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Water Quality of Harike Wetland (Punjab) and its Catchment Area

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Abstract
Wetlands are widely known as bio-geographical supermarkets. These fragile ecosystems support a wide range of fauna and flora and provide goods and services to society. At present, these ecosystems are diminishing and deteriorating due to various land use activities. To examine the character of wetland ecosystems, the present study deals with the Harike wetland of Punjab and its catchment area. In the present study, all the sites are found to be in the permissible limit, except for turbidity. It recorded beyond the permissible limit at all the sites during pre-monsoon season. Site 3 and 4 are affected by EC and TDS as these are situated near the settlements. These settlements are the main source of various point and nonpoint pollution sources. Site 3 is more affected among all sites. It is located in an urban area, which is the main source of industrial effluents, municipal waste, and agricultural runoff. The first four sites are more affected by pollution, are situated on the Sutlej river. The pre-monsoon data show that the Sutlej river and Harike wetland are more polluted than the Beas river. Major industrial towns are located on river Sutlej river discharges their unpredictable pollutants in Sutlej river contributing significantly to the pollution of the Harike wetland. Site 3 is the worst-affected among all the sites, located at Phillaur. Pre-monsoonal sites are more affected than post-monsoonal sites. Rainfall plays an important role in dilution. The water of post-monsoon season is much clearer than compared to pre-monsoon season.

Keywords: Wetland, Water quality, Catchment area, Pre-monsoon season, Post-monsoon season, Harike wetland.

Introduction
Wetlands are defined as "lands that transition between terrestrial and aquatic ecosystems and are characterised by shallow water over the water table." Because of the long food chain and abundant bio-diversity they support, wetlands are frequently referred to be "ecological supermarkets." These are crucial landscape elements that have a high biological productivity, enormous resource potential, and are regarded as food sources. (Mabwoga S.K., 2010). In India, wetlands cover 58.2 million hectares, of which 40.9 million hectares are used for rice agriculture, and constitute one of the most essential components of the ecosystem. (A.F. Pramod et al, 2011). Any region's local economy is linked to the wetlands' ecological well-being. Dependence on the wetlands for existence increases as the population grows (Wazniak E. Catherine et al, 2007).

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Water: The lifeline

More than 70 per cent of the human body is consists of water. Nobel laureate A. Szent-Gyorgy called water "The matrix of life (Sarkar & Bhattacharya, 2010). Our day-to-day actions are accomplished with the help of water. It is crucial for the survival of all forms of life. However, most of the water on the Earth's surface is saline. Only three per cent of water is found in fresh form maximum portion of which is found in glaciers and ice caps.

Rivers, wetlands, and lakes are the key sources of water for drinking and irrigation purposes in India. These water resources have been contaminated with harmful chemicals for the past few decades. Development activities are a big threat to aquatic ecosystems and humans alike (Kaur J. et al, 2015).

The state of Punjab (Fig. 1) is drained mainly by the rivers of Sutlej, Beas, and Ravi. These rivers provide water for drinking, irrigational, and industrial purposes in addition to acting as a source of riverine water for wetlands. Rivers play a vital role, especially in the economy of south-western Punjab. Nowadays, the rivers of Punjab have been polluted due to industrialization, urbanization, and development activities. Consequently, rivers and wetlands are also facing the problems of pollution.

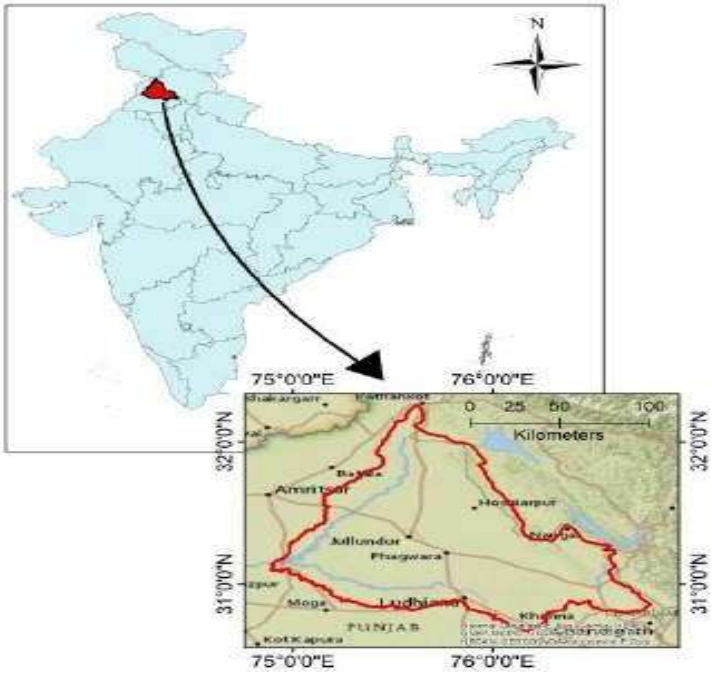

Fig. 1, Map of India

Location Map of Study Area

Harike Wetland

Harike wetland is a man-made water body, constructed on the confluence of the Sutlej and Beas rivers to provide drinking and irrigation water to south-west Punjab and parts of Rajasthan. It supports the congregation of many resident and migratory waterfowl as it has high productivity (Sonal D. et al., 2010).

