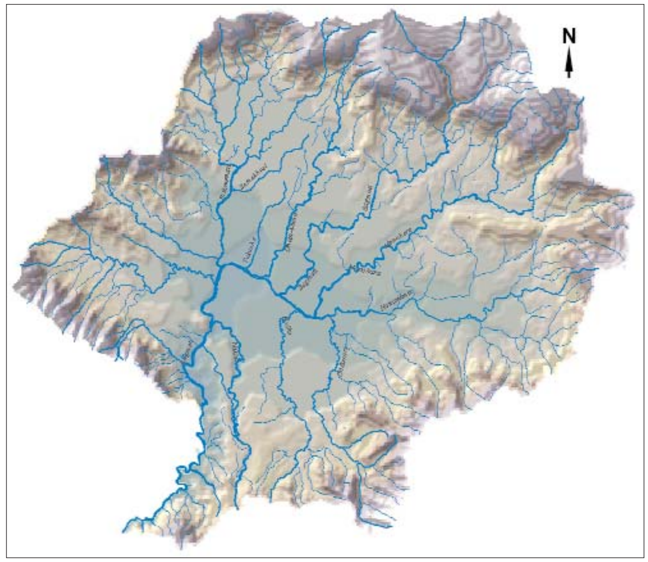
5

Drinking Water Resources

Water in the Kathmandu Valley is derived from two sources: surface water (rivers and ponds) and groundwater. They are basically fed with rainfall. Rivers are important running surface water in terms of water volume and potential development. Over time, requirements for water for drinking and personal hygiene, agriculture, religious activities, industrial production, and recreational activities, such as swimming and fishing, have increased in the valley. Nevertheless, the rivers are also the main repository for the valley's untreated sewage, solid waste, and industrial effluents.

Kathmandu Valley is drained by the multitude of tributaries that feed the main channel of the Bagmati river (Figure 24). So the Bagmati drainage system is the total system of down slope water flow from the point of arrival at the ground surface in the valley. It consists of a branched network of stream channels, as well as the sloping ground surface that contributes overland flow and inter-flow to these channels. There are altogether 20 tributaries of the Bagmati River system within the valley (Table 5.1).



Source: Data: B. Pradhan; Map: ICIMOD

Figure 24: The Bagmati drainage system

The Bagmati River is the principal river. It originates on Shivapuri lekh (ridge) at an elevation of about 2,650 metres and drops to 1,340m over a distance of about 8 km. The length of the Bagmati river from its origin Shivapuri ridge to the Chobhar gorge is about 35 kilometres. In the upstream region near Sundarijal, two streams, the Nagmati and the Syalmati, come to join this river. The valley basin begins some kilometres below Sundarijal over which it flows to the south, turns to the west and again turns to the south and the west and then finally to the south-west. In the valley basin, the Manohara River with its

Table 5.1: **The Bagmati River and its tributaries: places of origin, elevation, and length**

Name of river	Length (km)	Elevation (m)	Origin	Name of river	Length (km)	Elevation (m)	Origin
Bagmati	35.5	2732	Shivapuri bagdwaar	Manamati	6.1	2000	Bhangari danda
Bishnumati	17.3	2300	Shivapuri tarebhir	Manohara	23.5	2375	Manichur danda
Bosan	6.1	1800	Pokhari bhanjyang	Matatirtha	5.0	2000	Matatirtha danda
Dhobi	18.2	2732	Shivapuri danda	Nagmati	7.9	2443	Shivapuri danda
Godavari	14.8	2200	Phulchoki danda	Nakhu	17.6	2200	Bhardeu ridge
Hanumante	23.5	2000	Mahadevpokhari	Samakhusi	6.4	1350	Dharampur-east
Indrawati	16.8	1700	Dahachok danda	Sangla	10.7	2000	Aale dnada
Indrayani	7.0	2000	Bhangari danda	Syalmati	4.8	2200	Shivapuri danda
Kodku	14.9	2000	Tileswor danda	Tribeni	10.7	1700	Bhirkot
Mahadev	9.2	2000	Aale danda	Tukucha	6.4	1325	Maharajganj

Source: Pradhan 1998

tributaries the Salinadi, the Manamati, the Indrayani, the Hanumante, and the Kodku join the Bagmati River at Koteswor. Before the Bagmati turns to the south at Teku, other tributaries like the Dhobikhola (Rudramati), the Tukucha (Ichhumati), and the Bishnumati join it. Three other tributaries, the Balkhu, the Nakhu, and the Bosan, join the Bagmati River before leaving Chobhar Gorge.

Because of the relatively flat topography of the valley basin with soft, deep sedimentary deposits, these rivers have meandering courses and, in some areas, wide flood plains. The general slope of the valley area is towards the central part and then to the south-west. The central slope has an average gradient of above 1 in 236, and therefore all the tributaries flow centripetally towards the centre of the valley to meet with the Bagmati River which then emerges into an antecedent transaction valley cutting deeply in the south-west to flow out of the valley. The Chobhar Gorge, through which the Bagmati leaves the valley, has the lowest elevation of about 1,230 masl and it then directs to the south over the Terai plain of Nepal. The common feature of the rivers is that during monsoon season they often get flooded and deposit enormous amounts of sand and fine particles over their banks. In the dry season, their water level is unusually low despite the fact that they are perennial. Table 5.2 shows the discharge of water volume at three sites – head, middle, and end points – within the valley.

In addition to the rivers, there are four 'kunds' (ponds): Gauri, Godavari, Matatirtha, and Naudhara. They are the spring sources and, usually located on a hill slope, feed a continuous supply of water to the rivers in the valley. Kunds are protected sources and maintained as one of the important drinking water supply sources for the local inhabitants as well as for urban dwellers. These spring sources have been used primarily for domestic purposes. This particular aspect is very significant in regards to the location of many village settlements near the sources of springs over the mountain slopes.
The DPSIR analysis for water resources is presented below. Figure 25 presents the overall DPSIR framework schematically.

Table 5.2: **Discharge and catchment areas of the Bagmati River**

Description		Sundarijal	Gaurighat	Chobhar
Discharge (m^3/s)	Minimum	0.03	0.01	0.02
	Maximum	25.5	150	417
	Average	1.06	3.1	15.6
Catchment Area (km^2)		15.0	68.0	585.0

Source: DHM 1998

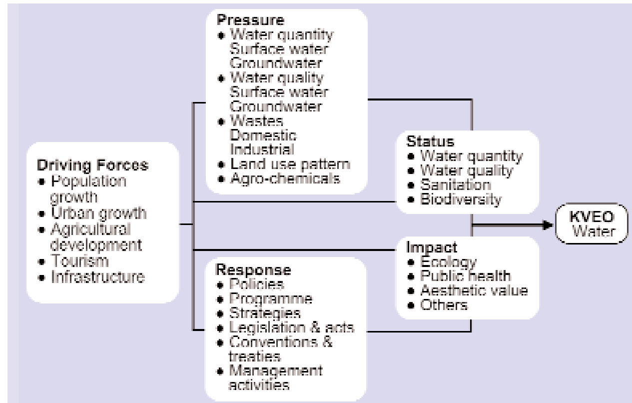


Figure 25: DPSIR framework for drinking water resources

Drivers

Use of water resources can be considered as a measure of development, since it is directly related to agricultural activities, environmental conservation, and human health. With increasing population and development activities, pressure on water resources is increasing. However, the use of water resources is diversified. Since water is a basic element in different types of activities, it is used by tapping most of the available sources and its use is being intensified in order to meet the growing demand for water. Thus water resources have implications on quality and human health, environment and watershed conservation, access to water sources and conflicts, and so on (Pradhan and Pradhan 2006)

The socioeconomic driving forces for describing drinking water resources are made in the following points.

