Biomonitoring Of Aquatic Ecosystem With Concept And Procedures Particular Reference To Aquatic Macro invertebrates

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ABSTRACT: The "biological monitoring" has been widely used to assess the environmental impact of pollutant discharges. The methodology must be evaluated in terms of false positives and false negatives. A false positive is an indication that an excursion beyond previously established quality control conditions (i.e., unacceptable conditions) has occurred when, in fact, one has not. A false negative is an indication that conditions are acceptable when, in fact, they are not. Statistics must play a more important role in biological monitoring because they are capable of explicit statements of confidence in the biological monitoring results. With appropriate statistical evaluation of the data, professional judgment on whether to initiate immediate action or wait for more confirming data will be more objective and reliable. In order to optimize the usefulness of biological monitoring, the selection of biological monitoring methodology shall not be based on the investigator's favorite organism or group of organisms. Neither can be a convenient methodology adopted by regulatory agencies. The selections must be based on the compatibility of data generated with the decision making process, including the statistical establishment of confidence in the result obtained.
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INTRODUCTION:

In recent years, the environment has been put to serious threat due to the discharge of harmful and toxic chemicals of various types which are primarily the byproducts of developmental activities like industrialization, urbanization, use of chemical fertilizers as well as pesticides and burning of fossil fuel emitting green house gases. Huge oil spills in the oceans and radioactive fallout are contaminating air, water and soil. In the event of large scale eco-degradation, it is necessary to monitor the nature and degree of change in environment so that the consumers may be warned and appropriate preventive and specific corrective measures may be adopted. After the UN conference on the Human Environment in Stockholm in 1972, the global Environmental Monitoring System (GEMS) has been set up. Literature is missing today. Environmental monitoring requires authentic data base and is considered as an useful tool in assesses the health of the environment. Furthermore, it is an indispensable prerequisite for Environmental Impact Assessment (EIA). Biomonitoring is an important exercise in the assessment of water quality. The present paper aims to discus the concept scope and procedure of biomonitoring. The concept of indicator species has been explained, species can be classified in tolerant facultative and sensitive groups. A holistic approach for water quality assessment has been suggested.

CONCEPT OF BIOMONITORING

Environmental monitoring is a systematic method of collecting qualitative & quantitative information about the status of environment by physico-chemical and biological methods. Monitoring by biological methods i.e. as "biomonitoring" is 'an ecological exercise where various kinds of biota are considered in ascertaining the extent of pollution in a water body'. These biota are known as bioindicators.

OBJECTIVE OF BIOLOGICAL MONITORING

Biological monitoring can be used for the following purposes:

1) To provide an early warning of a violation of quality control systems in time to avoid deleterious effects to ecosystems.
2) To detect episodic events such as accidental spills, failure of predictive models, failure of early warning systems or illegal disposal of wastes at night, etc.
3) To detect trends or cycles.
4) To determine information redundancy
5) To evaluate environment effects associated with the introduction of make it or concise part of introduction genetically engineered organisms into natural systems.

SCOPE OF BIOMONITORING

Biomonitoring has ample scope in ecology where biologists can play a meaningful role in environmental management. The idea of using appropriate organisms in the assessment of environmental quality originated at the beginning of twentieth century. It has been emphasized that nature and degree of pollution of any water body may be judged from the occurrence, abundance and composition of the inhabiting organisms. According to Forbes (1913) it is quite possible to arrange the plants and animals of a stream in order of their preference for or tolerance of organic impurities in such a way that their graded list may serve as an index to the level of contamination". Wilhm (1975) reported that environmental stresses eg. pollution induce changes in the structure and function of biological systems. Such changes may occur from the molecular to community level. In recent years biochemical, cytological and histological analysis are conducted with sophisticated instruments to assess the extent of pollution with much accuracy. Mason (1980) further stated that biological assessment of water quality involves three sequential steps: Suvey, surveillance and monitoring or research. The survey is the first step that apprises one about ecological condition of a given spot where the biomonitoring programme is to be followed. For example, In case of a lake, its geomorphology, ecogeography, nutrient status, inflow and outflows, point and non-point sources of pollution as well as biotic community may be known through survey. which should also take into account the anthropogenic influences such as socio-demographic, economic and cultural on the lake. The surveillance is vital practice of repeated measurements of the variables dependent or independent, of a particular habitat. The final step is monitoring the pollution status of the habitat concerned. The vast amount of data produced during surveillance is subjected to critical analysis for the final analysis & interpretation. The programme objective should be clearly defined and the sampling strategy outlined at the beginning of biomonitoring programme. Aquatic biota which can be are classified as follows:

