ADVANCES IN BIORESEARCH, Vol. 2 [1] June 2011: 33- 39

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http://www.soeagra.com/abr.htm
ISSN 0976-4585

RESEARCH ARTICLE

Impoundment after Damming the Rivers Change in Flow Regime and Effect in Water Quality of Chilime Hydropower Project in Rasuwa District Nepal

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ABSTRACT

Electrical power generation supports the development of the nation, but the river ecosystems suffer adversely specially effects on water quality and aquatic life forms due to impoundments after damming the rivers and change hydrologic regime.

The data obtained were standardized and subjected to principal components analysis (PCA) and Pearson's rank correlation was used to establish relations between physical, chemical, and bacteriological parameters.

The diversion of main flow of Chilime and Bemdang khola has found considerable impact on aquatic biodiversity and impact on downstream settlements The increases in pH appear to be associated with increasing use of alkaline detergents in residential areas. The Chilime khola display low EC and TSS relatively then the Bemdang khola, which shows that the Bemdang khola is more polluted than the Chilime khola. Dissolved oxygen concentrations ranged from 12.6 mgO$_2$/l in its origin Chilime khola, 10.6 mgO$_2$/l at Bhemdang khola 11.4 mgO$_2$/l at descending basin to 10.6 mgO$_2$/l at tailrace downstream powerhouse.

There is a great variation in the spatial distribution of faecal coliform (FC) counts. In Chilime khola, total FC was 91 Cfu/100 ml, 4.7X102 Cfu/100 at Bemdang khola, 1.0X102 Cfu/100 descending basin, and 1.5X102 Cfu/100 at tailrace powerhouse. This indicates the presence of untreated human wastes in these drains. The tailrace downstream of powerhouse receives relatively high concentrations of organic compounds, nutrients and oil & grease. 12mg/l oil and grease receives in tailrace as the major sources of pollution from powerhouse.

KEY WORDS: *Chilime Hydropower Project; Flow Regime; Hydrologic Alternations; Water Quality; Standards; Principal Components Analysis; Impacts; Pollution.*

INTRODUCTION

The ecosystem services of watercourses such as rivers and lakes directly or indirectly contribute to both human Welfare and aquatic ecosystem [1]. 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 [2,3]. Rivers are highly Vulnerable to pollution; therefore, it is important to Control water pollution, monitor water quality in river Basin [4], and interpret the temporal and spatial variations in water quality [5,2].

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 [6-9].

A number of factors influence water chemistry. Gibbs [10] proposed that rock weathering, atmospheric precipitation, evaporation and crystallization control the chemistry of surface water. The influence of geology on chemical water quality is widely recognized [10,11,12]. The influence of soils on water quality is very complex and can be ascribed to the processes controlling the exchange of chemicals between the soil and water [13]. Poor water quality and its effect on human health noticed by John Snow in 1854. The study on water quality in third world countries shows that the eighty percent diseases are directly related to poor sanitation and water quality [14]

In Nepal environmental issues addressed on policy and programs was 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 water resource sector has 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, Environment Protection Act, 1997 (EPA97) and the Environment Protection Regulation, 1997 (EPR97). According to the provision of EPA and EPR'97 all hydropower projects requires Environmental Assessment before its implementation. The EIA of Chilime Hydropower Project was approved in 2003.The present study focuses to identify impacts on river water quality regarding physicochemical and bacteriological characteristics with comparative analysis of before and after the project implementation. However, implementation of EIA may upset, reduce and minimizes the possible environmental impacts in maintaining downstream flow and river water quality.

STUDY AREA

Chilime Hydroelectric Project (CHEP) is located in Rasuwa district about 134 km north of Kathmandu, and is a peaking run-of-river type of scheme. The Project has started commercial operation on August 24, 2003 (Bhadra 8, 2060 B.S.). Intake of Chilime hydropower project is located at Goljung VDC 16 km far from powerhouse site (fig.1). The project has constructed 5 km access road for intake site. Water is diverted from snow feed river Chilime khola and Bemdang khola one of the major tributaries of Bhote Koshi River. The rivers have dependent flow from the snow fed watershed area. The annual discharge of Chilime khola is 182.0m^3/s and 168m^3/s in Bemdang khola.

