Plant Archives Vol. 18 No. 1, 2018 pp. 1074-1080 ***ISSN 0972-5210***

ECOLOGICAL ASSESSMENT OF GHAGGAR RIVER WITH DIATOMS

Ravi Kant Pareek[1], Ambrina S. Khan[2], Prateek Srivastva[2], Surendra Roy[3] and Sarika Grover[2]

[1]Department of Civil Engineering, Vivekananda Global University, Jaipur - 303 012 (Rajasthan), India.
[2]Amity Institute of Environmental Sciences, Amity University, Noida - 201 303 (Uttar Pradesh), India.
[3]Department of Civil Engineering, P.S.I.T., Kanpur - 209 305 (Uttar Pradesh), India.

Abstract

The ecological study of diatoms and river water chemistry in Ghaggar River was carried out throughout its stretch, for the period of May 2015. 27 diatom species were identified for water quality assessment. From the data it was found that the polluted water in the study area has presents the dominance of diatom species *Achnanthidium minutissimum*, *Achnanthidium petersenii*, *Navicula stroemi*, *Navicula symmetrica*, *Nitzschia acicularis*, *Nitzschia acuta*, *Nitzschia amphibia*, *Nitzschia cryptotenella*, *Synedra rumpen*s, *Synedra tabulata*, *Synedra ulna*, *Ulnaria ulna*. This is also evident by Principal component analysis. This study asses the reason for variation in community composition with location specific environmental characteristics.

Key words : Ecological assessment, diatom, water quality assessment and Ghaggar river.

Introduction

Since time immemorial, rivers have been considered the most important freshwater resource for human. Unfortunately, river waters are being polluted by indiscriminate disposal of sewerage, industrial waste and excess of other human activities, which affects the waters physico-chemical characteristics and microbiological quality (Chetanas and Somasekhar, 1997). Pollution of surface water with toxic chemicals and eutrophication of rivers and lakes with excess nutrients are of great environmental concern worldwide. Agricultural, industrial, and urban activities are considered as being major sources of chemicals and nutrients to aquatic ecosystems, while atmospheric deposition could be an important source to certain constituents such as mercury and nitrogen. The concentrations of toxic chemicals and biologically available nutrients in excess can lead to diverse problems such as toxic algal blooms, loss of oxygen, fish kills, loss of biodiversity, and loss of aquatic plant beds and coral reefs .Pollution of the aquatic environment is a serious and growing problem (ShamSundar, 2007; Sukhdev, 2012).

River Ghaggar, a major river of northern India, originates in the Shivalik Hills of Himachal Pradesh and flows through Punjab, Haryana and Rajasthan. In Haryana, it flows through south-west of Sirsa and by-the-side of Talwara Jheel in Rajasthan and then disappear itself in the sands of the Thar Desert. Patiala Nadi joins the Ghaggar at Ratnedi, Punjab, Markandya River near Kaithal and a dried out channel of the Sutlej, joins the river Ghaggar near Sadulgarh (Hanumangarh), the Naiwal channel. The Ghaggar then joins with the dried up Drishadvati (Chautang) river.

Yet there are no reports available in literature on the level of ecological assessment throughout the stretch of river Ghaggar. This is the first report on ecological assessment of the river Ghaggar for whole stretch.

Water quality parameters can be broadly classified into three different types: physical, chemical and biological. Physical parameters consist of temperature, turbidity, color and odor; chemical parameters include things like pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), Nitrogen and Phosphorus; and Biological parameters consist of occurrences of Fecal Coli-form and other pathogens. Physico-chemical properties of water are routinely utilized for understanding environmental quality. Diatoms are used as bio-indicators to assess the water quality of surface waters. Diatoms are the main producers in rivers. Diatoms are present in all the aquatic environments. Diatoms can be easily collected and preserved. Due to their rapid response to environmental changes, deterioration of water quality especially from impacts such as nutrient enrichment, acidification and metal contamination diatoms have been used widely for biomonitoring of aquatic ecosystems (Kelly and Whitton, 1995). Diatoms are one of the basic components of river bio-monitoring and assessment of ecological status of rivers.

River diatoms are sensitive to pollution or other events and are therefore commonly used for However, diatoms of fresh water rivers have been studied extensively in India (Mishra and Saksena, 1993; Trivedy and Khatavkar, 1996). Various diatom groups prefer to exist in various kinds of water.

