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Research Paper

BIOMONITORING OF WATER ENVIRONMENT IN RIVERS, PONDS AND LAKES

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Abstract

Over the decades, the water environment is being polluted by anthropogenic sources. Various methods of study pollution, either identifying the type of pollutants by analytical techniques or indirect method i.e. impact on water quality have been developed. Algae and benthic macro invertebrates are useful to assess long-term impact of pollution in small stream, ponds, large rivers and reservoirs. Assessment of water quality is presently practiced by analyzing the physicochemical parameters and biological flora and fauna. Water is used for drinking, recreational purpose, transport and obtaining valuable food commodities. However, the increasing importance of getting purified water for different uses becomes quality demand. Indicator organism concept prevails from as early in the 1910, when German biologists have tried to defined pollution in existing water bodies. The article summarized the Saprobity in water.

Key words: Aquatic pollution, Biocenoses, Bioindicator, Saprobic index, Trophic index.

INTRODUCTION

Saprobity is pollution of organic matter in the water bodies of geographical regions. Progress is being taking place in water quality monitoring at every nooks and corners. However, water is largely affected by pollution chemically sometimes addition of toxic substances or organic wastes which on decomposition depletes the oxygen content. Conductivity also significantly correlated with eight out of twelve water quality parameters studied based on regression analysis [1]. Similarly, water quality and it's evaluation based on physico-chemical and biological parameters has a prime consideration in recent years also agriculture purpose the quality of water is determined by salts and silt content of water [2]. The concentration of Sodium, Potassium, Calcium, Magnesium, Chlorides, Sulphates, Carbonates and Bicarbonate usually decide the quality of water. The amount of minerals also decides if any possible harmful physical or chemical effects are there in soil [3].

In a trophic level, water temperature also strongly influence fishes distribution and vulnerability of fishes and over all water shade management [4]. Variation of phytoplankton compared with reference site usually linked either with physicochemical parameters or numbers and diversity indices of the organisms. Assessment of biological community is usually done by application of diversity indices i.e. Shannon wiener index, species richness index, species evenness index, similarity index etc including various statistical methods [5]. Approaches leads to classified clean, mesotrophic, eutrophic waters and pollution status of lakes largely depend upon physico-chemical parameters, indicator species and different ways to define diversity e.g. Shannon wiener index [6]. Waste degradation is part of heterotrophic activities of microorganisms. Biological quality was observed significantly poor of river chittar water, e.g. TC/FC but not highly polluted [7]. Earlier findings of abiotic parameters correlated phytoplankton monitoring included saprobiological analyses conducted in upper-Tisa river, Hungary [8]. Saprobity indicator species in general use in Germany which also widely occur on the Indian subcontinent [9]. Saprobity index for assessment of biologically polluted waters of Hartala lake and Velhala lake are important lakes of Jalgaon District of Maharashtra [10]. Phytoplankton based water quality assessed in water-cooling reservoir at Berezovskaya SDPP-1 (Krasnoyarsk Territory) [11]. Earth surface is covered by 71% of the water but only 3% freshwater is available for drinking purpose, being scare and vital for well being of men, plants and animals.

BIOCENOSES

Organic substances are discharged in to water body are attacked by microorganisms and integrate them into the ecosystem's chemical metabolism. Decomposers (e.g. bacteria, fungi) breakdown the organic matter into inorganic compounds which can be used in turn by producers (algae), utilize by decomposers. Functional changes are confirmed by other investigators. Biological water analysis must not focus on the individual organism but on the biological community as a whole i.e. the biocenoses.

