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Impact of Human Activities on Water Quality and vice versa on Ranikhola River in Sikkim, India

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Abstract : *Ranikhola River, rising in the Sikkim Himalaya (the Lesser Himalaya), is one of the multitudes of south-west flowing Himalayan Rivers of rain-fed characteristics. Different types of human activities along the riverbanks are the main threats to the Ranikhola River. The prime objective of the present study is to analyze the impact of human activities on the pollution status of Ranikhola river and vice versa. For such a study, six sample sites have been chosen from the lower portion of the Ranikhola River depending on the nature of human activities that can affect the river. Samples from those sites have been collected in the pre-monsoon season of 2016 and the post-monsoon season of 2017 to determine the water quality of the river. The ratio of BOD-COD of the sample sites is less than 0.2 in the pre-monsoon season and not biodegradable. The Most Probable Number (MPN) results and the number of bacterial colonies indicate that the water of Martam Khola and Namli areas (two sample sites) is much more pathogenically contaminated in both seasons than in other places. During the monsoon season, the local villagers do not get fresh water due to the presence of murky water in some areas. Due to ongoing construction works along the river, the water gets contaminated through the mixing of waste material from those sites particularly in the dry season. The local people suffer from different waterborne diseases due to impurified drinking water, water shortage in the dry season, and lack of proper awareness.*

Keywords : *Water pollution, DO, BOD/COD, Bacterial colonies, Waterborne diseases*

Introduction

Streams assume a critical job as they fill not just the need for water supply for residential, modern, farming, and power age yet also used to transfer sewage and mechanical waste and put it under enormous weight (Subin and Husna, 2013). The surface water structure is subject to standard elements (geographical, land, meteorological, hydrological and natural) in the seepage bowl and shifts with occasional contrasts in overflow volumes, climate conditions, and water level. During the most recent couple of decades' urbanization, modern activity, and agricultural creation has a widespread effect on water assets. Thus, highly complex connections between financial elements and common hydrological and environmental conditions have been created. Net natural

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contamination prompts unsettling influence of the oxygen balance, which is frequently joined by severe pathogenic defilement because of advancements with supplements of different inceptions, especially household sewage, agricultural run-off, and agro-industrial effluents. The principal issues related to farming are salinization, nitrate and pesticide pollution, and disintegration, prompting a high grouping of suspended solids in waterways and streams and the siltation of impoundment (Bandyopadhyay & De, 2017). Enteric pathogenic microorganisms are transmitted by water or wastewater to people and living life forms, which causes water-borne maladies (Adhikari et al., 2013). The development of dams on the waterway is not free of cost; these structures' ecological expense is likewise outstanding (WCD, 2000).

Water contamination in India is one of the significant ecological issues. A few occurrences of water contamination have been accounted for in India (Katyal and Satake, 1989); just a couple of episodes of such contamination have been accounted for in Sikkim (Sherpa, 2005). The nature of water accessible to man has been the indispensable factor in learning his prosperity (Trivedi and Goel, 1986). Several developmental activities along the river, such as road construction (NH31A), bridges, eight pharmaceutical companies, one food preservation factory, and MBPC Ltd. Dam construction site, agricultural activities, become the main threat of Ranikhola River. Moreover, the river is passing by some highly densely populated areas such as Gangtok city, Ranipool, Martam, Simgtham, where the city drainage system is directly connected with the river. In rural areas, villagers are dependent on the river. They use the river water for drinking, bathing, fishing purposes also. It is assumed that these human activities are responsible for changing the water quality of the river.

Till today such a vital issue related to the water quality of the Ranikhola river has hardly been addressed by any researcher. Keeping this in view, the present work aims to determine the water quality and contamination heap of Ranikhola River, one of the major tributaries of river Teesta, and analyze the impact of human activities on the river and vice versa.

The Study Area

Ranikhola River rising in the Sikkim Himalaya (the Lesser Himalaya) is one of the multitudes of south-west flowing Himalayan Rivers of rain-fed characteristics. Ranikhola is 36 km long, and in its initial stretch, it flows as Rora Chhu. Ranikhola river basin is a canoe-shape, covering an area of 253 km^2 and is aligned in NE-SW direction, covering an elevation range of 3,772 m (from 4,122 m to 350 m). Two major tributaries of Ranikhola are Taksom Chhu and Re Chhu, which respectively join it on the left and right banks. The river originates near Bakthang waterfalls and falls into Teesta River near Singtam with the geographical location 27^{o}13'45.50''N to 27^{o}21'28.80''N and 88^{o}29'21.71''E to 88^{o}37'24.56''E respectively (Fig. 1).

Methodology

For the present study, six sample sites have been selected from the lower portion of Ranikhola river basin those are: (1) Adampool near STP, (2) under Ranipool bridge, (3) Namli near a dam construction site, (4) Martam Khola, (5) Marchak near dumping yard, and (6) Singtham near the confluence of river Tista and Ranikhola. For the household survey, ten settlement areas are selected

