Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(1), 289-300 | ISSN:2251-6727

Industrial Wastewater Discharge into Natural Drains: Spatial Assessment on the Impact on Surface and River Water Quality

Vijay Kumar†, Chandrajit Balo Majumder

Department of Chemical Engineering, Indian Institute of Technology Roorkee, Roorkee, 247664, India.

(Received: 27 October 2023 Revised: 22 November Accepted: 26 December)

KEYWORDS

Surface water quality, WQI, Ganga, Ramganga

ABSTRACT:

Industrial wastewaters are generally discharged into natural drains when these drains meet to surface and river water, water quality is affected. The river Ganga in Bijnor district, Uttar Pradesh receives such waters from its various tributaries. To assess such impact or the quality of water of the river Ganga, it was monitored monthly basis at selected 11 sites during September 2020 to March 2021 for 10 parameters such as temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), chloride, total dissolved solids (TDS), total suspended solids (TSS), nitrate and ammoniacal nitrogen. Temperature, pH, chloride, nitrate and ammoniacal nitrogen were within permissible limit in all selected 11 sites. Most of water quality parameters, e.g. BOD, COD, DO, TSS, and TDS were found several times higher than the permissible limit. Further water quality has been assessed using water quality index (WQI). It was observed to be poor at site 9, 10 and 11. The site location 9, 10 and 11 showed drastic ranges of pollution. These three sampling sites are fall under the category of heavily contaminated sites at Bijnor, U.P., India.

1. Introduction

Now a days it has become a major challenge before the people that they are facing the problem of surface water of developed countries and densely populated like India. With the rapid growth of industrialization, industrial effluents have become the major source of water pollution. Uttar Pradesh is one of the highly populated states of the country as per census 2011. There are numerous medium and large-scale industries from which complex and diverse effluents are released, resulting in drain and river contamination. The treated and untreated industrial effluents, released into various surface water bodies not only affect the water quality, also pollute the groundwater because of percolation of water-soluble pollutants [1]. The pollution of the water body is greatly influenced by these industrial effluents. The physical, chemical, and biological nature of the receiving water body may be altered by this effluent. The activity of industries has become the source of pollution stress on surface waters from industrial, agricultural and domestic sources [2].

The quality of river water is an important part of water management where the river ought to serve the water resources for various purposes that the program of river water quality monitoring has become necessary for the benefit of public health and to protect the valuable and important fresh water resources.

Some small and large tributaries fall in the river Ganga. Ramganga River is reported to carry significant load of pollutant [3]. It is the most important tributary of the Ganga River, India's most sacred and largest river basin. For successful Ganga management, it is necessary to examine the water quality of its tributaries. The current study examines the quality of surface water in Bijnor's drains and rivers. According to the Central Pollution Control Board (CPCB), roughly 235 MLD of untreated industrial wastewater and 227 MLD of residential sewage are discharged in Ramganga (directly or via tributaries) from Uttarakhand and Uttar Pradesh states, with an estimated BOD load of 132 TPD [3]. It is essential to identify the pollution sources for effective pollution control and its water resource management and their quantitative contributions [4].

To determine the quality of water it is necessary to analyses water quality parameters. Further water quality has been assessed using water quality index (WQI). It is used in surface water (for especially rivers and drains) and groundwater. The Bureau of Indian Standards [5],

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(1), 289-300 | ISSN:2251-6727

the Indian Council for Medical Research (ICMR 1975), and the World Health Organization [6] have defined the permitted limit for these parameters. The permissible limit of some physicochemical parameters of surface water are summarized in Table 1.

Table 1: Permissible limit of some physicochemical parameters in surface water.

S.N.	Parameter	BIS (2012)
1.	Temperature (ºC)	20-30
2.	Dissolved Oxygen (mg/L)	>4
3.	pH	5.5-9
4.	Total Dissolved Solids (mg/L)	500
5.	Chemical Oxygen Demand (mg/L)	250
6.	Biochemical Oxygen Demand (mg/L)	30
7.	Total Suspended Solids (mg/L)	100
8.	Chlorides (mg/L)	500
9.	Nitrates (mg/L)	45
10.	Ammoniacal nitrogen (mg/L)	50

Aim of the present study to assess the impact of industrial discharges on the quality of surface water in drains and rivers that are tributaries of the Ganga and Ramganga rivers. The present study extended to examine the physical, chemical, and biological features of water in order to detect polluted river segments and to estimate the severity of changes in river and drain water quality.

An aeronautical reconnaissance coverage geographic information system (ArcGIS) interpolation technique is used to develop surface water quality map [7]. This drainage map is prepared by using

ArcGIS 10.2.2. The sampling sites are shown in the map of the study area in Fig 1.