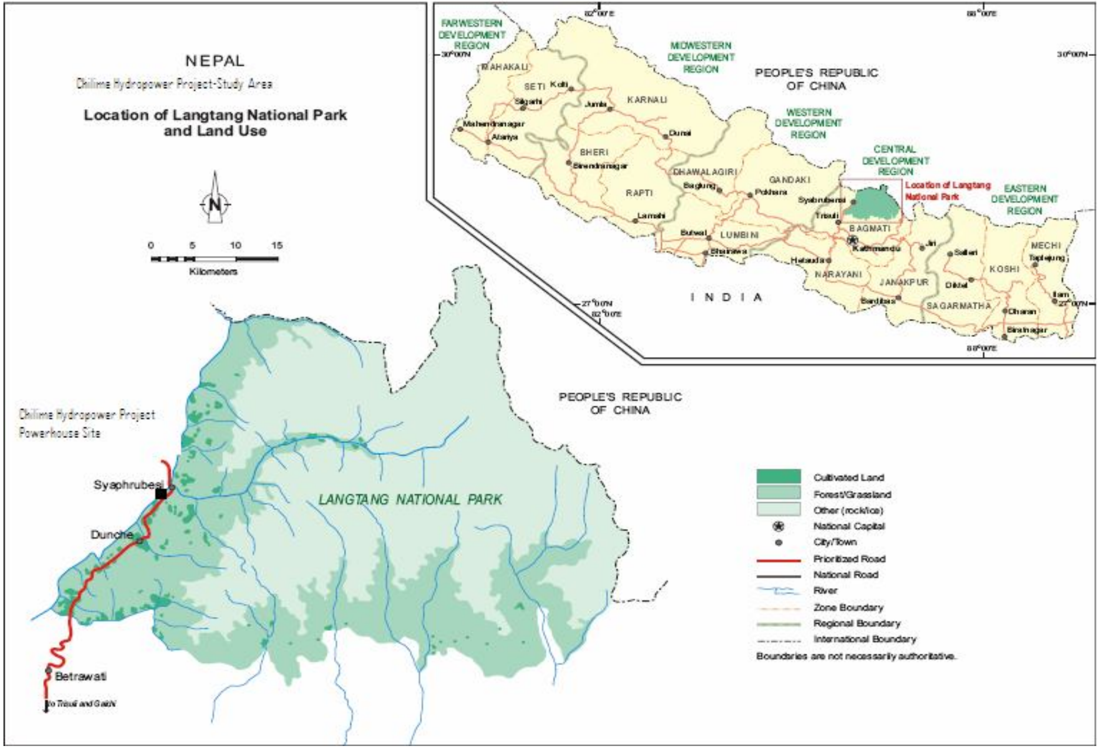

Fig 1. Location Map of Chilime Hydropower Project

Chilime Hydroelectric Project, with capacity of 22.1 Megawatts, is constructed in the 15 Kilometer north of Dhunche, a district headquarter of Rasuwa district. The project that is in vicinity of Goljung, Chilime and Syafrubeshi VDC is underground except the one-kilometer power canal that is visible above the surface. Headrace tunnel, penstock, powerhouse, and transformer room are built in underground tunnel. It is run of river type of hydroelectric project and it comes from Chilime and Bemdang River.

MATERIAL AND METHODS

To test the water quality of the river in Chilime projects different sampling locations were determined considering the project impact area as per pervious locations of EIA studies. Water sampling sites were upstream intake, intake/dam site, downstream intake/dam site, tailrace downstream powerhouse site. .Some physical and chemical parameters were checked at the spot and for other parameters, water samples were collected for laboratory test.

Samples were collected from four positions through Chilime and Bemdang River within Chilime hydropower project (table 1); through 6 July 2010 to 12 July 2010. Therefore, 14 parameters of four sampling locations were tested throughout this period. The samples were collected from just under water surface, for each sample 14 parameters (variable) had been done. These parameters including: Temperature, pH, Turbidity (NTU), Color (Chromacity unit), Electric Conductivity (µS/cm), Total Suspended Solids (mg/L), Total Dissolved solids (mg/L), Total Alkalinity (mg/L), Dissolved Oxygen (DO), Total Hardness (TH), Total Nitrogen (mg/L), T. Organic Matter (mg/L as C), Oil and Grease (gm/L) and Total Coliform (cfu/100ml). Therefore, the number of total parameters produced from laboratory work is 56 parameters.

