



A Study of River Water Quality using Macroinvertebrates as Bio Indicator: A Case Study

Bristi Dutta¹, Rimle Borah¹

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ABSTRACT

Background: Benthic macro invertebrates have a sedentary and long life span, sensitive community response to organic loading, thermal impacts, substrate alteration and toxic pollution. They are regarded as the most informative bio indicators of water pollution. Macro invertebrates and water quality are interrelated to each other, as macro invertebrates are a potential indicator of water quality and therefore have been most frequently used in biomonitoring studies.

Methods: The study area is the tailrace of Dikhow River, a 65 km. a southern tributary of the mighty river Brahmaputra. The stretch was demarcated into five sectors longitudinally. The study was done for a period of two years during which sampling collection was done using sampling methods. Appropriate sized net was used to sample macroinvertebrates. Identification was done using standard identification keys. Pollution tolerance of the species was measured using standard protocols. Using tolerance values, family biotic indices were measured by Hilsenhoff standard protocols.

Result: Number of pollution sensitive macroinvertebrates were found to be minimum in almost all stations indicating the level of pollution in the stations. Macroinvertebrates with higher tolerance levels were recorded in maximum number compared with the standard values to assess the water quality. A total of thirteen (13) species (*Rhynchobdellasp*, *Physellasp*, *Soletelinasp*, *Gammarussp*, *Fenneropeneussp*, *Isotomussp*, *Caeniussp*, *Gomphussp*, *Lethocerussp*, *Hydrophylussp*, *Chaobarussp*, *Chironomussp*) have been recorded during the study period. Among them the species with high pollution tolerance values were recorded in higher number during the study. While compared the family biotic indices as recorded from the stations with the standard data, then station I and station III have been found to be significant organic pollution and other three stations were found to be Fairly significant organic pollution.

Key words: Biomonitoring, Brahmaputra, Dikhow river, Macroinvertebrates, Pollution.

INTRODUCTION

Using the biological approaches to determine the ecological effects of pollution has been preferred widely for decades. These approaches have more advantages than determining the pollution with just using physico-chemical methods, because physico-chemical variables give information about only the situation of water at the time of measuring (Rosenberg and Resh, 1993). Biological assessments are being developed worldwide evaluating changes in genetic composition of specific populations, bioaccumulation of toxins and related occurrence of morphological deformities, changes in community composition and ecosystem functioning (Ostroumov, 2005, Sumudumali *et al.*, 2021). Biomonitoring, or biological monitoring, is generally defined as “the systematic use of living organisms or their responses to determine the condition or changes of the environment” (Gerhardt, 1999). Different organisms have been used as biological indicators including algae, diatoms, fish and macroinvertebrates (Rosenberg and Resh, 1993; Barbour *et al.*, 1999; Lopez and Seden, 2015). Aquatic macroinvertebrates are invertebrate organisms that are found in most rivers and streams and are large enough to see with the naked eye (Hauer and Resh, 2017). Benthic macroinvertebrates are differentially sensitive to many biotic and abiotic factors in their environment (Barbour and Yoder, 2000). Aquatic

¹Department of Zoology, Dergaon Kamal Dowerah College, Dergaon-785 614, Assam, India.

Corresponding Author: Rimle Borah, Department of Zoology, Dergaon Kamal Dowerah College, Dergaon-785 614, Assam, India. Email: borahrimlee@gmail.com

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macroinvertebrate communities reflect the quality of aquatic ecosystems (Stenert *et al.*, 2018). Several biomonitoring methodologies have been developed to measure water quality. Macroinvertebrates can be used as indicators of water quality, serving as a very useful and relatively inexpensive tool widely used throughout the world (Sumudumali and Jayawardana, 2021). Researchers use biotic indices to assess the water quality on the basis of tolerance of the macroinvertebrates to pollution. Biological Monitoring Working Party (BMWP) and Family Biotic Index (FBI) are commonly used biotic indices used to assess water quality of rivers and streams with the help of macroinvertebrates (APHA, 1998, 2001). The present study is based on family Biotic Index of all the selected stations

to assess the water quality of the river. This study aims to study the macroinvertebrate population of the river and to assess the water quality of the river.

