

Water quality of River Beas, India

Vinod Kumar^{1,2,*}, Anket Sharma¹, Ashwani Kumar Thukral¹ and Renu Bhardwaj¹

¹Department of Botanical and Environmental Sciences, Guru Nanak Dev University, Amritsar 143 005, India

²Department of Botany, DAV University, Sarmastpur, Jalandhar 144 012, India

This article is a review of the pollution status of River Beas, India as analysed by different workers over a period of time. River-water pollution is an important environmental problem because it is the main source of water for consumption by humans as well as aquatic species living in the river. Water quality index was determined using nine standard water quality parameters for River Beas and was found to be 60.93. The mean values of dissolved oxygen (DO) (8.82 mg/l), biological oxygen demand (BOD) (0.87 mg/l) and total coliform (1451.60 MPN/100 ml) were found for River Beas in Himachal Pradesh. The mean values of DO (7.29 mg/l), BOD (3.75 mg/l), chemical oxygen demand (COD) (48.89 mg/l) and total coliforms (562.88 MPN/100 ml) were also found for River Beas in Punjab. DO, COD, BOD and total coliforms ranges of the river were found above permissible limits of BIS for drinking water.

Keywords: Drinking water guidelines, pollution, river water, water quality index.

RIVERS are the essential natural resources for the development of human civilization and are being polluted by industrial and domestic waste discharges, which affect the physio-chemical and microbiological properties of river water. Water quality deterioration is an important problem and it is necessary to monitor the water quality of rivers¹. The Beas is a tributary of the Indus river system. River Beas originates in the Himalaya in central Himachal Pradesh (HP), India at 32.215°N, 77.050°E, and an altitude of 2050 m amsl. In HP, River Beas passes through Kullu, Mandi and Kangra. Prominent tributaries of the river are Parbati, Uhl, Lunj, Hurla, Baner and Banganga. On entering the Sivalik hills in Hoshiarpur, Punjab, the river turns to the north forming a boundary with Kangra district, HP. Then bending towards the base of the Sivalik hills, it flows to the south, separating the districts of Gurdaspur and Hoshiarpur in Punjab. After touching Jalandhar district, Punjab, for a short distance, River Beas forms the boundary between Amritsar and Kapurthala in Punjab. It merges with River Sutlej at Harike, Punjab. The length of River Beas is 470 km. It is the habitat of

Platanista gangetica minor R., an endangered freshwater dolphin² and the smooth-coated otter, *Lutrogate perspicillata*³. Freshwater is most important for the survival of life on earth. It is not only essential for human beings, but also for plants and animals. Water is an essential component of the environment and its management is important for the quality of the environment⁴. Water is also essential for regulation of climate⁵. Hanh *et al.*⁶ developed a water quality index (WQI) to evaluate the quality of surface water in Vietnam. Phadataré and Gawande⁷ studied the seasonal changes in water quality. To control the pollution of rivers, their monitoring followed by necessary measures must be undertaken. Yuceer and Coskun⁸ studied the water quality of rivers in Turkey. Surface water quality monitoring gives us information about the water status of environment⁹. Sohani and Singh¹⁰ reviewed the water quality of surface water. Phadataré and Gawande¹¹ reviewed the development of WQI. The present article compiles and statistically analyses data on River Beas.

Water quality parameters

The network of rivers on the earth is an interface between the land and the ocean. Rivers play an important role in controlling the hydrological cycle¹². Table 1 shows the water quality parameters of River Beas, while Figure 1 shows the map of River Beas. Water of River Beas is alkaline with pH ranging from 7.19 to 7.4. The river water exhibits seasonal variations both in quantity as well as nature of pollution. The trends of water quality parameters of the river for the years 2002 and 2008 were studied by the Central Pollution Control Board (CPCB)¹³. The range of dissolved oxygen (DO) was 5.2–11.5 mg/l for 2002 and 3.8–12.5 mg/l for 2008. The range of biological oxygen demand (BOD) was 0.3–5 mg/l for 2002 and 0.1–7.6 mg/l for 2008. Chemical oxygen demand (COD) also showed the same trend as BOD. The range of COD observed for 2008 was 1–28 mg/l (ref. 13). CPCB¹⁴ also reported the trend of water quality parameters of the river for the years 2009 and 2012. The range of DO was 6.4–11.8 mg/l for 2009 and 3.8–12 mg/l for 2012. The range of BOD was 0.1–2.8 mg/l for 2009 and 0.1–8.7 mg/l for 2012. Total coliform ranged from 7 to 2400 MPN/100 ml in 2009, and 34 to 1600 MPN/100 ml in 2012. The water

*For correspondence. (e-mail: vinodverma507@gmail.com)