Harike Lake suffers from several problems, such as encroachment, siltation, and weed infestation, particularly of water hyacinth, soil erosion, and overgrazing in the catchments (Patil et al., 2011). Furthermore, poaching is the foremost threat to this wetland. Hunters kill the birds once dark using powerful search lights, which blind them. They also use short guns and poisoned bird food with foratox, a common pesticide (Gupta R. et al, 2016). Harike Lake is more degraded by the Sutlej River receives industrial effluents from Ludhiana, Phillaur, and Ropar towns. As numerous studies have shown that the polluted water is responsible for a rise in various diseases like cancer cases in the region (Kumar et al). Fig.2 given below, shows the various causes of land degradation.

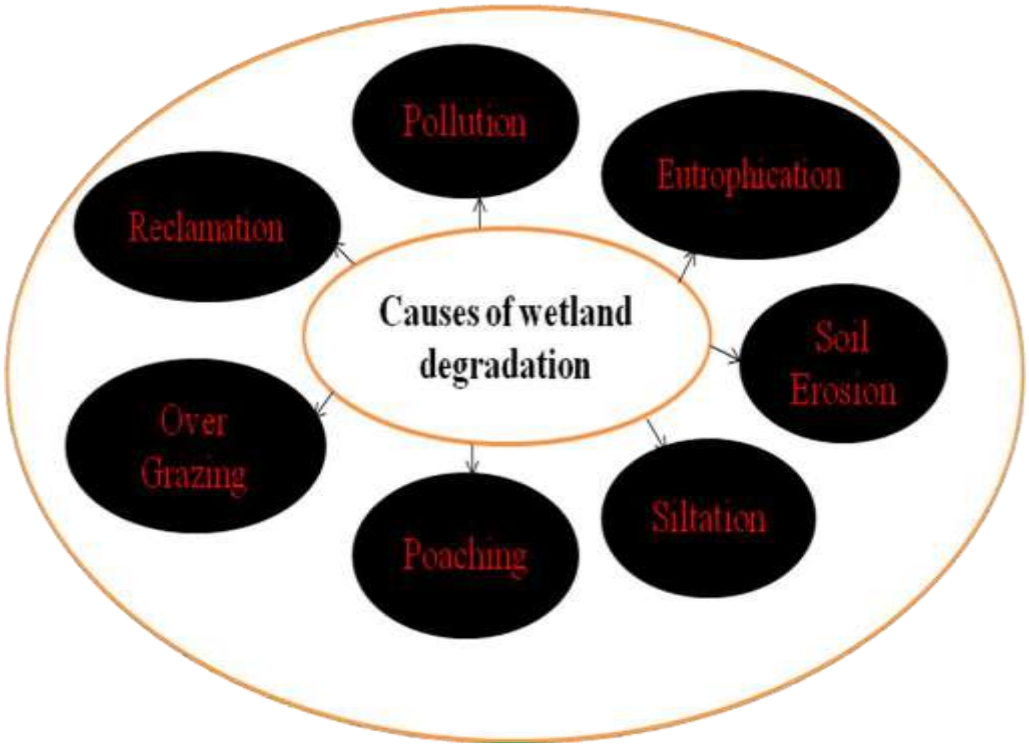

Fig. 2, Causes of Wetland Degradation

Various schemes have been launched by the state and central government to sustain this fragile ecosystem. A package was approved by the chief minister of Punjab and central leaders under 'Project *Sahyo*g' to check the degradation of the lake. However, this project has not solved the problem (Khanna D.R and Bhutiani R., 2008).

Sources of pollution to the rivers and wetlands

There are a number of nullahs and drains that are responsible for the pollution of the Sutlej and Beas rivers. Budhanullah, Mehmoodpurdrain, Chrandrain, Rahondrain, Phambradrain, Theongdrain, Dhainidrain, Kot Badal Khan, East Bein, West Bein, Chamkaur Machhhiwar drain, Krishan puradrain are located along the Sutlej river. Chakkiriver, Ghuralnullah, Gazi drain, Nikas Mansardrain, Kahnuwanswamp, Tanda Ram Sahai, Sewanullah, Sadarpurdrain, Longer choe, Dasuya group of choes, Satiala drain, Dihrowal drain, Naushera drain are located along the Beas river. About twelve drains/ nullahs fall into the Sutlej River, and 13 drains/nullahs fall into the Beas River. Most of the drains come through nearby settlements and industrial units. These collect enormous amounts of domestic sewage, industrial effluents, and agricultural runoff and discharge them into the concerned rivers. Budhanullah is the most polluted drain, which gets effluents from Ludhiana, the most densely populated city of Punjab,

and discharges the waste into the Sutlej river.

The drains alongside non-point sources contribute a huge pollutant load to the reservoir. The municipal and industrial wastes from nearby towns located in the catchments of both rivers are directly or indirectly discharged into the respective rivers, eventually reaching the lake and then the Harike wetland. A variety of agrochemicals, such as fertilizers, pesticides, and weeds, along with organic matter in runoff waters from the immediate catchment, pollute water quality.

