbulent and rapidly flowing waters of Nepal's rivers and streams have considerable self cleansing abilities through mechanical and oxidation processes. But lakes and reservoirs are more static, with slower turnover of water, and are particularly prone to rapid degeneration in water quality.

Few studies have been conducted on surface water quality in Nepal and information on fresh water ecology is scattered and fragmentary. Nowhere is monitoring carried out on a systematic basis. The quality of the Bagmati river in the Kathmandu valley is now receiving the most consistent attention.

Bagmati River

While sewage and industrial wastes are the most visible causes of contamination along the Kathmandu section of the Bagmati river, nonpoint sources such as air pollutants, pesticides and fertilisers carried to the rivers by the rain and the soil washing process also contribute to contamination.

The Bagmati river is the largest river in the Kathmandu valley, covering a length exceeding 30 km. It is an important source of city water supply. Studies on the pollution of the Bagmati river have been conducted by Shrestha (1980), Upadhyaya and Roy (1982), Khadka (1983), Napit (1987), Pradhanang *et al* (1988b), Vaidya *et al* (1988), DISVI (1988), RONAST (1988a,b), Shrestha (1990), and Karmacharya (1990).

The most comprehensive of these studies was that conducted by DISVI, in cooperation with RONAST, in 1988. Water samples and biological samples were collected from seven sampling sites along the Bagmati river and from its three major tributaries. With assistance from RONAST, DISVI collected and analysed samples on alternate months from January to July. RONAST continued the study until September. Very similar studies were carried out by Shrestha (1990) and Karmacharya (1990).

DISVI classified the river into distinct zones according to water quality class as determined by the extended biotic index (EBI). The EBI indicates the degree of pollution of surface water using benthic invertebrates as indicators. The biotic index value of water quality is based on the known pollution tolerance of specific invertebrate species. Least polluted water is classified under class I, and most polluted as class V. Various chemical parameters such as COD, BOD, NH_3, PO_4, NO_3, Cl and conductivity have also been examined to determine the river water quality with similar results to those using the EBI. Table V summarises the findings of the various water quality studies on the Bagmati river system.

Table V: Water Quality of the Bagmati River System

Sample Site	Distance of Sample Site from Source	Water Quality Class (EBI)	Parameters Exceeding WHO Standard
BAGMATI RIVER			
Sundarijal	7 km	I	None
Gokarna	15 km	I	None
Pashupatinath	20 km	II	COD, PO_4
Thapathali	25 km	III	COD, NH_3, PO_4, and Conductivity
Sundarighat	28 km	V	All
Chobhar	31 km	Fluctuates	COD, NH_3, BOD
Khokana	35 km	III	COD, NH_3
TRIBUTARIES			
Manohara River, Phulbari		II	None
Dhobi Khola River, Baneswore		III	BOD, COD, NH_3, Cl, and Conductivity
Bishnumati River Kalimati		V-V	All

Source: DISVI (1988), RONAST (1988a), Shrestha (1990), Karmacharya (1990).

Chemical parameters including levels of detergents were found to increase downstream of Sundarijal, and then slightly decrease downstream of Chobhar. Bacteriological analysis showed high faecal coliform contamination of the river water at most of the sample sites. The diversity of macroinvertebrates was higher in the unpolluted zone of the river than in the polluted zone. Only a few taxa were reported present in the polluted zone.

The river water quality varied with seasonal variation. Pollution load was highest in summer, while it decreased in winter and during the rainy season.

Among the Bagmati river sampling sites, Sundarighat was the most polluted, and among the tributary sampling sites Bishnumati river at Kalimati was found to be the most polluted. Among the three important tributaries studied, the Manohara river contributed less pollution load to the Bagmati river than the Dhobi Khola and Bishnumati rivers.

In summary, the Bagmati river and its tributaries maintain good chemical and biological quality until they enter the urban areas. The destruction of the aquatic ecosystem at this point in the river is caused by the untreated sewage of Kathmandu and Patan entering the river, as well as the untreated wastewater discharge of industries. Industrial effluents are discharged by various small and medium sized industries directly into the river or its major tributaries.

The self purification capability of the Bagmati river is degenerating. The river has a high concentration of pollutants and now has a reduced number of organism groups 10 km downstream from Kathmandu, at the Khokana site.

In 1982, Upadhyaya and Roy studied chemical parameters in six rivers and rivulets — Dhobi Khola, Manohara, Nakhu Khola, Balkhu Khola, Bishnumati and Bagmati. A wide seasonal variation was noted in water chemistry. This is to be expected as the quantity of rain water discharged into the river varies with the seasons, the highest discharges being in the monsoon months from June to September.

The total dissolved solids (TDS) value (a significant pollution indicator) in Dhobi Khola was minimum in September and reached a maximum in May before the onset of the rains. As the Manohara river does not pass through the city, it was not polluted with industrial and municipal discharges. The TDS values for this river were comparatively lower than those for other sites. In the Nakhu Khola, where trucks, cars and domestic animals are washed, there was a sudden increase in specific conductance value, perhaps due to organic matter. The Balkhu Khola, Bishnumati and Bagmati rivers pass through the city and receive municipal discharges throughout the year. However, the values of water chemistry parameters in the rainy season were lower than those during the winter and summer seasons. This was due to increased water volume and dilution ratio. The Bagmati and Bishnumati had higher TDS values, specific conductance, and concentrations of Na, K and Cl.

CEDA (1989) found the level of total coliform and faecal coliform in the Bagmati, Bishnumati and Dhobi Khola rivers to be a staggering 720,000 cells/100 ml in each case. Of the chemical parameters tested, only the Cl value in each river proved to be higher than the WHO standard. Dissolved oxygen (DO) in the Bagmati and Bishnumati rivers was slightly lower than the desired level of 6 mg/l which suggests that at times of low flow these rivers may be susceptible to eutrophication or anaerobic conditions. Water tested from the Dhobi Khola had a chromium (Cr) level of 0.10 mg/l, probably due to the discharge of Bansbari tannery effluent into the river. However, it was not known whether Cr was non-toxic trivalent or highly toxic hexavalent.

Shrestha (1990) tested water samples from the Bagmati river for organic pollution. As with the DISVI and RONAST study of 1988, he found that the river had definite zones of pollution depending on proximity to urban areas and industry. The Bagmati was classified into six zones — a healthy zone, moderate upstream pollution zone, polluted zone, moderate downstream pollution zone, recovery zone, and clean zone.

The pollutants were classified into four groups: inert inorganic material, putrisible wastes, toxic wastes or biocides, and sewage effluents. The chief sources of pollution were identified as domestic wastes; garbage; faecal matter; finely divided organic matter in suspension; detergents; acid, alkalies and salts from hospitals, laboratories, tanneries and distilleries; and petroleum products from laundries and automobile workshops.

Approximately 50 percent of these pollutants were found to be discharged into the Bagmati river by two very polluted feeder streams — the Dhobi Khola and Tukucha. These streams were so polluted that, in 1983, the Royal Drugs Research Laboratory of His Majesty's Government (HMG) was said to have refused to test the water from Dhobi Khola rivulet for fear that the equipment would be damaged by the heavily polluted samples (Sharma, 1986; Himal, 1987).

The impact of toxic substances on fish in the Bagmati river is dramatic. Dead fish collected during early spring and late monsoon showed some morbid changes in gills, scales and intestines. High fish mortality occurs every year in the Bagmati river over the months of July and August. One of the causes of this massive mortality rate is the very low level of DO, approximately 2 to 3.5 mg/l (Shrestha, 1980).

Direct human activity in the river also increases pollution. In 1983, Khadka studied major ions in the Bagmati river near Pashupatinath Temple on the day of Mahashivaratri festival and found that the concentration of major ions, especially Na and Cl, was higher in samples collected downstream of the temple than upstream. The ion imbalance resulted from many people bathing in the Bagmati at the temple site during the festival.

Napit (1988) also investigated pollution of the Bagmati river in Pashupati area. He found that physical characteristics such as colour, turbidity and suspended particles exceeded desirable levels. However, the chemical parameters tested did not exceed the WHO standards. Pradhananga *et al* (1988b) tested water samples of the Bagmati river at different sites in the Pashupati area and found parameters such as pH, conductivity, DO, PO_4, and NH_3-N within the permissible value for water supply, fisheries and industry. However, the values for suspended solids and BOD exceeded WHO standards. Vaidya *et al* (1988) investigated pollution of the Bagmati river in the Pashupati area on the basis of a diversity index for macro-invertebrate fauna and found the level of pollution rising from low at upstream sites to moderate and high at downstream sites. The higher population of pollution-tolerant species in each sampling site during the month of May to August indicated that the pollution level increased in summer. They speculated that the high degree of pollution could be due to municipal discharge and agricultural runoff.

Phewa Lake

In 1990, Rana assessed water pollution in Phewa lake at Pokhara. The Phewa lake is a multipurpose reservoir for recreation, irrigation, hydropower generation, fisheries, washing, drinking and waste disposal.

The main contributors to the pollution load of Phewa lake have been sewage discharge from households and small hotels situated in the lake periphery and surface runoff, from both urban and agricultural areas within the lake catchment. The study showed that the lake water quality was deteriorating due to the large quantity of nutrients received from point and non-point sources and through sedimentation, leading to the growth of algae and rooted plants. Average phosphorus (0.122 mg/l) and nitrogen (0.71 mg/l) concentrations were particularly high. It was estimated that the lake retained 38 percent of total phosphorus (130 kg/day) and 78 percent of ortho phosphorus (28 kg/day) of the daily inflow. The annual phosphorus loading for the lake was calculated at 14 tonnes. BOD and COD were found to be higher in the bottom lake strata than in surface waters. Total coliform and faecal coliform counts in tributaries flowing into the lake were high (at 17,000 and 900 cells/100 ml, respectively). Fe and Mn concentration were found to be 8 and 1 mg/l respectively, which also exceeded WHO drinking water quality standards.

The relationship of land-use to water quality was difficult to assess, but it was concluded that the impact of non-point sources of pollution was greater than for point sources. Agricultural land, which occupied 50 percent of the catchment area, was thought to be the primary source of nutrients and sediment in the lake.

Impact of Industrial Effluent on Surface Water

Kathmandu Valley

The major industries discharging effluents into rivers in Kathmandu are the Bansbari Tannery, Balaju Industrial District (BID), carpet factories, the Jawalakhel Distillery, Patan Industrial District (PID) and the Himal Cement Factory. Various studies have examined the different chemical and bacteriological content of the effluents of these industries.

Sharma and Rijal (1988) carried out a study of microbial and chemical pollution of the Bagmati river, Bishnumati river, and Dhobi Khola. The quality of effluents from Bansbari Leather and Shoe Factory, Balaju Industrial District, carpet factories of Bouddha, and Jawalakhel Distillery were tested. In addition, water samples were collected from the receiving stream at the mixing zone, and 200 meters downstream of that point. The samples were analysed for bacteria, fungi and a range of other water quality indicators. Samples were taken during the summer season and again during the rainy season to assess seasonal variations.

The sampled effluents and river water were found to be biologically and chemically polluted to a high degree. Water quality of receiving streams was generally worse during the summer than during the rainy season due to the lower dilution rate. As expected, water quality improved for most parameters going from the discharge point to the downstream sampling point. Effluent from the tannery and carpet factories had the lowest dissolved oxygen (DO) levels, and was anaerobic during the summer season. Nitrite (NO_2) concentrations were highest in distillery effluent while COD was highest in effluent from the tannery and carpet factories.

