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Assessment of Coastal Water Quality using Aquatic Health Index (AHI)

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Abstract
The coastal and estuarine zone of West Bengal (India) is noted for its rich biodiversity owing to the presence of Sundarbans mangrove ecosystem. However, due to intense industrialization and urbanization, many of the pockets have become ecologically sensitive. The present paper is an attempt to evaluate the Ecologically Sensitive Zone (ESZ) through enumeration of Aquatic Health Index (AHI). In the present programme, three stations in and around Indian Sundarbans namely Canning, Junput and Sagar Island were selected and the aquatic health index value of these stations varied as per the order Sagar Island > Canning > Junput. The lower value of the index reflects deteriorated condition of the coastal water due to excessive industrial, agricultural and domestic run-off. The high values of the index are the indicators of congenial coastal environment.

Keywords: Aquatic Health Index (AHI), Coastal environment, Sundarbans mangrove ecosystem.

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1. Introduction

India, with a long coastline of over 8,000 km and 2 million km^2 of EEZ (Exclusive Economic Zone) has great potential for utilizing the marine and estuarine resources for the economic benefit of the country. West Bengal, a maritime state of the northeastern part of the country, adjacent to Bangladesh, is indented in the south by numerous river openings. The state has a coastal area of 10,055 km^2 spread in three major districts namely 24 Parganas (N), 24 Parganas (S) and Midnapur (E). The Hugli-Matla estuarine complex adjacent to coastal West Bengal is one of the most dynamic estuaries of the world, which is serving as the nursery of several varieties of finfishes and shellfishes that have great potentiality in strengthening the economic backbone of the country. However, it has become a significant conveyor of pollutants of different categories as because this system receives domestic, agricultural and industrial wastes containing cellulose, acids, alkalis, nitrogenous compounds, heavy metals, fly ash, phenol, sulphides and pesticide residues, which adversely affect the fish food organisms, near the outfall regions (Mitra, 1998) [1]. Matla and other eastward estuaries receive Kolkata and suburban sewage with organic load, heavy metals, ammonia and synthetic detergents flowing down (through the Kulti and Bidyadhari estuaries Mitra, 2013) [2]. The chain of the industries situated in and around Haldia port-cum-industrial complex (Annexure 1) has aggravated the situation in the western sector of Indian Sundarbans. Regular monitoring of the entire process is of utmost importance in this context to keep an eagle's eye on the quality of aquatic phase in and around Indian Sundarbans. One important step towards this is scaling of the water quality of different site through consideration of most relevant parameters, which are functions of space and time. The process of scaling is done by developing an index through which a single value can be assigned to the aquatic phase for the purpose of its scoring in terms of status, use and management. Thus AHI aims at giving a single value to a particular aquatic system on the basis of list of constituents (parameters/variables) and their concentrations in the said aquatic system. One can then compare different samples for quality on the basis of the index value of each sample. The present article is an approach to compare the AHI (Aquatic Health Index) of three sites in different salinity zones in and around Indian Sundarbans, with the aim to prepare a scorecard for rating these water bodies in connection to the ecologically sensitive zone.

2. Materials and Methods

The entire network of the present programme consists of the evaluation of the health of coastal and estuarine water with respect to selective physicochemical variables like surface water salinity, pH, temperature, transparency, dissolved oxygen (DO), nitrate, phosphate, silicate, oil and grease, dissolved Pb, dissolved Zn and dissolved Cu during June, 2016. Samplings have been carried out at three stations in and around Indian Sundarbans namely Canning (low saline zone), Junput (high saline zone) and Sagar Island (high saline zone).

For convenience, the entire working procedure has been divided into three phases as mentioned below:

- Phase A: Site Selection.
- Phase B: Analysis of hydrological parameters of water bodies.
- Phase C: Evaluation of water quality index.