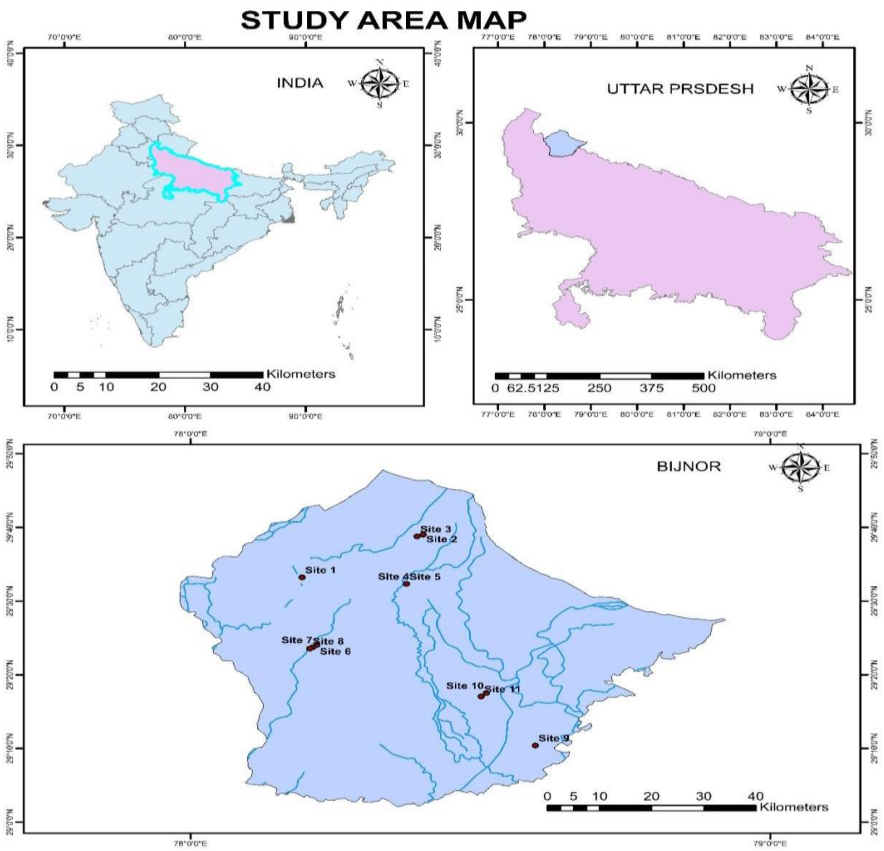


Fig 1. The sampling sites are shown in the map of the study area

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(1), 289-300 | ISSN:2251-6727

2. Materials and Methods

Bijnor district occupies the area around 4561 Sq. Km. Two Major River Ganga and Ramganga pass through the Bijnor district. These rivers have their own watershed while the Ramganga is also a tributary of Ganga River. The district Bijnor alone has the total population about 3,682,713 numbers of Individuals as per 2011 census. The major portion of population in the district depend upon occupation of agriculture. Besides a few sugar factories, distilleries, Pulp and Paper industry and food process unit support the economic health.

2.1. Selection of sampling sites

The selection of surface water sampling sites was dependent on the industrial effluent discharge into the drain. Most of the samples are taken from the sites which are located either just downstream or upstream of industries at drain and river. It was helpful to examine the quality of water from where the pollutant industries discharge into drain, directly or indirectly along with tributaries. Location of various sampling sites are summarized in Table 2.

Table 2: Different sites location

Site no.	Drains/Rivers name	Site area	Co-ordinates	Tributaries
Site 1	Malin	Bhojpur bridge	Lat N 29º33'13" Long E 78º11'32"	Ganga
Site 2	Chandanpur	Bhogpur	Lat N 29º39' Long E 78º24'4"	Ganga
Site 3	Chandanpur	Bhogpur	Lat N 29º38'46" Long E 78º23'27"	Ganga
Site 4	Gangan	Ganguwala	Lat N 29º32'21" Long E 78º22'21"	Ramganga
Site 5	Gangan	Naqipur Bamnouli	Lat N 29º32'19" Long E 78º22'20"	Ramganga
Site 6	Choyyia	Faridpur Chandan	Lat N 29º24'2" Long E 78º13'4"	Ganga
Site 7	Choyyia	Firozpur Hafiz	Lat N 29º23'43" Long E 78º12'37"	Ganga
Site 8	Choyyia	Abdulpur Munna	Lat N 29º23'33" Long E 78º12'20"	Ganga
Site 9	Nasiya	Saidpura	Lat N 29º10'24" Long E 78º35'41"	Ganga

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(1), 289-300 | ISSN:2251-6727

Site 10	Ekra	Dhampur	Lat N 29°17’31” Long E 78°30’37”	Ramganga
Site 11	Ekra	Dhampur	Lat N 29°17’3” Long E 78°30’4”	Ramganga

