Himalayan Nature
Representations and Reality

Edited by Erika Sandman and Riika J. Virtanen

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CONTENTS

EFFECTS OF URBANIZATION ON WATER QUALITY OF THE BAGMATI RIVER IN KATHMANDU VALLEY, NEPAL

Reena Amatya Shrestha, Xiang Huang & Mika Sillanpää

ABSTRACT

The Bagmati River is holy to the inhabitants of the Kathmandu Valley. Due to population growth and rapid urbanization, the river is under increasing pressure. The water quality of the Bagmati River in the valley is chemically and biologically so degraded that it cannot be used for any purpose, especially during the dry seasons (from March to May).

1. INTRODUCTION

Ancient texts describe Kathmandu Valley as a beautiful lake surrounded by hills and forests. Once a Chinese saint Manjushree formed Chobhar Gorge, drained the water and the valley was settled. Development of the valley began at this point (Jha 1996). It was ruled by Gopal Bansi, Mahisapalas, Kirat, Lichhavis and Malla. Gautam Buddha visited Kathmandu Valley in the Kirat period to develop Buddhism. For cultural, political and business development, the Lichhavis period is considered a golden age. Lastly, the valley was taken over by King Prithvi Narayan Shah from Gorkha in 1769 AD, because it was weakened after it was divided into the three sister kingdoms of Kathmandu, Lalitpur and Bhaktapur in the 15th century by the Malla kings. King Prithvi Narayan Shah made Kathmandu his capital city and united the country, Nepal. Migration of people from other parts of Nepal to the valley continues until the present today. Due to centralization of the administration and education, migration flow is always towards the capital city.

Life in Kathmandu Valley begins with the Bagmati River. The early settlements were located around this river. It is one of the holiest rivers for millions of Hindus throughout the world and for Buddhists. Hindus are cremated on the banks of the river and Buddhists are buried in the nearby hills. Many famous temples are situated along this river. Its source is Bagdwar, on Shivapuri Hill (2,660 m). It flows nearly in the middle of the valley, crossing Chobhar Gorge on the south, where it flows out of the valley to Terai and finally merges with the Ganges River. It is fed mainly by springs and runoff from monsoon rainfall and separates Kathmandu City from Lalitpur City. The river has seven tributaries: Hanumante Khola (from Bhaktapur), Manohora Khola (from Bhaktapur), Vishnumati (from Kathmandu), Dhobikhola (from Kathmandu), Balkhu (from Kartipur), Tukucha (from Kathmandu) and Nakhhu (from Lalitpur). In all, 1.7 million inhabitants live in the Kathmandu Valley, in the capital city along with the other four municipalities of Lalitpur, Bhaktapur, Kirtipur and Madhyapur Thimi. They depend on the water of the Bagmati River and its tributaries. Nearly half of the industries in Nepal are located in the valley. One of the main causes of degradation of the river is the discharge of industrial effluents with or without partial treatment (Paudel 1999). The Bagmati River is under pressure from the increasing population, which more than doubled between 1995–1996 and 2003–2004. The average population growth is estimated at 3.5% per annum for urban areas of the valley (Rajen, Biringer & Betsill 2000). Almost all the sewage effluent of this population drains into the river and its tributaries. Most of the agricultural land and forests have been converted into uncontrolled and unmanaged residential areas. Sand is taken from the river for constructing houses and buildings. This has led to decrease in the capacity for self-filtration and -cleaning of the river. Our major aim is to evaluate the effect of urbanization of the valley on water quality of the Bagmati River by analysing physiochemical properties and comparing them with secondary data.

2. MATERIALS AND METHODS

2.1 Sampling sites

From the historical point of view, the initial societies in Nepal were established along the river. While visiting along the river, we observed that industrial effluents and domestic sewage are discharged with or without partial treatment into the river. Many people were bathing, washing clothes and feeding animals along the river. At some places sand was still taken for building construction. Cremation is still carried out there. Huge amounts of solid domestic and industrial wastes were seen on the bank of the river. We selected 15 sampling sites along the river; the reasons for the selection are shown in Table 1 and Figure 1.