Population growth – population is one of the fundamental driving forces shaping the water environmental base in the Kathmandu Valley. The valley's population increased from 410,995 in 1952/54 to 1,645,091 in 2001. The population density increased from 457 persons/km^2 in 1952-54 to 1830 persons/km^2 in 2001. This has increased the demand for water enormously.

Urban growth and expansion – The valley with its five municipal towns has an urban population of nearly 1 million, constituting slightly over 60% of its total population, accounting for nearly 31% of the country's total urban population. The urban population in the valley increased from 181,082 in the 1950s to 995,966 in 2001. The main contribution to the rapid growth of urban population in the valley is migration. For instance, between 1981 and 1991 the valley's urban population increased by over 82%, in which migration accounted for 59%, the largest ever since the 1950s. The density of population for the urban areas ranges from 139 persons per km^2 (Kathmandu) to 72 persons per km^2 (Kirtipur). The urban areas have expanded in a rapid and haphazard manner. During four and half decades (1955-2000), the valley's urban areas grew from 2,180 to 8,253 ha. Some of the visible consequences of the haphazard urbanisation include the increase in volume of solid wastes and their haphazard disposal, level of pollution of water and air, and squatting on river banks, in open spaces, and on public land.

Agricultural development – The economically active population above 10 years of age constitutes 40.3% of the total population of the valley districts, which is less than the country average. Agriculture in the valley is the secondmost important sector and is characterised by very intensive farming — use of fertilisers, irrigation, human labour, and terracing of farmland.

Tourism – One of the economic and social developments in the valley is tourism. The valley is the first destination for tourists because of its cultural, social, and natural uniqueness. The number of tourist arrivals in the valley has increased each year. Tourism has many facets in terms of employment generation. As a result of increase in tourists, the number of hotels and associated activities like restaurants, travel and communication services, groceries, curio, and others have increased as well.

Infrastructural development – Roads are the most important infrastructure among the driving forces. The total road length in 2001 was 1,319 km compared to 820 km in 1981. Of the total road length of 1,319 km, blacktop accounted for 53.2%, followed by earthen (24.8%), and gravelled (22%).

Regarding health services in the valley, one health service unit (hospital + health post), excluding private clinics, serves an area of 17.4 sq.km and 32,257 persons. It seems that the available public health services in the valley bear the greatest pressure in terms of coverage of population.

Pressure

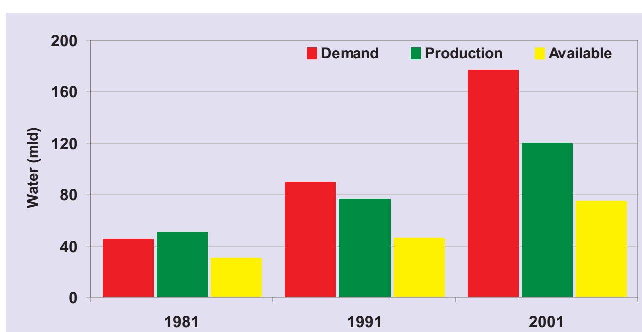
The amount of water required for drinking, domestic, industrial, and recreational uses has increased over time along with the increase in population, quality of life, economic activities and development activities in the valley. In particular, the rivers are not only the main source of water, but also the main repository for untreated sewage, solid waste, and industrial effluents.

Demand for water is always on the increase in the valley. The pressure on water sources is intense due to the limited amount of water available with respect to demand. Over the last few decades, the population has grown rapidly at over two per cent per annum, with migration as the main cause of rapid growth in the valley's urban areas (Pradhan 2004). This additional growth of population leads to demands for more housing. Increase in population obviously puts pressure on the existing water supply. Along with the increase in population, other activities such as industries, irrigation, motor workshops, and so on also require water. Natural factors, such as landslides and floods, also put pressure on water sources by damaging reservoirs, river channels, and irrigation canals. All these activities affect the quality of water.

Water quantity

The valley's surface water sources, such as rivers and kunds, have received tremendous pressure from increasing population and economic activities. The pressure on these water sources has also increased due to use of water for a more and more intensified agricultural system. Almost all major rivers have been tapped at source for drinking water supplies. This supply is only about 120 million litres per day (mld) during the rainy season, 80 mld during dry season of the estimated daily demand of 170 mld (NWSC 2001). In dry season, 60-70% of the water supply comes from groundwater. Only 79% of the total demand for water of the urban population has been met (Figure 26).

Groundwater is an important alternative source of water supply in the valley, and it is under immense pressure, as it is being heavily used for drinking and other



Source: NWSC 1999, 2001

Figure 26: Demand and supply of drinking water

purposes. This has resulted in a decline in groundwater level. A study by Metcalf and Eddy (2000) indicated that the groundwater level had dropped from nine metres to as low as 68m in the valley over a few years and, as a result, there has been a virtual drying up of the traditional dug wells and Dhungedhara (stone spouts). Because of lack of regular monitoring, however, the groundwater depletion rate is uncertain. Unfortunately the recharge areas in the surrounding mountains, which were once densely forested, have been turned into agricultural land, so 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 and Eddy 2000). These figures thus mean that the groundwater in the valley is overexploited.

The demand for drinking water in the valley is met by industrial mineral water. Supplies have increased in the last few years. There are 14 mineral water industries, including nine in the valley, supplying about 0.9 mld per day (DoI 2006).

Water quality

The rising demand for water in the valley has put pressure on the quality of water. The quality of both surface and groundwater has deteriorated.

Domestic waste

Domestic waste includes both grey and black water. In Nepal, only the Kathmandu Valley towns have a sewerage network system and the sewerage facility is provided to 15% of the houses only (NWSC 2001). Some households have septic tanks, but the majority of domestic sewers discharge directly into the rivers without treatment. Even so, much domestic wastewater percolates directly into the groundwater or flows as runoff into local streams. It is also seen even in the valley that people defaecate and urinate on open ground, often along the banks of rivers and streams. Based on the study of Tebbutt (1992), it can be estimated that if an average of 50g biological oxygen demand (BOD) per person per day is produced, it will produce 50,000 kg BOD/day from the one million inhabitants in the Kathmandu Valley. 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 (CEMAT 2000). On the basis of per person per day water use, the wastewater generated per person is estimated to be about 60 litres for the urban area (NPC 1997). About 85% of the total water used ends up as domestic wastewater. Table 5.3 shows the estimated volume of wastewater generated by each of the Kathmandu Valley's municipalities.

