Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 7, July 2021: 3217- 3239

Water Quality Assessment of Chhota Rangit River in Darjeeling Himalaya India, using Water Quality Index (WQI) approach

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Abstract

The streams and rivers are the only source of water for people living in the mountainous parts of the world. But due to increased population and increased human interferences both the quality and quantity of water has been rapidly deteriorating leading to problems of water scarcity and water pollution in these fragile regions. The study area falls within the hilly region in India that often faces water scarcity and problems of water pollution. Water samples were collected from the predetermined sites of the river basin and then the water samples were sent to the water testing laboratory to measure various physical, chemical and biological parameters. The analytical results were then compared with the water quality standard set by WHO (2004) and Indian Standard (2012).Finally the water quality of the river was measured using the water quality index (WQI). The analytical result shows that the water in the river basin is highly acidic in nature with pH value ranging between 5.2 -7.1. According to the result of water quality analysis the quality of water in the river basin coincides with four categories of water such as excellent, good, poor and very poor. The water quality index value observed in the sample water collected from Kankibong (94.17) and Bijanbari (76.21) is high which indicates poor water quality. The presence of such high water quality index values in these sites is due to the presence of high chemical and bacteriological parameters. The spatial distribution of water quality in the study area varies from site to site and shows that the poor quality of water is mostly associated with the areas where human interferences such as built up areas, agricultural villages, animal rearing etc are high.

Keywords

Water quality Index; Physio-chemical; bacteriological; anthropogenic interferences; river basin; water quality

1. Introduction

Water is an essential resource for continuation of civilization and survival of human life. There are various sources of water, however ground water is considered as the major sources of water (Bear 1979, Gopinath 2003, Das and Mukhopadhyay 2015) on which more than half of the world population depends for their livelihood (Foster 1995, U.S. Environmental Protection Agency 2002, Nickson et al. 2005). But besides these facts there are portions of people living in the mountainous parts of the world that does not have an access to ground water sources and they directly depend on the rivers and streams for their basic water requirements. Various geo-morphological factors such as relief, slopes, and aspects etc; highly restricts the infiltration and recharge of ground water and encourage the runoff leading to water scarcity in these regions. But in the recent times not only the availability of water but also the quality of water has been highly deteriorated due to increased human population and their interferences through mining, unscientific land use and land cover changes, urbanization, industrialization etc; (Subramani et al. 2005, Kumar et al. 2011, Prasanth et al. 2012, Tiri et al., 2018) which on the other hand has aroused the concern regarding the quality of water around the globe. Water pollution due to human interferences has become one of the most serious problems in the world (Umar et al., 2009, Sadat-Noori et al., 2014) because it not only affects the quality of water but also intimidates human health, economic development and social wellbeing (Milovanovic 2007). Thus the studies related to the quality of water and its suitability for various uses, as well as the impacts of polluted water on human health has gained a huge attention among the researchers and has become relevant field of research around the world in the recent times. Several scholars Robertson (1986), Frost et al., (1993), Chang (2005),Babiker (2007), Bhattacharya et al; (2010), Ferencz and Balog (2010), Mandal et al., (2010), Roy et al., (2011),Prasanth et al.,(2012), Oprean et al., (2013), Guettaf et al., (2014), Al-Mashagbah (2015), Hosseini et al.,2016, Kaur et al., (2016), Selvakumar et al., (2017), Tiri et al.,(2018), Dunca (2018) etc, has focused their studies on different issues related to the quality of water in various places around the world.

Water quality basically refers to the physical, chemical and biological characteristics of the water, which greatly affects the suitability of water for various usages. The physical characteristics of water include color, odor, temperature, turbidity, taste etc. The chemical characteristics of water constitute those substances that are dissolved in the water including the gaseous, metals, nutrients etc, while the biological parameters includes the living organisms and bacteria. Changes in any of these physical, chemical and biological parameters can lead to changes in the quality of water and its usability. Thus to understand the quality of water it is always required to assess theses parameters. Water quality can be assessed by assessing the physical, chemical and biological parameters (WHO, 2004) which is based either on compliance monitoring related to specific water uses or on the basis of index or score systems (Goethals and De Pauw 2001). However, assessment of water quality based on the Water Quality Index (WQI) is one of the most widely used and accepted methods for assessing the quality of water, which allows the comparison of the quality of water in a given area to the harmful limits for human health set at the global and national scales (Bordalo et al., 2006; Gold et al., 2003). The water quality index is a mathematical based index through which the different physical chemical and biological parameters could be converted into a numerical number which in turn helps to signify the level of water quality. The water quality index (WQI) summarizes a large number of water quality data into a simple terms like good, bad etc, (Nikoo et al., 2011) which further helps in understanding the general status of the quality of both the surface water as well as the ground water due to which this approach is widely applied in the assessment of both the surface water and ground water quality (Sharma and Kansal 2011, Tyagi et al., 2013, Bhutiani et al., 2014, Dash et al., 2015, Bora and Goswami 2018).

Water quality Index (WQI) was at first proposed by Horton in (1965) and since then it has been widely used by different agencies and individuals responsible for water supply and water pollution control like US National Sanitation Foundation’s Water Quality Index, British Colombia Water Quality Index, Florida Stream Water Quality Index (Debels et al., 2005, Kannel et al., 2007) to assess and manage the quality of water (Nikoo et al., 2011). The water quality index has also been widely applied by the scholars around the world like Tiwari and Mishra (1985),Bordaloet al., (2006), Sahu and Sikdar (2008), Guettaf et al., (2014), Vincy et al., (2015), Boateng et al., (2016), Tiri et al., (2018) has applied the water quality index (WQI) approach for their studies of water quality analysis of different places.

Surface water or the river water is the only source of water for people living in the hilly part of Darjeeling Himalaya including the Chhota Rangit river basin. However, the quality of water in the ChhotaRangit river basin has been under immense stress in the recent times due to increased demand for the water resources and increased human interferences. The region over the time, has seen drastic changes in its population growth and extension in its land use and land cover dynamicity which has given rise to many environmental issues including the deterioration of water quality in the region, making people living in the river basin more vulnerable to water pollution. Even though the water pollution and quality of water for different purpose has been a vital matter of concern in the region, there has been a complete lack of consciousness regarding the quality of water among responsible authorities. There is also a huge gap of literatures and research relating to the water quality for the whole of Darjeeling Himalayan region including the river basin. Thus this paper is an attempt to assess the spatial distribution of various physical chemical and biological parameters of water in the river basin and to analyze the existing quality of river water using the water quality index (WQI) approach which would help to categorize and understand the general status of water quality in the river basin. By measuring the water quality index, the areas of high and low quality of water can be identified very easily by the planners, authorities which would help them to tackle the problem of water pollution and also to restore the quality of water more efficiently in the river basin. This study fills up the gap that exists in the assessments of surface water quality in the Darjeeling Himalayan region and will also generate further interest among the scholars for undertaking similar researches in Himalayan regions as well as in the other mountainous areas of the world.