Materials and Methods

Study area

Samples of Ghaggar water were collected from sixteen different sites along the stretch of river. During its westward journey, a number of streams, drains and tributaries discharge their load into the Ghaggar. After flowing through Morni Hills before entering the plains, the Ghaggar River is joined by the Kaushalya Nadi in the foothills zone. The small streams *viz*. Kaushalya, Jhajra and Ghaggar get combined together near Chandimandir to form the main Ghaggar River. Further, at downstream sites various point and non-point sources are joining the Ghaggar River and discharging their untreated effluents into it. The area under investigation lies between North latitudes $30^0$45'5.93" to 29°11'49.29" and East longitudes $76^0$54' 36.79" to $73^0$13' 26.88" Area under investigation covers parts of different districts of Haryana, Punjab and Rajasthan like Panchkula, SAS Nagar (Mohali), Patiala, Ambala, Kaithal, Fathehabad, Sirsa, Hanumangarh and Sri Ganganagar. The research area enjoys humid to sub-humid type of climate characterized by extreme summers and chilly winters with large seasonal fluctuations in both temperature and rainfall. The temperature may raise upto 47°C in hottest month and may drop to less than 1°C in winter. In the upper part of the Shivalik hills precipitation of 1000-1500 mm and in lower regions precipitation is only 200mm.

The brief description of sampling stations is as follows:

1. S-1 (Amaravati Enclave): Sample was collected from Amaravati Enclave, here Ghaggar is known as Kaushalya River.
2. S-2 Chandi mandir- Here two streams meet, and from Here River is known as Ghaggar.
3. S-3 (Sec. 25 Panchkula): Further, downstream the Ghaggar River water was sampled near sec. 25 here another stream meets to Ghaggar river.
4. S-4 Daffarpur- Upstream to this sampling site Medkhali Nallah is joining the Ghaggar River course, so river water was collected from downstream side to check the impact of effluents.
5. S-5 (Mubarkpur): Here Baltana Drain meets Ghaggar River which carrying waste (industrial & sewage) Chandigarh and Panchkula.
6. S-6 (Bhagwanpur): this site is in-between Mubarkpur and tepla. Here there is no point source added into the Ghaggar river.
7. S-7 (Tepla): Here Jharmal Choe meets the Ghaggar River, which carrying industrial and domestic sewage of Derabasi, Lalru and Zirakpur.
8. S-8 (Surala): Here Dhakansu Drain meets the Ghaggar River which is a combined drain of Mohali, Chandigarh and Rajpura Industrial waste
9. S-9 (Ratnedi) downstream: Here Patiala River meets the Ghaggar River. Jacob drain meets the Patiala River which carries industrial waste from Patiala region. Patiala River itself carries the sewage and industrial waste from Patiala.
10. S-10 (Ratnedi) upstream
11. S-11(Khanori, Punjab) One Nallaha fell here carrying domestic waste of Khanori
12. S-12 (Jakhal). It is an agricultural area
13. S-13 (Ratia). Ratia is a municipal town of Haryana. Sewage and industrial effluents (mainly soap factories) discharged into the Ghaggar River.
14. S-14 (Sardulgarh). Sardulgarh is a municipal town of Punjab. Sewage and industrial effluents (mainly soap factories) discharged into the Ghaggar River.
15. S-15 (Dabwali Road, Sirsa): Here Samsabad drain meets the River, which carries the Sewage and industrial waste (Mainly card board industries, Soap industries, Rice mills).
16. S-16 (Ottu Wier): The river water is blocked at weir; as such the river does not have any water downstream. All river water was diverted to canal in Haryana.
17. S-17 (Talwara Jheel): Sampling is not possible here due to dry bed of river.
18. S-18(Hanumangarh): Sampling is not possible here due to dry bed of river.
19. S-19 (Drishadvati Chautang) River: Sampling is not possible here due to dry bed of river.

20. S-20 (Annopgarh Bridge):Sampling is not possible here due to dry bed of river.

Sample collection and laboratory testing : After determining the location of the sampling points, 16 samples of water was collected for physico chemical parameters. For heavy metal analysis the primary sampling point was in the surface water layer (0-5 cm from the surface) at main flow. Surface water was collected using acid-leached polythene bottles and chilled immediately to 3º to 4ºC. All samples were tested according to APHA (2005).