1. **Plankton**: Microscopic organisms having either relatively small / one power locomotion and drift in the water due to the subject to the action of waves, currents and other forms of water motion".
2. **Periphyton:** Periphyton are assemblage of minute organisms (both plants and animals) growing on free surfaces of submerged substrata, natural (e.g. plant parts) or artificial (e.g. rocks).
3. **Nekon** includes the organisms (animals) of larger size moving freely and independently, in aquatic environment.
4. **Neuston** are the organisms resting or swimming on the surface film of water.
5. **Pleuston** are floating / submerged in higher plants water.
6. **Benthos** organisms which live in or on the bottom sediments.

SPECIES AS INDICATORS

Using of indicator organisms for the assessment of water quality a thorough knowledge of the ecological tolerance of the organisms concerned. Depending on the sensitivity to pollution Gaufin (1958) categorized species as (1) intolerant or sensitive, (2) facultative and (3) tolerant. With the onset of pollution or stress, intolerant species are either eliminated or migrate to other places, if is scopes there. Facultative species are able to withstand moderate pollution, whereas the tolerant species can endure severe pollution. It has however been postulated that through the existence of tolerant species indicate the presence of pollution but the absence of intolerant or sensitive species also indicates the occurrence of pollution. Some examples of indicator species are cited as below:

Ephemera simulans (may fly) *Acroneuria evoluta (stone fly)*	Intolerant or sensitive species
Hydropsyche bronta (caddis fly) *Agabus stagninus (beetle)*	Facultative species
Chironomus riparium (true fly) *Limnodrilus sp.* *Tubifex sp.*	Tolerant species

Further say few words how benthic involucrate are different from the above species and why they are grouped. Richardson (1925) categorized benthic Macro invertebrates into three groups on the basis of their degree of tolerance to pollution:

Pollution Level	Type of macroinvertebrates
1. Pollutional or more or less tolerant species	Tubificid worms, midge larvae etc.
2. Cleaner preference species	Current loving snails, insects, crustaceans etc.
3. Clean water species	Snails of Viviparidae, insects or insect larvae or

	nymphs of Hemiptera, Odonata, Neuroptera, Coleoptera etc.

Kolkwitz and Marsson (1908, 1909) propounded saprobien system based on the observation that a river receiving a heavy input of sewage shows zones of decreasing pollution. These zones are polysaprobic, α - mesosaprobic, β - mesosaprobic and oligosaprobic and their sequence reflects self purification. Fzerdingstand (1963) proposed nine stream zones as follows: (i) Coprozoic (ii) α - polysaprobic (iii) β - Polysaprobic (iv) χ - polysaprobic (v) α - ,mesosaprobic (vi) β - mesosaprobic (vii) χ - mesosaprobic (viii) Oligosaprobic and (ix) Katharobic. Organisms are graded into four groups on the basis of tolerance to organic enrichment as follows: Fecal coliforms, especially *Escherichia coli* is a better indicator of sewage pollution than total coliform count. The count is made by the most probable number (MPN) technique. Fecal coliform count <5000 cells / 100 ml is the minimum standard.

1.	Saprobiontic species	Occurring only in heavily polluted waters (tolerant species)
2.	Saprophilic species	Occurring generally in polluted waters but may also be found in other communities (facultative species)
3.	Saproxenous species	Generally found in unpolluted waters but are able to survive in presence of pollution (facultative species)
4.	Saprophobous species :	Unable to tolerate presence of pollution (sensitive or intolerant species)

BIOMONITORING WITH COLIFORM BACTERIA

It has been estimated that average adult excretes about 2000 000 000 coliform each day and its number is a reliable measure of fecal pollution. The presence of fecal coliforms in a water body indicates that the fecal pollution has occurred. Earlier total coliform count was used as an indicator. It is now proved that the presence in water of

BIOMONITORING BASED ON TOXICITY TEST

The presence of toxic substance in aquatic medium may be determined by toxicity test. In which suitable organisms are placed in water containing toxic chemicals and observations are made on the mortality of the test organisms. The toxicity may be acute, chronic, lethal, sublethal and cumulative. Lethal concentration is considered as the criterion of toxicity. The percentage of experience are expressed with a number, say LC_{50} which indicates the percentage (50% in this case) of animals killed at a particular concentration. The time of exposure is also important in toxicity. Eg. 48-hour $LC_{50,}$ means the concentration of a toxic substance can kill 50% of the test organisms in 48-hours. Instead of ex *situ* observation, an in *situ* continuous flow system has been devised. In such cases, caged organisms are placed in the field. In toxicity test, various organisms like algae, protozoa, rotifers, insects, microcrustaceans etc. can be used.

