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Advances in Bioresearch

**ORIGINAL ARTICLE**

# Ecological Study of Sirsa Tributary of River Sutlej around Ghanauli Area Of Punjab, India

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**ABSTRACT**
*The freshwater resources are becoming dumping sites and act as repositories for disposal of domestic wastes, agricultural pollutants and industrial effluents. Such types of pollutant are deteriorating the water quality of recipient riverine system and act as serious threat to aquatic ecosystem in the long run.The present study deals with water quality in relation to organic pollution load of Sirsa tributary of river Sutlej which lies adjacent to BaddiBarotiwala Nalagarh Industrial area and act as an ultimate gutter for various types of industrial pollutants directly or indirectly. High values of dissolved oxygen (8.2-9.5 mg/L) and pH (8.4-8.7) at $S_1$ with rapid changes in turbidity were reported but all other parameters were well within permissible limits of WHO and CPCB. Further water quality also improving downstream after confluence at $S_3$ towards Ropar wetland. But, physico-chemical analysis of water samples showed higher values of TDS, BOD, COD, turbidity, nitrates, sulphates and phosphates and low values of pH and DO at site $S_2$ near Ghanauli Bridge and dominant with Spirogyra sp., Closterium sp., Oscillatoria sp., Fragilaria sp.,Brachionus sp., Forcipomypia sp.,Tubifex sp., Diaptomus sp., Cyclops sp., nauplii, Bosmina sp., Moina sp., Daphnia sp., and larvae of Culex sp., Chironomous sp. and Tanypus sp. This site is polysaprobic with more organic pollution load and water is not potable along the entire stretch of Sirsa tributary.*

***Key words:*** *Sutlej*, *Tributary, Wastewater*, *Pollution load, Bio-indicators*, *Potable and Restoration.*

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## INTRODUCTION

It is an intriguing problem during 21th century to know the impact of pollutants on river's health as the rivers itself has no beginning or end, in its beginning it is not yet the river, in its end it is no longer the river what we call the head waters is only a selection from among the innumerable sources which flows together to compose it by Eliot. The significant role played by rivers in the developmental programmes of a country hardly needs any elaboration. India is also facing serious problem of natural resource scarcity as seventy percent of Indian water resources are declared to be polluted. Water pollution is considered to be one of the major threat to environmental harmony at global level. Most of the freshwaters all over the world are getting polluted due to domestic wastes, industrial effluents and agricultural run-off. The ruthless discharge of industrial effluents into freshwater resources disrupts ecological balance and deteriorates water quality in recipient ecosystem. The health of rivers and their biological diversity are directly related to health of almost every components of the ecosystem. The alteration in any physico-chemical parameter also affects flora, fauna, its number and diversity. It is pertinent to state that aquatic species biodiversity perished due to pollution load and power of ecological succession mayoperate to replace more sensitive members by more tolerant one in due course of time. Hence, it has also become important to study immediate effects of industrial pollutants on the water quality of Sirsa tributary before its confluence with river Sutlej in the laps of sub- shivalik foot hills.

## STUDY AREA

River Sutlej is the most important tributary of Indus river basin in Northern region. It enters Ropar district of Punjab at a junction of Bhakra Nangal dam and flows sluggishly along the sub-shivalik foot hills towards Ropar wetland. Here, it receives two major tributaries namely Soan and Sirsa. The former is seasonal one and the latter is perennial. Sirsa tributary originates from the foothill of Kasauli near Kalka in Haryana having total length 54.00 km. After travelling 20.00 km in Haryana, it enters Himachal Pradesh near Baddi town and after covering 28.00 km stretch in Himachal Pradesh and it enters Punjab near Ghanaulibridge and thereafter flowing6.00 km in Punjab, it meets with Sutlej river near Chakdehra and finally, it enters Ropar district near village Banda. The study area includes three observation sites ($S_1$, $S_2$, and $S_3$) as demarcated in (Fig.1). Brief description of the collection sites includes; $S_1$: River Sutlej before confluence with Sirsa tributary 4 Km D/S Bharatgarh; $S_2$: It is situated on D/S Sirsa tributary near Ghanauli Bridge after receiving wastewater from Baddi Industrial hub; $S_3$: River Sutlej after confluence with Sirsa tributary towards Ropar Wetland.

