3.4 WATER QUALITY

3.4.1 Introduction

Water is Nepal's largest known natural resource. The major sources of water are rainfall, glaciers, rivers, and groundwater. Of these, rivers are the most important running surface water in terms of water volume and potential development. There are over 6,000 rivers in Nepal with an estimated total length of more than 45,000 km (CBS 1995). These rivers flow through the high mountains in the country and thus have turbulent and rapid flow and considerable self cleansing abilities through mechanical and oxidation processes. All large rivers are fed by snowmelt from the Himalayas, and hence they are perennial. The country has 660 lakes with stagnant surface water of more than one hectare in area. Mean annual rainfall is about 1,700 mm, 75% of which occurs during the monsoon season from June through September. The average annual renewable water volume of the country is about 224 billion m^3 (Yogacharya 1998).

Over time, the country's requirements for water for drinking and personal hygiene, agriculture, religious activities, industrial production, hydropower generation, and recreational activities such as navigating, rafting, swimming, and fishing have increased. Yet, the rivers are also the main repository for the nation's untreated sewage, solid waste, and industrial effluent.

Concerns about water include both quantity and quality of the resource and relate to human health standards. Normally, a person requires 2.5 litres of water per day for their basic physiological processes (Tebbutt 1992). In addition, water is also required for domestic hygiene such as washing, bathing, cleaning, and so on. An adequate supply of drinking water alone does not fulfil human health needs, as its quality is equally important. Water quality refers to the suitability of the water to sustain living organisms and other uses such as drinking, bathing, washing, irrigation, and industry. Changes in water quality are reflected in its physical, biological, and chemical conditions; and these in turn are influenced by physical and anthropogenic activities (Plates 16 and 17).

Plate 16: Polluted water in the holy River Bagmati near Pashupati temple, the most sacred site in Kathmandu (M. Khadka)

Plate 17: The Bagmati River is polluted by effluents from a carpet factory located on its bank *(S. Shakya)*

3.4.2 Pressure

There is intense pressure on the water resources being used in Nepal due to the limited amount available with respect to demand. Over the last few decades, the population in the country has grown rapidly at over two per cent per annum. Urbanisation caused by natural growth and migration is another factor that puts pressure on the existing water supply in urban areas. Other activities that need water are industries, irrigation, motor workshops, and so on. Natural factors, such as landslides and floods, also put pressure on water resources by damaging reservoirs and irrigation canals. All these activities affect the quality of water.

(a) Surface water

There is a big demand for surface water because of the rapidly increasing population. The annual drinking water supply is inadequate to meet the growing demand. Similarly, the use of water for agriculture is increasing. Table 3.26 shows that in 1998 the total annual withdrawal was 7.4% of the total available. In 1994, it was 5.8%. The relative share of agriculture in total water withdrawal is excessively high, with a trend towards an increasing share of total water withdrawal.

Table 3.26: Surface water availability and its use in Nepal

	1994	1995	1996	1997	1998
Total annual renewable surface water (km^3/yr)*	224	224	224	224	224
Per capita renewable surface water ('000 m^3/yr)	11.20	11.00	10.60	10.50	10.30
Total annual withdrawal (km^3/yr)	12.95	13.97	15.10	16.00	16.70
Per capita annual withdrawal ('000m^3/yr)	0.65	0.69	0.71	0.75	0.76
Sectoral withdrawal as % of total water withdrawal					
domestic	3.97	3.83	3.68	3.50	3.43
industry	0.34	0.31	0.30	0.28	0.27
agriculture	95.68	95.86	96.02	96.22	96.30

Source: WECS (1999); Yogacharya (1996, 1998); Bhusal (1999)
* including catchments outside Nepal

The pressure on drinking water supply is very heavy, particularly in the Kathmandu Valley. Almost all major rivers have been tapped at source for drinking water supplies; and the supply is only about 115 million l/day (mld) during the rainy season, 79% of the estimated daily demand of 145 mld (NPC 1998). Of the total drinking water supply, the carpet industries alone consumed about 6.1 mld of water and generated 5.5 mld of waste water (MOWR 1999).

Despite having 83,000 megawatts capacity for hydropower generation, only 252 megawatts are generated in Nepal, i.e., 0.3% of the total potential (NEA 1999). The demand for electricity has increased tremendously. During the last 15 years, electricity consumption increased from 313 in 1984 to 1,112.8 GWh in 1998. The per capita share of electricity is about 50 kWh per annum. The domestic sector, which includes the commercial and non-commercial sectors, uses the highest quantity of the electricity generated (Figure 2.1).

(b) Groundwater

The country's groundwater is being used for domestic, industrial, and irrigation purposes. It is estimated that the Terai region has a potential of about 12 billion m^3 of groundwater, with an estimate annual recharge of 5.8 to 9.6 billion m^3 (the maximum that may be extracted annually without any adverse effects) (WECS 1999). Current groundwater withdrawal is about 0.52 billion m^3 per year. The aquifers in this region, which consist of sediments of alluvial origin, are very favourable for water accumulation beneath the surface area. The Bhabar zone, which is an area contiguous with the Terai, as well as having better forest coverage, is the main recharge area for the latter. Groundwater is the best alternative source of water supply in the Terai region. Therefore, the forest in the Bhabar zone needs to be conserved, at least in its present condition, to ensure the present level of groundwater.

The groundwater of the Kathmandu Valley is under immense pressure as it is being heavily used for drinking as well as for other activities that require water, resulting in a decline of its water level. The study of Metcalf and Eddy (2000) depicts an alarming situation concerning a drop in pumping water level from 9m to as much as 68m in the valley over a few years (Table 3.27). However, because there is no regular monitoring programme, groundwater depletion rate is uncertain in the Kathmandu Valley. Unfortunately the recharge areas in the surrounding hills, which were once densely forested, have been turned into agricultural land so that there is little support from the surrounding watershed areas to replenish the groundwater in the valley. The total sustainable withdrawal of groundwater from the valley's aquifers is approximately 26.3 mld (Stanley 1994), but the total groundwater currently extracted is about 58.6 mld (Metcalf 2000). The studies indicate that the groundwater in the valley is overexploited. Since studies are not carried out on a regular basis, it is difficult to determine the real degree of overexploitation.

Table 3.27: Deep aquifer depletion at selected locations during the dry season, Kathmandu Valley

Location	Previous water level (m)			1999 Water level (m)		Decline	
	Base year	SWL	PWL	SWL	PWL	SWL	PWL
Bansbari	1997	48.08	67.60	80.63	136.14	32.55	68.54
Baluwatar	1976	FW	21.00	22.41	30.00	22.41	9.00
Pharping	1976	FW	25.00	13.00	44.00	13.00	19.00

Source: Metcalf and Eddy (2000); CEMAT (2000)
PWL = pumping water level SWL = static water level, FW = flowing well

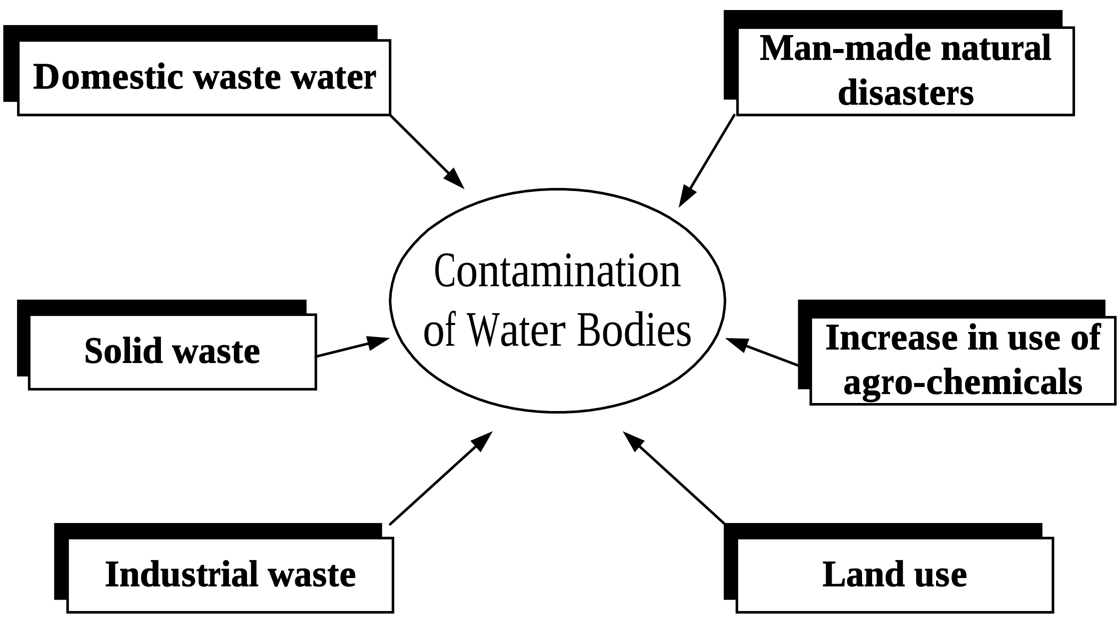
(c) Water quality

The rising demand for water by the population has put pressure on the quality of water. The quality of water sources at both surface and groundwater levels is degraded. The schematic representation in Figure 3.17 summarises the factors affecting water quality.

