Study on Physiochemical Parameters and Benthic Macroinvertibrates of Balkhu Khola in Kathmandu Valley, Central Nepal

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Abstract

Physiochemical parameters and macroinvertebrates together can give better picture of any wetland ecosystem. The major objective of this study was to assess the water quality of Balkhu Khola and its impact on structure and function of aquatic ecosystem. But this study was focused particularly on identification of the biological indicator of water pollution especially benthic macroinvertebrates along with physiochemical parameters. The water samples and bottom sediments were collected from upstream and downstream courses of Balkhu Khola in July, August and September 2003 and February 2004 and analyzed in the laboratory. Altogether 10 texa of invertebrates belonging to four phyla were recorded. The major groups identified were Oligochaetes, Diptera and Bivalvia. They show negative correlation with dissolved oxygen and positive correlation with carbon dioxide content. The values of physiochemical parameters were significantly different except temperature between upstream and downstream courses of river. The water was found more polluted at downstream course of Khola. Detailed study is essential to control the pollution in Balkhu Khola. Immediate preventive measure for direct discharge of sewage and industrial effluents and disposal of solid waste should be taken along the river course.

Keywords

Biological indicator, discharge; disposal, macroinvertebrates, Physiochemical parameters

Introduction

Water is an important and essential substance in protoplasm and is the basis of life. It has been responsible for evolving life in our planet. It represents the great circulation system of the earth, being it as the sap of plants, the blood stream of animals, and rainfalls on the surface of the lands of rivers flowing to the sea. Many lower organisms live in direct contact with water, in higher animals the cells are in contact with the intercellular fluid containing water. It serves as transport medium for nutrients hormones and enzymes inside the body.

Water is the most abundant and renewable resource, which helps to maintain the earth climate and dilute environmental pollution. Water is essential for life next to the air. Water is found to be 50% to 97% by weight to all plants and animals and about 70% of human body.

Water constitutes 80% to 90% of protoplasm, 83% of human blood, 75% of muscle and 22% of bone. Water forms a single worldwide resource distribution on land, sea and atmosphere and unified by hydrological cycle without which life would not be maintained. About 2/3 of the earth surface is covered with water (Smith, 1974).

Water quality refers to the ability of our water resources to support human, animal, and plant life. Good water quality is necessary for providing us with drinking water that is safe and clean; for providing habitat for aquatic bugs, plants, and animals; for providing recreational opportunities like wading, swimming, and fishing; and for providing a place for us to connect with nature. The quality of water is of vital concern for mankind since it is directly linked with human welfare. In fact, pollution is the result of anthropogenic activities, which has adverse impact on mankind. Water is regarded as polluted when it is changed in its quality or composition, directly or indirectly as a result of human activities. Consequently, it becomes less suitable for human consumption.

According to Kudesia, 1980 water is soul of nature and if polluted will perish the world. Water pollution is any chemical biological or physical change in water quality that has a harmful effect on living organisms or makes water unsuitable for desired uses (Miller 2002). Most of rivers have become polluted with sewage, inorganic chemicals, industrial effluents, organic wastes and other undesirable foreign matter. There are different sources of water pollution at specific locations through pipes, ditches or sewers into water bodies for example discharge of industrial effluents and sewage. Because of point sources are at specific location, they are fairly easy to identify, monitor and regulate. Non point sources are those that cannot be traced to any single site of discharge. They are usually large land areas or air shades that pollute water by surface runoff, subsurface flow or deposition from the atmosphere for example runoff of chemicals into surface water from cropland, livestock feedlots, urban street etc. Non-point pollution from modern agriculture includes sediments, inorganic fertilizers, manures, salts and pesticides.

The pollutants in aquatic bodies are organic wastes i.e. biodegradable which cause eutrophication changing the quality of water for example garbage. Non-degradable wastes such as plastics, polythene, glass and tin are perhaps the most persistent kinds of pollution since these can't be destroyed or decomposed biologically over long periods of time. It is indeed very dismaying that the number of such materials, especially polymers, chlorinated cyclic carbon compound and biocides are increasing in the rivers which are serious threat to the future of entire aquatic ecosystem and its flora and fauna.

Measuring physical, chemical and biological indicators assesses water quality. The traditional water quality assessment approach has been to collect stream water samples and analyze them in a laboratory for suspected physical and chemical pollutants. Unfortunately, because sampling and analysis are expensive and because concentrations of pollutants vary greatly with time and location, physical and chemical monitoring alone often cannot detect non-point source pollution problems.

A biological approach to water quality assessing/monitoring— bio monitoring— incorporates the use of stream organisms' themselves as a basis for pollution detection. Species that provide an indication as to the quality of the water based upon whether or not they can survive in it are referred to as biological indicators. Aquatic insects and other macroinvertebrates are often sampled in lakes and streams to assess the overall water quality. Other species, such as fish and algae are also used as biological indicators.

