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Application of Family Biotic Index in Assessment of two Rivers Affected by Oil Pollution in Assam, India

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Abstract

By using Family Biotic Index (FBI) two rivers viz. Dhansiri and its tributary river Kaliani were assessed from March, 2012 to February, 2014, dividing the entire period into four seasons as pre monsoon, post monsoon and winter. These two rivers were affected since its operation from the year, 2000 by the Numaligarh Oil Refinery of Assam. In the study, 23 genera and 2 tribes (Chironomidae family) belonging to 25 families of macro invertebrates have been recorded belonging to ten orders, four classes and three phyla. The annual FBI values were found to be lowest for the control area of Kaliani and most of the macro invertebrates that were found in that control area were relatively pollution intolerant. On the other hand, the point of effluent discharge (S6) of contaminated area receiving the refinery effluents with the highest FBI value has shown "Very poor" water qualities with severe organic pollution likely as the most of contributing families were highly tolerant to organic pollution.

Keywords: FBI, Tributary, Effluent, Point of effluent discharge, Seasons, Pollution intolerant, Organic pollution.

Introduction

The biomonitoring by Family Biotic Index (FBI) is under Rapid Bioassessment Protocol II that is based on benthic macro invertebrates and their identification up to family level. The history of biomonitoring can be traced back to Aristotle, who placed freshwater fish into seawater to observe their reactions. The first toxicity experiments were published in1816, and described longer survival of several species of freshwater molluscs in 2% than 4% saline solutions. In Biomonitoring the aquatic resident organisms of the different water bodies i.e. lotic (rivers and streams) and lentic (lake and pond) are used which are the sensitive bio indicator[1].

The Kaliani is a tributary of river Dhansiri and the Dhansiri is a perennial source of water located within 5-kms radial distance from the Numaligarh Refinery of Assam. They receive effluent from the refinery and reported to be contaminated since its operation from the year, 2000. The study period was from March, 2012 to February, 2014. The entire period was divided into four seasons as pre monsoon (March - May), monsoon (June - August), post monsoon (September - November) and winter (December – February).

Two study areas were used for comparisons, both with similar environmental but are different gradient level. To know the changes in biological community structures, one area located upstream of River Kaliani was considered as control area, where there is no contamination from refinery effluent. The control area of river Kaliani were divided into five stations as S1, S2, S3, S4 and S5. The refinery effluent contaminated areas of both the rivers were arbitrarily divided into five stations as S6 and S7 from the Kaliani River, while S8 near the confluence of river Kalani with the Dhansiri), S9 and S10 from the Dhansiri River.

Materials and Methods

FBI was calculated using the equation of Hilsenhoff[2] and FBI has been calculated as:

$$FBI = \sum \frac{x_i t_i}{n}$$

Where: "x_i" is the number of individuals in the "i^{th}" taxon, "t_i" is the tolerance value of the "i^{th}" taxon and "n" is the total number of organisms in the sample.

Tolerance which has been used in the calculation of FBI is a listing of tolerance values that range from 0 for organisms very intolerant of organic wastes to 10 for organisms very tolerant of organic wastes (Table-1).

Tolerance values for sampled macro invertebrates for application in the Modified Family Biotic Index were adopted from Bode *et. al.*[3]; Hauer and Lamberti[4]; Hilsenhoff[2] and Plafkin *et. al.*[5]

Sampling of macro invertebrates was carried out according to Barbour *et. al.*[6] and Mandaville[7]. At each segment, a 600 micron mesh "D" net was used to collect organisms from habitats likely to support the greatest taxonomic diversity. A total of approximately 1.0 m^2 of combined substrates were sampled and

collected macro invertebrates were tipped into a white tray that was half filled with river water. Families of macro invertebrates present were identified by the river side, recorded on a sheet, preserved in 70% ethanol and transported to the laboratory for sorting, abundance counts and to ascertain the accuracy of field identification. Macro invertebrates were identified with the help of standard literature of Edmonson[8], Pennak[9], Merrit and Cummins[10].

Table-1
Evaluation of water quality using the family-level biotic index (FBI)[2]

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

Results and Discussion

In the study, 23 genera and 2 tribes (Chironomidae family) belonging to 25 families of macro invertebrates have been recorded belonging to ten orders, four classes and three phyla. The Table-2 shows the taxonomic diversity of identified macro invertebrates of rivers Dhansiri and Kaliani during March 2012-February 2014.