2.2. Sampling sites

Samples were collected from 11 monitoring locations of drains and rivers at Bijnor. The sampling was done in every month from September 2020 to March 2021. The samples were analyzed for 10 parameters. These are temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD) - 3 days at 27°C, chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), Chloride, Nitrate and Ammoniacal nitrogen. To avoid collecting surface impurities such as oils, tree leaves, and other contaminants, the water sample was taken 40-50 cm below the surface. Two litres of samples were collected from each sampling sites and were transported to the laboratory under strict preservation conditions APHA 2017 [8]. Temperature and DO of the water were measured using DO meter on the sites. The rest of the parameters were determined in the laboratory using established techniques APHA 2017 [8]. Table 3 summarizes various water quality parameters, their units, and analysis methodologies.

Table 3: Water quality parameters, abbreviations and their analytical methods

Parameters	**Abbreviations**	**Analytical methods**
Temperature (°C)	Temp	Thermometer
pH	pH	pH meter
Dissolved oxygen (mg/L)	DO	HACH's DO meter
Chemical oxygen demand (mg/L)	COD	Dichromate open reflex method
Biochemical oxygen demand (mg/L)	BOD	Winkler azide method
Total dissolved solids (mg/L)	TDS	Gravimetric
Total suspended solids (mg/L)	TSS	Gravimetric
Chloride (mg/L)	Cl-	Argentometric method
Nitrate (mg/L)	NO_3-	Spectrophotometric
Ammoniacal nitrogen (mg/L)	NH_3-N	Titrimetric method

2.3. Data Analysis

The summary of surface water of all selected sites is presented in Table 5. Using Origin Pro. 10, the data of water quality parameters from drains and rivers were analyzed for significant differences. The variations in temperature, DO, pH, TDS, TSS, COD, BOD, chloride, nitrate, ammoniacal nitrogen of the surface water are shown in fig. 2.

2.4. Calculation of WQI

The water quality index was calculated by using the Weighted Arithmetic Index method [9] using 10 parameters which are temperature, pH, DO, BOD, COD, TDS, TSS, chloride, nitrate and ammoniacal nitrogen. The unit weights (W_i) for each parameter are calculated as follows:

$W_i = \frac{K}{S_n}$ and $W_n = \sum W_i$, where, K is proportionality constant and can be calculated as, $K = \frac{1}{\sum (1/S_n)}$

S_n is the standard allowable limit. The quality rating Q_n is calculated as follows:

$V_n - V_{io}$

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(1), 289-300 | ISSN:2251-6727

$Q_n = (\underline{\qquad})\times 100$
$Sn - Vio$
Where, V_n is the mean measured value and V_{io} is the ideal value of water. The water quality index is calculated as following [10]
$\sum QnWn$
$WQI = \underline{\qquad}$
$\sum W_n$
In table 4, the Water Quality Index is used to classify the water bodies into different groups.

Table 4: The water quality and its WQI value range.

S.N.	**Water quality**	**WQI**
1.	Excellent quality water	0–25
2.	Good quality water	26–50
3.	Poor quality water	51–75
4.	Very poor-quality water	76–100
5.	Unfit for drinking	>100

3. Results and Discussion

The variation in temperature at various sampling sites is shown in Fig. 2(a). The temperature levels at all sampling sites are under the prescribed limits of BIS. The variation in pH value at various sampling sites is shown in Fig. 2(b). The pH value is dependent on the nature of dissolved salts and minerals causes it as acidic or alkaline. The pH of surface water was ranged from 4.38 to 8.82 at different sites of location. The maximum value of pH was observed 8.82 in site 1. It's due to the relative higher concentration of bicarbonate ions which are considered as the important contributors to large pH**.** The minimum value of pH was observed 4.38 in site 9 and site 11. It is mainly due to the dissolved gases such as carbon dioxide and hydrogen ions which are the main contributors to small pH. Most of the samples have the pH values in the range set by BIS.

DO content in water plays an important role for aerobic oxidation of the wastes, discharge in river. DO levels are also found important in the natural self-purification capacity of the river. It is the most important indicators of river health, as it drops below 4-5 mg/L the forms of life begin to reduce significantly while the life goes in loss if it is found less than 2 mg/L that is necessary to maintain higher life forms. The variation in DO at various sampling sites is shown in Fig. 2(c). DO varies from 0.25 to 8.98 mg/L at different location sites. The worst condition of water quality was observed at the site 9, 10 and 11. The minimum value of DO at site 11 was observed 0.25 mg/L. It may be due to the organic and microbial load that were high oxygen-demanding wastes.