Table 5.3: **Estimation of wastewater generation in Kathmandu Valley urban region, 2001**

Municipality	Population 2001	Million litres/day
Bhaktapur	72,543	3.7
Kathmandu	671,846	34.3
Kirtipur	40,835	2.1
Lalitpur	162,991	8.3
Madhyapur Thimi	47,751	2.4
Total	**995,966**	**50.8**

Source: CBS 2001; NWSC 2001

Industrial waste

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 by 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.

Industrial pollution has been measured in terms of wastewater 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.

Increase in the use of agro-chemicals

Vegetable farming intensified in the valley due to an increased use of agro-chemicals. Altogether 250 types

Source: ENPHO

Carpet waste

of pesticides were used in Nepal and the average use of pesticide was 0.142 kg/ha in 1995 (Palikhe 1999). Presently, the number of pesticides used has increased to 319 of which 213 are insecticides, 71 fungicides, 23 herbicides, and 12 others. There are altogether 38 importers and 3,450 retailers in Nepal. A total of 177 tons (active ingredient – ai) per year are imported and 142 tons are used (48.3% insecticides, 46.2% fungicides, 4.4% herbicides, 1.1% others). These pesticides are organochlorides, organophosphates, carbamates, herbicides and pest repellents, and disinfectants. Organochlorides are persistent organic pesticides which pass through the food chain through the processes of bioaccumulation and biomagnification, and thus are hazardous to health (Palikhe 2005).

Change in land-use pattern

The land-use pattern in the valley has changed (Figures 27a and b). As noted in an earlier section, the urban area of the Kathmandu Valley increased from 26% in 1978 to 46.2% in 1996. Likewise, the rural built-up area increased from 11.2 to 24% during the same period (Pradhan 2004). The forest area of the surrounding watersheds decreased by 40% from 1955-1996. As a result, the groundwater recharge area decreased, affecting both the quality and quantity of groundwater sources.

State

Supply systems for water and sanitation

There are basically three agencies delivering water and sanitation services. The Department of Water Supply and Sewerage is the principal public agency for policy and programme formulations concerning water supply and sewerage, and for water supply in rural areas (Figure 28). Nepal Water Supply Corporation (NWSC) is a semi-government agency that supplies water mainly in the urban areas. However, since the supply of water by the public agency alone is not adequate, the additional requirement of domestic water is being supplied by the private sector. In addition, households also draw water by themselves from groundwater sources.

Water quantity

Two major sources of drinking water in the valley are surface water and groundwater. The surface water source is larger than the groundwater source in terms of volume. Yet, not all households have access to tap water (Table 5.4). On average, nearly 81% of households have access to this safe water source, with Bhaktapur having the least access (74.6%) among the valley districts. The groundwater sources together (well, tube well, and stone spout) are the secondmost important.

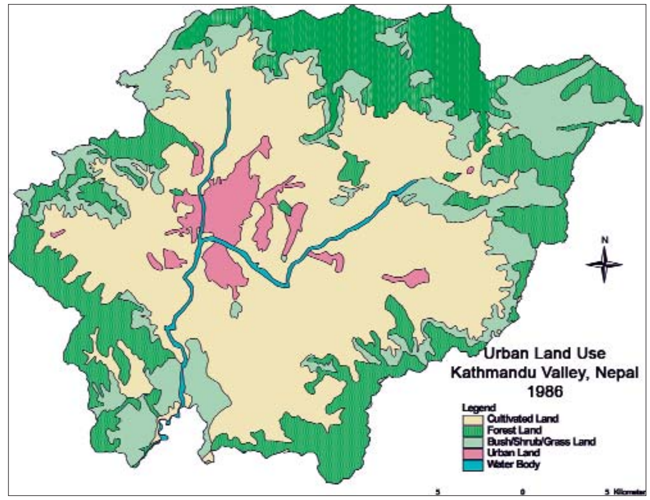


Figure 27a: Land-use pattern 1986

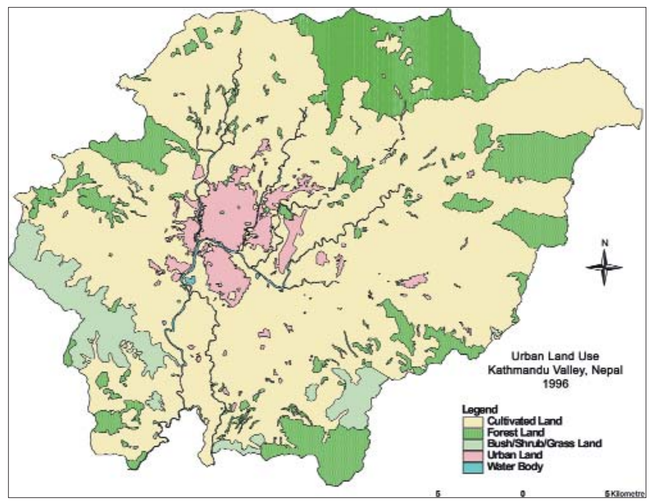


Figure 27b: Land-use pattern 1996

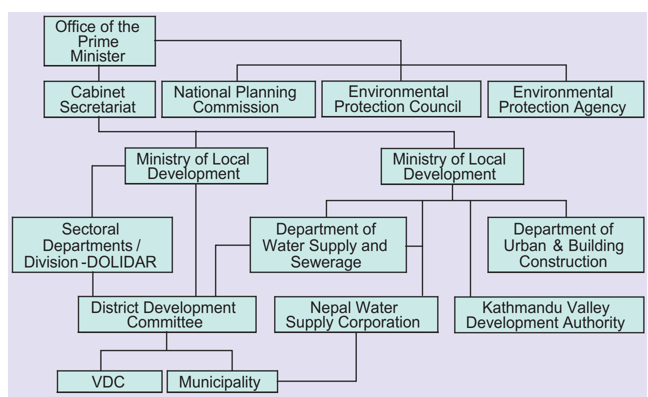


Figure 28: Institutions concerned with drinking water supplies

Table 5.4: **Access to drinking water by household at district level (%)**

District	Tap	Well	Tubewell	Spout	River	Other
Bhaktapur	74.55	11.74	7.22	4.93	0.07	1.49
Kathmandu	84.05	06.25	5.71	2.63	0.08	1.27
Lalitpur	83.05	09.79	1.20	4.50	0.16	1.31