Table 1: Water Quality Assessment in Different Location of Chilime Project Site

Parameters	**Unit**	**Method**	**Result**			
			1	2	3	4
Temperature	-	Thermometer	13.5 (13:00)	26.1 (13:30)	17.5 (13:50)	14.2 (6:30)
pH	-	Electrometric	8.4	8.1	7.2	7.3
Turbidity	NTU	Spectrophotometric	72	31	67	98
Electric conductivity	µS/cm	Electrometric	36	155	45	45
Total dissolved solids	mg/L	Electrometric	25	153	36	23
Color	TCU	Spectrophotometric	<1	2	<1	<1
Total Suspended Solids	mg/L	Filtration	343.9	248.2	150.2	190
T. Alkalinity	mg/L as $CaCO_3$	Titration and Electrometric	9	65	17	15
Dissolved Oxygen	mg/L	Azide Modification Method	12.6	10.6	11.4	10.6
Total Hardness	mg/L as CaCO3	Titration, Na2 EDTA	12	71	20	16
Total Nitrogen	mg/L	Spectrophotometric	-	-	-	0.8
T. Organic matter	mg/L as C	K2, Cr_2, O_7, Digestion	<1	<1	<1	<1
Oil & Grease	gm/L	Wet extraction	-	-	-	12
Total Coliform	Cfu/100 ml	Membrane filter	91	4.7X102	1.0X102	1.5X102

Source: Field Level Test and Laboratory Test at CEMAT Pvt. Ltd. July 2010

Statistical Analysis

The methods outlined in the Standard Methods for the Examination of Water and Wastewater [15] was followed for the analyses of all the physico-chemical parameters. 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. Pearson's rank correlation was used to establish relations between parameters. All tests were two-tailed. The analyses were executed by SPSS (version 12 for Windows, year 2003).

For hydrology and flow, regime study was carried out in the catchment area of the Chilime hydropower project on both river of Chilime and Bemdang khola at intake site, upstream and downstream dam desalting basin and powerhouse site. The maximum and minimum design flows required generating the estimated power, downstream discharge, design of dam and powerhouse, turbine system, tunnel outlet was inspected and observed respectively. A detailed framework, matrix and questionnaire design was developed after preliminary assessment of the study to obtain primary data's. The questionnaire, checklist and matrix were based on the preliminary survey, literatures, tools for assessment of ecological and statistical parameters and scientific practices. In addition, the representatives of the hydropower developer, and the other relevant resource users were also considered in the primary data collection. The mean annual flow and design discharge of Chilime hydropower project is given in salient features below in the table 2.

Table 2: Salient Feature of the Project of Chilime HEP

Description	Features
Project Type:	Run of River
Catchment Area: Chilime Khola Bemdangkhola	 227km2 27km2
Design discharge (Intake)	8.25m2/sec
Number of units	2
Turbine discharge	3.75m3/sec
Mean annual flow (Chilime Khola)	9.1m3/sec
Design flood 100 years Chilime khola Bemdang Khola	 182.0m3/s 168m3/s
90% Firm Flow Source of river Bemdang khola	 2.30m3/s 0.35m3/s
Poundage level at weir	1740.25m
Turbine Center line level	1389.25m
Gross Head	351m
Net Head	341m
Annual energy generation Firm energy Secondary energy	137GWh 86GWh 51GWh

Source: CHPCL, 2010

The measurement of water discharge has quantified with comparison of hydrological data recorded before and after EIA studies. Form this comparative analysis gaps and constraints of downstream and upstream flow were anal sized.

RESULT AND DISCUSSION

Water diversion can result in undesirable consequences downstream. These typically include, but are not limited to, depriving downstream users of water for irrigation and other traditional uses, degradation of water quality, and reduction in flows harming riparian ecosystems and aquatic life. Inundation upstream of dams can result in submergence of houses and settlements, fertile agricultural land, forest and other vegetation, and others. The discharge (fig. 2).

The diversion of main flow of Chilime and Bemdang khola has found considerable impact on aquatic biodiversity and impact on downstream settlements. Traditionally the downstream settlements were used river water in irrigation and watermill, which was found, replaced after the project operation. In this study, no any fish species was observed in the Chilime and Bemdam khola at head worksite. According to local peoples information the species diversity of fishes in Chilime khola upstream of Langtang khola portion of snow fed river has no any evidence of fish occurrence.

The altitude of Chilime khola at intake site is 1735m, as the river is snow feed with high current there is no recorded fish diversity since construction of the project. However, the project has followed the provision of EIA 10% downstream release of water whereas the provision was not found strictly followed as experiences several another hydropower's in Nepal. The discharge of the river has found no major change due the course snow melting starts in dry period and increases the river flow. Siltation is a major problem of the river. The value of powerhouse load R^2=0.700 is positively correlated with the total discharge R^2=0.131 of the river.