2. Study Area

The ChhotaRangit river basin is located between 26˚57’ N to 27˚20’ N latitude and 88˚6’ E to 88˚18’E longitude in the Hill area of Darjeeling district. The ChhotaRangit or the Little Rangit river is one of the important rivers of Darjeeling Hill area, originating below Tanglu in Singalila range on the Nepal border and flows in the North Easterly direction to meet the Great Rangit at Singla Bazar as its major right bank tributary. The total length of the ChhotaRangit River is 370.59 km. The ChhotaRangit river along with its major right and left bank tributaries like Kahelkhola, Hospital jhora, Rellingkhola, Serjan and Neora Jhora acts as the bloodstream particularly for the Darjeeling Pul bazar Block and parts of JorebunglowSukiapokhri Block and covers basin area of 140.98 km^2.The annual average rainfall and temperature of the study area is about 121.80cm and 67.5˚F respectively.

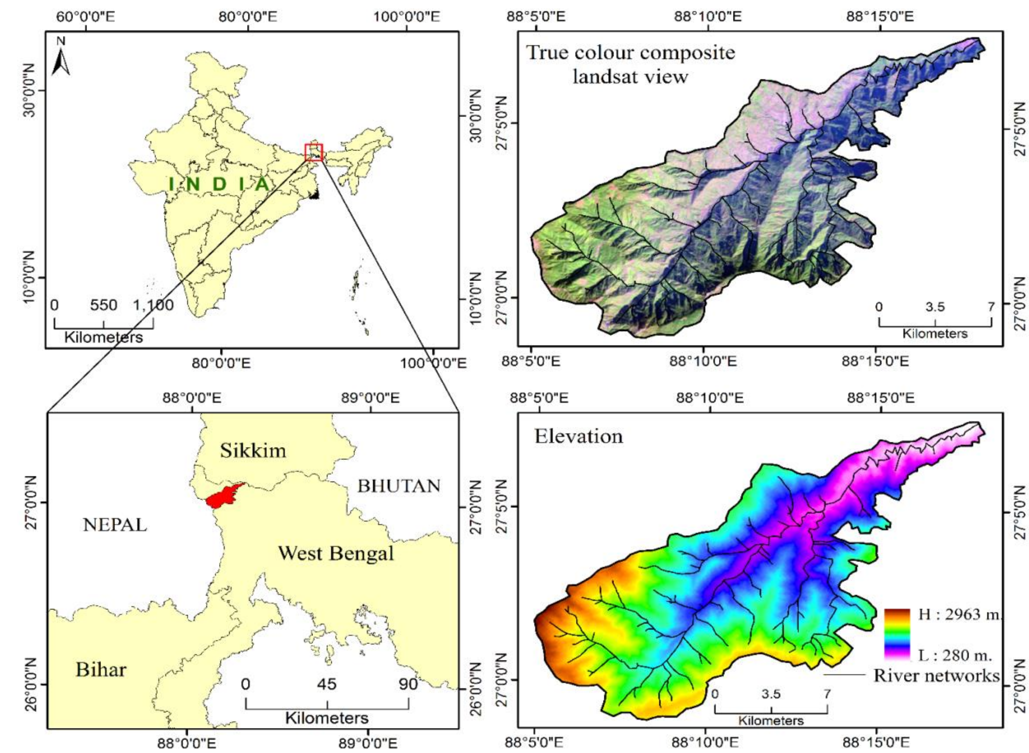

Figure 1: Location of the Study Area

2.1 Geology

The geological and lithological characteristics of an area are the important physical parameters which influence the quality of water. The rivers and streams flowing in different geological and lithological structures acquire their various physical and chemical characteristics from these underlying structures. A number of studies regarding the geological structures of Darjeeling Himalaya by various scholars likeMallet (1874),Pawde and Saha(1982),Starkel and Basu(2000)etc; and also according to the geological map prepared by National Atlas and Thematic Mapping Organization (NATMO), it is evident that the Darjeeling Himalaya is basically characterized by four geological formations, belonging to different ages, from the Pre-Cambarian to the late Tertiary times. According to the geological map (Fig. 2.) prepared on the basis of NATMO map,using Arc GIS 9.3, it is seen that the Chhota Rangit river basin has geological formations i.e. the Damuda series and Daling and Darjeeeling Gneiss.

2.2 Soil

Besides geology the soil is another important parameter which influences the quality of running water.Sometimes it dissolves the soluble particles and sometimes it carries the detached soil particles as un-dissolved solids in the water. The soil map (Fig.3) of the Chhota Rangit river basin has been prepared in Arc GIS 9.3 software based on map prepared by National Bureau of Soil Science (NBSS) India. The soil characteristics of the river basin falls under two distinct groups such as i) fine loamy-coarse loamy soils and ii) gravelly loamy-loamy skeletal soils.

2.3 Land Use and Land Cover

Land use and land cover is another important human induced parameter which influences the quality of water especially in these mountainous regions where people find an easy access to dump their household sewage and garbage into the rivers and streams. The land use and land cover map of Chhota Rangit river basin for the year 2017 has been prepared from Landsat-8OLI image using supervised classification techniques. The Land use and Land cover of the study area can be classified into seven different classes such as; water bodies, settlement, forest, social forestry, agriculture, plantation, agriculture/fallow land.