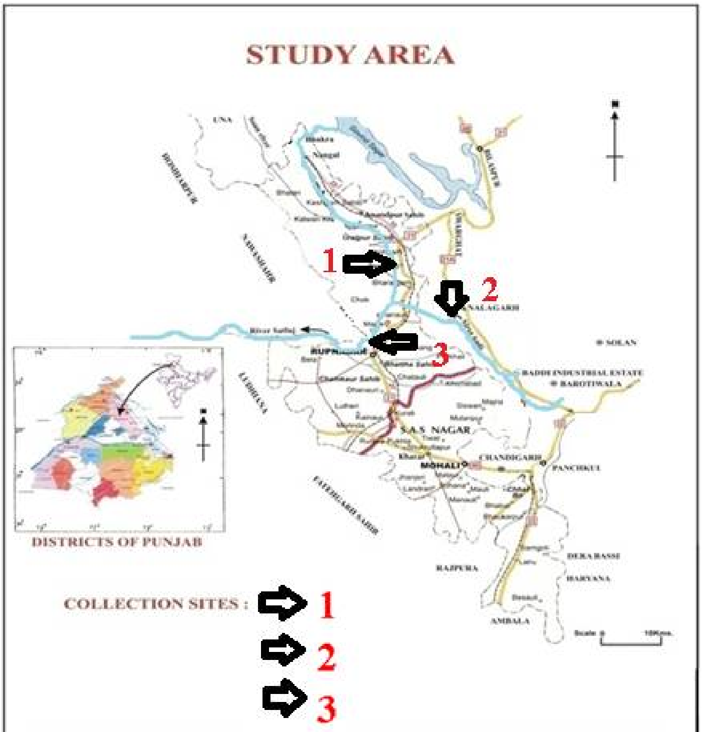

Fig. 1: BORDERLINE MAP SHOWING COLLECTION SITES

## MATERIAL AND METHODS

The water samples were collected for a duration of one year from river Sutlej and Sirsa tributary at three sites ($S_1$, $S_2$ and $S_3$)selected. Analysis of physico-chemical parameters were done as per standard protocols provided in [1] and [35]. The water temperature, pH, fixation of dissolved oxygen was determined at sampling sites and water was filtered for total dissolved solids, sulphates, nitrates and phosphates. Unfiltered water samples were used for estimation of BOD and COD.For the collection of biota a ring type terricot net (24meshes/$mm^2$) fitted with a wide mouthed plastic bottle was used. The samples collected was preserved in 5% solution of formaldehyde on the spot. The counting of plankton was done with 'Sedgwick-Rafter counting cell' as per the procedure laid downby [39]. The books consulted for the identification of plankton and insect larvae were; [14,27,37]

## RESULTS AND DISCUSSION

Physico-chemical fluctuations have been reported at selected sites as shown in Table 1 and may be due to change in lotic and lentic habitat of Sirsa river basin at this transition zone that resulted in variations ofhydrology. It was found that the discharge of industrial pollutants into Sirsa tributary, rapidly altering water quality in this foot hill region. High values of dissolved oxygen (8.2-9.5 mg/L) and pH (8.4-8.7) at $S_1$ with rapid changes in turbidity were reported but all other parameters were well within permissible limits. pH of water provides data regarding various geochemical equilibrium operating in waterbody and same was also reported by [20]that pH (6.7-8.4) is said tobe safe for aquatic flora and fauna to maintain productivity but pH below 4.0 and above 9.6 found to be hazardous. Very low value of pH (1.2-1.7) was observed at $S_2$ near Ghanauli bridge throughout the study period. It may be due to the presence of numerous insoluble blackish ash particles produced by industrial units of Baddi and comparatively high value of pH (4.2-6.7) has been recorded at $S_3$ due to mixing of crystal clear water from u/s site $S_1$.

Table 1: Physico-chemical data collected (August.2018-July 2019)

| Parameters | $S_1$:U/S River Sutlej | $S_2$:Effluent Nallah of Sirsa tributary | $S_3$:D/S River Sutlej after Confluence | WHO: Desirable Limits | CPCB: Desirable Limits |
|---|---|---|---|---|---|
| Temperature (°C) | 11.3-26.4 | 15.4-27.5 | 12.2-26.5 | 40 | 40 |
| P$^H$ | 8.4-8.7 | 1.2-1.7 | 4.2-6.7 | 7-8.5 | 6.5-8.5 |
| DO (mg $L^{-1}$) | 8.2-9.5 | 1.5-3.2 | 4.2-6.9 | 4-6 | 6 |
| Turbidity (NTU) | 4.5-11.2 | 74.7-163.3 | 27.5-42.6 | 5 | 5 |
| TDS (mg $L^{-1}$) | 155-235.2 | 1625-1712 | 255-430 | 300-600 | 500 |
| BOD (mg $L^{-1}$) | 1.5-2.0 | 35.2-86.3 | 12.5-26 | 2 | 2 |
| COD (mg $L^{-1}$) | 5.5-8.5 | 72-123.4 | 36-48.2 | 20 | 20 |
| Nitrates (mg $L^{-1}$) | 18.2-30.4 | 78.5-127 | 32.4-55.6 | 45 | 45 |
| Phosphates (mg $L^{-1}$) | ---- | 1.4-3.26 | 0.5-1.4 | 0.1 | ---- |
| Sulphates (mg $L^{-1}$) | 3.4-4.2 | 18.2-38.2 | 5.6-8.2 | 200 | 200 |

