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Assessment of Water Quality of River Sutlej in Himachal Pradesh and Punjab (India) Using Statistical Tool

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ABSTRACT

Water resources are important component in the development of the country which required utmost care for its qualitative and quantitative management. Present study focused on the assessment of water quality of river Sutlej in its pristine nature as well as in urban area. Characterization of the water quality at different location has been carried out for different pollution sensitive parameters which have been expressed numerically using statistical tools in terms of water quality index for easy understanding and better management of water quality. The study reveals that the water quality of river Sutlej has been deteriorated progressively in downstream in comparison to upstream i.e., at Olinda. Deterioration in the water quality of river Sutlej caused by the mixing of a drain emanating from an industrial area located in Himachal Pradesh as well as from the urban development.

Keywords: WQI, BOD, Sutlej, Pollution load.

INTRODUCTION

In the present era of modernization, the advancement in every phase of industrialization and urbanization which leads to generate pollutants this ultimately alters the aquatic ecosystem. The wide array of pollutants discharged into aquatic environment may have physico-chemical, biological, toxic and pathogenic effects [1]. The life of aquatic ecosystem is directly or indirectly depends on the water quality [2]. Water pollution is a major threat to human population and dumping of pollutants into water body resulted in rapid deterioration of water quality and effect the ecological balance in the long run [3]. Sutlej is one of the major rivers in the Northern region of India. It is major water resources for industrial units in Punjab after Bakhara dam and also receives of wastewater through different industrial drains such as Gowlthai drain which originates from Gowlthai industrial area, Himanchal Pradesh and many more.

The present study aims to assess water quality at downstream of Bakhara dam i.e., at Olinda, H.P. and at downstream of Nangal, Punjab (urban area).

MATERIALS AND METHODS

After preliminary survey of River Sutlaj, d/s of Bakhara dam at Olinda village (R1) in upstream of Nangal city and near Udhaw temple in Nangal city (R2) were selected to assess the water quality of river. Water samples were collected as per monitoring protocol during the period of July, 2010 to June, 2016 on quarterly basis and analysed for relevant parameter (pH, Temperature (^oC), EC (μmohs cm^{-1}), Ammonical-N (mg L^{-1}), TDS (mg L^{-1}), DO (mg L^{-1}), BOD (mg L^{-1}), COD (mg L^{-1}), Chloride (mg L^{-1}), Total Coliform (MPN 100mL^{-1}), Fecal Coliform (MPN 100mL^{-1}) and metals as per the APHA 22nd, 2012 method [4].

RESULTS AND DISCUSSION

The river Sutlej at R1 is almost in pristine nature except effect of small colonies located on the bank in the hilly area cannot be ruled out, whereas R2, is in downstream of Nangal city. Average of seasonal water quality data w.r.t.Physico-chemical parameters of these two locations were tabulated in Table 1.

pH: pH of water is an important indication of water quality and indicates various geochemical equilibrium. Higher value of pH is normally associated with high photosynthetic activity in water [5] and water are alkaline due to presence of sufficient quantities of carbonates. Many reactions are controlled by pH [6]. In this study pH value ranged between 7.1-8.3 and 7.4-8.0 at R1 and R2 locations respectively.

Table 1: Physico-chemical dynamics (range) observed during study periods i.e., 2010-2016