Table 1. Water quality parameters of River Beas, India

Location	Water quality parameters	Content	Reference
Upstream Manali	BOD	0.2 mg/l	13
	DO	9.1 mg/l	
	Total coliform	825 MPN/100 ml	
	Faecal coliform	56 MPN/100 ml	
	Conductivity	88 μ mho/cm	
Upstream Manali	BOD	0.1 mg/l	19
	DO	9.0 mg/l	
	Total coliform	397 MPN/100 ml	
	Faecal coliform	106 MPN/100 ml	
	Conductivity	85 μ mho/cm	
Upstream Manali	BOD	0.2 mg/l	14
	DO	8.7 mg/l	
	Total coliform	103 MPN/100 ml	
	Faecal coliform	26 MPN/100 ml	
	Conductivity	89 μ mho/cm	
Upstream Manali (January)	DO	10.6 mg/l	20
	pH	7.31	
	BOD	0.2 mg/l	
	TSS	2.0 mg/l	
	Total coliform	540 MPN/100 ml	
	Faecal coliform	27 MPN/100 ml	
Upstream Manali (April)	DO	8.9 mg/l	20
	pH	7.37	
	BOD	0.2 mg/l	
	TSS	27 mg/l	
	Total coliform	920 MPN/100 ml	
	Faecal coliform	79 MPN/100 ml	
Upstream Manali (July)	DO	8.2 mg/l	20
	pH	7.87	
	BOD	0.3 mg/l	
	TSS	52 mg/l	
	Total coliform	1600 MPN/100 ml	
	Faecal coliform	70 MPN/100 ml	
Upstream Manali (October)	DO	8.60 mg/l	20
	pH	7.32	
	BOD	0.2 mg/l	
	TSS	25 mg/l	
	Total coliform	240 MPN/100 ml	
	Faecal coliform	49 MPN/100 ml	
Downstream Manali	BOD	3.7 mg/l	13
	DO	8.2 mg/l	
	Total coliform	2200 MPN/100 ml	
	Faecal coliform	1093 MPN/100 ml	
	Conductivity	112 μ mho/cm	
Downstream Manali	BOD	0.2 mg/l	19
	DO	9.00 mg/l	
	Total coliform	889 MPN/100 ml	
	Faecal coliform	189 MPN/100 ml	
	Conductivity	74 μ mho/cm	
Downstream Manali	BOD	0.9 mg/l	14
	DO	8.6 mg/l	
	Total coliform	417 MPN/100 ml	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Downstream Manali (January)	Faecal coliform	88 MPN/100 ml	20
	Conductivity	105 μ mho/cm	
	DO	9.5 mg/l	
	pH	6.97	
	BOD	11.0 mg/l	
	TSS	60 mg/l	
	Total coliform	2400 MPN/100 ml	
Downstream Manali (April)	Faecal coliform	2400 MPN/100 ml	20
	DO	8.2 mg/l	
	pH	6.49	
	BOD	0.40 mg/l	
	TSS	25.00 mg/l	
	Total coliform	1600 MPN/100 ml	
	Faecal coliform	130 MPN/100 ml	
Downstream Manali (July)	DO	7.20 mg/l	20
	pH	7.11	
	BOD	2.80 mg/l	
	TSS	708 mg/l	
	Total coliform	2400 MPN/100 ml	
	Faecal coliform	920 MPN/100 ml	
Downstream Manali (October)	DO	7.9 mg/l	20
	pH	6.83	
	BOD	0.40 mg/l	
	TSS	32 mg/l	
	Total coliform	2400 MPN/100 ml	
	Faecal coliform	920 MPN/100 ml	
Upstream Kullu	BOD	0.4 mg/l	13
	DO	9.1 mg/l	
	Total coliform	1347 MPN/100 ml	
	Faecal coliform	197 MPN/100 ml	
	Conductivity	117 μ mho/cm	
Upstream Kullu	BOD	0.2 mg/l	19
	DO	9.0 mg/l	
	Total coliform	990 MPN/100 ml	
	Faecal coliform	130 MPN/100 ml	
	Conductivity	114 μ mho/cm	
Upstream Kullu	BOD	0.2 mg/l	14
	DO	8.9 mg/l	
	Total coliform	204 MPN/100 ml	
	Faecal coliform	52 MPN/100 ml	
	Conductivity	93 μ mho/cm	
Upstream Kullu (January)	DO	10.60 mg/l	20
	pH	7.45	
	BOD	0.60 mg/l	
	TSS	2 mg/l	
	Total coliform	2400 MPN/100 ml	
	Faecal coliform	350 MPN/100 ml	
Upstream Kullu (April)	DO	9.10 mg/l	20
	pH	6.75	
	BOD	0.50 mg/l	
	TSS	105 mg/l	
	Total coliform	2400 MPN/100 ml	
	Faecal coliform	350 MPN/100 ml	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Upstream Kullu (July)	DO	7.8 mg/l	20
	pH	7.33	
	BOD	0.30 mg/l	
	TSS	52 mg/l	
	Total coliform	540 MPN/100 ml	
	Faecal coliform	79 MPN/100 ml	
Upstream Kullu (October)	DO	8.7 mg/l	20
	pH	7.28	
	BOD	0.30 mg/l	
	TSS	14 mg/l	
	Total coliform	49 MPN/100 ml	
	Faecal coliform	8.0 MPN/100 ml	
Downstream Kullu	BOD	0.5 mg/l	13
	DO	9.1 mg/l	
	Total coliform	1458 MPN/100 ml	
	Faecal coliform	399 MPN/100 ml	
	Conductivity	115 μ mho/cm	
Downstream Kullu	BOD	0.3 mg/l	19
	DO	9.0 mg/l	
	Total coliform	954 MPN/100 ml	
	Faecal coliform	153 MPN/100 ml	
	Conductivity	102 μ mho/cm	
Downstream Kullu	BOD	0.2 mg/l	14
	DO	8.8 mg/l	
	Total coliform	190 MPN/100 ml	
	Faecal coliform	39 MPN/100 ml	
	Conductivity	107 μ mho/cm	
Downstream Kullu (January)	DO	10.60 mg/l	20
	pH	7.54	
	BOD	0.70 mg/l	
	TSS	2 mg/l	
	Total coliform	2400 MPN/100 ml	
	Faecal coliform	920 MPN/100 ml	
Downstream Kullu (April)	DO	9.10 mg/l	20
	pH	7.03	
	BOD	0.40 mg/l	
	TSS	87 mg/l	
	Total coliform	2400 MPN/100 ml	
	Faecal coliform	540 MPN/100 ml	
Downstream Kullu (July)	DO	7.9 mg/l	20
	pH	7.77	
	BOD	0.40 mg/l	
	TSS	88 mg/l	
	Total coliform	920 MPN/100 ml	
	Faecal coliform	110 MPN/100 ml	
Downstream Kullu (October)	DO	8.8 mg/l	20
	pH	7.38	
	BOD	0.30 mg/l	
	TSS	18.00 mg/l	
	Total coliform	110 MPN/100 ml	
	Faecal coliform	27 MPN/100 ml	
Upstream Mandi	BOD	0.5 mg/l	13
	DO	8.8 mg/l	
	Total coliform	9969 MPN/100 ml	
	Faecal coliform	1389 MPN/100 ml	
	Conductivity	206 μ mho/cm	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Upstream Mandi	BOD	0.2 mg/l	19
	DO	9.0 mg/l	
	Total coliform	722 MPN/100 ml	
	Faecal coliform	100 MPN/100 ml	
	Conductivity	117 μ mho/cm	
Downstream Mandi	BOD	0.7 mg/l	13
	DO	8.8 mg/l	
	Total coliform	1405 MPN/100 ml	
	Faecal coliform	849 MPN/100 ml	
	Conductivity	216 μ mho/cm	
Downstream Mandi	BOD	1.1 mg/l	14
	DO	8.0 mg/l	
	Total coliform	2327 MPN/100 ml	
	Faecal coliform	773 MPN/100 ml	
	Conductivity	233 μ mho/cm	
Downstream Pongdam	BOD	0.2 mg/l	14
	DO	8.5 mg/l	
	Total coliform	187 MPN/100 ml	
	Faecal coliform	45 MPN/100 ml	
	Conductivity	97 μ mho/cm	
Upstream Pathankot	BOD	0.6 mg/l	13
	DO	7.8 mg/l	
	Conductivity	300 μ mho/cm	
	Total coliform	350 MPN/100 ml	
	Faecal coliform	50 MPN/100 ml	
Upstream Pathankot	BOD	1 mg/l	19
	DO	7 mg/l	
	Conductivity	316 μ mho/cm	
	Total coliform	500 MPN/100 ml	
	Faecal coliform	95 MPN/100 ml	
Downstream Pathankot	BOD	0.7 mg/l	13
	DO	7.7 mg/l	
	Conductivity	320 μ mho/cm	
	Total coliform	550 MPN/100 ml	
	Faecal coliform	106 MPN/100 ml	
Downstream Pathankot	BOD	1 mg/l	19
	DO	7 mg/l	
	Conductivity	334 μ mho/cm	
	Total coliform	600 MPN/100 ml	
	Faecal coliform	158 MPN/100 ml	
Mirthal bridge	BOD	0.7 mg/l	13
	DO	7.6 mg/l	
	Conductivity	317 μ mho/cm	
	Total coliform	650 MPN/100 ml	
	Faecal coliform	143 MPN/100 ml	
Mirthal bridge	BOD	0.5 mg/l	19
	DO	8 mg/l	
	Conductivity	177 μ mho/cm	
	Total coliform	662 MPN/100 ml	
	Faecal coliform	66 MPN/100 ml	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Talwara (pre-monsoon season)	Temperature	25°C	15
	Transparency	33.3 cm	
	pH	7.53	
	DO	8.7 mg/l	
	BOD	9.0 mg/l	
	COD	32.7 mg/l	
	Alkalinity	80 mg/l	
	TDS	129.7 mg/l	
	Conductivity	260.7 μ mho/cm	
	Hardness	131.7 mg/l	
	Ca	27.3 mg/l	
	Mg	15.2 mg/l	
	Cl ⁻¹	32.3 mg/l	
	PO ₄ ⁻³	0.23 mg/l	
Talwara (monsoon season)	Temperature	28°C	15
	Transparency	20 cm	
	pH	7.50	
	DO	7.9 mg/l	
	BOD	3.83 mg/l	
	COD	20 mg/l	
	Alkalinity	71.3 mg/l	
	TDS	103.3 mg/l	
	Conductivity	208.7 μ mho/cm	
	Hardness	118.3 mg/l	
	Ca	20.3 mg/l	
	Mg	16.2 mg/l	
	Cl ⁻¹	13 mg/l	
	PO ₄ ⁻³	0.207 mg/l	
Talwara (post-monsoon season)	Temperature	22°C	15
	Transparency	51.7 cm	
	pH	7.50	
	DO	7.3 mg/l	
	BOD	6.4 mg/l	
	COD	32.3 mg/l	
	Alkalinity	58 mg/l	
	TDS	73.7 mg/l	
	Conductivity	149.3 μ mho/cm	
	Hardness	133.3 mg/l	
	Ca	23.7 mg/l	
	Mg	17.8 mg/l	
	Cl ⁻¹	17.3 mg/l	
	PO ₄ ⁻³	0.18 mg/l	
Talwara (winter season)	Temperature	18°C	15
	Transparency	56 cm	
	pH	7.6	
	DO	9.0 mg/l	
	BOD	12 mg/l	
	COD	32.4 mg/l	
	Alkalinity	64.7 mg/l	
	TDS	77.7 mg/l	
	Conductivity	156.3 μ mho/cm	
	Hardness	132.50 mg/l	
	Ca	27.7 mg/l	
	Mg	15.2 mg/l	
	Cl ⁻¹	15.0 mg/l	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Talwara	Silicate	1.60 mg/l	15
	PO ₄ ³⁻	0.125 mg/l	
	Temperature	23.3°C	
	Transparency	37.4 cm	
	pH	7.52	
	Conductivity	193.75 µmho/cm	
	TDS	96.08 mg/l	
	DO	8.22 mg/l	
	CO ₂	0.5 mg/l	
	Alkalinity	68.5 mg/l	
	Hardness	128.95 mg/l	
Cl ⁻¹	19.42 mg/l		
Silicate	1.405 mg/l		
PO ₄ ³⁻	0.185 mg/l		
Talwara	BOD	0.4 mg/l	13
	DO	8 mg/l	
	Conductivity	294 µmho/cm	
	Total coliform	290 MPN/100 ml	
	Faecal coliform	63 MPN/100 ml	
Talwara	BOD	0 mg/l	19
	DO	8 mg/l	
	Conductivity	285 µmho/cm	
	Total coliform	50 MPN/100ml	
	Faecal coliform	3.00 MPN/100 ml	
Mukerian (pre-monsoon season)	Temperature	26.3°C	15
	Transparency	50.7 cm	
	pH	7.63	
	DO	8.1 mg/l	
	BOD	12.7 mg/l	
	COD	45.7 mg/l	
	Alkalinity	82.7 mg/l	
	TDS	114 mg/l	
	Conductivity	228.7 µmho/cm	
	Hardness	135 mg/l	
	Ca	31 mg/l	
	Mg	15.2 mg/l	
	Cl ⁻¹	14 mg/l	
	Silicate	1.6 mg/l	
PO ₄ ³⁻	0.23 mg/l		
Mukerian (monsoon season)	Temperature	29.2°C	15
	Transparency	14.7 cm	
	pH	7.47	
	DO	6 mg/l	
	BOD	7.70 mg/l	
	COD	28.7 mg/l	
	Alkalinity	96 mg/l	
	TDS	125.7 mg/l	
	Conductivity	254.3 µmho/cm	
	Hardness	159.2 mg/l	
	Ca	28 mg/l	
	Mg	16.2 mg/l	
	Cl ⁻¹	11.1 mg/l	
	Silicate	0.52 mg/l	
PO ₄ ³⁻	0.207 mg/l		