Source: CBS 2001

Table 5.5: **Drinking water supply and demand, Kathmandu Valley cities**

Description	BKT	KTM	KIR	LAL	MPT
Water supply coverage % by DWSC	70	71	71	70	70
Total city water demand (m^3/day)	7,464	80,622	4,900	19,559	3,836
Total city water supply by DWSS (m^3/day)	3,732	40,311	2,450	9,779	1,918
Total volume of surface water supply (m^3/day)	2,612	28,218	1,715	6,846	1,343
Total volume of groundwater supply (m^3/day)	1,120	12,093	735	2,934	575
Individual extraction of groundwater for domestic purposes (m^3/day)	3,732	40,311	2,450	9,779	1,918

Key: BKT = Bhaktapur; KTM = Kathmandu; KIR = Kirtipur; LAL = Lalitpur; MPT = Madhyapur Thimi
Source: DWSS 2004

Table 5.6: **Status of water supply in Kathmandu Valley**

Description	1999	2001	2002	2003	2004
Production capacity million litres per day (mld)	125.0	132.0	141	144	165
Water demand (mld)	160.0	177.0	281	290	294
Average daily production (mld)	105.0	112.0	120	124	145
Water leakage (waste) in %	38.0	37.0	37	37	36

Source: NWSC 2004

Table 5.7: **Distribution of stone spouts by type of use**

Description	BKT	KTM	KIR	LAL	MPT	Total
No. of naturally operated stone spouts	31	35	8	42	43	159
DWSS operated stone spouts	25	2	0		6	33
Not used	24	34	0	4	9	71
Status not known	3	31	3	7	0	44
Total number of stone spouts	83	102	11	53	58	307

Key: BKT = Bhaktapur; KTM = Kathmandu; KIR = Kirtipur; LAL = Lalitpur; MPT = Madhyaput Thimi
Source: NGO Forum 2005

The only government-led agency, DWSC covers about 70% of the total demand for water in the urban areas (Table 5.5). The remaining needs are met the individual households themselves.

The status of water supply and demand in the Kathmandu Valley is shown in Table 5.6. The production capacity for drinking water in the valley increased from 125 in 1999 to 132 mld in 2001. Likewise the status of other parameters has also improved. The percentage of NWSC household connections is only 47.4% of the total households of 240,000 (NWSC 2001).

The distribution of stone spouts, one of the traditional sources of drinking water in the valley's municipalities, is shown in Table 5.7. One major problem with this source is that the number of stone spouts drying up is increasing due to lack of proper maintenance and management.

There are 37 man-made ponds (16, 4, and 14 in Bhaktapur, Kathmandu and Lalitpur districts respectively), and three natural ponds (one each in three districts), and one reservoir in Lalitpur district (Friends of Bagmati 2006).

Water quality

As stated above, the major sources of drinking water in both rural and urban areas of the valley are surface and groundwater. The water is used for different purposes: drinking, bathing, washing, swimming, irrigation and during cremation. The quality of water, as indicated by faecal coliform, must be zero per 100 ml for drinking purposes according to WHO guideline values.

Table 5.8 shows the bacteriological and chemical quality of drinking water sources. It is found that the values of selected chemical parameters lie within WHO guideline values, whereas the values of selected bacteriological parameters are not within WHO guidelines; they are contaminated either at the source or at the points of consumption.

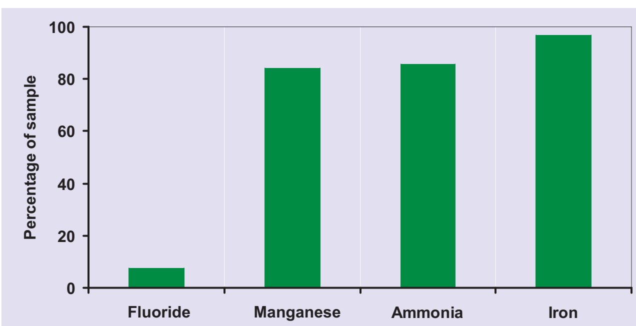
The groundwater source for drinking water is also contaminated (Figure 29). Arsenic contamination is found in some groundwater, water samples especially in deep tube wells, as shown in Figure 30 (JICA/ENPHO 2005).

The degraded quality of both surface water and groundwater in the valley is due to sewage, industrial effluents, leachate from solid wastes, and infiltration of agricultural residue. In the cities, 20,846 kg of domestic sewage is discharged daily into the Bagmati River, which constitutes 42% of the total BOD load produced. The total industrial BOD load discharged directly into the river is 3,151 kg/day (CEMAT 2000).

Table 5.8: **Bacteriological water quality of different water sources, Kathmandu Valley**

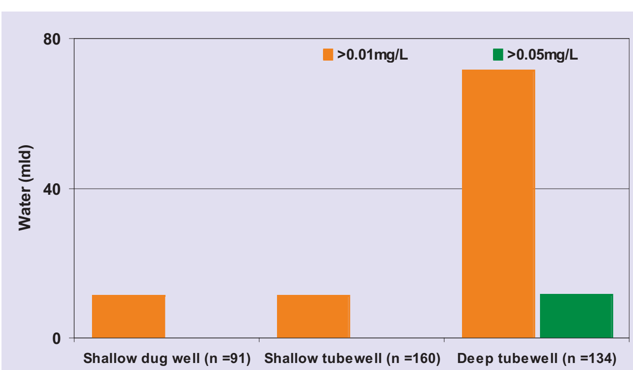
Parameters	Water Sources				WHO GV
	PTW	PUTW	Well	SS	
pH	6.5-8.2	6.5-7.5	7.5	7.5	6.5-8.5
Temp (°C)	13-18	12-15	15-18	15-18	25
Iron (mg/l)	ND-0.2	0.2	0.2	0.3	0.3 -3.0
Chlorine (mg/l)	ND	ND	ND	ND	0.2
Chloride (mg/l)	10-30	22-45	26-27	23-45	250
N-NH_4 (mg/l)	ND-0.2	0.2	0.2	0.2	0.04-0.4
PO_4 – P (mg/l)	0.1	0.1	0.1	0.1	0.4-5.0
Coliform bacteria (source points)	+/-	+	+	+	-
Coliform bacteria (consumption point)	+				-
E. coli cfu/100 ml	10-131	3-20	48-200	58	0

Source: Pradhan et al. 2005
Note: PTW = private tap water, PUTW = public tap water, SS = stone spout, WHO GV = World Health Organisation guideline value



Source: JICA/ENPHO 2005

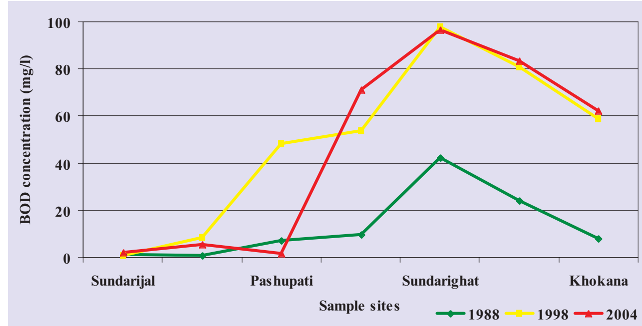
Figure 29: Contamination of groundwater, Kathmandu Valley



Source: JICA/ENPHO 2005

Figure 30: Arsenic concentration in groundwater (pre-monsoon season), Kathmandu Valley

BOD_5 is an indicator of organic pollution which has a direct relationship to the quality of river water. Figure 31 compares the change in concentration of BOD among 7 sites from the headwaters to downstream along the Bagamati River in three different years – 1988, 1998, and 2004 (DSVI/ENPHO 1988; Pradhan 1999; Kayastha 2005).



