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Assessment of nutrient status and water quality index of Rambiara stream, Kashmir Himalaya, India

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Abstract
The present study was conducted with an aim to assess the nutrient status and water quality index (WQI) of a Himalayan freshwater stream Rambiara which is one of the principal tributary of River Jhelum. The stream serves the citizens of south Kashmir as the main source of water. WQI values varied from a minimum of 43.47 to 48.74. Among the study sites, Site III (Hirpora village) revealed higher values of WQI while as lowest values was obtained at Site I (Sokh Sarai). Standard methodology (APHA 1998) was employed to examine physico-chemical parameters involving water temperature, pH, CO_2, total alkalinity, DO, total hardness, calcium, magnesium, PO_4^{3-}, total phosphorus, NH_4^+, NO_2, NO_3, dissolved silica and SO_4^{2-}. Pearson matrix revealed that significant positive correlation existed between total alkalinity and DO ($r = 0.958$, $p < 0.05$), total hardness and DO ($r= 0.775$, $p < 0.05$), PO_4^{3-} and water temperature ($r= 0.991$, $p < 0.05$), NH_4^+ and water temperature ($r= 0.973$, $p < 0.05$) dissolved silica and sulphate ($r= 0.947$, $p < 0.05$). While inverse relationship existed between water temperature and DO ($r = -980$, $p < 0.05$). Our results support that all the hydrological parameters are desirable and the water quality of the Rambiara stream falls under excellent category based on water quality index values. It is concluded that immediate attention is needed to limit anthropogenic activities in its riparian zone from where sediments and nutrients are brought into the stream. Riparian tree planting should be encouraged to prevent soil erosion. In addition, public awareness programs should be raised about these precious natural resources.

Keywords: Rambiara stream, water quality index, nutrient status

Introduction
Water being the renewable natural resource is the most precious of all. It is a basic requirement for the sustenance of all living organisms and for the maintenance of healthy ecosystem. Surface water quality deterioration has become a major environmental concern worldwide due to increased anthropogenic pollution (Scanlon *et. al*, 2007; Ohn *et. al.*, 2014) [14, 69]. Nutrient enrichment of streams in India is widespread due to diffusion from modern agricultural practices and also due to their accessibility for disposal of wastewaters (Samarghandi *et. al.*, 2007; Yadaw and Kumar, 2011) [41, 63]. However, natural sources also contribute to degradation of water quality through run-off during precipitation events, soil erosion, weathering of crustal materials (Issaka and Ashraf, 2017) [61] and damage their utility for drinking, recreational, and other purposes (Jarvie *et. al.*, 1998; Simeonov *et. al.*, 2003; Mahvi *et. al.*, 2005; Nouri *et. al.*, 2008; Karbassi *et. al.*, 2008a, b; Rashid and Romshoo, 2012) [29, 70, 2, 5, 8, 30]. Due to increasing population and urbanization, large quantities of untreated sewage are discharged directly into the streams, as a result, the self-purification capacity of streams is altered leading to damage of these important aquatic ecosystems (Pernet-Coudrier *et al.* 2012; Zhang *et. al.*, 2018) [12]. The addition of nutrients in streams and rivers cause deterioration of water quality and eutrophication which consequently cause algal blooms, oxygen depletions and fish kills and ultimately deterioration of the health of aquatic ecosystems (Shan *et. al.*, 2012; Hobbies *et. al.*, 2017) [13, 60]. Water quality and the health of aquatic ecosystems have become sensitive issues in different regions of the world particularly in developing countries where the fresh water bodies are facing range of problems on account of the anthropogenic pressure and unsustainable use (Yadav and Kumar 2011; El-serehy *et. al.*, 2018 and Bhagowati and Ahamad, 2019) [63, 10]. Moreover, the functioning of an aquatic ecosystem and its stability to support life forms depend to a great extent, on the health of a stream ecosystem. The interactions of both the physical and chemical properties of water play a significant role in distribution and diversity of aquatic organisms

(Mustapha and Omotosho, 2005; Sangpal *et. al.*, 2011; Murungan and Prabaharn, 2012; Deepak and Singh, 2014) [39, 54, 59].

Monitoring and assessing the aquatic systems for nutrient status is essential to mitigate or avert the harmful ecological and socioeconomic impacts (Devlin *et. al.*, 2011, Napiórkowska-Krzebietke and Hutorowicz, 2014; Ustaoğlu and Tepe, 2019; El-serehy *et. al.*, 2018) [37, 25]. Drinking water in Kashmir valley comes from streams, rivers, springs and lakes. However, fresh water streams are the major potable source of water for the region but unfortunately overexploitation of these resources for various purposes like drinking, domestic, agriculture, hydropower, these vital resources are getting not only degraded but also polluted as the human population grows. Furthermore, construction of new developmental projects like Mughal road passing through the mountainous terrain of the stream could lead to the ecological deterioration of the aquatic system. This has pushed the ecologists and environmentalists of the state to concern about the fragile ecosystems of Hirpora Wildlife sanctuary. Recognizing the significance of the Rambiara stream with regard to its suitability of its use for various human needs, the present study was undertaken to assess the nutrient status and water quality index of Rambiara stream of Kashmiri Himalaya.