Pollution level of Sutlej and Beas measured by the Punjab Pollution Control Board

The water quality of the Sutlej river as monitored and reported by the Punjab Pollution Control Board falls under the category 'C' (use quality of source of raw water for municipal supplies to be consumed only after conventional water treatment) or lower (Punjab Pollution Control Board 1989), with only a slight stretch from Nangal to Ropar described to be in the category 'B' (useable for bathing, swimming contact sports) or 'A' (drinking water and domestic supplies without treatment, but with disinfection). A decrease in the volume of water in the main river downstream of the Ropar head regulator is also accountable for the apparent increase in pollution reported. The Beas River, however, has a significantly better water quality due to fewer townships and industries being located along its banks. On the Sutlej side of the reservoir, that is on the left bank, the water quality is poor with severely eutrophic conditions, while on the right bank, where the Beas joins, the water quality is better, though mildly eutrophic. In the central area where the waters of the two rivers merge, the water quality, perhaps due to the swift flow of the rivers, is best (Ladhar et al, 1994).

Table 1, Sewage discharge by major towns into Sutlej and Beas rivers

Major towns discharge sewage into River Sutlej		
Sr. No	**Town**	**Waste water generated 1991(mld)**
1	Ludhiana	148.0
2	Jalandhar	68.0
3	Moga	14.0
4	Hoshiarpur	12.0
5	Kapurthal	9.0
6	Anandpur Sahib	1.1
7	Ferozpur	8.0
8	Nangal township	1.2
9	Naya Nangal	2.2
10	Phagwara	12.0
11	Phillaur	2.1
12	Ropar	3.3
13	Nawanshahr	1.47
14	Sultanpur Lodhi	1.43

Major towns discharge sewage into River Beas		
Sr. No	**Town**	**Waste-water generated 1991 (mld)**
1	Pathankot	18.97
2	Mukerian	0.06

Source: Punjab Water Supply and Sewage Board, 1991

Table 1 shows that a total of 14 cities are located on the bank of the Sutlej River and two on the bank of the Beas. These towns discharge various types of domestic, industrial, and municipal sewage into the rivers. Ludhiana produces the highest sewage among all the urban centers. It discharges 148 million liters of sewage daily into the Sutlej River. Ludhiana is the most densely populated and an industrial city of Punjab. Jalandhar is the third most populous city of Punjab. It discharges 68 mld (millions of liters per day) into the river Sutlej. Both towns discharge the highest amount of sewage into the Sutlej river. Other towns of Punjab like Moga, Hoshiarpur, Phagwara, and Kapurthala are also the source of pollution for the Sutlej river. On the other hand, Pathankot is a major source of pollution to the Beas river, which discharges 18.97 million litres of sewage daily. The above discussion shows that the maximum number of towns is located around the river Sutlej as compared to the Beas river. Therefore, the Sutlej river is more affected as compared to river Beas.

Table 2, Location of major industries along the Sutlej and Beas rivers

Location of Major Industries Along River Sutlej and Beas	
Sr. No	**Name of the industry**
1	National Fertilizer Ltd., Naya Nangal
2	PNFC, Naya Nangal
3	Punjab Alkalies, Naya Nangal
4	Ropar Thermal Plant, Ropar
5	M/s Swaraj Mazda, Asraon
6	M/s United Pulp and Paper Mills, Asron
7	M/s Zenith Paper Mills, Bannah
River Beas	
S. No	**Name of the industry**
8	Mukerian Paper Mills, Mukerian
9	Goindwal Industrial Complex, Goindwal

Source: Punjab water supply and sewage board, 1991

Table 2 shows that 7 major industrial units are located along the Sutlej river and two along the Beas river. These units are the major source of pollution for these rivers. These industries discharge their effluents into the rivers directly and indirectly. National Fertilizer Ltd. and Ropar Thermal Power Plant are the major sources of pollution. These units affect the water chemistry of rivers. Therefore, polluted water affects the ecology as well as the humans of the region at large. The above table shows that Sutlej

river is more affected by pollution as compared to the Beas river.

Sampling sites

Water is an invaluable inorganic element, and its quality is being degraded owing to overuse/misuse. Domestic, agricultural uses, and industrial waste disposal are affecting the water quality. Consequently, water bodies are shrinking on the one hand and are getting polluted on the other. It is in this light that the physical and chemical properties of water have need to be studied. As mentioned above, Harike Lake is located at the confluence of the Beas and Sutlej rivers. The former flows north while the latter flows from the east of the Harike wetland. On their way from the source to the mouth, various drains join these rivers, hence mixing their polluted water into these rivers. At last, the rivers Sutlej and Beas join the Harike wetland and discharge numerous types of point and non-point pollutants into this wetland. Moreover, Harike lake receives pollution from the various land use practices going on in its vicinity (Praksh D. Raut et al., 2011).

