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WATER QUALITY IMPACTS OF HYDROPOWER PROJECT OPERATION IN BHOTEKOSHI RIVER BASIN SINDHULPALCHOWK DISTRICT IN NEPAL

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ABSTRACT: This study examines the impacts to Bhotekoshi River due to construction of a hydropower system in it. Bhotekoshi is a snow fed River, which originates from Himalayas in Tibet and pass through Nepal and confluences to Saptakoshi River. A range of physical, chemical and bacteriological water quality parameters around the project were studied from three different period, 1995-during EIA study, 1998- monitoring period and 2010- this study. The 1995 study showed high levels of total coliform, large volume of suspended load, high turbidity and lower BOD. During construction period in 1998, there was decrease in turbidity, suspended solids, and substantial improvement in other chemical and biological parameters because of the controlled conditions. It recorded increased temperature, reduced hardness upstream to downstream, more acidic pH, dissolved oxygen ranging between 7.50 and 8.50 mg/L as well as very poor microbial quality. The 2010 study revealed that the water was moderately hard (mean range of 5-72 mg/L $CaCO_3$), salty and neutral with mean *p*H of 7.98±0.852643. Conductivity, TDS, and the major ions varied with elevated levels in the rainy season. The higher range of mean temperature, natural pH, increasing magnitude of mean conductivity downstream of powerhouse and decreasing trend in upstream powerhouse, higher turbidity at dam and downstream powerhouse site and lower turbidity in other stations, reduced hardness from upstream to downstream, higher DO in dam site etc are the main attributes found out in 2010. Total coliform pollution found occurred in all sampling stations, which suggests that the river water is unsuitable for domestic use due to increasing upstream discharges, riverside settlements, and release of households waste into the river. The finding have revealed that the project operation enhanced the cumulative impacts on the river system and mitigation measures taken during construction did not helped much to maintain the river water quality.
Keywords. Water quality Parameters, Bhotekoshi River, Hydropower project, Variations, Cumulative Impacts

INTRODUCTION

The Upper Bhotekoshi River is a tributary of Saptakoshi River system and one of the important freshwater resources of Nepal. It originates from Tibet where it is known as Poiqu. The Bhote Koshi and Sun Koshi can be considered together as one basin. The Sunkoshi River meets with Bhotekoshi at about 25 km downstream of the Upper Bhotekoshi Hydropower Project (UBHP) site. After which the river is known as Sunkoshi all along until it joins with Sapta Koshi River. The Trishuli basin is located in the west and the Arun basin in the east and north of the Bhotekoshi-Sunkoshi basin. All other Major tributaries of the Bhote Koshi that drains from the south of the Himalaya originate in Nepal.

The construction of dam in the riverine system changes the biological and ecological conditions of rivers. Alteration occurs in the floral and faunal characteristics near the dammed site (Ogbeibu and Oribhabor, 2002). The developments like construction of dams and barrages along the river results in low water flow (Hassan et al., 1998a, 1998b). Dams causes physical alteration of tail waters or downstream areas, changes in water temperature, channel morphology or stream substrates and loss of spawning and rearing habitat due to upstream flooding, thus impacting indigenous fishes (Shrestha, 1981).

The river basins in Nepal have undergone extensive changes and exponential demographic growth, thus created adverse effects to aquatic bio-diversity especially the native fish fauna. The greatest danger occurs to the migratory fishes, as the dam obstructs their migratory path, and so they may be totally displaced (Naidu, 1993; Shrestha, 1997; Shrestha et al., 2001; Arya et al., 2001). Fisheries resources of Nepal have been drastically reduced due to the barrier effect of dams, environmental changes, and pollution in waterways. Damming sets a blockage to fish movement, upstream or downstream. In passing through the turbines, spillways or in the diversion, fishes are subjected to injury by physical contact, pressure change, shear force, or eddies (Naidu, 1993; Moss, 1998). It may change the flow downstream by making it more irregular. The nature of the river bottom will change, the water quality may change too (Moss, 1998; Gutzer et al., 2002). Study on the impact of dams on different rivers in Nepal indicated its potential to alter the health and integrity of the rivers with effects being more serious upstream (Jha et al., 2007).

Biological monitoring methods have been used to complement physical and chemical measurements in assessing river condition. Several bio-monitoring methods have been developed all over the world for the evaluation of water quality (Sharma, 1996). To study the biological monitoring processes we need application of site-specific biological criteria assessment process (Roshenberg and Resh, 1993; Sharma and Moog, 1996).

The ecosystem services of watercourses such as rivers and lakes directly or indirectly contribute to both human Welfare and aquatic ecosystem (Costanza etal., 1997). Rivers also play an important role in the assimilation and transport of domestic and industrial wastewater, which represent constant pollution sources, and agricultural runoff, which is temporal and commonly affected by climate (Singh, Malik, Mohan, & Sinha, 2004; Vega Pardo, Barrado, & Deban, 1998). Rivers are highly Vulnerable to pollution; therefore, it is important to Control water pollution, monitor water quality in river Basin (Simeonov etal. 2003), and interpret the temporal and spatial variations in water quality (Dixon & Chiswell, 1996; Singh etal., 2004). Water resources are under pressure and are in danger because of potential pollution and contamination due to rapid industrialization, increasing population pressure, urbanization, modern agricultural activities, and other anthropogenic activities (Hatcher & McGillivary, 1979; Hutley, 1990; Agarwal et al., 2006 and Singh et al., 2007).