This is in accordance with other polluted Indian rivers having discharge of industrial effluents having alkaline or acidic pH [10,34]. The effect of pollutants on waterbody was depend upon the nature of waste materials dumped into itand level of oxygen balance in the ecosystem. The amount of oxygen decreases with increase in temperature and with the oxidation of organic matter [38]. As the concentration of dissolved oxygen decreased it imposes thrust to deteriorate the water quality of river system.The dissolved oxygen was estimated more(8.2-9.5mg/L)at $S_1$due to constant flushing of water waves. The amount of DO near to Ghanauli bridge at $S_2$was low(1.5-3.2mg/L) may be due to high content of organic matter, thereby more growth of less oxygen requiring microorganisms. The value of DO range was (4.2-6.9 mg $L^{-1}$) at $S_3$. This present result may be related with studies of[3]that dissolved oxygen may be declined due togrowth of phytoplankton population and the growth of algae and aquatic weeds was favored due to presence of excessive amount of nutrients and also temperature of water body [38]. Water temperature recorded (°C) was (11.3-26.4) at $S_1$, (15.4-27.5) at $S_2$ and (12.2-26.5) at $S_3$. The role of temperature in water quality assessment showeda direct correlation with air temperature, nitrates, phosphates, BOD and an inverse correlation with dissolved oxygen and pH. This is in concurrence with the findings of [7,11,13,16,25]. The penetration of light in water was (74.7-163.3mg/L) at $S_2$, (27.5-42.6mg/L) at $S_3$ while at $S_1$ it was (4.5-11.2mg/L). Site $S_2$ was found to be more turbid due to presence of cattle grazers and it was also observed that turbidity was higher in the month of July and August due to heavy floods in river Sutlej's major tributaries such as Sirsa and Soan with high turbulence that stirred up the non-living matter at bottom zone of the river's basin. Similar findings of [5] at river Vamuraand at river Ganga by [18] were reported as well as [23] at river Panchnanda but in summer season. The chemical density act as a fitness factor in terms of dissolvedions or salts in an aquatic ecosystem [15]. The waterbody with high TDS resulted in inferior palatability that may induce undesirable metabolic changes in consumers. Very high values of TDS were reported at $S_2$ (1625-1712 mg/L) may be due to release of wastewater carrying residuals of pharmaceutical industry but TDS do not exceed permissible limits at $S_3$ (255-430 mg/L). It was in conformity with findings of [36] at river Kalpi to work out its pollution status. It may be noted that high concentration of TDS especially at $S_2$ site of Sirsa tributary near Ghanauli was also due to the colour of water found to be grayish black and muddy pale brownish. The amount of oxygen required by micro-organisms to degrade organic matter or to the clean detritus in a waterbody by aerobic oxidation is an essential chemical parameter to know about organic pollution load [4]. It was observed that Biochemical Oxygen Demand at $S_2$ was (35.2-86.3 mg/L) near Ghanauli bridge maybe due to more presence of rotifers, protozoan, dipterans larvae, diatoms and Palmer's algal blooms. The concentration of Biochemical oxygen demand at$S_3$was (12.5-26 mg/L) after confluence with $S_2$. BOD value was more at $S_2$ as it receives partially treated or untreated pollutants from Baddi industrial estate via Sirsa tributary with maximum organic pollutants near Ghanauli bridge. Present results of BOD can be correlated with others workers; High values of BOD was reported by [32] at Varansi of river Ganga and also similar work was reported by[22]. Chemical Oxygen Demand is a powerful tool to assess industrial pollutants in which inorganic substances were oxidized by using oxygen content present in given water sample. This was done by Shrivastava[30] at Khandesh region of Tapti riverwith high value of COD (74 to 154 $mgL^{-1}$) and at Sultanpur area of Gomati river by [31]. The COD content of river Cauvery also showed, the release of organic pollutants [28] and at river Kalpi, more COD concentration (425 $mgL^{-1}$) was reported by [36] may be due to high pollution load. In present studies, it ranges (72-123.4 mg/L) at $S_2$ and at $S_3$ (36-48.2 mg/L). COD was more before monsoon as there was low water level, sluggish water inflow, rapid discharge of industrial pollutants from Baddi and Barotiwala industrial hub into Sirsa river basin, high temperature, high dissolved solids or salts, relatively stagnant water conditions prevailing due to lentic terrain were also in conformity with the findings of [12] on a river stream at Solan district and it was also observed that higher chemical oxygen demand is due to pouringof industrial effluents and municipal waste. Nitrates in water serve as an essential micronutrient for autotrophic production. In rivers and streams, blue green algae and microorganisms fix the nitrogen.The process of nitrification is oxidation of nitrogenous organic matter of waterbody into nitrates in the presence of micro-organisms. Higher concentration of nitrates act as macro-nutrients and will lead to eutrophic conditions, thereby also polluting waterbody.The growth of aquatic weeds and algal flora will increase total suspended solids and also reduce oxygen supply, pH, alkalinity and less penetration of light resulted in decrease rate of photosynthesis in accordance with [19,21].It is noted by [29]that nitrates beyond desirable limits in drinking water will cause certain serious disorders and use of fertilizers, industrial effluents, decayed vegetables, domestic wastewaters, sewage or sludge disposal, atmospheric reactions like precipitation and dumping sites were considered to be potential sources of nitrate pollution. In present studies on nitrates showed high values of it at site $S_2$ (78.5-127mg/L) near Ghanauli bridge due to release of nitrogenous substances by Baddi industry, may also depicting its relevance with eutrophy prevailing there but at $S_3$ it decreases to permissible range (32.4-55.6 mg/L) in accordance with works of [24] at river Narmada.Phosphate is a key nutrient in biological productivity as it is required for proper growth of aquatic plants andalso resulted in eutrophication in higher concentration. Major sources of phosphates are domestic sewage, industrial wastes, agricultural chemicals and detergents. It also comes indirectly from organisms or directly from weathering of phosphate rocks and surface run-off from catchment area. The value of phosphates in mg $L^{-1}$ was (1.4-3.26) at $S_2$ and (0.5-1.4) at $S_3$. A marked depletion in the concentration of phosphates has been noticed at the time of plankton abundance as there was definite relationship reported between plankton and phosphates similar with the results of [29]. It may be due to agricultural run-off and industrial effluents released into Sirsa tributary basin. The decomposition of organic detritus of phytoplankton and aquatic macrophytesas well as any protein residual material containing Sulphur will lead to produce sulphates in waterbody with biochemical reactions directly or indirectly reported by [40].The value of sulphatesat $S_2$ (18.4-38.2 mg/L) and at $S_3$ (5.6-8.2 mg/L) found to be within permissible limits of WHO and CPCB. The result was similar with observations of [8] at Pune of river Muthain relation to phytoplankton and eutrophic conditions and [9] at Ludhiana of river Beas also depicted that phytoplankton population was directly proportional to concentration of sulphates, nitrates, alkalinity, phosphates and bicarbonate. Hence, the hydrobiology of river tributary system is unique and dynamic as it affects its physico-chemical characteristics firstly, then systematically destroying the diversity, thereby disturbing delicate ecological food chain and ultimately dangerous to public health.