For Diatom water samples were collected separately in 250 ml plastic bottles from all obtainable habitats such as plants (epiphytic) and stones (epilithic) following Karthick *et al*. (2010). Further, diatom samples were collected by brushing stones with a toothbrush, following recommendations of Kelly *et al*. (1998). At least five, pebbles to cobble (5-15 cm) sized stones were collected from the river bottom. They were brushed and the diatom suspension was put in a small plastic bottle. In all studies, diatom samples were preserved in formaldehyde (4%). In the laboratory, diatoms samples were cleaned with hot HCl and $KMnO_4$ to remove organic coatings. This method is based on Hasle (1978) and adapted by Round *et al*. (1991). It has been found suitable for cleaning diatom samples collected in India (Karthick *et al*., 2010). Permanent slides were prepared using Naphrax (Brunel Microscopes Limited; Refractive index of 1.64. The identification and counting of taxa were carried out under a light microscope (Leica, DM750) at a 100 × magnification using immersion oil. More than 800 diatoms frustules were counted for each slide for the computation of relative abundances of species and calculation of diatom indices. For ensuring taxonomic accuracy, SEM was performed with a Carl Zeiss EVO 18 at AIAE, Amity University, Noida, India.

Statistical analyses comprising Principal component analysis (PCA) was performed using CANOCO software version 4.5, to explain the water quality variation.

Results and Discussion

Physical-chemical characteristics of river water

The physico-chemical characterization of the surface waters samples is given in table 1. In surface waters samples, temperature ranges from 27.8 to 33°C with a mean of 30.51°C. In general, in entire Ghaggar river system surface water samples temperature values crossed the prescribed range of WHO (2004) for drinking water. Field investigations revealed that the pollution in these locations is due to the discharges of sewages and industrial effluents. Colour of the samples varies from 25 to 500 on cobalt scale. pH of water varied from 7.2 to 7.69 with a mean of 7.34. In our study, water was showing slightly alkaline nature. pH of all the water samples was within the safe limits. The electrical conductivity (EC) varied in the range from 0.49 to 1.94 with a mean value of 1.04. At various sampling sites point sources wastewaters were affecting the river water conductivity. EC has a wide applicability with respect to agricultural uses. But for drinking point of view high conductivity denotes proportionately high value of calcium, magnesium, sodium and potassium. Total dissolved solids (TDS) varied from 302to 1275 mg/l with a mean value of 648.5 mg/l. Water containing less than 500 mg/l of dissolved solids is suitable for domestic use. Although, the mean values of dissolved solids in water samples were rather similar to the proposed WHO drinking water standards, though at two sites it crosses the maximum permissible limit. High concentration of salts of sodium, calcium and magnesium is generally responsible for high concentrations of TDS. The sources of dissolved solids in water are natural as minerals in soils and anthropogenic as agrochemicals. Bicarbonate contents varied from 189 to 308 mg/l with mean of 256.31 mg/l. All the samples showed the bicarbonate values within the prescribed limits. Chloride occurs in all natural waters in widely varying concentration. Chloride normally increases as the mineral contents increases (Dubey, 2003). Water containing more than 250 mg/l of Cl^- ion has salty taste. In our study, chloride is ranged from 29 to 261 mg/l with a mean value of 99 mg/l. In our study, chloride concentration remains well within the prescribed limit at 15 sites except S7. The concentration of sulfate varied from 18 to 98 mg/l with a mean value of 42 mg/l. All the samples are within safe limit. The concentration of phosphate varied from 0.03 to 22.48 mg/l with a mean value of 7.98 mg/l. Further, 16% surface waters samples were showing sodium concentration above the prescribed limit of WHO (2004). In our study, potassium ranged from 3 to 19 mg/l with a mean concentration of 10.81 mg/l. Concentration of potassium is within the limit. None of the sample shows pesticides. The concentration of Total Phosphorous varied from 0.04 to 34.54 mg/l with a mean value of 10.59 mg/ l. It shows great variation, lower sites shows more strength of total phosphorous. Ghaggar River is contaminated throughout its stretch as the range of MPN (*E. coli*) varies from 21000 to 4300000/100 ml with a mean of 830562.50/ 100 ml. Contamination is due to direct discharge of sewage into the river. Heavy metals (Fe, Hg, As, Pb, Cu, Zn, Cd, Ni, Cr) were analysed. All in all, the dominancy of the analyzed heavy metals in the surface water of Ghaggar followed the sequence: Fe> Zn > Ni >

Table 1 : Physical and chemical variables measured in the surface water of the 16 sites.