SAPROBITY

The saprobes are called soil microorganisms. In the surface runoff e.g. rainy season's flowing water makes soil dissolution and turbidity in water, transportation of minerals, organic matters similar to agriculture run off are a significant source of pollution and saprobity to rivers, estuaries, reservoirs and coastal zone. Saprobic levels referring to as the Prague convention defined are the bioactivity within a body of water. **Saprobity is the sum total of all those metabolic processes (activities lead to production of organic matter) which are the antithesis of primary production).** As a result of changing nutrient and food situation in both polluted and unpolluted river, a characteristic longitudinal succession of biocenose develops. The Succession can be utilized to identify the condition of flowing water ecosystem and sprobic or sprobiont classification systems came into existence. According to (Schwoerbel, 1986) biological analysis of polluted bodies of water is particularly valuable for determining

- The extent of pollution existing
    - The capacity for biological self-purification based on organisms diversity
    - Whether or not situation of biocenotic imbalance exists

The deleterious effects on the organisms and degree of pollution can often be measure just in case identifying them microscopically, though it is leading in saprobity. Criticisms of the saprobity system with a few quotation.

"Nature distinguishes no systems. All systems are made by man and have the characteristics of human work"- Kothe (GTZ,1991) [12].

"Each classification is an approximation of actual conditions and therefore must be viewed with caution" - Wachs (GTZ,1991) [12].

DIFFERENCE IN TROPHIC OR SAPROBIC WATERS

The water of static nature lake, ponds reservoir are considered based on above mentioned classification. The oligosaprobic water with low nutrient availability and thus low production also the number of organisms is relatively low. Eutrophic condition is applied to a body of water, rich in plant nutrients and therefore has a high number of organisms. The term saprobity has to do with a water body's content of decomposable organic matter and consequences, which its breakdown has. The purity of water increases in oligosaprobic waters to Kath biotic water bears organic matter is at minimum e.g Upper reaches of stream or in oligosaprobic lake which has a zone with low nutrients and characteristic flora extremely purity of the water has an effect similar to the pollution and another zone resulting in a small and characteristic flora at the other end of the scales severely polluted. The survival of different form of algae as plankton, periphyton or attached filamentous forms, successive higher forms of algae belongs to chlorophyceae and rhodophyceae are indicator of these zones and occurrence of changes in additional species in geological broaden areas [13]. Caprozoic zone is one of extreme polluted by unpurified sewage, supporting no algae at all. In water polluted by toxic chemicals even the bacterial flora may be killed and no breakdown of effluent is possible. Short term pollution of this type may be difficult to detect chemically. Since the effluent may pass away rapidly but biological examination revealed algal status (Placoderm & Saccoderm desmids) and appearance of resistant algae e.g. species of *chlamydomonas* and *Euglena*. Indicators are *Lamanea* and *Batracho-spermum* spp. of the β mesosaprobic zone through to water of kathobiotic status is an ecological rather than a pollution problem. Indicators varies according to degree of pollution of the type of water. Slight increase in domestic pollution increases the growth and in encouraging the development of certain algal species. Stimulating effect of mild inorganic pollution on some planktonic lake algae e.g. *Fragilaria crotonenasis*, *Melosira islandica*, *M. granulate* and *Rhizosolenia eriensis* which then pass in to a zone of extreme pollution from sulphite discharge from a wood pulp factory and were eliminated or reduced in number but replaced by chlorococcales e.g. *Dichtylosporium pulchellum*.

ENVIRONMENTAL MONITORING

WATER QUALITY

Recent data, sampling and analysis of water body over a period of years, a model for computer assisted water quality simulation should be useful developed on the basis of physical, chemical and biological analyses. This would provide a better assessment that predicts impacts and an instrument to planners.

Water quality simulation can make a more or less comprehensive contribution to system data and impact analysis. The following parameters can be simulated however certain characteristic flora and fauna are good bioaccumulator of heavy metals, periphytons, mosses, higher aquatic plants, filiform algae, bristle worms, amphipods, mussels are well known for their bioaccumulation capabilities. The biocoenotic situation at the time of low water makes difference in contamination of different river sections particularly apparent. It is necessary to perform separate studies covering all the seasons. Relative uniformity or heterogeneity of river section is investigated contains a diversity of microhabitants therefore more samples will be needed. Different instruments must be used for obtaining samples of sedentary and substrate linked microorganisms since as a rule these are suitable for water quality. The sample analysis data should incorporate

- Clearly described the "master form"
- Physiographic conditions i.e. the factors of relevance for the plants and animal populating the site
- Macroorganisms all plants and animals are listed which can be detected at sampling site by visual observation & identifying for saprobic index
- Microorganisms the result of microscopic analysis" Aufwuchs" or periphyton also useful for saprobic index

The frequency of occurrence of sedentary and substrate bound organisms is estimated semi quantitatively and expressed in terms. It is therefore the sum total of all those processed which are accompanied by a loss of potential energy. In combination with the biogenic and physical oxygen component, it determines the saprobity level of water. This level can be ascertained both by metabolic dynamic measurements and by analysis of the living communities.