Benthic “macroinvertebrates” are bottom-dwelling invertebrates large enough to be seen with the naked eye. They are usually greater than 1 mm or 1/32 inch long. They are aquatic insects and other aquatic invertebrates associated with the substrates of water bodies (including, but not limited to, streams and rivers). Most species of stream macroinvertebrates are aquatic insects although crustaceans (crayfish, sideswimmers, aquatic pillbugs), molluscs (snails, mussels, clams), oligochaetes (earthworms, leeches), and arachnids (aquatic mites) also occur commonly.

Macroinvertebrates can be useful indicators of water quality because these communities respond to integrated stresses over time, which reflect fluctuating environmental conditions. Community responses to various pollutants (e.g. organic, toxic, and sediment) may be assessed through interpretation of diversity, known organism tolerances, and in some cases, relative abundances and feeding types.

There are several studies conducted on water quality and pollution of major rivers in Kathmandu valley. But very few studies have been put forwarded in Balkhu Khola. However these works also are not totally focused on it for instance Guvaju et al (2000) just mentioned about physiochemical parameters as well as flora and fauna of this stream while conducting research on Bagmati river system under Biodiversity Conservation Center Project. Similarly Tamrakar et al (1999) discussed about some sort of ecological aspect of this stream on Fishery and ecological Study of Bagmati River under Melamchi Water Supply Project. Due to tremendous growth and indiscriminate migration of human population from other parts of the country, rapid urbanization and industrialization in Kathmandu Valley water quality of Balkhu Khola is continuously declining along with other streams. It has enhanced by direct discharge of sewage and industrial effluents into the river without any treatment and haphazard disposal of solid wastes onto the stream bank. Under this circumstance the need of comprehensive study in Balkhu Khola was felt and this study was planned with major emphasis on physiochemical parameters and benthic macroinvertebrates to fulfill its main aim of assessing the water quality of the stream.

Objectives

The major objective of this study is to assess the water quality of Balkhu Khola.
The specific objectives are as:

- To analyze some of the important physiochemical parameters of Balkhu Khola
- To identify the biological indicator of water pollution by assessing macro invertebrates of Balkhu Khola

Materials and Methods

Study Area
Balkhu Khola emerges from the peak of Chanragiri range, altitude of which is 2561 m. It lies between 27°38’59” and 27°43’02” latitude and 85°11'25.85" to 85°18'05.49" longitude. It is a tributary of Bagmati River, which is the major river system of Kathmandu Valley and originates from Baghdwar, northern part of Kathmanu Valley at an altitude of 26,540 m. There are mainly 24 tributaries origaniting from Mahabharat and Siwalik hills, which feed Bagmati River (Tuladhar, 1979). Among them five are major rivers including Balkhu. Major

streams drain in Balkhu are Gkhcha Khola (South-West), Thosne Khola and Kalo Khola (North), Dhaksi Khola (South), Ghatte Khola and Thulo Khola (South-East).

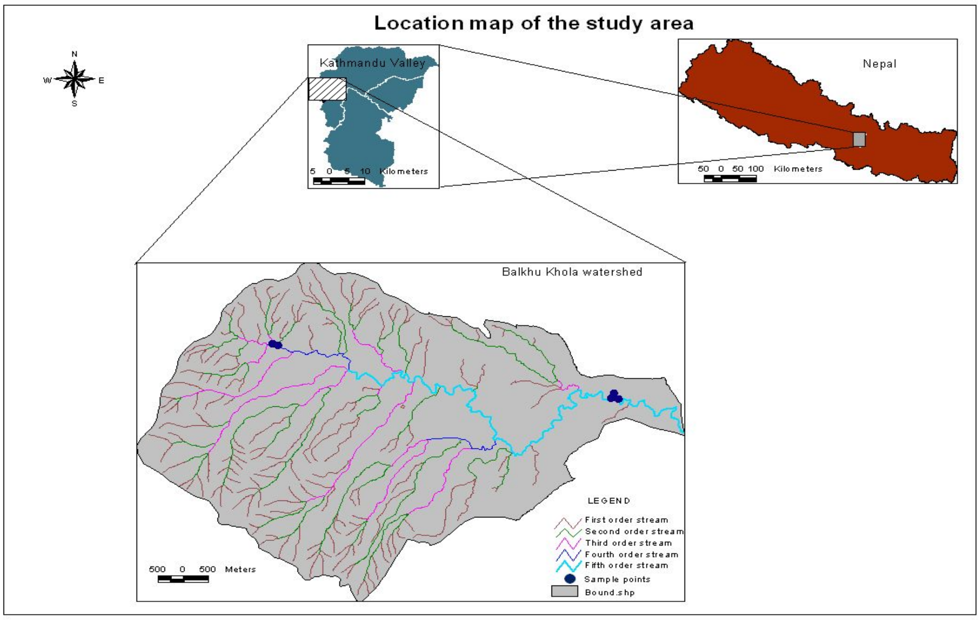

Figure 1: Location Map of Balkhu Khola.