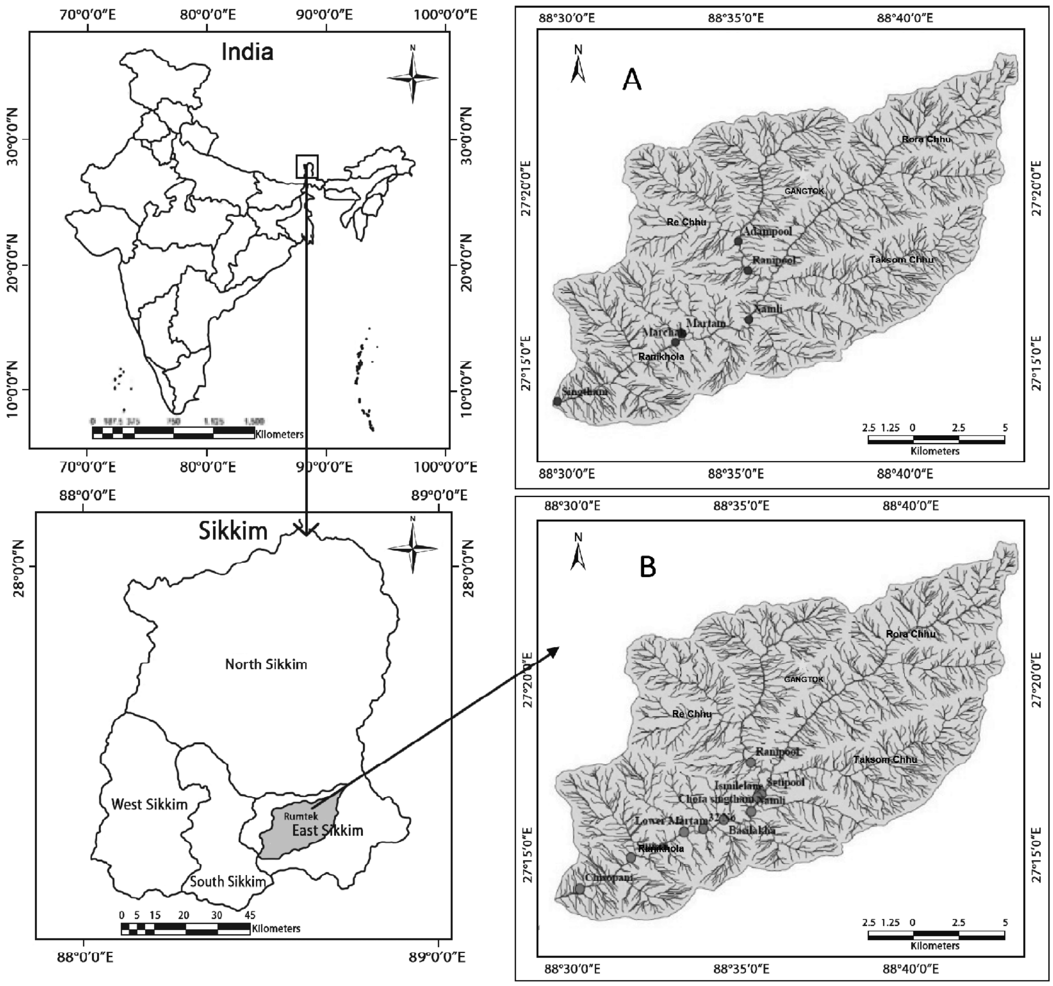

Fig. 1. Location of the Ranikhola River basin with (A) water sample sites and (B) settlements surveyed

those are: (i) Sumen, (ii) Ranipool, (iii) Chisopani, (iv) Lower Martam, (v) 32no, (vi) Bashilakha, (vii) Chotasingtham, (viii) Namli, (ix) Setupool, and (x) Ismail lane. All these sites and villages are chosen based on the sources of contamination. From those ten settlements 221 respondents are selected randomly to ask different questions related to the source and scarcity of drinking water, and the perception about the water-borne diseases.

The present study aims at exploring the physicochemical properties of the lower portion of the Ranikhola River. Water sample has been collected from the river in pre-monsoon April 2016 and post-monsoon Feb 2017 which incorporate water temperature, pH, Total Dissolved Solids (TDS)

Total Suspended Solid (TSS), Turbidity, Electrical conductivity (EC), Turbidity, Total alkalinity, Total Hardness, Dissolved oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The research methods for laboratory analysis of the parameters are adopted from the “Standard Methods for Examination of Water and Wastewater” 18th edition 1992 and 21st edition 2005 published by APHA. The collected samples are examined at State Pollution Control Board, Sikkim, and Meghalaya pollution control Board. An extensive household survey for ten settlement areas is conducted along the river. To determine the permissible limits of physical, chemical and biological parameters the International Organization of Standardization (ISO) scale has been followed.

Physical Parameters

All the physical parameters are tested in the laboratory using APHA 18th and 21st edition Standard Methods for the Examination of Water and Wastewater. The temperature of the water is recorded by a standard mercury thermometer. The total dissolved solids (TDS) are estimated utilizing a TDS meter. For total suspended solids (TSS), 100ml of water sample is filtered, and the weight of residues is determined by weighing. Total solids are determined by adding the values obtained from Dissolved solids and Suspended solids. Electrical conductivity quantifies how much electricity is being led through a centimetre of water and is generally expressed in ìS/cm of water. The particular conductivity of the water will likewise increase with temperature; hence its estimation is typically standardized at 25°C. The turbidity of the water test is estimated utilizing a nephelometric turbidimeter.

Chemical Parameters

pH values are determined by utilizing pH paper of universal indicator, Merck brand in the field. It is also confirmed electrometrically using a pH meter (ELICO brand, Model LI - 613).

$$pH = \log 1 [Hz]$$

Where, [Hz] is the amount of Hydrogen- ions in a solution in moles per litre.

Total Hardness

Hardness is directly measured by titration with ethylene diamine tetra acetic acid (EDTA) using Eriochrome black T (EBT) as an indicator. The EBT reacts with the divalent metallic cations forming a complex which is red in colour. The EDTA replaces the EBT in the complex, and when the replacement is complete, the solution changes from red to blue. If 0.01 M EDTA is used, 1.0 ml of the titrant measures 1.0 mg of hardness as CaCO3.The total hardness is calculated as shown in equation.

$$Total\ Hardness\ (mg / l\ CaCo_3) = \frac{Volume\ of\ EDTA\ utilized\ in\ ml \times 1000}{Volume\ of\ test\ utilize}$$

Total Alkalinity

The alkalinity of water can be controlled by titrating the sample with Sulphuric acid of known estimations of pH, volume, and concentrations. Based on the stoichiometry of the response and the number of moles of Sulphuric acid expected to arrive at the end-point, the convergence of alkalinity in water is calculated. Alkalinity is then expressed as milligrams per litre of CaCO3. If 0.02 N H2SO4 is utilized in the titration, at that point, 1 ml of the acid will neutralize 1 mg of alkalinity of CaCO3. In this manner, the amount of acid required to titrate a sample to pH 4.5 is equal to the total alkalinity of the water. The calculation is done using the following formula.

$$Alkalinity\ (moles / l) = \left[HCO_3^{-}\right] + 2\left[CO_3^{-2}\right] + \left[H^{+}\right]$$

$$Total\ \ Alkalinity\ (mg / l\ CaCo_3) = \frac{Volume\ of\ \ H_2So_4\ \ Normality \times 50,000}{Volume\ of\ \ sample\ taken}$$

Dissolved Oxygen (DO)

The Winkler method is adopted to determine the DO of the given water sample. In this method, the water is mixed with Manganese Sulphate (MnSO4) and an alkali-iodide reagent (NaOH + KI). The MnO2 (red ppt.) is formed with the help of available DO. In the water sample and H+ ions (created in the test by addition of concentrated H2SO4) oxidize Iodine ions (I-) released by the alkali iodide reagent to Iodine (I2). The amount of I2 formed in the test has been computed by titrating the solution against the standard 0.025N sodium thiosulphate. The quantity of I2 in the test is equivalent to the dissolved oxygen (0.5 O2, having equivalent wt. =8) in the original sample. The DO value is finally computed by using the following equation.