 

## BIOINDICATORS AND POLLUTION STATUS

It was based on BOD5 and Palmer's Algal index [26] that saprobity index was applied to determine organic pollution load of study area and species richness found to be in order; S2> S1> S3 whereas species diversity was S1> S2> S3. The abundance of species at S2 may be due to presence of more nutrients produced by geochemical recycling of salts released in the process of self-purification of waterbody near Ghanauli bridge. It was also resulted in disappearance of sensitive forms and survival of tolerant forms at S2 representing some members of Euglenophyceae and Cyanophyceae in phytoplankton and colorless rotifers or flagellates in zooplankton in concurrence with results of [6,17]. Water at S3 was categorized as oligosaprobic after confluence, at S1 as mesosaprobic with some freshwater indicators and at S3 near Ghanauli bridge it was polysaprobic as per classification given by [33]. The degree of organic load is more at S2 in major tributary (Sirsa river) of river Sutlej as compared to main riverine ecosystem.

## CONCLUSION

In the light of above study, it was imperative to work on river tributaries so that pollution status of Indian riverine system as a whole could be determine properly in near future. It is an attempt in this direction to assess a little part of water quality of world renowned Indus river system in the foot hills of Himalayan region.Baddi city is bestowed with Asia's biggest Pharma hub with 2120 units of leading pharmaceutical, FMCG and textile companies. Unfortunately, Sirsatributary of river Sutlej act as an ultimate dumping sitefor disposal of all untreated or partially treated effluents at $S_2$ near Ghanauli bridge a borderline area of Punjab and Himachal Pradesh. This site in present study was found to be polysaprobic with more organic pollution load, so water is not potable along the entire stretch of Sirsa tributary and it may also be unfit for irrigation [2]. Hence, it has become necessary to estimate the ultimate impacts of pollutants on water quality in relation to ecology and biodiversity of rivers and remain continued with such works to predict future changes in water quality so that proper restoration programmes can be undertaken to improve the water quality for sustainable development of a country.

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## INTRODUCTION

It is an intriguing problem during 21$^{th}$ century to know the impact of pollutants on river's health as the rivers itself has no beginning or end, in its beginning it is not yet the river, in its end it is no longer the river what we call the head waters is only a selection from among the innumerable sources which flows together to compose it by Eliot. The significant role played by rivers in the developmental programmes of a country hardly needs any elaboration. India is also facing serious problem of natural resource scarcity as seventy percent of Indian water resources are declared to be polluted. Water pollution is considered to be one of the major threat to environmental harmony at global level. Most of the freshwaters all over the world are getting polluted due to domestic wastes, industrial effluents and agricultural run-off. The ruthless discharge of industrial effluents into freshwater resources disrupts ecological balance and deteriorates water quality in recipient ecosystem. The health of rivers and their biological diversity are directly related to health of almost every components of the ecosystem. The alteration in any physico-chemical parameter also affects flora, fauna, its number and diversity. It is pertinent to state that aquatic species biodiversity perished due to pollution load and power of ecological succession mayoperate to replace more sensitive members by more tolerant one in due course of time. Hence, it has also become important to study immediate effects of industrial pollutants on the water quality of Sirsa tributary before its confluence with river Sutlej in the laps of sub- shivalik foot hills.

**STUDY AREA**

River Sutlej is the most important tributary of Indus river basin in Northern region. It enters Ropar district of Punjab at a junction of Bhakra Nangal dam and flows sluggishly along the sub-shivalik foot hills towards Ropar wetland. Here, it receives two major tributaries namely Soan and Sirsa. The former is seasonal one and the latter is perennial. Sirsa tributary originates from the foothill of Kasauli near Kalka in Haryana having total length 54.00 km. After travelling 20.00 km in Haryana, it enters Himachal Pradesh near Baddi town and after covering 28.00 km stretch in Himachal Pradesh and it enters Punjab near Ghanaulibridge and thereafter flowing6.00 km in Punjab, it meets with Sutlej river near Chakdehra and finally, it enters Ropar district near village Banda. The study area includes three observation sites ($S_1$, $S_2$, and $S_3$) as demarcated in (Fig.1). Brief description of the collection sites includes; $S_1$: River Sutlej before confluence with Sirsa tributary 4 Km D/S Bharatgarh; $S_2$: It is situated on D/S Sirsa tributary near Ghanauli Bridge after receiving wastewater from Baddi Industrial hub; $S_3$: River Sutlej after confluence with Sirsa tributary towards Ropar Wetland.