(i) Domestic Waste

Domestic waste includes both grey and black water. Few houses are connected to a waste water system. Many people, even in urban areas, defecate on open ground, often along the banks of rivers and streams. There is no sewerage network system in the country's rural region or any of the municipal

Figure 3.17: Factors leading to deterioration in water quality



areas apart from the Kathmandu Valley towns. Even in the Valley towns, only 15% of the houses have access to a sewerage facility (NWSC 1999). Increasingly, pit latrines are being introduced, particularly in county areas, and some people have septic tanks. Even so, much domestic waste water percolates directly into the groundwater or flows as runoff into local streams. Likewise, all domestic sewers discharge directly into rivers without treatment. Analysis of domestic waste, based on Tebbutt (1992), shows that if an average of 50g biological oxygen demand (BOD)/person/day is produced in the Kathmandu Valley, it will produce 50,000 kg BOD/day from the one million inhabitants. An average of 20,846 kg BOD/day has been recorded for the Bagmati River at the outlet, constituting 42% of the total BOD load produced by the valley's people (CEMAT 2000). The waste water generated per person is estimated on the basis of per person per day water use, which is about 60 l for the urban area (NPC 1997). About 85 % of the total water used ends up as domestic waste water. The estimated volume of waste water generated by each municipality is depicted in Map 3.8.

(ii) Industrial waste

Industries causing water pollution constituted 40% of the total 4,271 industrial establishments recorded in the country in 1991/92. The number of officially recorded industrial establishments (with more than ten employees) between 1981 and 1996 is shown in Table 3.28. It is not known whether the drop in 1996 reflects a real decrease, or a change in data collecting methods, or even willingness by businesses to register.

Table 3.28: Number of industrial establishments or plants (with ≥10 employees)

Census year	Number of factories/plants
1981	971
1986	2054
1991	4271
1994	4487
1996	3557

Source: CBS (1998)

Table 3.29 shows that the Kathmandu Valley hosts more than 72% of the country's water-polluting industries. Many of these industries discharge effluents into local rivers without treatment, spoiling the quality of river water. The study of Devkota and Neupane (1994) indicates that the contribution of industrial effluents to the rivers is about seven per cent of the total effluents (domestic and industrial) in the Kathmandu Valley.

Table 3.29: Water polluting industries compared to total industrial units (1992)

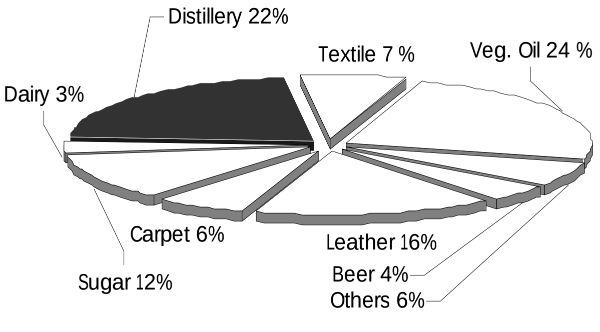
Location	Country total	Kathmandu Valley	% of total units in the Valley
Total industrial units	4,271	2,174	50.9
Water-polluting industrial units	1,714	1,241	72.4

Source: Devkota and Neupane (1994)

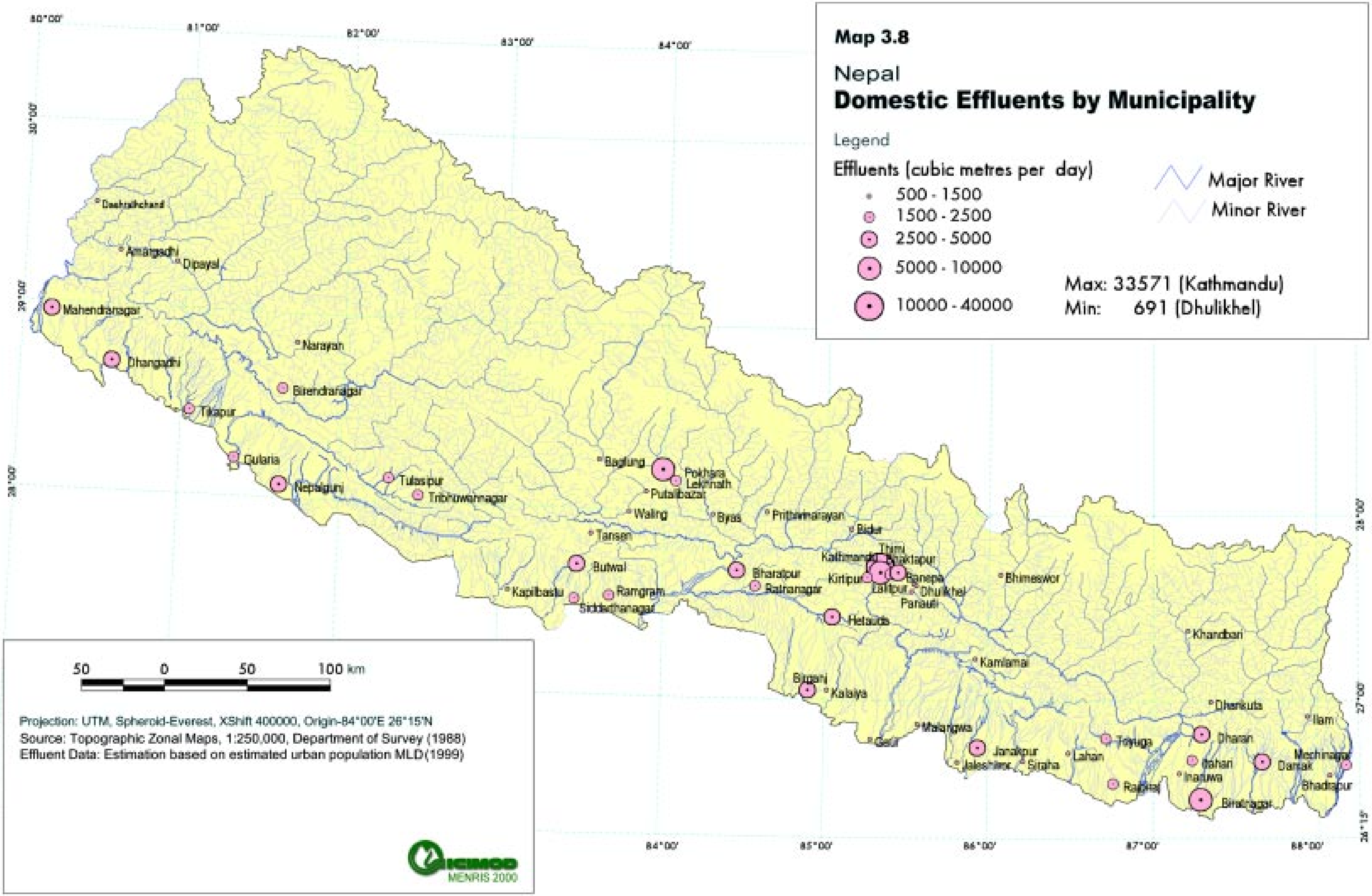
Ten years ago a total of 125 industrial plants throughout the country were identified as industrial pollution 'hot spots' (IUCN 1991). Sixty plants were identified as highly polluting hot spots. These included brewery and distillery, cement, cigarette and tobacco, feed, iron and steel, rosin and turpentine, soap and chemical solvent, oil and vegetable ghee, jute, 'kattha' (*Acacia catechu*), leather and tannin, marble and magnetite, quarry, paper and pulp, sugar and 'khandsari' (raw sugar paste), and textile industries.

Industrial pollution by industries has been measured in terms of waste water volume, biological oxygen demand (BOD), and total suspended solid (TSS) loads of the effluents. In terms of relative contribution of BOD load, the major polluting industries are the vegetable oil, distillery, and leather industries (Figure 3.18).

Figure 3.18: Major industrial sectors responsible for BOD load in Nepal (Total BOD 5,741 tonnes)



Source: Devkota and Neupane (1994)


Map 3.8
Nepal
Domestic Effluents by Municipality
Legend
Effluents (cubic metres per day)
500 - 1500
1500 - 2500
2500 - 5000
5000 - 10000
10000 - 40000
Major River
Minor River
Max: 33571 (Kathmandu)
Min: 691 (Dhulikhel)
Mahendranagar
Dhangadhi
Amargadhi
Dipayal
Narayan
Birendranagar
Tikapur
Gularia
Nepalgunj
Tulsipur
Tribhuwannagar
Baglung
Pokhara
Lekhnath
Putalibazar
Waling
Byas
Prithivinarayan
Tansen
Butwal
Kapilbastu
Siddharthanagar
Ramgram
Bharatpur
Ratnanagar
Bidur
Kathmandu
Thimi
Bhaktapur
Banepa
Kirtipur
Lalitpur
Dhulikhel
Panauti
Hetauda
Bhimeswor
Kamlamai
Khandbari
Birganj
Kalaiya
Malangwa
Gaur
Janakpur
Jaleshwor
Siraha
Lahan
Triyuga
Rajbiraj
Dharan
Dhankuta
Itahari
Inaruwa
Biratnagar
Damak
Mechinagar
Bhadrapur
Ilam
50 0 50 100 km
Projection: UTM, Spheroid-Everest, XShift 400000, Origin-84°00'E 26°15'N
Source: Topographic Zonal Maps, 1:250,000, Department of Survey (1988)
Effluent Data: Estimation based on estimated urban population MLD(1999)
MENRIS 2000

Box 3.3: Carpet industry pollutes river

The carpet industries of the Kathmandu Valley have generated waste water containing contaminants such as dirt, fibres, residual dyes, and other chemicals which contributed 74% of the total industrial effluents, 31% of the industrial BOD load, and 53% of the industrial TSS load.