$$Do\ (mg / l) = \frac{Sodium\ thiosulphate\ utilized\ \ (ml) \times 0.025N \times 8 \times 1000}{Volume\ of\ \ water\ test\ (ml)}$$

Biochemical Oxygen Demand (BOD)

The BOD is estimated by determining the oxygen consumption from a sample put in an air-tight container and kept in a controlled environment for a preselected timeframe. In the standard test, a 300 ml BOD bottle is used, and the sample is incubated at 20°C for five days. Light is excluded from the incubator to prevent algal growth that may produce oxygen in the bottle. Because the saturation concentration for oxygen in water at 20°C is approximately 9 mg/l, dilution of the sample with BOD-free, oxygen-saturated water is necessary to measure BOD values. The BOD of a diluted sample is calculated using the equation.

$$BOD(mg / l) = \frac{\left(D_o - D5 - BC\right) \times Volume\ of\ \ the\ weakened\ \ sample}{Volume\ of\ \ test\ taken\ (ml)}$$

Where, D_o = Initial DO of the diluted sample, D5 = DO at the end of 5 days for diluted sample. BC = Blank correction.

Chemical Oxygen Demand (COD)

The laboratory assessment of COD lies in using a strong oxidant like potassium dichromate (K2Cr2O7) or potassium permanganate (KMnO4) solution to oxidize the organic matter. In this test, a known quality of wastewater is blended with a known quality of K2Cr2O7, and the mixture is warmed. The organic matter is oxidized by K2Cr2O7 within the presence of H2SO4. The subsequent solution of K2Cr2O7 is titrated, and the oxygen utilized in oxidizing the wastewater is resolved. The COD is determined using this equation.

$$COD(mg/l) = \frac{(A - B \times N \times 8 \times 1000)}{Volume\ of\ test\ taken\ (ml)}$$

Where, A = Volume of ferrous ammonium sulphate for blank, B = Volume of ferrous ammonium sulphate for sample, N = normality of ferrous ammonium sulphate.

Biological Parameters

Total Coliform and Standard Plate Count test are conducted in the laboratory with the Serial dilution technique. A multiple tube fermentation technique is used to determine the most probable number (Prescott and Harley, 2002).

Total Coliform Counts

The total coliform bacteria test is an essential marker of “potability,” appropriateness for consumption, of drinking water. It quantifies the concentration of total coliform bacteria related to the possible presence of disease-causing organisms.

Serial dilution techniques (APHA 2005)

At first, 9 ml 0.85% NaCl (saline) is prepared in test tubes. Test tubes are autoclaved in 15lb/ 1210C for 20 minutes. Then 1 mL of water is transferred to the 1st tube making 10-1 dilution (dilution factor 1×10). From the 1st tube, we transfer 1mL to the 2nd tube making dilution 10-2 (dilution factor 2×10). Likewise, we processed to dilution up to 10-6.

Standard Plate Count (Scott, 2011)

In this test, 0.1mL each from dilution 10-5, 10-6 for 6 samples are inoculated into the Nutrient Agar plate, and the spread plate technique is followed. After that, those tubes are incubated at 37°c for 24 hours. After incubation, we observed the colony formation and counted the number of the colony that developed from the plate. Finally, calculate the Colony Forming Unit (CFU) per ml of sample.

$$CFI = \frac{Number\ of\ colonies \times dilution\ factor}{Amount\ of\ sample\ plated}$$

Most Probable Number: (Blodgett, 2010)

MPN is a procedure to estimate the population density of viable microorganisms in a test sample. Presumption confirmed and complete are the three steps for the MPN test.

Presumptive Test: In this test, 1 mL of each from dilution 10-4, 10-5, 10-6 for five samples (STP, Adampool, Namli, Ranipool, Marchak) and Martam Khola 10-1, 10-2, 10-3 dilution are inoculated into Lactose broth containing Durham's tube. Then all the tubes are incubated at 37°C for 24 hours in a shaker incubator. Lastly, the gas production is observed in Durham's tube after 24 hours of incubation.

Confirmed test: From the positive tubes, one loopful is inoculated into Brilliant Green Blue (BGB) broth and incubated for 24 hours at 370C. Then the gas production is observed, which confirms the presence of coliform bacteria.

Complete Test: We streak one loopful of bacterial culture into EMB (Eosin methylene Blue) Agar plate from confirmed positive tubes. Plates are incubated in an inverted position for 24 to 48 h at 370C and observed for metallic sheen colonies.

Results and Discussion

Physical Parameters

The concentration of TDS for the present study varies between 30mg/l to 189.9mg/l, which is within the permissible limit. Maximum TDS concentration is found near STP in the pre-monsoon season, and the minimum value is found near Martam Khola in post-monsoon season (Fig 2). There is not much fluctuation in concentration of TSS during post-monsoon but follows an increasing pre-monsoon period pattern, especially near STP (Adampool) 640mg/L (Fig 3). Conductivity value increases in the pre-monsoon season due to the augmented sediment load produced by rain-splash erosion, especially near Namli and STP, and the amount is 189 and 147.9µs/cm, respectively (Fig 4). Lower values of TS are observed near Martam Khola 40µs/cm as it is a tributary of river Ranikhola having less amount of sediment accumulation in it in both pre-and post-monsoon season (Fig 5). Maximum turbidity is seen in the pre-monsoon season near Singtham 183NTU, the confluence points of river Ranikhola and river Teesta (Fig 6). In this area, household wastewater, soap, and detergent produce stable colloids that results the increase of turbidity. Minimum Values are observed during the post-monsoon season near Martam Khola.

The high concentration of TDS and TSS happens due to dissolved material outcomes from the solvent action of water on solids, liquids, and gases and are carried away from dense settlements near STP(Adampool) and nearby industrial sites. The turbidity analyses show that river water quality starts degrading at the beginning of the monsoon season. The surface runoff contributes to the turbidity of the river in greater magnitude. Further, the wastewater from the houses entering the river Ranikhola also adds turbidity and degrades its quality.