Study sites were located near Basnetchhap at an altitude of 1414 m at upstream and sites at downstream are located at Khasibazaar near Kalanki at an altitude of 1297 m. There is cultivated land and less settlement at upstream with less disposal of sewage and waste into the stream. Downstream course of stream is darkened with sewage and industrial effluents. This part also forced to receive solid waste. Local people near Basnetchhap do not use water for domestic purposes due to frequent fecal contamination by workers at different Brick Factories but in downstream part people use water from Balkhu Khola for cleaning, bathing and washing purposes without knowing adverse effects on health by polluted water. It is happening due to lack of water at downstream settlements.

Figure 2: Analyzing chemical parameters in the field.

Site Selection

Sites were selected on the basis of objective of this study. Study of geographical description and pre-field visit were done before selection the sites. The sites at upstream were selected near cultivated land at Basnetchhap. Less settlement and lower number of industries were located at upstream part of stream. Sites at downstream were selected in Khasi Bazaar south of Kalanki where the stream was polluted due to high load of sewage, industrial effluents and solid wastes.


Figure 3: Washing the sediments with benthic macroinvertibrates to remove clay.

Collections, Preservation and Analysis of Sample

Physiochemical Parameter
Temperature and velocity were observed in the field. For dissolved oxygen water samples were treated partially in the field by adding two milliliter of each manganous sulphate and potassium iodide solutions.


Figure 3: Analyzing Chemical Parameters in the Laboratory.

To analyze other physiochemical parameters, water samples were collected in clean plastic bottles. Details including sampling site, date and time of sample collection were written in sampling bottles.

Samples were carried to laboratory at Central Department of Environmental Science, Tribhuvan University. Winkler's Method was followed to analyze Dissolved Oxygen (DO) and initial DO for Biological Oxygen Demand (BOD). The other sets of BOD bottles were incubated in BOD indicator for analysis of final DO. P^H, Conductivity, Total hardness, Total alkalinity, Free carbon dioxide, Chloride and chemical Oxygen Demand (COD) were analyzed in same day following methods suggested by APHA, 1998 and Trivedy and Goel, 1984.


Figure 4: Setting for COD refluxing.

Biological indicator

Benthic macro invertebrates were collected using Grab sampler of area 0.02498 m^2. For this firstly sampler was locked then subjected to the stream bottom vertically with the help of nylon rope. When the sampler touched the bottom it automatically unlocked grabbing the sediments. Then the sampler pulled out from the stream and sediments were transformed in buckets. Sediments were sieved putting on sieve of 0.4mm mesh size so that clay particles could remove. Macroinvertebrates retained on the sieve with some water were collected in labeled sample bags and carried to the laboratory for further processing.


Figure 5: Putting BOD bottles inside BOD incubator.

Sorting and identification of macroinvertebrates were done in next day referring Pennak, (1953), Needham and Needham (1996) and Enmondson (1959). Macro invertebrates were sorted and identified transferring samples into white enameled tray. Macroinvertebrates after identification were counted separately and stored in different bottles. 5% formalin was used as preservative to preserve macroinvertebrates except Mollusca. In case of Mollusca 70% alcohol was used as preservative agent.

Statistical Analysis

Whole data set is tabulated and charts were prepared using MS Excel. Species density, species diversity, Evenness index, T- test and Pearson correlation were analyzed manually using standard formulae (Odum 1996 and Swain 2002).

Result and Discussion

Result

Physiochemical Paramaters

Temperature

Water temperature of the Balkhu Khola was found to be various according to site and month. Temperature was found maximum (25.5^{0}c) in July at downstream and minimum (18 ^{0}c) was found in February at upstream part of the stream (Table 1).

Table 1: Variation on Temperature in water of Balkhu Khola.

Site/ Month	July	August	September	February
Upstream	22.5	25.0	19.0	18.0
Downstream	25.5	26.0	19.0	18.5

Velocity

Water velocity was found to be in between 0.2 to 1.38 m/sec. The highest velocity was recorded at upstream in August and September and the lowest was at downstream in February. In general it was recorded higher at upstream in every visit (Table 2).

Table 2: Variation on velocity in water of Balkhu Khola (m/sec).

Site/ Month	July	August	September	February
Upstream	1.25	1.38	1.38	0.41
Downstream	0.85	0.83	0.84	0.208

Surface Water P^H

Surface water P^H was ranged from 7.9 to 8.6 at upstream and 8.5 to 9.5 at downstream. It was found higher at downstream course (Table 3).

Table 3: Variation on surface water P^H in water of Balkhu Khola.

Site/ Month	July	August	September	February
Upstream 1	8.2	8.6	7.9	8.4
Upstream 2	8.3	8.6	8.1	8.5
Downstream 1	8.5	8.9	9.1	9.0
Downstream 2	8.5	8.9	9.4	9.0
Downstream 3	9.1	8.9	9.5	9.3

Conductivity

Water conductivity was found 10 to 21 Us/sec at upstream and 22.9 to 33.4 Us/sec at downstream part of the stream (Table 4).

Table 4: Variation on conductivity in water of Balkhu Khola.

Site/ Month	July	August	September	February
Upstream 1	20.1	12.0	10.0	20.2
Upstream 2	21.6	13.6	10.7	21.0
Downstream 1	32.9	32.1	22.9	33.0
Downstream 2	32.7	30.9	22.9	33.2
Downstream 3	33.3	30.9	23.1	33.4

Chloride

Chloride ion concentration was found to be lower in monsoonal months than in February. Maximum concentration was 25.56 mg/l at downstream in February and minimum value was recorded as 8.52 mg/l in September at upstream (Table 5).