In Nepal, environmental issues are addressed on policies and programs since 1980s. The sectoral policy such as Water Resources Development Policy (2002), Water Resources Act (1992); Electricity Act (1992); Electricity Regulation (1993), and Hydropower Development Policy (1992) etc. have emphasized environmental issues to address significant adverse environmental impacts of development activities in terms of physical, biological, socio-economic, and cultural aspects and their management dimensions. The National Environmental Impact Assessment Guidelines (NEIAG) in 1993 was the first lesson-learnt document to introduce EIA system and process in Nepal. Later on Government of Nepal has enacted legally binding documents as, Environment Protection Act, 1997 (EPA97) and the Environment Protection Regulation, 1997 (EPR97). According to the provision of EPA and EPR 1997, all hydropower projects require Environmental Assessment before its implementation. The EIA of Bhotekoshi Hydropower Project was conducted by International Union for Conservation of Nature (IUCN) in 1995 and environmental monitoring during the construction and now project is in operation since 2002. Thus, the study now focuses to identify impacts on river water quality regarding physicochemical and bacteriological characteristics making a comparative analysis with the studies made during the project implementation. The mankind intervention towards hydropower development is a major concern maintaining river water quality and its aquatic ecosystem.

Study Area/Location

The Bhote Koshi River originates from the Tibet Autonomous region of China and set steep across the high Himalayan zone (Figure 1).

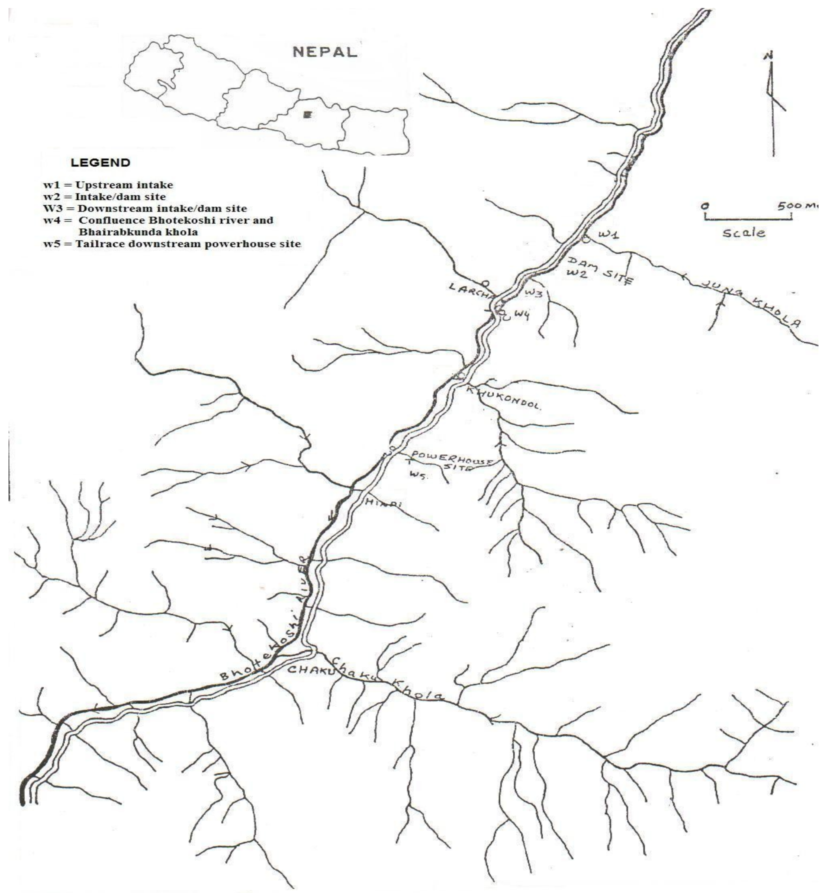

Figure 1. Location of Sampling Stations at Bhotekoshi River

Thus, its catchment area occupies both side of Himalaya. At this project site, total catchment area of Bhote Koshi is 2,132 sq km. of which 2,050 sq km (about 96 percent of total basin area) lies in Tibet. Only 26 sq km of the area in Tibet and 30 sq km of the area in Nepal lies below 3,000 m. The total length of the Bhote Koshi within the Tibetan highland, where it is known as Poiqu, is about 81 km, 9 sizeable tributaries of Bhote Koshi in the north of Himalaya's drains entirely from Tibet. Two streams in the south of Himalaya – Liping Khola and Jung Khola drain both Nepalese and Tibetan territories. All other Major tributaries of the Bhote Koshi that drains from the south of the Himalaya originate within Nepal.