Chemical Parameters

pH beneath 4 produces a sour taste, and a higher incentive above 8.5 gives an alkaline taste (CPHEEO, 2005). In this study, the pH values vary between 5-7. The pH value is natural near Martam Ranipool and STP area in the pre-monsoon season but decreases in the post-monsoon season (Fig 7). The lowest pH value of 5 can be observed near Marchak Water. Hardness has no antagonistic impacts; however, purposes include staining dishwashers, scaling boilers, and lathering. The hardness varies from 1064mg/l - 32mg/l (Fig 8). The range of alkalinity varies between 26mg/l – 62mg/l with no major variation in both seasons (Fig 9). Martam Khola is receiving the highest values due to direct human interference as compared to other areas. DO is an important factor of water pollution that varies from 0.805 – 8.85mg/l, which is not within the permissible limit (Fig 10) for all the stations during both pre- and post-monsoon period. BOD values are high near STP 170mg/l, and it decreases in the lower stretch followed by Singtham 9mg/l (Fig 11). COD concertation is also higher in the first three sites than the permissible limit (Fig 12). The lowest BOD/COD ratio is seen near Ranipool and STP area, 0.029 and 0.075 respectively (Fig 13), which is very less than the standard level.

The lowest pH value can be observed near Marchak due to the dumping yard and near Ranipool due to organic-chemical pollutants (such as residue of crops, pesticides, fertilizers). High hardness values are seen during the pre-monsoon season as the after-effect of precipitation, which washes away all the waste materials. Martam Khola is receiving the highest alkalinity values due to direct human interference as compared to other areas. Phosphates originating from detergent in wastewater releases likewise add to alkalinity. Most of the people who are directly dependent on the river water in Martam Khola have gastrointestinal issues and skin irritations due to excess alkalinity in the body. The lower DO values show that the river is polluted by human activities, with the maximum contamination seen near Ranipool, a densely populated area. Likewise, as the river flows downstream, there is a slight improvement in DO esteems, which may imply the role of the development of water in the process of aeration. Higher turbulence in the monsoon period increases river water velocity, and a decrease in altitude further improves the aeration process. BOD values are significantly rising in the post-monsoon season, and in this season, all the construction works are going on along the river. As a result of the high-water hyacinth concentration and algae near Ranipool, the river's aquatic organisms become stressed and suffocated. The BOD and COD values in some of the stations indicate that the water in those stations is highly polluted and needs immediate treatment. The proportion of BOD/COD for untreated wastewater is in the range from 0.3 to 0.8. If the BOD/COD proportion for untreated wastewater is 0.5 or more prominent, it is considered effectively treatable by biological means. If the proportion is below about 0.3, either the waste may have some toxic components, or accustomed microorganisms might be required in its stabilization.