Site	Color	Temp	Turb	pH	EC	TSS	TDS	Ca	Mg	Cl	SO_4	TA	Acidity	TH	Na	K
1	25	27.8	0.54	7.62	0.559	11	364	54	34	30	23	205	0	276	6	3
2	28	27.8	0.85	7.5	0.51	12	321	53	32	32	21	212	0	283	8	5
3	30	27.9	0.85	7.69	0.487	13	302	53	34	29	18	203	8	270	9	4
4	121	30.2	241	7.3	0.622	65	411	51	41	32	21	200	16	276	12	6
5	250	32.3	279	7.23	0.822	82	537	48	43	63	32	210	26	301	14	8
6	181	32	181	7.2	0.773	65	450	65	42	69	32	202	25	298	16	7
7	150	33	199	7.32	0.973	92	626	64	47	261	42	302	20	353	19	11
8	150	31.2	258	7.28	0.691	72	451	61	45	47	29	292	16	340	13	7
9	500	32.1	44	7.4	1.501	118	849	69	39	143	61	289	10.9	341	21	19
10	287	32	78	7.28	0.973	71	511	41	23	211	32	334	23	331	21	9
11	200	30.1	202	7.16	1.701	162	1120	72	56	138	98.5	308	18.2	414	32	18
12	500	30.2	40	7.2	1.301	112	829	69	38	111	58	280	10.4	330	23	15
13	500	30.2	30	7.26	1.277	152	817	70	36	108	54	276	12	326	28	13
14	500	31.6	60	7.36	1.935	130	1275	66	38	104	49	277	11.2	324	24	18
15	500	31.2	44	7.3	1.401	116	821	61	37	117	59	290	10.6	334	19	16
16	250	28.6	65	7.31	1.035	145	692	58	48	97	48	300	13.2	346	21	14
Max	500	33	279	7.69	1.94	162	1275	72	56	261	98	334	26	414	32	19
Min	25.00	27.80	0.54	7.2	0.49	11	302	41	23	29	18	200	26	270	6	3
Mean	260.75	30.51	107.7	7.34	1.04	88.63	648.5	59.69	39.56	99	42	261.25	13.78	321.44	17.88	10.81

Site	$CaCO_3$	Bicarbonate as $CaCO_3$	Cl_2	DO	BOD (3 days)	COD	Fe	Hg	As	Pb	Cu	Zn	Cd	Ni	Cr
1	0	205	0	7.9	7	57	0.156	0	0	0.021	0	0	0	0	0
2	0	189	0	7.8	7	59	0.184	0	0	0	0	0	0.018	0	0
3	0	203	0	8	6	53	0.156	0	0	0	0.023	0.023	0	0	0
4	0	201	0	6	16	54	1.11	0	0	0	0.016	0.045	0	0	0
5	19	210	0	2.8	18	60	1.21	0.081	0	0.039	0.015	0.044	0.034	0.002	0
6	16	198	0	5.5	16	116	0.85	0.058	0	0	0.025	0	0.012	0.003	0.04
7	6	302	0	7.7	9	82	2.13	0	0	0.062	0.062	0.013	0	0.002	0
8	6	292	0	4.2	21	54	1.23	0	0	0.071	0.052	0.058	0.021	0.002	0.023
9	5	278	0	2	29	205	0.69	0	0	0	0.036	0.03	0.022	0	0.05
10	0	302	0	4.2	12	81	0.31	0	0	0	0	0.012	0	0	0
11	0	308	0	7.2	29	236	0.9	0	0	0	0	0	0	0	0
12	0	280	0	7.5	17	137	0.6	0	0	0	0	0	0	0	0
13	0	276	0	7.4	16	133	0.49	0	0	0	0	0	0	0	0.086
14	12	277	0	7.6	15	127	0.66	0	0	0.075	0.019	0.0225	0	0	0.011
15	12	278	0	7.4	21	148	0.71	0	0	0.028	0	0.026	0	0	0
16	0	302	0	7.6	16	131	0.4	0	0	0	0.011	0.013	0.031	0.0125	0.018
Max	19.00	308	0	8	29	236	2.13	0.08	0	0.08	0.06	0.06	0.03	0.01	0.09
Min	19.00	189	0	2	6	53	0.16	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00
Mean	4.75	256.31	0	6.30	15.94	108.31	0.74	0.01	0	0.02	0.02	0.02	0.01	0.00	0.01