Table 1 Reasons for selection of sampling sites.

No.	Sampling sites	Reasons for selection
1	Shivapuri, Bagdwar	source of the Bagmati River
2	Sundarijal	entrance point to the city
3	Gokarna	park area with fewer inhabitants
4	Boudha	highly populated area
5	Gaurighat I	upstream wastewater treatment plant
6	Gaurighat II	downstream wastewater treatment plant
7	Pashupati Aryaghat	main religious area, nearby cremation site
8	Tilganga	populated area
9	Sinamagal	populated area
10	Minbhawan	before entering Dhobikhola tributary
11	Babarbahal	just after entering of Dhobikhola
12	Thapathali	nearby Patan
13	Balkhu	just after entering Balkhu tributary
14	Teku	just after entering Vishunumati tributary
15	Chobhar	exit of the Bagmati River from Kathmandu Valley

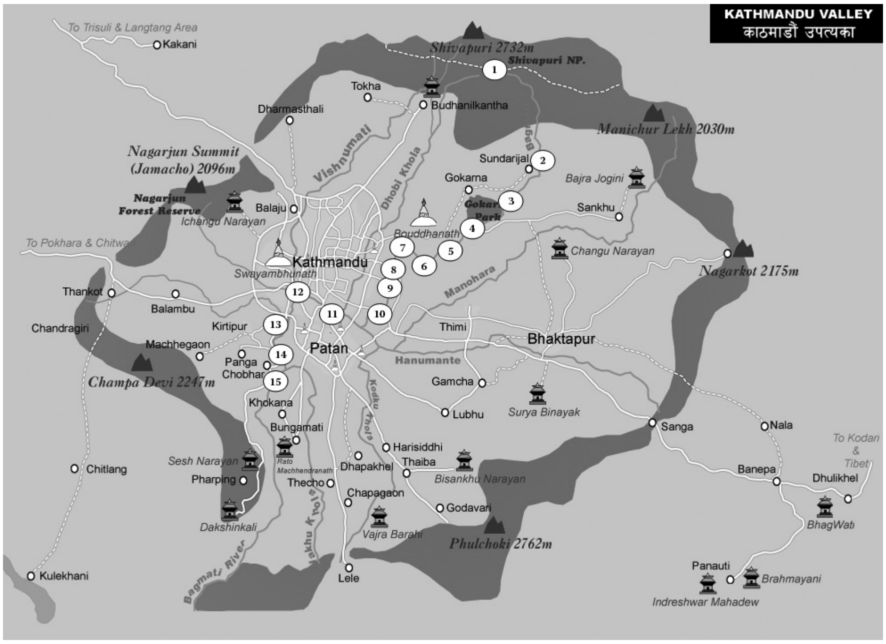


Figure 1 Sampling sites along the Bagmati River. Published with permission from Rirun (www.Lirung.com).

2.2 Sampling

The river water was sampled three times in September 2006, May 2007 and December 2007. The samples were collected in high-density polyethylene and glass bottles cleaned with nitric acid. The bottles and caps were rinsed three times before sampling with water from the sampling site. The samples were kept at 2–5 °C after filling. Suspended matter, sediment, algae and other microorganisms were removed at the time of sampling by filtration (WHO 1996) and preserved as shown in Table 2.

Table 2 Required containers, preservation techniques, and holding times (American Public Health Association 1995).