Table 5: Variation on Chloride in water of Balkhu Khola.

Site/ Month	July	August	September	February
Upstream 1	12.78	11.36	8.52	15.62
Upstream 2	14.20	12.78	8.52	17.04
Downstream 1	22.72	17.04	15.62	24.14
Downstream 2	21.30	18.46	15.62	25.56
Downstream 3	24.14	19.88	17.04	25.56

Total Hardness

Total Hardness of water was recorded between 40 to 68 mg/l at upstream and 70 to 108 mg/l at downstream. Maximum concentration was recorded in February at downstream and minimum was recorded in July at upstream (Table 6).

Table 6: Variation on total hardness in water of Balkhu Khola.

Site/ Month	July	August	September	February
Upstream 1	40	38	42	68
Upstream 2	41	28	44	68
Downstream 1	80	82	70	100
Downstream 2	82	82	70	102
Downstream 3	82	86	74	108

Total Alkalinity

Total alkalinity was recorded between 1.2 to 3.8 mg/l at upstream and 1.8 to 4.2 mg/l at downstream course of stream. The highest value was recorded in February at downstream and the least was recorded in September at upstream (Table 7).

Table 7: Variation on total alkalinity in water of Balkhu Khola.

Site/ Month	July	August	September	February
Upstream 1	1.4	1.4	1.2	3.0
Upstream 2	1.4	1.4	1.2	3.8
Downstream 1	2.0	2.0	1.8	4.0
Downstream 2	1.8	2.0	1.8	4.0
Downstream 3	1.8	2.2	2.2	4.2

Free Carbon dioxide
Free carbon dioxide was ranged between 4.4 to 28.6 mg/l at upstream and 8.8 to 48.4 mg/l at downstream course of the stream. The concentration was found minimum in August in all sampling sites and the highest concentration was recorded in February at downstream (Table 8).

Table 8: Variation on free carbon dioxide in water of Balkhu Khola.

Site/ Month	July	August	September	February
Upstream 1	17.4	4.4	8.8	22.0
Upstream 2	17.6	4.4	8.8	28.6
Downstream 1	26.4	8.8	15.4	30.8
Downstream 2	26.4	8.8	17.6	44.0
Downstream 3	30.8	8.8	17.6	48.4

Dissolved Oxygen (DO)
Dissolved oxygen concentration was found high in July and it showed the decreasing trend till February in all sampling sites. It was recorded less at downstream than at upstream part of the stream (Table 9).

Table 9: Variation on dissolved oxygen in water of Balkhu Khola.

Site/ Month	July	August	September	February
Upstream 1	5.69	5.69	5.00	4.05
Upstream 2	6.00	5.69	5.00	4.05
Downstream 1	5.28	4.87	3.75	2.27
Downstream 2	4.87	4.87	3.92	2.03
Downstream 3	4.87	4.47	4.20	2.02

Biological Oxygen Demand (BOD)
BOD was determined 80 mg/l at upstream and 150 mg/l at downstream part of the stream in February 2004.

Chemical Oxygen Demand (COD)
Chemical oxygen demand was found to be less in September in all sampling sites. The value was ranged between 57.6 to 179.2 mg/l at upstream and 112.0 to 208.0 mg/l at downstream course of the stream (Table 10).

Table 10: Variation on COD in water of Balkhu Khola.

Site/ Month	July	August	September	February
Upstream 1		96.0	57.6	166.4
Upstream 2		96.0	64.0	179.2
Downstream 1		112.0	83.2	198.4
Downstream 2		153.6	89.6	204.8
Downstream 3		179.2	102.4	208.0

Benthic macroinvertibrates
Altogether 10 texa of four phyla were recorded (Table 11). *Branchiura sowerbye* has the highest percentage i.e. 35% and *Libula sp.* and coleopterans were recorded only at upstream and were below 1% (Figure 7).

Table 11: Species composition of macroinvertebrates in Balkhu Khola.

Phylum	Order	Class	Family	Genus and Species
Annelida		Oligochaeta	Tubificidae	*Branchiura sowerbye*
				Tubifex sp.
	Hirudinea	-	-	-
Arthopoda	Diptera	-	Chironomidae	*Chironomus sp.*
			Culcidae	*Culex pipiens*
	Coleopera	-	-	-
	Odonata	-	Libulidae	*Libula sp.*
Mollusca	-	Gastropoda	Lymnaelidae	*Lymnea sp.*
		Bivalvia	Musculiumidae	*Musculium sp.*
Nemaphhelmiths	Nematoda	-	-	*Diplogaster sp.*