TDS comprises of inorganic salts and some small amounts of organic matter. The variation in TDS at various sampling sites is shown in Fig. 2(d). TDS were varied from 146 to 1890 mg/L at different location. The maximum value of TDS at site 5 was observed 1890 mg/L, which may be caused by carbonate deposits, salt deposits, agricultural runoff, and point/non-point wastewater discharges. TDS value were observed above permissible limit at all sites except site 1, 2, 3 and 4.

TSS are particles which are larger than 2 microns found in the waste water. Smaller than 2 microns solids are considered a dissolved solid. Most suspended solids belong to inorganic materials while bacteria and algae can also contribute to the total solid concentration. The variation in TSS at various sampling sites is shown in Fig. 2(e). TSS were ranged from 5 to 562.4 mg/L at different sampling sites. The maximum value of TSS was observed 562.4 mg/L at site 1. TSS value were observed above
permissible limit at site 9 and 11.

Table 5: Minimum, maximum, mean and Standard deviation (S.D.) of parameters of different surface water quality at different location at Bijnor during September 2020-March 2021.

Parameters	**Temp (°C)**	**DO (mg/L)**	**pH**	**TDS (mg/L)**	**TSS (mg/L)**	**COD (mg/L)**	**BOD (mg/L)**	**Cl^- (mg/L)**	**NO3- (mg/L)**	**NH_3-N(mg/L)**

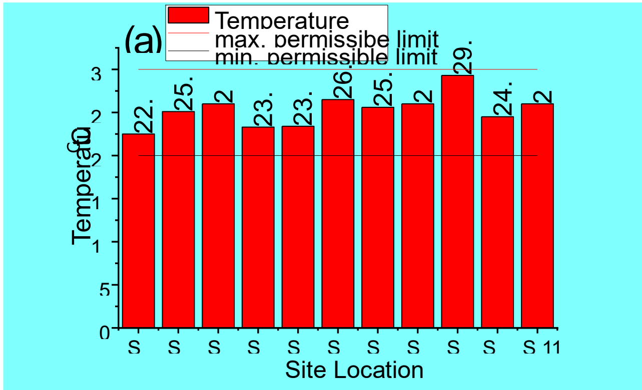
Site 1	**Min**	12	6.6	7.62	146	54	5 102	2	15	0.58	1
	Max	31.5	8.98	8.82	455	562		20	35.1	2.4	6.4
	Mean± SD	22.51± 6.87	8.32± 0.75	8.23± 0.37	358.71± 93.60	197.77± 178.23	49.29± 33.48	10.57± 6.32	27.04± 6.25	1.49± 0.64	3.41± 2.59
Site 2	**Min**	15.1	7.04	7.58	333	5	5	2	7	0.02	1
	Max	33.8	8.68	8.38	480	25.5	32	5	53.4	1.6	2.4
	Mean± SD	25.07± 6.65	7.99± 0.51	8.01± 0.26	396.29± 43.87	14.54± 8.38	11.00± 8.94	4.14± 1.36	21.97± 13.86	0.87± 0.62	1.43± 0.62
Site 3	**Min**	14.9	6.84	7.5	194	10	5 148	2	7	0.02	1
	Max	34.9	8.53	8.42	436	154		28	29.1	2.4	6.8
	Mean± SD	26.00± 7.08	7.83± 0.60	8.01± 0.27	361.00± 71.91	57.64± 46.89	27.43± 49.28	7.43± 8.50	19.36± 7.64	1.32± 1.01	2.23± 2.10
Site 4	**Min**	14.4	6.6	7.6	272	8 208	5 110	2	7	0.7	1
	Max	31.8	8.8	8.45	482			23	34	3.4	14.6
	Mean± SD	23.29± 5.75	7.87± 0.72	7.88± 0.27	349.86± 67.56	52.57± 65.97	32.00± 34.85	7.79± 6.44	19.40± 8.21	1.83± 1.07	3.34± 4.63
Site 5	**Min**	15.7	3.27	7.39	314	5 233	5 298	2	17	0.5	1
	Max	30.3	8.76	7.94	1890			85	728.5	4.4	29.2
	Mean± SD	23.36± 5.22	6.54± 1.95	7.70± 0.19	731.29± 516.45	58.66± 73.08	82.43± 99.59	20.21± 27.63	148.84± 242.10	1.61± 1.22	6.56± 9.54
Site 6	**Min**	24.2	5.85	7.195	813	9	5 118	4	36.4	0.05	1
	Max	29.2	6.64	7.62	1194	26		28	441.9	2.8	12