The project site is located along the deep Bhote Koshi gorge. The elevations at the dam and powerhouse site are 1,440 m and 1,285 m above mean sea level respectively. Bhairabkunda and Khukundol Khola are the main streams that drain into the Bhote Koshi. Further downstream from the project site the notable streams draining in the Bhote Koshi are Jimrinha Khola, Chaku Khola and Kamlung Khola located approximately 5 km east of Jhirpu (powerhouse site) before it mix with Sunkoshi.

The Upper Bhote Koshi Hydroelectric Project (UBKHEP) is a run-of-the-river scheme constructed on the Bhote Koshi River, a tributary of the Sun Koshi River, in Sindhupalchowk District of central Nepal. The project is located approximately 110 kilometers northeast capital of Kathmandu near the Sino-Nepal border. Water diverted from the side intake is conveyed to a surface powerhouse through a headrace conveyance system comprising a surface desanding basin located adjacent to the weir, a 3.3-kilometer-long headrace tunnel, a restricted-orifice type surge tank and a 450-meter-long, 2.8-meter diameter steel penstock. The Project has an installed capacity of 45 MW, with two turbine/generator units however the project is generating 36MW as per Power Purchase Agreement (PPA) to the Nepal Electricity Authority.

The powerhouse is constructed at Jhirpu Village located approximately 3.7 kilometers downstream of the diversion dam. The entire Project is accessible from Arniko Highway, which connects Kathmandu with the Sino-Nepal border at Kodari. Bhote Koshi Power Company Pvt. Ltd. (BKPC) has undertaken development of the Upper Bhote Koshi Hydroelectric Project. The UBKHEP Plant was synchronized to the NEA grid on January 3rd 2001, and commercial operation started on January 24th 2001. The water quality tested in project impact area during EIA study in 1995 and environmental monitoring period in 1998 are the main reference values to identify the impacts on the water quality in present study.

MATERIAL AND METHODS

Different sampling locations were determined considering the project impact area. To determine sampling locations pervious locations of EIA studies, locations determined during monitoring period were considered to facilitate comparative analysis. In this study, five sampling locations (W_1= upstream intake, W_2= intake/dam site, W_3= downstream intake/dam site, W_4=confluence between Bhotekoshi River and Bhairabkunda khola, W_5=tailrace downstream powerhouse site) in the project area on the river basin were selected considering the pervious water sampling locations (Fig.1).

Water quality parameters like temperature, pH, total dissolved solids, and electric conductivity were measured in the sites using, a thermometer, pH meter, conductivity meter and TDS meter respectively. For dissolved oxygen (DO), samples were collected into 300-ml plain glass bottles and the DO fixed using the azide modification of the Winkler's method. Samples for bacteriological analyses were collected into sterilized plain glass bottles. For oil, grease, and other parameters samples were collected in simple plastic bottles. All samples of 5 stations were stored in an icebox and transported to Kathmandu University's Laboratory for analyses. The method used for water quality test are presented below in the Table 1.

The results obtained were also compared against the threshold values of Basic procedures followed were based on WHO guideline (1987), National Drinking Water Quality Standards (NDWQS 2062 B.S.) and Guidelines set by European Union. Descriptive statistics of the data set are presented in (table 4). The data obtained were standardized and subjected to principal components analysis (PCA) extraction to simplifying its interpretation and to define the parameters responsible for the main variability in water quality variance.

In this study, temporal variations in water quality Parameters were primarily evaluated using Spearman's R coefficient, a non-parametric test often used to evaluate the correlation structure between water quality parameters with non-normal distributions (Singh etal. 2004; Shrestha & Kazama, 2007; Wunderlin etal. 2001).

The water quality test result of 15 parameters of two sampling stations collected in 14 February 1995 during the EIA study and 11 parameters of 3 designed locations tested in 1998 during construction period of Bhotekoshi Hydropower Project were examined. The variations in water quality parameters from 1995, 1998 and 2010 were evaluated and standardized.

Mean values of different physico-chemical and biological characteristics (Mean±*SD* and range) from 1995 to 2010 are shown in Table 2, 3 and 5. Significant variations have been observed in the values of temperature, pH, conductivity, TSS, TDS, alkalinity, hardness.

Table 1. Water quality test methods and test units

Parameters	Test unit	Method
Temperature **1**/	^{0}C	Thermometer
pH **1**/	-	Electrometric
Turbidity	NTU	Spectrophotometric
Electrical Conductivity **1**/	µS/cm	Electrometric
Total dissolved solids**1**/	mg/l	Electrometric
Total suspended solids	mg/l	Filtration
Total alkalinity	mg/l as $CaCO_3$	Titration & Electrometric
Total hardness	mg/l as $CaCO_3$	Titration, Na_2EDTA
Total Nitrogen	mg/l	Kjeldabl method,
Lead (pb)	mg/l	Atomic absorption Spectrophotometric
Dissolved oxygen (DO)	mg/l	Titration and Electrometric
Chemical Oxygen Demand (COD)	mg/l	$K_2Cr_2O_7$, Digestion
Biological Oxygen Demand (BOD)	mg/l	5 days incubation
Total Coliform	Cfu/100 ml	Membrane filter
Faecal Coliform	Cfu/100 ml	Membrane filter

1/ These parameters are tested both on field and in laboratory

The available data related to the concentration of water quality variables were standardized to make them compatible. To standardize the concentration of the water quality pollutant such as TDS, the measured concentration was divided by the corresponding standard value. For some water quality variables such as DO, which a higher concentration shows a better water quality condition, the observed concentration is standardized by dividing the measured concentration by the related standard.