The phylum Arthropoda included a single class (Insceta) with the six orders namely- Decapoda, Diptera, Epemeroptera, Megaloptera, Odonata and Trichoptera; phylum Annelida included the two classes- Oligocheta (with the order Haplotaxida) and Hirudinea (with the order Rhynchobdellidae); phylum Mollusca included a single class (Gastropoda) of two orders Basomatophora and Veneroida (Bivalvia).

A total number of 24390 macroinvertebrates have been collected during March 2012 to February 2014 (Table-3) of which 12587 were collected in the first year and 11803 were collected in the second sampling year. The most abundant genus recorded was *Heptagenia* with an annual mean value of 773.00±180.80 and the less common genus was *Hirudinea* with an annual mean of 9.30±7.75.

Discussion: Hilsenhoff[11] developed the Biotic Index to provide a single 'tolerance value' that is the average value of the tolerance scores of all species within the specific benthic arthropod macro invertebrate community. Based on their tolerance to organic pollution, the Biotic Index was subsequently modified to the family-level (FBI, RBP-II) by giving the tolerance values ranging from 0 for the very intolerant organisms to 10 for the highly tolerant organisms. The index values are related to how well the family can tolerate organic pollutants, increased nutrient and sediment loads and dissolved oxygen (DO) limitations. Recent evidence shows only 20 organisms are necessary for accurate results[7].

The annual FBI values were found to be lowest for the control area of Kaliani (Table-4). The predicted water quality at different sampling stations were ranged from "Very Good" indicating possible slight organic pollution at S1 to "Fair" at S5 indicating fairly substantial pollution likely and "Good" at the three other stations (S2, S3 and S4) indicating some organic pollution probable. Most of the macro invertebrates that were found in that control area were relatively pollution intolerant *viz.* Tipulidae (tolerance value 3), Baetidae (tolerance value 4), Ephemeridae (tolerance value 4), Heptageniidae (tolerance value 4), Oligoneuriidae (tolerance value 2), Polymitarcyidae (tolerance value 2), Sialidae (tolerance value 4), Aeshnidae (tolerance value 3), Gomphidae (tolerance value 1) and Macromiidae (tolerance value 3), Hydropsychidae (tolerance value 4) and Lepidostomatidae (tolerance value 1), all of these were the contributor of lower FBI values indicating the relatively clean water quality.

On the other hand, the point of effluent discharge (S6) of contaminated area receiving the refinery effluents with the highest FBI value has shown "Very poor" water qualities with severe organic pollution likely. The most of contributing families were highly tolerant to organic pollution *viz.* Blood-red Chrionomidae (Chironomini, tolerance value 8), other Chrionomidae (including pink, tolerance value 6), Glossiphoniidae (tolerance value 10), Physidae (tolerance value 8), Sphaeridae (tolerance value 8), Corduliidae (tolerance value 5), Tudificidae (tolerance value 8) and Naididae (tolerance value 8). The further downstream (S7, S8, S9 and S10) of contaminated area has shown lower FBI values than the point of effluent discharge (S6) but higher than the control area of Kaliani. The variations were from "Very poor" (S7) indicating severe organic pollution likely to "Fairly poor" (S10) indicating substantial pollution likely and "Poor" at the other two stations (S8 and S9) indicating very substantial pollution likely. The contributing taxa were Atyidae (tolerance value 6), Blood-red Chrionomidae (Chironomini, tolerance value 8),other Chrionomidae (including pink, tolerance value 6), Caenidae (tolerance value 7), Glossiphoniidae (tolerance value 10), Lymnaeidae (tolerance value 6), Physidae (tolerance value 8), Sphaeridae (tolerance value 8), Calopterygidae (tolerance value 5), Coenagrionidae (tolerance value 9), Corduliidae (tolerance value 5), Tudificidae (tolerance value 8) and Naididae (tolerance value 8).