(iii) Man-made natural disasters

In most parts of the country's hill region, the conditions of watersheds and gullies are deteriorating as a result of deforestation and cultivation of sloping areas. As a result, landslides and soil erosion occur quite often at varying magnitudes, and these directly affect the quality of surface water. The annually increasing turbidity of the Rapti River, for instance, may be due to land degradation in its watershed area (Table 3.30).

Table 3.30: Water quality of the Rapti River at Pidnighat, central Terai, Nepal

Constituents	1995	1996	1997	1998
Turbidity, NTU	15	67	64	116
Ammonia, µg/l-N	110	225	370	125
Nitrate, µg/l-N	125	60	40	20
Nitrite, µg/l -N	2	16	3	4
Phosphate, µg/l-P	147	136	130	30

Source: CEMAT (1999)
NTU = nephelometer turbidity unit

(iv) Increase in the use of agro-chemicals

Plate 18: Intensive, cultivated fields contribute chemical fertilisers to the Kodku River polluting its water, which at the same time is being used by local people for washing clothes and bathing *(B. Pradhan)*

The agricultural system in Nepal has been intensified in some areas by increasing use of chemical fertilisers and pesticides (Plate 18). The average use of chemical fertilisers, such as nitrogen, phosphorus, and potassium (NPK), per hectare has increased tremendously in the country from 7.6 kg in 1975 to 26.6 in 1998. In the agriculturally prosperous area of eastern Chitwan district, the use of fertilisers is estimated to be 420 kg/ha. However, the present level of use is still the lowest in South Asia (Basnyat 1999). The average nutrient level recorded in one of the rivers of the Central Terai is seen to fluctuate, as shown in Table 3.30. However, the concentration of nutrients is within the permissible level for river water quality.

Altogether 250 types of pesticides are used in Nepal. The average use of pesticide was 0.17 kg/ha in 1986 (CBS 1998) and 0.142 kg/ha in 1995 (Palikhe 1999). All these pesticides are organochlorides and organophosphates. Organochlorides are persistent organic pesticides, which pass through the food chain through the processes of bioaccumulation and biomagnification, and thus are hazardous to health. Organochloride pesticides in the range of 34–100 ppb were detected in samples of fish flesh and plankton in three lakes, viz., Begnas, Phewa, and Rupa, in the Pokhara Valley, west Nepal (Palikhe 1999).

(v) Change in land-use pattern

Nepal has witnessed a dramatic change in land-use pattern over the last few decades as a result of the rapid growth in and migration of population. The forest area is declining, while agricultural land is being extended to sloping and/or degraded areas of land, as well as forest lands (although such instances are not obvious from the data). Likewise, the area covered by urban settlements, roads, and other activities is on the increase. Agricultural land increased from 1,592,000 ha in 1975 to 2,968,000 ha in 1985 and remained constant till 1999 (MoA 1998), whereas the forest area declined from 5,617,000 ha in 1978/79 to 4,269, 000 ha in 1994 (DFRS 1999). The decline in forest area has affected not only the water recharge capacity of groundwater sources, but it has also aggravated landslides, soil erosion, and floods. The latter are responsible for increasing the turbidity of surface water.

The land-use pattern in most of the settlements in Nepal has changed. There are indications that the urban area of the Kathmandu Valley increased from 26% in 1978 to 46.2% in 1996. Likewise, the rural built-up area also increased from 11.2% to 24% during the same interval (Pradhan 2000). As a result, the groundwater recharge area has decreased, affecting both quality and quantity of groundwater sources. The forest area of the valley's surrounding watersheds decreased by 40% from 1955-1996, and this has seriously affected the recharge capacity of groundwater sources.

3.4.3 State

The total available surface and groundwater potential of the country is 224 billion m^3 and 12 billion m^3 respectively (WECS 1999). Figure 3.19 depicts the schematic surface water balance for Nepal. The total water demand for various purposes, such as domestic, industry, and commerce, was estimated to be 1,239.7 million mld in 1998. It is expected that all people living in both rural and urban areas will have access to drinking water by 2008 (Table 3.31).

The water quality of selected rivers across the country, as shown in Table 3.32, is at an acceptable standard. The satisfactory level may be due to their high discharge rate and limited human interference. As a result, pollutants are easily diluted and assimilated.

Like the major urban rivers (see below), the water quality of the lakes in the only lake valley, Pokhara, is polluted. Of the four lakes shown in Table 3.33, Phewa, Begnas,

Table 3.31: Population (million) forecast for access to drinking water for the period 1998–2008

Year	Rural population (millions)		Urban population (millions)		Total population (millions)		
	Total	Benefit	Total	Benefit	Total	Benefit	%
1998	18.8	11.3	3.2	1.9	22	13.2	60
2003	20.4	17.5	3.6	3.1	24	20.6	86
2008	21.8	21.8	4.2	4.2	26	26	100

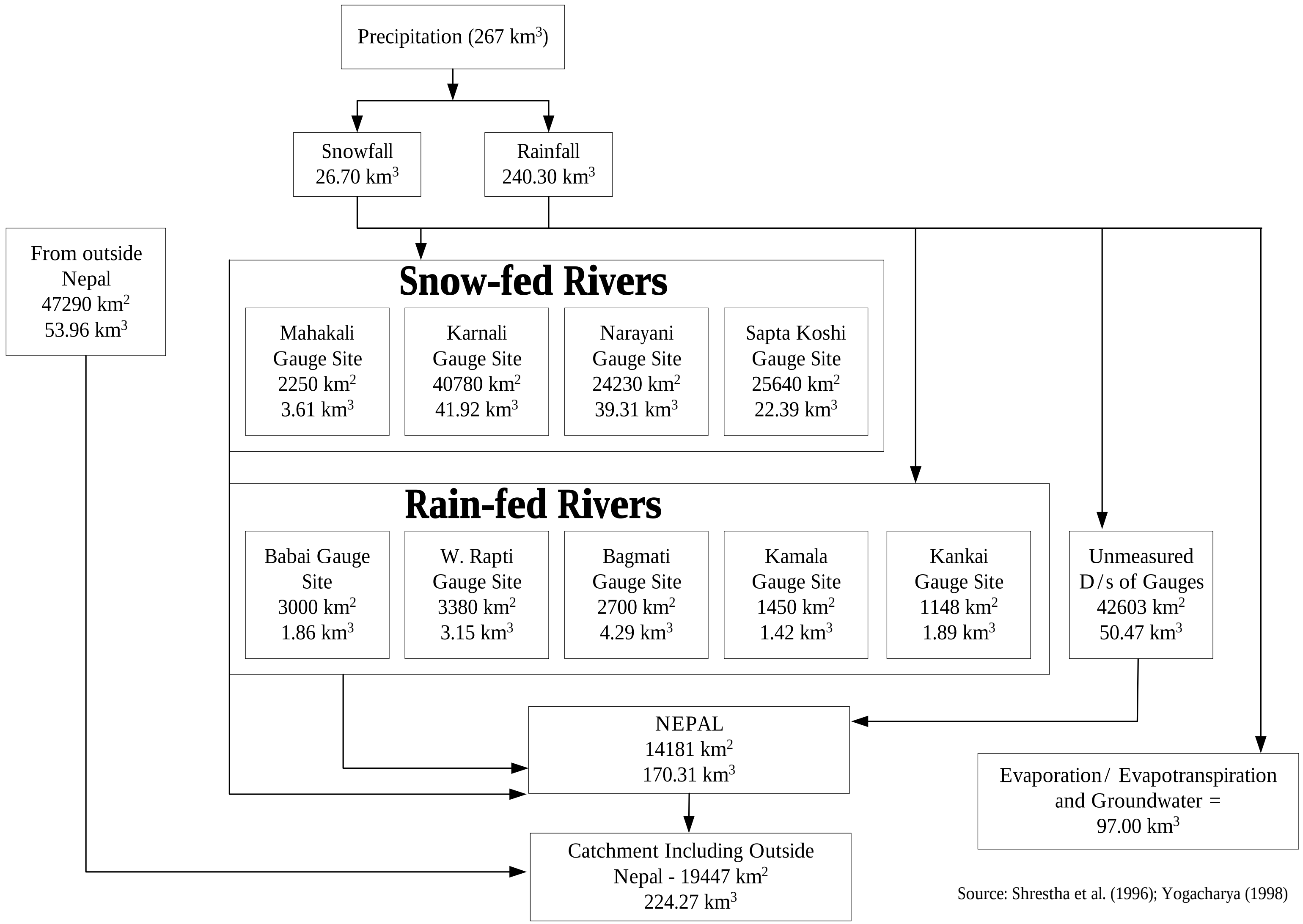
Source: CBS (1998)

Table 3.32: Water quality of major rivers during the dry season in various regions of Nepal

Location of Rivers	pH	TDS (mg/l)	DO (mg/l)	BODs (mg/l)
Mahakali at Pancheswar, Far West	8.8	110	5.0	2.0
Karnali at Chisapani, Far West	8.9	264	10.5	1.5
Bheri at Chatgaon, Mid West	7.8	208	9.3	1.1
Seti at Ramghat, West	8.2	222	9.3	2.0
Rapti at Sauraha, Central	7.8	213	8.7	2.5
Arun, East	6.5	200	9.1	2.1
Kankai, East	7.7	60	8.7	2.0
Mechi, East	8.3	30	8.9	1.8

Source: CBS (1998); DHM (1999)
DO = dissolved oxygen, BOD = biological oxygen demand,
TDS = total dissolved solids

Figure 3.19: Schematic water balance of Nepal in billion cubic metres (km^3)



Source: Shrestha et al. (1996); Yogacharya (1998) and Rupa, in the Pokhara Valley have a high level of nutrients (eutrophic condition), indicating poor quality water. Gosainkund, which is located in the remote area north of the Kathmandu Valley, shows better quality of water because there is less human interference.