Contribution of agriculture to pollution and saprobic matters affects biogeochemical cycle notably in terms

- Discharge of methane and ammonia contributing to the green house effect
- Use of insecticides and other pesticides affecting plant species, cultivated or not, enters in the soil affecting soil fertility.
- Saprobity is also use of oil to nutrients runoff from silage and slurry manure actively participation of microorganisms i.e. use of fertilizers leading to eutrophication.

Pollution from heavy metals, persistent organic pollutants (POPs) and radioactive substances may target small living organisms. As a result, heavy metals cations bind to short chains of atom carbon or particularly have strong affinity to sulfur in living organisms.

Different types of evaluation procedures and analysis are conducted for assessment of water parameters.

1. PHYSICAL AND CHEMICAL WATER ANALYSIS

Physical and chemical water analysis it is possible to obtain quality of water at the time and place. Various samplers e.g. Van-dorn water sampler, and Van-veen sediment grab sampler. Number of parameters should be measured for water to obtain more precise data. physiochemical analysis are necessary for water e.g. light or irradiance, temperatures, DO, pH, turbidity, Conductivity of water presence of organic carbon, ammonium, nitrite, nitrate, silicates and orthophosphate biochemical oxygen demand (BOD), alkalinity, and $CaCO_3$ hardness. These parameters can even be analyzed for diurnal, seasonal and annual observations. Additional information can be obtained by means of toxicity test on the concentration of toxic substances.

2. BIOLOGICAL PROCEDURES BASED ON THE USE OF

A) BIOINDICATORS

The definition of bioindicators is given by Ellenberg according to which "A bioindicator is a related group or community of organisms whose occurrence or an easily observed trait can be so closely correlated with certain environmental conditions that it can be utilized as a pointer or quantitative test (Hermann Ellenberg, GTZ, 1991). The evaluation of aquatic pollution with the help of bioindicators are temporal i.e. these reactions can take place in the form of growth and /or increased population density, modified activity reduced growth, a decline in population or even death and degradation. Reacting organisms to pollution in water certainly become changed i.e. size, generation time, degree of complexity in organisms. Factors and organisms of different species act faster or slower. The bacteria adapt very quickly to environmental changes. Protozoa and algae takes longer time and some of the insects which spend one year or so as larval stage reacts longer period for positive environmental change. As rule organisms, which have longer generation times respond also more quickly to negative changes if it exceeds beyond the limits of what, is tolerable. For instance, higher organisms are migrating to zone with satisfactory living conditions or dies. In contrast to physical or chemical analysis, the indicator organisms integrate and reflect environmental conditions over an extended period. Never the less critical evaluation of the species compositions of a biocoenose can yield sufficient data on the temporal change and the range of fluctuation in environmental conditions and situation of a body of water. In addition, it is upon this recognition, that the aquatic systems are based with the aid of bioindicator concept, foremost among them is the "Saprobity system".

B) BIOMONITORS

Biomonitor or so-called monitor species distinguished between two types of monitoring species may be used to yield qualitative and quantitative information on contaminants. Reactive monitors which provides information or the type and concentration of a given water pollutant whereas cumulative monitors i.e. species that store and sometimes concentrate organic pollutants, heavy metals and the like other in their bodies. The overall process starts at the level of autotrophs or heterotrophs is referred as self purification.