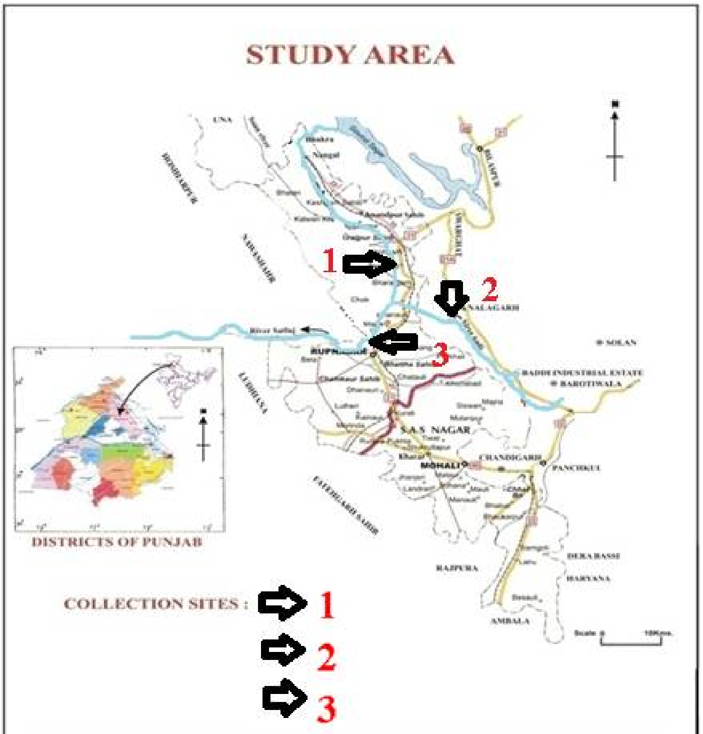


Fig. 1: BORDERLINE MAP SHOWING COLLECTION SITES

**MATERIAL AND METHODS**

The water samples were collected for a duration of one year from river Sutlej and Sirsa tributary at three sites ($S_1$, $S_2$ and $S_3$)selected. Analysis of physico-chemical parameters were done as per standard protocols provided in [1] and [35]. The water temperature, pH, fixation of dissolved oxygen was determined at sampling sites and water was filtered for total dissolved solids, sulphates, nitrates and phosphates. Unfiltered water samples were used for estimation of BOD and COD.For the collection of biota a ring type terricot net (24meshes/$mm^2$) fitted with a wide mouthed plastic bottle was used. The samples collected was preserved in 5% solution of formaldehyde on the spot. The counting of plankton was done with 'Sedgwick-Rafter counting cell' as per the procedure laid downby [39]. The books consulted for the identification of plankton and insect larvae were; [14,27,37]

## RESULTS AND DISCUSSION

Physico-chemical fluctuations have been reported at selected sites as shown in Table 1 and may be due to change in lotic and lentic habitat of Sirsa river basin at this transition zone that resulted in variations ofhydrology. It was found that the discharge of industrial pollutants into Sirsa tributary, rapidly altering water quality in this foot hill region. High values of dissolved oxygen (8.2-9.5 mg/L) and pH (8.4-8.7) at $S_1$ with rapid changes in turbidity were reported but all other parameters were well within permissible limits. pH of water provides data regarding various geochemical equilibrium operating in waterbody and same was also reported by [20]that pH (6.7-8.4) is said tobe safe for aquatic flora and fauna to maintain productivity but pH below 4.0 and above 9.6 found to be hazardous. Very low value of pH (1.2-1.7) was observed at $S_2$ near Ghanauli bridge throughout the study period. It may be due to the presence of numerous insoluble blackish ash particles produced by industrial units of Baddi and comparatively high value of pH (4.2-6.7) has been recorded at $S_3$ due to mixing of crystal clear water from u/s site $S_1$.

Table 1: Physico-chemical data collected (August.2018-July 2019)

| Parameters | $S_1$:U/S River Sutlej | $S_2$:Effluent Nallah of Sirsa tributary | $S_3$:D/S River Sutlej after Confluence | WHO: Desirable Limits | CPCB: Desirable Limits |
|---|---|---|---|---|---|
| Temperature (°C) | 11.3-26.4 | 15.4-27.5 | 12.2-26.5 | 40 | 40 |
| $P^H$ | 8.4-8.7 | 1.2-1.7 | 4.2-6.7 | 7-8.5 | 6.5-8.5 |
| DO (mg $L^{-1}$) | 8.2-9.5 | 1.5-3.2 | 4.2-6.9 | 4-6 | 6 |
| Turbidity (NTU) | 4.5-11.2 | 74.7-163.3 | 27.5-42.6 | 5 | 5 |
| TDS (mg $L^{-1}$) | 155-235.2 | 1625-1712 | 255-430 | 300-600 | 500 |
| BOD (mg $L^{-1}$) | 1.5-2.0 | 35.2-86.3 | 12.5-26 | 2 | 2 |
| COD (mg $L^{-1}$) | 5.5-8.5 | 72-123.4 | 36-48.2 | 20 | 20 |
| Nitrates (mg $L^{-1}$) | 18.2-30.4 | 78.5-127 | 32.4-55.6 | 45 | 45 |
| Phosphates (mg $L^{-1}$) | ---- | 1.4-3.26 | 0.5-1.4 | 0.1 | ---- |
| Sulphates (mg $L^{-1}$) | 3.4-4.2 | 18.2-38.2 | 5.6-8.2 | 200 | 200 |