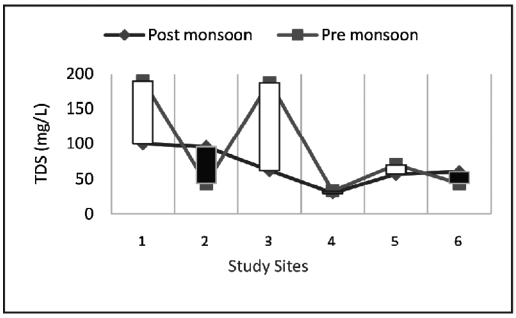

Fig 2. TDS concentration

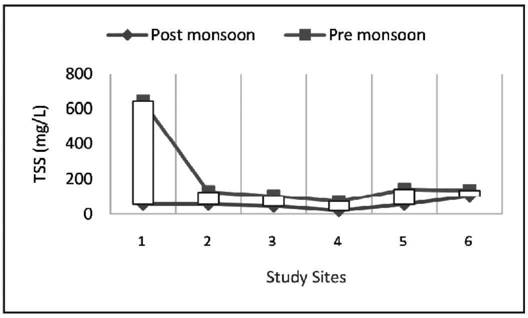

Fig 3. TSS concentration

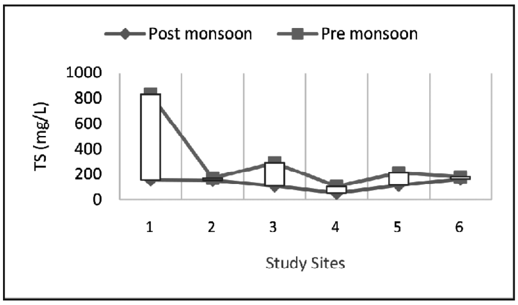

Fig 4. TS concentration

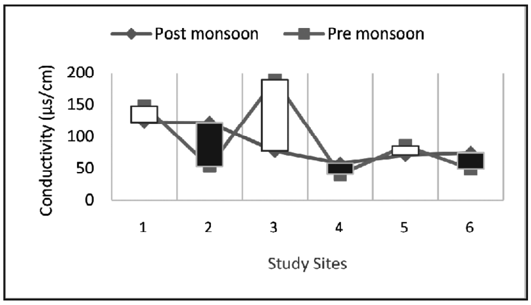

Fig 5. Conductivity Concentration

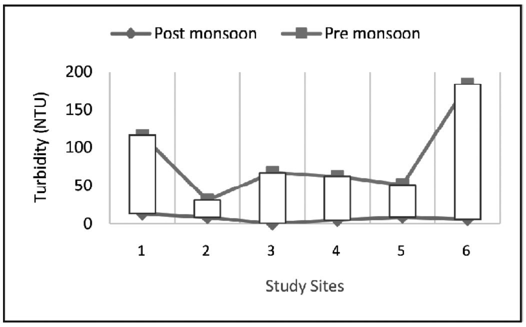

Fig 6. Turbidity concentration

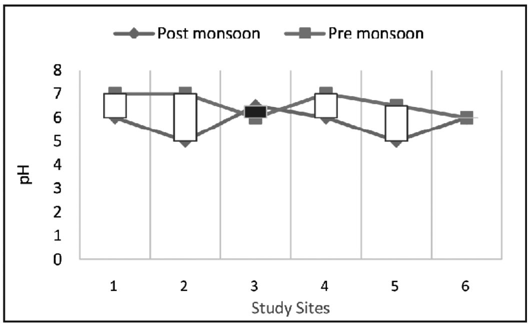

Fig 7. pH concentration

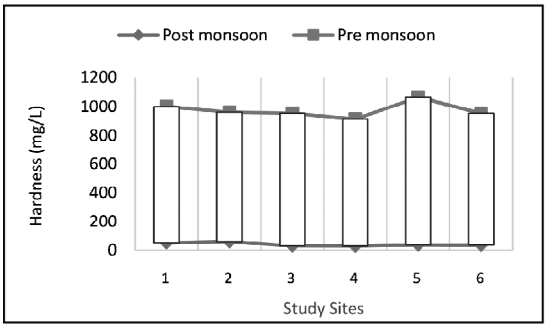

Fig 8. Hardness concentration

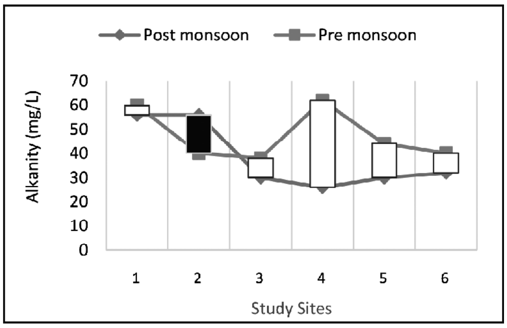

Fig 9. Alkalinity concentration

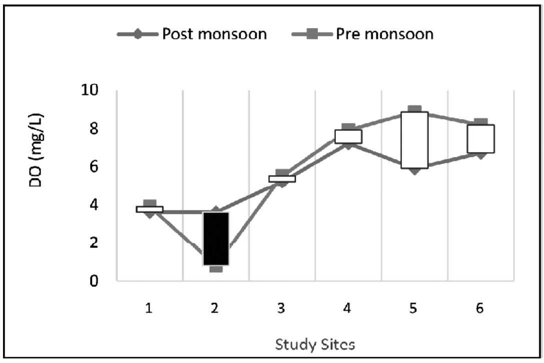

Fig 10. DO concentration

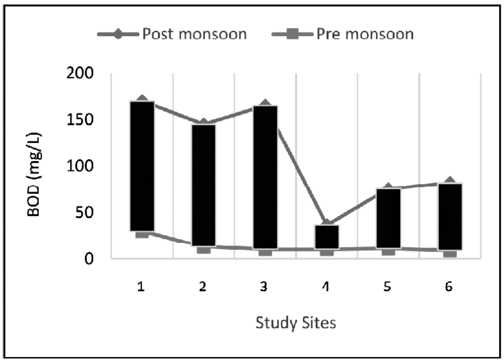

Fig 11. BOD concentration

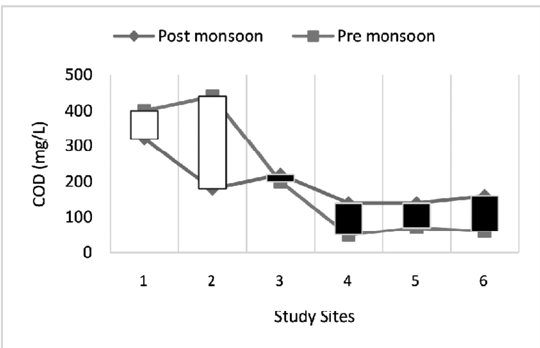

Fig 12. COD concentration

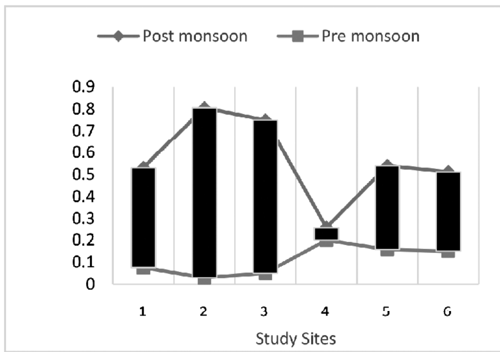

Fig 13. Ratio of BOD and COD

Note: The numbers along horizontal axis in Figures 2-13 indicates the study sites. (1) STP(Adampool), (2) Ranipool, (3) Namli, (4) Martam Khola, (5) Marchan, and (6) Singtham.

Biological Parameters

A high population of bacterial cells for both pre-and post-monsoon season is found in Martam Khola, one of Ranikhola River's tributary and near Martam village is situated (Tables 1 and 2). Likewise, in Namli, near a Dam construction site, a high population of bacterial cells is found for pre-monsoon season. The moderate population of bacterial cells is found in 3 places: Ranipool,

Table 1. Standard Plate Count ($10^{-1}/10^{-2}/10^{-3}/10^{-4}$), Total Coliform Test for Post-monsoon

Sampling Site	Dilution	No. of colonies/ colony forming unit (CFU/ml)	Result
M T	10^{-1}	TNTC	Too numerous to count
M T	10^{-2}	TNTC	Too numerous to count
M T	10^{-3}	TNTC	Too numerous to count
M T	10^{-4}	172	17.2×10^{5}/ml
M K	10^{-1}	103	10.3×10^{2}/ml
M K	10^{-2}	72	7.2×10^{3}/ml
M K	10^{-3}	21	2.1×10^{4}/ml
M K	10^{-4}	2	2.0×10^{5}/ml
RANI	10^{-1}	TNTC	Too numerous to count
RANI	10^{-2}	TNTC	Too numerous to count
RANI	10^{-3}	293	29.3×10^{4}/ml
RANI	10^{-4}	80	8.0×10^{5}/ml
NL	10^{-1}	TNTC	Too numerous to count
NL	10^{-2}	TNTC	Too numerous to count
NL	10^{-3}	TNTC	Too numerous to count
NL	10^{-4}	30	3.0×10^{5}/ml
STP	10^{-1}	120	12.0×10^{2}/ml
STP	10^{-2}	110	11.0×10^{3}/ml
STP	10^{-3}	76	7.6×10^{4}/ml
STP	10^{-4}	52	5.2×10^{5}/ml
SI	10^{-1}	104	10.4×10^{2}/ml
SI	10^{-2}	100	10.0×10^{3}/ml
SI	10^{-3}	65	6.5×10^{4}/ml
SI	10^{-4}	2	2.0×10^{5}/ml

Singtham, and Adampool near STP (sewage treatment plant) for pre-monsoon, and Ranipool are moderately high in post-monsoon season due to human obstruction along the river. The less bacterial population is found in Marchak and Namli for pre-monsoon on account of fewer human settlements. It's in Marchak, Adampool close to STP (sewage treatment plant), and in the Singtham area for post-monsoon.