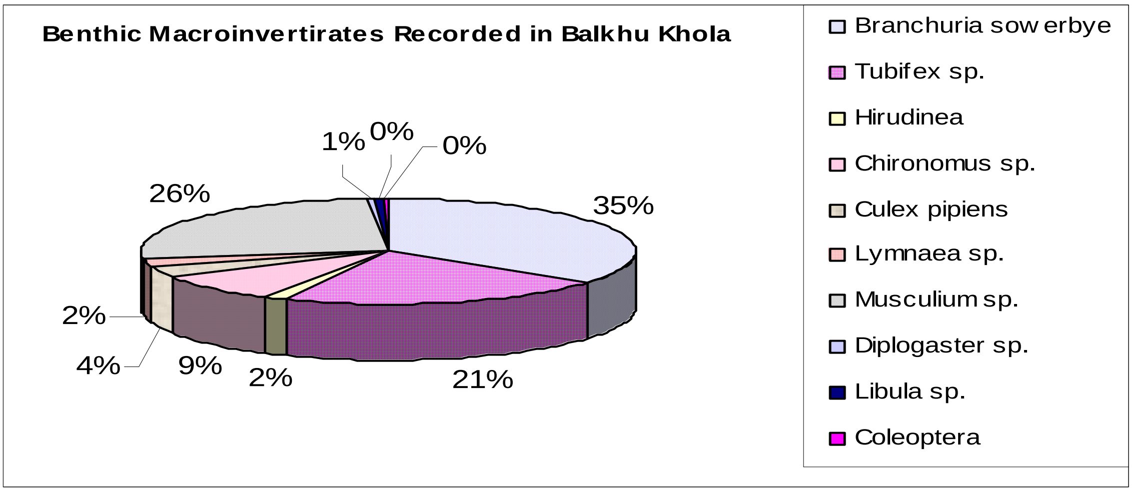

Figure 7: Benthic macroinvertebrates recorded in Balkhu Khola.

Total Population density of benthic macroinvertibrates at upstream was found to be 330.32ind/m^2. *Branchuria sowerbye* was the most dominant species i.e. it has the highest density value (110.08ind/m^2). The least dominant species recorded were *Culux pipiens* and coleoptera (10ind/m^2). Diversity index and evenness index were found to be 0.85 (Table 12).

Table 12: Density and diversity of benthic macroinvertibrates at upstream course of Balkhu Khola.

Species	Total	Mean	Density			Diversity index	Evenness index
			Density	Range at 95% CL (t= 2.365)	Range at 99% CL (t= 3.499)		
Branchiura sowerbye	22	2.75	110.08	37.62-281.45	0-363.61	0.85	0.85
Tubifex sp.	13	1.62	65.05	0-180.66	0-218.57		
Hirudinea	7	0.87	35.02	0-91.70	0-118.88		
Chironomus sp.	5	0.62	25.02	0-64.76	0-83.81		
Culux pipiens	2	0.25	10.00	0-25.70	0-33.23		
Lymnaea sp.	3	0.37	15.01	0-24.82	0-36.72		
Musculium sp.	5	0.62	25.02	0-26.01	0-83.82		
Diplogaster sp.	4	0.50	20.01	0-67.31	0-95.05		
Libula sp.	3	0.37	15.01	0-39.83	0-101.85		
Coleoptera	2	0.25	10.00	0-25.70	0-33.23		
			330.22				

Total Population density of benthic macroinvertibrates at downstream was found to be 1937.64ind/m^2. *Branchuria sowerbye* was the most dominant species i.e. it has the highest density value (683.86ind/m^2). The least dominant species recorded were *Hirudinea* (13.21ind/m^2). The diversity index and evenness index were found to be 0.65 and 0.77 respectively (Table 13).

Table 13: Density and diversity of benthic macroinvertibrates at downstream course of Balkhu Khola

Species	Total	Mean	Density			Diversity index	Eveness index
			Density	Range at 95% Cl (t= 2.365)	Range at 99% CL (t= 3.499)		
Branchiura sowerbye	205	17.08	683.86	0-1396.42	0-1689.40	0.65	0.77
Tubifex sp.	126	10.50	420.33	142.04-698.63	28.02-812.65		
Hirudinea	4	0.33	13.21	0-42.54	0-54.60		
Chironomus sp.	52	4.33	173.33	33.05-313.62	0-178.28		
Culux pipiens	21	1.75	70.05	21-118.77	1.32-138.79		
Lymnaea sp.	10	0.83	33.23	0-73.51	0-90.08		
Musculium sp.	163	13.58	543.63	0-1403.00	0-2669.56		
			1937.64				

All species have negative correlation with DO and positive correlation with CO_2. Except Nematoda, Coleoptera and Hirudinea all other species have strong correlation with these two chemical parameters (Table 14).

Table 14: Pearson correlation of benthic macroinvertibrates with DO and CO_2.

Groups	r with DO	r with CO_2
Bivalvia	**-0.64**	**0.68**
Coleoptera	-0.12	0.08
Diptera	**-0.75**	**0.78**
Gastropoda	**-0.67**	0.47
Hirudinea	-0.35	0.27
Nematoda	-0.11	0.23
Oligochaeta	**-0.63**	0.28

Discussion

Physiochemical Parameters

Above 30°c there is a general suppression of benthic invertebrate's population but in this study maximum temperature was recorded as 25.5°c (Table 15).