Table 3.33: Water quality condition of selected lakes, Nepal

Parameters	Phewa	Begnas	Rupa	Gosainkund
BOD, mg/l	2.0	2.0	2.68	NK
$N\text{-}NO_3$, mg/l	0.12	0.1	0.1	0.2
TN, µg/l	260	233.6	176.4	210.0
TP, µg/l	45.0	43.5	59.6	8.6
$P\text{-}PO_4$, µg/l	30.0	18.7	23.3	3
Chlorophyll a, µg/l	8.0	5.5	6.5	1.2
E.coli/100 ml	8.0	28.9	393.3	NK

Source: ENPHO (1995, 1998a); COSMOS (2000)
NK = Not known

(a) Urban water

In Nepal, the urban population is growing and both the percentage of population being served by drinking water connections and the total connections have increased. However, the remarkable point is that the consumption per capita or per connection has decreased (Table 3.34). With the increase in population, the total water demand per year has also increased. Nevertheless, the per capita consumption (of piped water has decreased because of scarcity of water. This has put pressure on groundwater extraction, especially in the Kathmandu Valley. Another striking feature of the drinking water supply system in the urban towns of Nepal is unaccounted for water or 'leakage', which accounts for 40% of the total supply. Water supply seems to be one of the most crucial problems in the country.

Table 3.34: Water supply and coverage in urban areas of Nepal

Particulars	Before 1992		End of 1998	
	Kathmandu Valley towns	Towns outside the Valley	Kathmandu Valley towns	Towns outside the Valley
Population ('000)	780	640	1097	878
Population served (%)	68	56	87	57
Total produced (mld)	87	55	107	63
Total surface water produced (mld)	61	26	78	36
Total groundwater produced (mld)	26	29	29	27
Water sold (mld)	52	33	64	38
Unaccounted water (%)	40	40	40	40
Per capita consumption (lcd)	98	92	67	76
Consumption per connection (lcd)	674	927	636	721
Total connections	77468	35588	100916	52379

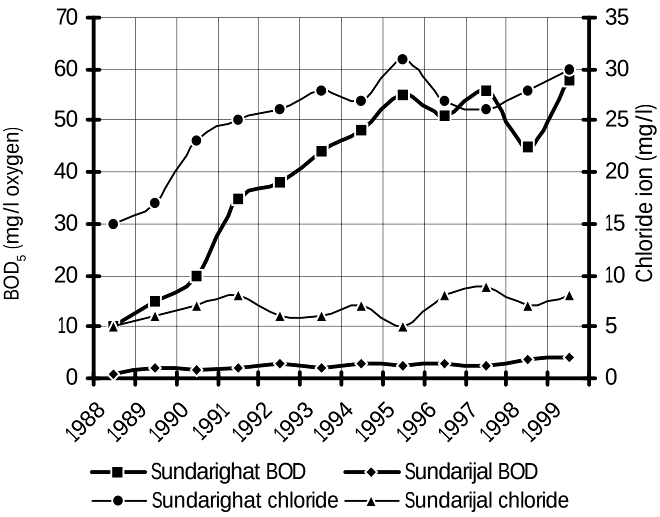
Source: Nepal Water Supply Corporation (1999)
lcd = litre consumption /day; mld = million litre/day

The issue of water pollution in the urban areas of Nepal is related to the municipal sewerage system and storm-water drainage. The municipal sewerage system is directly related to the river environment since the untreated sewage is discharged directly into the rivers. After the formation of the Town Development Fund Board (TDFB) in 1987, several municipalities begin to construct storm drains with the Board's financial assistance (MoPE/HMG 1998). In Kathmandu Valley, the storm-water drainage system has been mixed with the sewerage system. This is mainly because the sewers are connected to the storm drains.

The quality of water in urban rivers is decreasing CEMAT (1999); ENPHO (1996a); GEOCE 1999; MoPE (2000); NEC/SEC (1999); NESS (1995); Pradhan (1998). The Bagmati River in the

Kathmandu Valley is an example (Figure 3.20). Two pollution indicating parameters, BOD_5 and chloride (Cl^-), were measured at two points on the Bagmati River: Sundarijal at the headwater in the north and Sundarighat on the city outskirts in the south-west (ENPHO 1996a;1996b, Pradhan 1998; CEMAT 1999). The quality of the river water is very poor at Sundarighat, as indicated by its higher BOD_5 and chloride ion values. This site has also shown an increasing trend in concentration of these parameters, while the Sundarijal site has shown little marked change in the concentration of parameters. The trends of the parameters clearly indicate that the Sundarighat site is more affected by anthropogenic factors than the Sundarijal site. Map 3.9 shows that the quality of the Bagmati River and its tributaries is very poor in the city centre and improves beyond the valley at the south-west point (Pradhan 1998; CEMAT 1999) where additional freshwater streams mix with the main river.

Figure 3.20: BOD and Cl^- trend at two sites of the Bagmati river



Source: ENPHO (1996), Pradhan (1998), CEMAT (2000)

(b) Aquatic Biodiversity

The rivers of Nepal flow through diverse geographic environments and thus possess a variety of species of aquatic macro-invertebrates. Most of them are pollution indicators and therefore they can be used to determine the river water quality. As the quality of the water body changes, the aquatic animals (macro-invertebrates) in that particular area will also change. They are either washed away or die depending upon their sensitivity to pollution.

Table 3.35: Aquatic animals (macro-invertebrates) of Nepal

Group of Aquatic Animals	Total number of species	
	Kathmandu Valley*	Nepal**
Coleoptera	15	181
Diptera	55	202
Ephemeroptera	33	29
Megaloptera	1	NK
Odonate	5	202
Oligochaeta	5	NK
Trichoptera	14	59
Gastropoda	7	NK
Heteroptera	7	NK
Plecoptera	9	67
Hirudinia	2	NK

Source:*Pradhan (1998); **Sharma (1998)
NK = Not known

There are very few detailed studies on characteristic features of the aquatic insects of Nepal. No information is available on how many of the total aquatic animals are threatened or extinct. Some aquatic macro-invertebrates of the Kathmandu Valley and the country as a whole are listed in Table 3.35. The study of the Valley rivers shows that the Bagmati River and its tributaries are rich in aquatic biodiversity, particularly in the headwater region, and become poor because of organic pollution as they flow through the core city area.

(c) Groundwater quality

Groundwater is the main source of drinking water in Nepal's Terai region. However, concentrations of iron and manganese in the groundwater are on the whole above World Health Organisation (WHO) standards (Table 3.36). As shown in the table, a water quality analysis for seven sites indicated that water is contaminated (not free from coliform bacteria) at all but two sites. People consume water ignoring its quality.

Box 3.4: Paper mills pollute the Narayani and the Orahi rivers

Two paper mills - Bhrikuti and Everest, are located on the banks of the Narayani and Orahi rivers, respectively. The Bhrikuti Paper Mill lies in the Chitwan valley and the Everest Paper Mill is in Mahendranagar in the Far West. The effluent from the former is discharged directly into the Narayani River. The effluent flows barely 500 metres from the mill. The river has endangered species such as dolphin, gharial, and mugger and flows through the Royal Chitwan National Park, which is listed as a world heritage site. The effluent of the Everest Paper Mill is collected first in a nearby pond and then discharged into the Orahi River, 300 metres away from the mill. However, the discharge rate from the two rivers is quite varied. The average discharge rates for the Bhrikuti and Everest mills were 0.25 m^3/s and 0.112 m^3/s respectively. While the BOD values upstream of both rivers - Narayani and Orahi - were 1.5 and 1.6, downstream they were 10 and 70.2 respectively (Pradhanang et al. 1988). Because of the greater dilution effect, the impact of discharge on local river ecology is less in the former than in the latter.

Source: IUCN (1991)

Table 3.36: Water quality of shallow groundwater aquifers in the Terai region (1990)

Sites (District)	Chloride (mg/l)	Ammonia-N (mg/l)	Nitrate-N (mg/l)	Iron (mg/l)	Manganese (mg/l)	Coliform (cfu/100ml)
Panchgacachi (Jhapa)	15.4	0.70	0.2	6.0	0.8	11.1
Baijnathpur (Morang)	16.4	0.50	0.2	4.5	0.5	15.9
Bayarban (Morang)	17.6	0.50	2.4	6.0	0.6	0.0
Takuwa (Morang)	21.0	1.00	1.0	10.4	0.4	45.9
Shreepur Jabdi (Sunsari)	37.2	0.90	0.2	8.0	0.6	25.5
Bandipur (Siraha)	195.6	0.70	3.5	0.4	0.4	0.0
Naktiraipur (Saptari)	54.5	1.20	0.3	12.0	1.3	16.0
WHO standard	250.0	1.24	10	3.0	0.5	nil
Source: ENPHO (1990)						

The groundwater quality in the Kathmandu Valley is also contaminated due to polluted surface water, leachate, and sewage. None of the water from groundwater sources, such as dug-wells, deep tubewells, stone spouts, ponds, and piped water in the valley, as given in Table 3.37, is guaranteed free from faecal contamination (ENPHO 1999; NWSC 1999). The studies of ENPHO (2000), CEMAT (1999), and Jha et al. (1997) indicate that the concentration of ammonia-N even in deep wells is above WHO standards. Similarly, nitrate-N concentration is also higher in shallow and dug wells than the WHO standard.