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Mukerian (post-monsoon season)	Temperature	19.3°C	15
	Transparency	42.7 cm	
	pH	7.30	
	DO	8.5 mg/l	
	BOD	8.2 mg/l	
	COD	28.7 mg/l	
	Alkalinity	58 mg/l	
	TDS	107 mg/l	
	Conductivity	211.3 µmho/cm	
	Hardness	139 mg/l	
	Ca	31.7 mg/l	
	Mg	17.8 mg/l	
	Cl ⁻¹	18.7 mg/l	
Silicate	1.9 mg/l		
PO ₄ ⁻³	0.180 mg/l		
Mukerian (winter season)	Temperature	17.5°C	15
	Transparency	55 cm	
	pH	7.60	
	DO	8.6 mg/l	
	BOD	16.8 mg/l	
	COD	51 mg/l	
	Alkalinity	66 mg/l	
	TDS	76.5 mg/l	
	Conductivity	153.5 µmho/cm	
	Hardness	133.75 mg/l	
	Ca	29 mg/l	
	Mg	15.2 mg/l	
	Cl ⁻¹	10 mg/l	
Silicate	1.60 mg/l		
PO ₄ ⁻³	0.125 mg/l		
Mukerian	Temperature	23.8°C	15
	Transparency	39.87 cm	
	pH	7.47	
	Conductivity	218.87 µmho/cm	
	TDS	109.18 mg/l	
	DO	7.61 mg/l	
	Alkalinity	78.6 mg/l	
	Hardness	143.05 mg/l	
	Cl ⁻¹	13.93 mg/l	
	Silicate	1.955 mg/l	
	PO ₄ ⁻³	0.240 mg/l	
Mukerian (2002)	Fe	0.05 mg/l	21
	Cr	0.09 mg/l	
	Ni	0.001 mg/l	
Mukerian (2003)	Fe	0.19 mg/l	21
	Cu	0.001 mg/l	
	Pb	0.001 mg/l	
	Ni	0.001 mg/l	
Mukerian	BOD	1.1 mg/l	13
	DO	7.5 mg/l	
	Conductivity	335 µmho/cm	
	Total coliform	850 MPN/100 ml	
	Faecal coliform	255 MPN/100 ml	
Mukerian	BOD	1 mg/l	19
	DO	7 mg/l	
	Conductivity	334 µmho/cm	
	Total coliform	738 MPN/100 ml	
	Faecal coliform	370 MPN/100 ml	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Kapurthala	BOD	0.7 mg/l	14
	DO	7.5 mg/l	
	Conductivity	292 μ mho/cm	
	Total coliform	700 MPN/100 ml	
	Faecal coliform	158 MPN/100 ml	
Kapurthala	BOD	0.8 mg/l	19
	DO	7 mg/l	
	Conductivity	317 μ mho/cm	
	Total coliform	567 MPN/100 ml	
	Faecal coliform	133 MPN/100 ml	
Beas bridge (pre-monsoon season)	Temperature	27.3°C	15
	Transparency	50.7 cm	
	pH	7.39	
	DO	8 mg/l	
	BOD	12.7 mg/l	
	COD	42 mg/l	
	Alkalinity	78 mg/l	
	TDS	117 mg/l	
	Conductivity	236 μ mho/cm	
	Hardness	105 mg/l	
	Ca	26.7 mg/l	
	Mg	9.2 mg/l	
	Cl ⁻¹	24.7 mg/l	
	Silicate	1.7 mg/l	
PO ₄ ⁻³	0.26 mg/l		
Beas bridge (monsoon season)	Temperature	27.3°C	15
	Transparency	12 cm	
	pH	7.39	
	DO	6.5 mg/l	
	BOD	8.30 mg/l	
	COD	26.2 mg/l	
	Alkalinity	74 mg/l	
	TDS	102.7 mg/l	
	Conductivity	207.7 μ mho/cm	
	Hardness	125.8 mg/l	
	Ca	23 mg/l	
	Mg	16.4 mg/l	
	Cl ⁻¹	9.0 mg/l	
	Silicate	0.46 mg/l	
PO ₄ ⁻³	0.241 mg/l		
Beas bridge (post-monsoon season)	Temperature	20.2°C	15
	Transparency	47 cm	
	pH	7.16	
	DO	6.9 mg/l	
	BOD	9.8 mg/l	
	COD	30.5 mg/l	
	Alkalinity	49.7 mg/l	
	TDS	77.3 mg/l	
	Conductivity	155.3 μ mho/cm	
	Hardness	134.2 mg/l	
	Ca	24 mg/l	
	Mg	17.8 mg/l	
	Cl ⁻¹	15.3 mg/l	
	Silicate	2.4 mg/l	
PO ₄ ⁻³	0.25 mg/l		