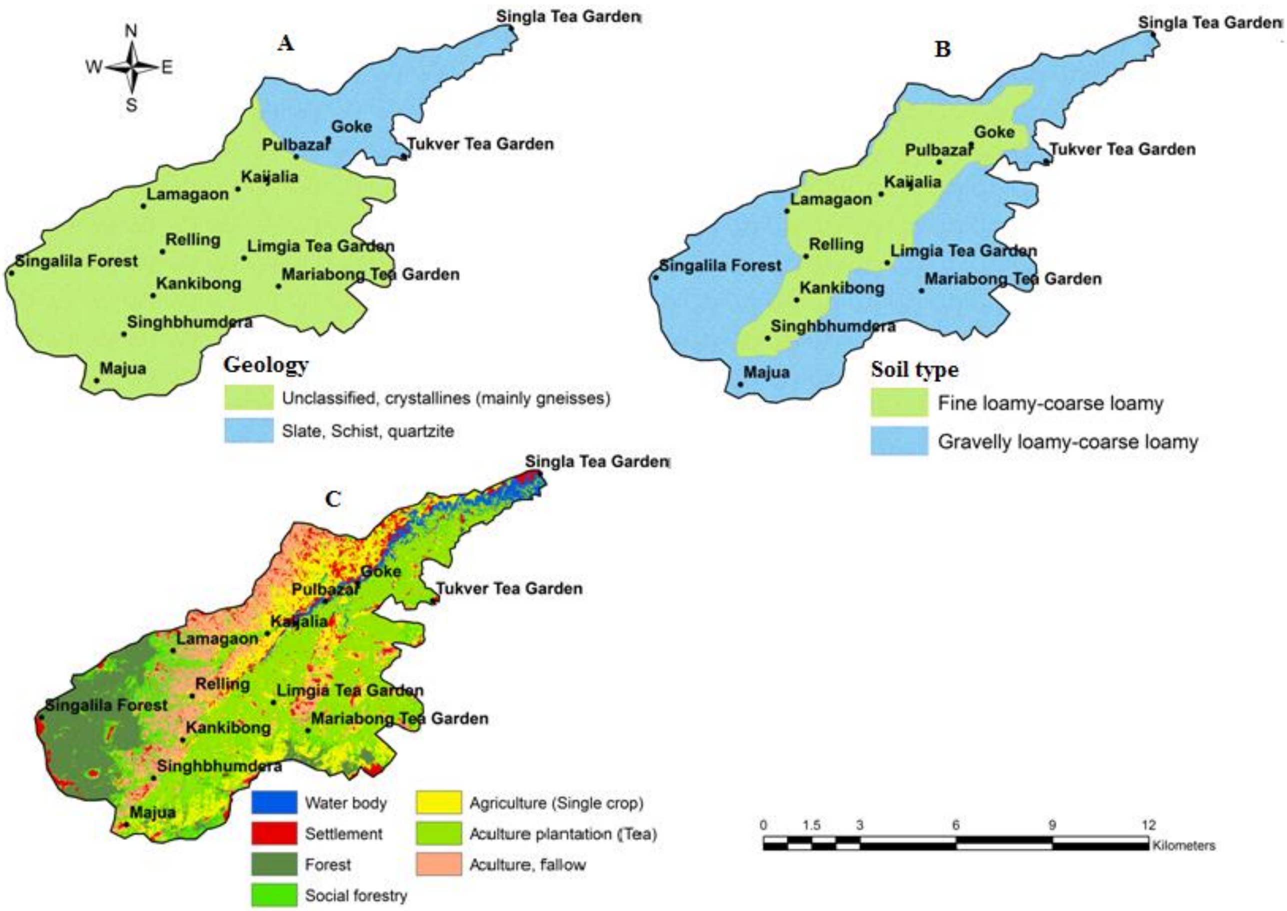

Figure 2 : A. Geology map, B. Soil map and C. Land use/cover map of Chhota Rangit river basin

3. Materials and Methods

To analyze the water quality of the Chhota Rangit river 14 water samples were collected from the predetermined 14 different sample site viz. Singalila Forest, Majua, Singbumdera, Kankibong, Relling, Lamgia, Mariabong, Lamagoan, Bijanbari, Pulbazar, Kaijalia, Goke, Tukver, Singla which are located on the downstream distance from source to mouth of the river during the period of December to February 2018. The geographical location of these sample sites (Fig.3) were determined by using Global positioning system (GPS) the samples were collected from different stream orders in different mouzas covering the river basin. The samples were collected in new polyethylene bottles that were rinsed thoroughly at least thrice in the water to be analyzed. The samples were then carefully labeled and kept at around 5˚C before transported to the water testing laboratory Malda Division, Public Health Engineering Department. Set of most commonly used water quality parameters like pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Turbidity, Fluoride (F), Iron (Fe), Arsenic (As), Manganese (Mn), Nitrate (No_3), Coliform and Fecal Coliform were considered to analyze the water quality of the river.

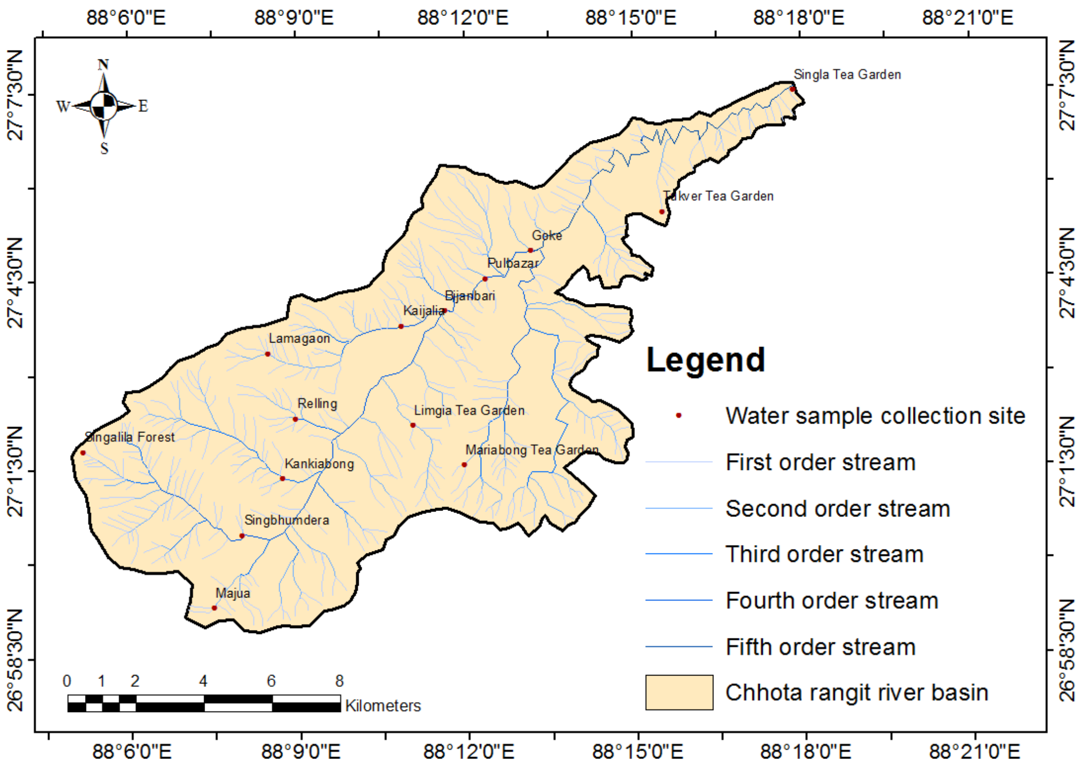

Figure 3: Water Sample Collection Site

3.1 Methods for Computing water quality index

The water quality index is a mathematical based index through which the different physical chemical and biological parameters could be converted into a numerical number which in turn helps to signify the level of water quality. Initially 12 different physio-chemical and biological parameters were considered, but after the analytical results from the laboratory, which showed that the parameters like Flouride (F), Arsenic (As), Nitrate (No_3), Magnanese (Mn) were below the detectable limit thus only the eight other parameters like pH, Electrical Conductivity (EC), Total Dissolved Solids (T.D.S), Total Hardness (TH), Turbidity, Iron (Fe), Coliform and Fecal Coliform were considered to calculate the water quality index of Chhota Rangit river, using the standards set by Bureau of Indian Standard for drinking purposes (IS 10500, 2012) and WHO 2004 (Table 1). Three basic steps are applied to compute the water quality index (WQI) (Sahu and Skidar(2008).