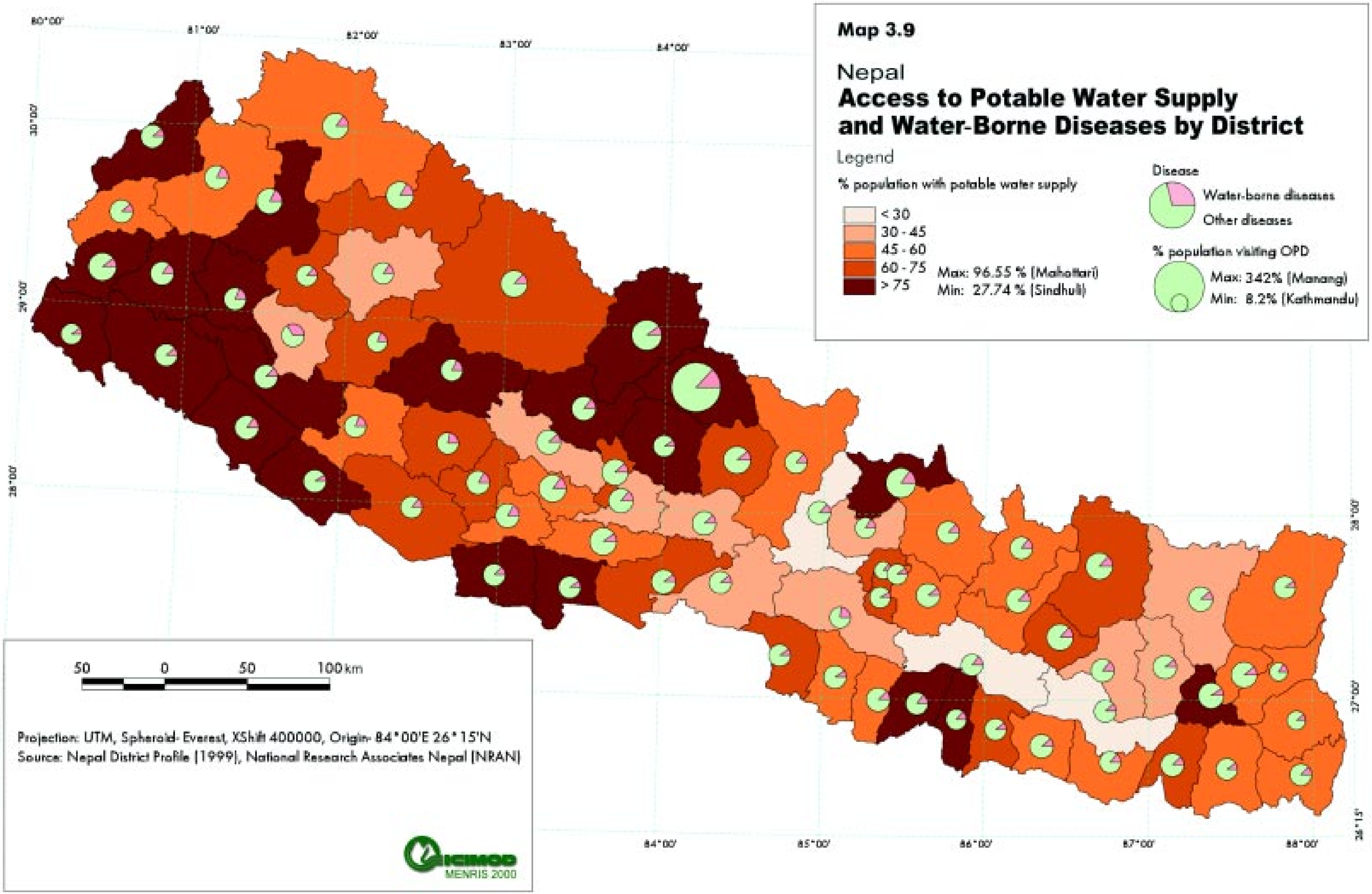
Table 3.37: Bacteriological water quality from different sources, Kathmandu Valley

Faecal coliform /100 ml	Value as % of sample units of 15							WHO guideline value
	Dug well	Shallow well	Deep well	Spring	Stone spout	Pond	Piped water*	
0	0	60	80	40	20	0	60	0
1-100	40	30	15	30	40	0	20	-
101-1000	30	5	5	30	40	0	20	-
>1000	30	5	0	0	0	100	0	-
Source: ENPHO (1999) * NWSC (1999)								

Map 3.9

Nepal

Access to Potable Water Supply and Water-Borne Diseases by District



3.4.4 Impacts

Water pollution is the most serious public health issue in Nepal. There is a vital connection between water and health. The rivers are the main places for disposal of urban solid waste, domestic effluents, and industrial effluents, which are responsible for polluting the water and causing water-borne diseases. Yet, government policy has given little emphasis to this issue (UNICEF 1987).

(a) Water quality and water related diseases

Despite the poor quality of water supplied, treatment of water is given very little priority throughout the country except in the Kathmandu Valley where water supplies are treated with disinfectant chlorine. Table 3.38 shows that the percentage of treatment in the total water supply is very low. In the Kathmandu Valley's urban areas, the percentage of treated water in the total water supply was over 80% in 1998 (NWSC 1999). However, the residual chlorine level in the drinking water of the majority of water samples in the valley is lower than the WHO standard (0.2 mg/l) (ENPHO 2000). This means the treatment of drinking water is not effective.

Table 3.38: Water supply and treatment capacity

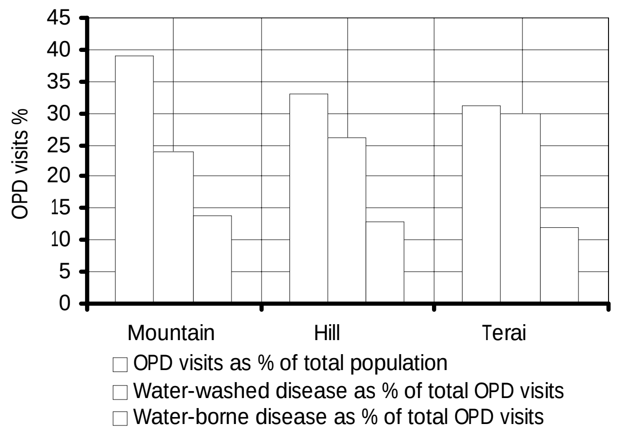
Water condition	Year		
	1992	1995	1998
Total water supply (mld)	142	151	170
Total water treatment capacity (mld)	35.3 (24.8%)	83.9 (55.5 %)	87.9 (51.7%)

Source: NWSC (1999)

Per capita water consumption in Nepal is also low compared to that of other developing countries. This means that both quality and quantity of drinking water in the country are substandard, and this is responsible for causing different types of water-washed and water-borne diseases* (Plate 19). Diseases caused by contaminated water are among the ten most prevalent diseases in Nepal (DoHS 1998). Figure 3.21 shows the percentage of total outpatient department (OPD) visits as a percentage of the population and the proportion of these related to water-borne and water-washed disease. The Terai region has the largest percentage of total OPD visits related to water-washed disease. Diarrhoea, which is caused by poor sanitation, hygiene, and water quality, is one of the most prevalent water-borne diseases in Nepal. During 1995/96, the

Plate 19: Use of polluted water from the Bagmati River in Kathmandu Valley for bathing *(M. Khadka)*

Figure 3.21: Water-related disease, Nepal (1998)



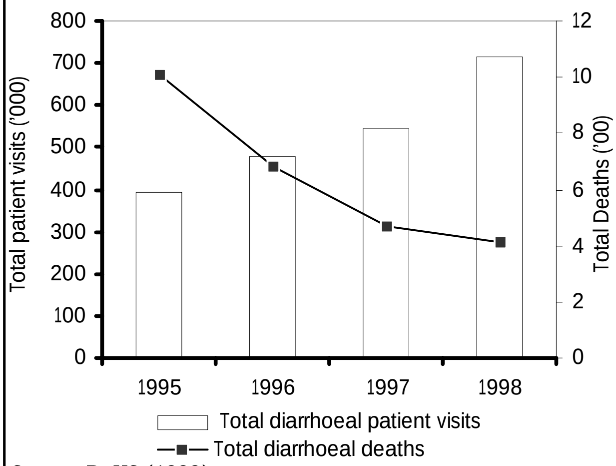
Source: DoHS (1999)

* Water-borne diseases like diarrhoea and typhoid result from the consumption of contaminated water; water-washed diseases like certain skin diseases and intestinal worms are caused by poor sanitation.

incidence of diarrhoea among children below five years of age was 131 per 1,000 children. The mortality rate due to diarrhoea was 0.34 per 1,000 children under five years of age, while the case fatality rate was 2.56 per 1,000 (CBS 1998).

On the whole, the incidence of diarrhoea is on the increase. A report obtained from Teku Hospital in Kathmandu shows that 16.5% of all deaths were due to water-borne diseases (Metcalf and Eddy 2000).

