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Insight into Aquatic Potential of Kunah Stream, Hamirpur (HP) by Analysis of Water Quality Parameters using Weighted Arithmetic Water Quality Index

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ABSTRACT

Water quality index (WQI) gives the complete information regarding overall quality of particular water body and is an important tool for assessing the quality of surface water. Present research article focuses on the water quality assessment of Kunah stream in Hamirpur district of Himachal Pradesh state in India using Weighted Arithmetic water quality index method, which was determined using different water quality parameters viz., Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Electrical Conductivity (EC), pH, Total Hardness, Hardness due to Ca^{2+} and Mg^{2+}, concentration of chlorides, nitrates and phosphates. Water sampling was done at two sites (upstream and downstream) of the stream. The value of WQI ranges from 61.97454 upstream to 50.50388 downstream shows that at upstream water quality is poor due to varied anthropogenic activities like bathing, washing clothes, mining and many more (reported upstream), whereas water quality is nearly good downstream supporting diverse biotic communities. But overall stream water is not suitable for drinking prior proper treatment. So, there is urgent need to appraise and monitor anthropogenic activities occurring in the stream.

Keywords Weighted Arithmetic Water Quality Index (WAWQI), Physico-chemical parameters, Kunah, Hamirpur, Himachal Pradesh.

INTRODUCTION

Water is essential for survival of every organism (Yadav 2016). Water is an indispensable constituent of the environment and its management is important for the eminence of the environment (Ojekunle *et al*. 2016). About 4% of world's total freshwater resources are present in India (Shinde *et al.* 2009, Chandra *et al.* 2017, Pathak *et al.* 2019). Rivers and their tributaries are important inland water resources providing habitat to variety of biotic communities. But due to increasing human population natural water resources are being continuously degraded, which affects the ecological status of these water bodies. Water quality deterioration is an important problem and it is necessary to monitor the water quality of natural water bodies (Mishra *et al.* 2009). In addition to anthropogenic factors, some natural factors such as flooding, weathering of parent rocks, topography, climate and many more, deteriorates the quality of the water (Vadde *et al.* 2018).

Water quality index assimilates the complex data and aids to comprehend water quality status by

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appraising water quality trends (Aher *et al*. 2020, Dhumal 2021). Quality of water is estimated by using different methods such as Weighted Arithmetic Water Quality Index Method (WAWQI), Al-Olthman method (2015), Oregon Water Quality Index (OWQI), National Sanitation Foundation Water Quality Index (NSFWQI), British Columbia Water Quality Index (BCWQI) and The Canadian Council of Ministers of Environment Water Quality Index (CCMEWQI).

Pioneer work on WQI in India is of Bhargava (1983), gives water quality range between 0–100, where 0 represents highly polluted and 100 represents unpolluted water. Water quality index of major Indian rivers has been widely examined by Tiwari and Mishra (1985). Water Quality Index (WQI) of river Yamuna, Cauvery and Beas was analyzed by Sharma and Kansal (2000-2009), Kalavathy *et al.* (2011) and Kumar *et al.* (2020), respectively. Naik and Purohit (2001) analyzed water quality of river Brahmani in Sundargarh district, Orissa. Evaluation of River Subernarekha by using water quality index for drinking purposes was done by Parmar and Parmar (2010). Ghosh *et al.* (2013) analyzed pond water quality in Sirsakala village, Chhattisgarh by using the weighted arithmetic index method. Water quality assessment of River Beas using multivariate and remote sensing techniques has been done by Kumar *et al.* (2016). Analysis of various physico-chemical parameters using Al-Othman WQI method of Gaj and Baner rivulet in Kangra district was done by Brar *et al.* (2023). Chidiac *et al*. (2023) gave comprehensive review of water quality indices. In the present study WAWQI method was used, as this method surpass other methods because multiple water quality parameters are used to dictate the health of particular water body and describes the aptness of water resources for human utilization (Chandra *et al.* 2017). It quantifies the suitability of water concerning the needs of biotic species and human requirements (Johnson *et al.* 1997).

