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Surface Water Quality Quality Assessment using Water Quality Index Method

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Abstract : Assessment of surface water quality is a complicated issue as they are used for agriculture, domestic and industrial purposes. In India particularly water pollution is a serious problem as nearly 70 percent of its surface water is contaminated by biological, toxic, organic and inorganic pollutants. Hence, to protect this natural resource proper water management strategies are essential. In this context, the present study aims to evaluate the water quality of the river Hooghly in West Bengal, India. Both pre-monsoon and post-monsoon samples were collected from eleven points distributed along the entire river stretch for the parameters namely Chloride, Conductivity, Dissolved O_2 (DO), Fecal Coliform, Magnesium, Total Coliform, Total Dissolved Solids (TDS), Total Suspended Solids(TSS) and Turbidity and tested at laboratory. Based on the tested results Water Quality indices were calculated to assess the water quality of the river . Finally , based on these results digital cartographic maps depicting the water quality status of the river were generated using ARC GIS 10.3 software in order to develop a cost effective regular monitoring system.

Keywords : Water Quality Parameters, WQI, Pollutants, Monitoring , ARC GIS 10.3 .

1. INTRODUCTION :

Deterioration of surface water quality has become a growing threat to human society and natural ecosystems in recent years. This decline is directly related to the discharge of municipal and industrial wastes as well as surface runoff from agricultural lands and makes the water vulnerable to pollution. Therefore it has become an essential work to restore this natural resource through identification of pollutants , reduction of pollution load from these sources and continuous monitoring.

Quality of surface water is generally determined by collection of samples for the water quality parameters such as temperature, pH ,chlorophyll-a, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Dissolves Solids (TDS), Secchi Disk depth , Fecal Coliform etc. from various locations and analyzing them at laboratory to know the concentration of different water quality parameters. There after the large datasets which are generated are calculated through a mathematical instrument called water quality index (WQI) which provides a single number that expresses overall water quality at a certain location and time, based on several physico-chemical and biological water quality parameters.

The present study aims to evaluate the water quality status of river Hooghly in West Bengal, India through estimation of water quality index using weighted arithmetic water quality index method.(WAWQI) and GIS technology . Here an attempt has been made to identify the locations where the desired and actually existing water quality is not matching and need a pollution control measure to demonstrate the ability of these technologies to identify the most critically polluted sites along the entire river stretch for establishing a sustainable water quality monitoring system.

2. STUDY AREA:

The **river Hooghly** or the **Bhāgirathi-Hooghly**, traditionally called 'Ganga' or Kati-Ganga, is an approximately 260-kilometre-long (160 mi) distributary of the river Ganges in West Bengal, India. The river flows through the Rarh region i.e. the lower deltaic districts of West Bengal and eventually into the Bay of Bengal. The upper riparian zone of the river is called Bhagirathi while the lower riparian zone is called Hooghly. Major rivers that drain into the Bhagirathi-Hooghly include Mayurakshi, Jalangi, Ajay, Damodar, Rupnarayan and Haldi rivers other than the Ganges. The study area lies between 86°E to 89°E and 21°30´N to 27° N and surrounded by Maldah district to the north, Jharkhand , Purba & Paschim Medinipur to the West, Bangladesh to the east and Bay of Bengal to the south .

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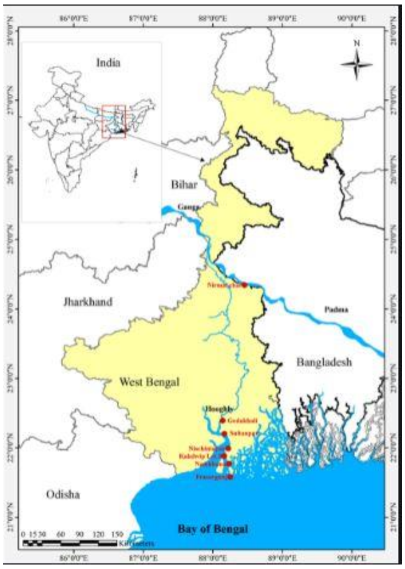

Figure 1: Location Map of the Study Area

3. MATERIALS AND METHODS:

3.1 Sampling and Data Analysis

Water samples were collected during pre-monsoon (May, 2018) and post-monsoon (October, 2018) seasons from eleven sites along the entire river stretch starting from Baharampur to Diamond Harbour for the parameters namely Chloride, Conductivity, Dissolved O2(DO), Fecal Coliform, Magnesium, Total Coliform, Total Dissolved Solids(TDS), Total Suspended Solids(TSS), and Turbidity as they are the indicators of water quality . These samples were further analyzed at the laboratory using APHA,2005 standard method (1-4) .