At first weight (w_i) is assigned to each of the parameters according to its effect on health as well as its significance in global quality of water. The maximum weight of 5 is assigned to those parameters which are assumed to have the major effect on human health and the minimum weight of 2 is assigned to those parameters which are considered less dangerous to health (table 2).

Then the relative weight (Wi) is calculated using the equation 1.

$Wi = \frac{wi}{\sum_{i=1}^{n} wi}$.................................... **Equation 1**

Where, Wiis the relative weight, wiis the weight of each parameter and n is the number of parameters.
Secondly the quality rating scale (qi) for each parameter was calculated by using the equation 2.

qi = (Ci / Si) * 100 .... **Equation 2**

Where ***qi*** is the quality rating, ***Ci***is the concentration of each parameter in each water sample in mg/L, and ***Si*** is the Indian standard for drinking water for each parameter in mg/L.

Next the water quality sub-index (SI_i) is determined for each parameter using the equation 3

SI_i = Wi. * qi.................................... **Equation 3**

Where Wi is relative weight and qi is the quality rating.

Finally, the WQI is computed by using the equation 4.

WQI = Σ SI_i.................................... **Equation 4**

Higher the WQI value lower will be the quality of water and vice versa.

Table 1: Water Quality standards by Indian Standard (IS) (2012), WHO (2004) and the existing range in the study area

Sl. no	Water quality parameters	WHO International Standard (2004)		Indian Standard (IS:10500: 2012) Permissible Limit	Range in the study area
		Desirable limit	Maximum allowable limit		
1	pH	6.5	8.5	6.5- 8.5	5.2 – 7.1
2	EC	1400 µmhos/cm	-	4000 µ.s.	25.6 – 81.6
3	T.D.S	500 mg/l	1500mg/l	2000 p.p.m	12.6 – 41.6
4	TH	100 mg/l	500 mg/l	600 mg/l	16 - 48
5	Turbidity	-	-	5 NTU	0.11 – 6.69
6	F	0.25 mg/l	2.30mg/l	1.5 mg/l	
7	Fe	0	0.4	0.3 mg/l	0.0097 – 0.13
8	As	0.05	-	0.05 mg/l	BDL
9	Mn	0.4	-	0.3 mg/l	BDL
10	No_3	-	-	45 mg/l	BDL
11	Coliform	0 per 100ml[4]	3 coliform/100ml (Untreated water)	-	4 - 25
12	Fecal Coliform	-	-	-	1 - 12

Table 2: Assigned weight (w_i) for each parameter and the calculated relative weight (W_i)

Parameters	Weight (w_i)	Relative Weight (W_i)
pH	4	0.13

EC	3	0.1
T.D.S	4	0.13
TH	3	0.1
Turbidity	2	0.07
Fe	4	0.13
Coliform	5	0.17
Feacal Coliform	5	0.17
Σ	$\Sigma w_i = 30$	$\Sigma W_i = 1$

4. Result and Discussions

4.1 Spatial distribution of physical chemical and biological parameters

To understand the status of the existing water quality in the river basin various physical, chemical and biological parameters of the sample water were examined. The details of the statistical summary for each selected physical chemical and bacteriological water quality parameters of the sample water are summarized in (**Table 3**) and their spatial distribution are presented in (**Figure 4 & 5**).
The pH measurement provides information regarding the acidic and alkaline characteristics of the water. Water with pH values less than 7 are normally regarded as acidic in nature and the pH value of 8 or above are considered as alkaline in nature. The analytical results of the pH in the Chhota Rangit River ranges between 5.2 – 7.1 and does not cross the permissible limit set by WHO 2004 and Indian Standard 2012 **(Table 1)**. The pH values especially of the water samples collected from the parts of river which was near the settlement areas, market areas, and tea garden areas like Bajanbari (5.88), Pulbazar (5.42), Goke (5.46), Tukver tea garden (5.54), Singla tea garden (5.23) are less than 6-6.5. Thus, looking at the determined results for the pH in the river basin, it can be said that the surface water in the study area is highly acidic in nature.

Electrical conductivity (EC) is the measurement of water's ability to conduct an electric current. It is highly determined by the other physical and chemical parameters such as temperature, concentration of salts and other dissolved chemicals in the water (Hem 1985). The desirable limit of EC as prescribed by WHO (2004) is 1500 µmhos/cm and according to Indian Standard (IS: 10500:2012) the permissible limit of EC in water is 4000 µ.s. The Electrical Conductivity (EC) in the ChhotaRangit ranges between 25.6 – 81.6 µ.s (Fig.8.3) with an average EC value of 51.56 µ.s. Based on the analytical result it can be said that the presence of EC in the study area is far lower than the prescribed permissible as well as the desirable limits by World Health Organization and Indian Standard limits which indicates the absences of required concentration of salts and other dissolved chemicals necessary for human and animal consumptions.

The Total Dissolved Solids or TDS in water refers to the inorganic substances such as calcium, magnesium, potassium, sodium, bicarbonates, chloride etc; that are dissolved in water (Basavarajappa and Manjunatha 2015). According to world health organization (WHO) the most desirable limit of TDS in water is 500 mg/l and maximum permissible limit is 1500 mg/l. and according to Indian Standard 2012 the permissible TDS limit is 2000 p.p.m. The total dissolved solids in the sample water ranges between 12.6 p.p.m – 41.6 p.p.m, with the mean value of 25.65 which is far lower than the desirable limit and permissible limit set by both world health organization and Indian standard. The Total Hardness (TH) of water is usually the results of concentration of certain metallic ions such as magnesium and calcium. The desirable limit of TDS in water according to WHO is 100 mg/l and maximum permissible limit is 500 mg/l, whereas the permissible limit set by Indian Standard is 600 mg/l. The analytical results of TH in the study area falls under the permissible limits set by both WHO 2004 and IS 2012, which is 16-48mg/l with the mean hardness of 25.14.