Table 15: Physiochemical parameters of Balkhu Khola at upstream.

Parameter/ Month	Unit	July	August	September	February
Temperature	^0c	22.5	25	19	18
Velocity	M/sec	1.25	1.38	1.38	0.41
P^H		8.2	8.6	8.0	8.9
Conductivity	Us/sec	20.8	12.8	10.3	20.6
Chloride	mg/lit	13.5	12.1	8.5	16.3
Total Hardness	mg/lit	40.5	38.0	43.0	68.0
Total Alkalinity	mg/lit	1.4	1.4	1.2	3.4
Free Carbon dioxide	mg/lit	17.6	4.4	8.8	25.3
Dissolved Oxygen	mg/lit	5.84	5.7	5.0	4.05
Biological Oxygen Demand	mg/lit				80.0
Chemical Oxygen Demand	mg/lit		96.0	60.8	172.8

Temperature is high in summer month and low in February (Figure 8) it is due to the influence of weather.

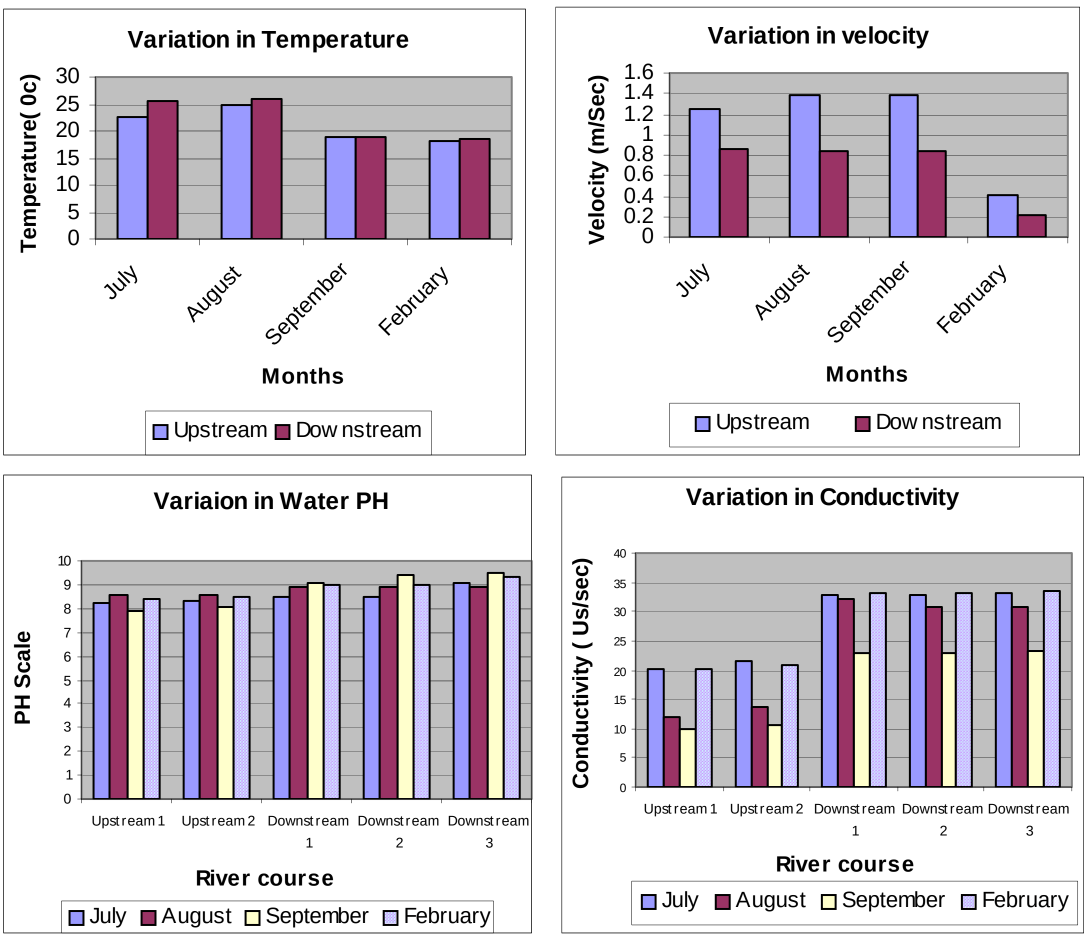

Figure 8: Variation in different physical parameters at upstream and downstream part of Balkhu Khola.

P^H is another important parameter and directly influences the abundance and distribution of the organisms. In natural water P^H is ranged as 5-8.5. Water receiving industrial effluent has usually low pH. This study has shown the increasing trend towards downstream course it may be due to high discharge of sewage into the river. P^H was recorded lower in August and July than in September and February (Figure 8) such type of result was recorded by Guvaju et al (2000) i.e. 8.5 in July and 9.0 in November in Naikap area of Balkhu Khola which lies in between the two sampling stream part in this study.

Conductivity is related to dissolved solid particles in water. Its value becomes greater with increase of the degree of pollution. It has shown increasing trend towards downstream course of the stream (Figure 8), which indicate the increasing trend of pollution along the length of the river.