2.1. Phase A: Site Selection

Samplings were carried out from three stations in and around Indian Sundarbans namely Canning (Stn. 1), Junput (Stn. 2) and Sagar Island (Stn. 3) during premonsoon season (June, 2016).

2.2. Phase B: Analysis of hydrological parameters of pond water

The relevant hydrological parameters in connection to identification of ecologically sensitive zone in the coastal stretch of West Bengal and associated estuaries are surface water salinity, fecal coliform, BOD (Biological Oxygen Demand), dissolved oxygen (DO), oil and grease, dissolved Pb, dissolved Zn, dissolved Cu, transparency, water temperature, pH, nitrate, phosphate and silicate.

Surface water salinity was measured in the field by refractometer and cross-checked in the laboratory by argentometric method. Transparency was measured in the field by using a Secchi disc of 30 cm in diameter. Surface water temperature was measured by a Celsius thermometer and pH of the pond water was measured by a portable pH meter (sensitivity = ± 0.02). BOD, DO, oil and grease, nitrate, phosphate and silicate were measured as per the procedure stated in Strickland and Parsons (1972) [3] and APHA (1995) [4].

The dissolved metal (Zn, Cu and Pb) analysis of water samples through Atomic Absorption Spectrophotometer (AAS) were carried out as per Chakraborti *et al.* (1987). [5]

For microbial analysis of the coastal water in terms of *Fecal Coliform* load, the Most Probable Number (MPN) procedure by Multiple Fermentation Technique was followed as stated in APHA (1995). [4]

2.3. Phase C: Water quality index evaluation

For evaluating the water quality of the coastal water through AHI the following expression was adopted, which is a modification of Brown's index (1970) [6]:

$$\sum_{i=1}^{n} W_i \cdot q_i \qquad (1)$$

where, W_i = *weight* of i^{th} *parameter*, q_i = *quality* of the i^{th} *parameter* (a number between 0 and 100). Depending on the importance of the parameter they are allotted a ranking value of 1 (highest) to 10 (lowest). To convert ratings into weights, a temporary weight of 1.0 was assigned to the parameter, which received the highest significance ratings (here salinity received the topmost score). All other temporary weights were obtained by dividing the highest ranking with each individual rating. Each temporary weight was then divided by the sum of all the temporary weights to arrive at the final weight of each parameter. The sum of the product of the individual final weight W_i and individual quality rating q_i was used.

3. Results and Discussions

The Ecologically Sensitive Zone (ESZ) may be defined as the zone which sustains endemic gene pool and restricts activities that pose adverse impact on the biodiversity and the physical environment of the zone. The basis of evaluating the ESZ is to understand the magnitude of human interference on natural system. In the present *era* the adverse impact on natural system has increased due to intense industrialization and rapid urbanization in the coastal zone. The mushrooming of shrimp farms and unplanned proliferation of tourism unit has increased the magnitude of deterioration of water quality in the coastal zone. It is in this context the environmental quality assessment its monitoring and survey have, received prime importance.

Water Quality Index (WQI) evaluation is an approach to understand the health of the aquatic system by considering all the parameters relevant for determining the ecologically sensitive zone in the coastal stretch. Evaluation of water quality index is a step to monitor the health of the aquatic ecosystem. The index has gained currency during the last three decades but the concept in its rudimentary form was first introduced more than 150 years ago – in 1848 – in Germany where presence or absence of certain organisms in water was used as indicator of the fitness or otherwise of a water source. [Mitra and Zaman, 2016] [6]. Since, various European countries have developed and applied different systems to classify the quality of the waters within their regions. These water classification systems are usually of two types:

- those concerned with the amount of pollution present, and
- those concerned with living communities of microscopic or microscopic organisms.