Turbidity is one of the important parameters to measure the suitability of water for drinking and other uses. High turbidity of water is often associated with high levels of disease causing organisms (Memon et al. 2016). The permissible limit of turbidity as set by Indian Standard 2012 is 5NTU (Nephelometric turbidity unit). In the sample water the turbidity of the study area ranges between 0.11 – 6.69 NTU with the mean turbidity of 0.81 NTU. The maximum turbidity of 6.69 is found in the sample collected from Relling which is beyond the permissible limit set by Indian Standard (2012). The turbidity of the remaining 13 samples falls under the permissible limit but as verified from the field and personal experience it can be said that the turbidity of the entire river crosses the permissible limit especially during the monsoon seasons.

The desirable limit of fluoride in water according to World Health Organization 2004 is 0.23 mg/l and maximum allowable limit is 2.30 mg/l. and according to Indian Standard 2012 the permissible fluoride limit is 1.5 mg/l. The analytical results of the collected samples from the study area shows that out of 14 samples only one sample i.e. the sample collected from Singla Tea Garden which is at the source of the river shows the presence of fluoride of about 0.10 mg/l which is within the permissible limits set by both WHO 2004 and SI 2012.

The presence of Iron (Fe) is another important parameter for considering water quality. The presence of excess amount of Iron in water makes it unsuitable for drinking and harmful for human health. The presence of iron (Fe) in the sample water ranges from 0.0097 – 0.13 mg/l with an average iron content of 0.034 mg/l. Thus both the range and average iron content in the sample water lies within the permissible limit set by WHO (2004) and Indian Standard (2012) which ranges from 0 -0.4mg/l and 0.3 mg/l respectively. Besides the above discussed physio-chemical parameters of water the concentration of Arsenic (As), Nitrate (No_3) and Manganese (Mn) was also analyzed but the analytical results showed that their presence in the sample water is below the detectable limit.

Bacteriological parameter is important to ensure the suitability of water for drinking and other uses because, the most common and undeniable dangers associated with water is the contamination due to direct and indirect sewage disposal and contamination due to human and animal excrement (WHO 1984). Thus the bacteriological parameters like coliform and fecal coliform were analyzed for the sample water.

Coliform is a bacteria present in nature such as in soil, surface water etc; even though their mere presence are not likely to cause illness but their presence in drinking water certainly indicates the possible presence of harmful disease causing pathogens which are unsuitable for human consumption. According to World Health Organization the desirable limit of coliform in treated water is 0 per 100 ml[4] and in untreated water the maximum allowable limit is 3 coliform/100 ml of water and according to Indian standard 2012 it is 0 per 100 ml. The presence of coliform varies from 4 – 25 coliform/100 ml in the sample water, which is much higher than both the desirable limit and maximum allowable limit set by World Health Organization (WHO 1984). The average coliform count in the study area is 11.92 which are also higher than the limit set by World Health Organization (WHO 1984).

Fecal coliform is the bacteria found in the feces of warm- blooded animals like people, pet, livestock etc. The presence and amount of fecal coliform in streams and rivers are highly attributed by the sewage disposal and direct human and animal interventions into these water bodies. The analysis and count of fecal coliform in the water is one of the best indicators of water contamination and its quality and it is not at all desirable in the water. The presence of fecal coliform in the drinking water supply largely exposes the people depending on such water supply to various pathogenic bacteria. The analysis of the water samples of ChhotaRangit river basin shows the presence of fecal coliform in the water which has exposed the people living in the region to the dangers of water contamination. The count and presence of fecal coliform in the sample water ranges from 1 -12 per 100ml of water with the average of 4.33 per 100 ml of water.

The usability of the water is highly determined by the existence of various physical chemical and bacteriological parameters. The analytical results of different physical chemical and bacteriological parameters in the waters of Chhota Rangit river basin show that the water is highly acidic in nature as the pH in almost all the sample water is below the limit of 6.5-8.5. The low concentration of many required dissolved minerals in the sample water also confirms the existing poor quality of water in the river basin. However, analytical results show the high concentration of fecal contamination in the sample water, which clearly indicates the high human interferences through disposal and the risk associated with the direct consumption of the river water. Thus the examination of various physical, chemical and bacteriological parameters of the river water shows that the water in the river basin is highly contaminated due to bacteriological causes than the physical and chemical causes.

Table 3: Analytical results of Physio- Chemical & Bacteriological Parameters in the Sample water of ChhotaRangit River

Sample details				**Physio-chemical Characteristicsof river water in the study area**										**Bacteriological Characteristics CFU/100 ML**	
Sl. No.	**Sample Location Site**	**Longitude**	**Latitude**	**pH**	**Conductivity (µ.s.)**	**TDS (p.p.m)**	**Turbidity (N.T.U)**	**Fluoride (F)mg/l)**	**Iron (Fe) mg/l**	**Arsenic (As) mg/l**	**TotalHardness mg/l**	**Nitrate (No_3) mg/lt**	**Manganese (Mn) mg/lt**	**Coliform**	**Fecal Coliform**
1	**Singalila Forest**	**88˚5’8.52”E**	**27˚1’46.56”N**	**6.7**	**25.6**	**12.6**	**0.14**	**BDL**	**0.0097**	**BDL**	**16**	**BDL**	**BDL**	**10**	**2**
2	**Majua**	**88˚7’28.27”**	**26˚59’15.37”**	**6.76**	**42.8**	**21.1**	**0.37**	**BDL**	**0.03**	**BDL**	**32**	**BDL**	**BDL**	**4**	**1**