Figure 3.22: Diarrhoeal disease pattern in Nepal



Source: DoHS (1999)

Figure 3.22 indicates that the number of patients with diarrhoeal disease in the country increased, while deaths due to this disease have decreased. This clearly indicates that the government's attempts to minimise deaths from diarrhoea have been successful, but only limited attempts seem to have been made to control the disease through preventative measures. The latter are considered to be important for sustainable health. Map 3.10 depicts the relationship between potable water supply and water-borne disease by district, while Map 3.11 indicates the relationship between access to sanitation and water-washed diseases by district. There is a marked variation among the districts of Nepal in accessibility to drinking water and sanitation facilities and water-related disease patterns. Overall access to drinking water and sanitation facilities in the country is 61 and 21% respectively. In Nepal, water-related diseases have the highest share of the total OPD visits, of which diarrhoeal and skin diseases constitute 10% and 42% respectively (DoHS 1999).

The analysis of the accessibility of people to sanitary facilities versus water-washed diseases by district, as shown in Figure 3.23, shows that the relationship between them is very poor ($r^2 = 0.007$). Likewise, the relationship between potable water and water-borne diseases by district, as shown in Figure 3.24, is also very poor ($r^2 = 0.034$). From these analyses, it is clear that the water provided is not of potable standard and that the sanitary conditions are still inadequate to reduce the water-borne and water-washed diseases significantly.

Figure 3.23: Relationship between water-washed disease and sanitary facilities

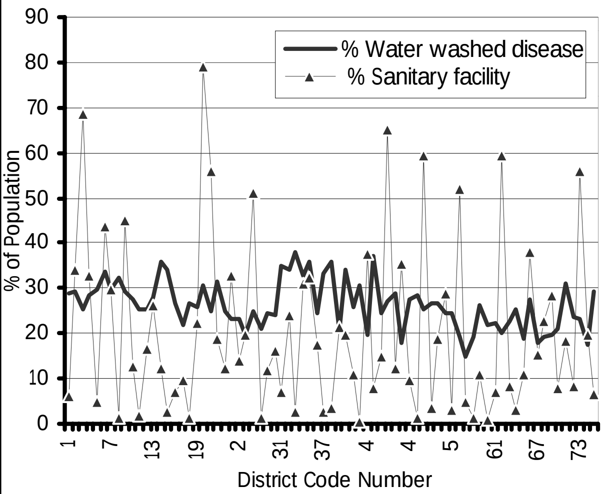
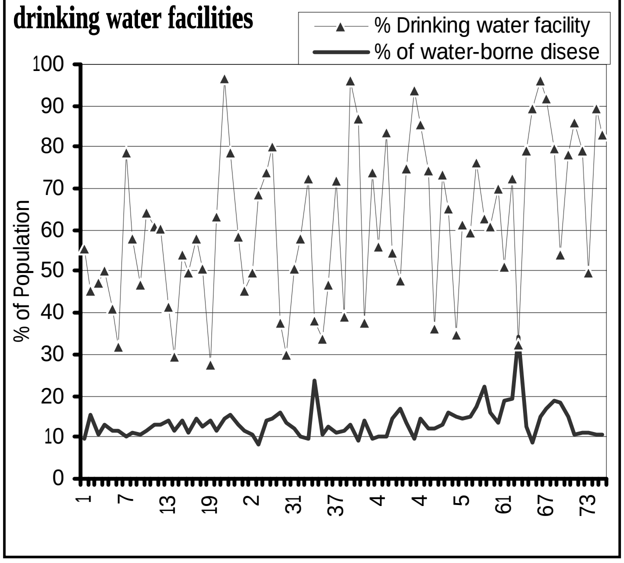
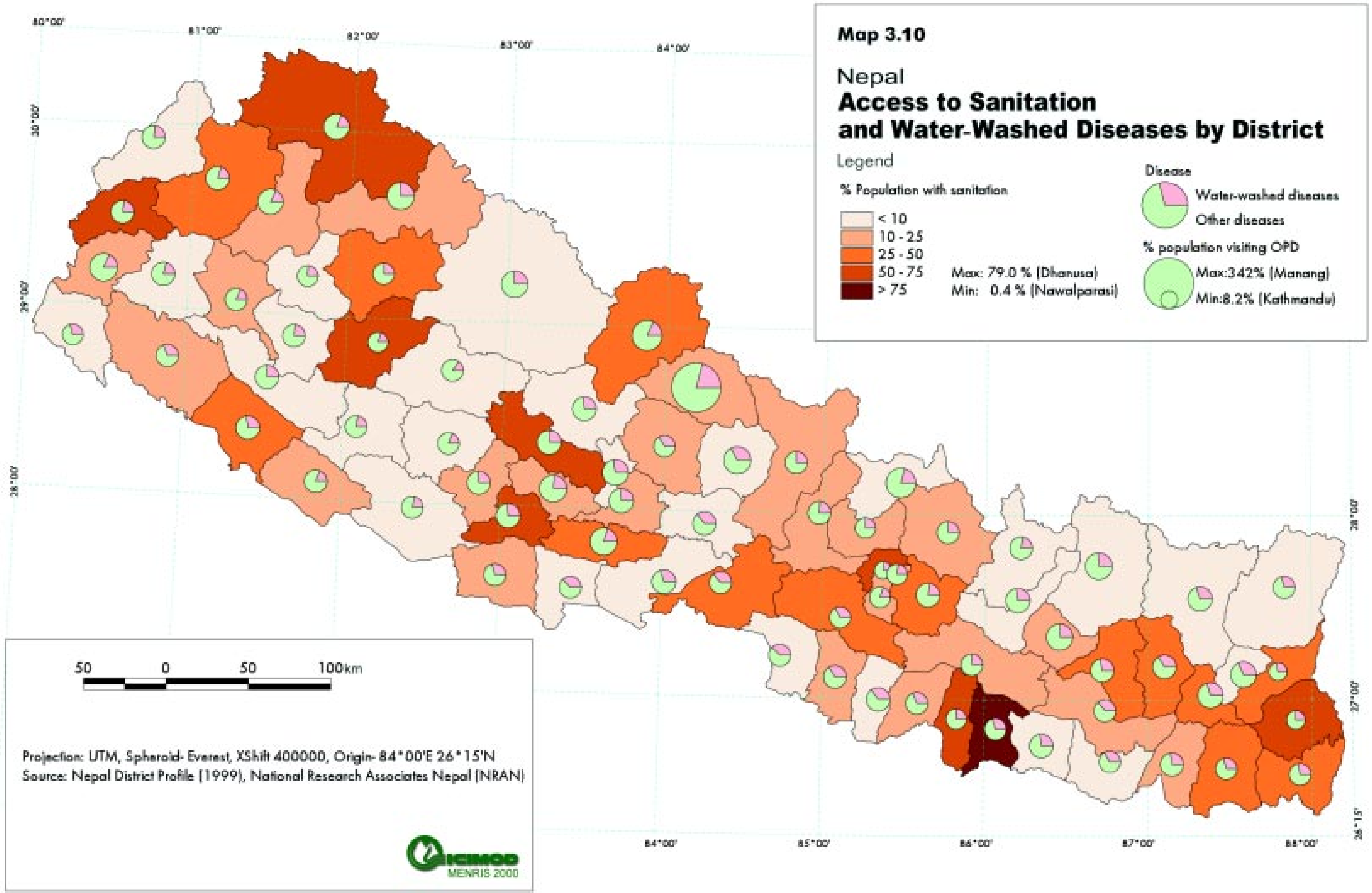


Figure 3.24: Relationship between water-borne disease and drinking water facilities