This is in accordance with other polluted Indian rivers having discharge of industrial effluents having alkaline or acidic pH [10,34]. The effect of pollutants on waterbody was depend upon the nature of waste materials dumped into itand level of oxygen balance in the ecosystem. The amount of oxygen decreases with increase in temperature and with the oxidation of organic matter [38]. As the concentration of dissolved oxygen decreased it imposes thrust to deteriorate the water quality of river system.The dissolved oxygen was estimated more(8.2-9.5mg/L)at $S_1$due to constant flushing of water waves. The amount of DO near to Ghanauli bridge at $S_2$was low(1.5-3.2mg/L) may be due to high content of organic matter, thereby more growth of less oxygen requiring microorganisms. The value of DO range was (4.2-6.9 mg $L^{-1}$) at $S_3$. This present result may be related with studies of[3]that dissolved oxygen may be declined due togrowth of phytoplankton population and the growth of algae and aquatic weeds was favored due to presence of excessive amount of nutrients and also temperature of water body [38]. Water temperature recorded (°C) was (11.3-26.4) at $S_1$, (15.4-27.5) at $S_2$ and (12.2-26.5) at $S_3$. The role of temperature in water quality assessment showeda direct correlation with air temperature, nitrates, phosphates, BOD and an inverse correlation with dissolved oxygen and pH. This is in concurrence with the findings of [7,11,13,16,25]. The penetration of light in water was (74.7-163.3mg/L) at $S_2$, (27.5-42.6mg/L) at $S_3$ while at $S_1$ it was (4.5-11.2mg/L). Site $S_2$ was found to be more turbid due to presence of cattle grazers and it was also observed that turbidity was higher in the month of July and August due to heavy floods in river Sutlej's major tributaries such as Sirsa and Soan with high turbulence that stirred up the non-living matter at bottom zone of the river's basin. Similar findings of [5] at river Vamuraand at river Ganga by [18] were reported as well as [23] at river Panchnanda but in summer season. The chemical density act as a fitness factor in terms of dissolvedions or salts in an aquatic ecosystem [15]. The waterbody with high TDS resulted in inferior palatability that may induce undesirable metabolic changes in consumers. Very high values of TDS were reported at $S_2$ (1625-1712 mg/L) may be due to release of wastewater carrying residuals of pharmaceutical industry but TDS do not exceed permissible limits at $S_3$ (255-430 mg/L). It was in conformity with findings of [36] at river Kalpi to work out its pollution status. It may be noted that high concentration of TDS especially at $S_2$ site of Sirsa tributary near Ghanauli was also due to the colour of water found to be grayish black and muddy pale brownish. The amount of oxygen required by micro-organisms to degrade organic matter or to the clean detritus in a waterbody by aerobic oxidation is an essential chemical parameter to know about organic pollution load [4]. It was observed that Biochemical Oxygen Demand at $S_2$ was (35.2-86.3 mg/L) near Ghanauli bridge maybe due to more presence of rotifers, protozoan, dipterans larvae, diatoms and Palmer's algal blooms. The concentration of Biochemical oxygen demand at$S_3$was (12.5-26 mg/L) after confluence with $S_2$. BOD value was more at $S_2$ as it receives partially treated or untreated pollutants from Baddi industrial estate via Sirsa tributary with maximum organic pollutants near Ghanauli bridge. Present results of BOD can be correlated with others workers; High values of BOD was reported by [32] at Varansi of river Ganga and also similar work was reported by[22]. Chemical Oxygen Demand is a powerful tool to assess industrial pollutants in which inorganic substances were oxidized by using oxygen content present in given water sample. This was done by Shrivastava[30] at Khandesh region of Tapti riverwith high value of COD (74 to 154 $mgL^{-1}$) and