The annual mean of FBI (Figure-11) have shown the maximum value of 7.80±0.08 at the point of effluent discharge (S6) of the contaminated area and a gradual decrease of values from S7 with a 7.44±0.13 to S10 with a 6.48±0.05 indicating a subsequent recovery from the organic load. On the other hand, the sampling stations of control area have shown increasing FBI tendencies from S1 with a 3.85±0.23 to S5 with a 5.03±0.17 indicating a gradual loss of cleanness.

Table-2
Taxonomic diversity of identified macro invertebrates of Rivers Dhansiri and Kaliani

Sl no	Name of genus/species	Family	Order
1.	*Neocaridina davidi*	Atyidae	Decapoda (crayfish)[6]
2.	Chironomini	Blood-red Chrionomidae (Chironomini) (non-biting or true midges)[4]	Diptera (Two-winged or "true flies")
3.	Tanytarsini[3]	Other Chrionomidae (including pink)[3]	
4.	*Tipulaoleracea*[3]	Tipulidae[4]	
5.	*Baetis intercalaris*	Baetidae	Ephemeroptera (mayflies)
6.	*Caenispunctate*[6]	Caenidae	
7.	*Ephemera guttulata*	Ephemeridae	
8.	*Heptagenia culacantha*	Heptageniidae	
9.	*Oligoneuriella pallida*	Oligoneuriidae	
10.	*Tortopus circumfluus*	Polymitarcyidae	
11.	*Hirudinea granulosa*	Glossiphoniidae	Rhynchobdellida (leeches and bloodsuckers)
12.	*Sialis* lutaria[3,6]	Sialidae[4]	Megaloptera (dobsonflies, alderflies)
13.	*Lymnaea acuminate*[3]	Lymnaeidae	Basommatophora (pulmonates)
14.	*Physellastagnalis*[3]	Physidae	
15.	*Sphaerium corneum*	Sphaeridae	Bivalvia (clams & mussels)
16.	*Aeshna grandis*	Aeshnidae	Odonata (dragonflies and damselflies)
17.	*Calopterix* virgo	Calopterygidae	
18.	*Ischnura aurora*	Coenagrionidae	
19.	*Neurocordulia obsoleta*	Corduliidae	
20.	*Ophiogomphus cecilia*	Gomphidae	
21.	*Macromia splendens*	Macromiidae	
22.	*Branchiurasowerbyi*[3]	Tudificidae[6]	Haplotaxida (aquatic worms)
23	*Pristina aequiseta*	Naididae	
24	*Hydropsyche sparna*	Hydropsychidae[4]	Trichoptera (caddisflies)
25	*Lepidostoma basale*	Lepidostomatidae	

Table-3
Total abundance of macroinvertebrates of Rivers Dhansiri and Kaliani

Taxa	Control area					Contaminated area					Total	Mean±STD
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10		
1.*Neocaridina*	20	51	136	157	171	0	23	98	149	301	1106	122.89±88.32
2.Chironomini	25	51	63	68	117	240	191	145	165	92	1157	115.70±68.67
3.Tanytarsini	17	50	77	56	118	112	87	197	226	263	1203	120.30±81.80
4.*Tipula*	108	112	97	94	102	0	0	0	0	0	513	102.60±7.47
5.*Baetis*	337	258	293	302	178	0	0	0	0	0	1368	273.60±60.38
6.*Caenis*	128	190	178	168	201	0	133	77	70	85	1230	136.67±50.54
7.*Ephemera*	140	166	200	307	287	0	0	0	0	0	1100	220.00±73.78
8.*Heptagenia*	1060	688	605	835	677	0	0	0	0	0	3865	773.00±180.89
9.*Oligoneuriella*	147	116	84	113	102	0	0	0	0	0	562	112.40±23.05
10.*Tortopus*	173	153	105	122	104	0	0	0	0	0	657	131.40±30.55
11.*Hirudinea*	13	3	3	1	2	25	15	13	13	5	93	9.30±7.75
12.*Sialis*	320	306	178	183	97	0	0	0	0	0	1084	216.80±94.35
13.*Lymnaea*	137	244	171	186	196	0	33	83	121	231	1402	155.78±69.04
14.*Physella*	24	107	58	184	167	163	120	136	134	124	1217	121.70±49.24
15.*Sphaerium*	5	41	45	153	165	132	141	147	84	102	1015	101.50±55.49
16.*Aeshna*	139	62	146	185	189	0	0	0	0	0	721	144.20±51.13
17.*Calopterix*	9	39	23	51	94	0	64	98	127	128	633	70.33±43.67
18.*Ischnura*	63	99	137	174	158	0	44	85	55	26	841	93.44±52.51
19.*Neurocordulia*	27	71	75	125	100	11	41	55	114	185	804	80.40±52.10
20.*Ophiogomphus*	24	32	34	57	80	0	0	0	0	0	227	45.40±22.91
21.*Macromia*	33	118	130	156	99	0	0	0	0	0	536	107.20±46.34
22.*Branchiura*	8	15	20	27	53	193	142	157	88	78	781	78.10±65.93
23.*Pristina*	9	12	17	22	34	113	103	119	89	75	593	59.30±44.81
24.*Hydropsyche*	67	85	96	86	75	0	0	0	0	0	409	81.80±11.12
25.*Lepidostoma*	523	296	229	159	66	0	0	0	0	0	1273	254.60±172.57
Total	3556	3365	3200	3971	3632	989	1137	1410	1435	1695	24390	2439.0±1195.95