RESULT AND DISCUSSION

Water Quality during EIA Study, before Project Construction (1995)

The surface water in the project area was relatively clear in the dry season due to very low sediment load and few sources of pollution. The range of Biological Oxygen Demand (BOD) was 0.04 to 0.6mg/l with its standardized value of Mean±*SD* (32±0.395) which indicated low level of contaminants including solids and BOD (Table 2). The range of Total Coliform was 23 to 1200 MPN Index/ 100 ml with its standardized value of Mean±*SD* (611.5±832.264) which was much higher in each sample than the value (0 in 250ml of sample) of WHO guideline.

High levels of coliform, was probably due to discharge of domestic sewage from the upstream settlements such as Tatopani, Kodari, Khasa and Nyalam into the river and open defection along the riverbanks. During the monsoon, the turbidity of Bhote Koshi and its tributaries was found increases due to large volume of suspended load. BOD level was lower probably because of the higher volume of flow.
Water from both Bhote Koshi and Bhairabkunda Khola was not found suitable for drinking without appropriate treatment including disinfection. The level of physical and chemical pollution, however, lies within the WHO guideline value for drinking and recreational water quality in natural rivers.

Water Quality during Monitoring, Project Construction Period (1998)

The test result show marked decrease in turbidity, suspended solids and substantial improvement in the chemical and biological qualities of river water in comparison to the similar test carried out in pervious study. The DO range 6.5 to 8.5mg/L with Mean±*SD* (5±1) contents are good towards the test result of 1995 and corresponding range of BOD with 1.5-2.52 mg/L with Mean±*SD* (2.093±0.530), COD range of 3-18.5 mg/L with Mean±*SD* (9.333±8.129) and low in concentration oil and grease range of 1-2.75mg/L with Mean±*SD* (2.126±0.977) respectively (table 3). This was due to:

- Natural decrease in turbidity and suspended solids at the end of raining season.
- The construction activities and spoil disposal in the riverbanks was minimized
- Household effluents were controlled.

Table 2. Water Quality Analysis in 1995 during EIA Study (before construction of the project)

Parameters	**Sampling Stations**		**Standardized Value**		**Standards**	
	W_1	**W_4**	Mean±*SD*	**Range**	**WHO**	NDWQS
Temperature (°C)	6	8	7±1.414	6-8	-	-
pH	7.23	8	7.615±0.5444	7.23-8	6.5-8.5 **1**/	6.5-8.5
Turbidity (NTU)	200	1	100.5±140.714	1-200	<5 NTU**1**/	-
Color (chromacity unit)	0.05	0.05	0.05±0	0.05-0.05	15 mg/l Pt-Co**1**/	-
Total suspended solids (mg/L)	3.6	1.6	2.6±1.414	1.6-3.6	-	-
Electric conductivity (µS/cm)	102	56	79±32.526	56-102	-	1500 (Max)
Total dissolved solids (mg/L)	93	48.5	70.75±31.466	48.5-93	100	1000 (Max)
Total Solids (mg/l)	96.6	50.1	73.35±32.880	50.1-96.6	-	-
Oil and grease(mg/l)	6.4	6.4	6.4±0	6.4-6.4	-	-
Sodium (mg/l)	3.75	1.75	2.75±1.414	1.75-3.75	200 mg/l	-
Dissolved Oxygen (mg/L)	9.7	9.4	9.55±0.2121	9.4-9.7	Less than 75% of the saturation concentration **1**/	-
Total Coliform (MPN Index/ 100 ml)	1200	23	611.5±832.264	23-1200	0 in 250ml of sample **2**/	-
E-coli (MPN Index/100ml)	11	0	5.5±7.778	0-11	Nil	-
Biological Oxygen Demand (BOD mg/l	0.6	0.04	0.32±0.395	0.04-0.6	-	-

Source: IUCN Nepal (February 1995).
1/these are the desirable level set by WHO but are not the set guidelines.
2/Guidelines set by European Union
Sampling Locations: W_1= upstream intake and W_4=confluence between Bhotekoshi River and Bhairabkunda khola (Upstream Powerhouse).

The wastewater at Jhirpu was discharged on the adjacent Jholong khola. The Khola had a measured flow of 2 litter of per second. Since the turbidity values of the Bhotekoshi river water have considerably reduced to near about 10, the aquatic environment for fresh water fish might not be impaired due to turbidity alone. The value of other water quality parameters were also observed better as compared to the values observed during pervious tests of construction period (table 3).