Dikhow River is a Southern tributary of Brahmaputra which flows across certain areas of Sivsagar, a District of Assam. This river is a source of water and various purposes like irrigation, industrial purposes and agricultural purposes for the communities near the river. It has also been seen that the river is contaminated by various organic as well as chemical pollutants to which certain sensitive macroinvertebrate can respond. Therefore the main objectives of this study is to identify the macroinvertebrates present there and to assess the water quality with the help of these macroinvertebrates using Family Biotic Index as water quality evaluating criteria.

MATERIALS AND METHODS

The studied part of the river is a 65 km. stretch which is summarised in Fig 1. Five stations were selected for the study (Fig 1). The stations were selected longitudinally in such a way that they can represent the whole studied area (Fig 1). The stations are:

Sector I: Silghat- Nazira (N-26°54'51.6" and E-94°44'14.6").

Sector II: Kujibali- Hanhsora (N-26°57'2.3" and E- 94°42'30.2").

Sector III: Dikhow bridge- Sivasagar (N-26°58'35.1" and E-94° 37'49.2").

Sector IV: Baliaghat-Gourisagar (N-26°57'48.9" and E-94° 30'49.4").

Sector V: Dikhowmukh (N- 26°59'58.5" and E-94°28'03.9").

The last station is Dikhowmukh where the river confluent to Brahmaputra. The selected study area is the tail race of river Dikhow.

Macroinvertebrate sampling

Macroinvertebrate samples were collected seasonally over a period of three years (pre-monsoon, monsoon, post-monsoon and winter) for 2019-2021. Collection of macroinvertebrates samples was conducted in accordance with the SASS5 protocol (Dickens and Graham, 2002). Macroinvertebrate sampling was done using a net (30 × 30 cm frame with mesh size 1000 µm). Collected macroinvertebrates were tipped into a white tray that was half filled with river water. Families of macroinvertebrates present were identified by the river side, recorded on a sheet, preserved in 70% ethanol and transported to the Dibrugarh University Life Science laboratory and S.P.P. College

laboratory, Sivsagar, Assam for sorting, abundance counts and to ascertain the accuracy of field identification. Identification was done in Dibrugarh University Life Sciences Laboratory by using identification keys described by Wierdelholm (1983) and Cranston (1996).

Calculation of FBI

The tolerance values are derived from a combination of the abundance of each family and the total number of individuals in a sample.

The index value is obtained by summing the tolerance values of each family (t_i) multiplied by the number of organisms (n_i) and dividing this by the total number of individuals (N) collected

$$FBI = \frac{\sum (n_i \times t_i)}{N}$$

The value obtained is associated with a category of water quality, which are listed in Table 1.

Biological water quality criteria

CPCB adopts an in-house developed Biological Water Quality Criteria (BWQC) for water quality evaluation and bio-assessment of the health of river. Central pollution control board of India has derived a Biological water quality criteria (BWQC) to assess the actual health of water bodies, by water quality evaluation of water. This system is based on the range of saprobic values and diversity of the benthic macro invertebrate families with respect to water quality. Saprobic score method involves a quantitative inventory of the presence of Macro-Invertebrate benthic fauna up to family level of taxonomic precision. All possible families having saprobic indicator value are classified on a score scale of 1 to 10 according to the preference for saprobic water quality. The families which are more sensitive to pollution are getting a score of 10 while the most pollution tolerant families are getting a score of 1 and 2. This system is based on the range of saprobic values and diversity of the benthic macro-invertebrate families with respect to water quality.

Saprobic score

Measure of organic pollution tolerance in relation with taxonomic composition of biotic community inhabiting the riverine ecosystem. Saprobic score determines the presence of biodegradable organic material or in other terms, availability of Dissolved Oxygen in the water body.

Table 1: Classification of water quality according to the FBI value (adapted from Gutiérrez *et al*).

FBI	Water quality	Extent of pollution	Category
0.00-4.24	Excellent	Little organic contamination	1
4.25-5.11	Very good	Mild organic contamination	2
5.12-5.98	Good	Some organic contamination	3
5.99-6.85	Regular	Substantial organic contamination	4
6.86-7.72	Regular-poor	Very substantial organic contamination	5
7.73-8.59	Poor	Severe organic contamination	6
8.60-9.46	Very poor	Very severe	7

To calculate saprobic score, multiply each taxon's abundance by its saprobic values or tolerance of the macroinvertebrates to organic pollution, sum these products and then divided by the total abundance of all taxa.