Source DSVI/ENPHO 1988; Pradhan 1999; Kayastha 2005

Figure 31: BOD trend of the Bagmati River

BOD concentration increased rapidly in all five downstream sites from 1988 to 2004, except for the Pashupatinath site where BOD concentration decreased considerably between 1998 and 2004. This decrease or improvement in water quality may be due to the treatment plant.

Sanitation

Sanitation generally is defined as activities that improve and sustain hygiene in order to raise the quality of life of an individual. It may include personal hygiene; food hygiene; proper handling, storage, and use of drinking water; human excreta disposal; and solid and liquid waste disposal.

Sanitation here is measured in terms of availability of toilets and sewerage facilities. According to CBS (2001), not all households in the valley districts have toilet facilities. The households with toilets account for 81% in Lalitpur district, 90% in Bhaktapur district, and 92% in Kathmandu district (CBS 2001). The households that do not have toilets practice open defaecation. This is the major reason for the contamination of water sources. In Kathmandu city, however, the municipal government has provided public toilets in its core areas.

Most of the households' toilets do not have septic tanks and they are directly connected to the sewerage lines that also discharge into the nearby river. For the households having septic tanks, a municipal service is available for emptying the septic tanks on a demand basis. But even the municipal authority allows the septage being pumped up from the septic tanks to be dumped on the banks of nearby rivers. There are treatment plants for the municipalities (Table 5.9).

Domestic wastewater makes up approximately 93% of the total wastewater generation by the cities, and the remaining seven per cent is industrial wastewater (Table 5.10).

Table 5.9: **Sewerage coverage in Kathmandu Valley**

Description	1999	2000	2001
Total length of sewers (km)	220	225	232
Interceptors	33.7	38.7	40
Laterals	186.3	186.3	192
Number of treatment plants	4	4	5
Population served	390,000	400,000	420,000
Population coverage (%)	40	40	40

Source: NWSC 2001

Table 5.10: **Wastewater production**

Description	Bhaktapur	Kathmandu	Kirtipur	Lalitpur	Madhyapur-Thimi
Total domestic wastewater generated (mld)	5,971	64,497	3,920	15,647	3,069
Volume of industrial wastewater generated (mld)	418	4,515	274	1,095	215
Total wastewater generated (mld)	6,389	69,012	4,195	16,742	3,284
Volume of wastewater collected (mld)	3,195	34,506	2,097	8,371	1,642

Source: Documents from the municipalities; CBS 2001; and discussions with experts, field observations, and estimations

There is a sewerage system in the cities. Even so, the sewer treatment plants are not functioning, except for the Bagmati treatment plant. An additional sewer line to extend services in urban areas and the actual operations of two new defunct sewerage treatment stations at Dhobighat are being programmed this year for Kathmandu and Lalitpur. There is a problem with the sewer system. Overflow often occurs during the rainy season due to poor maintenance of sewer lines. The problem also occurs due to flooding in the rivers which receive direct discharges of domestic and industrial waste.

The sewer system in the valley's core areas is both a closed and open drain system. The newly expanded residential areas are usually devoid of sewers. In a few cases, however, sewage is channelled through humpipe lines connecting to nearby rivers. The storm water is managed by a combined sewer system. City households do not dispose of kitchen, laundry, and bath wastewater separately.

Due to the direct discharge of sewage and wastewater into the rivers without treatment, all the rivers in the valley have been turned into open sewers. It is estimated that about 50,000 kg of BOD_5 per day is produced in the valley. 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 (CEMAT 2000).

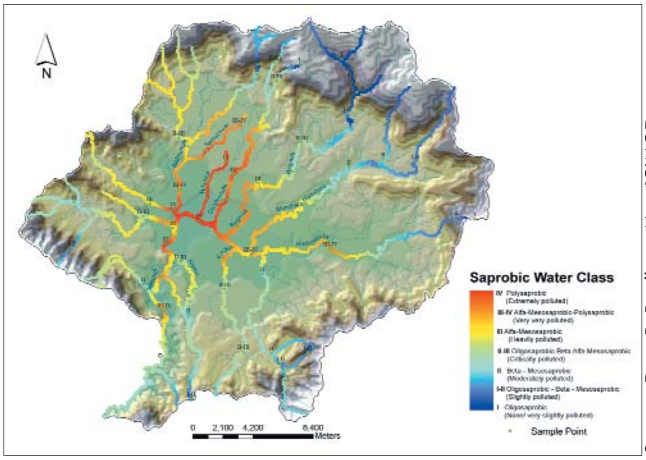
Aquatic biodiversity

The Bagmati River and its tributaries flow through diverse environments in the valley and have varieties of aquatic macro-invertebrate species. Aquatic fauna species include fish, amphibians, and reptiles and all are known as 'vertebrates'. Aquatic flora include benthic, macro, and micro invertebrates. Most of them are pollution indicators and therefore they can be used to determine the quality of river water.

One serious problem with fresh river fish species is that the indigenous fish stocks are declining due to over-fishing, harmful fishing practices (electro-fishing, dynamiting, use of chemicals), pollution and development work. Development work, such as river damming or creation of reservoirs, has affected the river ecology and aquatic flora and fauna. Unlike fish, aquatic insects in the are little known. No information is available about how many aquatic animals are threatened or extinct.

By using the Saprobic method that describes the relationship between riverine ecology and river water quality, the quality of the Bagmati River water can be divided into four major classes ranging from best (pristine) to worst: SWQ Class I (*oligosaprobic* – no to very slight pollution with a variety of species), SWQ Class II (*beta-mesosaprobic* – moderate pollution rich in individuals, biomass, and species' number), SWQ Class III (*alpha-mesosaprobic* – heavy pollution with tolerant macroforms), and SWQ Class IV (*polysaprobic* – extreme pollution with macro benthic life restricted to air-breathing animals). Three intermittent sub-classes of these four major Saprobic Water Qualities (SWQ), viz. I-II, and II-III and III-IV can also be identified. By doing so, the Bagmati River water shows a continuum state of water quality in terms of macro-invertibrates (Figure 32). The description of each water quality class is based on abundance and diversity of macro-zoobenthos present in the river.