Sr.N	Parameters	Summer Location R1: U/S Olinda	Season Location R2: D/S Rive	Monsoon R1: U/S Olinda (HP)	Season R2: D/S River (PB)	Winter R1: U/S Olinda	Season R2: D/S Ri	Standards CPCB/BIS
1.	Temperature	14 – 24	17-25	15-21	16-17	15-18	14-20	-
2.	pH	7.6-8.3	7.4-8.0	7.1-8.0	7.3-8.0	7.7-8.3	7.5-7.9	6.5-8.5
3.	EC	211-256	198-263	104-244	113.3-203	187-242	225-240	-
5.	Ammonical-N	0.04-0.36	0.03-0.43	0.02-0.24	0.02-0.376	0.03-0.65	0.2-0.71	0.5
6.	TDS	107-423	126-476	102-375	109-402	107-224	112-324	2000
7.	DO	8.5-10.0	8.8-10.0	8.8-9.8	8.0-8.9	8.0-9.4	8.0-9.4	> 6
8.	BOD	0.9 -1.0	0.9-1.0	0.9-1.9	1.0-1.2	0.9-1.0	0.9-1.0	< 2
9.	COD	4.9 -5.0	4.9-5.0	4.9-5.3	5.0-5.0	4.9-5.0	4.9-5.0	-
13.	Chloride	1.8 -4.6	3.0-10.3	3.0-5.4	1.3-3.0	3.1-19.4	3.6-4.9	< 250
14.	Total Coli (MPN/100ml)	< 1.8 -35000	3300-92000	1200-7900	1100-24000	< 1.8-2200(	1400-2200(	
15.	Fecal Coli (	< 1.8 -17000	20-28000	620-4900	2300-790	< 1.8 19000	37-190000	

BOD -0.9 mg L^{-1} is BDL value, COD 4.9 mg L^{-1} is BDL

* all units in (mg L^{-1}) except pH, temp (^0C) & TC/FC (MPN 100 mL^{-1})

Table 2. Metallic content (mg L^{-1}) in river Sutlej at studied locations (Average)

Location	Iron	Nickel	Cadmium	Chromium	Copper	Lead	Manganese	Zinc
R1	0.63	0.07	BDL	BDL	BDL	BDL	1.96	0.04
R2	0.65	0.06	BDL	BDL	BDL	BDL	0.09	0.04

Dissolved Oxygen: The effect of wastewater released in a water body largely determined by discharge of oxygen demanding waste and oxygen balance of the system. The exchange of oxygen across the air, water interface depends upon temperature, partial pressure of gases, solubility, photosynthetic activity of plant and respiration by bacteria, plants and animals in the water [7]. Temperature and salinity affect the dissolution of oxygen. As a result DO levels drop below 5.0 mg/L, aquatic life put under stress [8]. DO concentration in the study area was found above the desired value (5 mg L^{-1}) as per WHO and BIS

guidelines at both sampling stations due to significant turbulence in the river waters. As the concentration of dissolved oxygen deplete, it imposes thrust on aquatic life. The DO content ranged 8.0-10.0 mg L^{-1}at R1 and 8.0 - 9.8 mg L^{-1}at R2 locations, which does not show any abnormality.

Biochemical Oxygen Demand: Biochemical Oxygen Demand (BOD_5) is an index of organic pollution to measure the amount of DO required by microbial community in decomposing the organic matter present in a water sample by aerobic biochemical action [9]. The concentration of BOD ranged between 0.9-1.9 mg L^{-1} at R1 and 0.9-1.2 mg L^{-1} at R2 locations which are lower than prescribed standards i.e. 2 mg L^{-1}, it indicates the water quality fall in the class A as per the DBU classification at both locations.

Chlorides: The most important source of chloride in natural water is discharge of sewage and it plays vital role in photophosphorylation reaction in autotrophs. Sreenivasan [10], documented that chloride concentration between 4-10 mg L^{-1}indicates purity of water. In this study concentration of chlorides ranged from 1.8-19.4 mg L^{-1}at R1 and 1.3-10.3 mg L^{-1}at R2 respectively. All the values were found within the permissible limits i. e. 250 mg L^{-1}.

Nitrate: The Nitrate –N concentration found in surface water is generally low in concentration, but it can be increased due to addition of agricultural runoff or from contamination by human or animal wastes. For a sensitive fish such as salmon, the recommended concentration is 0.06 mg L^{-1}. During study nitrate content fluctuated between 0.305-1.56 mg L^{-1}at R1 and 0.334 -1.2 mg L^{-1}at R2 respectively, which is well below the prescribed limit even well below the limit prescribe for the drinking water.