Table 2. Standard Plate Count ($10^{-5}/10^{-6}$), Total coliform Test for Pre monsoon

Sampling Site	Dilution	No. of colonies/ colony forming unit (CFU/ml)	Result
MT	10^{-5}	TNTC	Too numerous to count
MT	10^{-6}	TNTC	Too numerous to count
MK	10^{-5}	99	9.9×10^{6}/ml
MK	10^{-6}	85	8.5×10^{7}/ml
RANI	10^{-5}	115	11.5×10^{6}/ml
RANI	10^{-6}	88	8.8×10^{7}/ml
NL	10^{-5}	81	8.1×10^{6}/ml
NL	10^{-6}	59	5.9×10^{7}/ml
STP	10^{-5}	188	18.8×10^{6}/ml
STP	10^{-6}	99	9.9×10^{7}/ml
SI	10^{-5}	158	15.8×10^{6}/ml
SI	10^{-6}	73	7.3×10^{7}/ml

In the pre-monsoon season, there is no gas production in the 3 samples of Ranipool, Marchak, and Singtham. For Namli and STP samples, only one tube each showed a positive presumptive test, i.e., there is gas production in Durham's tubes from a total of 9 tubes, and for Martam Khola, 7 tubes showed positives results in those 9 tubes. In the post-monsoon season Ranipool, Namli, and STP samples, one tube from each sample showed a positive presumptive test. For Martam, Marchak gas production is there in some tubes, but no growth is found. There is no gas production in Durham's tubes, only in Singhtam. For the pre-monsoon season, after 24 h of incubation, all the tubes showed gas production from Martam, Namli, and STP samples and no coliform from Ranipool, Marchak and Singhtam. In the post-monsoon season, all the tubes showed gas production from Ranipool, Namli, STP samples and no gas production in Martam and Marchak tubes. Table 3 shows that after incubation in the pre-monsoon season, metallic sheen colonies are observed from three samples: Martam, Namli, and STP. Other Enterobacteriaceae families like klebsiella, shigella also grew, which doesn't show metallic sheen colonies. In the post-monsoon test, metallic sheen colonies are observed from the sample of Namli. Other Enterobacteriaceae families like klebsiella, shigella also grew, which doesn't show metallic sheen colonies in Ranipool and STP samples.

Table 3. Most Probable Number for Post- and Pre-monsoon seasons

Sample site	Post monsoon						Pre ponsoon								
	10^{-3} RANI	10^{-3} RANI	10^{-3} STP	10^{-3} STP	10^{-3} NL	10^{-3} NL	10^{-1} MT	10^{-1} MT	10^{-2} MT	10^{-2} MT	10^{-3} MT	10^{-3} MT	10^{-3} MT	10^{-4} NL	10^{-4} STP
Tube no.	1	2	1	2	1	2	1	2	1	2	1	2	3	2	2
Bacteria presence	OEB	OEB	OEB	OEB	*E.coli*	*E.coli*	OEB	OEB	OEB	OEB	*E.coli*	OEB	OEB	*E. Coli*	*E. Coli*

(Nb: OEB= Other Enterobacteriaceae Bacteria, RANI= Ranipool, STP= Sewage Treatment Plant NL= Namli)

The highest MPN is found in Martam Khola, which is 6/100ml water, and in Ranipool, STP, Namli, it is 2/100ml water for pre-and post-monsoon, respectively (Tables 4 and 5). Moderate MPN is found in Namli and STP (Adampool) area, which is 2/100ml water for the pre-monsoon. The

Table 4. Determination of MPN from multiple tube test for the post-monsoon season

Sampling Site	Dilution	Combination of positive tubes	MPN/100ml	95% confidence Limit	
				Lower	Upper
Ranipool	10^{-4}	0-0-0	<2	1.0	10
	10^{-5}	0-0-0	<2	1.0	10
	10^{-6}	0-0-0	<2	1.0	10
Marchak	10^{-4}	0-0-0	<2	1.0	10
	10^{-5}	0-0-0	<2	1.0	10
	10^{-6}	0-0-0	<2	1.0	10
Singtham	10^{-4}	0-0-0	<2	1.0	10
	10^{-5}	0-0-0	<2	1.0	10
	10^{-6}	0-0-0	<2	1.0	10
Namli	10^{-4}	0-1-0	2	1.0	14
	10^{-5}	0-0-0	<2	1.0	10
	10^{-6}	0-0-0	<2	1.0	10
STP	10^{-4}	0-1-0	2	1.0	14
	10^{-5}	0-0-0	<2	1.0	10
	10^{-6}	0-0-0	<2	1.0	10
Martam khola	10^{-1}	1-1-0	4	1.0	15
	10^{-2}	1-0-1	4	1.0	15
	10^{-3}	1-1-1	6	2.0	18

lowest MPN is found in Singtham, Marchak, and Ranipool area, which is <2/100ml water for the pre-monsoon and Singtham, Marchak, and Martam Khola area <2/100ml water for post-monsoon. Therefore, from this analysis it is clear that the water of STP (Adampool) and Namli are considerably pathogenically contaminated in both pre- and post-monsoon seasons due to lack of sanitation and more utilizing public lavatory.

Table 5. Determination of MPN from multiple tube tests for the pre-monsoon season

Sampling Site	Dilution	Combination of positive tubes	MPN/100ml	95% confidence Limit	
				Lower	Upper
Ranipool	10^{-4}	0-0-0	<2	1.0	10
	10^{-5}	0-0-0	<2	1.0	10
	10^{-6}	0-0-0	<2	1.0	10
Marchak	10^{-4}	0-0-0	<2	1.0	10
	10^{-5}	0-0-0	<2	1.0	10
	10^{-6}	0-0-0	<2	1.0	10
Singtham	10^{-4}	0-0-0	<2	1.0	10
	10^{-5}	0-0-0	<2	1.0	10
	10^{-6}	0-0-0	<2	1.0	10
Namli	10^{-4}	0-1-0	2	1.0	14
	10^{-5}	0-0-0	<2	1.0	10
	10^{-6}	0-0-0	<2	1.0	10
STP	10^{-4}	0-1-0	2	1.0	14
	10^{-5}	0-0-0	<2	1.0	10
	10^{-6}	0-0-0	<2	1.0	10
Martam khola	10^{-1}	1-1-0	4	1.0	15
	10^{-2}	1-0-1	4	1.0	15
	10^{-3}	1-1-1	6	2.0	18

Different types of wastes are generated from the surrounding settlements. Most of those wastes are directly coming down the river. Moreover, there is a urban solid waste dumping ground near Marchak that also supplies both solid and liquid wastes to the river. Most of these are solid wastes that contaminate the river water on one side and supply extra sediment to the river bed. According to the primary field survey and people's perception it is found that 96% of industrial waste is dumping directly on the river bed. In contrast, agricultural waste is less than 11% because

Sikkim has been nominated as the first organic state of India, and they cannot use any pesticides while farming (Fig 14). It is also found from the same survey that 43% of respondents are suffering from water scarcity.