Chloride in fresh water generally remains quite low and increases by the contribution of agriculture runoff, sewage and industrial effluent. Besides, human beings and other animals exert high quantities of chlorides together with nitrogenous compounds. The chloride concentration is harmless up to 1500 mg/l though it produces salty taste at 200-250mg/l (Trivedy and Goel, 1984).

Three different groups contribute total alkalinity: hydroxyl (OH^-), bicarbonate ($HCO3^-$) and carbonate ($CO3^{--}$). Alkalinity is change with change in P^H and is governed by photosynthesis and microbial decomposition in natural water. The total alkalinity of Balkhu Khola was found to be due to HCO_3^-. It is increasing along with the length of the river (Table15, 16).

Table 16: Physiochemical parameters of Balkhu Khola at downstream.

Parameter/ Month	Unit	July	August	September	February
Temperature	^{0}c	25.5	26	20	18.5
Velocity	M/sec	0.8	0.8	0.8	0.2
P^H		8.7	8.9	9.3	9.5
Conductivity	Us/sec	32.9	31.3	22.9	33.2
Chloride	mg/lit	22.7	18.5	16.1	25.1
Total Hardness	mg/lit	81.3	83.3	71.3	103.3
Total Alkalinity	mg/lit	1.3	2.1	1.9	4.1
Free Carbon dioxide	mg/lit	27.8	8.8	16.8	41.0
Dissolved Oxygen	mg/lit	5.0	4.73	3.9	2.1
Biological Oxygen Demand	mg/lit				150
Chemical Oxygen Demand	mg/lit		148.26	91.73	203.7

Free carbon dioxide in water accounts from atmosphere and biological metabolism (respiration of aquatic plants and animals). Maximum concentration of free CO_2 was found in February (Figure 9); it may due to less volume of water existing in the river.