Diversity score

Diversity score is the measure of environment health in relation with taxonomic richness of biotic community of freshwater ecosystem. Biotic communities with the maximum species diversity of their respective populations usually indicate least stressful conditions of their aquatic environment. Low species diversity may be attributed to pollution. Diversity score ranges between 0 to 1 where, low score indicates less diversified macro-invertebrate community and high score indicates highly diversified community.

The diversity score is the ratio of the total number of different animals (runs) and the total number of organisms encountered. He standard values of saprobic and diversity scores to determine water quality criteria are given in Table 2.

RESULTS AND DISCUSSION

Macroinvertebrates

Macroinvertebrate taxa of the tailrace of Dikhow River with their relative densities and percentage composition are presented in Table 3. Bivalvia were recorded in maximum number as compared to others followed by gastropoda,

Fenneropeneus indicus. It is to be mentioned that these three are pollution tolerant species as compared with the standard tolerance values. Tolerance and Family biotic index values are summarized in the Table 4 and Table 5 respectively. Tolerance values of recorded macroinvertebrates ranged between 4 and 10. Among the taxa the highest community was contributed by pollution tolerant Gastropods, Bivalvia, Decapoda (prawns) and Diptera (midges) with tolerance level 8.

Biological water quality criteria (BWQC)

The result of biological water quality criteria in the studied stations are summarized in Table 6. Based on the range of saprobic and diversity values of the benthic macro invertebrate families were displayed for the five sampling sectors. In sector I, lower saprobic value was seen during pre-monsoon season (5.38), followed by winter (5.39) and post-monsoon (5.42) as compared to that of monsoon. Diversity score also comparatively lower in post-monsoon season (0.35). In sector II, lower saprobic values were seen during pre-monsoon, post-monsoon and winter seasons (5.5 in each) as compared to monsoon (6). Diversity score also decreased from post monsoon (0.42) and pre-monsoon (0.40). In sector III, saprobic score was found to be lower in pre-monsoon (3.96) followed by winter (4) and post-monsoon (4.55). Diversity score also comparatively higher in monsoon (0.42) and lower in pre-monsoon (0.32). In sector IV, lower saprobic score was recorded during pre-monsoon and winter (5), followed by

Table 2: Biological water quality criteria.

of Saprobic score (0-10)	Range of diversity score (0-1)	Water quality	Biological water quality class	Indicator colour*
7 and more	0.2-1.0	Clean	A	Blue
6-7	0.5-1.0	Slight pollution	B	Light blue
3-6	0.3-0.9	Moderate pollution	C	Green
2-5	0.4-less	Heavy pollution	D	Orange
0-2	0-0.2	Severe pollution	E	Red

Table 3: Relative densities of macroinvertebrates in five selected stations of dikhow river.

Phyla	Class	Species	Densities					Mean± SD
			I	II	III	IV	V	
Annelida	Hirudinea	<i>Rhynchobdella sp</i>	20	10	4	10	5	10±5.67
Mollusca	Gastropoda	<i>Physella sp.</i>	15	30	30	25	25	25±5.47
	Bivalvia	<i>Lamellidens sp</i>	5	10	7	10	40	14±12.94
Arthropoda	Crustacea	<i>Gammarus sp.</i>	1	5	0	2	0	2±1.86
		<i>Fenneropeneus indicus</i>	20	10	20	24	15	18±4.83
	Insecta	<i>Isotomurus sp</i>	0	0	1	0	0	0
		<i>Caenius sp</i>	0	5	6	3	2	3±2.13
		<i>Gomphus sp</i>	5	5	10	5	5	6±2
		<i>Lethocerus sp</i>	2	2	4	5	2	3±1.26
		-	0	0	1	1	1	1±0.51
		<i>Hydrophilus sp.</i>	1	2	3	0	1	1±0.51
		<i>Chaoborus sp</i>	15	11	9	6	2	9±4.4
		<i>Chironomus sp</i>	5	10	6	9	2	6±2.87

post-monsoon season (5.32). Diversity score also higher during monsoon (0.51) and lower during winter (0.45). In sector V, saprobic score was comparatively lower winter (6.4) and higher in monsoon (6.8). Diversity score was

also lower in winter (0.56) and higher in monsoon (6.8). Thus it has been noticed that in all the sectors, the trend of water quality was same, that is only slight improvement during monsoon seasons and back to same condition at

Table 4: Tolerance level of macroinvertebrates of the tailrace of River Dikhow.