3.2 Water Quality Index (WQI)

Water Quality Index is a mathematical method which provides a single number that expresses overall water quality at a certain location and time, based on various water quality parameters .It gives an indication how suitable the water is for various purposes.

Table 1 : Status of water quality

Status and Index level (WQI) of water quality(Brown et al.,1972)	
Water Quality Index Level	**Water quality status**
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unsuitable for drinking

In the present study water quality index has been estimated using Weighted Arithmetic Index Model In this model, different water quality components are multiplied by a weighting factor and are then aggregated using simple arithmetic mean (Table-6). Weighted arithmetic water quality index method classified the water quality according to the degree of purity by using the most commonly measured water quality variables (5-8,15)..

Here ,for assessing the quality of water, the quality rating scale (Qi) for each parameter was Calculated by using the following equation;

$q_n = 100 (V_n – V_{io}) / (S_n – V_{io})$

(Let there be nwater quality parameters and quality rating or sub index (qn) corresponding to nth parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value).

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q_n=Quality rating for the nth Water quality parameter.

V_n=Estimated value of the nth parameter at a given sampling station obtained from laboratory analysis.

S_n =Standard permissible value of the nth parameter.(here recommended CPCB standard are used)

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Vio= Ideal value of nth parameter in pure water, (i.e.,0 for all other parameters except the parameter pH and Dissolved oxygen (7.0and 14.6 mg/L respectively) can be obtained from the standard Tables.
Unit weight was calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameter.
Wn =K / Sn
Wn= Unit weight for the nth parameters. Sn= Standard value for nth parameters. K= Constant for proportionality.
Proportionality constant " K " value using formula
where "si" is standard permissible for nth parameter.
The overall Water Quality Index calculated by aggregating the quality rating with the unit weight linearly.
WQi = ΣQiWi/ Σ Wi
Where, Qi = Quality rating, Wi = Relative weight

4. RESULTS AND DISCUSSIONS

The comparison of laboratory tested results of the parameters with CPCB standard limits for both pre and post-monsoon season (Table-2 and Table-3) indicate that the concentration of parameters vary with space and time and some parameters are highly exceeding the national standard (9-19).

Table 2: Pre-Monsoon Water Quality Results

National Standard Limits	**1000** mg/l	**2000** µs/cm	**6** mg/l	**500** MPN/100ml	**30** mg/l	**500** MPN/100ml	**2100** mg/l	**100** mg/l	**10** NTU
Station Names	Chloride	Conductivity	Dissolved Oxygen (DO)	Fecal Coliform	Magnesium	Total Coliform	Total Dissolved Solids(TDS)	Total Suspended Solids(TSS)	Turbidity
Ganga at Khagra	13.5	334	5.8	90000	10	140000	112	26	6.9
Ganga at Baharampore	15	344	6.7	3E+05	10	4E+05	126	30	14.6
Ganga at Gorabazar	12	331	6.8	70000	10	110000	124	32	6.2
Ganga at Nabadwip	12	322	6.8	11000	13	14000	182	60	51.7
Ganga at Tribeni	18.31	341	6.7	11000	11	17000	208	108	69.4
Ganga at Palta Shitalatala	13.5	361	5.9	50000	15	70000	220	202	54.2
Ganga at Serampore	12.37	412	3.8	50000	19	70000	232	38	35.6
Ganga at Dakshmineswar	16.99	352.8	5.1	22000	13.12	3E+05	166	36	42
Ganga at Howrah-Shibpur	14.99	371	5.3	2E+05	36.45	3E+05	212	86	4.83
Ganga at Uluberia	19.99	369.1	7	22000	14.09	26000	176	52	6.96
Ganga at Diamond Harbour	1099.66	8180	6	21000	36.45	33000	4970	336	175

Table 3: Post-Monsoon Water Quality Results

National Standard Limits	**1000** mg/l	**2000** µs/cm	**6** mg/l	**500** MPN/100ml	**30** mg/l	**500** MPN/100ml	**2100** mg/l	**100** mg/l	**10** NTU
Station Names	Chloride	Conductivity	Dissolved Oxygen (DO)	Fecal Coliform	Magnesium	Total Coliform	Total Dissolved Solids(TDS)	Total Suspended Solids(TSS)	Turbidity
Ganga at Khagra	8.67	260	6.2	30000	7	70000	238	286	67.6
Ganga at Baharampore	8.67	265	6.1	30000	7	50000	136	248	46.4
Ganga at Gorabazar	8.67	257	5.9	30000	7	50000	190	266	59.2