Owing to increased human population, industrialization, and intensive agriculture, the natural aquatic ecosystem is suffering from severe pollution (Reddy K.R. & Gale P.M., 1994). Therefore, to examine water quality, 10 sites have been selected around the wetland. It was hypothesized that the sample sites would bear pollution and other qualities of water. (Fig.4). In light of the above, physicochemical analysis is carried out on various parameters in the Harike wetland ecosystem.

Water quality standards

Many organizations have developed their own water quality standards. Important amongst these are the World Health Organization (WHO), the United States Environmental Protection Agency (USEPA), and the Central Pollution Control Board etc. (Table 3.4).

Table 3, Water quality standards for drinking and irrigation purposes

Parameter	Units	USEPA	WHO	ISI	ICMR	CPCB
Ph		6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.2	6.5-8.5
EC	Ms/cm	_	_	500	_	2000
TDS	mg/l	_	_	500	_	_
Cl	mg/l	250	200	250	1000	1000
BiC	mg/l	150*				
TH	mg/l	_	500	300	600	600
Ca2+	mg/l	_	75	75	200	200
Mg2+	mg/l	_	50	30	_	100
Na+	mg/l					
K+	mg/l	2.5-5.2*				
Tur	mg/l	_	_	10	25	10
SO4	mg/l	_	_	150	400	400
F	mg/l	4	1.5	.6-1.2	1.5	1.5
Copper	mg/l	1.3	1	0.05	1.5	1.5
Mn	mg/l	_	_	0.1-0.3	_	_

Arsenic	mg/l	0.05	0.05	0.05	0.05	No Relax
Lead	mg/l	_	0.05	0.1	0.05	No Relax
Iron	mg/l	_	0.1	0.3	1	1
Zinc	mg/l	_	5	5	0.1	15
Chromium	mg/l	0.1	_	0.05	_	No Relax
Cobalt	mg/l	.001-.04*				
Nickel	mg/l	_	_	0.02	_	_

Source: USEPA, Washington, D.C. Nov. 2016, WHO-2011, ISI, New Delhi IS 10500: 2012
CPCB-Ministry of Environment, Forest & Climate Change Govt. of India, New Delhi Oct. 2019

Table 3 above shows the water quality standards for drinking and irrigation purposes. These have been published by various institutions such as the United Nations Environment Protection Agency (UNEPA), World Health Organization (WHO), Indian Standard Institute (ISI), Indian Council of Medical Research (ICMR) and Central Pollution Control Board (CPCB). These organizations have fixed the range of various parameters on the basis of their own research.

Water quality parameters

Physical and chemical aspects of the Harike water body are required to be assessed and determined for its suitability for drinking and irrigation purposes. To study the water quality of Harike wetland and its catchment area, 10 samples from different sites were collected during the pre- and post-monsoon seasons. A total of 14 parameters like pH value, temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Chloride, Calcium (Ca), Magnesium (Mg), Total Hardness (TH), Sulphate, Sodium, Potassium, Turbidity, Fluoride and Bicarbonate were analyzed.

Location of sites

Quality of life depends on the quality of water that people drink. For the study of water quality, a total of 10 samples (Table 4) were collected during the pre- and post-monsoon seasons from the different sites of the Sutlej, Beas, and Harike wetland. Four sampling sites were selected along the Sutlej river, including Nangal barrage, Ropar barrage, Phillaur, and Gidderpindi. Three samples were collected from different sites on Harike Lake. These were identified at the Makhu bird sanctuary, Harike barrage and Harike village. And three samples were collected from different sites of the Beas river like Dhun village, Goindwal Sahib (1000 D/S), Naushera Pattan, Mukerian. It is hypothesized that the Sutlej river is more affected by pollution as compared to Beas river.

Table 4, Location of water sampling sites

Site ID	Lat.	Long.	Pre-monsoon sites	Post-monsoon sites
1	31º22'	76º21'	500 m downstream of Nangal barrage, Sutlej river	Near Nangal barrage, Sutlej river
2	30º58'	76º29'	Near Ropar barrage, Sutlej river	Near Ropar barrage, Sutlej river
3	30º59'	75º47'	Near Phillaur, Sutlej river	Near Phillaur, Sutlej river
4	31º08'	75º06'	Near Gidderpindi bridge Makhu road, Sutlej river	Near Gidderpindi bridge Makhu road, Sutlej river
5	31º07'	74º58'	At bird sanctuary Makhu, Harike wetland	At bird sanctuary Makhu, Harike wetland

6	31º08'	74º56'	Harike barrage, Harike wetland	Harike barrage, Harike wetland
7	31º09'	74º56'	200 Meter D/S, Harike village, Beas river	200 Meter D/S, Harike village, Beas river
8	31º12'	75º01'	500 Meter D/S Dhun village, Harike wetland	500 Meter D/S Dhun village, Harike wetland
9	31º22'	75º09'	1000 Meter D/S Goindwal Sahib, Beas river	1000 Meter D/S Goindwal Sahib, Beas river
10	31º59'	75º33'	At Naushera Pattan , Beas river, Mukerian	At Naushera Pattan , Beas river, Mukerian