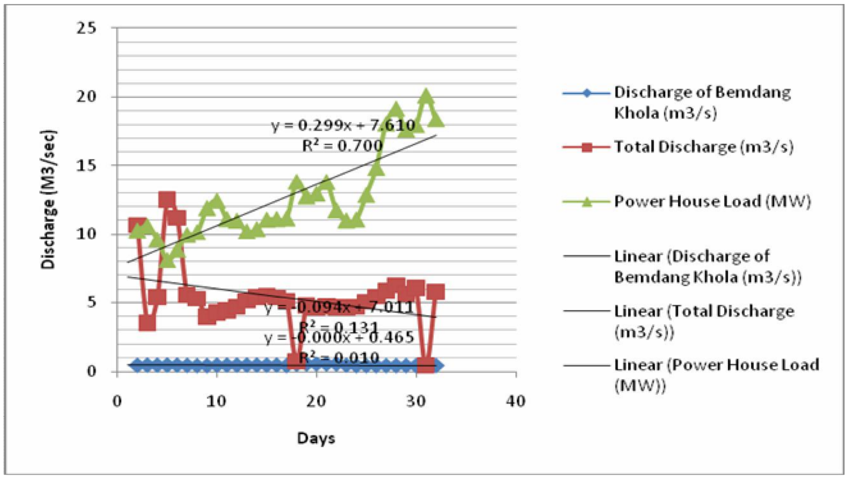

Fig. 2. Discharge of Chilime HP March 2009

Consequences of Hydrology and Flow Rgime

Physiographic risks. There is a high risk of damage to civil structures and plants by landslides as a result of the fragile physical setting of the Himalayan range and monsoon floods in Chilime HEP. These may not only damage the project but can also sweep away settlements, and destroy land and property downstream. The risk of reservoir siltation is also very high in the mountainous terrain of Nepal (Chilime).

Impact on migratory fish. The existing dams found as barriers to migration of fish, and projects activities was barriers to the movement of animals or adversely affect their habitat. It is now accepted that hydropower development needs to consider environmental and social consequences, and environmental assessment is now generally required to ensure this. Mitigation and compensation measures which was the part of the environmental assessment; measures such as compensation for loss of property, ensuring minimum downstream flow all the time, supporting the development of areas surrounding the project, and social upliftment programs in affected communities which were not fully respected in all sampled projects.

Statistical analysis of Water Quality Impact

The water temperature highest 26.1°C at Bemdang khola and lowest was observed at Chilime khola. The turbidity (NTU) was recorded highest 98 at tailrace downstream powerhouse, 67 at descending basin intake, 31 Bemdang khola and 72 at Chilime khola respectively. Turbidity measures the “cloudiness” of water using the penetration of light through water. The increased levels of turbidity are caused by matter sediment and other matter suspended in the water column. Scientific literature indicates that turbidity reduces growth of aquatic plants and interferes with the ability of fish to catch prey. Increased turbidity levels also reduce the desirability of waters for recreational uses. High levels of suspended sediment, usually measured as turbidity for regulatory purposes, can cause public drinking water treatment systems to shut down and increase operation and maintenance costs.

pH, EC and TSS: pH, EC (electrical conductivity) and TSS (total suspended solids) were measured with the portable multi-parameter instrument in the field during sampling.

Although not definitive, pH of the aquatic systems is an important indicator of the water quality and the extent pollution in the watershed areas [16]. As illustrated in Fig.3 the pH was found to be 8.04, 8.01, 7.02 and 7.03m respectively during average water flow .

As illustrated in Fig. 3 water at descending basin and Tailrace Rivers were more acidic than the main origin of Bemdang and Chilime khola. Tailrace has indicated that natural river water is slightly acidic because of its origin of rainwater and because of tannin and leave acids released from the forest floors [17]. Any increase in the pH is thus likely due anthropogenic influence, since also the host rock (granite) does not support buffering. Visible is the slight increase in pH going downstream, especially the steep increase at descending basin to tailrace after passing through tunnel. The Chilime and Bemdang khola has mentioned that the increases in pH appear to be associated with increasing use of alkaline detergents in residential areas [18] and alkaline material from this picture remains largely the same; except that more Bemdang and Chilime khola; with lower pH. Wastewater in residential areas. During high water flow, dilution of the main course occurs due the addition of the Bemdang and Chilime khola in descending basin.