Description of the study area and study sites

The present study was carried out on Rambiara stream (Fig. 1a, 1b) in Hirpora wildlife sanctuary situated in Shopian district of Kashmir valley. Hirpora wildlife sanctuary is located about 63 km south of Srinagar, the summer capital of Jammu and Kashmir (Northern India). The wild life sanctuary is just 12 kms away from Shopian. Shopian (literally it means "forest of snow") is situated in the laps of foothills of Pir Panjal range and most of its area is hilly terrain. Shopian town – the District Headquarter is located at a distance of 51 kms from Srinagar. The district is also known as ''Apple Bowl" of the state as it is famous for Horticulture sector.

Rambiara Stream is one of the major and widest tributary of the River Jhelum in Kashmir. The stream finds its source from the Rupri peak of Pir Panjal range (4085 m), deriving water from Bhagsar Lake at Rupri Peak on one side and Naba Pass (4253 m) on the other. The two headwater streams, Yanga Nar and Rupri Nar merge near Sukh Sarai to form the Rambiara stream. The stream flows through Hirpora wildlife sanctuary and then passes through Shopian district and meets Vishaw stream at Naiyun after traversing about 68 Kms and then enters into the River Jhelum. The Rambiara stream has a huge catchment area of about 270 Km^2 (Thoker *et. al.*, 2015) [38].

In the present investigation, three sites namely Sukh Sarai, Dabjan, and Hirpora village located in Shopian district were selected for the assessment of water quality and calculation of Water Quality Index (Table 1, Fig. 1a and 1b). Among the three sites, Site I (Sukh Sarai) has steep mountainous terrain, good riparian vegetation and is without human habitations. Site I is located close to Mughal road and is 7.3 Kms away from Hirpora village. Mughal road passes over the Pir Panjal mountain range through Hirpora wildlife sanctuary and connects Kashmir valley to Poonch and Rajouri districts and to the rest of India. Site II (Dabjan) is 5.9 kms away from Hirpora village and lies between Hirpora village and Sokh Sarai. The site has forest vegetation on one side and patches of denuded forests and agricultural fields on the slopes of other side. Anthropogenic interference including grazing of domestic livestock is common around this location. Site III (Hirpora village) is 7 kms away from main Shopian town. The site has dense human settlements with well-established horticultural fields where apple orchard are grown on fertile soils of karewas or wudr in local language. These karewas are fertile fluvio-glacial sediments of Plio-Pleistocene glaciation (Ahmad *et. al.*, 2013).

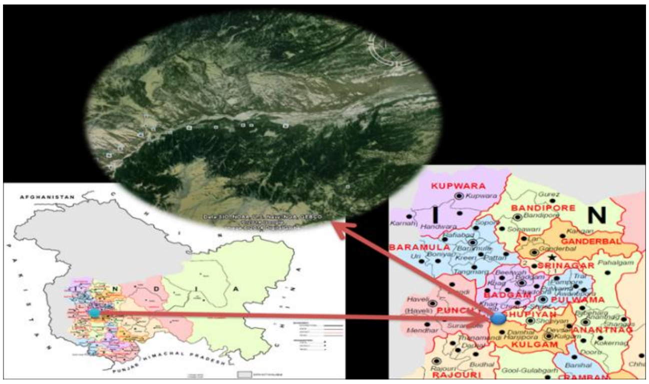

Fig 1a: Location map of the study area**.** Source**:** Google Earth

Fig 1b: Map showing study sites

Table 1: Location of three sampling sites

Site	Sampling sites	Latitude N	Longitude E	Elevation (m)
I	Sokh Sarai	33° 39´ 51´´	74° 39´ 39´´	2516
II	Dabjan	33° 40´ 29´´	74° 40´ 51´´	2510
III	Hirpora village	33° 41´ 01´´	74° 44´ 38´´	2507

Material and methods

Water samples were collected on monthly basis from June, 2013 to November, 2013 from three different sites. Collected water samples were preserved and transported to laboratory and analyzed within 24 hour as per the standard analytical procedures recommended by (CSIR 1974; APHA 1998). In situ parameters like pH and water temperature were measured on the spot by means of a mercury thermometer and digital pH meter. Dissolved oxygen (DO) was analyzed by modified Winkler method (APHA 1998). The other selected water quality parameters include free CO_2 (F-CO_2), total alkalinity (T. alkalinity), total hardness (T. hard), calcium hardness (Ca hard), magnesium hardness (Mg hard), ammonical-nitrogen (NH_4-N), nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N), orthophosphorus (PO_4^{3-}), total phosphorus (total-P), dissolved silica (D-silica) and sulphate (SO_4^{2-}). Careful calibration and blank measurements were performed to acquire accurate values (APHA 1998; CSIR 1974).