FISH ALARM SYSTEMS

It is well established that fishes show distinct physiological and behavioral responses to pollutants. The behavioral responses can be seen and observed by various techniques. An automatic fish monitor tank with required gadgets has been devised. If the polluted water is allowed to enter such a tank, recording of movement and other responses will be automatically done from which the quality of water can be assessed.

BIOCHEMICAL OXYGEN DEMAND AND BIOMONITORING

The BOD values serve as good indicator of organic pollution. Although often considered as a component of chemical monitoring but in reality, it is based on a biological process and therefore, it may be regarded as an aspect of biomonitoring.

Water quality according to BOD values
(as followed in UK)

Water quality	**BOD_5 at 20^0c (mg/l)**
Very clean	<1
Clean	1-2.5
Fairly clean	2.5-4
Poor	6-10
Bad	10-15
Very bad	15-20

MISCELLANEOUS METHODS OF BIOMONITORING

Weber and McFarland (1969) used ash-free weight of periphyton and concentration of chlorophyll a in assessing the water quality. They proposed the following index (I_q) to characterize water quality I_q =

$$\frac{ash-free\ weight\ of\ perphyton\ (gm^{-2})}{Chlorophyll\ a\ \ (gm^{-2})}$$

According to the author the index values in unpolluted or slightly polluted waters contain mostly populations of algae and therefore, the index value should be lower than in polluted areas having large populations of filamentous bacteria and non-chlorophyll bearing organisms.

Odum (1956) found that the ratio between production and respiration (P/R) might serve the purpose of biomonitoring. According to him in the septic (polluted) zone of a stream, the respiration fax exceeds production and obviously the P/R ratio would be less than one. In the recovery zone, production increases and exceeds respiration and as a result P/R ratio would exceed one.

1.0 – 1.5	Oligosaprobic	No pollution
1.5 – 2.5	β - mesosaprobic	Weak organic pollution
2.5 – 3.5	α - mesosaprobic	Strong organic pollution
3.5 – 4.0	Polysaprobic	Very strong organic pollution

The ratio between production and biomass (P/B) may also serve as an indicator of environmental conditions. It is now known that pollution by organic phosphorous insecticides can be assessed by determining the brain acetylcholinesterase of the experimental fish. Analysis of serum and other blood components are also useful in the detection of pollution. Radioactive pollution can be determined by studying banding patterns in chromosomes.

MATHEMATICAL APPROACH IN BIOMONITORING

A large number of mathematical formulations (or indices) have been developed in biomonitoring. Surveillance programme over time produces voluminous data on various aspects of environment. Such data must be analysed to make the surveillance worthwhile. The analysis of surveillance data may be done by multivariate analysis or by using biotic or diversity indices. Multivariate analysis can be carried out on both qualitative (presence/absence) and quantitative data. Green (1979) strongly recommended that Principal Component Analysis (PCA) should from the basis of multivariate analysis. However, some biotic and diversity indices are briefly given below:

BIOTIC INDICES

A biotic index takes into account the sensitivity of tolerance of individual species or groups to pollution and assigns them a value, the sum of which gives an index of pollution for a site. The data may be qualitative (presence/absence) or quantitative (relative abundance or absolute density). These indices are designed mainly to assess the organic pollution in water bodies.

The saprobien system of Kolkwitz and Marsson (1908, 1909) is the earliest biotic index. Polysaprobic, α - mesosaprobic, β - mesosaprobic and oligosaprobic zones from the higher organic enrichment to decreasing state in a river are recognized and the presence or absence of indicator species in the said zones are recorded. This information is used to monitor pollution. Pantle and Buck (1955) also developed the saprobien system to take into account the relative abundance of organisms in a sample. They assigned a value (h) to express the abundance of each organism in the different Saprobien groups as well as a value (s) for the saprobic grouping.