Taxa	Class	Family	Species	Tolerance level	References
Annelida	Hirudinea	Hirudinidae	<i>Rhynchobdella sp</i>	10	Barbour <i>et al.</i> , 1999
Mollusca	Gastropoda	Physidae	<i>Physella sp.</i>	8	Bode <i>et al.</i> , 1996
	Bivalvia	Unionidae	<i>Lamellidens sp</i>	8	Barbour <i>et al.</i> , 1999
Arthropoda	Crustacea	Gammaridae	<i>Gammarus sp.</i>	4	Bode <i>et al.</i> , 1996
		Penaediae	<i>Fenneropenaealndicus</i>	8	Barbour <i>et al.</i> , 1999
	Insecta	Isotomidae	<i>Isotomurus sp</i>	5	Bode <i>et al.</i> , 1996
		Caenidae	<i>Caenius sp</i>	7	Hauer and Lamberti, 1996
		Gomphidae	<i>Gomphus sp</i>	5	Bode <i>et al.</i> , 1996
		Belostometidae	<i>Lethocerus sp</i>	5	Barbour <i>et al.</i> , 1999
		Nepidae	-	5	-
		Hydrophilidae	<i>Hydrophilus sp.</i>	5	Bode <i>et al.</i> , 2002
		Chaoboridae(midges)	<i>Chaobarus sp</i>	8	Bode <i>et al.</i> , 1996
		Chironomidae	<i>Chironomus sp</i>	8	Hauer and Lamberti, 1996

Source: (Hilsenhoff, 1988; Barbour *et al.*, 1999; Hauer and Lamberti, 1996; Bode *et al.*, 1996, 2002).

Table 5: Family biotic index (FBI) in the downstream of River Dikhow.

Sector	FBI value	Water quality	Degree of organic pollution
I	6.52	Fairly poor	Significant organic pollution
II	6.38	Fair	Fairly significant organic pollution
III	7.47	Fairly poor	Significant organic pollution
IV	6.28	Fair	Fairly significant organic pollution
V	6.31	Fair	Fairly significant organic pollution

Table 6: Biological water quality of the downstream of dikhow river during pre-monsoon, monsoon, post-monsoon and winter seasons during the study period.

Sectors	Seasons	Saprobic score	Diversity score	Water quality	Water quality class
I	Pre-monsoon	5.38	0.39	Moderate pollution	C
	Monsoon	5.55	0.42	Moderate pollution	C
	Post-monsoon	5.42	0.35	Moderate pollution	C
	Winter	5.39	0.39	Moderate pollution	C
II	Pre-monsoon	5.5	0.40	Moderate pollution	C
	Monsoon	6	0.52	Slight pollution	B
	Post-monsoon	5.5	0.42	Moderate pollution	C
	Winter	5.5	0.42	Moderate pollution	C
III	Pre-monsoon	3.96	0.32	Moderate pollution	C
	Monsoon	4.96	0.42	Moderate pollution	C
	Post-monsoon	4.55	0.325	Moderate pollution	C
	Winter	4	0.35	Moderate pollution	C
IV	Pre-monsoon	5	0.48	Moderate pollution	C
	Monsoon	5.32	0.51	Slight pollution	B
	Post-monsoon	5.30	0.48	Moderate pollution	C
	Winter	5	0.45	Moderate pollution	B
V	Pre-monsoon	6.5	0.55	Slight pollution	B
	Monsoon	6.8	0.71	Slight pollution	B
	Post-monsoon	6.5	0.65	Slight pollution	B
	Winter	6.4	0.56	slight pollution	B

post monsoon which may be due to a higher flow rate and flooding nature of the river during monsoon, as all were seen to be flood prone areas.