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Ganga at Nabadwip	7.71	269	6.4	80000	7	1E+05	164	284	178
Ganga at Tribeni	13.5	292	5	13000	8	23000	220	348	176
Ganga at Palta Shitalatala	11.57	317	5.7	2E+05	9	3E+05	156	290	159
Ganga at Serampore	9.64	280	5.2	2E+05	7	3E+05	212	195	175
Ganga at Dakshmineswar	9.00	284.4	4.7	300000	29.16	900000	210	110	73.5
Ganga at Howrah-Shibpur	16	333.2	3.1	240000	15.07	300000	182	128	42.2
Ganga at Uluberia	9.00	317.3	4.2	300000	14.58	900000	82	78	37.7
Ganga at Diamond Harbour	149.95	685.2	5.3	3000	29.16	7000	290.0	296.0	201.0

The concentration of Chloride and Conductivity are very high near Diamond Harbour during pre-monsoon than post-monsoon. The reason behind this high concentration could be due to the occurrence of more anthropogenic pollution like application of chemical fertilizers and run off from agricultural field .
Significant increase in Conductivity during pre-monsoon may be an indicator of the presence of various ions such as nitrate, phosphate, and sodium through surface runoff, erosion of river bank and dredging activity.
In case of Dissolved Oxygen(DO) there is no significant changes in concentration in both the seasons except a little increase in the upper stretch only which may be due to the effect of increased dilution particularly in the post monsoon.
Excessive concentration of Coliform is noticed at both the seasons. It well known that Fecal Coliform bacteria enters rivers through a number of sources such as animals waste , human sewage , agricultural and surface runoff etc. so there are chances of contribution of these factors behind this heavy load of Coliform in this water body.
Concentration of Magnesium and Total Dissolved Solids(TDS) are also within the standard limit at all the sampling stations except at Diamond Harbour during pre-monsoon only . Whereas concentration of Total Suspended Solids(TSS) was comparatively higher in post-monsoon than pre- monsoon may be due to increased siltation after monsoon.
Turbidity is a measure of particles suspended in water to affect water clarity. The results show that concentration of Turbidity is very high in post monsoon than pre monsoon because of rain water carries the sediments into the water body along with other anthropogenic agents and increases its concentration
Observing the significance and variations among parameters, Water Quality Index (WQI) was calculated for both the seasons to know the overall water quality of the entire stretch (Table 4 -5).

Table 4 and 5: Water Quality Index during Pre and Post -Monsoon

SL NO	STATIONS	WQI
1	Ganga at Khagra	47.94307952
2	Ganga at Baharampore	108.3868496
3	Ganga at Gorabazar	39.00687292
4	Ganga at Nabadwip	33.26096884
5	Ganga at Tribeni	40.62537151
6	Ganga at Palta Shitalatala	49.59602187
7	Ganga at Serampore	44.14712276
8	Ganga at Dakshineswar	72.89930757
9	Ganga at Howrah-Shivpur	91.50604654
10	Ganga at Uluberia	17.67027623
11	Ganga at Diamond Harbour	86.94626584

SL NO	STATIONS	WQI
1	Ganga at Khagra	52.77522834
2	Ganga at Baharampore	42.01661163
3	Ganga at Gorabazar	47.48306044
4	Ganga at Nabadwip	106.0453665
5	Ganga at Tribeni	85.4177926
6	Ganga at Palta Shitalatala	145.456303
7	Ganga at Serampore	150.9492922
8	Ganga at Dakshineswar	39.4800973
9	Ganga at Howrah-Shivpur	30.87538714
10	Ganga at Uluberia	22.60550647
11	Ganga at Diamond Harbour	90.17535575

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Table 6: Calculation of water Quality Index

Parameters	Observed Values	Standard Values(Sn)	1/Si	Unit Weight (Wn)	Quality Rating(qn)	Wnqn
Chloride	15	1000	0.001	0.00036528	1.5	0.000547917
Conductivity	344	2000	0.0005	0.00018264	17.2	0.003141391
Dissolved O_2(DO)	6.7	6	0.166667	0.06087967	91.25	5.555269583
Fecal Coliform	280000	500	0.002	0.00073056	56000	40.911136
Magnesium	10	30	0.033333	0.01217593	33.33333	0.405864444
Total Coliform	350000	500	0.002	0.00073056	70000	51.13892
Total Dissolved Solids(TDS)	126	2100	0.000476	0.00017394	6	0.001043651
Total Suspended Solids(TSS)	30	100	0.01	0.00365278	30	0.1095834
Turbidity	14.6	10	0.1	0.0365278	146	5.3330588
			2.737643	1.00040656		108.4309151

k= 0.365278

WQI=£Wnqn/£(Wn

K=1/£(1/Si)