Source: Researcher demarcated the locations using GPS

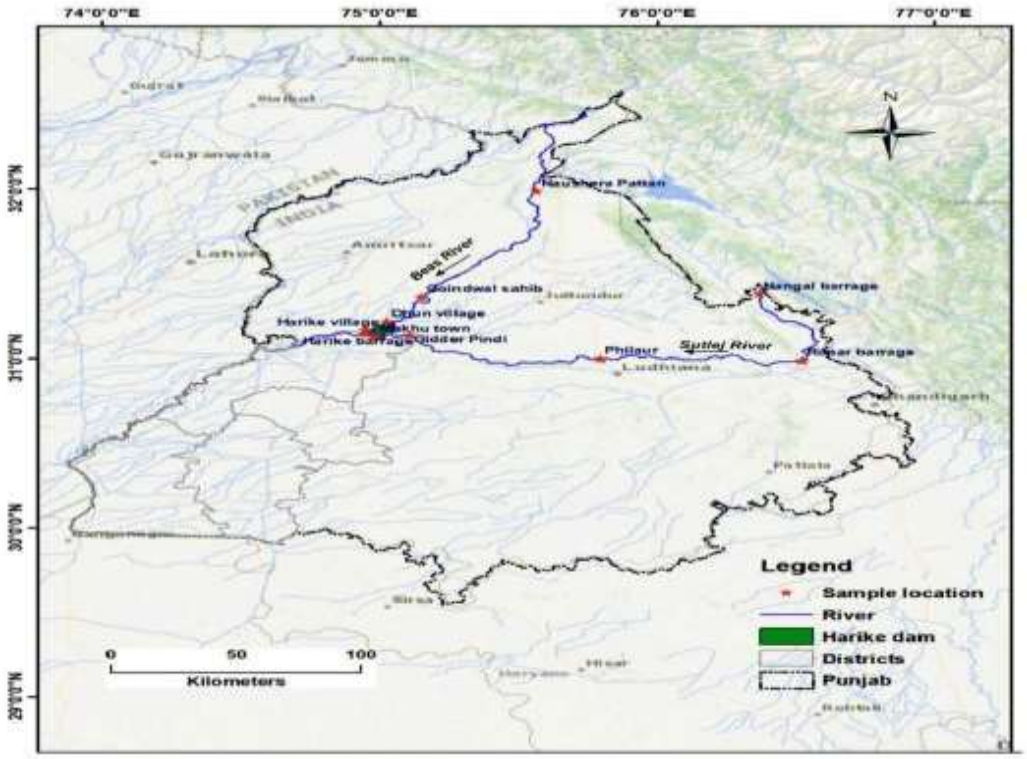

Fig. 3, Location of water sample sites.
Source: Prepared by the researcher using Landsat May 2022

Table 4 and Fig. 3 show the location of various sites identified alongside the Sutlej river, Harike lake, and Beas river from the North-Eastern to West and Northern directions, respectively. The above map shows that the whole catchment area of the Harike wetland is covered by ten sites. Along the Sutlej river, major towns were selected for sample collection. These are Nangal, Ropar and Fillaur, and Gidderpindi. Three sites were identified along the Harike wetland. These include the Harike bird

sanctuary, Harike barrage, and Harike village. And the other three sites were selected along the Beas river like Dhun village, Goindwal Sahib, and Naushera Pattan.

All these sites affect the ecology of the Harike wetland, directly and indirectly. Water samples were collected covering almost the entire wetland and its catchment area as well. It is a must to analyze the water of these water bodies because a number of towns and industrial units are located alongside these water bodies, which discharge into these rivers. Therefore, it may give a better picture of the water quality of the Sutlej and Beas rivers.

Objective

Harike lake and its catchment area are suffering from a number of threats like industrial run off, extensive agricultural activities around these and sewage discharge into these water bodies. Various life forms depend upon the Harike wetland for their existence. Therefore, it is important to assess the water quality of Harike lake and the Sutlej and Beas rivers.

Methodology

Several methods have been used for the interpretation of the information/data. In the light of the above objectives and database, the following methods were used in this study. The pre-monsoon samples were collected in May 2020, and the post-monsoon samples were collected in October 2020. To access the ecological properties of the study area, a total of ten different sites of Harike Lake, Sutlej, and Beas rivers were selected. The sites are Nangal barrage, Ropar barrage, Phillaur, Gidderpindi, Makhu, Harike barrage, Harike village, Dhun village, Goindwal Sahib and Naushehra Pattan. Four samples were collected from the Sutlej river, three around Harike Wetland and three from the Beas river. The Sutlej and Beas rivers discharge water to the Harike wetland. Samples were collected in pre-cleaned one-litre white polypropylene bottles. Samples were collected during the morning time from 8:00 am to 10:00 am and stored in the freezer at 4°C until used as per APHA norms. Locations of sample sites were fixed by Global Positioning System (GPS). Physicochemical parameters such as temperature and pH were measured in situ. To calculate EC and pH, a Thermo Scientific instrument was used. For the analysis of Fluoride, a Thermo Scientific ISE meter was used. For the analysis of Sulphate, Systronics (Digital Nephlo-Turbidity metre 132) was used. For the calculation of Potassium and sodium, a Systronics flame photometer was used. To access turbidity, an Eutech Turbidity meter was applied. Therefore, variations in those parameters were analyzed using the standard procedure prescribed by the American Public Health Association (APHA, 23rd edition, 2017).