Calculating of Water Quality Index (WQI)

The water quality index (WQI) calculation is very useful and efficient method as it provides a comprehensive picture of the quality of water for most domestic uses. The water quality index (WQI) is defined as a rating that reflects the composite influence of different water quality parameters (Sahu and

Sikdar, 2008; Ravikumar *et. al.*, 2013) [47, 46]. For calculating the WQI in the present study, 7 parameters namely, pH, total alkalinity, total hardness, calcium, magnesium, nitrate, sulphate have been considered (Table 2-4). Several workers (Bhat and Pandit, 2014; Yaseen *et. al.*, 2015 and Rafiq *et. al.*, 2018) [57, 65, 40] have successfully used WQI as a tool to determine the quality of waterbodies of Kashmir. The water quality index was calculated by the following given equation

Water Quality Index (WQI) = ∑ QiWi / Wi

Where, Qi = Quality rating of n th water quality parameter

Wi = Unit weight of n th water quality parameter

Quality rating (Qi) = (Va- Vi) / (Sn-Vi) × 100

Where,
Va = actual value of n th water quality parameter at a given site, Vi = Ideal value for n th parameter in pure water. (Vi for pH = 7 and 0 for all other parameters) Sn = standard permissible value of n th as recommended by WHO and BIS (1998).

Unit weight (Wi) = k/Sn
K (constant) = [1 / ∑ 1/Sn=1,2.n]

Table 2: Summary statistics of physico-chemical parameters of water of Rambiara stream

S. No.	Parameter	Average	Stand. Dev.	Min	Max
1	water temperature	12.4	3.43	6.0	17.0
2	pH	7.7	0.19	7.4	8.1
3	Total alkalinity (mg/L)	162.1	4.32	154.9	169.4
4	Free CO2 (mg/L)	11.5	2.71	7.9	14.3
5	Dissolved oxygen (mg/L)	8.9	1.43	7.1	11.7
6	Total hardness (mg/L)	142.2	5.31	131.3	151.5
7	Calcium hardness (mg/L)	104.1	6.13	96.2	113.2
8	Magnesium hardness (mg/L)	9.3	1.47	6.9	11.9
9	Ortho-phosphorus (µg/L)	37.8	6.33	25.0	50.0
10	Total phosphorus (µg/L)	66.7	5.49	54.0	79.0
11	Ammonical-nitrogen (µg/L)	63.0	6.03	51.0	75.0
12	Nitrite-nitrogen (µg/L)	7.8	4.87	0.5	16.0
13	Nitrate-nitrogen (µg/L)	197.0	6.29	181.0	213.0
14	Dissolved silica (mg/L)	8.0	3.68	3.0	15.0
15	Sulphate (mg/L)	8.6	3.53	1.0	14.0

Table 3: Water Quality Index of Site I

Parameter	Observed value	Standard value	RA	Unit weight (Wi)	Quality rating (Qi)	WiQi
pH	7.67	8.5	WHO	0.706267	44.44444	31.38965
T. alkalinity mg/L	163.80	200	BIS	0.030016	81.9	2.458339
T. hardness mg/L	141.60	300	BIS	0.020011	47.2	0.944514
Ca hardness mg/L	104.20	75	BIS	0.080044	138.9333	11.12072
Mg hardness mg/L	9.10	30	BIS	0.200109	30.33333	6.069973
NO3-N mg/L	0.189	45	BIS	0.133406	0.42	0.056031
Sulphate mg/L	8.000	200	BIS	0.030016	4	0.120065
				∑Wi		∑WiQi

Water Quality Index (WQI) = ∑WiQi/∑Wi = 43.47

Table 4: Water Quality Index of Site II

Parameter	Observed value	Standard value	RA	Unit weight (Wi)	Quality rating (Qi)	WiQi
pH	7.70	8.5	WHO	0.706267	46.66667	32.95913
Total alkalinity	161.95	200	BIS	0.030016	80.975	2.430574
Total hardness mg/L	143	300	BIS	0.020011	47.66667	0.953853
Ca mg/L	103.65	75	BIS	0.080044	138.2	11.06203
Mg mg/L	9.56	30	BIS	0.200109	31.86667	6.376807
NO3-N mg/L	0.195	45	BIS	0.133406	0.433333	0.057809
Sulphate mg/L	8	200	BIS	0.030016	4	0.120065
				∑Wi		∑WiQi

Water Quality Index (WQI) = ∑WiQi/∑Wi = 44.97

Table 5: Water Quality Index of Site III

Parameter	Observed value	Standard value	RA	Unit weight (Wi)	Quality rating (Qi)	WiQi
pH	7.80	8.5	WHO	0.706267	53.33333	37.66758
Total alkalinity	160.46	200	BIS	0.030016	80.23	2.408212
Total hardness mg/L	142.08	300	BIS	0.020011	47.36	0.947716
Ca mg/L	104.32	75	BIS	0.080044	139.0933	11.13353
Mg mg/L	9.18	30	BIS	0.200109	30.6	6.123336
NO3-N mg/L	0.195	45	BIS	0.133406	0.433333	0.057809
Sulphate mg/L	9.83	200	BIS	0.030016	4.915	0.14753
				∑Wi		∑WiQi