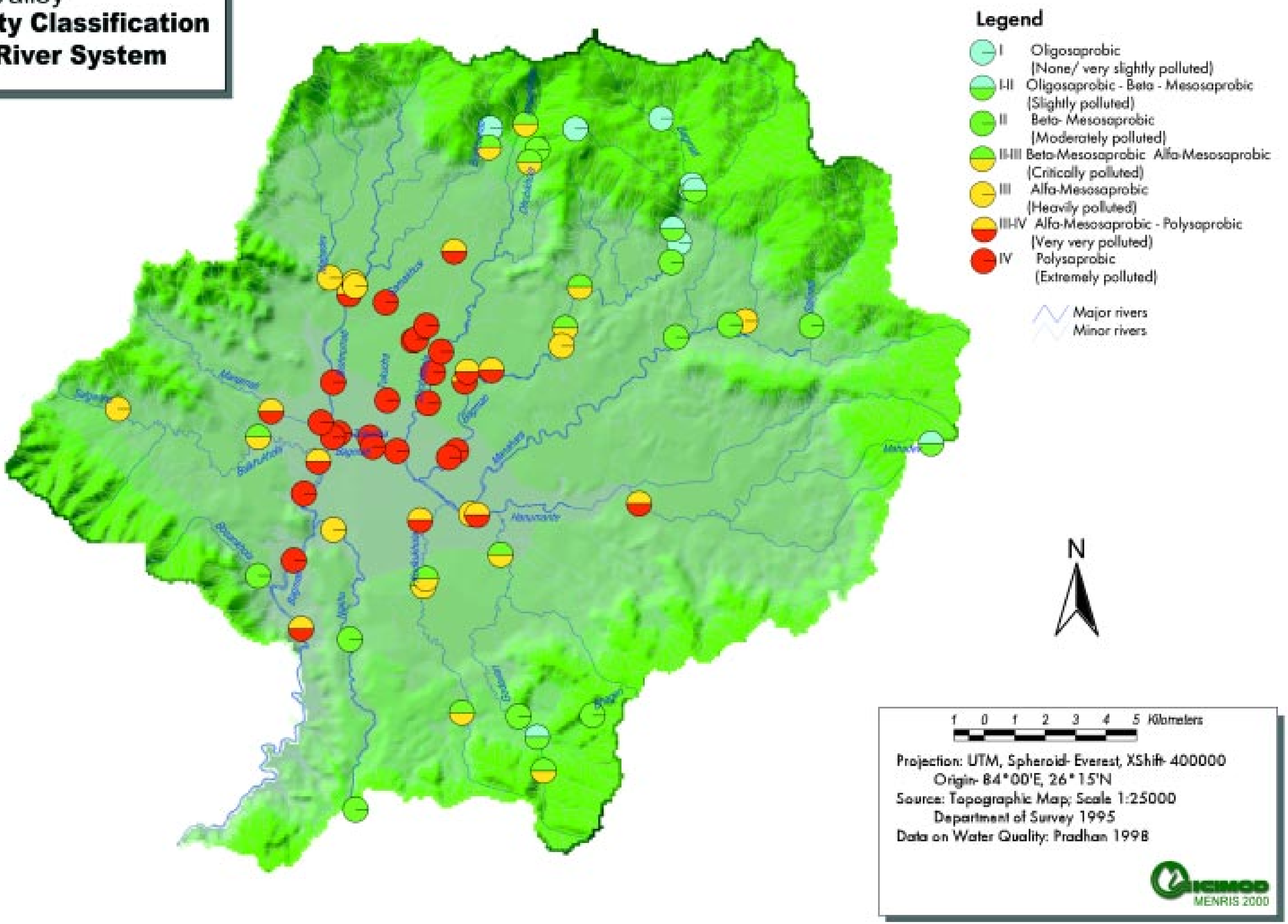



Map 3.10
Nepal
Access to Sanitation and Water-Washed Diseases by District
Legend
% Population with sanitation
< 10
10 - 25
25 - 50
50 - 75
> 75
Max: 79.0 % (Dhanusa)
Min: 0.4 % (Nawalparasi)
Disease
Water-washed diseases
Other diseases
% population visiting OPD
Max:342% (Manang)
Min:8.2% (Kathmandu)
50 0 50 100km
Projection: UTM, Spheroid- Everest, XShift 400000, Origin- 84°00'E 26°15'N
Source: Nepal District Profile (1999), National Research Associates Nepal (NRAN)
ICIMOD
MENRIS 2000

Map 3.11

Kathmandu Valley

Water Quality Classification of Bagmati River System



(b) Impact on water ecology

The economic use of local stream water is increasing. Using local rivers as sources of water for consumption and for irrigating vegetable fields are examples of their economic use. Both relate to urban demand. Quarrying of sand and stone from rivers is also intensifying because of urban demand (Plate 20). Such phenomena seem to have occurred basically in rivers flowing in and around large cities such as Kathmandu, Lalitpur, and Pokhara. These have caused the river water to become turbid.

Plate 20: Disturbance in the river ecology due to sand quarrying in the Manohara River, Kathmandu Valley (S. Shakya)

Cleaning vegetables with polluted river water for supply to the urban market may have adverse effects on human health. Bathing in polluted streams and rivers is also common practice, and this badly affects human health.

Economic activities and use of rivers for waste disposal can have an adverse impact on the aquatic flora and fauna of streams, ponds, and lakes; for instance, biodiversity is measured in terms of abundance and type of fauna, and both have declined sharply in the polluted section of the Bagmati River and its tributaries (Pradhan 1998).

(c) Impact on aesthetic values

In Nepal, water bodies like rivers, lakes, ponds, and spring sources (*kund*) are considered to be sacred places for performing religious activities. However, aesthetic values of water bodies have been greatly affected by haphazard construction of urban houses, encroaching on the river bank, dumping and discharging of household wastes and sewerage, discharge of industrial effluents into rivers, and quarrying of sand and stone (Plate 21). These activities, which are associated mostly with urban development, are considered injurious to the preservation of the aesthetic values of water bodies. They are not beneficial from an ecological perspective either.

Plate 21: Garbage dumped on the river bank leads to water pollution and loss of aesthetic value *(B. Pradhan)*

3.4.5 Responses

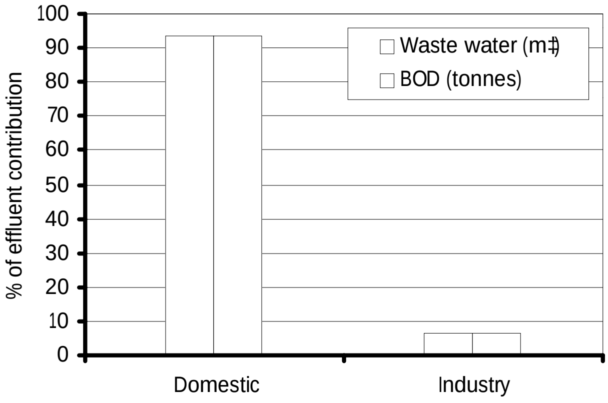
Realising the ecological, economic, and social importance of water resources, various attempts have been made by the government to improve the situation through adoption of various development programmes, organisational adjustments, and research activities. Government and semi-government organisations have been directly or indirectly involved in development, management, conservation, and planning of water resources in the country, either through their own efforts or through economic and/or technical assistance from international and bilateral agencies.

(a) Waste-water management efforts in Kathmandu city

Because of the direct discharge of waste water into rivers without treatment, all the rivers in Kathmandu Valley have been turned into open sewers. The study of Devkota and Neupane (1994) indicates that about 93% of the pollution load is from domestic sewage and the remaining 7% from industrial effluents (Figure 3.25). It has also been estimated that the present waste water production in the valley is 40 mld (CEMAT 1999). Table 3.39 summarises the total capacities and present condition of the four treatment plants in the Kathmandu Valley.

Very few industries in Nepal have treatment plants. Table 3.40 gives the types of effluent treatment plants in the country.

Figure 3.25: Domestic and industrial effluent contribution, Kathmandu Valley (1994)



Source: Devkota and Neupane (1994)

Table 3.39: Condition of waste-water treatment plants in Kathmandu

Treatment plant	Year of est.	Capacity mld	Type of plant	Area coverage	Existing situation
Hanumanghat	1975	0.5	Aerated lagoon	A part of Bhaktapur city	Operating inefficiently as a non-aerated lagoon
Sallaghari	1983	1	Aerated lagoon	North and south part of Bhaktapur city	Operating inefficiently as non-aerated lagoon and receives waste water only from the southern part of the city
Dhobighat	1982	15.4	Stabilisation pond	Waste water from the north-east part of Kathmandu	Out of order
Kodku	1982	1.1	Stabilisation pond	A part of Patan city	Operating inefficiently

Table 3.40: Industries with waste-water treatment plants in Nepal

Name of industry	Type of treatment
Colgate Palmolive	Primary treatment plant
Nepal Liver	Primary treatment plant
Shree Ram Sugar Industry	Anaerobic digester
Gorkha Brewery	Primary treatment plant
Surya Carpet Industry	Preliminary treatment
Narayani Leather	Chromium recovery unit & effluent treatment plant
Shree Distillery	Anaerobic digester
Tribeni Distillery	Anaerobic pond
Himal Distillary	Anaerobic digester
Everest Leather	Common effluent treatment plant

Source: Personal communication (2000)

(b) Local initiatives

Some examples of successful local initiatives are shown in Boxes 3.5 to 3.7.

Box 3.5: Recycling used motor oil

Used motor oil from vehicles is becoming an extremely serious pollutant of surface and groundwater. The Chandra Lubricating Works (Pvt) Ltd in Birganj has been demonstrating since 1988 how to process such oil to make further use of it. The used oil is collected from garages. It undergoes a simple process to separate it into various grades of product. About half of the oil can be re-used as industrial grade oil and the waste is sold to local brick manufacturers as fuel for brick kilns. Thus it substitutes, to some extent, the need for industrial grade oil and fuel for the brick industry. The plant is a local initiative with very small capital. Such plants can easily be established elsewhere in other municipalities of Nepal.

Source: GTZ/UDLE/LUDTC (1992)

Box 3.6: NGO effort on waste-water management

Since 1997, an NGO called ENPHO has been installing and helping to operate small-scale localised waste water treatment plants, for example, at Teku for KMC, Dhulikhel Hospital, Malpi International School, and at Sushma Koirala Hospital in Sankhu. The treatment system is based on a constructed wetland system. KMC is collecting the sludge with 10-15 truckloads (each load with 6 m^3) from private houses' septic tanks and treats it before discharging it into the river.

Source: ENPHO (2000)

Box 3.7. The Gorkha Brewery treats its waste

The Gorkha Brewery of Nepal produces 2.5 million litres of beer a year. The Brewery has set up a sewage treatment plant to treat up to 35 cubic metres of water per hour. Besides, the Brewery is also able to sell sewage sludge as a soil conditioner.

Source: GTZ/UDLE/LUDTC (1992)

(c) Water rights

Awareness in local communities is rising about water use rights to streams flowing through their own areas. Upstream communities have begun to demand the right to control the use of water from streams originating or flowing through their own areas. For instance, the inhabitants of the Melamchi area have demanded the right to share in the use of the water of the Melamchi River with the inhabitants of the Kathmandu Valley for drinking purposes. They are demanding compensation for use of water from the river.

(d) Policy responses

(i) Legislation

Efforts to conserve water resources undertaken by the government through legal measures are summarised in the acts and regulations given below.