3	Singhbhumdera	88˚7’57.41”	27˚0’24.05”	6.83	81.6	41.1	0.35	BDL	0.0128	BDL	48	BDL	BDL	25	12
4	Kankibong	88˚8’42.25”	27˚1’20.32”	6.97	60.1	29.9	0.60	BDL	0.0114	BDL	28	BDL	BDL	11	3
5	Relling	88˚8’57.62”	27˚2’20.61”	6.83	57.1	28.4	6.69	BDL	0.0128	BDL	36	BDL	BDL	15	9
6	Limgia Tea Garden	88˚11’4.03”	27˚2’11.07”	6.72	57.2	28.7	0.21	BDL	0.013	BDL	20	BDL	BDL	11	8
7	Mariabong Tea Garden	88˚11’56.32”	27˚1’31.92”	7.10	33.9	17.1	0.11	BDL	0.0270	BDL	20	BDL	BDL	8	2
8	Lamagaon	88˚8’36.13”	27˚3’24.98”	6.85	54.4	27.3	0.30	BDL	0.0278	BDL	20	BDL	BDL	14	11
9	Bijanbari	88˚11’34.69”	27˚3’59.37”	5.88	44.0	21.2	0.71	BDL	0.04	BDL	24	BDL	BDL	15	3
10	Pulbazar	88˚12’19.29”	27˚4’28.25”	5.42	46.4	22.3	0.37	BDL	0.03	BDL	16	BDL	BDL	16	2
11	Kaijalia	88˚10’51”	27˚3’44.63”	6.98	40.3	20.1	0.32	BDL	0.0247	BDL	24	BDL	BDL	11	4
12	Goke	88˚13’9.18”	27˚4’58.97”	5.46	60.0	30.1	0.38	BDL	0.13	BDL	24	BDL	BDL	10	1
13	Tukver Tea Garden	88˚15’29.84”	27˚5’33.60”	5.54	56.4	28.1	0.30	BDL	0.03	BDL	24	BDL	BDL	8	3
14	Singla Tea Garden	88˚17’52.51” E	27˚7’30.30” N	5.23	62.1	31.1	0.59	0.10	0.08	BDL	20	BDL	BDL	9	1
Minimum				5.23	25.6	12.6	0.11		0.0097		16			4	1

Maximum		**7.1**	**81.6**	**41.1**	**6.69**		**0.13**		**48**			**25**	**12**
Mean		**6.38**	**51.56**	**25.65**	**0.81**		**0.034**		**25.14**			**11.92**	**4.43**
SD		**0.69**	**13.93**	**7.11**	**1.69**		**0.033**		**8.66**			**4.98**	**3.86**

BDL (Below Detectable Limit**) SD**(Standard Deviation)

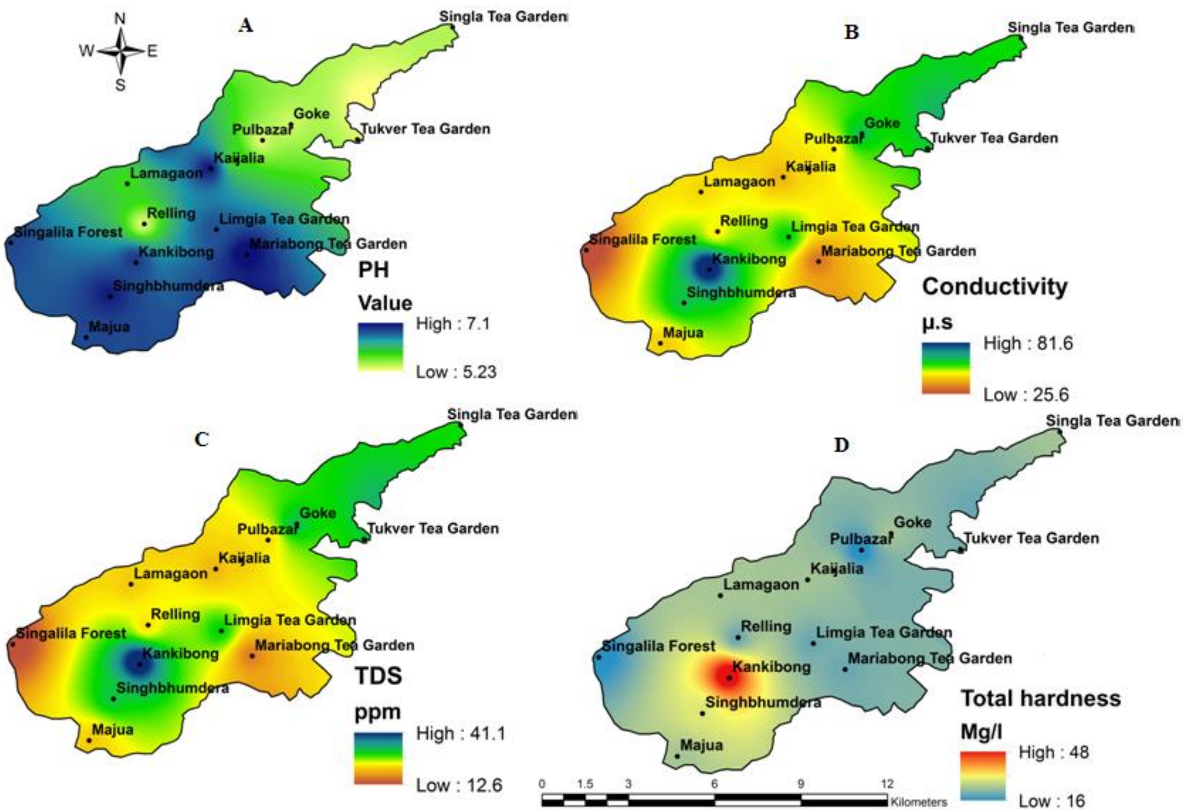

Figure 4: Spatial distribution of (A) Ph, (B) Conductivity, (C) TDS, (D) Total Hardness