Water Quality Index (WQI) = ∑WiQi/∑Wi = 48.74

Results and Discussion

The summary statistics of water quality parameters of Rambiara stream is given in Table 2. Pearson Correlation Analysis was employed to determine the relationship between the physico-chemical variables (Table 6, 7 and 8). In the present study, the water temperature varied significantly on monthly basis (ranged from 6 °C to 17 °C). The hydrological parameters showing significant negative correlation with water temperature are total alkalinity ($r = -0.979$, $p < 0.05$) and calcium ($r = -0.942$, $p < 0.05$). pH is an important water quality parameter as it influences many biological and chemical processes within a water body (Gray, 1999; Shah and Pandit, 2013; Yaseen *et. al.*, 2015) [43, 31,65]. The pH of the water fluctuated between 7.4 units and 8.1 units, indicating slight alkaline nature of water. Consistent with (Ormerod *et. al.*, 1990; Kang *et al.*, 2001) [62, 32] alkaline pH of the water body may be related to the occurrence of carbonate rocks in the upper mountainous area of Rambiara stream. The downward increase in pH from Site I to Site III may be attributed to increasing pollution pressure due to agricultural activities in its catchment area pH could not depict significant correlation with any of the physico-chemical variables.

Alkalinity is a quantitative capacity of water to neutralize acids. The alkalinity in water is mainly due to dissolution of carbonates and alumino-silicates (Das and Dhiman, 2003) [11]. Higher values of total alkalinity indicate poor water quality (Barman and Gupta, 2014) [9] and encourage high primary productivity. Significant positive correlation was observed between total alkalinity and dissolved oxygen ($r = 0.958$, $p < 0.05$). However, negative correlation was also observed with ammonical-nitrogen ($r = -0.965$, $p < 0.05$) and nitrate-nitrogen ($r = -0.977$, $p < 0.05$). The stream water was alkaline (154.9 and 169.4 mg/L) throughout the monitoring period. Alkaline nature of Himalayan waterbodies has been reported by Bhat anf Yousuf, (2004) [7], Yousuf *et. al.*, (2007) [23] and Hamid *et. al.*, (2016) [3] and attributed it to the dissolution of limestone in the catchment.

Free carbon dioxide exists naturally in water in varying amounts. In polluted water bodies, CO_2 is released during oxidation of organic matter. In the present study, free CO_2 varied from 7.9 mg/L in June to 14.34 mg/L November. Free CO_2 revealed significant positive correlation with calcium hardness ($r = 0.979$, $p < 0.05$). The lower values in summer months may be the consequence of maximum utilization of CO_2 from the water column by the photosynthetic activity of aquatic flora (Hutchinson, 1957) [26].

Dissolved oxygen (DO), being one of the valuable parameter helps in determining the water quality criteria of a water body. Its concentration is essential to support the biodiversity of aquatic ecosystems (Parna and Burrows, 2005; Matta *et. al.*, 2015) [27]. Maximum DO (11.7 mg/L) at Site I in November and minimum DO (7.1 mg/L) was obtained at Site III in June. The Site I (Sokh Sarai) maintained high DO throughout the investigation period which may be related to the combination of various factors which include low temperature, photosynthetic activity of phytoplankton, high altitude, high turbulence and low anthropogenic pressure (Yousuf *et. al.*, 2007; Amin *et. al.*, 2018) [7, 42]. Low DO concentration was observed in the month of June. Significant negative correlation between DO and water temperature was observed ($r = -980$, $p < 0.05$). Temperature is known to regulate the concentration of dissolved oxygen in aquatic systems (Khanna *et. al.*, 2012a, b) [22,21]. Under natural conditions, inverse relationship exists between water temperature and DO, because cold water can hold more oxygen and becomes easily saturated at low temperatures (Wetzel, 2001) [50].