Area of study

The present study aimed at Kunah stream located between 31°34’17” N latitude to 31°46’36” N latitude and 76°21’59” E longitude to 76°40’31” E longitude, in the lap of Shiwalik ranges of Northwestern Himalayas (Fig.1). It is left bank tributary of River Beas in Hamirpur district of Himachal Pradesh. The

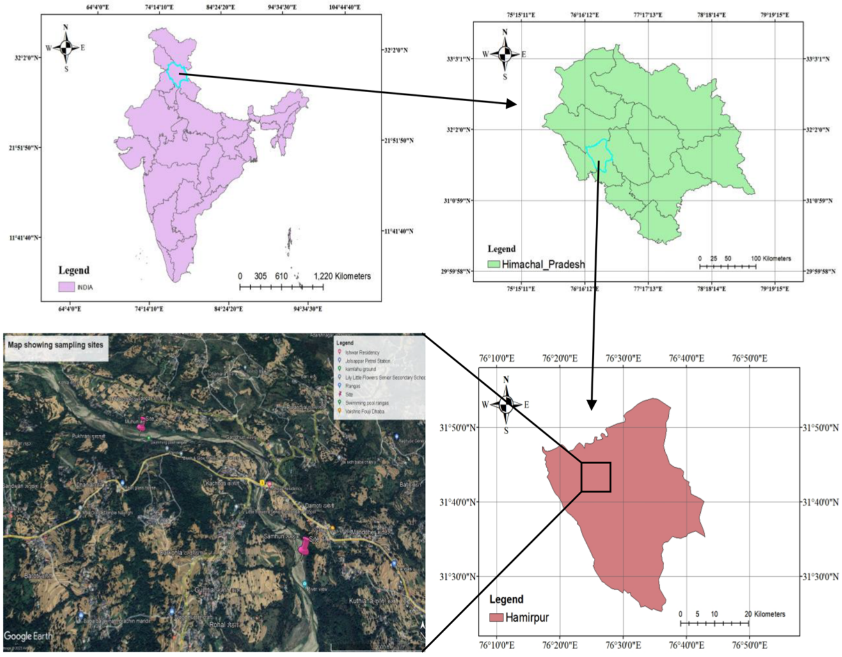

Fig. 1. Map showing area of study.

Table 1. Sampling sites.

Name of locality	Latitude	Longitude	
Site 1 (Rangas)	31°43′33.7″N	76°26′23.88″E	Upstream
Site 2 (Fatehpur)	31°45′7.03″N	76°24′5.69″E	Downstream

stream originates near Awahdevi and after covering a distance of about 48 km finally meets with Beas River at Vilikleshwar, Hamirpur (HP).

MATERIALS AND METHODS

Water samples from the stream were collected from two sampling sites (Table 1) on monthly bases from July 2022–June 2023. Different physico-chemical parameters viz., pH, DO, TDS, conductivity, Total Alkalinity, Total Hardness, Hardness due to Ca^{2+} and Mg^{2+}, concentration of chlorides, nitrates and phosphates were analyzed. Air temperature, Water temperature, pH, DO, TDS and conductivity were analyzed in the stream using digital probes. Other parameters including Total Alkalinity, Total Hardness, Hardness due to Ca^{2+} and Mg^{2+}, concentration of chlorides, nitrates and phosphates were analyzed titrimetrically in the laboratory as per APHA (1998). WAWQI method was used to measure water quality index of the stream. Interpretation of WQI was done using the range of WQI given in Table 2 Brown *et al.* (1972), Chatterjee and Raziuddin (2002).

RESULTS AND DISCUSSION

Total 11 physico-chemical parameters viz., pH, DO, EC, TDS, Alkalinity, Total Hardness, Hardness due to Ca^{2+} and Mg^{2+}, concentration of chlorides, nitrates and phosphates were taken to analyze the water quality of the stream. The range and mean value of these physico-chemical parameters were given in Table 3. The observed values were compared with standard drinking water values (S_n) given by WHO (World Health Organization), Bureau of Indian Standards (BIS, IS 10500-2012), ICMR (Indian Council of Medical Research) and United States Public Health Services (USPHS) (Table 4).

Table 2. Depiction of water quality status by using water quality index (WQI).

WQI values	Water quality
0–25	Excellent
26–50	Good
51–75	Poor
76–100	Very poor
>100	Inapt for drinking

Source: Brown *et al.* (1972), Chatterjee and Raziuddin (2002).