Site	Nitrate (as N)	Total Nitrogen (as N)	Phosphate (as P)	Total Phosphorus (as P)	Aldrin	Dieldrin	Endosul-fan	DDT (o,p&p,p-isomers of DDT, DDE & DDD)	MPN
1	3.65	1.32	0.04	0.04	BDL	BDL	BDL	BDL	56,000
2	3.85	1.58	0.04	0.04	BDL	BDL	BDL	BDL	85,000

Table 1 continued...

Table 1 continued...

3	3.88	1.68	0.03	0.12	BDL	BDL	BDL	BDL	101,000
4	3.21	6.23	1.23	0.98	BDL	BDL	BDL	BDL	98,000
5	7.35	9.98	7.27	10.86	BDL	BDL	BDL	BDL	112,000
6	6.21	6.21	5.12	2.2	BDL	BDL	BDL	BDL	112,000
7	6.58	12.32	7.11	11.67	BDL	BDL	BDL	BDL	1,200,000
8	7.72	10.62	6.44	9.45	BDL	BDL	BDL	BDL	950,000
9	8.03	24.18	11.8	12.69	BDL	BDL	BDL	BDL	2,310,000
10	5.12	11	8.11	12.21	BDL	BDL	BDL	BDL	211000
11	11.65	26.32	22.48	34.54	BDL	BDL	BDL	BDL	21,000
12	8.03	20.39	10.9	12.72	BDL	BDL	BDL	BDL	213,000
13	7.36	20.42	13.29	16.59	BDL	BDL	BDL	BDL	110,000
14	9.23	22.63	12.47	16.98	BDL	BDL	BDL	BDL	2,300,000
15	8.03	24.18	12.8	13.48	BDL	BDL	BDL	BDL	4,300,000
16	8.43	21.3	8.59	14.85	BDL	BDL	BDL	BDL	1,110,000
Max	11.65	26.32	22.48	34.54	0.00	0.00	0.00	0.00	4300000
Min	3.21	1.32	0.03	0.04	0.00	0.00	0.00	0.00	21000
Mean	6.77	13.77	7.98	10.59	0.00	0.00	0.00	0.00	830562.50

Table 2 : Diatom indices value for Ghaggar river.

	NB spec.	SLA	DESCY	IDSE/5	SHE	WAT	TDI	%PT	GENRE	CEE	IPS
S1	13	16.5	15	4.47	17.1	16	13.3	0	16.2	18.9	18.6
S2	15	16.3	14.9	4.42	17.6	17	13.7	0	16.4	19.1	18.8
S3	11	15.4	15.1	4.37	17.3	15.4	10.9	0	15.5	18.5	18.7
S4	13	14.3	13.7	4.1	17.4	15.2	10.2	0	14.9	18.1	14.7
S5	15	13.8	12.3	4.11	17	15.2	10.4	0	13.7	17.2	16.2
S6	15	11.4	11.7	3.52	16.5	14	11.7	0	13.4	14.3	13.5
S7	17	13	8.6	3.75	16.8	13.5	10	0	13.2	16	14
S8	19	13.1	12.6	3.93	17.3	14.4	12.8	0	15.8	17.7	17.1
S9	22	10.4	7.4	3.34	14.8	12.2	6	0	12.1	13.7	9.9
S10	19	11.1	6.6	3.32	14.6	11.5	6.8	0	12.2	12.2	12.3
S11	18	11.1	6	3.42	14.5	11.1	4.2	0	10.5	13.5	9
S12	16	12.2	7	3.67	15.6	9.3	5.9	0	12.7	15.3	10.2
S13	15	12	6.2	3.41	14.8	9.3	5.3	0	10.6	14.7	9.5
S14	14	11.5	8.9	3.7	15.3	10.9	5.8	0	13	14.1	9.9
S15	15	12.4	8.2	3.73	16.1	8.5	6.8	0	14.9	15.4	10.6
S16	12	11.6	8	3.7	14.9	11.5	7	0	12.4	15.6	9.6

Cu > Cd > Cr >Pb > Hg >As. Arsenic was absent in all the samples. Heavy metals can affect the humans through food chain (Abida *et al*., 2009).