Total hardness describes the magnitude of mineralization of water mainly in terms of Ca and Mg, bicarbonate, sulphates, nitrates, and chlorides. It gives an idea about the suitability of water for various uses of domestic, drinking and industrial purposes. The total hardness of water ranged between 131.3 and 151.5 mg/L and was found to be positively correlated with DO ($r= 0.775$, $p < 0.05$). The higher values of total hardness obtained at Site III can be explained on the basis of higher mobilization rate of hardness causing elements like Ca and Mg to be released from the subsurface ground waters having higher hardness (Badrakh *et. al.*, 2008; Sharma *et. al.*, 2016) [1, 48]. Total hardness of any waterbody is a function of lithology and pedogenic setup of the catchment. Calcium is the most abundant ion present in natural waters in the form of carbonates and sulphates which is dissolved from rocks pertaining to limestone and gypsum (Chapman, 1996) [53]. Calcium content of Rambiara stream ranged from 96.18 to 113.16 mg/L. The high calcium content may be attributed to the presence of Triassic limestone which constitutes the bedrock of the headwaters of the Rambiara stream (Ahmad *et. al.*, 2013) [22]. The decrease in calcium content during warmer months is the consequence of dilution effect due to melting of nearby glaciers (Bhat, 2015) [65]. Calcium revealed significant positive correlation with total alkalinity ($r = 0.995$, $p < 0.05$) and free CO_2 ($r = 0.979$, $p < 0.05$). The concentration of magnesium in Rambiara stream fluctuated between 6.9 mg/L at Site I to 11.9 mg/L at the same site.

Phosphorus is a key element used for the assessment of water quality. Higher levels of phosphorus in water stimulates growth thereby increasing productivity of aquatic systems (Wetzel, 2001; Mehner *et. al.*, 2008; Hickman and Gray, 2010; Stoddard *et. al.*, 2016) [50]. Maximum concentration of orthophosphate (PO_4^{-3}) was observed at all sites in the month of July. The higher value in warmer periods is due to regeneration and subsequent resuspension of phosphate from the decaying sediment into water column due to high discharge (Sihaba, 2003; Bhat, 2015) [51, 65]. Among all the three study sites, Site III (Hirpora village) maintained high concentration (50 µg/L) which may be related to the increasing agricultural activity in the catchment area resulting in the runoff and leaching of nutrients (Osborne and Wiley, 1988; Smart *et al.*, 2005) [36, 53]. PO_4^{-3} depicted significant positive relationship with water temperature ($r= 0.991$, $p < 0.05$). The most significant negative relationship was observed with total alkalinity ($r= -0.973$, $p < 0.05$) and DO ($r= -0.975$, $p < 0.05$). The concentration of total phosphorus was found to be low (54 µg/L) at Site I in November. Whereas it depicted peak concentration at Site III (79 µg/L) in July. Minimum level of total phosphorus in November can be explained on the basis of decreased rate of decomposition and low suspended phytoplankton material (Bhat and Yousuf, 2004). While in summer months increased planktonic growth in the water column and application of fertilizers in surrounding agricultural area may be responsible for increasing level of total phosphorus (Lenat and Crawford, 1994; Latimer and Quinn, 1998; Grimaldi, 2004) [22, 34, 16]. Agricultural activities are predominant on karewa soils surrounding the Site III. Significant positive correlation was evident between total phosphorus and water temperature ($r= 0.983$, $P < 0.05$) and PO_4^{-3} ($r= 0.974$, $p < 0.05$).

Both nitrogen (N) and phosphorus (P) compounds are the main cause of poor water quality. Decomposition of nitrogenous compounds in water can cause oxygen depletion which in turn affects the aquatic life. In rural areas, domestic waste and sewage and agricultural runoff containing fertilizers are major threats responsible for nutrient enrichment (Dubey *et. al.*, 2016) [55]. Nitrate-nitrogen (NO_3-N), ammonical-nitrogen (NH_4-N) and nitrite-nitrogen (NO_2-N) are the most frequent inorganic nitrogen compounds assimilated by autotrophs, showed both monthly as well as spatial variation. Maximum NH_4-N concentration was obtained in June (75 µg/L) at Site III while minimum concentration of 51 µg/L was depicted by Site I in November. The highest value of NH_4-N at Site III is attributed to the enhanced bacterial decomposition of nitrogenous organic matter with rise in temperature (Kaul, 1977; Wetzel, 2001) [50]. This site faces maximum anthropogenic pressures than the upstream sites. Correlation analysis revealed significant positive relationship with water temperature ($r= 0.973$, $p < 0.05$), total phosphorus ($r= 0.998$, $p < 0.05$). On the other hand, it showed negative correlation with calcium ($r= -0.991$, $p < 0.05$) and DO ($r= -0.947$, $p < 0.05$). Nitrite is an intermediate product produced during the oxidation of ammonia, varied between 0.5 and 16 µg/L. Due to its unstable nature, NO_2-N is found in low concentration (Kelly, 1997). Nitrate is the most abundant form of oxidized form of nitrogen present in aquatic systems, ranged between 181- 213 µg/L. Maximum value of NO_3-N at Site III is related to the loading from non-point sources, agricultural and horticultural areas which are being supplemented with fertilizers containing nitrates (Rashid and Ramshoo, 2012; Yaseen *et. al.*, 2015; Hamid *et. al.*, 2016) [3, 65]. The parameter of NO_3-N showed significant positive relationship with NH_4-N ($r= 0.999$, $p < 0.05$) and total phosphorus ($r= 0.994$, $p < 0.05$).