The saprobic index of Pantle and Buck

The saprobic index ranges are

Saprobien groups		**Relative abundance**	
	s value		h value
Oligosaprobic	1	Occurring incidentally	1
β - mesosaprobic	2	Occurring frequently	3
α - mesosaprobic	3	Occurring abundantly	5
Polysaprobic	4		

Mean saprobic index (S) = $\frac{sh}{h}$

Trent biotic index (TBI)

Considers the presence and absence of species and species richness, but animals does not need counting. The sensitivity to organic pollution of different species or groups is used in determining the index. In grossly polluted waters, where no macro-invertebrates are present, a TBI of zero is obtained.

The maximum score in unpolluted water with a species rich invertebrate fauna is 10.

Chandler Biotic Score (CBS) –

According to Chandler Biotic Score (1970), the abundance of organisms within the community as well as the species richness, is of value assess the degree of pollution. This index has five levels of abundance, the score of each indicator species being weighted in relation to its abundance. If a species intolerant of pollution is abundant, it is given a high score of 100, whereas an abundant, pollution tolerant species is given us a lower score of 4. The allocation of scores is somewhat arbitrary because the lower limit of the score is zero while there is no upper limit when no macro-invertebrates are present,

Community Similarity Indices (Plafkin *et al*, 1989):

These indices are used in situations where a reference community exists either through sampling or through prediction for a region. Data sources or ecological data files may be available to predict a reference community to be used for comparison. These indices are designed with either species level identifications or higher taxonomic levels. Three of the many community similarity indices available are discussed as below

(Sample A = reference station [or mean of reference database]

Sample B = station of comparison)

- Community Loss Index- it measures the loss of benthic taxa between a reference station and the station of comparison. This is an index of compositional dissimilarity with values increasing as the degree of dissimilarity with the reference station

Increases. Values range from 0 to ∞. This index seems to provide greater discrimination than either of the following two community similarity indices. The formulae for the Community Loss Index is:

$$Community\ Loss = \frac{d-a}{e}$$

Where

a = number of taxa common to both samples

d = total number of taxa present in Sample A

e = total number of taxa present in Sample B

- Jaccard Coefficient of Community Similarity- Measures the degree of similarity in taxonomic composition between two stations in terms of taxon presence of absence. The Jaccard Coefficient discriminates between highly similar collections. Coefficient values, ranging from 0 to 10, increase as the degree of similarity with the reference station increases.

The formulae for the Community Loss Index and the
Jaccard Coefficient are:

$$Jaccard\ Coefficient = \frac{a}{a+b+c}$$

where

a = number of taxa common to both samples

b = number of taxa present in Sample B but not A

c = number of taxa present in Sample A but not B

- Pinkham and Pearson Community Similariy Index- Incorporates abundance and compositional information and can be calculated with either percentages or numbers. A weighting factor can be added that assigns more significance to dominant taxa. The formula is:

$$S.I._{ab} = \sum \frac{\min(x_{ia}, x_{ib})}{\max(x_{ia}, x_{ib})} \left[\frac{x_{ia}}{x_a} \cdot \frac{x_{ib}}{x_b} \div 2 \right]$$

(Weighting factor)

where

x_{ia}, x_{ib} = number of individuals in the i^{th} taxon in Sample A or B

DIVERSITY INDICES

Mason (1980) stated that biotic indices have been developed to measure responses to organic pollution and may be unsuitable for detecting other forms of pollution. Diversity indices are used to measure stress in the environment. It has been seen large number species are found in unpolluted environment, with no single species making up the majority of the community and a maximum diversity is obtained when a large number of species occur in relatively low number in a community. When an environment becomes stressed, species sensitive to that particular stress tend to disappear. As a result species richness will be reduced, and the density of the surviving species will increase. Species diversity indices usually take account of both the number of species (species richness) and their relative abundance (evenness). There are number of diversity indices but the most widely used is Shannon index of general diversity, which is based on information theory. According to Southwick (1976) “Information theory is a branch of science and mathematics which deals with measurable and quantifiable units of information”. It involves the numerical analysis of systems which transmit, process, or store information". Southwick (*op cit.*) further emphasized that "information theory provides the numerical basis for analyzing systems of all types, living as well as non-living".