Rather than assigning a numerical value to represent water quality, these classification systems categorized water bodies into one of several pollution classes or levels. By contrast, indices that use a numerical scale to represent gradations in water quality levels are a recent phenomenon, beginning with Horton's index in 1965. [7]

In course of time, the National Sanitation Foundations Water Quality Index (NSFWQI) developed by Brown *et al.* (1970) [8], gained much importance, but the index does not recognize and incorporate specific water supply, agriculture, industry *etc*. Later on another Coastal Water Quality Index (CWQI) was established by another group of researchers to better understand the coastal water quality in Taiwan by using Delphi [It is a process that aims to determine the extent to which experts or lay people agree about a given issue and with each other and in areas where they disagree, achieve a consensus opinion. Delphi technique is usually conducted through questionnaires] to select several parameters from Marine Water Quality Standard (CZMP, 1996) [9]. However, the parameters identified by them are pH, DO, BOD, cyanide, Cu, Zn, Pb, Cd and Cr. These indexes also does not reflect parameters related to coastal and estuarine environment like salinity, silicate level, oil and grease *etc*, which have great influence on regulating the health of those ecosystems. On this background, the present index is an addition of relevant parameters on the skeleton of Brown's index (1970) [8].

The Aquatic Health Index (AHI) in the present area of investigation is in the order Stn. 3 (Sagar Island, 50.5049) > Stn. 1 (Canning, 43.4687) > Stn. 2 (Junput, 41.3285). The order reflects the congenial environment at Sagar Island, which is at the confluence of the river Hugli and the Bay of Bengal. The presence of mangroves and the tidal flushing of the seawater (from Bay of Bengal) are the probable causes for environmental upgradation in this zone. The Junput and Canning on the other hand are constantly under anthropogenic pressure due to presence of fish landing stations, markets, tourism and other human activities. It is become of human interference the coastal health undergoes deterioration and subsequently the value of aquatic health index gets reduced. In case of Canning the lower AHI value may be due to the proximity of the station to the highly urbanized and industrialized city of Kolkata, which regularly unload huge quantum of wastes of complex characters in the Kulti lock gate zone. But in case of Junput the lower AHI value may be attributed to excessive tourist load (as it is much nearer to the tourists spots of Digha and Shankarpur) (Mitra, 2013). [2] In addition to this, the presence of fish landing stations at Junput is another prominent cause behind the lowering of the aquatic health index in this zone. The fishing vessels and trawlers contribute appreciable amount of Zn, Cu and Pb (from the antifouling paints that are used for conditioning the vessels), oil and grease in the ambient aquatic phase. Absence of proper treatment facility in the landing stations resulted in enhancement of the value of BOD and microbial load.

4. Conclusion

The coastal and estuarine waters, being the cradle of several of finfish, shellfish, seaweeds of commercial importance, needs regular monitoring, as a part of safe-guarding the ecosystem. The enumeration of Aquatic health index is a definite approach to pinpoint the magnitude of deterioration of the coastal zone on the basis of which proper planning can be done to keep the ecosystem intact and stable.

References

[1] Mitra, A. **Status of coastal pollution in West Bengal with special reference to heavy metals**. Journal of Indian Ocean Studies, 5 (2): 135-138, (1998).

[2] Mitra, A. In: **Sensitivity of Mangrove Ecosystem to Changing Climate by Dr. Abhijit Mitra**. Publisher *Springer* New Delhi Heidelberg New York Dordrecht London, 2013 edition (August 31, 2013); ISBN-10: 8132215087; ISBN-13: 978-8132215080., copyright *Springer*, India 2013; ISBN 978-81-322-1509-7 (eBook), (2013).

[3] Strickland, J. D. H. and Parsons, T. R. A. **Practical Handbook of Seawater Analysis**. 2ed. In: Bulletin Fisheries Research Board of Canada, 167: 310, (1972).

[4] APHA (American Public Health Association). **Standard methods for the examination of water and waste water**. 20th edition, APHA, Washington, D. C. (1995).