Dissolved silica is an important constituent of diatom cell wall, called the frustule. Silica is released into natural water as result of dissolution of silicate minerals and its solubility in water is directly proportional to temperature (Fournier, 1983). The average value of silica in natural water ranges between 1.0 and 30.0 mg/L (Davis, 1964; Pradeep *et. al.*, 2016) [45]. Evaluation of data pertaining to silica concentration in Rambiara stream, revealed maximum silica of 15 mg/L in August and minimum of 3 mg/L in November. Pearson Correlation analysis yielded significant positive relationship with sulphate ($r= 0.947$, $p < 0.05$). Increase in the silica concentration may be related to various factors which includes, natural weathering of silicate minerals in the immediate mountainous landscape, increased input of groundwater into the stream during summers which has high silica content, constant water-rock interaction and increased silica fluxes from agricultural activity. Similar findings have been documented by Pradeep *et. al.*, (2016) [35].

Sulphate (SO_4) is found in almost all-natural waters. The origin of sulphate compounds in water is the oxidation of sulphate minerals which include, barite ($BaSO_4$), gypsum ($CaSO_4 \cdot 2H_2O$) and epsomite ($MgSO_4 \cdot 7H_2O$) (Greeenwood and Earnshaw, 1984). Sulphates of Ca and Mg are two common constituents of hardness. World Health Organization (WHO, 1993) has suggested a maximum level of 500 mg/L for human consumption. Sulphate concentration in Rambiara stream fluctuated between 1 and 14 mg/L. The concentration of sulphate in stream water is governed by many factors which include overall dominance of bed rock in the catchment, contribution of pedogenic sulphate and desorbing sulphate of mainly anthropogenic origin (Kellogg *et. al.*, 1972; Alewell *et. al.*, 1999; Morth *et. al.*, 2008) [71, 99, 17].

Water Quality Index (WQI)

Water Quality index (WQI) is a powerful tool to evaluate water quality. This is a systematic technique based on the comparison of physicochemical parameters of water with respect to regulatory standard (Khan *et. al.*, 2003) [24]. WQI is computed to give an idea about the suitability of water for various uses including human consumption.

Table 6 displays the classification of water quality based on water quality index (WQI). The calculation of WQI of Rambiara stream is presented in Table 3, 4 and 6. The study revealed that the WQI of the Rambiara stream varied from a high of 43.47 at Site I to a low of 48.74 at Site III with an average value of 45.73 (Fig. 2). Maximum value of WQI obtained at Site III may be related to the fact that this site receives runoff from large agricultural fields in its immediate catchment. On the other hand, lower value of WQI measured at Site I may be attributed to its closeness to the glacial source, dense forest cover in surrounding areas and minimum anthropogenic pressure (Kanth and Hassan, 2012; Yaseen *et. al.*, 2015) [66, 65]. On the basis of calculation of WQI, it is evident that the WQI value of all sites of the stream fall under category I (<50) revealing excellent water quality. However, Site III is polluted to some extent based on WQI values. The stream needs immediate attention as the waterbody serves the citizens of south Kashmir as the main source of drinking water.

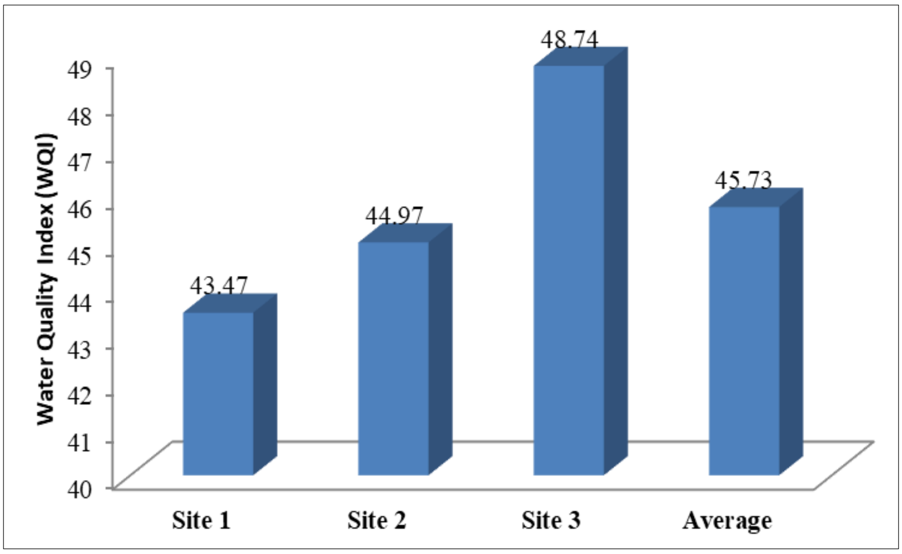

Fig 2: Variation of WQI of different sites of Rambiara stream.