In related studies the effluents of the Bansbari Tannery, the Jawalakhel Distillery, BID, carpet factories and Patan Industrial District were studied by A. P. Sharma (1986) and then by CEDA (1989) which confirmed his findings.

Industrial effluents and domestic sewage play a significant role in water pollution. Since small to medium sized industries are not equipped with pollution control measures, their effluents are discharged untreated into rivers. The pollution of Dhobi Khola, through the effluent discharge of the Bansbari Tannery, is so high that farmers in the area have stopped using the water for irrigation.

The tannery wastewater is discharged at different production stages which require considerable amounts of water. Khadka *et al* (1981), Sharma (1987) and Miyoshi (1987) analysed water samples from Dhobi Khola to record physical, chemical and biological quality. The composite effluent of Bansbari Tannery effluent consists of a high amount of Cr, salt, suspended solids, and high BOD value (EISP, 1987). Even if the BOD value of the effluent were not so high, the organic matter discharged would undergo bio-degradation, thereby depleting oxygen and threatening the survival of aquatic life. The alkaline effluent inhibits the photosynthetic activity of aquatic plants.

A high pollution load was noted just below the effluent discharge site, and significant dilution occurred as it reached the Dhobi Khola. The Bansbari Tannery's effluent volume was 240

m^3/day, and the concentration of pollutants was very high (Miyoshi, 1987).

Miyoshi (1987) measured the levels of different parameters in domestic sewage at three places in Kathmandu — Bouddha, Balaju and Kalimati. In all cases, the number of total coliform was 4,800 cells/100 ml. The level of DO was very low in all cases, and at no point higher than 1 mg/l. The BOD and COD values were highest for Kalimati sewage, at 582 mg/l and 250 mg/l respectively.

In 1983, Forestry Services examined the effluent of the Himal Cement Factory and pollution parameters of the Bagmati river. The factory effluent contained heavy metals such as lead (Pb), mercury (Hg) and Cr, as well as dissolved solids. The values for Pb and Cr in the effluent and in river water were 0.2 mg/l and 0.1 mg/l respectively. These metals are known to concentrate in plants and animals.

Narayani and Orahi Rivers

RONAST (1987) and Pradhananga *et al* (1988a) analysed samples collected at different sites of the Narayani and Orahi rivers to examine the impact of paper mill effluents on the local biotic systems. The pollution caused by effluents of the Bhrikuti and Everest Paper Mill was high at some points along the course of rivers, especially at the zone of active decomposition and the initial zone of mixing. The pollution was more severe in the Orahi river, due to its low dilution ratio. In the case of the Narayani river, the water 15 km downstream of the initial mixing zone returned to almost normal quality.

The Bhrikuti Paper Mill is located on the Narayani river, at Gaindakot in Nawalparasi district, about 90 km southwest of Kathmandu. The effluents of this factory are discharged directly into the river which flows barely 500 meters away from the mill. The Narayani river is considered to be the habitat of endangered species such as Dolphin, Gharial and Mugger. The river also flows by the Royal Chitwan National Park, which is listed as a World Heritage Site and is a rich habitat for a wide variety of terrestrial and aquatic flora and fauna. The local people use its water for drinking, washing and irrigation purposes.

The Everest Paper Mill is situated on the Orahi river, at Mahendra Nagar in Dhanusha District, approximately 110 km southeast of Kathmandu. The effluent of this mill enters into a pool in a nearby field and is then discharged into the river which is 300 meters away from the mill. The Orahi is a small river.

These paper mills discharge their effluents directly into the river system without any treatment (RONAST, 1987; Pradhananga *et al*, 1988b). Public concern has been growing over the pollution, especially that caused by effluents of the Bhrikuti Paper Mill. Some preliminary studies had been conducted by Bhattarai *et al* (1986) and ISC (1984).

Pradhananga *et al* studied water samples taken from upstream, the effluent mixing zone, and downstream, as well as effluent samples from both paper mills. Physical properties such as temperature, colour, and flow rate were noted and various chemical properties were analysed. Biological samples comprising phytoplankton, zooplankton, algae, invertebrates and fishes were collected, as appropriate.

Considerable change in colour and odour was observed between the upstream and downstream water of the Orahi river. The magnitude of temperature increase due to effluent discharge in both mills was well within the specified standard.

The discharge rate of the Bhrikuti Paper Mill effluent, as measured by Bhattarai *et al* (1986), was 0.25 m^3/s which is very low compared with the high mean monthly flow of the Narayani river, in the range of 790 to 4,970 m^3/s. There is a high dilution ratio leaving little possibility for significant pollution effects. The situation is very different in the case of the Everest Paper Mill effluent and the Orahi river. The discharge rate of mill effluent was 0.112 m^3/s, while the average monthly flow of the Orahi is only 0.179 m^3/s. The dilution ratio is only 1:1.6, and there is no thorough mixing of effluent and river water, as shown in the difference of pH values at opposite banks.

Values for suspended solids in both rivers were within acceptable limits, ranging between 17 to 21 mg/l, as was the case for silicon dioxide (SiO_2), Ca, magnesium (Mg) and Na. However, the value for iron ion concentration in Orahi river water exceeded the standard specification following mixing with factory effluent. The values for copper (Cu), silver (Ag), lead (Pb) and zinc (Zn) were less than 0.2 mg/l and hence within the standard value. There were no significant differences in DO values between upstream and downstream waters of either river.

The COD value of Narayani river water 1.5 km downstream was 40 mg/l, which is a maximum threshold limit for river water as specified by the European Economic Community (EEC). COD for the Orahi river, however, exceeded the maximum level up to 3 km downstream. The COD values of the effluents of both the paper mills far exceeded the standard specifications of the EEC (160 mg/l) and the Nepal Bureau of Standards and Metrology of HMG (250 mg/l) (Pradhananga *et al*, 1988 b).

The BOD values, which were very high for effluents from both mills, far exceeded standard limits set by EEC (40 mg/l) and Nepal (30-100 mg/l) (Pradhananga *et al*, 1988b). The BOD value for Bhrikuti Paper Mill effluent was 918 mg/l whereas that for the river water upstream was 1.5 mg/l with 10 mg/l downstream due to the high dilution ratio. Such was not the case for the Orahi river. Water upstream of the Everest Paper Mill had a BOD value of 1.6 mg/l. Mill effluent was 180 mg/l while downstream water BOD remained high at 70.2 mg/l, due to the low dilution ratio.

Certain biological parameters were also studied in both the rivers. In the upstream waters, pollution-sensitive algae species were abundant and species diversity was high. At the initial zone of mixing in both rivers, pollution-tolerant species were growing extensively and species diversity decreased substantially. Pollution-tolerant invertebrates were present in low diversity at this zone, along with larvae of *Eristalis* spp and *Simulium* spp; both of these species are excellent indicators of high pollution, and were abundantly present. The downstream waters of the Narayani river, unlike those of the Orahi river, recovered their original quality.

The water quality studies of the Narayani and Orahi rivers found high levels of pollution at some points along the course of the rivers due to the paper mills, especially at the zone of active decomposition and initial zone of mixing. The extent of pollution was severe in the Orahi due to the river's low dilution rate. The studies did not examine the effects of pollution on the aquatic food chain in either of the rivers. The impact of pollution on higher vertebrates including endangered species such as Gangetic Dolphins, Gharial and Mugger which the Narayani river is known to harbour, was not assessed.

CEDA (1989) analysed industrial effluents in Pokhara and Biratnagar. The levels of organic pollutants were particularly high. In each case the number of total coliform and faecal coliform reached 4,800 cells/100 ml, and the value for DO was far below the desired level. The BOD and COD values were almost always extremely high, at 610 and 880 mg/l respectively in the Pokhara Industrial District effluent; 988 and 1,480 mg/l respectively in the effluent of Raghupati Jute Mill, Biratnagar; and 28 and 43 mg/l respectively in Goloha Iron Industry effluent, Biratnagar. The iron concentration in effluent from the iron industry in Biratnagar was 82.50 mg/l. Effluents of the Raghupati Jute Mill and Goloha Iron Industry in Biratnagar were highly acidic, with pH values as low as 2.7 and 3.3, respectively. These results show that industrial effluents in Pokhara and Biratnagar have high pollution potential. The water quality of the receiving water bodies was not tested.

EISP (1987) studied the river water pollution caused by effluents discharged by Nepal Leather and Tanning Industry in Birgunj and

Nepal Leather Industry in Bhairhawa, as well as that caused by the Bansbari Tannery in Kathmandu.

The Birgunj tannery discharges its effluents without any treatment directly into the Sirsiya river via a small irrigation canal called *paini*. The Bhairhawa tannery discharges its untreated effluent directly into the Ghagra river.

The pollution load of the Birgunj tannery effluent was less than that of the Bansbari tannery, but this may be due to sampling at a time when the tanning process was not complete. The waste water, however, did not meet the environmental quality standards proposed for Nepal for inland waters (EISP, 1987) (Annex II).

The Bhairhawa tannery was found to contain 1,780 mg/l of total dissolved solids and 800 mg/l of total suspended solids. The wastewater also contained a high amount of heavy metals such as arsenic (As) (Kunwar, 1985). The local people have stopped using the effluent mixed river water for drinking purposes.

The Nepal Bureau of Standards and Metrology of His Majesty's Government has proposed tolerance limits for inland surface waters receiving industrial effluents, as listed in Annex II.

AIR POLLUTION

In contrast to the wealth of data available in developed countries on air pollution, no systematic monitoring has been undertaken to examine the situation in Nepal. The lack of air pollution information conceals a significant public health problem, and hampers development of control measures.

In 1990, the World Resources Institute (WRI) estimated Nepal's contribution to the global greenhouse effect through the emission of CO_2 (expressed in terms of total carbon content), methane (CH_4), and chlorofluorocarbons (CFCs). WRI reported that, in 1987, Nepal's anthropogenic additions to the CO_2 flux included 14,000 tonnes of carbon from cement production, 62,000 t of carbon from combustion of solid fossil fuels, 150,000 t of carbon from combustion of liquid fossil fuels, and 6.7 million tonnes of carbon from annual land use change, totalling 6.9 million tonnes of carbon. Destruction of forests by flaring and combustion of fuel gas made a negligible contribution. The per capita contribution in that year was 0.4 t of carbon, which is very low when compared to the average Asian per capita contribution of 0.8 t, European per capita of 2.4 t, North and Central American per capita of 3.8 t, and South American per capita of 5.8 t.

Nepal's per capita addition to the methane (CH_4) flux (0.07 t) was, however, more than the average Asian (0.04 t), European and African contributions and equal to the average South American contribution. The total CH_4 emission for Nepal included 38,000 t from solid waste, 490,000 t from livestock and 660,000 t from wet rice.

The extent to which Nepal is adding CO_2 and CFC to the atmosphere is virtually negligible and likely to remain so for a long time (Banskota *et al*, 1990). However, emissions of CH_4 from the agricultural sector are significant.

Localised sources of air pollution in Nepal include combustion of fossil fuels, vehicular exhausts, industrial emissions, unmanaged solid wastes, and burning of biomass with resulting smoke emission. In Nepal, industries and automobiles are significant contributors to air pollution in urban areas, while in rural areas the principle source is domestic burning of plant material for cooking and heating.