Table 3. Showing range and average of different physico-chemical parameters in the stream.

Parameter	Upstream	Downstream
pH	7.9 – 10 (9.51)	8 – 10.1 (9.48)
DO (Dissolved Oxygen) (mg/l)	6.1 – 8.9 (7.3)	6.2 – 9.2 (7.8)
EC (Electrical Conductivity) (µS/cm)	260 – 350 (305.55)	270 – 360 (310)
TDS (Total Dissolved Solids)	107 – 140 (121.7)	114 – 140 (127.7)
Alkalinity (mg/l)	156 – 240 (190.03)	150 – 285 (191.08)
Total hardness (mg/l)	130 – 200 (161.16)	124 – 220 (162.28)
Hardness due to Ca^{2+} (mg/l)	56 – 134.4 (98.66)	64 – 156 (103.9)
Hardness due to Mg^{2+} (mg/l)	38 – 90 (62.66)	31.6 – 82.4 (59.18)
Chlorides (mg/l)	12 – 54 (36.41)	9.8 – 42 (27.66)
Nitrates (mg/l)	0.015 – 0.120 (0.068)	0.010 – 0.117 (0.0609)
Phosphates (mg/l)	0.023 – 0.110 (0.06)	0.030 – 0.220 (0.068)

Table 4. List of drinking water standards given by different agencies.

Sl. No.	Parameters	WHO	IS 10500-2012	ICMR	USPHS
1	Color	-	-	-	Colorless
2	Odor	-	Unobjectionable	-	Odorless
3	DO	-	3.0	-	4.0–6.0
4	pH	6.5–9.2	6.5–8.5	6.5–9.2	6.0–8.5
5	TDS	500	500	-	500
6	EC	-	-	300	300
7	Alkalinity	-	200	120	-
8	Total hardness	-	200	300–600	-
9	Calcium	100	75	75-200	100
10	Magnesium	150	30	50-150	30
11	Chlorides	500	250	250-1000	250
12	Nitrates	45	45	20-50	10
13	Phosphates	-	-	-	0.1

All units are in mg/l except color, odor, pH and EC (µS/cm) .

In the current investigation, the pH of the stream falls within the range of 7.9–10.1, indicating an alkaline nature. However, these pH values are slightly higher than the standard limits of WHO, IS 10500-2012, ICMR and USPHS. This variance may be attributed to human activities such as bathing, laundry and dishwashing, which can influence water quality. Kumar *et al.* (2017) recorded Beas River water to be alkaline with pH ranging from 7.19 to 7.4 also, Jindal *et al.* (2022) reported a pH range within the acceptable limit in Beas River. pH and alkalinity are two interconnected parameters, as pH increases alkalinity also increases and vice-versa. Total alkalinity in the stream during the study spans from 150–285 mg/l, which also slightly exceeds permissible limit as defined by BIS (IS 10500-2012) and ICMR.

It's worth noting that elevated levels of DO destroys water pipes but is virtuous for consumption (Brar *et al.* 2023). In this study, DO ranges from 6.1–9.2 mg/l, falling within the acceptable range according to FMEnv (2011). Comparatively, Kamboj *et al.* (2021) reported DO ranges between 6.83–10.18 mg/l in the selected stretches of River Beas in Punjab, which is slightly higher than the present observations. Sharma *et al.* (2022) reported the value of DO ranges from 7.20-8.69 mg/L in the upper Ganga River basin, which is nearly similar to present observations.

EC and TDS are two interconnected parameters, exhibiting a direct correlation. TDS in the stream ranges from 107–140 mg/l, complying within the limits set by BIS, WHO, USPHS and ICMR. Brar *et al.* (2023) reported nearly similar value of TDS in Gaj rivulet. However, the EC values, ranging from 260–360 μS/cm in this study, slightly exceed the acceptable limits of ICMR and USPHS (300 μS/cm). Gangwar (2013) reported conductivity of Beas River ranges from 53 to 517 μmho/cm.