Table 6: Water quality classification based on WQI values (Ramakrishnaiah *et. al.*, 2009) [19]

WQI levels	Description
<50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor (bad) water
>300	Unsuitable (unfit) for drinking

Conclusion

From the observations, it may be concluded that the water quality of the Rambiara stream falls under excellent category based on water quality index. The present study revealed that downstream site (Site III) is experiencing anthropogenic pollution which has slightly polluted the water. Run-off and sediments from surrounding agricultural fields into the stream has resulted in the increase of nutrients particularly nitrate and phosphate. Our findings suggest that the afforestation in riparian zones be encouraged to prevent soil erosion and leaching of nutrients into the stream. Moreover, timely monitoring of water quality will be helpful in the management of this precious natural resource.

Table 7: Pearson' s correlation coefficient (r) between physico-chemical variables of Rambiara stream water at Site I (Sokh Sarai) Kashmir, India

	Temp	pH	T. alkal	F-CO_2	DO	T. hard	Ca	Mg	PO_4^{3-}	total-P	NH_4-N	NO_2-N	NO_3-N	D-silica	SO_4^{2-}
Temp	1	-0.064	-0.956	-0.813	-0.970	-0.615	-0.942	0.126	0.991	0.983	0.973	0.970	0.968	0.582	0.753
pH	-0.064	1	0.190	-0.152	0.302	-0.184	0.218	-0.347	0.021	-0.075	-0.110	-0.245	-0.176	-0.145	-0.327
T. alkal	-0.956	0.190	1	0.876	0.948	0.364	0.992	-0.409	-0.930	-0.988	-0.990	-0.992	-0.984	-0.359	-0.600
F-CO_2	-0.813	-0.152	0.876	1	0.721	0.234	0.894	-0.460	-0.838	-0.895	-0.905	-0.834	-0.802	-0.060	-0.276
DO	-0.970	0.302	0.948	0.721	1	0.571	0.941	-0.168	-0.942	-0.949	-0.947	-0.979	-0.960	-0.622	-0.821
T. hard	-0.615	-0.184	0.364	0.234	0.571	1	0.361	0.696	-0.662	-0.478	-0.450	-0.447	-0.425	-0.926	-0.843
Ca	-0.942	0.218	0.992	0.894	0.941	0.361	1	-0.418	-0.925	-0.982	-0.991	-0.989	-0.956	-0.343	-0.594
Mg	0.126	-0.347	-0.409	-0.460	-0.168	0.696	-0.418	1	0.067	0.290	0.325	0.325	0.322	-0.638	-0.364
PO_4^{3-}	0.991	0.021	-0.930	-0.838	-0.942	-0.662	-0.925	0.067	1	0.974	0.965	0.946	0.931	0.585	0.739
total-P	0.983	-0.075	-0.988	-0.895	-0.949	-0.478	-0.982	0.290	0.974	1	0.998	0.985	0.974	0.428	0.638
NH_4-N	0.973	-0.110	-0.990	-0.905	-0.947	-0.450	-0.991	0.325	0.965	0.998	1	0.988	0.967	0.403	0.625
NO_2-N	0.970	-0.245	-0.992	-0.834	-0.979	-0.447	-0.989	0.325	0.946	0.985	0.988	1	0.980	0.460	0.692
NO_3-N	0.968	-0.176	-0.984	-0.802	-0.960	-0.425	-0.956	0.322	0.931	0.974	0.967	0.980	1	0.448	0.662
D-silica	0.582	-0.145	-0.359	-0.060	-0.622	-0.926	-0.343	-0.638	0.585	0.428	0.403	0.460	0.448	1	0.947
SO_4^{2-}	0.753	-0.327	-0.600	-0.276	-0.821	-0.843	-0.594	-0.364	0.739	0.638	0.625	0.692	0.662	0.947	1

Correlation significant at the 0.05 level

Table 8: Pearson's correlation coefficient (r) between physico-chemical variables of Rambiara stream water at Site II (Dabjan) Kashmir, India