Relative few organisms occur in aquatic habitats that are capable of indicating presence of specific substances in the water. Organism has ability to assimilate certain contaminants such as heavy metals or pesticides etc. through the gills or skin or in the food they uptake and to accumulate it in their bodies. Biomonitors are also used for assessing brackish and marine water, in the other words **water, which it has not yet been possible to develop a "Saprobity system".** The other organisms that can provide information on the concentration and kind of pollutants, these are so called reactive indicators i.e. bioindicators e.g. *Metapuses* a ciliate is useful indicator species of Hydrogen sulfide, *Gnathonomus petersi* (Mormyridae) indicator species of certain toxic substances, and in their presence, the electrical discharges it emits such organisms are used for evaluation of drinking water.

C) REMOTE SENSING

Aerial photography can yield quantitative and qualitative information on changes in environmental conditions. Similarly, changes in the condition of large water bodies can be detected in this way.

According to saprobe classification, certain species associated with the purity or contamination of bodies of water. The considerable amount of space is given to the so-called "Saprobic system" for classification of water pollution.

SAPROBITY ANALYSIS

(i) Composition of biological population according to the four indicator groups concept

Slightly polluted water

Moderately polluted water

Heavily polluted water

Grossly polluted water

Over 140 years ago, in Europe, the first observation was published on domestic sewage is capable of changing the natural population patterns of flowing waters. The ability of living organisms to react positively or negatively to to the changes in their environment was observed in natural water which has photosynthetic activity of phytoplankton and filter-feeding crustaceans. Many organisms are able to assimilate and sometimes accumulates substances are reportedly present in the water.

It is also important to list indicator organisms for oligosaprobic, mesosaprobic and polysaprobic waters based on pollution (Table-1). According to this preliminary approach, standing waters are assigned to quality classes on the basis of their saprobic levels i.e. their nutrient status and its effect on oxygen content.

(ii) Biologically relevant organic pollution,

Kolkwitz did the comparison of saprobic and trophic levels. Liebmann rejected this approach for him the concept of oligosaprobic and oligotrophic are virtually identical but he is unable to correlate the concept of eutrophic with any saprobic level at all (Table-2). Die landerarbeitsgemeinschaftwasser (LAWA-GTZ) in 1985 has given most recent appraisal to water quality and saprobity. The water quality map only covers flowing water beside community of organisms, a few physical and chemical parameters are incorporated (Fig.1). Water quality classification was based on 7 level system.

Kolkwitz and marsson as well as later investigators considered biochemical oxygen demand, ammonium (NH_4^+) and Oxygen (O_2) contents. (Table-3)

Libmann also cited typical biocoenose of indicator organisms e.g. in standing and slowly flowing waters" of the α and β mesosaprobic and oligosaprobic zones while number of workers have attempted to arrange saprobiontic algae, which are capable of tolerating various degree of pollution.

Initially distinguished three level of self-purification

- Polysaprobic zone is predominantly reducing process e.g polysaprobes decomposing domestic sewage in standing and flowing waters.
- Mesosaprobic zone is partly decomposed, with oxidizing processes dominating. e.g. mesosaprobes in well drained fish pond
- Oligosaprobic zone is exclusively oxidizing processes e.g. Oligosaprobes

The saprobic zones of pollution affected water bodies and by visual observation show reducing zones where changes oxygen concentration to somewhere near zero and only sulphur reducing bacteria (fam.: Chromataceae- purple and green sulphur bacteria) are present.

Autotroph, particularly in biological evaluation techniques provides a distinction between use of bioindicators i,e, water quality evaluation with the saprobic classification system and methods that make use of biomonitoring or monitoring species i.e. species that assimilate and accumulate contaminants.

As the world population grows, numbering are placing ever increasing demand so on their environment. This also applies to the earth's bodies of water, oceans, seas, lakes and rivers. In developed countries, several problems of water bodies have already been caused by contamination with garbage and substances used in agriculture (such as mineral fertilizers and pesticides) due to its persistent nature in water bodies. Industrial activity namely chemical pollutants such as heavy metals and organic compounds. adversely affect aquatic flora and fauna. Thermal pollution caused by the discharge of heated water. The organisms migrate from particular zone. Increasing industrialization and population growth are leading to particularly serious problem of usage of water. The situation is further aggravated by the facts the numerous industrial production facilities in developing countries. In which the wages are lower and less stringent environmental legislation exists.