Table-4
Seasonal and annual mean variations of FBI values and water qualities of Rivers Dhansiri and Kaliani

Areas and Stations		Seasonal FBI and water quality								Annual mean FBI and water quality		
		Pre monsoon		Monsoon		Post monsoon		Winter				
		FBI	WQ	FBI	WQ	FBI	WQ	FBI	WQ	FBI	WQ	Degree of organic Pollution
Control area	S1	3.67 ±0.06	E	4.18 ±0.07	VG	3.92 ±0.06	VG	3.64 ±0.06	E	3.85 ±0.23	VG	Possible slight organic pollution
	S2	4.37 ±0.03	G	4.88 ±0.09	G	4.43 ±0.11	G	4.11 ±0.27	VG	4.45 ±0.30	G	Some organic pollution probable
	S3	4.53 ±0.04	G	4.78 ±0.04	G	4.51 ±0.20	G	4.33 ±.27	G	4.54 ±0.20	G	Some organic pollution probable
	S4	4.70 ±0.05	G	5.07 ±0.01	F	4.76 ±0.12	G	4.50 ±0.03	G	4.76 ±0.21	G	Some organic pollution probable
	S5	4.95 ±0.01	G	5.29 ±0.11	F	4.96 ±0.01	G	4.92 ±0.15	G	5.03 ±0.17	F	Fairly substantial pollution likely
Contaminated area	S6	7.71 ±0.14	VP	7.86 ±0.03	VP	7.82 ±0.01	VP	7.79 ±0.02	VP	7.80 ±0.08	VP	Severe organic pollution likely
	S7	7.52 ±0.09	VP	7.46 ±0.07	VP	7.33 ±0.29	VP	7.45 ±0.18	VP	7.44 ±0.13	VP	Severe organic pollution likely
	S8	7.20 ±0.04	P	7.26 ±0.08	VP	7.04 ±0.08	P	7.15 ±0.01	P	7.16 ±0.09	P	Very substantial pollution likely
	S9	6.90 ±0.06	P	6.92 ±0.26	P	6.65 ±0.17	P	6.77 ±0.01	P	6.81 ±0.15	P	Very substantial pollution likely
	S10	6.50 ±0.01	FP	6.49 ±0.05	FP	6.42 ±0.08	FP	6.50 ±0.04	FP	6.48 ±0.05	FP	Substantial pollution likely