Parameter	Container	Preservative	Maximum holding time
Conductivity (EC)	P,G	cool, 4 °C	immediately
Flow rate (V)	-	-	immediately
Chemical oxygen demand (COD)	P,G	cool, 4 °C H_2SO_4 to pH < 2	28 days
Chloride (Cl)	P,G	none required	28 days
Hydrogen ion (pH)	P,G	none required	immediately
Nitrite/Nitrate (NO_2/NO_3-N)	P,G	cool, 4 °C H_2SO_4 to pH < 2	28 days
Metals	P,G	HNO_3 to pH < 2	6 months
Orthophosphate (PO_4 -P)	P,G	filter immediately cool, 4 °C	48 hours
Oxygen, dissolved probe (DO)	G	none required	immediately
Total dissolved solids (TDS)	P,G	cool, 4 °C	7 days
Total suspended solids (TSS)	P,G	cool, 4 °C	7 days

* P = plastic, G = glass

2.3 Physiochemical analysis

Water pH, temperature, appearance, odour and flow rate were measured in situ, using adequate sensors. Dissolved oxygen (DO) and conductivity (EC) were measured on site (Chemito Technologies Pvt. Ltd. (Thermo Fisher Scientific Inc.) Mumbai, India). The concentration of nitrite/nitrate (NO_2/NO_3-N) and orthophosphate (PO_4-P) were determined spectrophotometrically (Chemito) within several days after sampling. Total suspended solids (TSS) were determined gravimetrically, using Whatman 41 filter paper (Whatman International Ltd. (GE Healthcare), Maidstone, Kent, UK). Total dissolved solids (TDS) were measured by with a TDS meter (HANNA Instruments Inc, Woonsocket, RI, USA). Metals were determined by AES (atomic emission spectrometry) and AAS (Chemito, Thermo Electron Corporation, 949940021001, Solar MAA system). Measurement of BOD_5 (biological oxygen demand; the amount of dissolved oxygen consumed in 5 days by biological processes breaking down organic matter) and COD (chemical oxygen demand) were carried out as in *Standard Methods* (American Public Health Association 1995).

3. RESULTS AND DISCUSSION

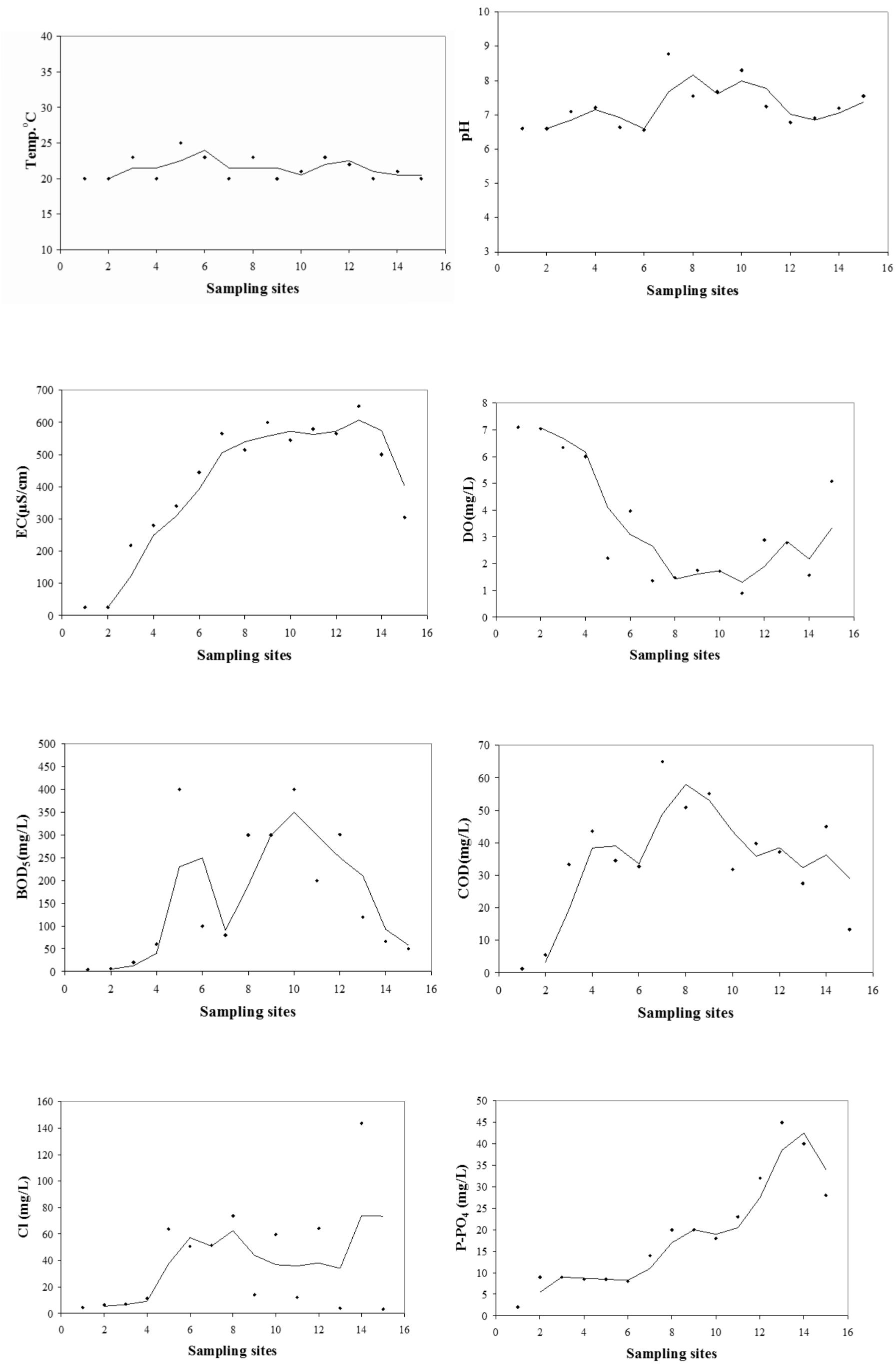
3.1 Physiochemical condition of the Bagmati River