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[5] Chakraborty, D., Adams, F., Van Mol, W. and Irgolic, J. K. **Determination of trace metals in natural waters at nanogram per litre levels by electrothermal atomic absorption spectrometry after extraction with sodium diethyldithiocarbamate**. In: Analytica Chemica Acta, 196: 23-31, (1987).

[6] Mitra, A and Zaman, S. **Basics of Marine and Estuarine Ecology.** Springer, ISBN 978-81-322-2705-2, (2016).

[7] Horton, R. K. **An index number system for rating water quality**. Journal of Water Pollution Control Federation, 37(3): 300-305, (1965).

[8] Brown, R. M., McLelland, N. J., Deininger, R. A. and Tozer, R. G. A **Water Quality Index, Do We Dare?** Water & Sewage Works: 339-343, (1970.).

[9] CZMP for West Bengal, Environment Department, Gov. of W. B., (1996).

Tables and Annexure

Table 1. Significance, Ratings and Weights of the relevant parameters in connection, to Coastal Water Quality determination.

Parameter	Ranking	Temporary weight	Final weight (W_i)
Salinity (‰)	1.2	1.0000	0.2060
Fecal Coliform (n^o./100 ml)	1.5	0.8000	0.1648
BOD (5-day)	2.5	0.4800	0.0989
Dissolved O_2 (mg/l)	2.9	0.4137	0.0852
Oil and grease(mg/l)	3.1	0.3871	0.0797
Dissolved Pb (µg/l)	4.5	0.2667	0.0549
Dissolved Cu (µg/l)	4.7	0.2553	0.0526
Dissolved Zn (µg/l)	4.9	0.2449	0.0504
Transparency (cm)	5.7	0.2105	0.0433
Temperature (^{0}C)	6.5	0.1846	0.0380
pH	7.1	0.1690	0.0348
NO_3 (µg at/l)	7.9	0.1519	0.0313
PO_4 (µg at/l)	8.1	0.1481	0.0305
SiO_3 (µg at/ l)	8.5	0.1412	0.0290
		$\sum$ 4.8530	$\sum$ 0.9994

Table 2. Determination of Aquatic Health Index (AHI) for Canning (Stn 1).

Parameters	**Final weight (W_i)**	**Measured Value**	**Optimum value ***	**Individual quality rating (q_i)**	**w_iq_i**
Salinity (‰)	0.2060	24.45	25.00	98	20.1880
Fecal Coliform (n^o./100 ml)	0.1648	550.00	100.00	0	0
BOD (5-day)	0.0989	6.20	3.00	0	0
Dissolved O_2 (mg/l)	0.0852	5.12	5.00	98	8.3496
Oil and grease (mg/l)	0.0797	2.90	0.10	0	0
Dissolved Pb (µg/l)	0.0549	34.57	10.00	0	0
Dissolved Cu (µg/l)	0.0526	152.47	50.00	0	0
Dissolved Zn (µg/l)	0.0504	483.12	100.0	0	0
Transparency (cm)	0.0433	14.60	30.00	49	2.1217
Temperature (^{0}C)	0.0380	34.00	32.00	94	3.5720
pH	0.0348	7.79	8.00	97	3.3756
NO_3 (µg at/l)	0.0313	13.59	15.00	91	2.8483
PO_4 (µg at/l)	0.0305	2.45	1.50	37	1.1285
SiO_3 (µg at/ l)	0.0290	107.67	80.00	65	1.8850
					$\sum w_iq_i$ = 43.4687

Table 3. Determination of Aquatic Health Index (AHI) for Junput (Stn 2).