The highest population of macroinvertebrates is contributed by Physidae family of class Gastropoda of Phylum Mollusca followed by family Pannidae of class crustacea. Pannidae is followed by family Anomidae of class Bivalvia, followed by population of family Hirudinidae of class Hirudinea (Fig 2). Family chaoboridae of class Insecta followed Hirudinidae. Chaoboridae is followed by family chironomidae of class insect (Fig 2). Family Gomphidae, Belostomatidae and caennidae of class insect contributed with very low population compared to above mentioned families (Fig 2). Family gammaridae of class Crustacea, nepidae and isotomidae of class insecta showed lowest population during the study period (Fig 2).

The Biotic Index was originally developed by Hilsenhoff (1982) to provide a single 'tolerance value' which is the average of the tolerance values of all species within the benthic arthropod community. The Biotic Index was subsequently modified to the family-level with tolerance values ranging from 0 (very intolerant) to 10 (highly tolerant) based on their tolerance to organic pollution creating the Family Biotic Index (FBI). FBI was further developed by the State of New York to include other macroinvertebrates for the use of the U.S. EPA Rapid Bioassessment Protocol II (Plafkin *et al.*, 1989; Bode *et al.*, 1991). The FBI was thus used to evaluate the water quality of each Sector. Although the BI may be applicable for other types of pollutants, it has only been evaluated for organic pollutants (Hilsenhoff, 1987). In the present study, it was found that in sector II, IV and V, the FBI values were found within 5.51-6.50 that is 6.38, 6.28 and 6.31 respectively, the water quality can be considered as fair. Thus, there may be fairly significant organic pollution (Hilsenhoff, 1987). But in sector I and III, as the values were (6.52 and 7.47 respectively), between the range of 6.71-7.50, the water quality can be considered as fairly poor and significant organic pollution (Hilsenhoff, 1987). The reason behind the organic pollution can be described as various anthropogenic factors including disposal of organic wastes, solid waste, animal and human excreta, fly ash, insecticides, bathing, mixing of detergents, soap with water continuously (Xu *et al.*, 2020; Surendra *et al.*, 2023). The influence of anthropogenic factors were found to be greater in these two sectors.

The FBI score was complemented by BWQC which has been developed by Central pollution Control Board (CPCB) in 1999. In the present study it was reported that in sector V, the saprobic scores were found to be comparatively higher than the rest sectors. The diversity scores were also comparatively higher in this sector. The water quality in all the seasons in this sector was found to be slightly polluted: but in other four sectors, the water quality was moderately polluted. However, slight pollution was seen during monsoon in sector II and IV. The range of pollution in sector I and III was found to be higher as compared to other sectors. This may be as a result of various anthropogenic factors and local land uses. Besides, these sectors can be influenced by the discharge of domestic effluent and by community bathing. Interestingly during pre-monsoon. From the study, it can be said that sector II, IV and V are less influenced by the human activities when compared to sector I and III. Due to the increase in flow of the stream during monsoon, pollution level seems to decrease slightly and water quality improved and impact of monsoon pilgrimage became evident only during post monsoon where water again became moderately polluted (Sreejith *et al.*, 2008, As and Biswas, 2023). Abundance of pollution tolerant species of benthic fauna is a clear indication of organic contamination and the enrichment of organic matter in the river (Mason, 2002; Sreejith *et al.*, 2008).