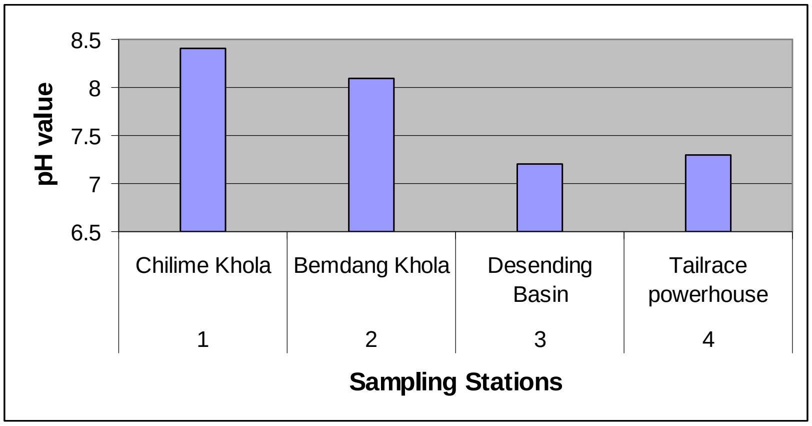

Fig. 3: pH Variations in sampling stations of Chilime and Bemdang Khola

As shown in Fig. 4 Electrical conductivity was found to be 36, 155, 45 and 45µS/cm during average water flow at four sampling stations respectively. While TSS amount 343.9, 248.2, 150.2 and 190 mg/L was very high. The Chilime khola display low EC and TSS relatively then the Bemdang khola. Which shows that the Bemdang khola is more polluted than the Chilime khola? It can be supported by similar result in the research that was done by Polprasert, C., [19] as a very high EC and TSS, so addition of this wastewater may cause the EC and TSS to increase at Bemdam khola. The steep slope and silt into the river is the most significant factor of high TSS.

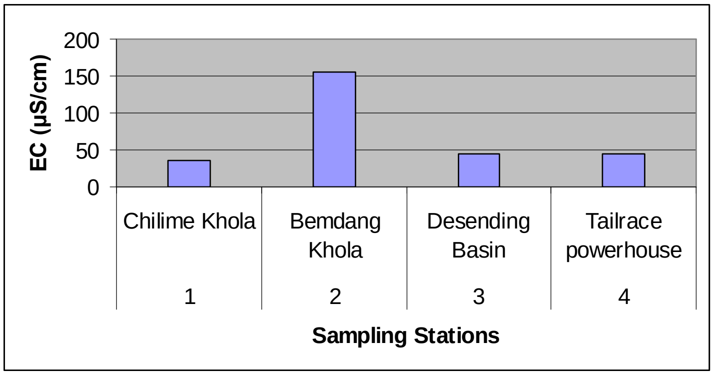

Fig. 4: Electrical Conductivity Variations in sampling stations

Dissolved oxygen concentrations ranged from 12.6 mgO_2/l in its origin Chilime khola, 10.6 mgO_2/l at Bhemdang khola 11.4 mgO_2/l at descending basin to 10.6 mgO_2/l at tailrace downstream powerhouse respectively. This indicates that pollution loading is depleting oxygen levels as the river moves down stream. Total dissolved solids (TDS) increased from 31 mg/l up to 98 mgO_2/l, but the values are still within the permissible limits.

From the available data, it can be concluded that there is a great variation in the spatial distribution of faecal coliform (FC) counts. In Chilime khola total FC was 91 Cfu/100 ml, 4.7X102 Cfu/100 at Bemdang khola, 1.0X102 Cfu/100 and 1.5X102 Cfu/100 at tailrace downstream powerhouse respectively. Levels were recorded very high at Bemdang khola. It is worth mentioning that the FC counts in the water samples taken from the specific riverbank where the drain water is pumped are even higher. This indicates the presence of untreated human wastes in these drains, a situation that requires special attention. This is primarily because of the high dilution effect and the fact that sediments tie up trace metals and other constituents.

This study provides an overview of the impact of planned water diversions on water quality in the Chilime assuming that the changes in the other activities follow the probable development. The tailrace downstream of powerhouse receives relatively high concentrations of organic compounds, nutrients and oil & grease. 12mg/l oil and grease receives in tailrace as the major sources of pollution were powerhouse rather other stations has no received amount of oil and grease. The organic matter receives <1 mg/L as C in all stations.

The water quality assessment of this study shows that the downstream changes in river water quality are primarily due to a combination of land and water use as well as water management interventions such as: (a) different hydrodynamic regimes regulated by the hydropower operation, (b) agricultural return flows, and (c) domestic waste discharges, including oil and wastes from hydropower plants. (d) Water diversion from main river channel and (e) the presence of untreated human wastes and drains in main river channel. Although already narrow, floodplain width and the abundance and spatial distribution of various patch types also typically decline. An unaltered hydrologic is crucial to maintaining the diversity and viability of the riparian area.

ACKNOWLEDGEMENT

The author thanks CEMAT Lab Pvt. Ltd. for the facilities provided. The author also thank to the Department of Environmental Science and Engineering, Kathmandu University for technical support.

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