A PCA was performed based on the physic-chemical data to explain the relationship between sampling sites and environmental variables. The first four axes explained 87.38% of the total variability. The PC1 had an eigen value of 0.5789, accounted for 57.89% of the total variability while PC2 had an eigen value of 0.1304. Physical and chemical parameters such as BOD, total alkalinity, total hardness, Mg, COD and $CaCO_3$ had high loading values along the PC1 axis and are closely associated with the sites S9 and S11. Variables such as temperature and Fe showed strong positive correlation along the PC2 axis. Sites such as S1, S2 and S3 are closely associated with the vector of pH and these sites are found to be more alkaline as compared to the other sampling sites. Parameters such as DO and temperature showed negative correlation from each other. Some of the sites along the PC2 axis are not associated with any of the physic-chemical parameter. Site S9 were the most polluted site and are strongly associated with the vectors of BOD, TSS, TDS and COD.

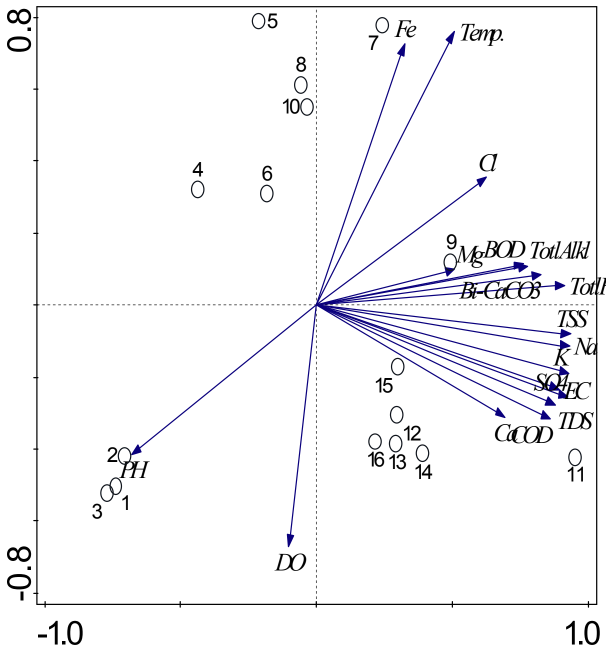

Fig. 1 : Principal component analysis showing site distribution based on physico-chemical parameters.

Table 3 : Class Limit value for diatom indices (Eloranta & Soinium, 2002) for IPS.

Range	Quality Class	Trophic Status
>17	High Quality	Oliogotrophic
15—17	Fine Quality	Oligo-mesotrophic
12—15	Moderate Quality	Mesotrophic
9—12	Low Quality	Meso-eutrophic
<9	Poor Quality	Eutrophic

Diatom distributions

A total of 25 diatom species belonging to 16 genera are recorded in the samples collected from the Ghaggar river. The diatom species recorded and identified in the present study are as follows: *Achnanthidium minutissimum*, *Achnanthidium petersenii*, *Aulacoseira granulata*, *Bracysira vitrea*, *Calonies beccariana*, *Cyclostephanos dubius*, *Cyclotella meneghiniana*, *Cocconeis pediculus*, *Cocconeis placentula var lineata*, *Cyclotella stelligera*, *Gomphocymbelopsis ancyli*, *Gomphonema exillissimum*, *Gomphonema sphaerophorum*, *Navicula cataracta-rheni*, *Navicula cryptotenella*, *Navicula stroemii*, *Navicula symmetrica*, *Nitzschia acicularis*, *Nitzschia acuta*, *Nitzschia amphibia*, *Nitzschia cryptotenella*, *Synedra rumpens*, *Synedra tabulata*, *Synedra ulna* and *Ulnaria ulna*.