Total Dissolve Solids: TDS value useful to determine whether water is suitable for drinking purpose, agriculture and industrial purposes. The TDS values in the present study vary between 102 to 423 at R 1 and 109 to 476 mg/l at R2 respectively. All the values were found within the prescribed limit i.e. 2000 mg L^{-1}.

Total Hardness: Water with Hardness above 200 mg L^{-1}may cause scale deposition in the distribution system and results in excessive soap consumption and subsequent formation [7]. The hardness values in the present study were found in range between 80.7 to 128 mg L^{-1}at R 1 and mg L^{-1}at R2 respectively.

Sulphate: Sulphate is naturally present in surface waters as SO_4^{-2}. It is the stable, oxidized form of Sulphur and is readily soluble in water (with the exception of lead, barium and strontium sulphates which precipitate).The sulphate ion concentration in the present study was found in order of 19.43 to 42 at R 1 and 18.4 to 41.23 mg L^{-1}at R2 respectively. The concentrations of sulphate in the river Sutlej at both locations (R1 & R2) were found well within the prescribed norms for drinking water i.e. mg L^{-1}.

Ammonical Nitrogen: Ammonia is produced by microbial activity of organic nitrogenous matter and its presence is mainly due to decaying plants, sewage, industrial discharge and fertilizer containing ammonia. High concentration of Ammonical nitrogen is toxic to fish and aquatic biota. In this study concentration of ammonia varies from 0.02-0.65 mg L^{-1}at R1, and 0.02 -0.71 mg L^{-1}at R2 respectively. It is observed that the maximum concentration recorded during the study were exceeded the prescribed limit i.e. 0.5 mg L^{-1}, which indicates the potential of Ammonical nitrogen source around the sampling locations.

Coliform: The coliform family is made up of several groups, one of which is Faecal coliform, which is found in the intestinal tracts of warm blooded animals including humans. The presence of Faecal coliform in water is evidence of contribution of sewage in to the studied aquatic system. In the present study number of Total coliform found in order of < 1.8 to 2.2 $x10^5$ at R1 and 1100 - $2.2x10^5$ MPN 100 mL^{-1} at R2 respectively whereas total number of Faecal coliform were found in order of 1.8-1.9 $x10^5$ and 20-1.9 x 10^5 at R1 and R2 respectively. The water quality w.r.t. Total coliform and faecal coliform MPN 100 mL^{-1} does not confirm even C class as per DBU classification. The reason behind the higher number of MPN of

TC/FC, must be due to addition of untreated or partially treated wastewater from urban sprawling [11], through drainage system which is affected the water quality of greater extent.

Metallic Concentration: Out of these pollutants, heavy metals are of major concern because of their persistent and bio-accumulative nature [11]. Concentration of toxic metals i.e, Cr, Cd, Pb, and Cu were found BDL at all location in all season (Table-2), concentration of Zn was found well within the prescribed limit, whereas Fe and Mn were found higher than the prescribed standards may be due to geogenic sources.

Water Quality Index (WQI): Water Quality Index (WQI) may be defined as the rating which reflects the composite influence of a number of water quality factors on the overall quality of water. Water quality is assessed on the basis of calculated water quality indices [12-14]. The water quality indices concept is based on the comparison of the water quality parameter with respective regulatory standards [15]. It reduces the large amount of water quality data in to a single numerical value. It is one of the most effective ways to communicate information on water quality trends to policy makers, to shape sound public policy and implement the water quality improvement programmes efficiently. The chief objective of this study is to link the quality of water in river Sutlej through WQI and compare the water quality with standards.
Using the water quality index, all the samples were categorized into the following four classes: Excellent (0 - 25); Good (26 - 50); moderately polluted (51 - 75); severely polluted (76 - 100).