	Temp	pH	T. alkal	F-CO_2	DO	T. hard	Ca	Mg	PO_4^{3-}	total-P	NH_4-N	NO_2-N	NO_3-N	D-silica	SO_4^{2-}
Temp	1	-0.217	-0.881	-0.626	-0.980	-0.695	-0.836	0.281	0.940	0.859	0.901	0.645	0.841	0.836	0.506
pH	-0.217	1	0.020	-0.253	0.162	0.369	0.018	0.243	0.040	-0.005	0.194	-0.485	0.115	-0.131	-0.865
T. alkal	-0.881	0.020	1	0.853	0.952	0.324	0.995	-0.688	-0.973	-0.985	-0.903	-0.778	-0.979	-0.546	-0.311
F-CO_2	-0.626	-0.253	0.853	1	0.755	-0.111	0.846	-0.857	-0.798	-0.918	-0.829	-0.704	-0.933	-0.429	-0.167
DO	-0.980	0.162	0.952	0.755	1	0.544	0.920	-0.464	-0.975	-0.942	-0.929	-0.743	-0.925	-0.758	-0.479
T. hard	-0.695	0.369	0.324	-0.111	0.544	1	0.265	0.460	-0.477	-0.237	-0.432	-0.071	-0.219	-0.713	-0.379
Ca	-0.836	0.018	0.995	0.846	0.920	0.265	1	-0.734	-0.948	-0.973	-0.859	-0.790	-0.966	-0.457	-0.278
Mg	0.281	0.243	-0.688	-0.857	-0.464	0.460	-0.734	1	0.537	0.729	0.487	0.677	0.735	-0.081	-0.011
PO_4^{3-}	0.940	0.040	-0.973	-0.798	-0.975	-0.477	-0.948	0.537	1	0.951	0.964	0.653	0.959	0.687	0.273
total-P	0.859	-0.005	-0.985	-0.918	-0.942	-0.237	-0.973	0.729	0.951	1	0.912	0.812	0.992	0.578	0.358
NH_4-N	0.901	0.194	-0.903	-0.829	-0.929	-0.432	-0.859	0.487	0.964	0.912	1	0.535	0.938	0.778	0.203
NO_2-N	0.645	-0.485	-0.778	-0.704	-0.743	-0.071	-0.790	0.677	0.653	0.812	0.535	1	0.738	0.325	0.707
NO_3-N	0.841	0.115	-0.979	-0.933	-0.925	-0.219	-0.966	0.735	0.959	0.992	0.938	0.738	1	0.573	0.249
D-silica	0.836	-0.131	-0.546	-0.429	-0.758	-0.713	-0.457	-0.081	0.687	0.578	0.778	0.325	0.573	1	0.499
SO_4^{2-}	0.506	-0.865	-0.311	-0.167	-0.479	-0.379	-0.278	-0.011	0.273	0.358	0.203	0.707	0.249	0.499	1

Correlation significant at the 0.05 level

Table 9: Pearson's correlation coefficient (r) between physico-chemical variables of Rambiara stream water at Site III (Hirpora village) Kashmir, India

	Temp	pH	T. alkal	F-CO_2	DO	T. hard	Ca	Mg	PO_4^{3-}	total-P	NH_4-N	NO_2-N	NO_3-N	D-silica	SO_4^{2-}
Temp	1	-0.649	-0.979	-0.753	-0.963	-0.662	-0.825	0.470	0.875	0.955	0.967	0.746	0.973	0.612	0.806
pH	-0.649	1	0.566	0.127	0.565	0.717	0.169	0.187	-0.257	-0.407	-0.437	-0.658	-0.457	-0.371	-0.318
T. alkal	-0.979	0.566	1	0.790	0.958	0.637	0.842	-0.499	-0.933	-0.955	-0.965	-0.782	-0.977	-0.746	-0.910
F-CO_2	-0.753	0.127	0.790	1	0.650	0.039	0.979	-0.922	-0.930	-0.891	-0.858	-0.689	-0.848	-0.479	-0.773
DO	-0.963	0.565	0.958	0.650	1	0.775	0.757	-0.349	-0.847	-0.918	-0.944	-0.595	-0.953	-0.648	-0.814
T. hard	-0.662	0.717	0.637	0.039	0.775	1	0.174	0.321	-0.360	-0.466	-0.527	-0.326	-0.554	-0.546	-0.483
Ca	-0.825	0.169	0.842	0.979	0.757	0.174	1	-0.877	-0.949	-0.951	-0.928	-0.621	-0.916	-0.453	-0.773
Mg	0.470	0.187	-0.499	-0.922	-0.349	0.321	-0.877	1	0.737	0.687	0.635	0.439	0.610	0.169	0.508
PO_4^{3-}	0.875	-0.257	-0.933	-0.930	-0.847	-0.360	-0.949	0.737	1	0.956	0.947	0.715	0.951	0.707	0.933
total-P	0.955	-0.407	-0.955	-0.891	-0.918	-0.466	-0.951	0.687	0.956	1	0.997	0.678	0.994	0.562	0.831
NH_4-N	0.967	-0.437	-0.965	-0.858	-0.944	-0.527	-0.928	0.635	0.947	0.997	1	0.664	0.999	0.579	0.835
NO_2-N	0.746	-0.658	-0.782	-0.689	-0.595	-0.326	-0.621	0.439	0.715	0.678	0.664	1	0.687	0.721	0.761
NO_3-N	0.973	-0.457	-0.977	-0.848	-0.953	-0.554	-0.916	0.610	0.951	0.994	0.999	0.687	1	0.620	0.858
D-silica	0.612	-0.371	-0.746	-0.479	-0.648	-0.546	-0.453	0.169	0.707	0.562	0.579	0.721	0.620	1	0.914
SO_4^{2-}	0.806	-0.318	-0.910	-0.773	-0.814	-0.483	-0.773	0.508	0.933	0.831	0.835	0.761	0.858	0.914	1

Correlation significant at the 0.05 level

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