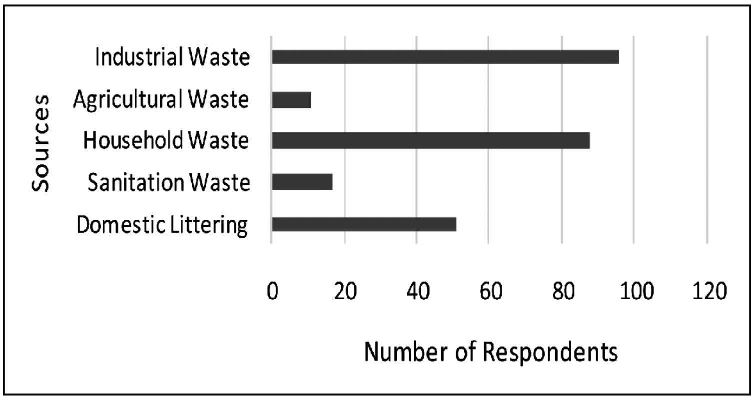

Fig. 14. Opinion of the respondents of the selected villages about the sources of river water health deterioration in the Ranikhola river

Out of 221 respondents from the selected villages 138 people agree that the cause of water scarcity during monsoon period is the presence of murky water in the river and 77 people agree that dried water sources in upstream areas are responsible for water scarcity during the winter season. Some of the respondents remained silent to answer. As all the rivers in these regions are rain-fed, and the maximum drinking water sources are private water supply with the help of pipe, the people are suffering most near Martamkhola and Namli during winter. Whereas, near Singtham and Ranipool, 26% of households are getting municipality water regularly (Fig 15).

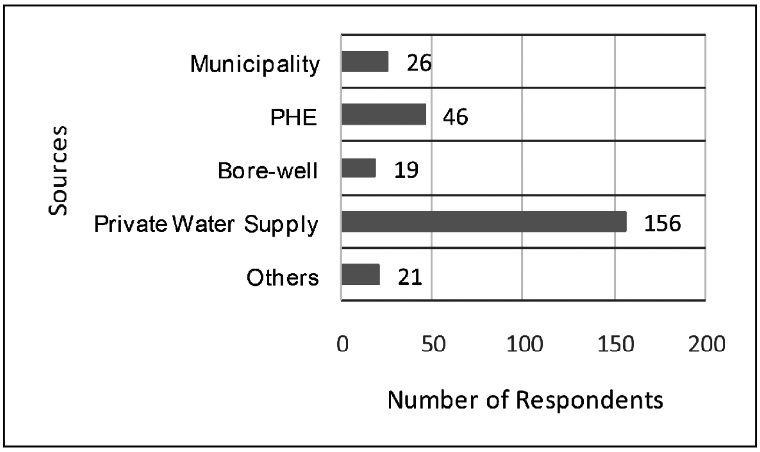

Fig 15. Primary sources of drinking water in the study area

Sikkim has long been an agricultural society. However, in recent years, industry has become increasingly significant in the state's economy. Nine large-scale industries are situated along the right bank of the Ranikhola River. Among them seven are Pharmaceutical companies, those are Torrent Pharmaceuticals Ltd unit II, Sun Pharma, Unit 2, Sunpharma plant 1, Glenmark Pharmaceuticals Ltd., Heba Pharmaceuticals LLP, Macleods Pharmaceuticals Ltd., STP Pharmaceuticals Pvt. Ltd. and the other two factories are Pristine Life Science, Sikkim Supreme Orange Juice Factory (Fig 16). Water sample 1 (Adampool) indicates that the source of the water pollution in mainly the presence of Sewage Treatment Plant and household wastage. Whereas Water sample 2 (Ranipool) shows that source of the pollution is primarily from household wastage. However, water sample 3 (Namli) and 4 (Martam) indicates the source of the pollution is from Industry. 6 Pharmaceutical companies

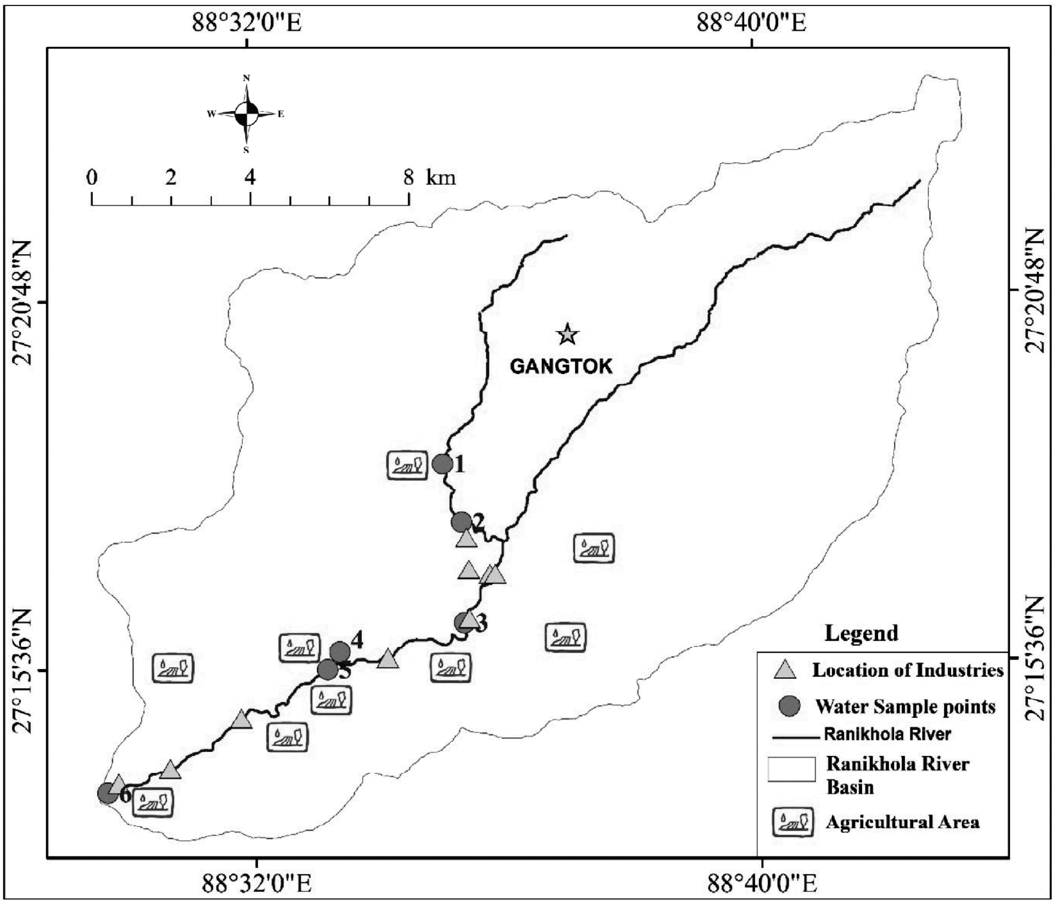

Fig. 16. Location of Industries and Agricultural areas in Ranikhola Basin

are situated in between this area. One dumping yard is the main source of the pollution near Water sample 5 (Marchak). Water sample 6 (Singtham) shows the source of the water pollution are from Industry and household wastage.