Total hardness of the stream falls within the range of 122–220 mg/l, adhering to ICMR standards but slightly surpassing BIS (IS 10500-2012) guidelines. This indicates that the water is hard to very hard (Durfor and Becker 1964). Hardness of water is predominantly due to Ca^{+2} and Mg^{+2} ions. Ca^{+2} comes from rocks containing calcium (limestone/gypsum). In the present investigation, the Ca^{+2} and Mg^{+2} ranges from 56–156 mg/l and 31.6–90 mg/l, respectively, exceeding BIS standards. However, Sharma and Walia (2016) and Brar *et al.* (2023) found Ca^{+2} and Mg^{+2} within acceptable limit given by BIS and WHO in Beas River and Gaj and Baner streams, respectively.

Excessive chloride concentration can render water unsuitable for drinking and other household purposes as well as irrigation (Kumar *et al.* 2018). Concentration of chlorides ranges from 9.8–54 mg/l, which fall within WHO's (500 mg/l) and BIS or USPHS (250 mg/l) permissible limits. Moza and Mishra (2007) recorded chloride concentration in Beas River ranges from 13–19.42 mg/l. Brar *et al.* (2023) recorded chlorides concentration ranges between 21.7–24.6 and 16.89–21.53 mg/l in Gaj and Baner rivulets, respectively.

Nitrate concentrations in the stream ranges from 0.010–0.120 mg/l while 0.92–2.7 mg/l of nitrate concentration was reported in Beas River by Kumar *et al.* (2017). Moreover, Brar *et al.* (2023) reported nitrate concentration ranges between 0.4–0.9 mg/l and 0.5–0.13 mg/l in Gaj and Baner streams in Kangra, respectively, which was higher than present findings. Qureshimatva *et al.* (2015) reported nitrate concentration in Chandlodia Lake ranged from 6.3 to 7.9 mg/l, which was very high than present observations. Phosphate concentration ranges between 0.023–0.220 mg/l in present stream. Nearly similar concentration was recorded by Brar *et al.* (2023) in Gaj and Baner stream of Beas River in Kangra district.

Calculation of water quality index (WQI)

Weighted Arithmetic Index method originally proposed by Horton (1965) and further developed by Brown *et al.* (1972) was used for calculation of water quality index. The WQI was calculated using following formula:

Step 1: Calculation of the unit weight (W_n) factors for each parameter by using formula

$$W_n = \frac{K}{Sn}$$

Where

$$K = \frac{1}{\sum 1/Sn}$$

$$\sum \frac{1}{Sn} = \frac{1}{S1} + \frac{1}{S2} + \frac{1}{S3} + ... + \frac{1}{Sn}$$

Sn = Standard desirable value of the n^{th} parameters

On summation of all selected parameters unit weight factors, W_n = 1 (unity)

Step 2: Calculation of the Sub-Index (Q_n) value by using the formula

$$Qn = \frac{[(Vn - Vo)]}{[(Sn - Vo)]} * 100$$

Where

V_n = Mean concentration of the n^{th} parameters
S_n = Standard desirable value of the n^{th} parameters

V_o = Actual values of the parameters in pure water (generally V_o = 0, for most parameters except for pH and DO) (pH = 7.0, DO = 14.6 mg/l)

For, pH the ideal value is 7 because of pure water and permissible value is 8.5. So, the calculation of quality rating for pH is done by following equation:

$$QpH = \frac{[(VpH - 7)]}{[(85 - 7)]} * 100$$

VpH = Observed value of pH

Whereas, for Dissolved Oxygen (DO) ideal value is 14.6 and permissible value is 5. So, calculation for D.O. is done by following equation:

$$Q_{DO} = \frac{[(VDO - 14.6)]}{5 - 14.6} * 100$$

V_{DO} = observed value of DO

Step 3: Combining Step 1 and Step 2, WQI is calculated as follows:

$$\text{Overall WQI} = \sum WnQn / \sum Wn$$

The Kunah stream WQI (61.97454 upstream and

Table 5. Depiction of water quality index (WQI) of Kunah (upstream), Hamirpur.