Table 5, Water quality of Harike wetland and its catchment area (pre-monsoon season)

Site	pH	Tem	EC	TDS	Cl	TH	Ca 2+	Mg 2+	Na +	K+	Turbidity	SO4	F
			Ms/cm	mg/l	mg/l	mg/l	Mg/l	Mg/l	mg/l	mg/l	Mg/l	mg/l	mg/l
1	7.9	26	228	145.7	20.6	104	25	10	0.2	1.3	32	109	0.2
2	7.9	27.1	227	145.6	12.4	116	27	12	0.4	1.3	33.7	118	0.2
3	7.9	26.3	299	191.4	16.5	160	41	14	11	3.9	74	116	0.3
4	8	27.4	299	191.3	24.7	103	24	10	4.1	1.7	87.2	44.5	0.2
5	7.8	28.3	267	170.7	28.8	138	30	15	5.4	2.1	10.7	61.7	0.2

6	7.9	27	230	146.9	20.6	121	34	8.9	3.8	1.6	82.6	35.5	0.2
7	7.8	29.2	267	171.1	20.6	141	32	15	5.4	2	142	58.1	0.2
8	7.9	25.8	227	141.9	16.5	109	28	9.4	4.5	1.5	36.6	30.6	0.2
9	8	27.2	226	144.8	20.6	119	29	11	4.4	1.6	44.6	31.8	0.2
10	7.9	29	230	147.1	20.6	137	32	14	4.6	1.5	69.3	29	0.2
Ave*	7.9	27.3	250	159.7	20.2	125	30	12	4.3	1.9	61.3	63.4	0.2

Source: Prepared by the scholar using APHA, 23rd edition 2017 Note: Ave depicts average*

Table 5 shows that the pH value varies from the range of 7.8 to 8.0. The lowest value was observed at site 7, and the highest was recorded at sites 4 and 9, respectively. The average value registered 7.9, which shows a slightly alkaline nature. The pH is an important indicator of water quality, which determines the suitability of water for a number of purposes. A comparison of the findings with the recommended levels of salinity for protection of aquatic life as per USEPA-1979 (6.5-9.0), irrigation as per ISI-1979 (5.5-9.0), domestic use as per ICMR-1975 (7.0-8.5) indicates that the water of wetland is suitable in terms of pH for all uses of all the sites. The higher values are due to the concentration of saline water, while the lower values are due to dilution of saline water caused by freshwater inflow (Praksh D. Raut et al., 2011).

During sample collection in the study area, the Harike wetland's catchment area's average water temperature was measured at 27.3 °C. The aquatic vegetation is influenced by water temperature in a significant way. The temperature may have an impact on the lake's phytoplankton's seasonal cycle. The growth and development of plants have certain favourable and unfavourable impacts. Plants thrive best at temperatures between 20^0 and 35^0C. Temperatures above 35^0 C are hazardous to plant growth (Reddy K.R. & Gale P.M., 1994).

Electrical Conductivity (EC) lies in the range between 226 and 299 mS/cm with an average value of 250 micrometer/siemens. However, all sites are found in the permissible limit, but the highest value of EC was noticed at sites 3 and 4. These sites are located near Philaur and Gidderpindi, respectively, which receive waste matter from more than 12 drains. High value may be because of pollution from industry and domestic waste entering from catchment area. The potential reasons for the high EC values may be the input of large amounts of surface run off containing sediments from the catchment areas, which have intensive agricultural crops and human habitation near these stations (Vineetha S. et al., 2010).

During the pre-monsoon season, Turbidity ranges between 10.7 and 142. The highest value is recorded at site 7, which is situated at the Harike barrage. It is the intermixing site of the waters of the Sutlej and Beas rivers. The high value is caused by the presence of aquatic macrophytes. The presence of clay, silt, organic matter, phytoplankton and other microscopic organisms may be the reason for high turbidity in natural water (Vineetha S. et al., 2010).

Sulphate varies from 29 mg/l being the lowest to 118 mg/l being the highest, with an average of 63.4 mg/l. It recorded the highest at site 2, which is located near Ropar barrage on the Sutlej river. The presence of high content of sulphate at this site is mainly because of the breakdown of organic substances in soil, leachable sulphate present in fertilizer, and other influences (Kumar A. et al., 2009).

Chloride registered between 12.4 to 28.8 mg/l. The highest value recorded at site 5. It is located at Harike bird Sanctuary near Harike wetland. It may be affected from various anthropogenic activities and sediment weathering. These dispose of their waste in the Sutlej river, hence contaminating the water body. Chloride and Sulphate also come from sewage, agricultural fields, and industrial effluents.