Suspended particulate matter and gaseous chemicals are the main forms of air pollution and are potential health and ecological hazards. Particulates consist of fine solids, or liquid droplets suspended in air which are collectively called suspended particulate matter (SPM). The larger sized particulates are grit, dust, soot and fly ash, and the smaller sized are smoke, fumes, mist and aerosols. Gaseous emissions from combustion of fossil fuels are dangerous air pollutants. Incomplete combustion of fossil fuels such as petrol, diesel, kerosene, and coal produce large amounts of carbon monoxide

(CO), sulphur dioxide (SO_2), oxides of nitrogen (NO_x), unburned hydrocarbon, and tar droplets. In addition, lead is released into the atmosphere through the use in Nepal of petrol with a high lead content.

Industrial emissions which contain SO_2, CO, Hg, cadmium (Cd), and arsenic (As) are serious air pollutants. In addition, the decomposition of unmanaged solid wastes emits hydrogen sulphide (H_2S) and airborne pathogens which create a health and aesthetic hazard. Open air defecation due to limited toilet facilities and hygiene awareness aggravates this situation. ADB (1985) noted that there was no data on rural sanitation practices in Nepal but defecating in open air situations was the norm.

Pollutants emitted from combustion of biomass fuels used for cooking and heating in rural households of Nepal pose serious health hazards. Poorly ventilated households intensify the effects of these emissions. Many lung and eye diseases among Nepalese women are ascribed to indoor pollution.

General air pollution is noticeable in Nepal in the late spring and early summer months at which time a haze formation results through a combination of wind-blown dust and the smoke of many grass and forest fires in both lowland and midland Nepal. The Kathmandu valley is especially vulnerable to air pollution due to its bowl-like topography, dense population, valley centric industrial development and relatively large number of automobiles (Fleming, Jr., 1977). The bowl-like topography restricts wind movement and retains the pollutants in the atmosphere, especially during periods of thermal inversion over Kathmandu where cold air flowing down from the mountains is trapped under a layer of warmer air which acts like a lid over a bowl. Improperly placed factories could contribute significantly to air pollution in Kathmandu and the incidence of respiratory illness among valley residents.

INDUSTRIAL EMISSIONS

The main sources of air pollutants from the industrial sector are the combustion of fossil fuels for heating and power, and waste gases and dust from industrial processes and sites. The burning of fuels produces heat energy and gaseous and particulate waste products. When combustion is complete the main gaseous product is CO_2, but in the event of incomplete combustion and oxidation, more harmful CO is produced in addition to hydrocarbons. Fossil fuels also contain 0.5 - 4.0 percent of sulphur, which is oxidised to SO_2 during combustion.

Many industrial manufacturing processes are also potential sources of other toxic gases, heavy metals and complex organic compounds which may have carcinogenic effects. The industrial plants that appear to be the major sources of pollution include iron and steel foundries, coking ovens, pulp and paper mills, chemical plants and cement works (Dix, 1981).

Although the level of industrialisation is still low in Nepal, localised air pollution problems have become significant. Moreover, the number of manufacturing industries is on the rise. In the 20 years to 1986/87, the number of industrial establishments increased by seven times to 9,359, primarily in the Eastern, Central and Western Development Regions (CBS, 1989).

A few studies have been undertaken to examine industrial emissions, but they do not provide a consistent quality of information. Lack of appropriate instruments and laboratory facilities was a major constraint to those studies. Additionally, in the absence of national standards on industrial emissions and ambient air quality, the study results assumed less than desired significance. One study suggested that U.S. ambient air quality standards, as listed in Annex III, may be followed for the time being.

In 1983, a study by Forestry Services reported that no capacity existed in Nepal for sampling and analysis of the chemical composition of ambient air and emitted gases. The assessment of air quality was therefore conducted by interview. The two largest industries in Kathmandu (Himal Cement Factory, Bansbari Leather and Shoe Factory) and various brick and tile factories were selected as case studies.

The Industrial Services Centre (now renamed Economic Services Centre - ESEC) conducted a survey in 1987 and covered industries in various parts of the country. The industries selected for the study included cement, leather tanning, pulp and paper, sugar, distillery and textiles. In the same year Miyoshi reported to ESEC on various aspects of industrial pollution control including some information on emissions from various industries within and outside Kathmandu. Miyoshi's report did not give much information on the methodology of the study. Although several types of industries were covered by his studies, the information presented in his report is limited. The industries studied were textile, steel, food and beverage, cement, pulp and paper, leather tanning, brick and tile, and chemical.

Cement Industry

The major air pollutants of the cement industry are particulates and gaseous wastes such as SO_2, CO and NO_x which are emitted from chimneys or smokestacks. Dust from the limestone mines, coal yards and cement clinkers is emitted into the air, together with dust from various processes such as crushing and clinkerisation. Dust emitted generally contains carbonate, silicate, aluminate, fluoride and alkalihalide. Higher amounts of silica and alkalihalide will be present in the dust if low grade limestone is used.

The Himal Cement Factory at Chobhar near Kirtipur in the Kathmandu valley has attracted considerable public attention for its dust emissions which at times can be seen from any point in the valley. Commissioned in 1974, the company has expanded its production capacity from 160 to 400 tonnes of clinker per day. Limestone required for this factory comes from the limestone deposits in the Chobhar hills. ISC (1987) reported that the flue gas emitted from the cement kiln before the factory's expansion contained various gaseous compounds, including NO (200 ppm), NO_2 (30 ppm), and SO_2 (5 ppm). Carbon dioxide (CO_2) formed 16 percent of the flue gas and CO, 2.6 percent. Emissions of NO_x and SO_2 were within international standards but the dust emission was high even from the new kiln. Miyoshi (1987) also reported that the emission of NO_x and SO_2 was low.

Dust was also emitted from the limestone crusher, saw mill, raw material storage yard and limestone excavation processes. These emissions have not been measured, but the factory plans to install the equipment needed to reduce the amount of dust emitted into the air.

According to the Forestry Services 1983 study, Himal Cement's two vertical shaft kilns and a rotary kiln together produced five to six tonnes of dust every 24 hours. Of this, about 1.25 tonnes were particles less than 10 mm in size, and as such can remain suspended in the air. Such smaller sized particles are responsible for many respiratory diseases.

No meteorological parameters such as wind speed and direction, vertical temperature gradient and flux were available to the 1983 study, and thus dispersal rates and areas could not be calculated. There was no stack sampling or monitoring of emissions. However, a reconnaissance survey of the area surrounding the factory revealed very heavy dustfall within a 300 m radius from the base of the stack. *Himal* (1987) reported that depending on the wind conditions, Chobhar village near the factory and Sanga village across the Bagmati river were enveloped in dust. Miyoshi (1987) confirmed that everything near the factory was covered with dust and looked whitish grey. The lack of adequate dust collectors was cited as the reason for high dust emission.

According to some observers Himal Cement's silica dust, ash and smoke do not remain restricted to the immediate environs and villages, but spread in a thin haze throughout the valley. These emissions have affected the health of the factory workers as well as inhabitants of surrounding villages (*Himal*, 1987).

Another major cement factory is Hetauda Cement Industries. Established in 1985 with a production capacity of 750 tonnes of clinker per day, this factory is located about 3 km south-west of Hetauda town at Lamaure. The production process of the factory is based on rotary kiln technology. ISC (1987) reported that the flue gas emitted by the factory was composed of 18 percent CO_2, and only 0.1 percent CO. The amount of NO_x was 150 ppm and SO_x was 50 ppm. This composition of flue gas is within international emission standards. This is due to the fact that an electrostatic precipitator (ESP) has been installed in the kiln. However, the ISC report states that the ESP could reduce emissions even more if it were functioning properly. Miyoshi (1987) reported that almost all dust was emitted from the factory stack when the ESP stopped functioning. It was reported that malfunctioning of the ESP occurred frequently.

The factory also installed dust filters in every station to control dust concentrations in the exhaust so that the collected dust is recirculated in the process. These dust filters were installed in all the dust emitting sections, from the raw material handling section to the packaging sections.

Four cement plants are in operation in Central Nepal, two of which are large-scale. Uprety (1988) investigated these four cement factories and reported that the dust emitted from these factories was seriously affecting the health of local people as well as the factory workers. This was true despite the installation of pollution control equipment and provision of pollution control measures to the workers in all but one case. It was estimated that the Hetauda Cement Factory emitted dust equivalent to 6 tonnes of cement per day, and the Himal Cement Factory the equivalent of 400 tonnes of cement each year (*Himal*, 1987; Uprety, 1988). The Triveni Cement Factory lacked pollution control equipment and was located adjacent to a village, posing a serious public health hazard.

Leather Tanning Industry

Steam is required at many stages of the leather tanning process, and is generated by burning steam coal and oil as fuels. This combustion results in the emission of gases such as SO_x, NO_x, CO and CO_2. These emissions are generally low.

According to Forestry Services (1983), Bansbari Leather and Shoe Factory in Kathmandu consumed only 150 tonnes of fuel per year and had no significant emissions of gaseous pollutants. Miyoshi (1987) confirmed this view and reported that the amount of SO_2 emitted by the operation of two boilers was 55 to 100 ppm. A strong, offensive odour, however, prevailed in the open air yard where the solid wastes of the factory such as pelts and flesh are dumped. The odour was severe within an area at least 500 m downwind of the factory, and was strongest in the rainy season. The areas downwind were unsuitable for residential purposes as the stench from the dumping yard was strong enough to cause nausea and vomiting. The Forestry Services report recommends that a burial practice be adopted or that the wastes be used for other purposes.

Brick Factories

There are two large, modern brick factories in the Kathmandu valley: one at Harisiddhi in Lalitpur, and the other at Bhaktapur. In addition, there are approximately two hundred brick kiln chimneys throughout the valley, particularly in Bafal area in Kathmandu, and in Harisiddhi.

The burning of coal and fuelwood in brick kilns releases a complex mixture of gases and particulates, the most hazardous being SO_2. Yet the Forestry Services 1983 survey of crops in areas surrounding the large factories did not reveal any signs of crop injury due to SO_2. Miyoshi (1987) concluded that as Harisiddhi Brick Factory's stack was tall (65 m) and facilitated a well dispersed dust fall, it was not environmentally significant. The quantity of dust particles emitted by brick and tile factories was not as high as for cement factories but the cumulative effects of so many kilns throughout the valley needs to be assessed. Miyoshi (1987) emphasised the need to estimate the exhaust gas volume. ADB (1990) indicated that the amount of smoke from brick kilns is rapidly increasing, especially in Kathmandu valley.

Bhattarai (1990) surveyed brick kilns of the Kathmandu valley area and reported that brick kilns were markedly contributing to air pollution in the valley. Firewood, coal and lignite are used as fuel at a typical kiln. This process releases SO_2, NO_x, and carbon and dust particles to the atmosphere. These emissions contribute to the smog in the valley which is evident during thermal inversions.

Pulp and Paper Industry

The pulp and paper industry uses coal and heavy oil as fuel at various stages of the manufacturing process. Coal is used to produce steam for cooking pulp and drying paper, and heavy oil is used for generating electricity. The chimney exhaust contains gases such as SO_x, NO_x, CO, CO_2 and particulate matter. The steam that escapes has an offensive odour.

Two large paper mills are in operation in Nepal: the Bhrikuti Paper Mill in Gaindakot, Nawalparasi, and the Everest Paper Mill in Mahendranagar near Janakpur, Dhanusha. Although water pollution caused by these mills has been studied in detail, the extent of air pollution due to smoke stack emission has yet to be examined.