Parameter	Standard values (S_N)	Recommended agency for standard values	1/Sn	$K = 1/\sum \frac{1}{sn}$	$W_n = K/S_n$	V_o	V_n	$Qn = \frac{Vn}{Sn} *$ 100	W_nQ_n
H	8.5	BIS, ICMR	0.117647	0.0961	0.011306	7	9.51	167	1.888075
DO	5	BIS, ICMR	0.2	0.0961	0.01922	14.6	7.3	76.04	1.461483
TDS	500	BIS, ICMR, WHO, USPHS	0.002	0.0961	0.000192	0	121.714	24.3428	0.004679
EC	300	ICMR, USPHS	0.003333	0.0961	0.00032	0	305.55	101.85	0.032626
Alkalinity	200	BIS	0.005	0.0961	0.00048	0	190.03	95.015	0.045655
Total Hardness	200	BIS	0.005	0.0961	0.00048	0	161.16	80.58	0.038719
Ca^{+2}	75	BIS, ICMR, WHO	0.013333	0.0961	0.001281	0	98.66	131.5467	0.168554
Mg^{+2}	30	BIS, WHO	0.033333	0.0961	0.003203	0	62.66	208.8667	0.669067
Chlorides	250	BIS, USPHS	0.004	0.0961	0.000384	0	36.41	14.564	0.005598
Nitrates	45	BIS, WHO	0.022222	0.0961	0.002136	0	0.068	0.151111	0.000323
Phosphates	0.1	USPHS	10	0.0961	0.960996	0	0.06	60	57.65976
			$\sum \frac{1}{Sn}$ = 10.40587		1				$\sum$ WnQn /$\sum$Wn = 61.97454

Table 6. Depiction of water quality index (WQI) of Kunah (downstream), Hamirpur.

Parameter	Standard values V (S_n)	Recommended agency for standard values	1/Sn	$K = 1/\sum \frac{1}{Sn}$	$W_n = K/S_n$	V_o	V_n	$Qn = \frac{Vn/}{Sn} * 100$	W_nQ_n
pH	8.5	BIS, ICMR	0.117647	0.0961	0.011306	7	9.48	81.17647	0.917768
DO	5	BIS, ICMR	0.2	0.0961	0.01922	14.6	6.9	2554.28	49.09306
TDS	500	BIS, ICMR, WHO, USPHS	0.002	0.0961	0.000192	0	127.714	62	0.011916
EC	300	ICMR, USPHS	0.003333	0.0961	0.00032	0	310	63.69333	0.020403
Alkalinity	200	BIS	0.005	0.0961	0.00048	0	191.08	81.14	0.038988
Total Hardness	200	BIS	0.005	0.0961	0.00048	0	162.28	51.95	0.024962
Ca^{+2}	75	BIS, ICMR, WHO	0.013333	0.0961	0.001281	0	103.9	78.90667	0.101105
Mg^{+2}	30	BIS, WHO	0.033333	0.0961	0.003203	0	59.18	92.2	0.295346
Chlorides	250	BIS, USPHS	0.004	0.0961	0.000384	0	27.66	0.02436	9.36E-06
Nitrates	45	BIS, WHO	0.022222	0.0961	0.002136	0	0.0609	0.151111	0.000323
Phosphates	0.1	USPHS	10	0.0961	0.960996	0	0.068	81.17647	0.917768
			$\sum \frac{1}{Sn}$ = 10.40587		1				∑ WnQn /∑Wn = 50.50388

50.50388 downstream) reveals that stream water quality is poor (Tables 5-6). Kumar *et al.* (2017) calculated WQI of Beas River to be 60.93 which was similar to present findings. Nearly, similar observations were also made by Ali and Muhammad (2022) in Astore River basin, Western Himalayas and Brar *et al.* (2023) in Gaj and Baner rivulets of Beas River in Kangra district. Anthropogenic activities like bathing, washing of clothes and utensils, bed material removal/mining contributes to the poor water quality of the stream. So proper conservation plans should be made and implemented to conserve the natural water resource including biodiversity partly or wholly dependent on these vital aquatic treasures.

CONCLUSION

The Kunah stream, situated in the Hamirpur district of Himachal Pradesh, is a crucial tributary of Beas River, serving as a vital water resource for the local residents. Preserving the integrity of this natural water resource is of utmost importance. Moreover, the stream sustains a diverse array of living organisms and eventually flows into the Beas River, making it imperative to safeguard its water quality to prevent adverse effects on the river's overall health. Additionally, this research offers valuable insights for environmentalists, policymakers, and the general public engaged in conservation and management efforts.

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