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Beas bridge (winter season)	Temperature	15.5°C	15
	Transparency	33.7 cm	
	pH	7.32	
	DO	8.1 mg/l	
	BOD	12.6 mg/l	
	COD	41.5 mg/l	
	Alkalinity	66.7 mg/l	
	TDS	98 mg/l	
	Conductivity	196.7 $\mu\text{mho/cm}$	
	Hardness	130.8 mg/l	
	Ca	32 mg/l	
	Mg	12.2 mg/l	
	Cl ⁻¹	15.7 mg/l	
	Silicate	2.30 mg/l	
PO ₄ ⁻³	0.171 mg/l		
Beas bridge	Temperature	22.83°C	15
	Transparency	35.08 cm	
	pH	7.34	
	Conductivity	187.75 $\mu\text{mho/cm}$	
	TDS	93.27 mg/l	
	DO	7.53 mg/l	
	CO ₂	0.15 mg/l	
	Alkalinity	63.25 mg/l	
	Hardness	125.76 mg/l	
	Cl ⁻¹	16.33 mg/l	
	Silicate	1.72 mg/l	
	PO ₄ ⁻³	0.235 mg/l	
	Beas bridge (pre-monsoon season)	pH	
Temperature		27.14°C	
Turbidity		33.34 NTU	
Conductivity		230 $\mu\text{S cm}^{-1}$	
TDS		108 mg/l	
BOD		8.06 mg/l	
COD		33.34 mg/l	
DO		7.91 mg/l	
NO ₃ ⁻¹		1.84 mg/l	
PO ₄ ⁻³		0.08 mg/l	
Hardness		108.67 mg/l	
Alkalinity		113.34 mg/l	
Cl ⁻¹		17.95 mg/l	
Na		10.01 mg/l	
K		3.14 mg/l	
Ca		28.31 mg/l	
Mg		9.25 mg/l	
Mn		0.11 mg/l	
Cr		0.006 mg/l	
Cu	0.011 mg/l		
Co	0.006 mg/l		
Beas bridge (post-monsoon season)	pH	7.86	22
	Temperature	23.70°C	
	Turbidity	59.34 NTU	
	Conductivity	150.00 $\mu\text{S cm}^{-1}$	
	TDS	160.00 mg/l	
	BOD	5.64 mg/l	
	COD	80.00 mg/l	
	DO	5.90 mg/l	
	NO ₃ ⁻¹	2.70 mg/l	
	PO ₄ ⁻³	0.028 mg/l	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
	Hardness	76.00 mg/l	
	Alkalinity	105 mg/l	
	Cl ⁻¹	21.27 mg/l	
	Na	19.84 mg/l	
	K	31.24 mg/l	
	Ca	66.26 mg/l	
	Mg	17.14 mg/l	
	Zn	0.046 mg/l	
	Mn	0.61 mg/l	
	Cr	0.048 mg/l	
	Cu	0.010 mg/l	
	Co	0.0006 mg/l	
Beas bridge (winter season)	pH	7.21	22
	Temperature	13.77°C	
	Turbidity	48.67 NTU	
	Conductivity	314.50 $\mu\text{S cm}^{-1}$	
	TDS	222.67 mg/l	
	BOD	12.05 mg/l	
	COD	33.34 mg/l	
	DO	8.31 mg/l	
	NO ₃ ⁻¹	1.96 mg/l	
	PO ₄ ⁻³	0.081 mg/l	
	Hardness	102.67 mg/l	
	Alkalinity	96.67 mg/l	
	Cl ⁻¹	7.95 mg/l	
	K	31.56 mg/l	
	Ca	24.74 mg/l	
	Mg	10.68 mg/l	
	Zn	0.0057 mg/l	
	Mn	0.094 mg/l	
	Cu	0.0044 mg/l	
Kishanpura (pre-monsoon season)	pH	7.93	22
	Temperature	28.10°C	
	Turbidity	31 NTU	
	Conductivity	226 $\mu\text{S cm}^{-1}$	
	TDS	106 mg/l	
	BOD	8.34 mg/l	
	COD	26.67 mg/l	
	DO	8.04 mg/l	
	NO ₃ ⁻¹	1.628 mg/l	
	PO ₄ ⁻³	0.11 mg/l	
	Hardness	110.67 mg/l	
	Alkalinity	126.67 mg/l	
	Cl ⁻¹	19.85 mg/l	
	Na	9.82 mg/l	
	K	2.84 mg/l	
	Ca	27.78 mg/l	
	Na	37.30 mg/l	
	Mg	10.07 mg/l	
	Mn	0.13 mg/l	
	Cr	0.012 mg/l	
	Cu	0.009 mg/l	
	Co	0.008 mg/l	
Kishanpura (post-monsoon season)	pH	7.71	22
	Temperature	25.00°C	
	Turbidity	110.67 NTU	
	Conductivity	160.00 $\mu\text{S cm}^{-1}$	
	TDS	179.34 mg/l	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
	BOD	8.12 mg/l	
	COD	53.34 mg/l	
	DO	6.16 mg/l	
	NO ₃ ⁻¹	1.44 mg/l	
	PO ₄ ⁻³	0.036 mg/l	
	Hardness	80.00 mg/l	
	Alkalinity	111.67 mg/l	
	Cl ⁻¹	20.32 mg/l	
	Na	23.20 mg/l	
	K	32.50 mg/l	
	Ca	60.35 mg/l	
	Mg	18.31 mg/l	
	Zn	0.045 mg/l	
	Mn	3.61 mg/l	
	Cr	0.079 mg/l	
	Cu	0.029 mg/l	
Co	0.0006 mg/l		
Kishanpura (winter season)	pH	7.25	22
	Temperature	14.14°C	
	Turbidity	60.67 NTU	
	Conductivity	315.50 µS cm ⁻¹	
	TDS	219.67 mg/l	
	BOD	12.74 mg/l	
	COD	26.67 mg/l	
	DO	8.45 mg/l	
	NO ₃ ⁻¹	2.18 mg/l	
	PO ₄ ⁻³	0.107 mg/l	
	Hardness	104 mg/l	
	Alkalinity	100 mg/l	
	Cl ⁻¹	8.46 mg/l	
	Na	45.63 mg/l	
	K	29.10 mg/l	
	Ca	17.57 mg/l	
Mg	10.81 mg/l		
Mn	0.068 mg/l		
Goindwal	BOD	1.0 mg/l	19
	DO	6.9 mg/l	
	Conductivity	309 µmho/cm	
	Total coliform	700 MPN/100 ml	
	Faecal coliform	166 MPN/100 ml	
Goindwal upstream	BOD	0.7 mg/l	13
	DO	7.2 mg/l	
	Conductivity	298 µmho/cm	
	Total coliform	550 MPN/100 ml	
	Faecal coliform	113 MPN/100 ml	
Goindwal upstream	BOD	1 mg/l	19
	DO	7 mg/l	
	Conductivity	310 µmho/cm	
	Total coliform	650 MPN/100 ml	
	Faecal coliform	180 MPN/100 ml	
Goindwal downstream	BOD	0.65 mg/l	19
	DO	7 mg/l	
	Conductivity	320 µmho/cm	
	Total coliform	725 MPN/100 ml	
	Faecal coliform	185 MPN/100 ml	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Goindwal Sahib (pre-monsoon season)	pH	8.07	22