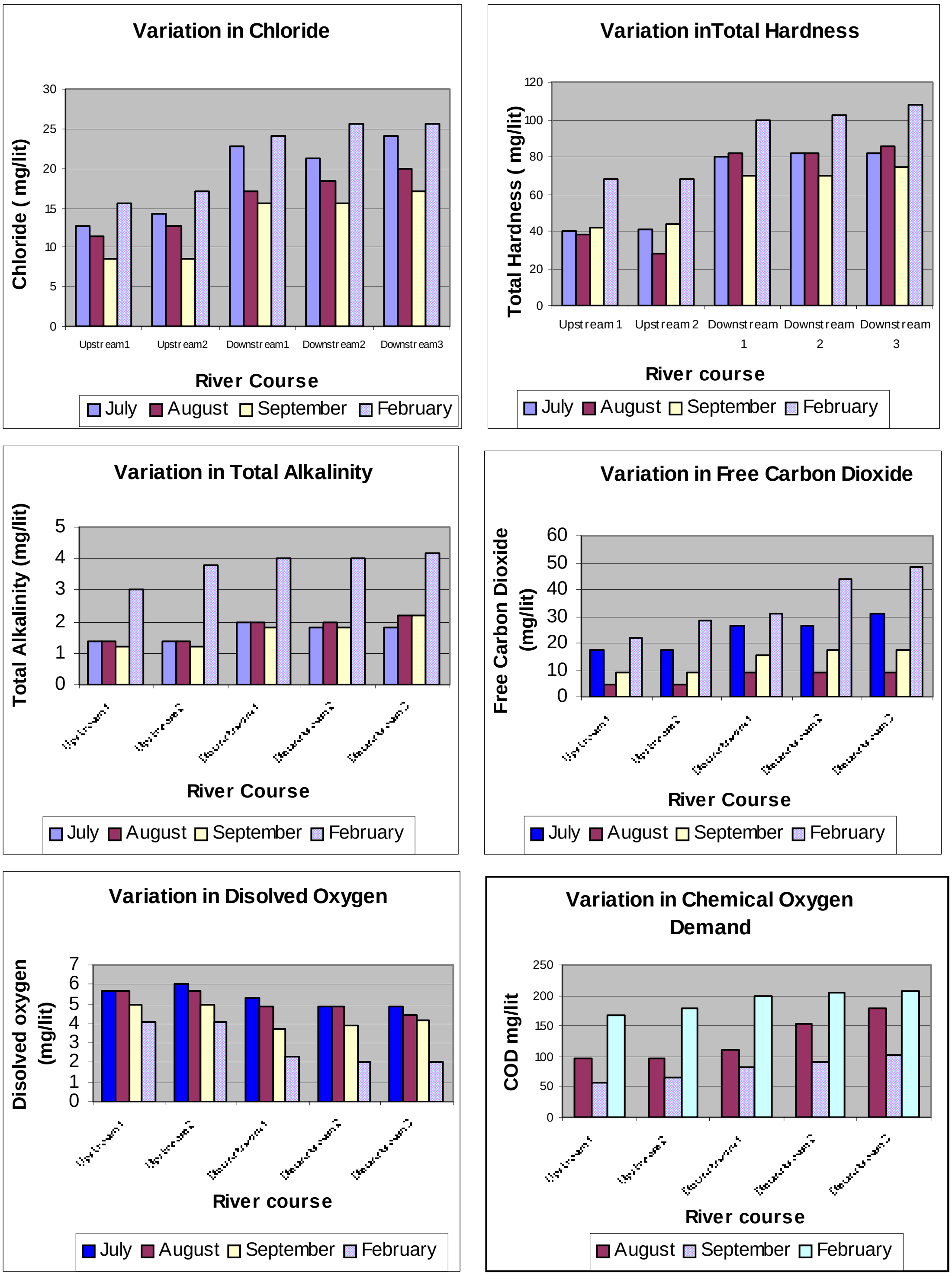

Figure 9: Variation in different chemical parameters at upstream and downstream part of Balkhu Khola.

High dissolved oxygen is an important index of clean and healthy water. Increased temperature triggers biological and chemical reaction and consequently decreases the DO. The concentration of oxygen in an aquatic environment is a function of biological process such as photosynthesis or respiration and physical processes as velocity of water and temperature. Low oxygen concentration is generally associated with organic pollution, in some cases heavy contamination may totally result in the anoxic condition. Organisms have specific requirement for DO so lower concentration may affects the survival of aquatic organisms. For healthy fresh water body at least 5 mg/l DO is essential (WHO, 1971). In this study DO is below permissible limit in February at upstream (Table 15) and it is below the permissible limit in all months except July at downstream (Table 16). It was recorded quite higher value i.e 9.0-11.0mg/l in July and 6.0 mg/l in November by Guvaju et al (2000).

BOD is used as an index of organic pollution in water. In this study BOD found to be increased along the length of river (Table 15, 16).

COD is the measure of oxygen equivalent of the organic contents of the water that is susceptible to oxidation by strong chemical oxidant. In this study COD was recorded as maximum in February in all sampling sites it may due to high load of pollution and low volume of water in river in winter (Figure 9).

Except Temperature all physiochemical parameters were significantly different between upstream and downstream course of the stream (Table 17).

Table 17: Test of significance (T-test) for physiochemical parameters.

Parameters	X_{up} bar*	X_{dn*} bar	S^2	T calculated	T at 5% level of confidence	Remarks
Temperature	21.1	22.52	3.61	1.27	2.31	Not significant
P^H	8.4	9.12	0.38	4.48	2.10	Significant
Conductivity	16.15	30.15	4.63	13.52	2.10	Significant
Chloride	12.6	20.59	3.53	10.01	2.10	Significant
Total Hardness	47.37	84.83	12.55	13.34	2.10	Significant
Total Alkalinity	1.85	2.48	0.97	2.91	2.10	Significant
Free Carbon dioxide	14.02	23.65	11.75	3.66	2.10	Significant
Dissolved Oxygen	5.15	3.95	1.04	5.21	2.10	Significant
Chemical Oxygen Demand	109.80	147.9	51.56	28.64	2.16	Significant

* X_{up} and X_{dn} bar = mean value at upstream and downstream.

Benthic macroinvertibrates

Forbes (1913) considered biological parameters to be more dependable in certain ways than that of chemical ones to assess water quality. Basically polluted water contains Oligochaetes, Dipterans and Gastropods and pure water contains Ephemeropterons, Trichopterons, Plecopterons and Odonates and they are very sensitive to pollution. Dipteran and Oligochaetes are pollution tolerant groups. In this study pollutant tolerant organisms were found to be more dominant since Species of Oligochaetes, Dipterans and Gastropods have high density. Absence of Odonata and Coleopteran shows higher degree of pollution at downstream than upstream part of the river. On the other hand presence of more texa shows less pollution at upstream than downstream. Diversity index and evenness index are also high at upstream, which shows diverse ecosystem and good sharing of resources amongst the different organisms group (Table 12, 13). Balkhu Khola has become polluted since pollution tolerant groups are dominant in all sites.

Organism found in this study in the stream shows the negative correlation with DO and positive correlation with CO_2, which further give strong evidence of high degree of pollution (Table 14).

Conclusion and Recommendation

Conclusion

- Balkhu Khola was found to be polluted by various chemicals, effluents, sewage and solid wastes; the degree of pollution was found to be increased along the downstream course of stream
- Strong relationship was found between physiochemical parameters and pollution as almost all physiochemical parameters were significantly different at downstream compared to upstream
- Species composition, species diversity and evenness index of macroinvertebrates were high at upstream while number and density of population were high at downstream part of the stream
- Macroinvertebrates showed negative correlation with dissolved oxygen and positive correlation with free carbon dioxide; Dipterans showed high degree correlation with both of the parameters

Recommendation

Following measures can be put forward to prevent further deterioration of water quality of Balkhu Khola

- Domestic and industrial wastes should be treated before releasing it into the Stream
- Solid waste disposal in and around the stream course should be discouraged
- People should make aware about the importance of clean and pure water body and community mobilization should be encouraged to prevent direct waste disposal into the stream
- Detail study should be done on the ecological and other ongoing natural as well as anthropogenic processes in the stream course

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