Figure 2 shows the average water quality data of the Bagmati River. The pollution increases gradually after entering the cities and decreases after leaving the valley. The average temperature was about 25 °C throughout the river. The pH increased after sampling site 6, possibly due to religious rites. At point 7, ash may have led to an increase in pH value as a result of cremation. The river then enters the highly populated areas. At the exit point of the river (point 15), the pH decreased to neutral. The EC levels increased gradually after point 2 with increase in population. The average DO decreased after point 6, sometimes to anoxic levels. BOD_5 levels increased rapidly after point 4; at points 6 and 7, the BOD_5 values were low, probably due to the wastewater plant in Gaurighat.

Otherwise, the BOD_5 levels in the Bagmati increased until exit point 15. Up to this point, the water is not drinkable in terms of BOD_5 value. DO and BOD_5 are the best indicators for the health of the river (Mahat, Chhetri & Ale 2007). Most of the industrial units are on the banks of the river and its tributaries. Paudel (1999) estimated that the daily BOD_5 generation in the Kathmandu Valley from industries and the population is about 42 tonnes. Not only the BOD_5, but also the COD was very high for the river after point 2. The values of chloride (Cl), and ammonium-nitrogen (NH_4-N) are relatively high, probably due to low DO concentrations (Bhatt & McDowell 2005). Figure 2 gives the average water quality values, but the physiochemical parameters were almost constant during the post- and pre-monsoon periods. The worst conditions were observed during the dry season in the river, the water quality was slightly improved during the monsoon period (data not shown). Sharma & Shakya (2006) showed that population density is the most important driving force in degradation of the water quality of the Bagmati River in the Kathmandu Valley.

3.2 Pollution trends in the Bagmati River

Several studies were carried out in recent decades to assess the water quality of the Bagmati River. In comparing the parameters at certain points, it was


Temp. °C
Sampling sites
pH
Sampling sites
EC(µS/cm)
Sampling sites
DO(mg/L)
Sampling sites
BOD5(mg/L)
Sampling sites
COD(mg/L)
Sampling sites
Cl (mg/L)
Sampling sites
P-PO4 (mg/L)
Sampling sites