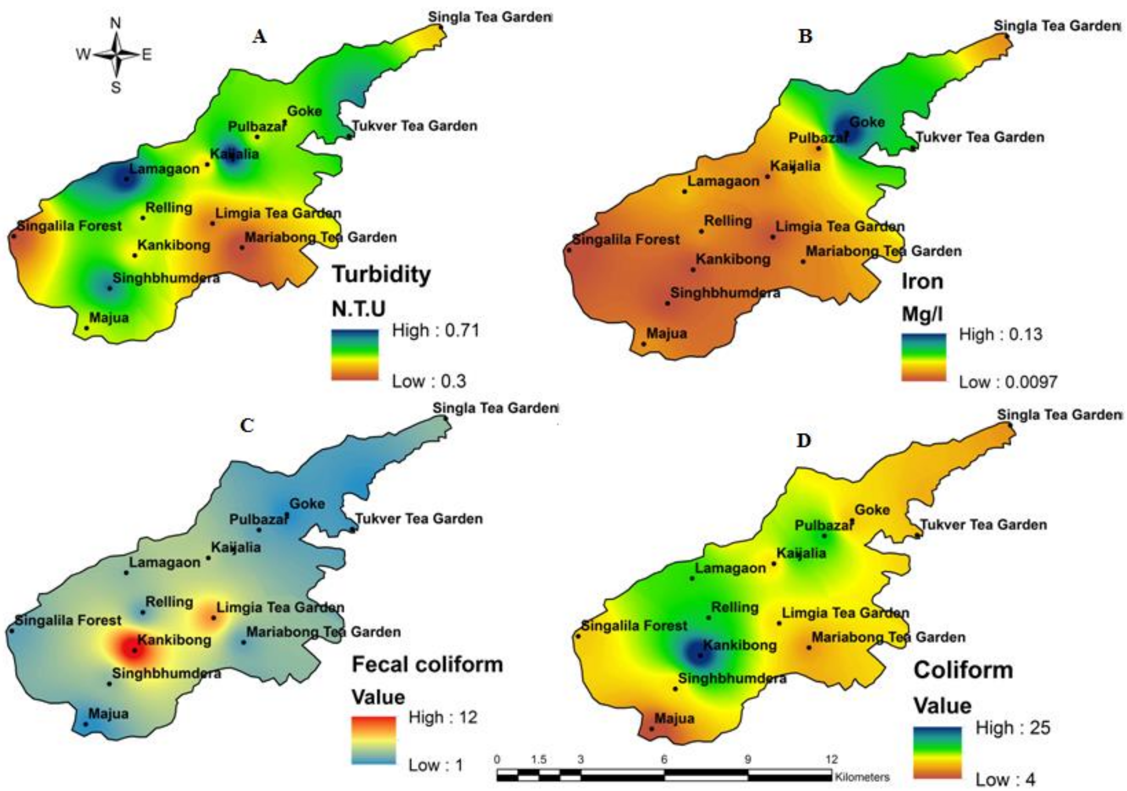

Figure 5: Spatial distribution of (A) Turbidity, (B) Iron, (C) Fecal Coliform (D) Coliform

4.2 Water Quality Index Analysis of ChhotaRangit river basin

To have a better insight about the quality of the water in the ChhotaRangit River the Water Quality Index (WQI) has been calculated. The computed water quality index values in the study area ranges from 24.83 to 94.17 (**Table 4**) and these WQI values are further classified into five water quality categories following Brown et al., (1970) and Murali et al., (2011) and the categories are as follows WQI range between 0 to 25 (Excellent water), < 25 WQI <50 (Good water), 50 < WQI <75 (Poor), <75 WQI<100 (very Poor) and WQI > 100 (unfit for drinking). However, the WQI result indicates that the sample water of the ChhotaRangit River coincides with four categories of water quality such as excellent, good, poor and very poor. From the computed results it is observed that the water sample collected from the first order stream in the Majua falls in the excellent water quality category with the WQI value of 24.83. The existence of such quality of water in Majua is highly due its existence in the upper catchment and minimum human interferences, the prominent land use and land cover pattern in the area is the agricultural area with intersperse thin forest and few hamlets. The water quality of the sample sites like Singalila Forest, Singbumdera, Lamgia Tea garden, Mariabong tea garden, Goke, Tukver and Singla tea garden falls within the good water quality category, where the WQI value ranges from 50.07, 48.31, 47.09, 37.75, 46.40, 36.33 and 41.46 respectively. The most common characteristics among these sample sites are either they are tea garden areas where the large part of the area is under tea bushes and clustered settlements, or they are the rural settlements with agricultural fields and sparse forests except for the Singalila Forest, which is under the cover of thick forest and a small forest village. The poor categories of water are existent in the sample sites of Relling with the WQI value of 73.80, Lamagaon with WQI value 57.93, Pulbazar with WQI value 62.79, Kaijalia with WQI value of 51.03. Sample sites like Relling and Lamagaon are the large village areas with huge agricultural fields and large number of animal rearing where most the agricultural products are for commercial purpose, which are cultivated basically using the animal dung, whereas the Pulbazar and Kaijalia are the built up area with daily market facilities. Thus the agricultural activities and dumping of sewage and other human activities are the major causes for poor water quality in these areas. Very poor quality of water is existent in the sample site of Kankibong with WQI value of 94.17, the sample was collected from the third order stream, the agricultural activities and animal rearing are the important causes for the existent of large number of coliform and fecal coliform in the sample water which resulted in the very poor quality of water in the area. The other sample site with very poor quality of water is the Bijanbari, with the WQI value of 76.21. The sample water was collected from the fourth order stream; Bijanbari is one of the largest build up area in the study area, where the human settlement has extended even within the river bed, and a large number of toilets, open drains from houses, animal shelters are present within the river bed. The major dumping site of the bazaar is also located within the river bed, thus the major causes for very poor quality of water in Bijanbari is due to human interferences.

The WQI analysis of the Chhota Rangit River shows that out of the 14 samples only one sample which is collected from the Majua falls into the category of excellent water quality, seven samples collected from Singalila forest, Singbumdera, Limgia Tea garden, Mariabong Tea garden, Goke, Tukver Tea garden, Singla Tea garden posses good quality of water. However remaining four samples collected from Relling, Lamagoan, Pulbazar, Kaijalia falls into a bad category of water quality and the two samples collected from Bijanbari and Kankibong falls into a very poor category of water quality which makes the water unfit of drinking. From the computed water quality index (WQI) in the Chhota Rangit River, and its spatial distribution it can be said that the impact of physical parameters like geology and soil are least on the quality of water, because the study area is covered by only two types of geological formations such as Damuda series, Daling and Darjeeling gneisses and the two types of soil such as Gravelly loamy and coarse loamy and Fine loamy and coarse loamy (**Fig.2A and B**), however the impact of land use dynamics and human interferences are accounted to be more on the status of water quality in the study area.

Table 4: Water Quality Index and water quality category in ChhotaRangit river basin

Sl. No.	Sample Site	Altitude in meters	Stream order	WQI	Water Quality
1	Singalila Forest	2829.76	1st	50.07	Good
2	Majua	1851.36	1st	24.83	Excellent
3	Singhbhumdera	1813.56	3rd	48.31	Good
4	Kankibong	1321	3rd	94.17	Very Poor
5	Relling	1385.01	2nd	73.80	Poor
6	Limgia Tea Garden	1342.34	2nd	47.09	Good
7	Mariabong Tea Garden	1420.67	1st	37.75	Good
8	Lamagaon	1905.30	2nd	57.93	Poor
9	Bijanbari	791.57	4th	76.21	Very Poor
10	Pulbazar	690.37	4th	62.79	Poor

11	Kaijalia	1387.15	3rd	51.03	Poor
12	Goke	873.25	2nd	46.40	Good
13	Tukver Tea Garden	1004.32	1st	36.33	Good
14	Singla Tea Garden	611.43	5th	41.46	Good

Table 5: Water Quality Index and water quality status in different (land-use, stream orders, geology, soil types and altitude) sample site