The total hardness of Harike wetland and its catchment area ranges between 103 to 160 mg/l. It registered the highest at site 3, which is located near the industrial town of Phillaur. It gets various types of effluents from point and non-point pollution sources. High value of hardness may be due to the regular discharge of effluents from nearby residential areas. According to the author, waters with more than 60.0 ppm hardness are 'nutrient-rich' (Kumar A. et al, 2009). Calcium is found to be between 24mg/l to 41 mg/l. The highest value is recorded at station 4. It is located at Phillaur, an industrial town of central Punjab. The average value of Magnesium, which is 12 mg/l recorded at all the sites. These may come from physical as well as anthropogenic factors.

Total dissolved solids (TDS) recorded the highest values, that is, 191.4 and 191.3, respectively, at sites 3 and 4. Both sites are located at the Sutlej river, which receives various types of industrial, agricultural, and municipal effluents from nearby areas. The maximum concentration of total dissolved solids may be due to the discharge of large quantities of sewage, household detergent, agricultural spillover, and disintegration of rocks.

It can be concluded from the above discussion that all the sites are found to be within the permissible limit, except for turbidity. It recorded beyond the permissible limit at all the sites. It is an intermixing site of the waters of the Sutlej and Beas rivers. The high value is caused by the presence of aquatic macrophytes. During the field survey, it has been seen that this region is most affected by water hyacinth. Site 3 and 4 are affected by EC and TDS as these are situated near the settlements. These settlements are the main source of various point and nonpoint pollution sources. The above discussion shows that site 3 is more affected among all sites. It is located in an urban area which is the main source of industrial effluents, municipal waste, and agricultural runoff. The first four sites are more affected compared to the other sites. These are situated on the Sutlej river. Therefore, pre-monsoon data shows that the Sutlej river and Harike Wetland are more polluted than the Beas river. Major industrial towns are located on the river Sutlej. Budha Nala is one of the most polluted drains that discharge its unpredictable pollutants into the Sutlej river. Thus, these contribute significantly to the pollution of the Harike wetland. These parameters can alter the ecology of the wetland, which may create an imbalance in the wetland ecosystem. The human population can also suffer because the wetland supplies water to the locals as well as many people living in far-off areas. Moreover, the river Sutlej is most affected among all these water bodies. Site 3 is the worst-affected among all the sites, located at Phillaur, an industrial town of Punjab. The river Sutlej covers the maximum distance from its source to its mouth. Major cities and industrial sites are located on the banks of this river, like Nangal, Ropar, Ludhiana, and Philaur, which discharge their sewage, effluents, and detergents into the Sutlej river, directly and indirectly. Moreover, Budhanala is the most polluted, which discharges the effluents into this river.

Table 6, Water quality of Harike wetland and its catchment area (post-monsoon season)

Site	pH	Tem ^{o}C	EC	TDS	Cl	TH	Ca2+	Mg2+	Na+	K+	Turbidity	SO4	F
			Ms/cm	mg/l	mg/l	mg/l	Mg/l	Mg/l	mg/l	mg/l	Mg/l	mg/l	mg/l
1	7.7	23.5	229	146.4	16.5	2.8	1.8	0.9	0.4	0.9	4.3	85.3	0.2
2	8	25.4	308	197.2	20.6	3.4	2.2	1.2	8.8	2	6.3	102	0.2

3	7.5	24.3	319	204	24.7	3.9	2.5	1.5	9.7	2.3	41	96	0.2
4	8	22.9	202	129.3	20.6	2.6	1.8	0.8	2.8	1.6	22.8	34.3	0.2
	6.9	24.1	277	170.7	24.7	3.1	1.9	1.2	10	0.4	4.4	68.7	0.3
6	8.1	26	202	177.5	16.5	2.7	1.5	1.1	2.6	1.5	70.7	35.3	0.2
7	8	25.7	202	129.3	12.4	2.8	1.7	1.1	2.7	1.6	28.6	38	0.2
8	8.1	23.7	201	129.2	16.5	2.6	2.2	0.4	2.6	1.5	82.1	38.8	0.2
9	8.1	24	204	128.9	12.4	2.5	2	0.5	2.6	1.5	30.3	33.5	0.2
10	8.1	25.1	205	130.8	16.5	2.3	1.6	0.7	2.4	1.4	20	33.6	0.2
Ave	7.9	24.5	235	130.9	18.1	2.9	1.9	0.9	4.4	1.5	31	56.6	0.2

Source: Prepared by the scholar using APHA, 23rd edition, 2017. Note: Ave depicts average*

Table 6 shows that the average values of pH (7.9) at all the sites represent the saline or slightly alkaline nature of water. The pH was recorded same in both pre- and post-monsoon seasons. The pH level refers to the potential presence of hydrogen ions in a substance. It measures the acidity and basicity of water. Generally, it ranges between 0-14. A pH value less than 7 indicates acidity, while more than 7 indicates basicity, whereas a value of 7 indicates neutrality. A measurement of pH value is important in chemistry, agronomy, medicine, water treatment, and so on.

The average water temperature of the study area is recorded as 24.5 °C in post post-monsoon season against 27.3°C in the pre-monsoon season. The above table shows that temperature declines in the post-monsoon season due to rainfall. The temperature that is less than 30 °C supports the growth and development of various types of vegetation.