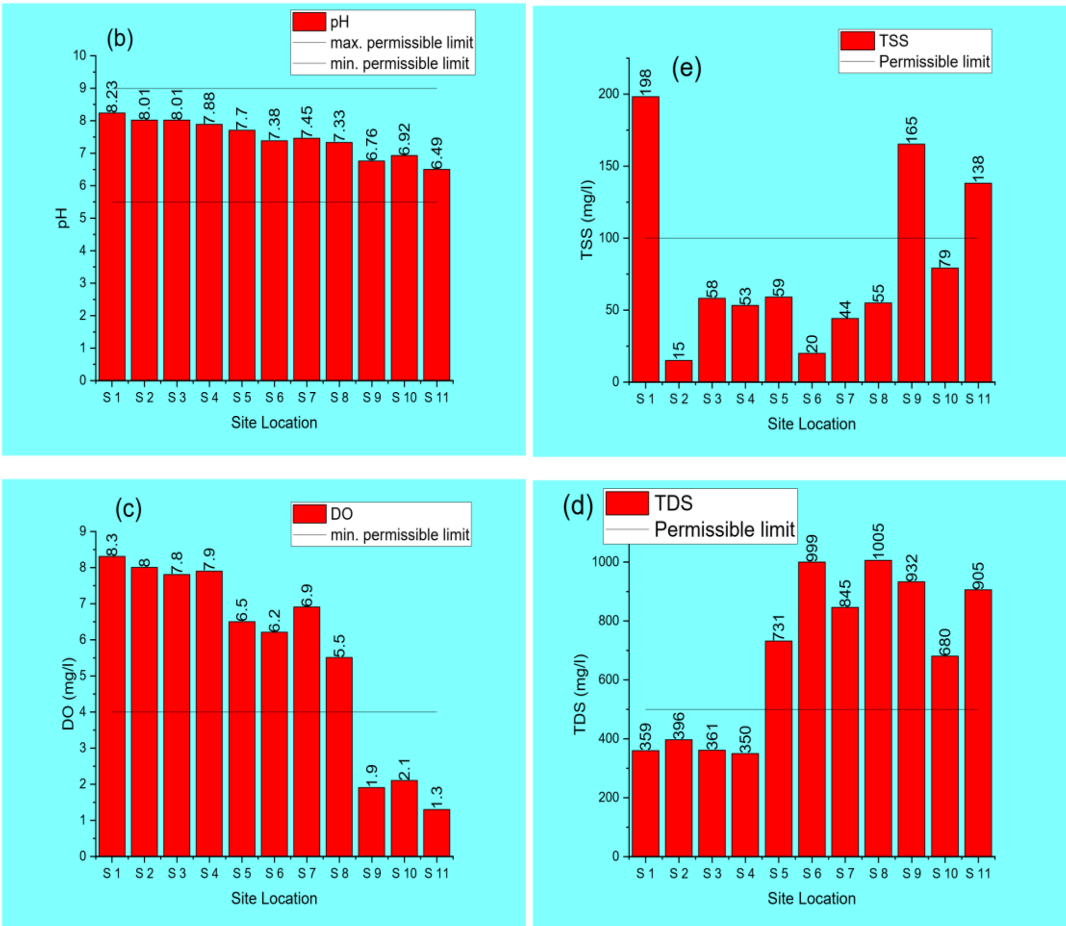
	Mean± SD	26.51± 1.72	6.15± 0.24	7.38± 0.14	999.00± 116.98	20.23± 5.80	63.57± 38.16	14.71± 8.56	294.62± 125.99	1.94± 0.94	4.99± 3.59
Site 7	**Min**	19.8	5.72	7.16	310	23.1	5 148	2	83	0.54	1
	Max	30	8.82	7.75	1197	94		41	421.5	3.4	20.4
	Mean± SD	25.63± 3.30	6.88± 0.96	7.45± 0.21	844.86± 275.42	44.44± 24.18	92.14± 54.52	20.86± 13.41	293.33± 112.79	2.00± 1.10	7.90± 6.41
Site 8	**Min**	20.3	2.84	7.11	398	10	5 352	2 110	80	0.36	1
	Max	30.1	8.59	7.51	1780	120			665.3	4.8	36.6
	Mean± SD	26.04± 3.18	5.53± 1.59	7.33± 0.15	1005.29± 416.08	55.43± 32.94	146.00± 109.29	36.71± 34.74	362.57± 186.11	2.08± 1.38	11.63± 11.25
Site 9	**Min**	17.2	0.96	4.38	550	62	104	18	59	0.9	1
	Max	36	3	7.6	1880	259	5880	3400	499.8	5.4	58.8
	Mean± SD	29.33± 6.50	1.88± 0.56	6.76± 1.00	932.29± 407.84	164.71± 60.68	1126.14± 1947.47	580.57± 1153.26	188.20± 153.48	2.96± 1.32	26.00± 18.85
Site 10	**Min**	16.6	0.54	4.75	462	22	124	22	22	0.54	2.4
	Max	33.8	4.03	7.44	888	142	1392	530	160.4	3.6	52.7
	Mean± SD	24.54± 5.75	2.11± 1.28	6.92± 0.89	680.29± 123.82	79.07± 40.85	362.86± 422.56	117.79± 169.05	91.67± 39.42	2.56± 1.18	21.91± 16.55
Site 11	**Min**	17.8	0.25	4.38	554	62.6	104	18	59.9	0.96	1.4
	Max	36.5	2.9	7.36	1888	208	5886	3400	2489.5	4.1	52.4
	Mean± SD	25.95± 6.14	1.27± 0.94	6.49± 1.06	905.29± 416.53	137.73± 43.59	1226.00± 1940.15	603.86± 1148.81	463.23± 832.11	2.74± 1.00	27.01± 17.15