ISC completed a study of the Bhrikuti Paper Mill in 1984. Situated on the Narayani river, this mill has a production capacity of 10 tonnes of writing and printing paper per day. Studies have yet to be conducted of the composition of chimney exhaust gases. Miyoshi (1987) reported that gases such as SO_2 and NO_x, as well as soot particles were emitted by operation of the boiler, but did not consider that the emission was causing significant adverse impact on the environment.

According to the ISC report, the mill had adopted appropriate measures for controlling air pollution. The dust collection chamber trapped the dust and foreign material emitted when *Sabai* grass and wheat straw were handled. The coke collecting equipment screened the smoke of burnt coal in the boiler house. The smoke emitted was thus assumed to contain no ash or small particles of unburnt coke. The tall 30 m high chimney would further reduce the emission of particulate matter. The mill's steam recovery system did not allow steam to escape, reducing the potential for the emissions of bad odours.

No studies have been carried out on the air quality effects of the Everest Paper Mill.

Sugar Mills and Distilleries

Sugar mills burn bagasse as boiler fuel. The black smoke or fly ash from the boiler chimneys contains gaseous chemicals such as SO_x, NO_x, CO and CO_2. Molasses, a useful by-product of sugar mills, give off an offensive odour if improperly stored.

Five sugar mills are operating in Nepal, along with about seven *khandsari* mills (which produce jaggery and sugarcane products).

ISC (1987) reported that the Birgunj Sugar Mill and Distillery, which is located very near the residential areas of Birgunj, had not installed any equipment for controlling air pollution. No analysis had been undertaken of the emitted gases and particulates.

Distilleries contribute to air pollution as they also burn coal, bagasse, wood and sal seed coke as boiler fuel, producing SO_x, NO_x and CO_2. In addition, a large volume of CO_2 is emitted as a result of the fermentation process. After making a brief study of nine food and beverage processing industries including sugar mills and distilleries, a dairy factory, soft drink bottling plant, vegetable ghee factory, noodles factory and biscuit factory, Miyoshi (1987) concluded that while pollution caused by these industries required urgent attention, their air pollution effects, in terms of SO_2 and NO_x emissions, were not significant.

Textile Mills

Fine dust is produced at various stages in textile mill operation, especially when weaving yarn into cloth which is a high speed, mechanical operation. Finely divided lint is present in the dust emitted in the vicinity of the mills, probably presenting a health hazard to workers, specifically respiratory disorders. Additionally, the boiler operation releases smoke into the atmosphere.

The country has two large, modern textile mills, one at Hetauda and the other at Balaju in Kathmandu. The ISC report states that these mills emit cotton dust into the factory premises. Miyoshi (1987) briefly surveyed the pollutants emitted by the operation of boilers at textile mills at Balaju and Hetauda, and Nepal Synthetic Industries and Raj Kamal Spinning Mills at Balaju. He found that although SO_2, NO_x and dust were emitted, the amounts were too small to cause concern. Also, except at Hetauda, fuel consumption was small and the quality high, with sulphur content less than 0.4 percent in the fuel oil used at Hetauda.

Chemical Industry

Miyoshi (1987) also studied several chemical industries within and outside of Kathmandu valley to examine the pollutants emitted by boilers or furnaces. The industries surveyed manufactured polythene, soap, paints, lubricating oil, wood products, matches, and batteries. He concluded that emission of SO_2, NO_x and dust was not significant.

Steel Industry

Miyoshi (1987) reported on the steel mills at Simra near Birgunj which use fossil fuels for furnace and boiler operation. The amount of oil consumed was small, ranging from 1.85 to 5.2 kl/day and once again he considered that emission from these factories was not significant.

AUTOMOTIVE VEHICLES

The rapid increase in motor vehicles during the last forty years in Nepal has led to serious adverse consequences for public health and the environment.

The number of vehicles in Kathmandu alone has quadrupled over the past decade (*Himal*, 1987). By February 1987, 13,460 cars and jeeps; 6,150 motorcycles; 4,510 buses, trucks and minibuses; 900 power tillers and tractors; and 620 autorickshaws were registered in Kathmandu — a total of 25,640 internal combustion engine vehicles. Elsewhere in the country, the number of vehicles registered during the fiscal years 1978/79 to 1987/88 is 2,872 buses, 4,759 trucks, and 10,574 jeeps and cars, totalling 18,178 motor vehicles (CBS, 1989). Many of these vehicles are badly maintained, thus emitting more carbon, sulphur and lead than normal.

Regular monitoring of vehicular exhausts in the country has not yet been carried out. Dhamala (1983), however, estimated the amount of gaseous compounds emitted by road vehicles into the atmosphere of Kathmandu valley, on the basis of a similar estimation in the United States by Ehrlich and Ehrlich (1972). The 30,000 vehicles operating in Kathmandu valley at that time contributed to the pollution level in the valley's atmosphere as follows:

Carbon monoxide (CO)	-	22,000 tonnes/year
Nitrogen oxides (NOx)	-	2,000 tonnes/year
Hydrocarbons	-	400 tonnes/year
Sulphur oxides (SOx) & particulates	-	333 tonnes/year

Furthermore, it was estimated that 67,500 liters of NO_x were emitted by vehicles every minute. It was noted that the circulation of air in the Kathmandu valley was not sufficient to effectively dilute and disperse the NO_x.

Gaseous emissions from vehicles in Kathmandu city can be estimated on the basis of figures for Bombay. Phatak and Warade (1987) reported that about 1,800 tonnes of pollutants were released into Bombay's atmosphere every day, and more than 50 percent of the pollutant load was contributed by 400,000 motor vehicles. Nine hundred tonnes of various air pollutants from this source entered the atmosphere each day. In 1987, Kathmandu city's 25,000 motor vehicles alone emitted more than 20,000 tonnes of various pollutants into the atmosphere every year.

The situation is rapidly deteriorating. About 40,000 tonnes of air pollutants are emitted every year. The number of vehicles in the Kathmandu valley is expected to double by the year 2010 (ADB, 1990).

The primary pollutants in vehicle emissions, particularly NO_2 and hydrocarbons, undergo a series of complex chemical reactions in the presence of sunlight to form secondary pollutants such as peroxyacetyl nitrate (PAN) and ozone (O_3). In areas of relatively high traffic density and atmospheric thermal inversion, such as Kathmandu valley, photochemical smog can be readily formed. Such smog consists of a mixture of primary and secondary pollutants, particularly PAN and ozone. Those pollutants are hazardous to health, cause deterioration in manufactured products and buildings and contribute to global warming.

Apparently the quality of gasoline and diesel entering Nepal is poor, adding to the air pollution problem. *Himal* (1987) reported that diesel available in Nepal contained a carbon residue which was 2 percent by weight, while in Japanese diesel this residue amounted to only 0.01 percent. Nepal's diesel is processed at the old Barauni refinery in Bihar, India. Worldwide, motor vehicles account for over 90 percent of the CO emissions in urban areas (Walsh and Karlsson, 1990).

Gasoline used in Nepal is of low octane and high lead content. High octane rating promotes thorough combustion with little carbon exhaust. While Nepal does import gasoline with a high 2.93 octane value, the gasoline available for public consumption has an octane value of only 1.87. Several compounds such as tetraethyl lead, ethylene dichloride and ethylene dibromide are added to the gasoline to improve octane quality. The combustion of low octane gasoline emits Pb into the atmosphere in the form of inorganic lead aerosol, which is inhaled by humans, and settles on soil and water. Food sold in the open air along city roads has also been found to contain high levels of Pb (UNEP/UNICEF, 1990). Walsh and Karlsson (1990) reported that approximately 90 percent of Pb in urban air came from combustion of petrol in motor vehicles. Widespread presence of Pb in the environment presents a significant health risk. Lead scavengers like ethylene dichloride and ethylene dibromide are also added to petrol to clear engines of lead. These lead scavengers have been identified as potential human carcinogens.

Bhattarai and Shrestha (1982) studied the Pb content of the dust of Kathmandu city roads. A direct correlation was found between heavy vehicular traffic and lead content in the dust from these roads, as shown in Table VI.

Although Bhattarai and Shrestha made no measurements of airborne Pb, their study showed that settled Pb particles were in high concentration. Lead is toxic to the human body in quite small concentrations. The WHO limit for lead in drinking water is 0.05 ppm. Maximum blood lead levels have been set at 0.7 ppm (Dix, 1981). Excessive lead in the body can cause weakness, lack of muscular coordination, miscarriage, anaemia, and damage to the nervous system and the kidneys. Children are more susceptible to lead poisoning (UNEP/UNICEF, 1990). Children up to about six years old are most at risk from exposure to Pb (WHO, 1977).

Davidson *et al* (1986) measured several pollutants in Kathmandu at a hotel courtyard. The ambient carbon concentration was high at 17 mg/m^3, resulting from high biomass and fuel combustion in the area. The suspended

Table VI: Road Traffic and Lead in Kathmandu

Location	Vehicles/day	Lead (ppm)
Heavy Traffic		
Maitighar	2,200	574
Kathmandu GPO	2,000	374
Narayanhity	1,600	323
Light Traffic		
Balaju	<100	34
Dharmasthali	<100	51
Budhanilkantha	<100	10

'<' less than
Source: Bhattarai and Shrestha (1982).

particulates concentration was also quite high, at 8,800 mg/m^3. The trace element concentrations at a busy street in Kathmandu were similar to those in the hotel courtyard. However, the concentration of Pb in the street was 0.80 mg/m^3, more than double the courtyard concentration. Combustion elements of SO_2, NO_3, and carbon in Kathmandu are present in concentrations comparable to urban areas in industrialised countries.

CEDA (1989) conducted a study of air pollution problems in the three major towns of Kathmandu, Pokhara and Biratnagar, with special attention to particulates. The air particulates were irregular in shape and were composed of carbon, silt, fungal spores, pollen grains, wood dust and other dust particles of various sizes.

Particulate concentration was measured by weighing the particulates deposited within a square meter area in an hour. In Kathmandu, the highest concentration of particulates was found in Kalimati, with 18.2 mg/(m^2.h), followed by New Road and Ratna Park. The lowest concentration was recorded at Paknajol, at 7.2 mg/(m^2.h). The highest concentration of particulates in Pokhara, 18.67 mg/(m^2.h), was recorded at Prithvi Chowk. The lowest concentration was recorded at Phewa lake area, at 4.01 mg/(m^2.h).

In Biratnagar, the highest density of particulates was recorded at the Tinpaini area, with 17.32 mg/(m^2.h).

These results show that air particulate density is high in areas where the density of vehicular traffic is high. The study also estimated the number of carbon, silt and other particulates per mm^2/h and the concentration of particulates in mg/(m^2.h). Table VII shows the highest estimated value for each particulate.

INDOOR BIOMASS COMBUSTION

Air pollution is most often associated with industrial, urban and outdoor locations where fossil fuels are burned, but in developing countries more people are affected by air pollution in agricultural, rural, indoor locations where biofuels are dominant (Smith, 1984). Indoor air pollution caused by combustion of biomass fuel for cooking and heating purposes in rural households has been studied in various parts of Nepal. Combustion of biomass fuels such as firewood, dried animal dung (*guintha*), and agricultural residues emit relatively high levels of respirable hydrocarbons, particulates of several categories, as well as CO. Poor ventilation contributes to high concentrations of emissions within rural houses, particularly in kitchens.