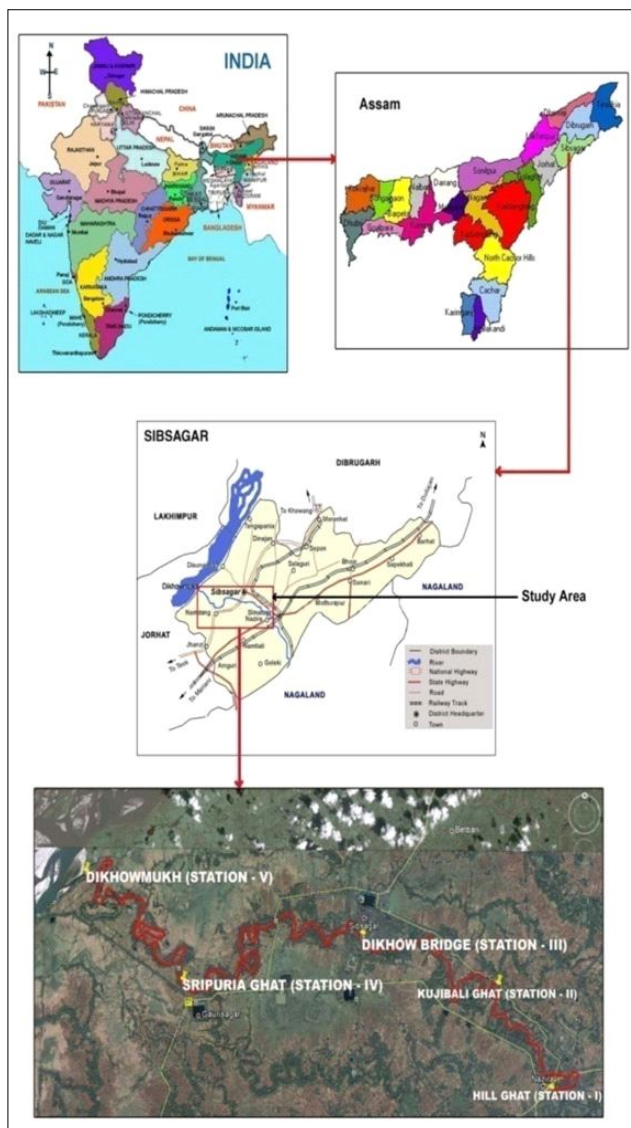


Fig 1: Location map of study area.

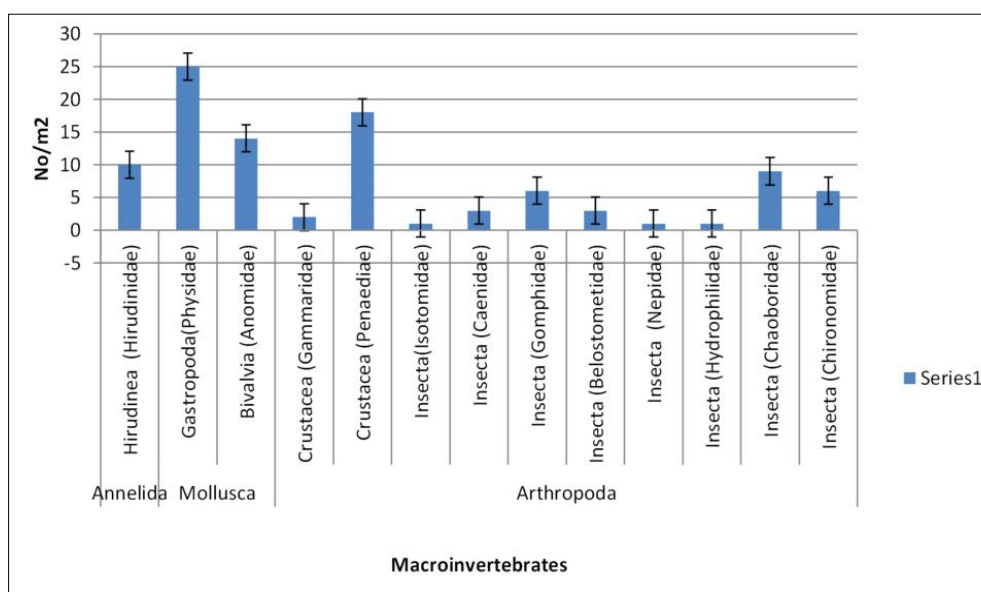


Fig 2: Population density of macroinvertebrates in the tail race of Dikhow River during the study period.

CONCLUSION

Rivers reflect the status and quality of their landscape, river bio-assessment of river through biological monitoring has to have a connection between water quality and quantity, ground and surface water and the interdependence of aquatic biota on water and the landscape. Because, biology is the ultimate integrator of these interactions and biology provides the most direct and effective assessment of the status of the rivers. Biological criteria provide sensitive tracking of resource condition, particularly because the impairment of water is predominantly caused by non-toxic and non-chemical factors. Additional strength of bio-monitoring include the ability to assess and characterize resource status, diagnose physical, chemical and biological impacts as well as their cumulative effects serve a broad range of regulatory as well as environmental program when integrated with chemical assessment and also provide a cost-effective approach to resource protection.

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Conflict of interest

The authors in this article declare that there is no conflict of interest.

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