Sl. No.	**Sample Location Site**	**WQI**	**Quality status**	**LULC types**	**Stream orders**	**Geology**	**Soil types**	**Altitude in meters**
1	Singalila Forest	50.07	Good	Thick forest with scattered hamlet.	1st order	Daling series and Darjeeling gneisses	Gravelly loamy and coarse loamy	2829.76
2	Majua	24.83	Excellent	Thin forest cover with scattered houses.	1st order	Daling series and Darjeeling gneisses	Gravelly loamy and coarse loamy	1851.36
3	Singhbhumdera	48.31	Good	The major portion of this sample site is covered with the agricultural lands, and scattered rural settlement and patches of trees and bushes.	3rd order	Daling series and Darjeeling gneisses.	It has both the Gravelly loamy/ coarse loamy and fine loamy/coarse loamy soil	1813.56
4	Kankibong	94.17	Very Poor	Large villages with maximum agricultural fields and animal rearing.	3rd order	Daling series and Darjeeling gneisses	It has both the Gravelly loamy/ coarse loamy and fine loamy/coar	1321

							se loamy soil	
5	Relling	73.80	Poor	Large Village area with cluster of hamlet, where there is well demarcated area for weekly market, the area also has a large portion of its area as cultivation fields, fruit orchards	2nd order	Daling series and Darjeeling gneisses	fine loamy and coarse loamy	1385.01
6	Limgia Tea Garden	47.09	Good	Tea garden area, with small sized clustered settlement,	2nd order	Daling series and Darjeeling gneisses	fine loamy and coarse loamy	1342.34
7	Mariabong Tea Garden	37.75	Good	Tea garden with settlement mainly on the ridge of the spur.	1st order	Daling series and Darjeeling gneisses	It has both the Gravelly loamy/ coarse loamy and fine loamy/coarse loamy soil	1420.67
8	Lamagaon	57.93	Poor	Large village with agricultural fields used for seasonal	2nd order	Daling series and Darjeeling gneisses.	It has both the Gravelly loamy/ coarse	1905.30

				crops and cash crops and animal rearing activities.			loamy and fine loamy/coarse loamy soil	
9	Bijanbari	76.21	Very poor	Bijanbari is the block head office and has urban characteristic. The important land use types of this site are the large settlement having concrete houses and dumping sites.	4th order	Daling series and Darjeeling gneisses	Fine loamy and coarse loamy	791.57
10	Pulbazar	62.79	Poor	Pulbazar is the second largest Built up area in the river basin. The major land use types are built up area with many new constructions; agricultural fields are rapidly converting into settlement areas.	4th order	Part of it has the daling and Darjeeling gneisses whereas the other part has the damuda series.	Fine loamy and coarse loamy	690.37

11	Kaijalia	51.03	Poor	Kaijalia is another large Built up area within the river basin.	3rd order	Daling series and Darjeeling gneisses	Fine loamy and coarse loamy	1387.15
12	Goke	46.40	Good	Goke is a small village area, having mixed land use like agriculture fields, scattered settlements , and wooded areas with different tree cover.	2nd order	Damuda series with the lithological characteristics of slate, schist and quartize.	Gravelly loamy and coarse loamy	873.25
13	Tukver Tea Garden	36.33	Good	Small Tea garden area where large part of the land is under the coverage of tea bushes, clustered settlement where the tea garden workers resides.	1st order	Damuda series with the lithological characteristics of slate, schist and quartize.	Gravelly loamy and coarse loamy	1004.32
14	Singla Tea Garden	41.46	Good	The important land use types are Tea garden with tea bushes and small settlements.	5th order	Damuda series with the lithological characteristics of slate, schist and quartize.	Gravelly loamy and coarse loamy	611.43

4.3. **Impact of human interferences on water quality of Chhota Rangit river basin**

Population growth and land use patterns, contribute to the pollution of surface waters leading to aquatic ecological stress and threats to animal and human health (Hossein et al., 2016, Withers and Jarvie 2008). To determine the quality of water in the Chhota Rangit river basin, a water quality index approach has been applied and it is observed that the quality of water in the study area can be categorized into four classes such as excellent, good, poor and very poor. The existent of such quality of water in the river basin shows a huge influence by the human interferences especially through the land use and land cover dynamics. It is observed from the results that the existent of the poor and very poor quality of water in the study area are associated with the samples collected from built-up areas or in areas with large villages where animal rearing and farming are the important human activities (**Table 5**). Very poor and poor quality of water are present in the sample water collected from Bijanbari, Pulbazar, Kaijalia, which are the major built-up areas with daily market facilities, and where the human settlements has extended even within the river bed, as well as a large number of toilets, open drains from houses, animal shelters are present within the river bed. It is also observed during the field survey that the major dumping site of these bazaars or the buildup areas is also located within the river bed. On the other hand Kankibng, Lamagoan, Relling are the large villages where people are mostly engaged in the commercial agricultural actives and animal rearing due to which the presence of coliform and fecal coilform were high in the water, which degraded the quality of water in these sample sites. However, the existent of excellent and good quality of water are associated with areas where forest cover is more, scattered settlements etc. It is also observed from the analysis that besides the land use and human interferences the other factors such as soil, altitude, and geology and stream order seem to have least amount of impact on the quality of water in the study area (**Table 5**).

5. Conclusion

River and stream are an important source of water resource for drinking and all other purposes for people living in the mountainous parts of the world. But with the increased population and increased human interventions both the quantity and quality of water are highly stressed and deteriorated exposing the people to the problems of water scarcity and water pollution. Thus timely examination of both quantity and quality of water sets the perfect ground for management and understanding the utilization suitability of the water resource in these areas. The present paper tried to assess the quality of river water in the Chhota Rangit river basin in Darjeeling Himalayan region in India based on Water Quality Index (WQI) approach and classify the water into different water quality category. However, according to the WQI analysis the river water of ChhotaRangit falls into four categories such as excellent, good, poor and very poor. The lowest water quality index of 24.83 with excellent water quality is seen in the sample collected from 1st order stream in Majua, the existent of such status of water quality in this sample site is especially due to the presence of low amount of physical, chemical and biological parameters. The high water quality index with very poor water is observed in the sample collected from Kankibong with WQI 94.17 and Bijanbari with WQI 76.21. The presence of high water quality index in these sites is mainly due to the presence of high chemical and bacteriological parameters. However the spatial distribution of the water quality index in the river basin shows a variations among different sites, and it is observed that the places with greater human interferences like Pulbazar, Kaijalia, Relling, Lamagoanetc has a poor water quality with moderately high water quality index. The water quality analysis is very important in context of Darjeeling Himalaya because the urban areas situated on the Darjeeling Himalaya are suffering from severe water crisis and if the quality of water of the mountainous streams like Chhota Rangit River is good then that could be use for drinking purpose.

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