Table 3. Water Quality Analysis in 1998 during project monitoring period

Parameters	Sampling Stations			Standardized Value		Standards	
	W_3	W_4	W_5	Mean±*SD*	Range	WHO	NDWQS
Temperature (°C)	11	18	17	15.333±3.785	11-18	-	-
pH	7.3	8	7.2	7.5±0.435	7.2-8	6.5-8.5	6.5-8.5
Turbidity (NTU)	10	9	9.5	9.5±0.5	9-10	<5 NTU	5(10) Max.
Electric conductivity (µS/cm)	73	266	81	140±109.1925	73-266	-	1500 (Max)
TSS(mg/l)	19.02	13.66	14.15	15.61±2.963	13.66-19.02	-	-
TDS (mg/l)	54	180	63	99±70.292	54-180	-	1000 (Max)
Oil and Grease (mg/l)	2.63	2.75	1	2.126±0.977	1-2.75		
COD (CODcr) (mg/l)	3	6.5	18.5	9.333±8.129	3-18.5		
BOD (BOD5) (mg/l)	2.26	2.52	1.5	2.093±0.530	1.5-2.52		
DO (mg/l)	7.5	6.5	8.5	7.5±1	6.5-8.5	Less than 75% of the saturation concentration **1**/	
Total Coliform (Cfu/100 ml)	15	1100+	210	112.5±137.885	15-210	0 in 250ml of sample **2**/	Nil

Source: IUCN Nepal (February 1998).

Sampling Locations: W_3= Downstream Dam Site, W_4= Upstream Powerhouse (Confluence between Bhotekoshi River and Bhairabkunda khola), W_5= Downstream Powerhouse **1**/These are the desirable level set by WHO but are not the set guidelines **2**/Guidelines set by European Union

Water Quality during Project Operation (2010)

The physico-chemical and bacteriological characteristics of River Bhotekoshi selected during 2010 are presented in Table 4.

The range of temperature in this study was observed between 11°C to 18°C with Mean±*SD* 13.1±3.015 which was comparatively high from the period of EIA study in 1995. The range of water temperature in 1995 was 6-8°C and 11-18°C in 1998 (table 2 and 5).

The mean *p*H of the river water was neutral at all stations for the study period with a range of 6.5–8.4 with Mean±*SD* 7.98±0.866. The *p*H fell within the range associated with most natural waters which is between 6.0 and 8.5 (Chapman, 1992), stipulated for drinking and domestic purposes.

Table 4. Water Quality Analysis in 2010

Parameters	Method	Test Result of Five Sampling Stations				
		W_1	W_2	W_3	W_4	W_5
Temperature (°C)	Thermometer	11(6:15AM)	11.5(6:40 AM)	14(7AM)	18(1:20 AM)	11(7:55AM)
pH	Electrometric	6.5	8.5	8	8.4	8.5
Turbidity (NTU)	Spectrophotometric	2	5.7	<1	<1	6.5
Electric conductivity (µS/cm)	Electrometric	21.8	24.4	31.7	18.1	24.9
Total dissolved solids (mg/L)	Electrometric	-	49	60	-	-
Dissolved Oxygen (mg/L)	Azide Modification Method	-	-	7.50	6.50	8.50
Total Hardness (mg/L as $CaCO_3$)	Titration, Na_2 EDTA	46	5	72	40	48
Total Nitrogen (mg/L)	Spectrophotometric	0.25	0.10	0.23	0.42	0.21
Lead (mg/L)		0.01	0.01	0.01	0.01	0.01
Total Coliform (MPN Index/ 100 ml)	Membrane filter	TNTC	-	15	210	1100+

TNTC: Too numerous to count. The data was collected in February 2010.

Physical characteristics

The mean conductivity of the river ranged between 18.1 and 31.7 µS/cm with Mean±*SD* 24.18±5.250. This order of increasing magnitude downstream and decreasing trend from next confluence from Bhairabkunda khola to downstream powerhouse. Relatively lower conductivity towards downstream is probably due to dilution from River Volta which has much lower conductivity (18.1–24.9 µS/cm) (Antwi & Ofori-Danson, 1993). The upstream was always high probably due to the nature of the soil at the water source. The EC increased by a factor of 0.5 between Jungkhola to downstream powerhouse was correlated with the proximity to the river (Fig.2, R^2 =0.25).

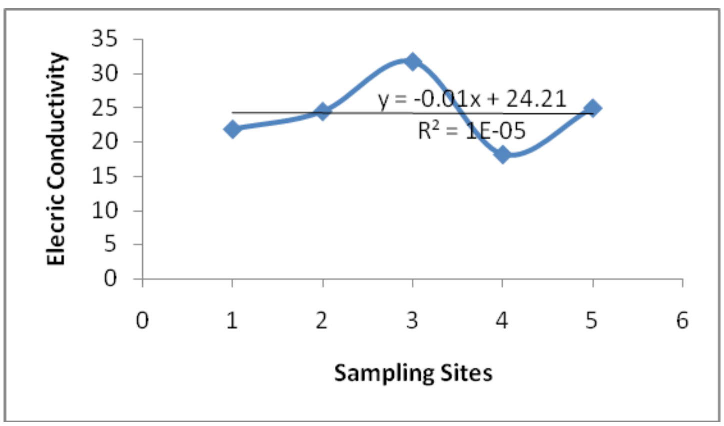

Figure 2. Electric Conductivity of upstream (Jung Khola), within dam and below dam site, Bharaibkund Khola (Below Dam site) and downstream (Powerhouse) of Bhotekoshi River

Mean values of Mean±*SD* 4.733±2.095, turbidity were 2 NTU, 5.7 NTU, <1 NTU, <1 NTU and 6.5NTU for the upstream dam site, downstream dam site and downstream powerhouse, respectively.