	Temperature	24.96°C	
	Turbidity	43.34 NTU	
	Conductivity	219 $\mu\text{S cm}^{-1}$	
	TDS	105.34 mg/l	
	BOD	7.27 mg/l	
	COD	60 mg/l	
	DO	6.7 mg/l	
	NO_3^-	1.711 mg/l	
	PO_4^{3-}	0.06 mg/l	
	Hardness	104.67 mg/l	
	Alkalinity	140 mg/l	
	Cl^-	15.59 mg/l	
	Na	9.95 mg/l	
	K	3.28 mg/l	
	Ca	29.38 mg/l	
	Mg	7.63 mg/l	
	Mn	0.002 mg/l	
Cr	0.009 mg/l		
Cu	0.003 mg/l		
Co	0.012 mg/l		
Goindwal Sahib (post-monsoon season)	pH	7.53	22
	Temperature	24.77°C	
	Turbidity	56.34 NTU	
	Conductivity	156.67 $\mu\text{S cm}^{-1}$	
	TDS	178.34 mg/l	
	BOD	5.89 mg/l	
	COD	66.67 mg/l	
	DO	6.55 mg/l	
	NO_3^-	1.47 mg/l	
	PO_4^{3-}	0.024 mg/l	
	Hardness	84.00 mg/l	
	Alkalinity	118.34 mg/l	
	Cl^-	27.88 mg/l	
	Na	18.26 mg/l	
	K	31.50 mg/l	
	Ca	45.81 mg/l	
	Mg	15.85 mg/l	
	Zn	0.017 mg/l	
Mn	1.29 mg/l		
Cr	0.021 mg/l		
Cu	0.0024 mg/l		
Goindwal Sahib (winter season)	pH	7.40	22
	Temperature	14.47°C	
	Turbidity	74.34 NTU	
	Conductivity	313.00 $\mu\text{S cm}^{-1}$	
	TDS	218.00 mg/l	
	BOD	9.49 mg/l	
	COD	26.67 mg/l	
	DO	7.51 mg/l	
	NO_3^-	2.07 mg/l	
	PO_4^{3-}	0.123 mg/l	
	Hardness	108 mg/l	
	Alkalinity	100 mg/l	
	Cl^-	8.27 mg/l	
	Na	46.53 mg/l	
	K	27.04 mg/l	
	Ca	21.54 mg/l	
	Mg	15.85 mg/l	
	Mn	0.123 mg/l	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Harike	Temperature	23.5°C	15
	Transparency	30.5 cm	
	pH	7.40	
	Conductivity	188.75 $\mu\text{mho/cm}$	
	TDS	93.75 mg/l	
	DO	7.70 mg/l	
	CO ₂	0.12 mg/l	
	Alkalinity	64 mg/l	
	Hardness	123.33 mg/l	
	Cl ⁻¹	17.42 mg/l	
	Silicate	1.77 mg/l	
PO ₄ ⁻³	0.246 mg/l		
Harike	BOD	0.9 mg/l	13
	DO	6.9 mg/l	
	Conductivity	286 $\mu\text{mho/cm}$	
	Total coliform	450 MPN/100 ml	
	Faecal coliform	105 MPN/100 ml	
Harike	BOD	1 mg/l	19
	DO	7 mg/l	
	Conductivity	304 $\mu\text{mho/cm}$	
	Total coliform	550 MPN/100 ml	
	Faecal coliform	130 MPN/100 ml	
Beas Harike (pre-monsoon season)	pH	7.97	22
	Temperature	26.04°C	
	Turbidity	43.34 NTU	
	Conductivity	231.5 $\mu\text{S cm}^{-1}$	
	TDS	114.34 mg/l	
	BOD	9.14 mg/l	
	COD	73.34 mg/l	
	DO	6.97 mg/l	
	NO ₃ ⁻¹	1.507 mg/l	
	PO ₄ ⁻³	0.12 mg/l	
	Hardness	104.67 mg/l	
	Alkalinity	146.67 mg/l	
	Cl ⁻¹	21.74 mg/l	
	Na	11.92 mg/l	
	K	3.78 mg/l	
	Ca	29.92 mg/l	
	Mg	7.3 mg/l	
	Mn	0.124 mg/l	
Cr	0.004 mg/l		
Cu	0.006 mg/l		
Co	0.013 mg/l		
Beas Harike (post-monsoon season)	pH	7.32	22
	Temperature	25.86°C	
	Turbidity	131.00 NTU	
	Conductivity	156.67 $\mu\text{S cm}^{-1}$	
	TDS	177.34 mg/l	
	BOD	4.79 mg/l	
	COD	66.67 mg/l	
	DO	5.35 mg/l	
	NO ₃ ⁻¹	0.92 mg/l	
	PO ₄ ⁻³	0.031 mg/l	
	Hardness	94.00 mg/l	
	Alkalinity	122.34 mg/l	
	Cl ⁻¹	24.57 mg/l	
	Na	24.90 mg/l	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
Beas Harike (winter season)	K	32.87 mg/l	22
	Ca	39.67 mg/l	
	Mg	15.37 mg/l	
	Zn	0.017 mg/l	
	Mn	0.59 mg/l	
	Cr	0.008 mg/l	
	Cu	0.024 mg/l	
	Co	0.0006 mg/l	
	pH	7.54	
	Temperature	14.74°C	
	Turbidity	70.00 NTU	
	Conductivity	307.67 $\mu\text{S cm}^{-1}$	
	TDS	216.34 mg/l	
	BOD	7.24 mg/l	
COD	53.34 mg/l		
DO	7.78 mg/l		
NO_3^-	1.87 mg/l		
PO_4^{3-}	0.072 mg/l		
Hardness	108 mg/l		
Alkalinity	106.67 mg/l		
Cl^-	7.82 mg/l		
Na	37.03 mg/l		
K	31.57 mg/l		
Ca	19.58 mg/l		
Mg	15.37 mg/l		
Zn	0.002 mg/l		
Mn	0.152 mg/l		
2002	Temperature	3–32°C	13
	pH	7.1–8.7	
	Conductivity	53–517 $\mu\text{mho/cm}$	
	DO	5.2–11.5 mg/l	
	BOD	0.3–5.0 mg/l	
	COD	1–13 mg/l	
	Total coliform	2–2400 MPN/100 ml	
2003	Temperature	4–29°C	13
	pH	7.3–8.9	
	Conductivity	76–559 $\mu\text{mho/cm}$	
	DO	7–12 mg/l	
	BOD	0.1–6 mg/l	
	COD	1–18 mg/l	
Total coliform	2–2400 MPN/100 ml		
2004	Temperature	2–29°C	13
	pH	6.9–8.5	
	Conductivity	60–396 $\mu\text{mho/cm}$	
	DO	6.8–11.8 mg/l	
	BOD	0.2–4.8 mg/l	
	Total coliform	$2-5 \times 10^4$ MPN/100 ml	
2005	Temperature	4–27°C	13
	pH	7–8.8	
	Conductivity	54–395 $\mu\text{mho/cm}$	
	DO	4.8–13 mg/l	
	BOD	0.2–10 mg/l	
	COD	1.8–22 mg/l	
Total coliform	$2-11 \times 10^3$ MPN/100 ml		
2006	Temperature	4–27°C	13
	pH	7–8.8	
	Conductivity	54–395 $\mu\text{mho/cm}$	