Table 3. Permissible values of various pollutants for drinking water (CPCB and Bureau of Indian standard)

Sl. No.	*Parameter	CPCB	IS (10500)
1	pH	6.5 - 8.5	6.5 - 8.5
2	TDS		500
3	Total Hardness		200
4	DO	6.0	-
5	BOD	2.0	-
6	Chloride	250	250
7	Sulphate		200
8	Nitrate		45
9	Calcium		75

*All values are expressed in mg L^{-1}except pH

Weighting: The word weighting implies relative significance of each of the factor in the overall water quality and it depends on the permissible level in drinking water, as suggested by Central Pollution Control Board (CPCB) and Bureau of Indian Standards (BIS: 10500) . Factors which have higher permissible limits are less harmful and have low weightings.
Therefore, Wi = K/Sn
Where,
Wi - Unit weight of chemical factor, K - constant of proportionality and is given as

$$K = \frac{1}{1/Vs1 \ldots\ldots\ldots\ldots 1/VSn}$$

Sn - Standard value of i^{th} parameter
Rating scale: Each chemical factor has been assigned a water quality rating to calculate WQI.

$$Qi = 100\ [(Va-Vi)/\ (Vs-Vi)]$$

Where,
Va - Average of measured values in the water sample for three months at one place
Vs - Standard value of i^{th} parameter
Vi - Ideal value for pure water (0 for all parameters except pH and DO)

The above equation becomes:

$$Qi = 100 (Va/Vs)$$

For dissolved oxygen (DO): The ideal value = 14.6 mg L^{-1}; permissible value = 6 mg L^{-1}, QDO = 100 [(Va-14.6)/(6-14.6)].

For pH: The ideal value = 7.0; Max. Permissible value = 8.5, QpH = 100 [(Va- 7.0)/(8.5-7.0)]

$$\text{Water Quality Index (WQI)} = [\Sigma (QiWi)/\Sigma Wi]$$

$$\Sigma(QiWi) - Qi (pH) X Wi (pH) + Qi (DO) X Wi (DO) + \ldots\ldots + Qi (Ca) X Wi (Ca).$$

Where,

ΣWi - Total unit weight of all chemical factors.

Using the water quality index, all the samples were categorized into the following five classes:

Excellent (0 - 25), Good (26 - 50), moderately polluted (51 - 75), severely polluted (76 - 100).

Table 4: Physico-chemical parameters and WQI of River Sutlej (R1) upstream at Olinda (HP)

Water Quality Index (WQI) of River Sutlej (R1) upstream Olinda (HP)									
Parameters	**2012**	**2013**	**2014**	**2015**	**2016**	**Va**	**Wi**	**Qi**	**WiQi**
pH	7.7	8.1	7.81	7.7	7.8	7.82875	0.136	7.2532	7.2532
DO	9.2	8.5	8.9	8.9	8.9	8.874875	0.192	12.5023	12.5023
BOD	1	1	1	1	1	1	0.577	2	1.154
Chloride	4.05	3.8	5.0	2.4	3.8	3.81	0.005	1.524	0.00762
TDS	113	131	130	154	131	131.8	0.002	26.36	0.05272
Total Hardness	101	128	75.8	80.7	94	95.89	0.004	31.96	0.12784
Sulphate	37.3	28.05	42	19.43	25.2	30.396	0.006	15.198	0.0911
Nitrate	0.944	0.305	0.4	0.593	1.56	0.7538	0.058	1.675	0.09715
Calcium	41.8	61.5	20.9	47.96	25.4	39.512	0.015	52.682	0.79023

WQI 50.07 Good

Table 5: Physico-chemical parameters and WQI at River Sutlej (R2) downstream at Nangal (PB)