The levels of turbidity recorded in this study were comparable to those reported for River Volta at Akuse (mean range 2.8–3.2 NTU) by Water Research Institute (1999). However, turbidity recorded in dam site (5.7NTU) and downstream powerhouses (6.5 NTU) were much higher than those observed in the study. The low turbidity throughout the sampling period suggests that discharges from domestic effluents and run-offs from agricultural activities that reach the river may be minimal or large particulates that readily settled to the bottom (Figure.3). The low turbidity of the river will facilitate water purification processes such as flocculation and filtration, which could reduce treatment cost.

The range of hardness was recorded 5-72 mg/L as $CaCO_3$ with Mean±*SD* 42.2±25.606 which showed that the hardness of the river reduced from upstream to the downstream. The upstream dam, dam site, downstream dam site, confluence of Bhairabkunda khola and downstream powerhouse recorded average hardness levels of 46, 5, 72, 40, and 48 mgl-1 $CaCO_3$, respectively. Alkalinity followed a similar trend as hardness.

Dissolved oxygen (DO) mean levels varied between 7.50 and 8.50 mg/L with Mean±*SD* 17.5±0.894. The downstream had relatively higher oxygen throughout the study. This might be due to the windy nature of the area and the regular mixing of the water with the Volta Lake, which has higher DO content. Pristine surface waters are normally saturated with DO, but such DO can be rapidly removed by oxygen demand of organic wastes. The measurement of DO provides a broad indicator of water quality (DFID, 1999). The concentration of DO in the Bhotekoshi River was above 5.0 mgl-1 and, therefore, the river water could be considered suitable for use of the aquatic ecosystem.

Bacteriological water quality

The results obtained for bacteriological analysis are shown in Table 5. The data collected indicated that the microbial water quality of the Bhotekoshi River was poor. Total and faecal pollution occurred at all sampling stations throughout the sampling period, rendering the water unsuitable for domestic use without treatment. However, the river is suitable for primary and secondary contacts such as swimming and fishing.

Table 5. Physicochemical Characteristic of Bhotekoshi River in 2010

Parameters	Sampling Stations (2010)					Mean±*SD*	Range
	1	**2**	**3**	**4**	**5**		
Temperature(°C)	11	11.5	14	18	11	13.1±3.015	11-18
pH	6.5	8.5	8	8.4	8.5	7.98±0.866	6.5-8.5
Turbidity (NTU)	2	5.7	<1	<1	6.5	4.733±2.095	2-6.5
Electric conductivity (µS/cm)	21.8	24.4	31.7	18.1	24.9	24.18±5.250	18.1-31.7
Total dissolved solids (mg/L)	-	49	60	-	-	54.5±5.5	49-60
Dissolved Oxygen (mg/L)	-	-	7.5	6.5	8.5	7.5±0.894	6.5-8.5
Total Hardness (mg/L as CaCO3)	46	5	72	40	48	42.2±25.606	5-72
Total Nitrogen (mg/L)	0.25	0.1	0.23	0.42	0.21	0.242±0.122	0.1-0.42
Lead (Pb)	0.01	0.01	0.01	0.01	0.01	0.01±0	0.01-0.01
Total Coliform (MPN Index/ 100 ml)*	TNTC	-	15	210	1100+	112.5±97.5	$15\text{-}1100^{+}$

*Only of 3, 4 and 5 sampling stations, Sampling

Source: Field Study 2010

Sampling Locations: W_1= upstream intake, W_2= intake/dam site, W_3= downstream intake/dam site, W_4=confluence between Bhotekoshi River and Bhairabkunda khola, W_5=tailrace downstream powerhouse site)

The mean range of total coliform counts for the upstream, selected site and the downstream were 112.5±97.5 MPN index/100 ml. (Figure 4) The Total Coliform counts were W_3 (15 MPN Index/ 100 ml); W_4 (200 MPN Index/ 100 ml) and W_5 (1100^+ MPN Index/ 100 ml). These counts were far above 0 cfu/100 ml, which is the recommended limit for no risk (WHO, 1987). These results imply that the water source poses a health risk to consumers. The presence of pathogenic organisms in the water could be attributed to human and animal wastes from the communities along the river.