Davidson *et al* (1986) measured the concentrations of different air pollutants in 18 houses in several villages in the Himalayas, including high altitude villages such as Lukla, Phakding, Namche Bazar and Khumjung. All the remote villages were characterised by the absence of industries and motor vehicle traffic, except for villages in Kathmandu District such as Alapot, Bhadrabas and Sundarijal, which had

Table VII: Air Particulates in Kathmandu, Pokhara and Biratnagar

Cities	No. of Carbon Particulates per mm^2/h	No. of Silt Particulates per mm^2/h	No. of Other Particulates per mm^2/h	Concentration of Particulates $mg/(m^2.h)$
Kathmandu	33,750	45,000	Too numerous to count	18.20
Pokhara	53,682	18,750	Too numerous to count	18.67
Biratnagar	33,750	52,500	Too numerous to count	17.32

Source: CEDA (1989).

infrequent traffic. Wood was the principal fuel, with lesser amounts of animal dung, charcoal, and crop residues. Charcoal emits less particulate matter and burns more efficiently than the other biomass fuels (WHO, 1984). Its cost, however, prevented widespread use in Nepali households. Serious energy supply problems were noted in the villages; per capita biomass fuel use averaged 8.2 kg/day at high elevations and 2.8 kg/day in the lower elevation villages.

Concentrations of suspended particulates were in the range of 3-42 mg/m^3. High concentrations of several trace elements were also found. Data for gaseous species showed appreciable levels of CO (21-37 ppm), CO_2, methane and several non-methane hydrocarbons.

Estimation of the average pollutant concentrations per household proved to be difficult. High outdoor concentrations of potassium and methyl chloride, traceable to biomass combustion, indicated degradation of the outdoor environment by indoor biomass combustion. The study found the most polluted air to be generally confined to the villages, and the more pristine air was found at high elevations. High per capita use of biomass fuels was thought to be responsible for the high pollutant concentrations.

The concentration of many of the particulate and gaseous species measured during the study was much greater than values typically found in developed countries. Indoor concentrations of total suspended particulate (TSP) mass measured in Nepal generally exceeded, often substantially, the ambient air quality standards established by the U.S. Environmental Protection Agency for suspended particulates (75 g/m^3 annual average, 260 g/m^3 for 24 h), CO (9 ppm by volume for 8 h, 35 ppm by volume for 1 h), and non-methane hydrocarbons (330 ppb of carbon for 3 h). In addition, many of the other trace gases were found by the study to be present in toxic concentration.

Energy consumption patterns are quite different in rural Nepali households to those of other Asian countries. Stove use for cooking and heating averages 11.6 h/day, with additional use of fireplaces in many instances. By contrast, stove use for cooking throughout most of the developing world is estimated at 2.9 h/day, mostly in regions where heating needs are minimal (WHO, 1984). Davidson *et al* (1986) observed that stove operation for heating purposes was continuous during daylight hours in several households and four households had fires burning 24 h/day. None of the houses had chimneys, although many had small holes in the roof above the stove to provide some ventilation.

Poor ventilation is even more common in alpine environments, as houses are tightly sealed against the cold. Indoor stoves tend to be used for heating as well as cooking and are lit for a longer period of the day and year than in the tropical or subtropical climates (Reid *et al*, 1986).

Reid *et al* (1986) monitored individual exposure to suspended particulates during cooking periods. The monitoring activity focused on 60 households in the middle hills of Nepal and took place after the monsoon season. The studies were conducted in Gorkha (Gorkha District) and Beni (Myagdi District). Both villages are situated along major trade routes. Beni is not influenced by any source of industrial or vehicular air pollution and Gorkha has infrequent traffic on a road that ends at the village. The third region of the study, the southern part of Mustang District, is higher, drier and colder. Filters for gravimetric analysis were exposed in rural households with traditional (without flue) and improved (with flue) cookstoves. Active stationary monitoring for NO_2 and formaldehyde was also conducted.

The study showed that exposure to airborne pollutants was significantly lowered by the use of improved cookstoves; the average exposure to suspended particulates was reduced by approximately 2.0 mg/m^3 and the CO concentration by 200 ppm.

Moreover, traditional metal tripod stoves (*agena*) with open fires had higher exposure levels than the traditional mud stoves (*chulho*) with enclosed fires. The improved cookstove decreased exposure to particulates by factors of 3.5 and 2.3 when compared with *agena* and mud stoves, respectively.

Carbon monoxide (CO) data showed an even greater improvement. The flues of improved cookstoves were found to reduce the CO concentration by factors of 3.6 to 5.6. Nitrogen dioxide (NO_2) and formaldehyde results were limited due to the small sample sizes. Higher concentrations were found in cooking areas as against sleeping areas, and NO_2 kitchen values were significantly lower in homes with improved stoves.

The study indicated that twice as many traditional cookstove owners (72 percent) than improved cookstove owners (36 percent) complained of eye problems and coughing.

Davidson *et al* (1986) did not compare stove types but the suspended particulates levels were within the same range in both studies. The CO concentrations were, however, found to be substantially lower (21-37 ppm) by Davidson *et al*. Reid *et al* remarked that it would seem unlikely that the high indoor CO concentrations reported by them represent actual exposure, given the acute poisoning that is known to result at these levels. Such poisoning was not observed.

Increasing attention has been given to the problems of indoor air pollution and its effects on health. Pandey and Basnet (1987) and Pandey (1987) have shown that the prevalence of chronic bronchitis in Nepal has a strong relation to domestic smoke pollution: 31 percent of the bronchitis cases were due to indoor smoke pollution in Chandannath of Jumla (mountains), 17 percent in Sundarijal and Bhadrabas (hills), 13 percent in Parasauni of Bara Districts (Terai) and 11 percent in urban Kathmandu. It was found that prevalence of smoking habit in Chandannath (78 percent) was not significantly higher than in Sundarijal and Bhadrabas (68 percent). The domestic smoke pollution level was considerably higher at the former site. However, tobacco smoking was also reported as causing bronchitis. In an earlier study conducted in Chandannath, Pandey *et al* (1982) noted evidence to show that parental smoking habit was an important factor contributing to the high incidence of acute respiratory illness among infants. A strong correlation of high incidence of chronic bronchitis and Acute Respiratory Infection (ARI) with domestic smoke pollution and tobacco smoking has been shown by Pandey (1984a, 1984b, 1986), Pandey *et al* (1985) and Smith (1987).

In summary, the burning of wood, charcoal, animal dung and crop residues for cooking and heating purposes in Nepali villages results in high indoor pollutant concentrations. These pollutants include particulate species such as trace elements, SO_2, NO_3 and carbon, as well as gaseous species such as CO and volatile hydrocarbons. The indoor emissions also influence the outdoor environment, creating a visible haze in the more populated areas of the Himalayas.

OUTDOOR BIOMASS COMBUSTION

Davidson *et al* (1986) measured the levels of pollutants caused by the outdoor combustion of biomass. Measurements were taken in a high altitude rural area, Thyangboche, an urban area, and Kathmandu. The high concentrations of some pollutants in Thyangboche suggested that indoor biomass combustion affected ambient air quality in the high altitude villages. For example, the mean organic carbon concentration of 4.4 g/m^3 suspended particulates was similar to levels reported for U.S. urban areas and far greater than expected for a remote rural site.

The influence of indoor combustion on ambient air quality was reflected in the trace gas measurements. Outdoor concentrations were greater than expected for clean ambient conditions. In all of the villages sampled, a light haze was seen near ground level with better visibility above.

LAND POLLUTION

URBAN SOLID WASTES

Solid waste is a pollutant of soil, air and water with important implications for public health (Thapa and Ringeltaube, 1981). It is also an aesthetic or visual pollutant. This is primarily an urban problem in Nepal, with localised solid waste pollution in some rural villages and along trekking routes.

About 8 percent of Nepal's 19 million people reside in urban areas, but the number of people living in towns is expected to double by 1995 (CBS, 1987). Nepal has the highest rate of urban growth in the SAARC region (UNICEF, 1987). The 300,000 residents of Kathmandu now produce 100 tonnes of refuse daily (Habitat, 1990). Thapa (1989) reported that the daily waste generation of 400,000 people in Kathmandu and Lalitpur towns was 160 tonnes in 1988. The daily per capita waste generation in the urban areas of Kathmandu valley was 400 g. The density of waste was estimated to be 350 to 400 g/cm^3.

By comparison, the per capita production of solid waste in India is 450 g/day in urban areas and half that in rural areas (Mahajan, 1985). Phatak and Warade (1987) estimated the solid waste generation in Bombay to be 400 to 425 g per person per day. Worldwide, the range of solid waste weight generated per person per day usually lies between 250 and 1,000 g, depending on the level of industrialisation and other factors (Flintoff, 1976). Cointreau (1983) concluded that a strong relation existed between the standard of living (as expressed in GNP) and the amount of waste generated per person per day. Low income countries with per capita income below US$ 360 in 1976 produced 0.5 kg (i.e., 500 g) per person per day, middle income countries with below US$ 3,500 produced 1.5 kg and high income countries with per capita income above US$ 3,500 produced 2.75 to 4 kg per person per day.

The Solid Waste Management and Resource Mobilisation Centre (SWMRMC) cleans about 50 percent of Kathmandu's roads and streets and its operation of waste collection points at various localities covers 70 percent of the city's area. In Lalitpur, 35 percent of the town area is covered by the operation of waste collection points at different locations (Sharma, 1986). CEDA (1989) found that 26 percent of households in Kathmandu dispose of solid waste in SWMRMC disposal containers, 8.5 percent use domestic waste for domestic composting and the rest, about 64 percent, dispose haphazardly. CEDA also undertook a solid waste survey of Pokhara and Biratnagar. The composition of solid waste materials was very similar to that of Kathmandu.

Manandhar *et al* (1987) conducted a study of the solid waste situation in Nepal. All the wards of Kathmandu were examined and none followed proper solid waste management practices.

The solid waste of Kathmandu consists of 78 percent biodegradable materials such as fat, protein and carbohydrates, and 22 percent non-biodegradable materials such as plastics, glasses and foam (CEDA, 1989). Thapa (1989) found the proportion of organic material in Kathmandu valley solid waste to be lower at 57 percent. He noted that the organic content of solid waste decreased with the increase in size of urban populations. Nepali towns with a population below 20,000 generated solid waste with as high as 87 percent organic matter that could be composted.

SWMRMC operates a compost plant at Teku which produces about 13 tonnes of compost manure per day for use by farmers of the valley (Thapa, 1989). The composting site at Teku is located close to a densely populated area as well as the Bagmati and Bishnumati rivers. The dumping site is a local nuisance in terms of aesthetics and smell and is a potential public health hazard due to air and water pollution, specially during the rainy seasons. These factors suggest the need for shifting the composting facility to a less environmentally sensitive area. Recent analysis of compost samples showed high concentrations of the heavy metals, copper and zinc (Schaumberg, 1991). This unpublished work needs to be verified due to its serious public health implications.

In fiscal year 1987/88, SWMRMC collected 62,583 m^3 of waste of which 51,584 m^3 of waste was transported to Gokarna sanitary landfill site (Thapa, 1989). In 1988, an average of 240 m^3 garbage was dumped and compacted at the Gokarna landfill site every day.