at Sultanpur area of Gomati river by [31]. The COD content of river Cauvery also showed, the release of organic pollutants [28] and at river Kalpi, more COD concentration (425 $mgL^{-1}$) was reported by [36] may be due to high pollution load. In present studies, it ranges (72-123.4 mg/L) at $S_2$ and at $S_3$ (36-48.2 mg/L). COD was more before monsoon as there was low water level, sluggish water inflow, rapid discharge of industrial pollutants from Baddi and Barotiwala industrial hub into Sirsa river basin, high temperature, high dissolved solids or salts, relatively stagnant water conditions prevailing due to lentic terrain were also in conformity with the findings of [12] on a river stream at Solan district and it was also observed that higher chemical oxygen demand is due to pouringof industrial effluents and municipal waste. Nitrates in water serve as an essential micronutrient for autotrophic production. In rivers and streams, blue green algae and microorganisms fix the nitrogen.The process of nitrification is oxidation of nitrogenous organic matter of waterbody into nitrates in the presence of micro-organisms. Higher concentration of nitrates act as macro-nutrients and will lead to eutrophic conditions, thereby also polluting waterbody.The growth of aquatic weeds and algal flora will increase total suspended solids and also reduce oxygen supply, pH, alkalinity and less penetration of light resulted in decrease rate of photosynthesis in accordance with [19,21].It is noted by [29]that nitrates beyond desirable limits in drinking water will cause certain serious disorders and use of fertilizers, industrial effluents, decayed vegetables, domestic wastewaters, sewage or sludge disposal, atmospheric reactions like precipitation and dumping sites were considered to be potential sources of nitrate pollution. In present studies on nitrates showed high values of it at site $S_2$ (78.5-127mg/L) near Ghanauli bridge due to release of nitrogenous substances by Baddi industry, may also depicting its relevance with eutrophy prevailing there but at $S_3$ it decreases to permissible range (32.4-55.6 mg/L) in accordance with works of [24] at river Narmada.Phosphate is a key nutrient in biological productivity as it is required for proper growth of aquatic plants andalso resulted in eutrophication in higher concentration. Major sources of phosphates are domestic sewage, industrial wastes, agricultural chemicals and detergents. It also comes indirectly from organisms or directly from weathering of phosphate rocks and surface run-off from catchment area. The value of phosphates in $mg\ L^{-1}$ was (1.4-3.26) at $S_2$ and (0.5-1.4) at $S_3$. A marked depletion in the concentration of phosphates has been noticed at the time of plankton abundance as there was definite relationship reported between plankton and phosphates similar with the results of [29]. It may be due to agricultural run-off and industrial effluents released into Sirsa tributary basin. The decomposition of organic detritus of phytoplankton and aquatic macrophytesas well as any protein residual material containing Sulphur will lead to produce sulphates in waterbody with biochemical reactions directly or indirectly reported by [40].The value of sulphatesat $S_2$ (18.4-38.2 mg/L) and at $S_3$ (5.6-8.2 mg/L) found to be within permissible limits of WHO and CPCB. The result was similar with observations of [8] at Pune of river Muthain relation to phytoplankton and eutrophic conditions and [9] at Ludhiana of river Beas also depicted that phytoplankton population was directly proportional to concentration of sulphates, nitrates, alkalinity, phosphates and bicarbonate. Hence, the hydrobiology of river tributary system is unique and dynamic as it affects its physico-chemical characteristics firstly, then systematically destroying the diversity, thereby disturbing delicate ecological food chain and ultimately dangerous to public health.