Shannon index $(\bar{H})$

Where ni = importance value for each

$$\bar{H} = -\sum \left(\frac{ni}{N}\right) \log\left(\frac{ni}{N}\right) (Odum,\ 1971)$$

Where ni = importance for each species and N = total of importance values

$$H^{'} = -\sum_{i=1}^{S} pi \log\ pi\ (Mason, 1980)$$

where pi is estimated from ni/N as the proportion of the total population of N individuals belonging to i^{th} species (ni)

On the basis of observation of the diversity index in a range of polluted and unpolluted streams Wilhm and Dorris (1968) reached at the following eonclusion.

H (Shannon index of diversity)	Condition of water quality
> 3	Clean water
1 - 3	Moderately polluted

BMWP Biotic Index (Armitage *et al*, 1983; Friedrich *et al*, 1996; Hynes, 1998; Mackie, 1998)

In order to limit the taxonomic requirement of earlier biotic indices to identify organisms to species level, some alternative indices have been developed which use only the family level of identification. An example is the Biological Monitoring Working Party-score (BMWP) which has been published as a standard method by an international panel (ISO-BMWP, 1979). This score was devised in the UK but was not specific to any single river catchment or geographical area. The new BMWP score attempted to take the advantages of earlier biotic indices. The Biological Monitoring Working Party (BMWP) score is calculated by adding the individual scores of all indicator organisms present (family level, except order Oligochaeta) (Friedrich *et al*, 1996).

The organisms are identified to the family level and then each family is allocated a score between 1 and 10. The score values (Table II-15) for individual families reflect their pollution tolerance; pollution intolerant families have high scores and pollution tolerant families have low scores. Mayfly nymphs score 10, molluscs score 3 and the least sensitive worms score 1. The number of taxa gives an indication of the diversity of the community (high diversity usually indicates a healthy environment, Friedrich *et al*, 1996).

Table II-15: Pollution sensitivity grades for families (higher levels in a few cases) of river macroinvertebrates for SIGNAL (S) and BMWP (B) scores. Families not occurring in North America have been omitted. N represents families found in N. America and are graded according to the inverse of Bode et al (1991) and Plafkin et al (1989) tolerance values to correspond to SIGNAL and BMWP scores (modified from Mackie, 1998)

Family	Grade			Family	Grade			Family	Grade		
	N	B	S		N	B	S		N	B	S
Acariformes	6	-	-	Gammaridae	4	6	6	Peltoperlidae	9	-	-
Aeolosomatidae	2	-	-	Gerridae	5	5	4	Perlidae	8	10	10
Aeshnidae	6	8	6	Glossiphoniidae	3	3	3	Perlodidae	8	10	-
Agrionidae	4	8	-	Glossosomatidae	10	-	8	Philopotamidae	7	8	10
Ancylidae	4	6	6	Gomphidae	6	8	7	Phryganeidae	7	-	-
Anthomyiidae	4	-	-	Gordiidae	8	10	7	Physidae	2	3	3
Anthuridae	4	-	-	Gyrinidae	5	5	5	Piscicolidae	5	4	-
Asellidae	2	3	-	Haliplidae	5	5	5	Planariidae	4	5	3
Arctiidae	5	-	-	Haplotaxidae	1	1	5	Planorbidae	3	3	3
Arrenuridae	4	-	-	Helicopsychidae	7	-	10	Platyhelminthidae	6	-	-
Astacidae	4	8	-	Helodidae	5	5	-	Pleidae	5	5	-
Athericidae	6	-	7	Heptageniidae	7	10	-	Pleuroceridae	4	-	-
Atractideidae	4	-	-	Hirudinea	0	-	-	Polycentropodidae	4	7	8
Baetidae	5	4	5	Hyalellidae	2	-	-	Polychaeta	4?	-	-
Baetiscidae	6	-	-	Hydridae	5	-	4	Polymetarcyidae	8	-	-
Belostomatidae	5	-	5	Hydrobiidae	4	3	5	Potamanthidae	6	10	-