Leachate caused by the anaerobic decomposition of organic wastes was also produced at the Gokarna site, posing a potential pollution threat to ground and surface water. The Gokarna landfill site is surrounded by hills on three sides. As small rivulets form during the rainy season in the catchment area, the volume of leachate increases. Control measures include pipes and drainage ditches. The garbage is compacted at a gradient of 2.5 to 6.0 so that direct rainfall runs off with limited percolation. A 60 m^3 capacity leachate pond has been constructed to collect the leachate and has been fitted with an overflow outlet. Such excess leachate is formed only during the rainy season when water reduces the concentration of pollution. The leachate collected is then passed through to processing ponds.

Monitoring wells have been drilled to sample the water for analysis. Water samples collected from the landfill area and 10 sites in the surrounding settlements were analysed at the Institute Freserius of West Germany in December 1988. The findings of the report showed that landfilling activities had polluted the groundwater. Water samples collected east of the landfill area showed high levels of nitrogen, which may be explained by nitrate fertiliser applied in large quantities by local farmers.

The Gokarna landfill site has been in operation since October 1986; it is now half full, and was expected to be in use until the late 1990s (Thapa, 1989). A search has begun for another landfill site within the valley due primarily to the emergence of a rock of religious significance in the remaining area at Gokarna. There are also indications that, as in the case of the Teku compositing facility, local opposition will accelerate the closure of the Gokarna landfill site.

A special concern in Nepal is the lack of a proper disposal system for hazardous solid wastes from industries and hospitals (Thapa, 1989). Dorfman (1987) studied both solid and liquid waste treatment and disposal practices of some industries in Kathmandu valley. Few of the industries observed disposed of solid waste in a proper way; a number dumped solid waste on open lands and river banks. It was found that Nepal Battery, a dry-cell battery manufacturing factory, practiced on-site disposal and dumping on the banks of the Bishnumati river. Bansbari Tannery dumped its solid waste, consisting of unused pelts and hide splits, in an open yard within the factory premises. The stench of rotting pelts, and vultures hovering over the dumpyard have become a local public nuisance (EISP, 1987).

Hospitals generate hazardous and infectious wastes. Of the 15 hospitals in the Kathmandu valley, only the two largest have incinerators, which are used irregularly (GTZ/SWMRMC, 1988). In Kathmandu hospitals wastes of a hazardous nature are handled through the domestic waste management system. Elsewhere in the country such wastes are just dumped on open fields or discharged into public drains and rivers (Thapa, 1989). The number of hospitals in Nepal has steadily increased over the years. In 1978/79 there were 72 hospitals and the number had reached 96 in 1987/88 (CBS, 1989). For cities that do not have adequate systems for the disposal of hospital wastes (and most Asian cities are deficient in this respect) there are risks of contagion and, in some cases, exposure to radioactive materials (Furedy, 1989).

RURAL SOLID WASTES

There is no systematic management of solid waste in villages in rural areas (Thapa, 1989). While the problem is not yet serious for most villages, for an increasing number the waste poses serious health hazards. No formal study has examined the extent of the problems.

A study was undertaken by Cullen (1986) on garbage produced by Himalayan mountaineering expeditions. It was noted that even simple dumping on-site caused despoiling of the environment, fouled water supplies, and presented health hazards. The costs of such pollution were largely borne by local communities and future visitors to the site.

Cullen noted that the practice of dumping unwanted materials might not be a problem if rapid breakdown of refuse materials occurred, if campsites were large in relation to the number of users, or if the number of users were small. These circumstances rarely apply. Typically, decomposition of wastes is slow in alpine regions. Even paper may take several years to disintegrate and discarded cans may remain intact for many decades (Cullen, 1986; L.W. Price, 1981; M. E. Price, 1985).

Cullen reported that a variety of refuse materials could be found at trek campsites: food, food containers, fuel containers, ropes, tools, batteries, film canisters, broken glass, old clothing, skis, packaging material, medicines, oxygen cylinders, cooking equipment, and utensils. Khadka (1986) investigated the nature and extent of solid waste pollution in the Sagarmatha National Park area. He weighed and sorted solid waste deposited along the trek route from Namche (3,440 m) to the Everest base camp (5,546 m), focusing on lodges and campsites. Khadka reported a greater percentage of non-biodegradable rubbish in Sagarmatha National Park than organic wastes, both by weight and quantity. The density of solid waste was found to range from 65 - 75 kg/m^3 and the highest density was found at the Everest base camp, where the process of solid waste degradation was slowest.

There has been a rapid increase in the number of climbing expeditions to the Himalayas. The quantity of material carried with these expeditions to the mountain can be substantial. Unsworth (1981) reported that a 1978 Everest expedition transported 185 tonnes of material and equipment to its base camp. By the end of the expedition a significant proportion of such material is dumped haphazardly as solid waste. Luhan (1989) observed that the South Col on Everest had become legendary as the highest garbage dump on earth.

The number and frequency of trekkers to the Everest base camp region has also increased significantly. On the Tibetan side of the Himalayas, the opening of the Kathmandu-Lhasa road to tourists has resulted in a steady stream of visitors to the Rongbuk valley and the Everest base camp. Jefferies (1982) reported that by the early 1980s, about 5,000 trekkers per year were visiting the Khumbu valley, some travelling as far as the Everest base camp. An estimated 40,000 climbers and trekkers every year continue to add to the growing garbage pile (Luhan, 1989).

Cullen's inspection of Everest base camp sites revealed large amounts of material at the sites and a state of near squalor. Although the size of climbing expeditions has been reduced, the quantities of wastes are increasing proportionally with total climber numbers.

Cullen suggested four possible means of dealing with expedition garbage: burning; covering with rocks; burying in glacier crevasses; and burying off-site. There are, however, problems associated with each method. Burning leaves behind incombustible materials. Covering the garbage with rocks is unsatisfactory unless the garbage is very thoroughly covered. Burying the garbage in glacier crevasses may be the only practical method available at glacier sites, but such garbage may be spewed out in original form decades later. Burying garbage on or off-site in pits seems to be best solution if well managed, but effort and transport costs for off-site burying are high.

The 1984 First Sagarmatha Cleanup Expedition chose the off-site burying strategy. In an attempt to reverse the growing reputation of Everest as the garbage dump of the Himalayas, Nepalese police, Sherpa climbers and American volunteers carried over 1,800 trash-can sized loads of garbage to an off-glacier site where it was buried (Salisbury, 1985).

Contrary to the mounting garbage problem in Sagarmatha region, Annapurna region in the Western Himalayas seems to be better placed in terms of garbage situation. Luhan (1989) reported that even though Annapurna region drew three times as many trekkers as did Sagarmatha, it was cleaner. It was noted that in the Annapurna region, the Annapurna Conservation Area Project (ACAP) had introduced a number of exemplary policies and activities to control solid wastes, one being to encourage trekkers to carry out of the area any wastes which they have generated.

Although Nepal has developed policies regarding garbage disposal in the Himalayas — to the extent that the protocol in climbing permits contains requirements regarding the disposal of garbage — at present they are widely ignored, or not enforced, as the garbage heaps testify (Cullen, 1986).

SOIL POLLUTION

Sharma (1987) reported that pesticide and fertiliser use is increasing in Nepal. Pesticides, chemical fertilisers, and polluted irrigation water on farmlands can significantly alter the physical, chemical and microbiological quality of soil. Such alterations eventually lead to deterioration in soil quality, reducing its structure and fertility. It can also lead to the accumulation of chemicals and heavy metals in crops.

About 20-25 percent of major food and cash crops in Nepal are destroyed by pests, especially insects (Pradhan, 1988) and crop productivity is declining.

Pesticides

Many of the insecticides, herbicides and fungicides (collectively known as pesticides) used in Nepal are toxic and persist in the food chain. Although the environmental impact of pesticides has not been assessed and no legislation currently exists regulating pesticide use, there is considerable concern about their cost-effectiveness and the associated dangers to users and the environment (ADB, 1987; Klarman, 1987).

Information on the nature and extent of pesticide use in Nepal is extremely limited. Sharma (1987) reported that nearly 250 types of pesticides were used, many restricted or banned in other countries. The major pesticides are parathion-methyl, carboforan, malathion, fenitrothion, demeton-methyl, vitavax seed dressing and DDT. Bhatta (1983) and Sharma (1987) found that seed dressing agents containing mercury were still in use. Mercurial compounds are known health hazards.

Since the late 1960s, the Division of Entomology within the Ministry of Agriculture has not recommended DDT for agricultural use. The Nepal Pesticide and Chemicals Company, produces 60 kilolitres of liquid pesticide and 3,000 tonnes of the organochlorine BHC annually (Klarman, 1987). There are also a few small-scale pesticide production plants.

ADB (1987) reported that farmers use pesticides on a "need" basis, usually in minimal doses but with little awareness concerning handling and storage methods. In addition, because persistent pesticides such as DDT and BHC have been used extensively in the past, residues may still be detected in food crops.

Although all types of pesticides — insecticides, herbicides, fungicides and rodenticides — adversely affect the environment, insecticides generally pose the most serious risks. Insecticides are acutely and chronically toxic to living organisms, persist in the environment, and exhibit cumulative properties.

Most fungicides and herbicides, and certain types of insecticides (organophosphates), bind to soil particles or break down relatively quickly into less harmful materials after application (although water may become contaminated when percolating through such soil). Persistent pesticides, such as organochlorines (DDT, BHC aldrin, heptachlor, dieldrin and chlordane) remain unchanged in the environment for long periods. The length varies with climatic conditions. The rate of decomposition is higher in tropical than in temperate climates.

In 1987, Klarman conducted a survey of pesticide use in Nepal and raised serious concerns about impacts on human health and the environment. Problems cited by Klarman included poor quality control; the complete lack of safe pesticide disposal methods; the absence of safety procedures during pesticide production and application; and the failure to disseminate information regarding proper pesticide selection and application. As a result the health risks to pesticide factory workers, farmers, those living near warehouses full of expired pesticides, and consumers of pesticide treated food are potentially very significant. Klarman speculated that pesticide consumption by residents of the Kathmandu valley was almost certain to be high due to the wide availability and heavy use of pesticides in the area. He noted that pesticides such as BHC and DDT which are persistent, and therefore accumulate over time, pose a potential threat to soil, surface water, and groundwater quality.

Conditions at Nepal's only pesticide production plant at Bahadurgunj, near Butwal, were particularly poor. Klarman observed a 1-2 mm layer of malatheon dust throughout the factory and leaking drums of methyl parathion. Because of these conditions and the fact that the workers there had inadequate safety equipment, it was concluded that the factory should not be allowed to operate.

Three papers were presented at a seminar in July 1990 in Kathmandu, all of which focused on problems related to pesticide use in Nepal (Giri, 1990). While acknowledging the importance of pesticides in increasing agriculture production and in disease control, all three authors pointed out serious problems with the way pesticide are produced, imported, stored, applied, and marketed in Nepal. Giri described the pesticide situation in Nepal as nothing less than chaotic. He was especially concerned about the widespread use of organochlorides (specifically BHC and DDT), a group of pesticides that has been banned in many other countries because of adverse health and environmental impacts.

These authors concluded that the key to improving the current pesticide situation lay in establishment of a pesticide regulatory and enforcement authority and in education of pesticide distributors and pesticide users. The Food and Agricultural Organisation (FAO) has prepared a series of technical guideline documents on the distribution and use of pesticides, which could be used as a basis for implementing necessary improvements (Giri, 1990).