Table 5.11 shows that varieties of clean river water species prevail in the headwater region (Classes I and I-II), and only a few tolerant species dominate in the



Source: Data B. Pradhan; Map ICIMOD

Figure 32: Saprobic water quality class, Bagmati River

Table 5.11: **Distribution of macro-invertebrates by SWQ class along the Bagmati River**

Group	Number of families by SWQ class							Total
	I	I-II	II	II-III	III	III-IV	IV	
Tricladida	1	1	1	1	1	0	0	5
Gastropoda	2	1	2	3	2	2	1	13
Oligochaeta	1	1	1	1	1	2	1	8
Hirudinea	1	0	1	1	1	1	0	5
Ephemeroptera	5	6	6	5	4	3	1	30
Odonata	3	2	3	2	2	2	0	14
Plecoptera	2	3	2	1	0	0	0	8
Heteroptera	2	2	3	3	5	3	1	19
Coleoptera	3	3	3	2	2	2	1	16
Megaloptera	1	1	1	1	0	0	0	4
Trichoptera	7	5	4	2	1	1	0	20
Diptera	6	7	4	3	4	5	2	31
Total families	34	32	31	25	23	21	7	173

Source: Pradhan 1998

highly-polluted city core region (Classes III-IV and IV). This indicates that aquatic biodiversity exists in the headwater region, and it is poor in the core areas of the cities because of organic pollution (Pradhan 1998).

Only SWQ Class I with simple physical treatment and disinfection and most of the sample sites of SWQ Classes I-II with normal full physical and chemical treatment with disinfection and SWQ Class II with intensive physical and chemical treatment with disinfection can be used as water for drinking.

Impact

Water ecology

Anthropogenic factors are undoubtedly solely responsible for altering the pristine state of the rivers. As mentioned earlier the rivers in the valley have been major sites for urban solid waste disposal, household effluents and open defaecation, and industrial effluents. Other activities such as dumping debris, agricultural residue, cremation of dead bodies, slaughtering, squatter settlements, animal sheds, washing clothes, and quarrying of pebbles and sand are also water-polluting factors (Tuladhar 2006).

As noted earlier the river water is already mixed with wastewater, which is extracted by pumping or by manual extraction for irrigation. Wastewater is accumulated in shallow ponds to settle for some days before using it for agriculture. Farmers are aware that they should never use wastewater directly in agriculture because it causes a decline in crop yields.

Source: D. Tuladhar

Squatter settlement along the river, Chandani Nagar, Kathmandu Valley

Wetlands

Since wetlands provide habitats for a number of endemic and threatened biological species, human groups rely on wetland resources for their livelihood and they are valuable for ecological maintenance and socioeconomic development. Unfortunately, however, the wetlands of the valley and their rich biological resources are facing threat due to the growing demand for land and a variety of products and services. Among these threats are siltation, eutrophication, over-exploitation and illegal harvesting of wetland resources, pollution, overgrazing, encroachment, development activities in adjoining areas, drainage, and floods. Due to conflicts among the local people over the resources in and around wetlands and absence of an effective mechanism to ensure efficient local-level management of these valuable resources, valuable biological species are gradually becoming extinct.

Eutrophication of most of the valley's water bodies is increasing rapidly due to human interference. For instance, a study of three ponds — Bhinpukhu, Lavapukhu, and Taudah — shows that the nutrient concentration in these ponds increased due to human interference. Water hyacinths in Taudah have increased. Likewise, the nitrogen and phosphorus and chl-a concentration has also increased, showing that the pond's environment is eutrophic. Further, there is a dominance of green algae, *Straustrum tetracerm,* in Taudah and blue green algae, *Microcystes* sp, in Bhinpukhu and Lavapukhu. The dominant animal species are *Copepoda* for Taudah and *Rotifera* for the other two ponds. The water quality in these three ponds is biologically not suitable for domestic purposes due to the presence of faecal coliform (>100cfu/100ml) and high heterotrophic counts (>10000cfu/ml). The productivity of these ponds seems to have increased through autochthonous (inner sources) and allocthonous sources (outside sources) of the water bodies.

Public health

Water pollution is the most serious public health issue in Kathmandu Valley. There is a vital connection between water and health. Solid waste disposal and dumping household and industrial effluents into the rivers and so on are responsible for the deteriorating quality of river water, causing water-borne diseases such as diarrhoea, dysentery, cholera, and skin diseases. Next are the water-washed diseases which occur as a result of poor sanitation.

In addition, when the total treatment capacity for drinking water is lower than the amount of water produced, the quality of drinking water becomes substandard. For instance, in 1998, treated water coverage of the total water supply was over 80% (NWSC 1999). However, most drinking water samples in the valley have residual chlorine levels lower than the WHO standard of 0.2 mg/l (ENPHO 2000). This means that the treatment of drinking water is not effective.

Source: P. Dangol

Bhinpukhu, Kirtipur, Kathmandu, Nepal

A report from Teku Hospital in Kathmandu shows that 16.5% of all deaths had been due to water-borne diseases (Metcalf and Eddy 2000). Table 5.12 summarises the occurrence of diseases caused by poor water quality.

Table 5.12: **Diarrhoeal and worm infestation diseases**

Area	Total OPD visits	Patients with diarrhoea		Patients with worms	
		No.	%	No.	%
Nepal	8,642,852	816,481	9.4	666,362	7.7
Bhaktapur	31,988	2,265	7.1	1,787	5.6
Kathmandu	173,042	15,144	8.8	9,193	5.3
Lalitpur	94,655	7,263	7.7	5,745	6.1

Source: Department of Health Services 2003

Table 5.13 shows the common types of intestinal parasites in stool samples (n=460) tested at the Communicable Diseases Hospital, Kathmandu. The positive samples account for nearly 37% of the total. All parasites in the stool samples are caused by poor hygiene and sanitation.

Table 5.13: **Types of parasites in stool samples**

Parasites	No.	%
Ascaris lumbricoids	48	28.40
Entamoeba histolytica	64	37.87
Hookworm	40	23.67
Giardia lamblia	10	5.92
Trichurus trichura	6	3.55
Hymenolepis nana	1	0.59
Total positive samples	169	100

Source: Teku Hospital, Kathmandu (date: 16 Jul to 16 Aug 2004

The status of health and environmental indicators directly and indirectly related to the quality of water is shown in Table 5.14. In most cases, the valley is better off than the total urban and country average in Kathmandu (worse than both country and urban averages), and access to safe water in Bhaktapur and Lalitpur is poorer than the urban average.

Aesthetic values of water bodies

Public perception is often related to the aesthetic value of river water quality which is generally measured in terms of taste, odour, colour, and clarity. Depending upon these four factors, people decide whether to use water for drinking or other domestic purposes.