Parameters	**2012**	**2013**	**2014**	**2015**	**2016**	**Va**	**Wi**	**Qi**	**WiQi**
pH	7.7	7.8	7.6	7.9	7.7	7.7	0.136	46.67	6.35
DO	8.8	8.9	8.45	9.0	9.2	8.9	0.192	66.28	12.72
BOD	1	1	1	1	1	1.0	0.577	50	28.85
Chloride	4.73	10.3	5.35	4.7	3	5.6	0.005	2.24	0.0112
TDS	97.5	138.5	42.8	136.0	135	110.0	0.002	16.9504	0.03390
Total Hardness	107.27	84.2	133.4	129	90.3	108.834	0.004	30.7692	0.12307
Sulphate	41.23	25.87	45.6	18.4	23.6	30.94	0.006	11.8546	0.07112
Nitrate	1.2	0.334	0.358	0.349	0.393	0.5268	0.058	0.7428	0.04308
Calcium	44.07	73.25	31.7	47.5	27.9	44.884	0.015	40.5330	0.60799

WQI 51 Moderately polluted

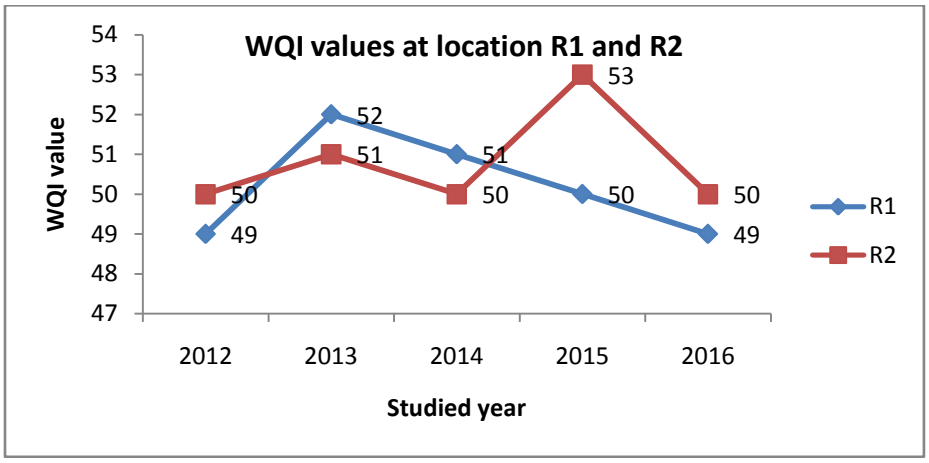

Figure 1: Yearly Variation in WQI of River Sutlej in HP and Punjab

The values of WQI at locations at R1 and R2 are 50.07 and 51.0 (Tables 4, 5). Stations R1 and R2 were falls in Good and moderately polluted water quality category respectively (Fig 1). The progressive increase in WQI from upstream to downstream may be due to mixing of treated and untreated wastewater. Although the water quality had getting improved at both location in comparison to past studied period. The higher values of WQI at R2 location is mainly due to the higher values calcium, chloride, nitrate, ammonical nitrogen and sulphate. Overall calculated WQI values suggests that quality of water got deteriorate after mixing of Golthai drain as well as the mixed kind of wastewater for urban area of nearby city.

APPLICATIONS

The results of this study are useful to understand the quality of river water. Water Quality Index is easy to calculate and can express water quality in one numerical value.

CONCLUSIONS

Though monitored parameters were within the prescribed limit but the presence of toxic metals even in low concentrations and high number of coliform recorded. Water quality of Sutlej River deteriorated at downstream due to mixing of Golthai drain as well as other mixed kind of untreated wastewater of urban origin which alter the water quality at downstream i. e. R2. An attention is required to be paid to stop the discharging of untreated wastewater from the industries located in Golthai industrial area of H.P. as well as proper sewage treatment plant/soak pits/in situ bioremediation system can be also deployed to treat the urban wastewater/ sewage emanating from the catchment area of the river Sutlej to avoid the organic pollution load and restore the water quality at desired level and support the sustainability of the aquatic ecosystem.

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