The variation in BOD at various sampling sites is shown in Fig. 2(f). The value of BOD throw light on the indication of organic pollution in the aquatic systems that severally affect the quality of river water and biodiversity. BOD varied from 2 to 3400 mg/L at different location sites. At site 9, site 10 and site 11, BOD was higher than other sites, possibly due to mixing of wastewater from drains from city and industries. The maximum value of BOD was observed 3400 mg/L in the site 9 and site 11. A significant relationship is also seen between BOD and DO that indicates directly organic pollutant load in surface water system.

The variation in COD at various sampling sites is shown in Fig. 2(g). It shows that COD has become an important parameter of water that indicate the health scenario of freshwater bodies. COD varied from 5 to 5886 mg/L at different sampling sites. The value of COD was observed above permission limit at site 5, 8, 9, 10 and 11. The worst condition of water quality were observed at the site 9, 10 and 11. The maximum value of BOD was observed 5880 mg/L in the site 9.

It has been observed that chlorides are considered as a common pollutant of water. It is found in water in most of time. Sources of chloride are rocks containing chlorides, agricultural runoff, wastewater from industries and effluent wastewater from wastewater treatment plants. The variation in chloride at various sampling sites is shown in Fig. 2(h). Chloride was ranged from 7 to 2489.5 mg/L at sampling sites. The maximum value of chloride was observed 2489.5 mg/L at site 11. The mean value of chloride was under the permissible limit at all sampling sites.





157

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(1), 289-300 | ISSN:2251-6727