Source: D. Tuladhar

Children bathing at a polluted site of the Bagmati River at Gothatar


Source: D. Tuladhar

Sand quarrying activities at Shankhamul

Table 5.14: **Health and environment indicators**

Municipality	Infant mortality/ 1000 live births	Population with access to sanitation (%)	Population without access to safe water %
Bhaktapur	24.01	83.16	19.71
Kathmandu	30.65	92.30	11.05
Lalitpur	40.12	81.42	15.85
Total urban	51.71	77.06	11.46
Nepal	68.51	39.22	20.48

Source: UNDP 2004

In Kathmandu Valley, water bodies like rivers, ponds, and spring sources (kund) are considered to be sacred places for performing religious activities, such as bathing, cremation of the dead, places to worship gods and goddesses, and recreation. The inhabitants now hesitate to perform these activities due to the poor quality of water. The aesthetic values of water bodies have also been greatly affected by the haphazard construction of houses, river bank encroachment, dumping and discharge of household waste and sewage, discharge of industrial effluents into the rivers, and quarrying of sand and stone. 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.

Box 5: Local people's awareness

The people of Chapagoan have raised their voices against the depletion of water sources caused by the Champapur and Purna Stone quarries, which are located in the Jyaluntaar Community Forest. They are continuously raising public awareness about it through publishing flyers and organising rallies.

Source: Pryawarnya (Nepali magazine), 2006, No. 64, pp 33-35

Others

Other activities can have an adverse impact on the aquatic flora and fauna of streams and ponds. The use of local stream water to sell for domestic supplies, irrigation for vegetables, and sand and stone quarrying is increasing, and as a result, employment generation has also increased. 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. This has caused danger to some of the bridges and they could collapse. Such phenomena seem to have occurred basically in the rivers flowing in and around the valley's cities. These have made the river water turbid and caused an increase in loss of biodiversity and the rivers' aesthetic values. The stone quarried from both the rivers and mines is being supplied to an estimated 89 stone crushers in the valley. The continuous quarrying of stone from mines covered by forest is leading to the drying up of water sources.

Response

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

Water resource acts

The Water Resources Act 1993 – This act is of great significance as it vests ownership of all water resources in the State. Private ownership is disregarded. The Act has appropriately recognised drinking water as the priority in terms of order of use, followed by irrigation, farming enterprises such as animal husbandry and fisheries, hydroelectric power, cottage industries, water transport, and others.

The National Water Resources Strategy 2002 – The NWRS aims to develop and manage water resources for sustainable use, ensuring conservation and protection of the environment in a holistic and systematic manner. The following are the major thrusts of the strategy.

- The strategy is to be implemented through adopting three phases of the Water Strategy Formulation Process (WSFP) (WECS 2002): (i) phase 1: 1995-97 – identification of issues, (ii) phase 2: 1998-2001 – formulation of the strategy, and (iii) phase 3: 2002-03 – the National Water Plan (NWP) and Environment Management Plan.
- In the NWRS, drinking water is stated to be the basic minimum need of all human beings. Provision of convenient, safe, and adequate drinking water is the declared commitment of the Government of Nepal. The Tenth Plan document mentions that 85% of the total water demand will be met by the end of the plan period (2008) with gradual improvements in service levels; appropriate sanitation services in rural and urban areas will be provided through community awareness programmes; and infant mortality will be reduced by bringing about a reduction in water-related diseases. To increase the access of the population to drinking water, the following efforts are underway.
  - Rainwater harvesting programmes in feasible areas
  - Community-based water supply and sanitation sector projects, particularly in the mid- and far-western regions
  - Rural water supply projects/water resource management programmes by national and international NGOs in different parts
  - A community-based rural water supply and sanitation programme
  - A small town water supply and sanitation programme
  - A water quality improvement programme
  - A sanitation education and hygiene promotion programme
- The Water Resources Strategy (WRS) formulated in 2005 (WECS 2005) envisaged three types of periodic plans to achieve the national water sector goal, 'living conditions of the Nepali people significantly improved in a sustainable manner'.
  - The three types of plan are short-term (5 years) – for implementing a comprehensive water resource strategy; medium-term (15 years) – for provision of substantial benefits to the people; and long-term (25 years) – to maximise benefits accrued from water resources in a sustainable manner

Table 5.15 summarises the estimated costs of water supply and sanitation.

- An NWP has been formulated for the first time in an integrated manner with different sub-sectors related to water. The NWP, which has been prepared through a series of consultations and workshops, contains several sub-programmes related to the water sector and each sub-programme has targets and action programmes (WECS 2005). The targets are specifically divided into three periodic plans: 2007, 2017, and 2027. The water sector sub-programmes are as follows: (a) Water Induced Disaster, (b) Environmental Action Plan on Management of Watersheds and Aquatic Ecosystems, (c) Drinking Water Supply, Sanitation and Hygiene, (d) Irrigation for Agriculture, (e) Hydropower, (f) Industries, Tourism, Fisheries and Navigational Uses, (g) Water Related Information System and River Basin Management, (h) Regional Cooperation, (i) Legal Frameworks, and (j) Institutional Mechanisms.
- In order to complete the planning process, the NWP has included other activities such as an investment plan, environmental management plan, and a monitoring, evaluation, and updating system.

Table 5.15: **Estimated programme costs for water supply and sanitation (in million Rs. at 2003/04 price levels)**

Programme costs	Short term	Medium term		Long term		NWP Total
	10th plan	11th Plan	12th Plan	13th Plan	14th Plan	
Kathmandu Valley	17,116.1	24,878.1	79,00.4	11,009.9	9,542.2	70,446.7
Total programme costs	29,028.8	42,744.9	48,951.4	53,243.7	57,389.3	23,1358.1

Source: WECS 2005

- The following observations can be derived from the drinking water programme of NWSSP (Nepal Water Supply and Sewerage Programme).
  - NWSSP basically emphasises enlarging drinking water coverage, but emphasis alone will not be adequate unless quality (potable) and quantity (per capita) aspects are determined. These two aspects are vital in terms of health and sanitation.
  - NWSSP's health and sanitation education programme to reduce water-related diseases will not be effective unless the water sector defines a potable water standard for Nepal. Further, to make it effective, the living standards of the rural communities need to be raised through providing income-generating activities. This will make them capable of paying the ever-increasing water and sanitation tariffs. However, this issue is not only one for the drinking water sector, it is interlinked with many other sectors related to water, sanitation, and health. A coordination mechanism is required at national, sub-national, and local levels because water-related diseases are connected to all of them.

Irrigation water payments

Farmers in the valley do not pay for the use of river water to irrigate their fields. Virtually there is no irrigation canal in the valley's urban areas and even the traditionally built Raj Kulos are not maintained and therefore are not working. However, the household pays for its sewer connection to the river each month together with the payment for drinking water.