In 1988, Pavey reported to ADB on the status of pesticide use in Nepal and proposed a more detailed programme for beginning to address the situation. After reiterating the problems described previously, Pavey made concrete suggestions for establishment of a legal authority to register and regulate pesticide use, for disposal of obsolete and out of date pesticides, and for improvements to working conditions at the pesticide formulation plant in Bahadurgunj. The report contains a comprehensive list of insects and pests causing damage to Nepali crops along with recommended control measures.

Fertilisers and Irrigation Water

Fertilisers are also known to affect soil and water quality but very few documented studies are available for Nepal. Use of ammonium sulfate is known to have appreciably increased the acidity of soil in the Bhaktapur area, thus reducing the crop yield.

Poudyal (1989) reported that soil in the Godavari area has been heavily polluted by excessive use of chemical fertiliser (including nitrogen and phosphorus), as well as by the Godavari marble quarry. In addition, effluent from a brewery and distillery and the careless management of domestic waste also contributed to soil pollution in this area.

Soil samples from agricultural land irrigated with effluent from various industries in Kathmandu were analysed for fungal colonies and chemical parameters by Sharma and Rijal (1988). The results showed that the effluent had altered the pH and chemical composition of the soil so that plant growth and productivity were decreased. The soil adjacent to the Bansbari Tannery was so polluted with chromium that crops were dying in the field. Use of river waters for irrigation is also known to have altered soil quality. The use of the Seti river water for irrigation of farmlands in the Pokhara region has been found to increase the alkalinity of farmland soil.

NOISE POLLUTION

Noise is generally defined as unwanted sound. It is slowly becoming recognised as an unjustifiable interference and imposition upon human comfort, health, and quality of modern life (Dix, 1981). As with many other pollutants, noise is concentrated where population is greatest (Shrestha and Shrestha, 1985). Noise is a public nuisance. Although noise does not change or damage the environment physically or chemically as do other pollutants, it affects people's health physically, pathologically, and psychologically.

Prolonged exposure to high noise levels may cause permanent hearing loss. The most commonly occurring ear damage is caused by continuous periods of high intensity noise. Besides progressive hearing loss, there may be instantaneous damage or acoustic trauma, caused by very high intensity noise impulses that can result from an explosion or sudden excessive noise (Dix, 1981). Pathological effects of excessive noise include nausea, dizziness, variation in blood pressure, reduction in visual reaction and breathing difficulties. Excessive noise can affect people's mental health by increasing irritation, tension, nervousness, anxiety and fear, all of which adversely affect work efficiency and peace of mind. Sharma (1987) remarked that animals are also stressed if subjected to high noise levels.

The hazardous effects of noise have not been studied in Nepal. Neither are there any specific legal or administrative mechanisms to deal with noise pollution. Although there are traffic bye-laws that prohibit use of vehicle horns near hospitals and schools, these are often ignored and no other rules exist for controlling vehicular noise.

Tiwari (1990) described noise as being insidious. Many people work and live in environmental conditions where the noise level is not obviously hazardous. Nevertheless, over long periods of time, they may suffer progressive hearing loss (Dix, 1981). Alternatively there are many environmental situations where the noise level is recognised as sufficiently high as to be immediately hazardous to hearing. Maximum permissible levels that have been recommended by the UK Department of Environment for some of these general situations appear as Annex IV.

Hazardous noise and disturbance noise are the two broad categories of noise occurrence. Hazardous noise is usually associated with industrial work situations, whereas disturbance noise is often described as the environmental noise to which people are subjected outside their place of work.

As in most other countries, transport noise, industrial noise, and community or neighbourhood noise represent the leading and significant forms of noise pollution in Nepal. Although noise pollution studies in Nepal are few, such surveys as have been conducted reveal that noise levels in urban areas are generally much higher than recommended international standards would permit.

The most comprehensive study on noise pollution in Kathmandu has been made by Shrestha and Shrestha (1985). They measured noise levels in various areas of the city associated with transport, industry and the community. Manandhar *et al* (1987) conducted a complementary study of traffic noise in additional areas of Kathmandu. Industrial noise was examined by Miyoshi (1987) in Kathmandu and a few other industrial towns of Nepal.

TRANSPORT NOISE

Road traffic noise produces disturbance to more people than any other noise source (Dix, 1981). This can be expected to increase with the increasing number of motor vehicles and road traffic density. There are currently about 50,000 automobiles in Kathmandu valley (Banskota *et al*, 1990), and ADB (1990) has predicted that this figure will double by the year 2010. With the increasing length of roads, more communities will be exposed to traffic noise. Nepal had 376 km of road in 1951 and 6,306 km in 1987 (CBS, 1989).

Road traffic noise has been assessed only in Kathmandu. Shrestha and Shrestha (1985) recorded traffic noise levels in five different areas of the city, including streets adjacent to noise-sensitive sites such as hospitals and college campuses. Manandhar *et al* (1987) measured noise levels in three additional locations of Kathmandu including residential areas. The noise levels found in these two studies are summarised in Table VIII.

The study finding suggests that an 80 - 100 decibels (dBA) range is typical for urban Kathmandu roads. These noise levels are much higher than those recommended in the United Kingdom for road traffic near residential areas (See Annex IV). Even noise-sensitive sites such as the college campuses and Bir Hospital were subjected to much higher noise levels than desirable. Some classrooms of Amrit Science Campus had become unfit for lecturing and had been abandoned. In Tri-Chandra Campus lecturing was often disturbed by traffic noise. Windows of a significant number of office buildings were kept closed to reduce disturbance by traffic noise.

It is common on urban roads to have peak traffic in the morning and evening as people travel to and from work (Dix, 1981). Shrestha and Shrestha, however, observed that although noise levels were slightly higher during the morning and evening rush hours, there was little significant variation throughout the day.

Traffic noise arises from engines, horns, road-tyre friction and gear box and exhaust systems. Power tillers that are widely used to transport goods, buses, heavy trucks and the ubiquitous three wheeler taxis are also significant contributors to the high noise levels in built up areas of Kathmandu. Engine and tyre noise increases with speed, and a wet road can

Table VIII: Road Traffic Noise Level in Kathmandu

Location	Noise Level (dBA)
Amrit Campus	75 - 85
Tri-Chandra Campus	80 - 90
Bir Hospital	90 - 95
Ratna Park	72 - 88
Teku	85 - 100
Lazimpat	80 - 99
Jhochhen	82 - 100
Putali Sadak	82 - 98

Source: Shrestha and Shrestha (1985), Manandhar *et al* (1987).

increase the noise by 10 dBA (Dix, 1981). There is no vehicle maintenance regulation in Nepal and older vehicles tend to produce more noise. There are also no effective controls over traffic flow and volume.

Aircraft produce very high levels of noise, although variable and intermittent. The noise levels peak when aircrafts are flying overhead, or are taking off and landing at airports. In 1988, Nepal had a total of 19,686 aircraft movements, both arrivals and departures, with 6,473 international flights and 13,213 domestic flights. These figures have remained fairly constant over the past decade. In 1978, there were 19,504 aircraft movements in international and domestic flights (CBS, 1989). Aircraft noise in the vicinity of airports has not been measured in Nepal, and its impact on people's health has not been examined. There are some provisions for the control of noise from aircraft in the Civil Aviation Act, 2015 (1958).

INDUSTRIAL NOISE

Industrial noise is produced by industrial machines and processes. It poses a significant occupational health hazard. While different industrial machines and processes produce varying levels of noise, permanent hearing damage is often found in connection with weaving, blasting, pressing, drilling, and metal chipping and riveting operations. If industrial workers in Nepal have suffered hearing damage, the cases have not been documented. Shrestha and Shrestha (1985) and Miyoshi (1987) have, however, measured the levels of noise produced by various machines and processes in different industries within and outside Kathmandu. Shrestha and Shrestha measured noise levels at three industries in the Balaju Industrial District (BID) of Kathmandu: Balaju Auto Works, Timila Metal Co., and Aluminium Industries. Miyoshi surveyed 25 different types of industries in Kathmandu and other industrial towns. Table IX summarises the noise levels measured in these two surveys.

Noise levels were high in textile industries, metal works, cement industries and flour mills, with noise levels exceeding 90 dBA. In several cases noise levels were higher than 100 dBA. The highest recorded level was 120 dBA at Balaju Kapada Udyog (Textile Mill). According to the recommended noise level for workers in the United Kingdom, at this level the maximum daily exposure period for workers should not exceed 30 seconds (see Annex V).

In the United Kingdom, the recommended maximum steady noise level for workers over a continuous 8 hour period is 90 dBA (Dix, 1981). Sharma (1987) reported that in the USA permissible noise exposure to workers is also set at 90 dBA for a duration of 8 hours. Some countries have an even lower maximum limit, as for example, in the Netherlands at 80 dBA. A high proportion of the industrial workforce in Nepal is at risk of hearing impairment. No regulations controlling industrial noise exist in Nepal. Some industries provide protective devices such as ear muffs but their use is not enforced.

COMMUNITY NOISE

Community or neighbourhood noise comes from a variety of sources which may cause disturbance and annoyance to the general public. It may be due to barking dogs or loud music in residential areas or the cumulative impact of many noises, as in a shopping centre. It may be present in the home or in public places.

In Nepal, there is very little information on the extent of disturbance from community noise. Shrestha and Shrestha (1985) measured community noise at the market area of Asan in Kathmandu. This is primarily a vegetable and grocery market and is usually very crowded throughout the day. Movement of motor vehicles is prohibited in this area. The recorded noise level in this area was 73 - 80 dBA. In other countries community noise level standards have been set far lower than these levels. Table X shows the maximum limits for community noise in different types of areas in Japan. There are no regulations dealing with community noise pollution in Nepal.

Table IX: Industrial Noise Level in Nepal

Industry and Location	Noise Level (dBA)
Textile:	
1. Balaju Kapada Udyog Ltd. (BID)	82 - 120
2. Raj Kamal Spinning and Weaving Mills (BID)	80 - 90
3. Hetauda Textile Mills (Hetauda)	90 - 95
4. Nepal Synthetic Industry (Hetauda)	90 - 92
Metal Works:	
5. Balaju Auto Works Pvt. Ltd. (BID)	86 - 109
6. Timila Metal Co. Pvt. Ltd. (BID)	109
7. Aluminium Industries Pvt. Ltd. (BID)	110
8. Balaju Yantra Shala Pvt. Ltd. (BID)	60 - 75
9. Hulas Steel Industries Pvt. Ltd. (Simra, Bara)	95 - 105
Cement:	
10. Himal Cement Co. Ltd. (Kathmandu)	80 - 100
11. Hetauda Cement Industries Ltd. (Hetauda)	80 - 106
Leather Tanning:	
12. Bansbari Leather and Shoe Factory Ltd. (Kathmandu)	75 - 87
Pulp and Paper:	
13. Bhrikuti Paper Mills (Gaindakot, Nawalparasi)	80 - 85
Food and Beverage:	
14. Dairy Development Corporation (BID)	85
15. Bottlers Nepal Pvt. Ltd. (BID)	90
16. Nepal Biscuit Co. (Nebico) Pvt. Ltd. (BID)	60 - 70

Industry and Location	Noise Level (dBA)
17. Nepal Vanaspati Ghee Industries (Hetauda)	85 - 90
18. Nepal Brewery Co. Pvt. Ltd. (Hetauda)	80
19. Khadya Udyog Pvt. Ltd. (Flour Mill) (Hetauda)	90 - 100
20. Birgunj Sugar Mills and Distillery (Birgunj)	80
21. Gandaki Noodles Pvt. Ltd. (Pokhara)	60 - 70
Chemical:	
22. Nepal Polythene and Plastic Ind. Pvt. Ltd. (BID)	60 - 75
23. Nepal Battery Co. Ltd. (BID)	85
24. Mahashakti Soap & Chemical Ind. Pvt. Ltd. (Hetauda)	80 - 85
25. Asian Paints (Nepal) Pvt. Ltd. (Hetauda)	80 - 90
26. Juddha Match Factory Ltd. (Birgunj)	80
27. Nepal Lube Oil Ltd. (Amlekhgunj, Parsa)	80
28. Nepal Wood and Allied Industry (Parwanipur, Parsa)	70

Source: Shrestha and Shrestha (1985), Miyoshi (1987).