(Contd)

Table 1. (Contd)

Location	Water quality parameters	Content	Reference
	DO	4.8–13 mg/l	
	BOD	0.2–10 mg/l	
	COD	1.8–22 mg/l	
	Total coliform	2–11 × 10 ³ MPN/100 ml	
2007	Temperature	2–22°C	13
	pH	6.2–8.9	
	Conductivity	86–470 µmho/cm	
	DO	5.9–12.8 mg/l	
	BOD	0.1–2.9 mg/l	
	COD	1.2–38 mg/l	
	Total coliform	0–2400 MPN/100 ml	
2008	Temperature	1.5–22°C	13
	pH	7–8.4	
	Conductivity	53–432 µmho/cm	
	DO	3.8–12.5 mg/l	
	BOD	0.1–7.6 mg/l	
	COD	1–28 mg/l	
	Total coliform	7–1600 MPN/100 ml	
2009	Temperature	5–26°C	13
	pH	7.1–8.5	
	Conductivity	46–338 µmho/cm	
	DO	6.4–11.8 mg/l	
	BOD	0.1–4.3 mg/l	
	COD	1.5–76 mg/l	
	Total coliform	7–2400 MPN/100 ml	
2010	Temperature	5–26°C	13
	pH	6.2–8.8	
	Conductivity	63–548 µmho/cm	
	DO	5.8–11.2 mg/l	
	BOD	0.1–2.8 mg/l	
	Total coliform	7–39,000 MPN/100 ml	
	2011	Temperature	
pH		6.5–8.87	
Conductivity		49–638 µmho/cm	
DO		5–12.5 mg/l	
BOD		0.1–1.5 mg/l	
Total coliform		8–2400 MPN/100 ml	
Faecal coliform		0–920 MPN/100 ml	
2012	Temperature	2–29.5°C	14
	pH	6.6–7.9	
	Conductivity	160–958 µmho/cm	
	DO	3.8–12 mg/l	
	BOD	0.1–8.7 mg/l	
	Total coliform	34–1600 MPN/100 ml	
	Faecal coliform	11–900 MPN/100 ml	
Beas river	Temperature	3–32°C	23
	pH	7.1–8.7	
	Conductivity	53–517 µmho/cm	
	DO	5.2–11.5 mg/l	
	BOD	0.3–5 mg/l	
	COD	1–13 mg/l	
	Total coliform	2–2400 MPN/100 ml	
	Faecal coliform	2–1600 MPN/100 ml	

BOD, Biological oxygen demand; DO, dissolved oxygen; COD, chemical oxygen demand; TSS, total suspended solids; TDS, total dissolved solids.

Table 2. Guidelines for inland surface water and drinking water

Parameters	EPR (1986) guidelines for inland surface water	BIS (2012) guidelines for drinking water
pH	5.5–9	6.5–8.5
BOD (mg/l)	30	0
COD (mg/l)	250	0
PO ₄ ³⁻ (mg/l)	5	–
NO ₃ ⁻¹ (mg/l)	10	45
Cl ⁻¹ (mg/l)	1.0	250
As (mg/l)	0.2	0.01
Hg (mg/l)	0.01	0.001
Pb (mg/l)	0.1	0.01
Cd (mg/l)	2.0	0.003
Cr (mg/l)	2.0	0.05
Cu (mg/l)	3.0	0.05
Zn (mg/l)	5.0	5
Ni (mg/l)	3.0	0.02
Fe (mg/l)	3.0	0.3
Mn (mg/l)	2.0	0.1
Total coliform (MPN/100 ml)	–	0

BIS, Bureau of Indian Standards; EPR, Environment Protection Rule.