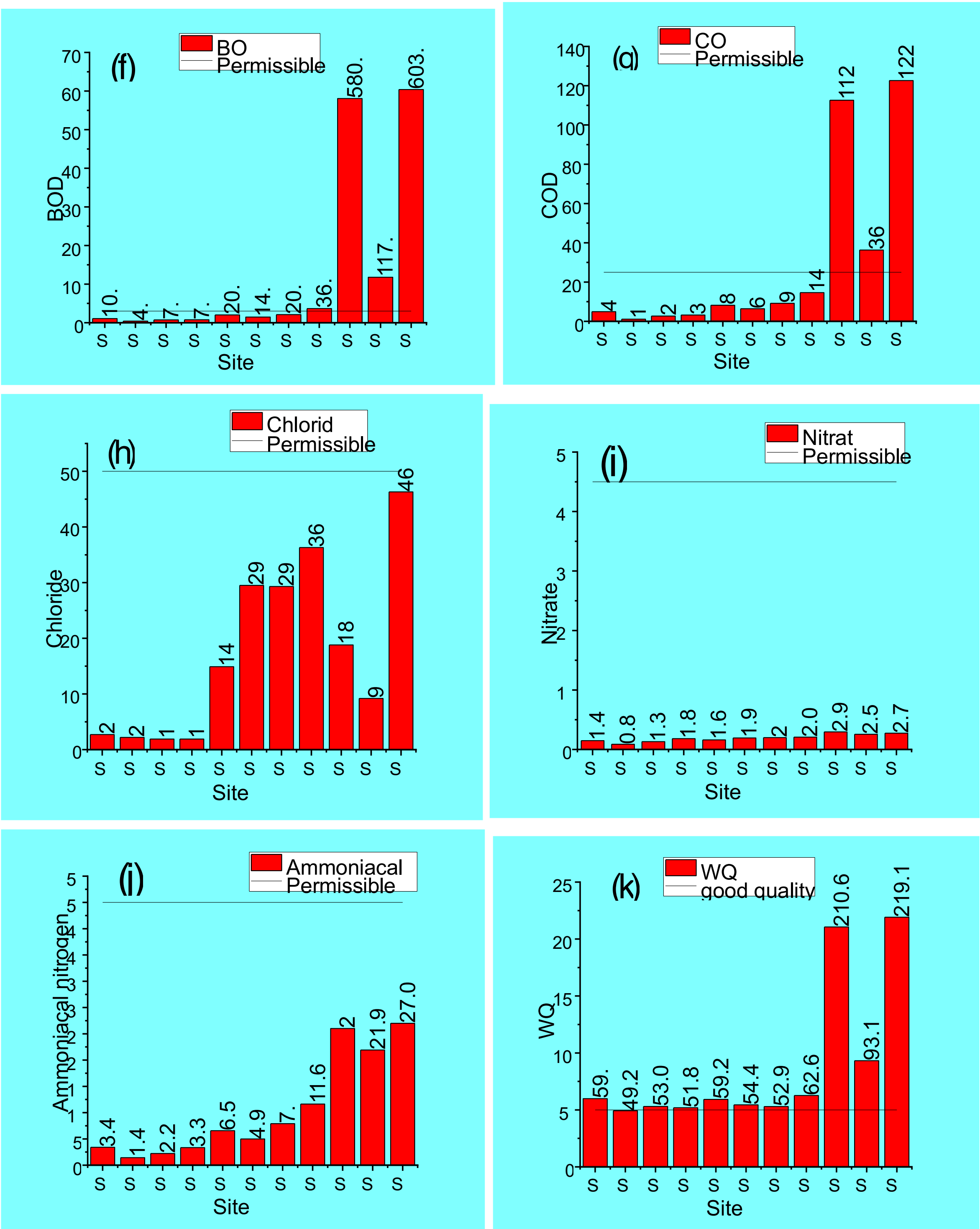


Fig. 2 (a-k) The variations in temperature, DO, pH, TDS, TSS, COD, BOD, chloride, nitrate, ammoniacal nitrogen and WQI.

The content of N in the river water is in the both organic and inorganic nitrogen form. The primary inorganic form of nitrogen are ammonia, ammonium, nitrite and nitrate. The organic form of nitrogen is found in amino acids of proteins, urea, living or dead organism and decaying plant material. Ammonium ions are toxic to aquatic life at higher concentration. In the drain/river, ammonium ions are transformed to nitrite, which is

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(1), 289-300 | ISSN:2251-6727

likewise hazardous to aquatic life. Finally, nitrites are transformed to nitrates, which are not as harmful as ammonium ions or nitrites but can cause eutrophication. The variation in nitrate at various sampling sites is shown in Fig. 2(i). Nitrate value were ranged from 0.02 to 5.4 mg/L at different sites location. It was under the permissible limit. The variation in ammoniacal nitrogen at various sampling sites is shown in Fig. 2(j). Ammoniacal nitrogen value were ranged from 1 to 58.8 mg/L at different sampling sites. The maximum value of Ammoniacal nitrogen was observed 58.8 mg/L at site 9. It may be agricultural runoff, discharge of untreated sewage and effluents, and nonoperation of existing treatment plants.

The water quality graph was made for each parameter and finally provides the overall WQI graph of all sites as shown in Fig. 2(k). As seen, only site 2 region had lower WQI and other sites had higher WQI. The worst water quality is found at site 9 and 11 where WQI value is more than 200. It is unfitted for drinking and other purpures. Table 6 summarizes the WQI of study areas.

Table 6: The results of WQI value and water quality status of all sampling sites.

Location	**WQI Value**	**WQ Status**
Site 1	59.9	Poor
Site 2	49.29	Good
Site 3	53.03	Poor
Site 4	51.86	Poor
Site 5	59.27	Poor
Site 6	54.42	Poor
Site 7	52.94	Poor
Site 8	62.61	Poor
Site 9	210.63	Unfit for consumption
Site 10	93.19	Very Poor
Site 11	219.17	Unfit for consumption

Table 7: Summary of surface water quality status at Bijnor area.

Parameters	**Range**	**Mean**	**S.D.**
Temperature	12-36.5	25.29	5.84
DO	0.25-8.98	5.67	2.74
pH	4.38-8.82	7.47	0.77
TDS	146-1890	687.65	387.37

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(1), 289-300 | ISSN:2251-6727

TSS	5-562.4	80.25	89.69
COD	5-5886	292.62	942.56
BOD	2-3400	129.51	540.58
Chloride	7-2489.5	175.48	314.47
Nitrate	0.02-5.4	1.94	1.22
Ammoniacal nitrogen	1-58.8	10.58	14.07

4. Conclusions

Table 7 provides an overview of surface water quality of the study area. It's apparent that the water quality is not good enough for residential or irrigation use. DO, TDS, COD, and BOD levels were several times higher than the allowed limit for critical water quality metrics. The pollution indicating parameters at sites 9, 10, and 11 revealed wide variations; yet, these three sampling sites fall into the group of severely polluted sites at Bijnor. The major thread of surface water quality at Bijnor was urban runoff and industrial wastewater discharges in drains. In general, the quality of river water for home and irrigation uses is poor.

Authors contribution

Vijay Kumar collected the water samples and analyzed in laboratory. Vijay Kumar and Chandrajit Balomajumder conceived and designed the analysis. Vijay Kumar performed the analysis and Chandrajit Balomajumder supervised the research. Vijay Kumar wrote the manuscript, and Chandrajit Balo Majumder edited the manuscript. All authors read and approved the final manuscript.