For the calculation of different diatom indices, the diatom species counts were entered into the diatom database program OMNIDIA version 8.1 (Lecointe *et al.*, 1993) and the following indices were calculated as shown in table 2.

Table 4 : Classification of quality of sites according to IPS indices (Eloranta and Soinien, 2002).

Site	IPS	Quality Class
S1	18.6	High quality
S2	18.8	High quality
S3	18.7	High quality
S4	14.7	Moderate quality
S5	16.2	fine quality
S6	13.5	Moderate quality
S7	14	Moderate quality
S8	17.1	High quality
S9	9.9	Low Quality
S10	12.3	Moderate quality
S11	9	Low Quality
S12	10.2	Low Quality
S13	9.5	Low Quality
S14	9.9	Low Quality
S15	10.6	Low Quality
S16	9.6	Low Quality

Specific Sensitivity Pollution Index (IPS)

Classification showed a significant correlation with phosphates, nitrates, BOD and COD. Results show that major pollution points along the Ghaggar River are sites that are located downstream of major cities as shown in table 4. This work present the baseline for future research and offers preliminary results of critical pollution points in the Ghaggar river.

References

Abida, B., S. Harikrishna and I. Khan (2009). Analysis of heavy metals in water, sediments and fish samples of Madivala lakes of Bangalore, Karnatak. *Inter J tech Res-CODEN* (USA), **2** : 249.

APHA (2005). *Standard methods for examination of water and wastewater*. **21**th ed. American Public Health Association, Washington, DC, USA.

Chetanas, A. and R. K. Somasekhar (1997). Ecological study on the Riverine Ecosystem of Karnataka physico chemical characteristics of river Cauvery. *J. Environ Pollut.*, **4(1)** : 57-63.

Dubey, N. (2003). A comparative status of quality of drinking water of Bhopal city filtration plants and groundwater with special reference to heavy metals and organo chemical. Unpublished *Ph.D. Thesis*, Barkatullah University, Bhopal.

Hasle, G. R. (1978). Some specific preparations: diatoms in Sournia A (Ed.), Phytoplankton manual, UNESCO, Paris 1-314.

Karthick, B., P. B. Hamilton and J. P. Kociolek (2013). An Illustrated guide to common diatoms of Peninsular India

Gubbi Labs. Gubbi 206.

Karthick, B., J. C. Taylor, M. K. Mahesh and T. V. Ramachandra (2010). Protocols for collection Preservation and Enumeration of Diatoms from Aquatic Habitats for Water Quality Monitoring in India. *The IUP Journal of Soil and Water Sciences*, **3(1)** : 25-60.

Kelly, M. G. and B. A. Whitton (1998). Biological monitoring of eutrophication in rivers. *Hydrobiologia*, **384** : 55-67.

Kelly, M. G. and B. A. Whitton (1995). The trophic diatom index: a new index for monitoring eutrophication in rivers. *J. Appl. Phycol.*, **7** : 433–444.

Lecointe, C. M., M. Coste and J. Prygiel (1993). BOmnidia: software for taxonomy, calculation of diatom indices and inventories management. *Hydrobiologia*, **269(270)** : 509–513.

Mishra, S. R. and D. N. Saksena (1993). Phytoplanktonic composition of sewage polluted Morar (Kalpi) river in Gwalior, MP. *Environment Ecology*, **11** : 625-629.

Round, F. E. (1991). Diatoms in river water-monitoring studies. *J Appl Phycol.*, **3** :129–145

ShamSundar (2007). Aqua chemistry of Gopalaswamy River in Chitradurga, Karnataka. *Indian J Env. Pro.*, **27(5)** : 420-424.

Sukhdev Kundu (2012). Assessment of Surface Water Quality for Drinking and Irrigation Purposes: A Case Study of Ghaggar River System. *Surface Waters Bulletin of Environment, Pharmacology & Life Sciences*, **1(2)** : 01-06.

Trivedy, R. K. and S. D. Khatavkar (1996). Phytoplankton Ecology of the River Krishna in Maharashtra with Reference to Bio indicators of Pollution. In: Assessment of Water Pollution Mishra SR (Edition) APH Publishing Corporation New Delhi 299-328.

WHO (2004). *Guidelines for drinking water quality* (**3**rd Ed.). Geneva, Switzerland: WHO.