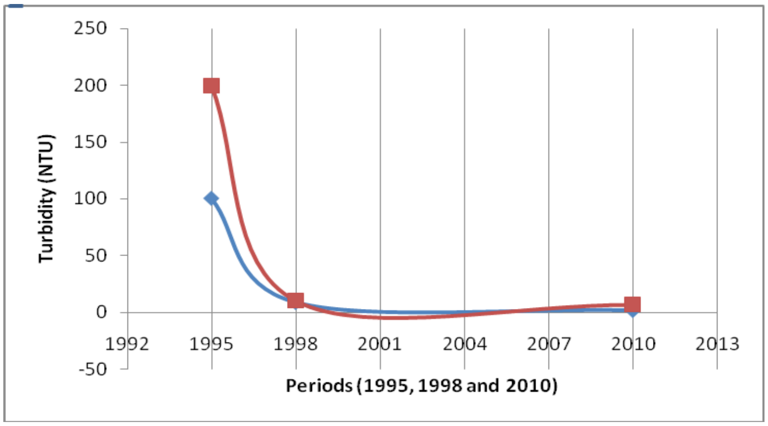

Figure 3. Decreasing Trend of Turbididity from 1995 to 2010

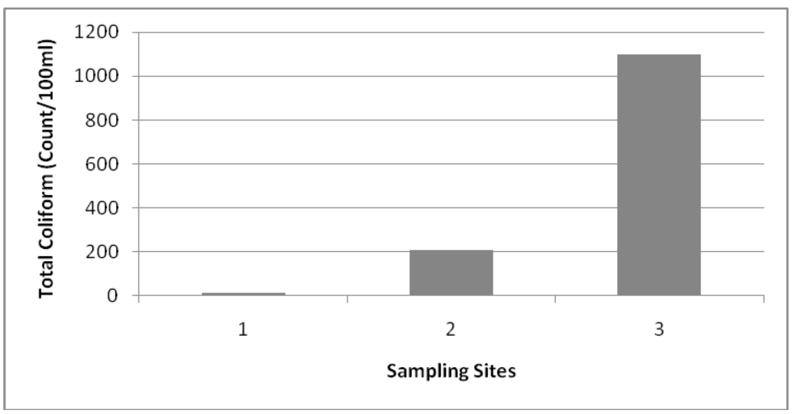

Figure 4. Mean ±SD total and faecal coliforms of upstream (Below dam site), Bharaibkund Khola (Below Dam site) and downstream (Powerhouse) of Bhotekoshi River

Although the value of total coliform was very low in Bhairabkunda khola downstream of dam site but this count was high above). The low value in 3 and 4 station was due to nearby settlements and release of household waste into the river. In the interpretation of microbial data, it is very important to note that microbial constituents have a strong non-conservative behavior in water. The concentration of the amount entering the water could change independently through various processes such as growth, settling to the sediments, chemical reactions and decay (DWAF, 2000).

Among the water quality parameters tested in 1995, 1998 and 2010, seven parameters were examined with threshold criteria against WHO guideline, National Drinking Water Quality Standards (NDWQS) and Guidelines set by European Union. A comparative analysis from 1995 to 2010 was also standardized with mean value and standard deviation. (Table 6). The analysis showed that pH value was found upper and lower limit of slandered value (6.5-8.5) of WHO guideline. Turbidity was found higher than the WHO limits (<5 NTU) except 3 sampling stations recorded in 2010.

Table 6. Comparative Analysis of Water Quality from 1995 to 2010

Parameters	1995		1998			2010					Standards	
	1	**2**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	WHO	NDWQS
Temperature	6	8	11	17	18	11	11.5	14	18	11	-	-
pH	7.23	8	7.3	7.2	8	6.5	8.5	8	8.4	8.5	6.5-8.5 **1**/	6.5-8.5
Turbidity (NTU)	200	1	10	9.5	9	2	5.7	<1	<1	6.5	<5 NTU**1**/	5 (10 Max.)
Electric conductivity (µS/cm)	102	56	73	81	266	21.8	24.4	31.7	18.1	24.9	-	1500 (Max)
Total dissolved solids (mg/L)	93	48.5	54	63	180	-	49	60	-	-	-	1000 (Max)
Dissolved Oxygen (mg/L)	9.7	9.4	7.5	8.5	6.5	-	-	7.5	6.5	8.5	Less than 75% of the saturation concentration **1**/	-
Total Coliform (MPN Index/ 100 ml)	1200	23	15	210	1100+	TNTC*	-	15	210	1100+	0 in 250ml of sample **2**/	NIL

*Too numerous count
1/These are the desirable level set by WHO but are not the set guidelines
2/Guidelines set by European Union

Total Coliform (MPN Index/ 100 ml) was also found higher in the WHO standard (0 in 250ml of sample). The water quality parameters tested from 1995 to 2010 showed that the water quality was found more deteriorated in latest study.
The figure 5 shows that the Electric conductivity was high during the project construction period in 1995 and low after the project operation. Moreover, Electric Conductivity were also correlated with data's of 1995 (R^2 =0.25) where as the ratio was R^2= 0.79 in 1998 with an intercept close to zero.