Key: FBI=Family Biotic Index, WQ= Water Quality

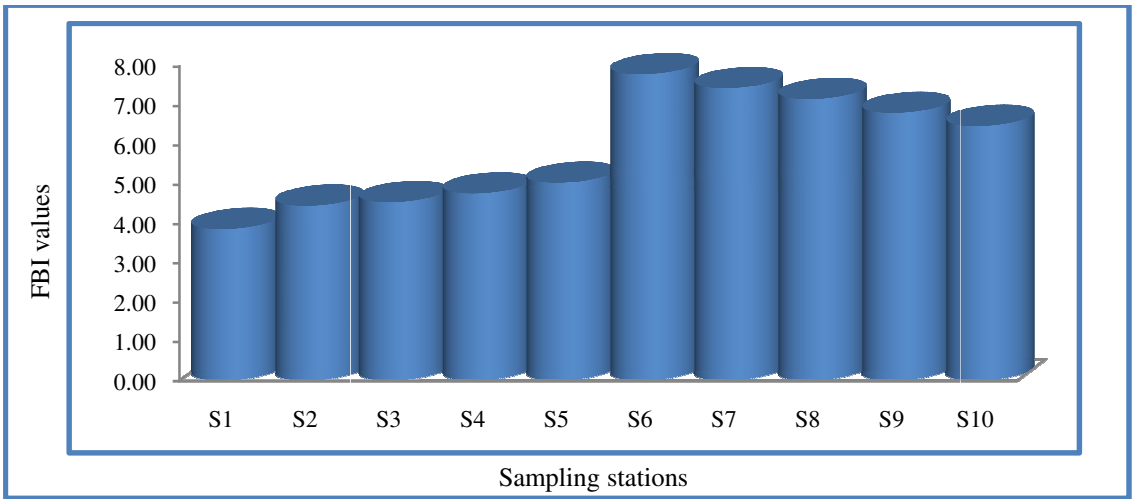

Figure-1
Annual mean variations of FBI of Rivers Dhansiri and Kaliani

Over the course of the year, the biotic water quality index varied for the two rivers[2]. Seasonally the FBI fluctuations in the two rivers found to be maximum in monsoon (6.02±1.32), followed by pre monsoon (5.81±1.50), post monsoon (5.78±1.41) and winter (5.72±1.56) shown in Figure-2. The variability of water quality given by the biotic index has been documented by various authors, and may be seasonal[12,13] or influenced by differences between sites[14]. Thus, according to Linke *et al.*[15], seasonality must be taken into account when using aquatic macro invertebrates as bioindicators, since this phenomenon may influence the results of bio monitoring analyses.

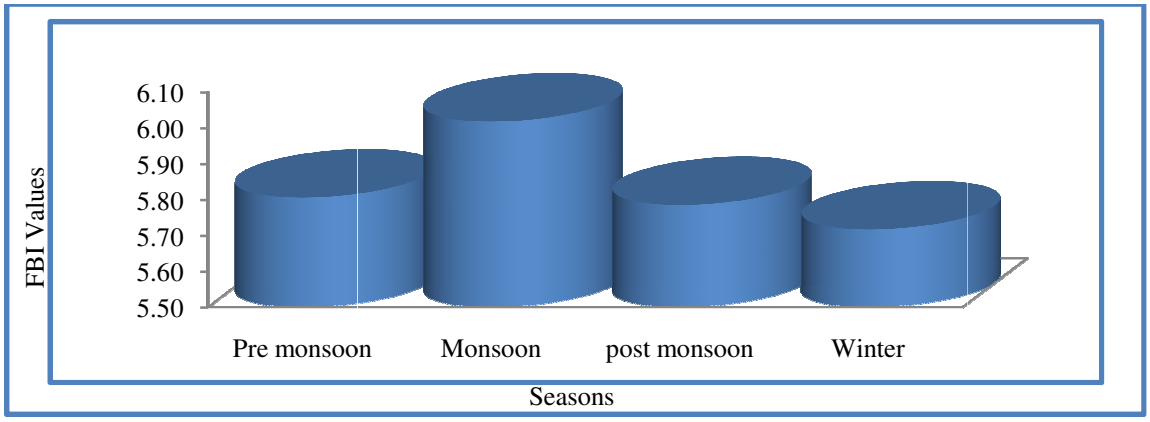

Figure-2
Seasonal mean variations of FBI of macroinvertebrates of Rivers Dhansiri and Kaliani

Conclusion

Among the sampling stations of contaminated area, the point of effluent discharge (S6), where the refinery effluent is discharged has experienced a considerable difference which is supported by the study of FBI of macro invertebrates. Although the FBI values of macro invertebrates indicated a variation of water quality of control area with "Very good" [(S1) to "Fair" (S5)], while S6 (point of effluent discharge) and S7 (downstream of the point of effluent discharge) were detected "Very poor"; whereas the further downstream stations of contaminated area were varied from "Poor" (S8 and S9) to "Fairly poor" (S10).

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