Table 3. Mean and range of water quality parameters of River Beas in Himachal Pradesh, India

Parameters		River Beas
pH	Mean	7.21
	Range	6.49–7.87
Conductivity (µmho/cm)	Mean	121.76
	Range	74–233
TSS (mg/l)	Mean	81.18
	Range	2–708
DO (mg/l)	Mean	8.82
	Range	7.2–10.6
BOD (mg/l)	Mean	0.87
	Range	0.1–11
Total coliform (MPN/100 ml)	Mean	1451.60
	Range	49–9969
Faecal coliform (MPN/100 ml)	Mean	479.16
	Range	8–3500

quality parameters from Beas bridge and Harike for the pre-monsoon season have been reported by several workers. Higher values of BOD (13.7 mg/l) and COD (43 mg/l) were observed in Beas bridge. Water from River Beas before merging into the Sutlej at Harike contained lower content of BOD (12.7 mg/l) and COD (42 mg/l) as compared to Beas bridge. DO content in water from Beas bridge was 8 mg/l, whereas at Harike it was 7.7 mg/l. PO₄³⁻ content in River Beas at Harike was 0.27 mg/l and at Beas bridge it was 0.26 mg/l (ref. 15).

Water quality vis-à-vis the standards

Table 2 presents the guidelines of Environment Protection Rule (EPR)¹⁶ and Bureau of Indian Standards (BIS)¹⁷

for inland surface water and drinking water respectively. Tables 3 and 4 present the mean and range of water quality parameters of River Beas in HP and Punjab. Ranges of pH, BOD, DO and total coliform of River Beas in HP are below the maximum permissible limits of EPR¹⁶ for inland surface waters. Ranges of pH, BOD, COD, PO₄³⁻ and NO₃⁻¹ of River Beas are below the maximum permissible limits of EPR¹⁶ for inland surface waters. Ranges of Fe, Pb, Cd, Cr, Cu, Zn and Ni are also below the permissible limits of EPR¹⁶. The range of Mn exceeds the maximum permissible limit of EPR¹⁶ for inland surface waters. Ranges of pH, TDS, NO₃⁻¹, Cl⁻¹, alkalinity, hardness, Ca and Mg of River Beas are below the maximum permissible limits of BIS¹⁷ for drinking water. Ranges of turbidity, DO, BOD, COD and total coliform of river Beas exceed the permissible limits of BIS¹⁷ for drinking

Table 4. Mean and range of water quality parameters of River Beas in Punjab, India

Parameters		River Beas
Temperature (°C)	Mean	20.79
	Range	13.76–25.86
pH	Mean	7.51
	Range	7.16–8.16
TDS (mg/l)	Mean	120.50
	Range	54–222.67
Turbidity (NTU)	Mean	63.50
	Range	31–131
Conductivity (µmho/cm)	Mean	270.04
	Range	150–335
DO (mg/l)	Mean	7.29
	Range	5.35–8.45
BOD (mg/l)	Mean	3.75
	Range	0.4–12.74
COD (mg/l)	Mean	48.89
	Range	26.67–80
PO ₄ ³⁻ (mg/l)	Mean	0.204
	Range	0.024–1.6
NO ₃ ⁻¹ (mg/l)	Mean	1.77
	Range	0.92–2.7
Cl ⁻¹ (mg/l)	Mean	16.74
	Range	7.82–32.3
Ca (mg/l)	Mean	34.24
	Range	17.56–66.26
Mg (mg/l)	Mean	12.80
	Range	7.3–18.31
Alkalinity (mg/l)	Mean	86.33
	Range	49.7–146.67
Hardness (mg/l)	Mean	117.03
	Range	75.8–159.02
Total coliforms (MPN/100 ml)	Mean	562.88
	Range	50–850
Faecal coliforms (MPN/100 ml)	Mean	137.72
	Range	3–370
Fe (mg/l)	Mean	0.22
	Range	0.04–0.6
Cr (mg/l)	Mean	0.023
	Range	0.004–0.079
Ni (mg/l)	Mean	0.0075
	Range	0.001–0.025
Pb (mg/l)	Mean	0.025
	Range	0.001–0.05
Cu (mg/l)	Mean	0.0121
	Range	0.002–0.029
Mn (mg/l)	Mean	0.583
	Range	0.068–3.61
Zn (mg/l)	Mean	0.022
	Range	0.002–0.046
Co (mg/l)	Mean	0.005
	Range	0.0006–0.013
Cd (mg/l)	Mean	–
	Range	–

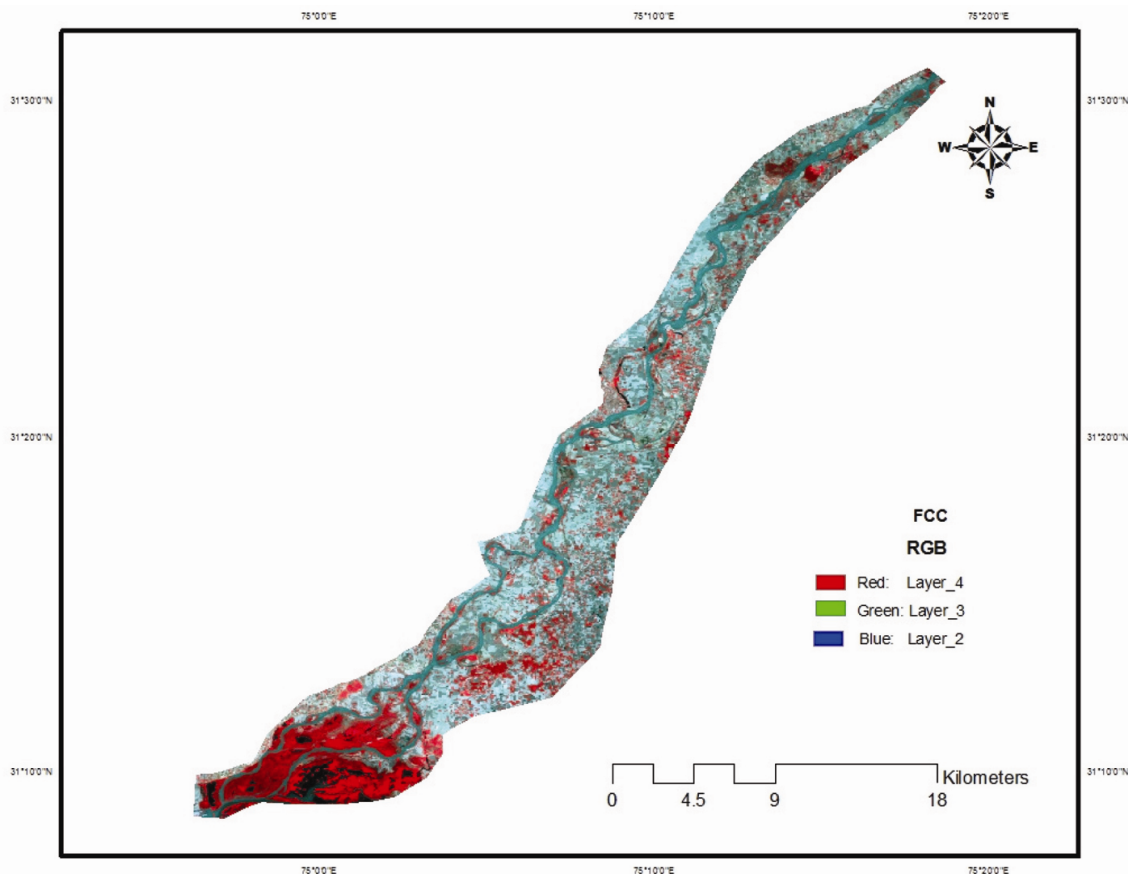


Figure 1. Map of River Beas, India.