Industries

MoEST is responsible for determining environmental standards. The maximum tolerance by different selected parameters has been determined by NBSM (2003) for three types of effluents, e.g., industrial waste into inland surface water, wastewater from combined wastewater treatment plants (CWTPs) into inland surface water, and industrial effluents into public sewers. Field observations show that these standards are not followed strictly in practice. Similarly, the general standard has been determined as the tolerance limit of wastewater effluents discharged into inland surface waters and public sewers for nine different industries: leather, wool processing, fermentation, vegetable ghee and oil, dairy products, sugar, cotton textiles, soap, and paper and pulp (NBSM 2001). However, the implementation of these standards is not in practice in most cases.

Legislations – acts

Efforts to conserve water resources undertaken by the government through legal measures can be described in terms of the acts and regulations; viz. the (a) Environmental Protection Act (EPA) (1997) and Environmental Protection Rules (EPR) (1997) and the Amendment of 1999; (b) Water Resources Act (1992), Water Resources Regulations (1993), (c) Solid Waste Act (1987), Solid Waste Regulations (1989), (d) Electricity Act (1992), (e) Soil and Watershed Conservation Act (1982), and (f) Aquatic Animals' Protection Act (1965).

However, 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.

Millennium Development Goals (MDG)

The activities planned to help meet the MDG goals by 2015 for drinking water and sanitation are as follows.

(i) Drinking water

- Water supply in Kathmandu is piped and the Melamchi tunnel built
- Total resource requirements estimated = $936 million for drinking water
- Provides 51% of the total drinking water for Kathmandu ($576 million)

(ii) Water and sanitation (WAS)

- Per capita cost for WAS technology for a small town = $40
- Per capita cost for WAS technology for Kathmandu = $312
- No. of additional households to be served per month per VDC = 1.8
- Urban area of an additional five households per ward to be served each month
- To meet the sanitation goals, 2.5 toilets in each VDC and five toilets in each municipal ward to be constructed each month

Future water supply projects

Table 5.16 describes the future water projects for Kathmandu Valley towns divided into three stages.

Table 5.16: **Future water projects – stages**

Duration	Project	Capacity
Short term	Small surface water and groundwater extraction	20 mld
Mid term	System rehabilitation	45 mld
Long term	Melamchi	170 mld

Key: mld = million litres per day
Source: WECS 2005

(i) Melamchi drinking water project

- The Melamchi drinking water project will bring a total of 510 mld to the Kathmandu Valley, and this will be sufficient up to the year 2030. The project will be completed in three stages, viz. (a) Stage I: 170 mld from the Melamchi River, (b) Stage II: 170 mld from the Yangri River, and (c) Stage III: 170 mld from the Larke River.
- Upon completion of the Melamchi water supply project, the consequences can be envisioned as follows.
  - The consumption of water will increase and, as a result, wastewater will also increase and eventually raise the water level in the rivers, rendering them capable of carrying away their loads.
  - The rate of extraction of groundwater will decrease and, as a result, groundwater recharge will increase and be maintained.
  - Settlements, particularly on the river banks, will be at risk due to an increase in the water levels.
  - Awareness in local communities will be raised about water use rights to streams flowing through their own areas. Upstream communities will begin 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 from the Melamchi River with the inhabitants of the Kathmandu Valley for drinking purposes. They are demanding compensation for use of the water from the river.

Other water sector activities

The Ministry of Physical Planning and Works (MPPW) in collaboration with different organisations, including local organisations, NGOs, and INGOs, has introduced the following activities to improve the water quality and environment of the Bagmati River.

ENPHO/ADB/UN-HABITAT/WAN have introduced community wastewater treatment in Madhyapur-Thimi by artificial wetland treatment for 200 households. About 50,000 litres of wastewater have been treated and reused, and an awareness programme is being implemented in the communities and schools.

- Kathmandu municipality has been operating a small-scale, localised wastewater treatment plant at Teku since 1998. The treatment system is based on a constructed wetland management system. KMC is collecting the sludge of 10-15 truckloads (each load with $6m^3$) from the septic tanks of private houses and treating it before discharging it into the river.
- Ecological sanitation (ECONSAN) – as per 2005, the number of Econsan units in the Kathmandu Valley has reached 124.
- The solar disinfection (SODIS) method for drinking water has been introduced by KMC and EDWAG /SANDEC particularly in squatter settlements and schools; it has targeted over 50,000 households for awareness raising). There are about 12,000 SODIS producers in Kathmandu Valley.
- The UN-HABITAT Water for Asian Cities (WAC) Programme Nepal has recently prepared terms of reference for cleaning the Bagmati River. The activities include (i) preparation of a comprehensive local catchment management strategy in one watershed area in the upstream reaches of the Bagmati River System for the Bagmati Area Sewerage Project (BASP), and (ii) preparation of a comprehensive faecal sludge management strategy for Kathmandu Valley for BASP. Likewise, to achieve one of the goals to improve water and sanitation under the MDGs, MPPW, in collaboration with WAC, has introduced programmes to improve water and sanitation in peri-urban centres in the Kathmandu Valley, e.g., Khokana, Bungamati, Siddhipur, and Lubhu.
- Other activities include rainwater harvesting, recharging shallow groundwater through dug wells and ponds, water quality standard acts for approval, wastewater standards approved for nine industries, and water guards.

Figure 33 demonstrates the water disinfectant practices in Kathmandu Valley. The Kathmandu Participatory River Monitoring (KAPRIMO) project is working on a demonstration of a functioning and non-functioning river monitoring system through a participatory approach.

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.

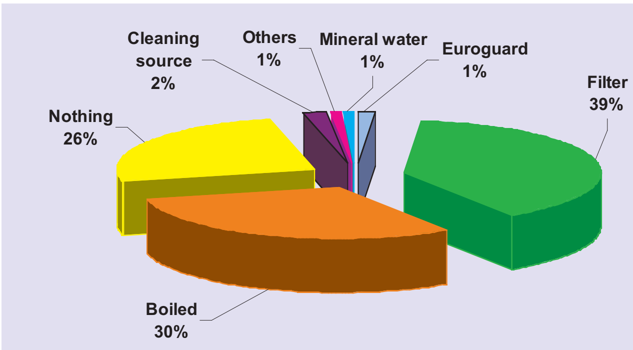


Figure 33: Disinfectant methods

In addition, Nepal is committed to various conventions, treaties, and agreements related to water and sanitation and ecology, such as the Convention on Wetlands which is of of international importance, especially for waterfowl habitats (Ramsar Convention) – to prevent the loss of wetlands, Convention on Biological Diversity (CBD) – to ensure conservation, sustainable use and equitable sharing of the benefits of biological resources, UN Convention to Combat Desertification (CCD) – to combat desertification and mitigate the effects of drought through effective action at all levels, the Basel Convention on Transboundary (international) shipments of waste, the Rotterdam Convention – prior informed consent (PIC) for shipment of chemicals, and the Stockholm Convention – Persistent Organic Pollutants (POPs)