Table X: Maximum Limits for Community Noise Level (dBA) in Japan

	Maximum Noise Limits (dBA)			
Type of Area	Morning	Afternoon	Evening	Night
Hospital area	40	45	40	35
Primarily residential area	45	50	45	40
Residential area near shops and factories	55	60	55	50

Source: Environment Agency (1981).

CONCLUSIONS

The majority of pollution-related studies conducted in Nepal have focused on drinking water quality in the Kathmandu valley. These studies, and similar ones conducted in Pokhara and Biratnagar, point to serious coliform bacteria contamination in urban areas, especially during the rainy season. This problem is so well documented that further study appears unnecessary. Rather, serious efforts are needed to reduce and eventually eliminate bacteriological contamination of water supply systems.

The initial emphasis should be placed on upgrading the water supply distribution systems to prevent the intake of sewage. This means re-laying water supply and sewage pipelines so that the water supply lines are well above, and not adjacent to, the sewage lines in the trenches. Leaking sewage would then flow downward by force of gravity, away from the water supply distribution lines. At the same time, leaks in both types of pipes should be repaired. Judging from the literature reviewed, these actions would greatly reduce the faecal coliform counts in the public water supplies. Attention could then be given to improving water quality monitoring systems at the water treatment plants.

Fewer quantitative studies were found dealing with the chemical quality of drinking water. Those reviewed, however, do not indicate that this is a serious problem, with the possible exception of some groundwater supplies. The results show that priority should first be given to addressing the bacteriological problems noted above.

However, there is evidence that Nepal's rivers are becoming increasingly contaminated by chemicals from industrial effluents. To the extent that these rivers are being, or will be, used as drinking and washing water sources, chemical contamination of public water supplies could become a problem in the not too distant future.

Many studies are available concerning the quality of the Bagmati river and its major tributaries. These waters exhibit a high degree of pollution from untreated sewage and industrial effluents in the greater Kathmandu area. Sewage treatment and industrial pollution control measures are clearly needed to prevent further degradation and to restore the river to the upstream water quality. The effluents of tanneries, carpet factories, distilleries and industrial districts in the Kathmandu valley have been studied. However, more quantitative work on the sources of industrial water pollution are needed before remedial action priorities can be set.

Outside of the Kathmandu valley, paper mill effluents, in addition to the industrial effluents cited previously, are degrading the quality of Nepal's rivers.

The studies reviewed on air pollution provided little quantitative data on ambient air quality. Indeed it appears that air sampling and chemical analysis capabilities in Nepal are inadequate, limiting research efforts in this area.

The sources of air pollution in Nepal are quite varied, indicating that the problem must be addressed on a number of different fronts. For example, more widespread use of wet scrubbers, electrostatic precipitators, filters, and tall stacks is needed to reduce dust and particulate emissions from cement factories, brick and tile factories, pulp and paper mills, distilleries, and textile mills. Institutional controls, on the other hand, are required to improve vehicle maintenance and fuel supply quality control, which are major factors in automotive vehicle pollution. Technology innovation and behavioural changes are necessary to solve the problem of indoor air pollution from traditional cookstoves. Where all three types of air pollution are present, as in the Kathmandu valley, the problem is serious enough to require immediate attention.

Studies show that most land pollution in Nepal stems from mismanagement of solid wastes, in both urban and rural settings, and the mishandling of pesticides and fertiliser in agricultural areas. The urban solid waste situation is particularly serious because of the high population density. Even where solid wastes are collected and landfilled, researchers found the collection systems to be inadequate and the landfill operation to be poorly managed. For example, at the Gokarna landfill, strong odours, methane gas and contaminated leachate were all polluting the local environment.

The rural situation is less critical, with the most offensive solid waste problems occurring along major trekking routes such as the Everest Base Camp route. The Annapurna Conservation Area Project (ACAP) has been fairly successful in controlling solid waste disposal in the Annapurna Range and could be used as a model in other problem areas.

While studies on pesticides raise alarming concerns about the types currently in use and the way they are handled, there is no actual documentation of the impacts on the environment. This is clearly an area where further study is required. There is little doubt that without improvements in the way pesticides are produced, imported, stored, applied and marketed in Nepal, more serious environmental and public health impacts can be expected. Both FAO and ADB have proposed methods for improved pesticide management in Nepal, and both agencies stress the need for establishment of a pesticide regulatory and enforcement authority.

Studies of noise pollution in Nepal show that noise levels in some urban areas are above international standards. Indoor noise pollution is also a problem in some factories. Solutions to the noise problem are not so much technological as cultural and educational. Teaching workers the importance of wearing ear protection when working with loud machinery, and making such safety equipment readily available, are simple examples of possible corrective actions. Improved traffic control measures in cities, such as restricting access to trucks and buses on small roads, increased use of traffic signals, and greater separation of pedestrians and bicycles from automotive vehicles could reduce the noise associated with heavy use of horns. Enforcement of requirements for vehicle maintenance would also help.

From this review of pollution studies, it can be seen that Nepal's environment is being degraded and efforts to reverse this trend are inadequate. Awareness of a problem is the first step in formulating a solution. However, limited management structure, technical capacity, and regulatory and institutional frameworks hinder the study of, and responses to, pollution problems in Nepal.

While these technical and infrastructural problems are being addressed, scope exists for further improvement in governmental and private sector investment in this field. Since most development initiatives in Nepal are project-led, good environmental impact assessment procedures would go a long way towards minimising future problems. Many multi and bilateral aid agencies now require environmental impact assessment of their aid projects, but much greater collaboration of effort is needed to integrate these activities with government decision-making procedures. In the long term systematic environmental planning at both national and local levels, incorporation of practical standards and guidelines based on studies, and monitoring of existing industries are also essential to minimising the degradation of Nepal's resource base through pollution.

WHO International Standards for Drinking Water

Parameters	Desirable Level	Permissible Level
Colour (° Hazen)	5	50
Turbidity (Jackson Units)	5	25
Taste and odour	unobjectionable	-
Total solids (mg/l)	500	1,500
pH	7-8.5	6.5-9.2
Anionic detergents (mg/l)	0.2	1.0
Mineral oil (mg/l)	0.01	0.3
Phenol (mg/l)	0.001	0.002
Total hardness (mg/l as $CaCO_3$)	100	500
Calcium (mg/l)	75	200
Chloride (mg/l)	200	600
Copper (mg/l)	0.05	1.5
Iron (mg/l)	0.1	1
Magnesium (mg/l)	30	150
Sulphate (mg/l)	200	400
Zinc (mg/l)	5.0	15
Ammonia-N (mg/l)	0.5	-
Nitrate (mg/l)	-	-
Fluoride (mg/l)		-
Arsenic (mg/l)	-	0.05
Cadmium (mg/l)	-	0.01
Cyanide (mg/l)	-	0.05
Lead (mg/l)	-	0.1
Mercury (mg/l)	-	0.001
Selenium (mg/l)	-	0.01

Coliform Bacteria

1. Coliform bacteria should not be present in 100 ml of any two consecutive samples of drinking water;
2. No sample should contain more than 10 coliform bacteria per 100 ml;
3. Throughout any year, 95 percent samples should not contain any coliform bacteria in 100 ml; and
4. No 100 ml samples should contain *E.coli* .

Source: WHO (1971).

Annex II

Tolerance Limits for Inland Surface Waters Receiving Industrial Effluents in Nepal

Parameters	Unit	Ambient Standard
1.Total suspended solids	mg/l	30 - 200
2.pH		5.5 - 9.0
3.Temperature	°C	40 (within 15 m downstream)
4.BOD, 5 days at 20°C, Maximum	mg/l	30
5.Oils and grease, Maximum	mg/l	10
6.Phenolic compounds, Maximum	mg/l	1.0
7.Cyanides, Maximum	mg/l	0.2
8.Sulphides (as S), Maximum	mg/l	2.0
9.Total residual chlorine	mg/l	1.0
10.Fluorides (as F), Maximum	mg/l	2.0
11.Arsenic (as As), Maximum	mg/l	0.2
12.Cadmium (as Cd), Maximum	mg/l	2.0
13.Hexavalent Chromium (as Cr), Maximum	mg/l	0.1
14.Lead (as Pb), Maximum	mg/l	0.1
15.Mercury (as Hg), Maximum	mg/l	0.01
16.Zinc (as Zn), Maximum	mg/l	5.0
17.Copper (as Cu), Maximum	mg/l	3.0
18.Silver (as Ag), Maximum	mg/l	0.1
19.Ammoniacal nitrogen, Maximum	mg/l	50
20.COD, Maximum	mg/l	250

Source: HMG/NBSM (1987).

Ambient Air Quality Standards in the USA

Pollutant	Average Time	Primary Standard g/m^3	Primary Standard ppm	Secondary Standard ug/m^3	Secondary Standard ppm
Carbon monoxide	1 h	40,000*	35*	40,000*	35*
	8 h	10,000*	9*	10,000*	9*
Nitrogen dioxide	Annual mean	100	0.05	100	0.05
Sulphur dioxide	3 h	-	-	1,300*	0.50*
	24 h	365*	0.14*	260*	0.10*
	Annual mean	80	0.03	60	0.02
Photochemical oxidants	1 h	160*	0.08*	160*	0.08*
Hydrocarbons	3 h (6-9 am)	160*	0.24*	160*	0.24*
Suspended particulates	24 h	260	-	150	-
	Annual geometric mean	75*	-	60*	-

* Not to be exceeded more than once a year.

Source: Jain *et al* (1981), Lohani (1984).

Maximum Permissible Noise Levels in the United Kingdom

Situation	Noise Level (dBA)
Road traffic near residential areas	70
Noise on building and construction sites	70
Ear protection should be worn	85
Factory work for an 8 hour day, 5 days per week	90
Prolonged noise causing permanent damage	100
Threshold of pain--duration of 30 seconds maximum	120
Absolute maximum with ears unprotected	135
Maximum for impulse noise	135
Maximum for instantaneous noise	150
Absolute limit with ears protected	150
Ear drum rupture	180
Lung damage	194

Source: Dix, (1981).

Noise Limits and Daily Exposure in the United Kingdom

Duration	Noise Limit (dBA) daily exposure
8 hours	90
4 hours	93
2 hours	96
1 hour	99
30 minutes	102
15 minutes	105
7 minutes	108
4 minutes	111
2 minutes	114
1 minute	117
30 seconds	120

Source: Dix, (1981).

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