Parameter	Final weight (W_i)	Measured Value	Optimum value *	Individual quality rating (q_i)	$w_i\ q_i$
Salinity (‰)	0.2060	29.18	25.00	83	17.0980
Fecal Coliform (n^o./100 ml)	0.1648	425.00	100.00	0	0
BOD (5-day)	0.0989	5.80	3.00	7	0.6923
Dissolved O_2 (mg/l)	0.0852	4.11	5.00	82	6.9864
Oil and grease(mg/l)	0.0797	3.10	0.10	0	0
Dissolved Pb (µg/l)	0.0549	18.46	10.00	15	0.8235
Dissolved Cu (µg/l)	0.0526	109.56	50.00	0	0
Dissolved Zn (µg/l)	0.0504	348.69	100.0	0	0
Transparency (cm)	0.0433	15.90	30.00	47	2.0351

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Temperature (^{0}C)	0.0380	33.90	32.00	94	3.5720
pH	0.0348	8.34	8.000	96	3.3408
NO_3 (µg at/l)	0.0313	13.15	15.00	88	2.7544
PO_4 (µg at/l)	0.0305	1.71	1.50	86	2.6230
SiO_3 (µg at/ l)	0.0290	87.62	80.00	91	2.6390

$\sum w_i q_i$ = 41.3285

Table 4. Determination of Aquatic Health Index (AHI) for Sagar Island (Stn 3).

Parameter	Final weight (W_i)	Measured Value	Optimum value *	Individual quality rating (q_i)	$w_i q_i$
Salinity (‰)	0.2060	28.11	25.00	88	18.1280
Fecal Coliform (n^o./100 ml)	0.1648	170.00	100.00	30	4.944
BOD (5-day)	0.0989	5.10	3.00	30	2.9670
Dissolved O_2 (mg/l)	0.0852	3.99	5.00	80	6.8160
Oil and grease(mg/l)	0.0797	2.10	0.10	0	0
Dissolved Pb (µg/l)	0.0549	18.91	10.00	11	0.6039
Dissolved Cu (µg/l)	0.0526	68.36	50.00	63	3.3138
Dissolved Zn (µg/l)	0.0504	229.08	100.0	0	0
Transparency (cm)	0.0433	16.80	30.00	44	1.9052
Temperature (^{0}C)	0.0380	33.90	32.00	94	3.5720
pH	0.0348	8.33	8.00	96	3.3408
NO_3 (µg at/l)	0.0313	14.15	15.00	94	2.9422
PO_4 (µg at/l)	0.0305	1.75	1.50	84	2.5620
SiO_3 (µg at/ l)	0.0290	102.41	80.0	72	2.0880

$\sum w_i q_i$ = 50.5049

Table 5. Score card of the selected stations according to AHI.

Station	**$\sum w_i q_i$**	**Health Position**
Stn. 1	43.4687	2
Stn. 2	41.3285	3
Stn. 3	50.5049	1

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Annexure 1. Major Haldia Industries: Waste generation, treatment and disposal.

Name of the Industry	**Size & Category**	**Status**	**Water Use (m^3/d)**	**Waste Generation**		**Status of disposal of Waste Effluent**		
				Effluent (m^3/d)	Solid (m^3/d)	Status of Effluent	Disposal of Effluent Discharged in the Sea	Waste
							Direct / Indirect	Solid Waste
Shaw Wallace & Co.	Large Pesticides	Private	265	50	0.007	Treated	Indirect	NA
Hindustan Lever Ltd.	Large Chemicals	Private	3750	1065	NA	Treated	Indirect	NA
Consolidated Fibers & Synthetic Chemicals Ltd.	Large Fiber	Private	3185	2303	0.002	Treated	Indirect	NA
Haldia Dock Complex	Large Dock	Private	2880	640	25	Untreated	Indirect	NA
IOC Ltd.	Large Oil & Refinery	Private	14650	13800	NA	Treated	Indirect	NA
Chloride Industries	Large Lead Battery	Private	446	402	0.008	Treated	Indirect	NA
HFC Ltd (Main Plant fertilizer not operating since 1978)	Large Fertilizer	Private	3400	3400	NA	Partly Treated	Indirect	NA

Source: CZMP for West Bengal, Environment Department, Gov. of W. B., 1996. [13]

NA= Not Available.