- Environmental Protection Act (EPA) (1996) and Environmental Protection Rules (EPR) (1997) and its Amendment (1999)

- Water Resources Act (1992), Water Resources Regulations (1993)
- Solid Waste Act (1987), Solid Waste Regulations (1989)
- Electricity Act (1992)
- Soil and Watershed Conservation Act (1982)
- Aquatic Animals Protection Act (1965)
- Patent, Design and Trademark Act (1965)

(ii) International conventions and treaties
Nepal is a party to a number of broader international conventions and treaties, including the Rio Conference of 1992 related to water, environment, and development. In addition, Nepal is committed to the following conventions, treaties, and agreements as shown in Table 3.41.

3.4.6 Conclusion

Although Nepal is rich in water resources, its people are not getting enough water to meet their needs nor is the available water potable. Incidence of water-borne diseases is rising mainly due to consumption of contaminated water.

Human activity is one of the major causes of polluted drinking water. The causes of water pollution are unprotected water sources, broken sewer lines, discharge of untreated industrial effluent into streams, municipal sewage, urban runoff, agricultural runoff, interrupted water supply, and open defaecation and garbage disposal in communal areas.

The issue of water pollution in the urban area of Nepal is related to the municipal sewerage system and storm-water drainage. The municipal sewerage system has a direct connection to the river environment since untreated sewage is discharged directly into rivers.

The existing laws and byelaws for managing the urban environment are not adequate. Furthermore, failure to enforce laws and byelaws and absence of clear-cut institutional responsibilities are major reasons for pollution of urban rivers.

Table 3.41: International conventions and treaties related to water quality

Conventions	Date	Nepal's signature	Main objective	Major obligation
Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention)	2 Feb 1971	17 Dec 1987	Prevent the loss of wetlands	Conservation and sustainable use of migratory stocks of wildfowl
Agreement on the Network of Aquaculture Centres in Asia and the Pacific	8 Jan 1988	4 Jan 1990	Aquaculture development for increasing rural income	Expand network of aquaculture centres
Convention on Biological Diversity	5 Jun 1992	15 Jun 1992	Ensure conservation and sustainable use of biological resources	Prepare and implement national strategies for the conservation of biodiversity.

(a) Gaps

- Lack of data on water quality and quantity for all parts of the country
- Inadequate monitoring of water quality
- No lead agency to manage and coordinate water quality among the water organisations at national level
- Lack of a central data bank on water quality
- No water quality standards
- No drinking water guidelines for industrial effluents
- Lack of commitment in implementing and enforcement of industrial standards
- Lack of commitment in implementing water quality control measures
- Lack of effective awareness programmes at local level about the conservation of water sources
- Lack of storm-water drainage systems
- Lack of study on health impact of components such as Fe, As, NO_3, NH_4, Hg, Cr
- Lack of study on the impact of water pollution on tourism

(b) Recommendations

- Efforts for managing waste disposal, maintaining drinking water and sewer pipelines, controlling open defaecation, and imposing minimum urban housing standards are urgently required.
- The ongoing practice of direct discharge of domestic sewage and industrial waste into rivers is one of the main causes of pollution. To solve this problem a practical, reliable and cheaper method of treating effluent before being passed into the river should be sought; biological wastewater treatment would be one of the best alternatives. Such treatment plants should be planned to treat the majority of industrial and domestic waste.
- Introduce proper management of solid wastes
- Provide potable water to the general population; in the long run the cost for treated water would be less than the cost for medicines for curing water-borne diseases
- Set up a lead agency to coordinate water-related organisations, and for water quality control, management, and planning (urgent)
- Introduce a water quality monitoring programme at national level through a proper agency
- Provide appropriate techniques for rainwater harvesting, particularly for major urban areas in Nepal, as there is a great seasonal disparity in rainfall distribution
- Conduct effective awareness activities about conserving water quality and quantity in all parts of the country
- Introduce techniques to recycle domestic grey water
- Minimise leakage of piped drinking water through adopting efficient monitoring mechanisms
- Carry out research on water source protection and management
- Introduce on-site treatment plants for treating domestic waste at the community level
- Analyse the effect of water-borne pollutants such as heavy metals on health
- Adopt and enforce industrial effluent standards

(c) Emerging issues

(i) Inadequate supply of drinking water

This is basically related to the demand for water for household consumption and other economic activities such as industry, hotels and restaurants, transport, and others. The piped water supply is far below the needs of the people. The gap between demand and supply is widening each year.

(ii) Deteriorating quality of water

The quality of water for drinking purposes has deteriorated because of the inadequacy of treatment plants, direct discharge of untreated sewage into rivers, and inefficient technical management of the piped water distribution system. Also the quality of water in rivers, ponds, and lakes in major urban areas is deteriorating rapidly. As a consequence of such unhygienic water quality conditions, water-borne diseases such as diarrhoea, dysentery, and gastro-enteritis occur often. These diseases are prevalent in both urban and rural areas throughout the kingdom. The aesthetic value of the so-called sacred rivers, lakes, and ponds has been badly damaged. Therefore, their religious importance and recreational activities, such as bathing, swimming, and fishing in the rivers, have declined.

(iii) Depletion of groundwater table and drying up of spring sources and ponds
The overexploitation of groundwater not only affects the groundwater table but may also have adverse health effects due to the change in the geological source.

(iv) Water rights
Awareness in local communities of Nepal is rising about water-use rights to the streams flowing through their own areas.

3.4.7 Proposed projects

A cost analysis of some proposed projects related to water quality is given below.

Project 1: Water Quality Monitoring

Executive and promoting organisation:	Ministry of Physical Planning, Ministry of Population and Environment
Implementing organisation:	Local NGOs and other private firms working in related fields
Duration:	At least 2 years
Location:	All 58 municipalities of Nepal
Cost:	The estimated annual cost for all 58 municipalities is US$ 443,971. This includes the cost for labour, sample stations, kit boxes, lab costs, report preparation, and analysis.
Rationale:	There are no arrangements for water quality assessment in the majority of municipalities. Water quality assessment has been carried out in a few municipalities but not with continuous monitoring except for the Bagmati River and its tributaries in the Kathmandu Valley and the lakes in the Pokhara Valley. The quality of drinking water sources is not yet known widely. It is known from health bulletins that the number of people with water-related diseases is rising. It is important to know the status trends of water quality (both drinking water supply and water sources) in order to plan mitigation and treatment measures.
Methodology:	General basic parameters for water quality monitoring include pH, conductivity, chloride, ammonia, BOD_5, total phosphate, *E. coli* and heterotrophic bacteria count. In addition to these, other parameters such as Fe, Mn, and As are to be considered for groundwater. The methods

are both laboratory and kit-based and should be used by well-trained personnel. Sample stations should be located at one kilometre distances along each river. Sample sites should include every pond, lake, and spring and 20% of the public standing taps. Monthly collection of water with three replicates from each sample site is required. The central office will prepare reports on water quality based on records obtained from all field offices.

Project 2: Rainwater Harvesting

Executive and promoting organisation:	Ministry of Water Resources
Implementing organisation:	Local NGOs and other private firms working in related fields
Duration:	At least 3 years
Location:	Districts with limited supplies of both ground and surface water
Cost:	The cost is calculated for two purposes, for domestic use and for irrigation. The estimated cost per rainwater collection vessel per house is US$ 143 and masonry for irrigation is US$ 343.
Rationale:	Water supplies to most towns and settlements are inadequate. Piped drinking water is provided to only 62% of the total population. Many of the rural areas are without piped drinking water. People in the rural areas have to spend many hours a day fetching water for domestic uses. On the other hand, the national economy relies heavily on the agricultural sector, which in turn is squarely dependent on the monsoon rain due to grossly limited irrigation. About 70% of the precipitation occurs in the months of June-September during the monsoon season and the rest of the months receive little to no rain. Therefore, rainwater harvesting is deemed essential for both domestic and irrigation purposes.
Methodology:	For domestic purposes, including drinking and other uses, rainwater can be collected from the roof. A ferro-cement vessel for each house with the capacity to hold 2,000 litres of water is suggested. Research still needs to be done, however, into the optimum size needed. For irrigation water, particularly for dry land to grow cash crops, stone-cement masonry with a capacity of 10,000 litres of water is required. This has been shown to be sufficient to grow an additional cash crop on 1.5 hectares sq.km.

Project 3: Recycling of Grey Water, Shrestha (2000)

Executive and promoting organisation:	Kathmandu Metropolitan City
Implementing organisation:	Local NGO working in a related field
Duration:	2 years
Location:	Kathmandu
Cost:	The estimated cost per household is about US $ 360 one-time cost but this should be borne by the consumer. The maintenance cost is negligible. The cost to the project is that of production and distribution of IEC materials and maintenance of a demonstration site.
Rationale:	Shortage of drinking water is a serious problem in urban Kathmandu. The present water supply is 115 mld compared to the demand of 150 mld in the Valley. It is known that the government is not able to meet the present demand for water. Despite the scarcity of potable water, a preponderant proportion of the total water output is used for non-consumptive uses such as washing clothes and dishes, bathing, and toilet flushing. Only about 10% is used for drinking. It is estimated that about 70% of the water used in non-consumptive uses can be recycled by constructing wetland systems.
Methodology:	Recycling of waste water produced by non-consumptive sectors by wetland systems has been shown to be practical at the household level. The method does not require any subsidy. Only information, education, and communication (IEC) materials need to be made available free of cost. The implementing organisation will use the media basically for promoting contact among the public and will recommend who such a service can benefit.

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