Electrical Conductivity (EC) ranged between 201 and 319 with an average value of 235 micrometer/siemens. Maximum concentration of EC is noticed at sites 3 and 2, respectively. Post-monsoon season recorded minimum EC as compared to the pre-monsoon season. It may be the reason of rainfall during the monsoon season.

Total Dissolved Solids varied between 129.2 and 204 mg/l with an average value of 130.9 mg/l. The highest value was recorded at stations 3 and 2, respectively. As stated earlier that these sites are located near settlements and industrial areas, which receive various types of industrial, agricultural, and municipal effluents from nearby areas. TDS enters water bodies through agricultural runoff as well as industrial effluents (Kumar V. et al, 2016). The table shows that post-monsoonal sites are less affected by pollution as compared to pre-monsoonal sites. Chloride ranged between 12.4 to 24.7 mg/l. The highest value is registered at sites 3 and 5. Site 3 is located in an urban area and may be affected by several types of industrial effluents and municipal sewage. Site 5 is located near the Harike bird sanctuary and may be affected by sediment weathering.

The average total hardness is recorded as 2.9 mg/l at all the sites. The highest value is registered at site 3, which is located in the urban area. It is repeatedly stated that a high value of hardness may be due to the regular discharge of large quantities of effluents from nearby residential areas. During post-monsoon, TH recorded the lowest at all the sites as compared to the pre-monsoon season.

Again, Calcium and Magnesium were recorded highest at station 3 as compared to other stations. The reason may be physical as well as anthropogenic factors, which pollute the site. The above table shows that post-monsoonal sites are affected to a lesser extent than the pre-monsoon sites.

The highest value of turbidity is found at sites 8 and 6, respectively. Both sites are located at the Harike wetland. Site 6 is located at Harike barrage, and site 8 is located at Dhun village, situated near the Harike wetland. The high value is caused by the presence of aquatic macrophytes and the high muddy sediment at the bottom. The above tables show that in respect of turbidity, the pre-monsoonal sites are more affected compared to the post-monsoonal sites.

Sulphate ranged between 33.5 to 102 mg/l. Like the pre-monsoon season, again, the highest value is registered at Ropar barrage (site 2). It may be due to the breakdown of organic substances in soil, leachable sulphate present in fertilizer and other influences.

The values of EC, TDS, Chloride, and TH are maximum in the water of the Sutlej river and Harike Lake as compared to the Beas river. Both calcium and magnesium were registered highest at site 3. The values of Sodium, Potassium, and Sulphate are recorded as maximum in Sutlej river and Harike Lake. Turbidity was recorded as highest in Harike lake and Beas river compared to Sutlej river. Sites 8 and 6, situated at Beas and Harike, respectively, are the most affected sites. The above table shows that among all the parameters, pre-monsoon sites are more affected as compared to post-monsoon sites.

It can be inferred from the above discussion that all the parameters are found within their permissible limit, except for the waters of sites 2 and 3, which are more affected by pollution as compared to other sites. In fact, these sites are located in the urban areas along the Sutlej river. This river is more affected by point and nonpoint pollution sources. This river brings unpredictable pollutants both from the catchments as well as nearby settlements. As a result, it changes the character of the Harike water body. The above discussion shows that pre-monsoonal sites are more affected than post-monsoonal sites. Rainfall plays an important role in dilution. So, the water of the post-monsoon season is much clearer than compared to the pre-monsoon season.

Conclusion

It concluded that all the parameters are within the permissible limit except turbidity, which recorded a maximum at the sites of the river Sutlej in both pre- and post-monsoon seasons in comparison to the Beas river. All the sites of the river Sutlej are located in urban areas, which are more affected by pollution as compared to other sites. This river is more affected by point and nonpoint pollution sources. This river brings unpredictable pollutants both from the catchments and from nearby settlements to the Harike wetland. As a result, it changes the character of the Harike water body. The pre-monsoonal sites are more affected than the post-monsoonal sites. Rainfall plays an important role in dilution. So, the water of the post-monsoon season is much clearer as compared to the pre-monsoon season.

Harike Wetland is being polluted from its catchment area and nearby settlements. It is located at the confluence of the Sutlej and Beas rivers at Harike Pattan. Several industrial units and urban towns are located along these rivers, which are the major reason for the pollution of these rivers. More industrial units and towns are located around river Sutlej as compared to the Beas river.

Intensive agriculture is prevalent in the vicinity of the Sutlej, Beas, and Harike wetland. Availability of water, fertile soil, and suitable climate around these areas are liable for the agricultural expansion in the adjacent areas. Settlements, agricultural fields, and industrial units located in the wetland catchment discharge various types of pollutants in the Beas and Sutlej rivers, resulting in the deterioration of water in both the rivers as well as the Harike wetland. Wetlands are called the backbone of any economy. This is because these fragile ecosystems provide numerous goods and services to society and also act as the habitat for flora and fauna species. Thus, these fragile ecosystems should be conserved and preserved at any cost.

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