## BIOINDICATORS AND POLLUTION STATUS

It was based on BOD5 and Palmer's Algal index [26] that saprobity index was applied to determine organic pollution load of study area and species richness found to be in order; S2> S1> S3 whereas species diversity was S1> S2> S3. The abundance of species at S2 may be due to presence of more nutrients produced by geochemical recycling of salts released in the process of self-purification of waterbody near Ghanauli bridge. It was also resulted in disappearance of sensitive forms and survival of tolerant forms at S2 representing some members of Euglenophyceae and Cyanophyceae in phytoplankton and colorless rotifers or flagellates in zooplankton in concurrence with results of [6,17]. Water at S3 was categorized as oligosaprobic after confluence, at S1 as mesosaprobic with some freshwater indicators and at S3 near Ghanauli bridge it was polysaprobic as per classification given by [33]. The degree of organic load is more at S2 in major tributary (Sirsa river) of river Sutlej as compared to main riverine ecosystem.

## CONCLUSION

In the light of above study, it was imperative to work on river tributaries so that pollution status of Indian riverine system as a whole could be determine properly in near future. It is an attempt in this direction to assess a little part of water quality of world renowned Indus river system in the foot hills of Himalayan region.Baddi city is bestowed with Asia's biggest Pharma hub with 2120 units of leading pharmaceutical, FMCG and textile companies. Unfortunately, Sirsatributary of river Sutlej act as an ultimate dumping sitefor disposal of all untreated or partially treated effluents at $S_2$ near Ghanauli bridge a borderline area of Punjab and Himachal Pradesh. This site in present study was found to be polysaprobic with more organic pollution load, so water is not potable along the entire stretch of Sirsa tributary and it may also be unfit for irrigation [2]. Hence, it has become necessary to estimate the ultimate impacts of pollutants on water quality in relation to ecology and biodiversity of rivers and remain continued with such works to predict future changes in water quality so that proper restoration programmes can be undertaken to improve the water quality for sustainable development of a country.


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