WQI=**108.3868496**

The values of water indices have been considered as the standard for drinking water (Table-6). In comparing these results with the water quality status (Table 1), it is evident that during pre monsoon (Table 4) water samples collected from Dakshineswar are falling under poor category (72.89) whereas water quality is comparatively good at Gorabazar, Khagra, Srerampoe, Tribeni and Palta. Not only that the WQI of the Howrah-Shivpur and Diamond Harbour are ranged from 80-95 and accordingly the quality are very poor . Worst result obtained from Baharampore where the quality is so bad (108) that it has become unsuitable for drinking which is distinctly visible at figure 2.

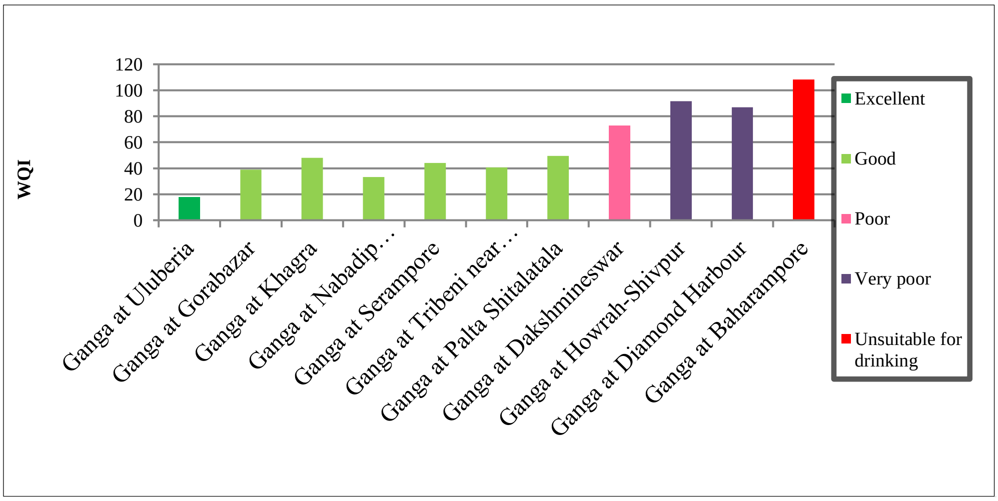

Figure 2: Assessment of Ganga Water Quality during Pre Monsoon

During post monsoon (Table-5) some variations from pre monsoon are noticed . During this season less pollution is observed at Uluberia, Howrah-Shivpur, Dakshineswar, Baharampur and Gorabazar as the WQI value is within 50 . Whereas the quality is more poor at Khagra (52.77) and very poor at Nabadwip and Srerampore. Very severely pollution effects are observed at Tribeni, Diamond Harbour and Ganga at Palta where WQI ranges between 85-145 and has been depicted through figure 3.

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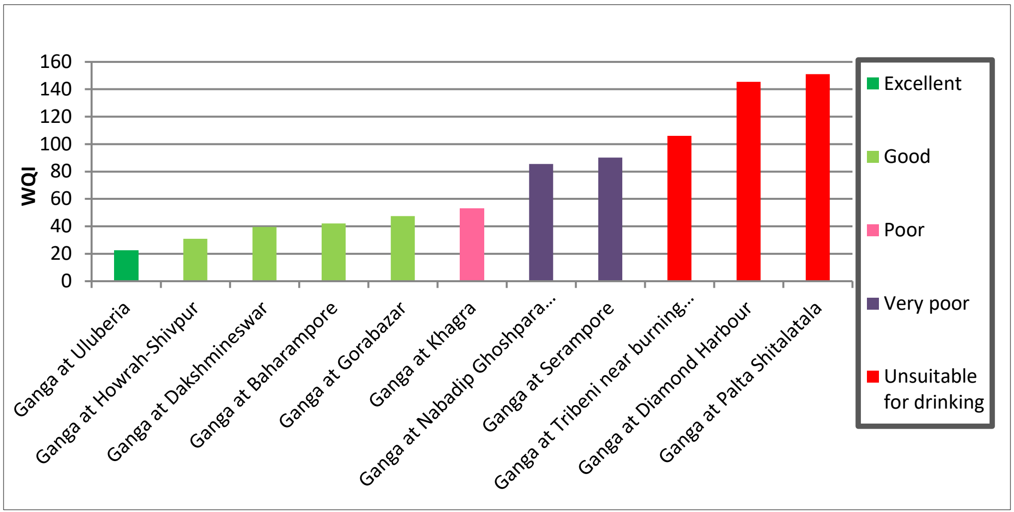