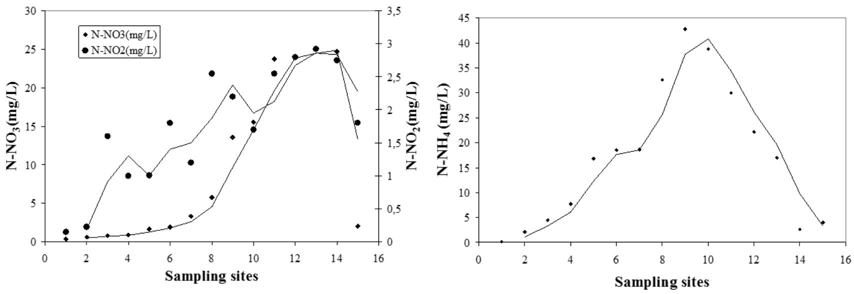


Figure 2 Average water quality data at the Bagmati River (2006–2007).

clearly seen that population growth, urban growth and expansion affected water quality. MoPE (1999) showed that between 1984 and 1994, the valley's urban area increased by 5,282 ha. Kathmandu Valley, being the economic and administrative centre of Nepal, has experienced a very high population growth rate in recent decades. The population census carried out in 1981 showed that the population was 766,345, which increased to 1,105,379 in 1991 census, with an annual growth rate of 4.2%. The population census data for 2001 revealed that there were 1,656,951 inhabitants in the Kathmandu Valley by late 2001; an annual growth rate of 4.9% per annum (ESPS 2003). These factors directly affect the water quality of the Bagmati River. There was tremendous increase in values, especially of EC, BOD_5, COD, NH_4-N and PO_4-P (Table 3).

4. CONCLUSION AND SUGGESTIONS

Water pollution is caused mainly by the discharge of partially treated or nontreated sewage, wastewater runoff from households and industrial effluents. The river water has deteriorated with respect to major water quality parameters such as DO, BOD_5, Cl, PO_4-P, pH etc.

Along with the physical development of Kathmandu Valley, the migration of human populations should be controlled. There is a partial or complete lack of refuse collection services and deficiency of sewage treatment. We strongly recommend that solid waste must be managed and wastewater from households and industries should be treated before discharging into the river. Rivers and their tributaries are national assets and have great economic value, thus we must protect them.

ACKNOWLEDGEMENTS

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Table 3 Pollution trends in various periods.

Sampling site/ parameters	2006–07	2000	1997	2006–07	2000	1997
	Gokarna			**Pashupati area**		
Temperature °C	23	16	-	20	17.4	-
pH	7.1	7.3	7.6	8.8	7	6.5
EC(μS/cm)	218	148.5	70	565	333.5	360
DO(mg/L)	6.3	7	6.7	1.4	1.55	<0.5
BOD5(mg/L)	20	17	-	80	47	-
COD(mg/L)	33.3	23.5	21.6	65	61.5	273.6
Cl(mg/L)	7.1	-	-	51.4	-	-
NO_3-N(mg/L)	0.8	1.6	-	3.3	4.3	-
NO_2-N (mg/L)	1.6	-	-	1.2		-
NH_4-N(mg/L)	4.48	4.5	0.16	18.6	14.13	16.8
PO_4- P(mg/L)	9	0.31	-	14	1.68	-
	2006–07	2000	1997	2006–07	2000	1997
	Minbhawan			**Teku**		
Temperature °C	21	15.5	-	21	14.7	-
pH	8.3	7.2	-	7.2	7.7	7.1
EC(μS/cm)	545	417.5	-	500	458	740
DO(mg/L)	1.72	1	-	1.57	1.43	<0.5
BOD5(mg/L)	400	56	-	66	41	-
COD(mg/L)	31.8	70.5	-	45	55.9	378
Cl(mg/L)	59.6	-	-	143.7	-	-
NO_3-N(mg/L)	15.55	3.61	-	24.8	2.86	-
NO_2-N(mg/L)	1.7		-	2.8	-	-
NH_4-N(mg/L)	38.8	20	-	2.6	17	42.8
PO_4- P(mg/L)	18	2.6	-	40	1.83	-