Acknowledgement

The financial support for this study was received from CPCB, MoEF, Govt. of India and IIT Roorkee.

The authors have no competing interests to declare that are relevant to the content of this article.

References

1. G. Matta et al. Impact assessment of Dhampur sugar mill effluent on water quality of Bijnor district (U . P .). Researcher 2016; vol. 8, no. 10, pp. 64–70. https://doi: 10.7537/marsrsj081016.11.Key.
2. Kanu, Ijeoma and Achi, O.K. Industrial Effluents and Their Impact on Water Quality of receiving rivers in Nigeria. Journal of applied technology in Environmental sanitattion 2011; vol. 1, no. 1, pp. 75–86.
3. S. K. Gurjar and V. Tare. Spatial-temporal assessment of water quality and assimilative capacity of river Ramganga, a tributary of Ganga using multivariate analysis and QUEL2K. J. Clean. Prod. 2019; vol. 222, pp. 550–564. https://doi: 10.1016/j.jclepro.2019.03.064.
4. K. P. Singh, A. Malik, and S. Sinha. Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques - A case study. Anal. Chim. Acta 2005; vol. 538, no. 1–2, pp. 355–374. https://doi: 10.1016/j.aca.2005.02.006.
5. BIS, Indian Standard Drinking Water Specification (Second Revision), vol. IS 10500, no. May. 2012. http://cgwb.gov.in/Documents/WQ-standards.pdf.
6. R. W. Herschy, Water quality for drinking: WHO guidelines. 2012. https://doi: 10.1007/978-1-4020-4410-6_184.
7. N. S. Kawo and S. Karuppannan. Groundwater quality assessment using water quality index and GIS technique in Modjo River Basin, central Ethiopia. J. African Earth Sci. 2018; vol. 147, no. January, pp. 300–311. https://doi: 10.1016/j.jafrearsci.2018.06.034.
8. E. W. R. Rodger B. Baird, Andrew D. Eaton. Standard methods: For the examination of water and waste water. 2017; vol. 23, no. 1. https://doi: 10.1016/0003-2697(90)90598-4.
9. Cude C: Oregon Water Quality Index: A tool for evaluating water quality management

effectiveness. Journal of American Water Resources Association 2011; 37, 125-137.

10. J. S.n. et al. Assessment of water quality Index and study of the impact of pollution on the rivers of Kerala. Mater. Today Proc. 2020; vol. 43, no. xxxx, pp. 3447–3451. https://doi: 10.1016/j.matpr.2020.09.084.
11. Bhutiani R, Faheem A, Tyagi V, Khushi R. Evaluation of water quality of River Malin using water quality index (WQI) at Najibabad, Bijnor (UP) India. Environment Conservation Journal 2018; 19 (1&2), pp 191-201.
12. Bora1 M, Goswami1 D C. Water quality assessment in terms of water quality index (WQI): case study of the Kolong River, Assam, India. Appl Water Sci. 2017; 7, pp 3125–3135.
13. ICMR. Manual of Standards of Quality for drinking water supplies. Indian Council of Medical Research. Spe. Rep. 1975; No.44:27.
14. Khan M Y A, Gani K M, Chakrapani G J. Assessment of surface water quality and its spatial variation. A case study of Ramganga River, Ganga Basin, India. Arab J Geosci 2016; 9:28.
15. Matta Gagan et al. Assessment of water quality of Choyyia Nadi (River) Catchment area in Bijnor District, Uttar Pradesh, India. Eco. Env. & Cons. 26 (November Suppl. Issue) 2020; pp (S402-S412).
16. Mokarram M, Saber A, Sheykhi V. Effects of heavy metal contamination on river water quality due to release of industrial effluents. Journal of Cleaner Production 2020; 277, 123380. journal homepage: www.elsevier.com/locate/jclepro.
17. Mukherjee D, Chattopadhyay M, Lahiri S C. Water quality of river Ganga (The Ganges) and some of its physico-chemical properties. The Environmentalist 1993; 13(3), pp 199–210.
18. Roy M, Shamim F. Research on the Impact of Industrial Pollution on River Ganga: A Review. International Journal of Prevention and Control of Industrial Pollution 2020; Vol. 6: Issue 1. www.journalspub.com.
19. Shrestha S, Kazama F. Assessment of surface water quality using multivariate statistical techniques: a case study of the Fuji river basin, Japan. Environ. Model. Software 2007; 22 (4), pp 464-475.
20. Suthar S, Sharma J, Chabukdhara M, Nema A K. Water quality assessment of river Hindon at Ghaziabad, India: impact of industrial and urban wastewater. Environ Monit Assess. 2010; 165, pp 103–112.