Figure 3: Assessment of Ganga Water Quality during Post Monsoon

Based on the observed Index value water quality map of the study area has been prepared using Arc GIS 10.3 software (figure 4).

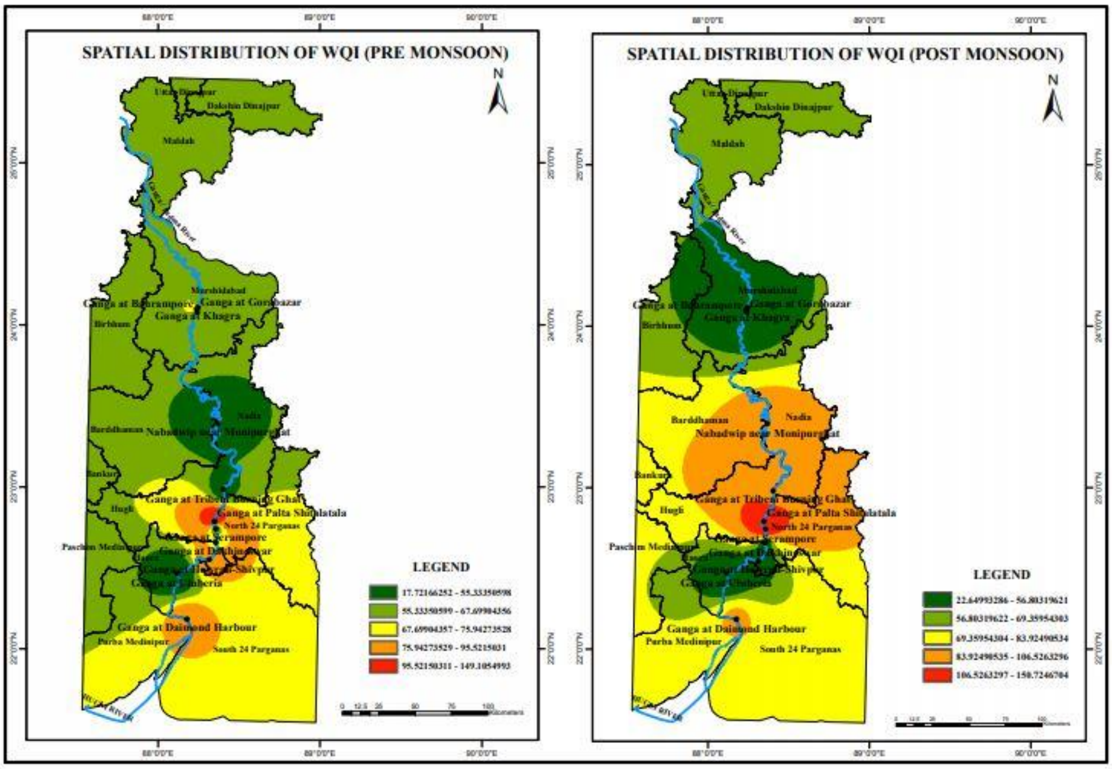

Figure 4: Water Quality Map of the Study Area

5. CONCLUSION:

The main objective of this study is to assess the water quality status of Hooghly river with the help of Mathematical method and GIS Technology for protecting this natural environment from degradation. The tested result of in situ collected data reveals that there are spatio–temporal variations in concentration of water pollutants mainly due to increasing anthropogenic activities and effect of rainfall during monsoon. Mathematical analysis provides appropriate methodology for locating the pollutants in the river water and subsequently, the spatial distribution maps of the pollutants were generated using Arc GIS software for developing a reliable and effective monitoring system of Hooghly River. So, it may be concluded that monitoring and assessment of surface water through mathematical analysis coupled with GIS technology can result in quality assessment and effective management of water resources. Along with this, the study suggests the need of a successful dialogue between scientists, policy makers, environmental managers, and stakeholders at all levels starting from national to local, which would otherwise lead to destruction of this blue environment.

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