Blephariceridae	10	-	10	Hydrometridae	5	5	5	Psephenidae	6	-	5
Branchiobdellidae	4	-	-	Hydrophilidae	5	5	5	Psychodidae	8	8	2
Brachycentridae	9	10	-	Hydropsychidae	6	5	5	Psychomyiidae	8	8	-
Caenidae	5	7	-	Hydroptilidae	5	6	6	Pteronarcidae	10	-	-
Calopterygidae	4	-	-	Hygrobiidae	5	5	5	Ptychopteridae	1	-	-
Capniidae	8	10	-	Idoteidae	5	-	-	Pyralidae	5	-	6
Ceratopogonidae	4	-	6	Isotomidae	5	-	-	Rhyacophilidae	9	-	7
Chaoboridae	2	-	-	Lebertiidae	4	-	-	Sabellidae	4	-	-
Chironomidae	1	2	1	Lepidostomatidae	10	10	-	Scirtidae	5	5	8
Chloroperlidae	10	10	-	Leptoceridae	6	10	7	Sialidae	6	4	4
Chrysomelidae	5	5	-	Leptophlebiidae	7	10	10	Simuliidae	5	-	5
Coenagrionidae	2	6	7	Lestidae	1	-	7	Siphlonuridae	8	10	-
Collembola	5?	-	-	Leuctridae	10	10	-	Sphaeriidae	4	3	6
Corbiculidae	4	-	6	Libellulidae	8	8	8	Spurchonidae	4	-	-
Corduliidae	7	8	7	Limnephilidae	7	7	8	Sisyridae	5	-	-
Cordulegasteridae	7	8	-	Limnesidae	4	-	-	Tabanidae	5	-	5
Corixidae	5	5	5	Limnocharidae	4	-	-	Taeniopterygidae	8	10	-
Corydalidae	6	-	4	Lumbriculidae	2	1	1	Talitridae	2	-	-
Culicidae	1	-	2	Lymnaeidae	4	3	-	Thiaridae	6	-	7
Dixidae	10	-	8	Mesoveliidae	5	5	4	Tipulidae	7	5	5
Dolichopodidae	6	-	-	Mideopsidae	4	-	-	Tricorythidae	6	-	-
Dreissenidae	2	-	-	Molannidae	4	10	-	Tubificidae	1	1	1
Dryopidae	5	5	-	Muscidae	4	-	3	Tyrellidae	4	-	-
Dytiscidae	5	5	5	Naididae	3	1	1	Unionidae	4	6	-
Elmidae	5	5	7	Nemouridae	8	7	-	Unionicolidae	4	-	-
Empididae	4	-	4	Nepidae	5	5	-	Valvatidae	2	3	-
Enchytreidae	1	1	-	Nepticulidae	5	-	-	Veliidae	5	-	4
Ephemerellidae	10	10	-	Notonectidae	5	5	4	Viviparidae	4	6	-
Ephemeridae	8	10	-	Odontoceridae	10	10	8				
Ephydridae	4	-	2	Oedicerotidae	4	-	-				
Erpobdellidae	3	3	3	Oligochaeta	2	-	-				

Note: The grades under (N) above should be used in the said indices (there is some question as regards the grades of the taxa which have been noted along with a `?')

BIOLOGICAL WATER QUALITY CRITERIA (BWQC)

To assess the actual health of water bodies, CPCB has derived a Biological Water Quality Criteria (BWQC) for water quality evaluation. This system is based on the range of saprobic values and diversityof the benthic macro-invertebrates families with respect to water quality. The system has been developed after making calibration study on the saprobic score and diversity score data on the presence of different taxonomic groups of benthic macro-invertebrate families in few lakes, ponds and reservoirs. To indicate changes in water quality to different grades of pollution level, the entire taxonomic groups, with their range of saprobic score from 1 to 10, in combination with the range of diversity score from 0 to 1 has been classified in to five different classes of water quality (Table 3). The abnormal combination of saprobic scorer and diversity score indicates sudden change in environmental conditions.

Table: 3 Biological Water Quality Criteria (BWQC) for Lakes/Ponds and Reservoirs

S.No. Score	Range of saprobic score	Range of diversity class	Water Quality Indicator	Water Quality	Colour
1.	7-10	0.5-1	A	Clean	Blue
2.	6-7	0.5-1	B	Slight pollution	Light blue
3.	3-6	0.3-0.9	C	Mod. Pollution	Green
4.	2-5	0.4 & less	D	Heavy pollution	Orange
5.	0-2	0-0.2	E	Severe pollution	Red

WHY BIO-MONITORING?