Table 5. Water quality index rating

>90–100 = Excellent
>70–90 = Good
>50–70 = Medium
>25–50 = Bad
0–25 = Very bad

water. Ranges of Pb, Cr, Ni, Fe and Mn also exceed the permissible limits of BIS¹⁷ for drinking water. Cd, Cu and Zn ranges of river Beas are below the permissible limits of BIS¹⁷ for drinking water.

Water quality index

WQI was calculated using nine water quality parameters following Thukral *et al.*¹⁸

$$WQI = \frac{\sum(Q \times W)}{\sum W}$$

where *Q* is the quality of each chosen water parameter at a scale of 0 to 100 and *W* is the weighting factor assigned to each water parameter depending upon its importance.

Table 5 shows the rating of water quality and Table 6 shows the WQI of river Beas. The WQI of River Beas was found to be 60.93, which is rated as medium quality water.

Conclusion

The present article shows that the ranges of DO, COD, BOD and total coliform in the river water are above the permissible limits of BIS for drinking water. The WQI of River Beas is rated as good. BOD (0.87 mg/l) of the upper stretch of river Beas (HP) is less than that of the lower stretch (3.75 mg/l; Punjab). Necessary prevention steps should be taken in order to treat the industrial and domestic wastewater, before it is discharged into the river. This will help in protecting the aquatic biodiversity of the river.

Table 6. Water quality index for River Beas

Factor	Mean test value	Q-value	Weighting factor (W)	Q*W
DO (% saturation)	7.29	86	0.17	1.004
Faecal coliform nos/100 ml	137.72	41.41	0.16	6.62
pH	7.51	92	0.11	10.12
BOD (mg/l)	3.75	62.5	0.11	6.87
Temperature range (°C)	20.79	93	0.10	9.30
Total phosphate-P (mg/l)	0.20	92	0.10	9.20
Nitrates (mg/l)	1.77	95.23	0.10	9.52
Turbidity (NTU)	63.50	31.84	0.08	2.54
Total solids (mg/l)	120.50	82	0.07	5.74
WQI = $\sum(W*Q)$				60.93 (medium)

- Mishra, A., Mukherjee, A. and Tripathi, B. D., Water resource pollution and impacts on the local livelihood: a case study of Beas river in Kullu district, India. *Int. J. Environ. Res.*, 2009, **3**, 395–402.
- Khan, S. M., Indus river dolphin: the survivor of river Beas, Punjab, India. *Curr. Sci.*, 2013, **104**, 1464–1465.
- Khan, M. S., Occurrence of the Smooth-Coated Otter *Lutrogale perspicillata* (Geoffroy, 1826) in Punjab, India. *IUCN Otter Spec. Group Bull.*, 2015, **32**, 3–7.
- Ojekunle, O. Z., Olurotimi, V., Azeem, A., Abayomi G. A., Opeyemi, R. T., Adewale, M. S. and Adekitan, A. A., Evaluation of surface water quality indices and ecological risk assessment for heavy metals in scrap yard neighbourhood. *SpringerPlus*, 2016, **5**, doi:10.1186/s40064-016-2158-9.
- Gorde, S. P. and Jadhav, M. V., Assessment of water quality parameters: a review. *Int. J. Eng. Res. Appl.*, 2013, **3**, 2029–2035.
- Hanh, P. T. M., Sthiannopkao, S., Ba, D. T. and Kim, K. W., Development of water quality indexes to identify pollutants in vietnam's surface water. *J. Environ. Eng.*, 2011, **137**, 273–283.
- Phadatare, S. S. and Gawande, S. M., A review paper on assessment of seasonal variation in quality of water bodies. *Imp. J. Interdiscip. Res.*, 2016, **2**, 576–578.
- Yuceer, M. and Coskun, M. A., Modeling water quality in rivers: a case study of Beylerderesi river in Turkey. *Appl. Ecol. Environ. Res.*, 2016, **14**, 383–395.
- Zheng, H., Yang, H., Long, D. and Jing, H., Monitoring surface water quality using social media in the context of citizen science. *Hydrol. Earth Syst. Sci.*, 2016, doi:10.5194/hess-2016-359.
- Sohani, S. S. and Singh, I. P., Surface water quality modeling: a review of the analysis of uncertainty. *Int. J. Sci. Res. Dev.*, 2015, **3**, 335–337.
- Phadatare, S. S. and Gawande, S., Review paper on development of water quality index. *Int. J. Eng. Res. Technol.*, 2016, **5**, 765–767.
- Garrels, R. M., Mackenzie, F. T. and Hunt, C., *Chemical Cycle and the Global Environment*, William Kaufman, New York, 1975.
- CPCB, Status of water quality in India – 2010. Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, Government of India (GoI), 2011.
- CPCB, Status of water quality in India – 2012. Central Pollution Control Board, MoEF&CC, GoI, 2014.
- Moza, U. and Mishra, D. N., River Beas Ecology and Fishery, Central Inland Fisheries Research Institute, 2007.
- EPR, Guidelines for Inland Surface Waters, Omitted by Rule 2(i)(iii) of the Environment (Protection) Third Amendment Rules, 1993, vide G.S.R. 801(E) dated 31.12.1993; 1986.
- BIS, Drinking Water specification. Bureau of Indian Standards, New Delhi, 2012.
- Thukral, A. K., Bhardwaj, R. and Kaur, R., Water quality indices. In *Statistical Accounting of Water Resources*, Central Statistical Organization, Ministry of Statistics and Programme Implementation, GoI, New Delhi, 2005.
- CPCB, Status of water quality in India – 2011. Central Pollution Control Board, MoEF & CC, GoI, 2013.
- Mishra, R. P. and Nadda, K. R., Water resource pollution and impacts on the local livelihood: a case study of Beas river in Kullu district, India. *J. Food Agric. Soc.*, 2014, **2**, 61–75.
- Punjab State Council for Science and Technology, State of Environment Punjab. MoEF & CC, GoI, 2007.
- Kumar, V., Sharma, A., Chawla, A., Bhardwaj, R. and Thukral, A. K., Water quality assessment of river Beas, India, using multivariate and remote sensing techniques. *Environ. Monit. Assess*, 2016, **188**, 137; doi:10.1007/s10661-016-5141-6.
- Gangwar, S., Water quality monitoring in India: a review. *Int. J. Inf. Comp. Technol.*, 2013, **3**, 851–856.

ACKNOWLEDGEMENT. V.K. thanks the University Grants Commission, New Delhi for providing research fellowship for this work.

Received 6 July 2016; revised accepted 26 October 2016

doi: 10.18520/cs/v112/i06/1138-1157