Impact on Human Health

Increasing water pollution is different sites of the Ranikhola river increases the propensity of different water-borne diseases among people in the selected settlements. The pipe materials, leakages in the pipe, poor maintenance, and drinking water without purification causes frequent malaria and diarrhea in every single house (Fig. 18). The presence of E.coli in this river shows that there is a direct or indirect dump of human feces into the rivers. Most of the drains in this area directly discharge their water into the river. Skin diseases are likewise observed in Martam Khola village due to daily uses of pathogenically contaminated water.

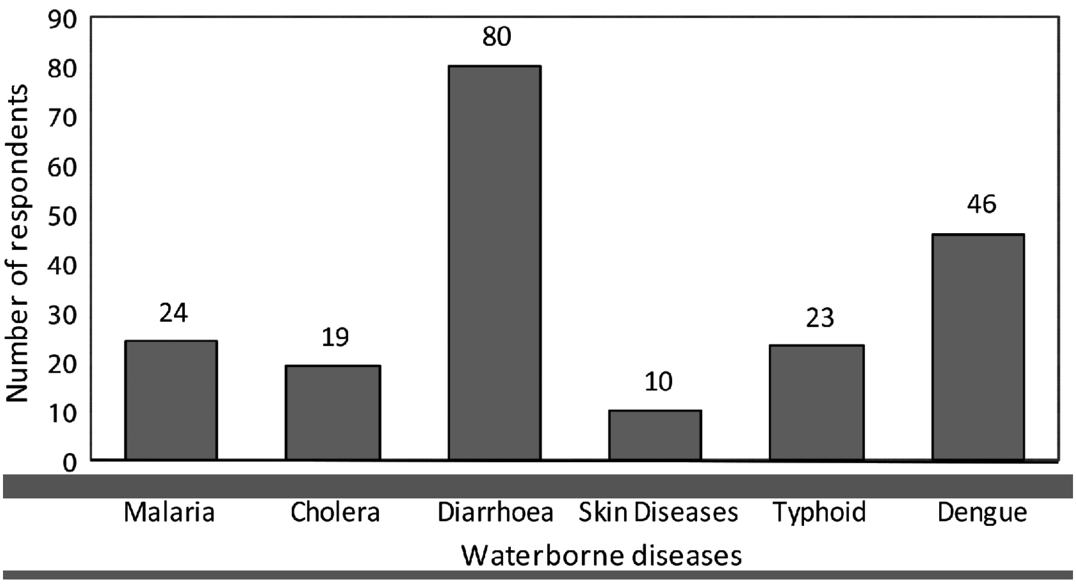

Fig. 17. Respondents' opinion regarding the waterborne diseases in study area

A Chi-square test is conducted to determine the relation between the source of drinking water and water-borne diseases. From the test, it is found that the households having private pipe are more prone to water-borne diseases (87.91%) than the other sources of water (Table 6). In private water supply areas, pipe supply causes more diseases than other areas because they do not use the conventional water treatment process for drinking water and household purposes.

Table 6. Chi -Square Distribution with Degree of Freedom

Source of Drinking Water	Water-borne diseases	
	Yes	No
Municipality	1	0
	(0.54)	(0)
PHE	9	23
	(4.95)	(58.97)
Bore-well	9	4
	(4.95)	(10.26)
Private pipe	160	12
	(87.91)	(30.77)
Others	3	0
	(1.65)	(0)

References

Adhikari, R.N., Singh. A.K., Math. S.K.N., Raizada. A., Mishra. P. K. and Reddy. K.K. (2013). Augmentation of groundwater recharge and water quality improvement by water harvesting structures in the semi-arid Deccan. *Current Science,* 104(11),1534-1542

APHA (1992). Standard Methods for the Examination of Water and Wastewater:18th and 21st edition. *Water Environment Federation*, Washington DC, USASS, 9–45.

Bandyopadhyay, S., and De, S. K. (2017). *Human Interference on River Health*. Springer International Publishing, Switzerland.

Blodgett, R. (2010). *BAM Appendix 2: Most Probable Number from Serial Dilutions*. Bacteriological Analytical Manual (BAM). US Food and Drug Administration.

CPHEEO (2005). Manual on Operation and Maintenance of Water Supply System. Central Public Health & Environmental Engineering Organisation, Ministry of Housing and Urban Affairs, Government of India, 1-20.

ISO Standards Catalogue (2018): 13.060 Water Quality. International Organization for Standardisation, Geneva, 2018b. https://www.iso.org/ics/13.060/x/ (Accessed on 25 May, 2021)

Katyal, T. & Satake, M. (1989). *Environmental Pollution*. Anmol Publication, New Delhi, 65-121.

Prescott, L.M., Harley, J.P. (2002). *Laboratory exercise in Microbiology: 5th Edition.* Mc Graw-Hill Companies Inc., New York, 133-183

Sherpa, Z. (2005). *Fish Diversity and Fisheries resources of Rangpo Khola, Sikkim.* A Dissertation submitted to the Institute of Science and Technology, Central Department of Zoology, Tribhuvan University, Nepal.

Subin, M.P. & *Husna* A. H. (2013). An Assessment on the Impact of Waste Discharge on Water Quality of Priyar River Lets in Certain Selected Sites in the Northern Part of Ernakulum District in Kerala, India. *International Research Journal of Environment Sciences* 2 (6), 76-84

Trivedy, R. K. and Goel, P. K. (1986) Chemical and Biological method for water pollution studies. *Environmental publication* (Karad, India), 6: 10-12.

WCD (2000). *Dams and Development*. World Commission on Dams. *http://awsassets.panda.org/downloads/wcd_dams_final_report.pdf* retrieved in November, 2020