1. Animals and plant communities respond to intermittent pollution, which may be escaped in a chemical sampling / monitoring programme.
2. Biological communities may respond to new or unsuspected pollutants in the environment, which are difficult to analyze chemically. It would be uneconomic and impracticable to regularly determine concentration of 1500 or so known pollutants.
3. The chemical analysis is relatively expensive in terms of equipment needed and number of analysis required to achieve results with comparable reliability, to those achieved by bio-monitoring.
4. Biological monitoring can reflect the environmental pollution levels as some chemical species are accumulated in the bodies of biotic organisms.

Table 1: Comparison of Physico-chemical monitoring with Biological monitoring.

S.No.	Characteristic	Physico-chemical Monitoring	Biological Monitoring
1.	Pollutant concentration	Good	Poor
2.	Assessment of intermittent, irregular pollution discharge	Not possible unless continuously monitored	Possible without continuous monitoring
3.	Kind of pollution assessment	Good	Poor
4.	Reliability (representation of data)	Poor	Good
5.	Measure of ecological effect	Not possible	Possible
6.	Monitoring	Relatively high	Relatively low

ADVANTAGES OF BIOLOGICAL ASSESSMENT

1. The biological methods are quite quick, economical and can be integrated with other relevant studies.
2. Much less equipments are required and large area can be surveyed in less time resulting in large amount of information suitable for assessment.
3. Provide cheaper option in comparison to physico-chemical assessment, where chemical analytical equipment, manpower and operational cost are very high.
4. Biological assessment methods do not eliminate the need for chemical analysis of water samples, however, these may provide information, which may be integrated with physico-chemical information.
5. The integration of biological method with physico-chemical method may provide a system, which is not too expensive and generate necessary information with maximum efficiency.

INFORMATION GENERATED BY BIOLOGICAL BIO-ASSESSMENT

Biological assessment relies on the fact that pollution of water body will cause changes in physico-chemical environment of water and that those changes will disrupt the ecological balance of the system. The measure of extent of ecological upset will depict the severity of pollution. The extreme kind of ecological upset may be clearly visible, such as – unusual color in water, increased turbidity, or presence of dead fishes or mortality, however, many form of ecological damage cannot be assessed without detailed examination of aquatic biota.

Biological assessment of often able to indicate an effect on ecosystem arising from a particular use of the water body. It can determine and depict the general effect of anthropogenic factors on ecosystem as well as the presence and effects of common pollution problems (eutrophication, toxicity and industrial inputs etc.) Biological assessments exhibit deleterious changes in aquatic communities and provide systematic information on water quality. The pollution transformation in water and in organisms can be determined through biological surveillance. The long-term effects of polluting substances in water body may be reflected by study of bio-accumulation and bio-magnification. The biological surveillance may depict the conditions resulting from disposal of wastewater, its character and dispersion as well as assess the effectiveness of environmental protection measure. Quantify the toxicity of substances under controlled, defined laboratory conditions (e.g. toxicity studies).

1. The biological systems used as water quality indicators should have following characteristics:

2. The sampling, sorting, identification and data processing should be as simple as possible involving minimum time and manpower.

SELECTION OF BIOLOGICAL ORGANISMS AS WATER QUALITY INDICATOR

1. It is impossible to study the entire biota present at a sampling area due to constraints of time and wide variety of sampling method required for different group of organisms.
2. The biomonitoring / surveillance must therefore be based on those organisms, which are most likely to provide right information regarding pollution effects.
3. The use of single species as water quality indicator is usually avoided because individual species depict high degree of temporal and spatial variation due to habitat and biotic factors.
4. The indicator species must be able to be used to detect subtle rather than gross and obvious effect of pollution.

CONCLUSION

The term "biological monitoring" has been widely used in this discussion to include almost any type of data gathered to assess the environmental impact of discharges. In our opinion, biological monitoring is limited to a continue collection of data to establish whether explicitly stated quality control conditions are being met. If these conditions are not being met, there will be an immediate decision to take corrective action. Purpose of biological monitoring include providing early warnings of hazards, detecting spills, detecting environmental trends or cycles, determining the best and least redundant information for monitoring, and evaluating the environmental effects associated with the introduction of genetically engineered organisms into natural systems. One design will not serve each purpose, but if the researchers have clearly defined goals for the monitoring program, powerful designs are possible.

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