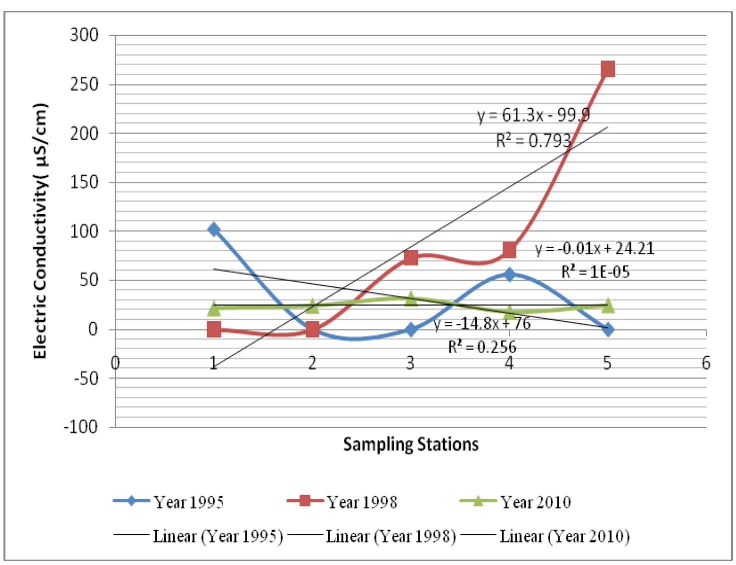

Figure 5. Variation in Electric Conductivity from 1995 to 2010

Water quality trend in figure 6 shows that temperature is higher in post period than pre observation. Water temperature is one important factor in aquatic environment as it affects the organism, as well as the chemical and physical characteristics of water (Delince 1992, Abdo 2005). The pH value Figure 7 shows that the higher and lower in comparison to pre study in 1995 and the monitoring period 1998.

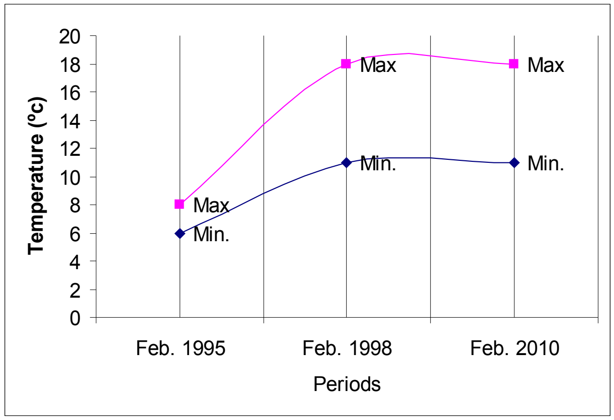

Figure 6. Periodic Variations in Water Temperature

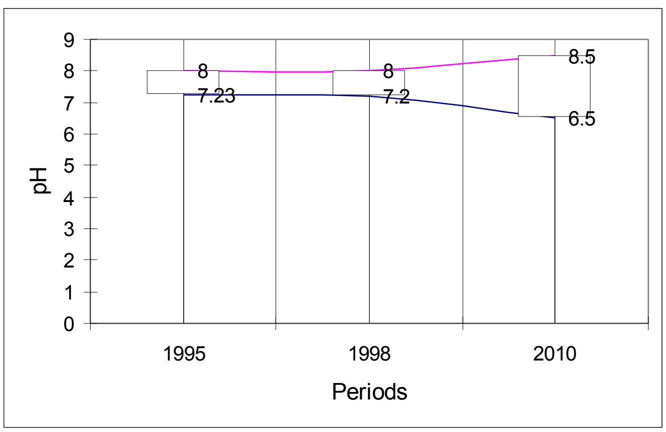

Figure 7. Periodic Variations in pH

Among various physico-chemical characteristics studied water temperature closely followed the trend of atmospheric temperature and pH showed the alkaline nature of the tank indicating that waters are well buffered and in high trophic status, however, decrease in the pH was noticed after
the dip, it may be due to increase in the phosphate level, which may shifts the pH towards acidic side but electrical conductivity showed no significant variations after the dip.

Conclusions

The results indicated that most of the physico-chemical quality parameters of River Bhotekoshi were within the WHO limits for drinking water and, therefore, may be suitable for domestic purposes. In contrast, however, the bacteriological quality of the water points, as suggested by the total and faecal coliform counts, exceeded the standard (0 cfu/ 100 ml) for potable water. In general, the bacteriological quality of the water was unacceptable, and would pose a serious risk to consumers without treatment. The poor bacteriological quality was due to direct contamination by animal and human wastes.

The striking characteristic of River Bhotekoshi is its high ionic content, which is reflected in high conductivity, total dissolved solids and sodium levels. Relatively higher levels of most physicochemical constituents occurred at the upstream while lower concentrations were observed downstream due to the influence of River Volta, which has lower ionic content. Conductivity, TDS and most major ions varied seasonally with elevated levels in the rainy season. However, nutrient levels were low during the study period and did not give any clear seasonal variation.

Finally, the result shows that the increasing trends of pollution agents in the river water after the project operation because of the increased human activities in region than the project itself. The water temperature was found increasing pattern after the project intervention. The water quality was more contaminated during construction period in 1998 and has not meet the natural condition of water, which was observed in 1995. However, water quality analysis of 2010 showed highly contaminated due to increasing load of sediments, excessive discharge of household effluents as expansion of riverside settlements and increasing runoff agricultural pesticides.

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