(iii) Saprobic index

Certain microorganisms in saprobic system respond to changing environment by intervening activities and are observed for their relative presence and tolerance. *Sphaertilus natans* (iron oxidizing bacteria survive in caprozoic zone and algae may not adjust to conditions. As the dispersion and dilution of pollutants increases to next saprobic zone (α, β, γ zones). Only few algal species *Oscillatoria*, C*hlorella*, S*pirulina jenneri*, *Euglena* sp. and few flagellates thrives algae growin the areas where Oxygen is not completely depleted. The dispersion of pollutant takesplace from the source of pollution and is spread out in concentric zone in ponds and lakes. The subdivision of this zone is often used. α - mesosaprobic zone which is polluted in the commonsense of the word. *Oscillatoria* spp. *Phormidium* sp. *Nitzschia palea Gomphonima parvulum* and S*tigoclonium tenue* appears as a result of improving in the water quality. β - mesosaprobic zone supports rich flora comparable to that of many eutrophic waters. *Nitzchia gracilis*, *N. palea*, *N. acicularia*, are present predominantly in polluted zone. γ - β mesosaprobic zone *Fragillaria capuciana*, *Voucheria sp.* may be observed throughout but more in polluted zone. There are β meso saprobic forms. *F.constuens* is found more only in polluted zone. α - β mesosaprobic to α-oligosaprobic zone, *Caloneis*, *Achnanthes*, *Cymbella* and *Surirella* are recorded. Kathbiotic zone *Cymbella* sp. *Surirella* sp., *Melosira* sp. have been reported from clean water zone.

The methodology also involves benthic organisms. All the organisms with given saprobic index , frequency of occurrence of individual species and weightage are useful for further observation at a sampling site. All planktonic organisms having saprobic indicator value are classified on a score-scale of 1-9 according to preference for saprobic water quality. High diversity of planktonic and benthic organisms supports a good quality of water. The organisms which are most sensitive to pollution are on the top of the list (score 10) while certain others are on the bottom of the list (score 1-2). e.g. *Cocconeis pediculus*, *Gamphonema olivaceum*, Oligochaete, worms and bloodworms (chironomids). Knopp used a 7-level frequency distribution scale together with species figures and their corresponding characteristic to calculated the relative quality (rQ):

$$rQ = \frac{\Sigma (os + \beta ms)}{\Sigma (os + \beta ms + \alpha ms + ps)} .100$$

And the "relative contamination" (rC) expressed as a percentage:

$$rC = \frac{\Sigma (ps + \alpha ms)}{\Sigma (os + \beta ms + \alpha ms + ps)} .100$$

A similar approach proposed by Pantle and Buck,1955,(GTZ,1991) is also used here, the saprobic index (s) is calculated according to the formula

$$S = \frac{\Sigma (s.h)}{\Sigma h}$$

Where :

S = saprobic index of each individual species

h = estimated frequency of occurrence of each species expressed in terms of a 3-level scale (1 = isolated finding, 3 = frequent occurrence, 5 = Massive occurrence)

Saprobic index (S) of sample can be calculated either manually or with the aid of a computer program.for the sampling sites This denote the degree of contamination of the water with the biodegradable organic waste on the basis of formula developed by Zelinka and Marvan

$$S = \frac{\Sigma\, s.\, h.\, g.}{\Sigma\, h.\, g}$$

Where:

s = saprobic index of each species

h = estimated frequency of the species

g = indicative weight of the species

The indicative weight considers the fact that most of the organisms are not restricted to a single saprobity zone; instead, their distribution range is merely concentrated in one zone.

Parallel to biological studies in the LAWA system above indices yield supplementary data which round out the picture obtained by biological system. WHO world health organization included these methods in its international standard of drinking water.

(iv) The R-P-C system and BIP

Interconnection among the three major groups of organisms (producers, consumers and decomposers) based on their biological importance had developed by Gabriel-GTZ in 1946. In more strongly polluted zone the decomposers or reducers (R) predominated. In the next zone, the number of consumers (C) which feed on the decomposers, increases and finally with increasing self purification i.e.mineralization) the autotrophic producers (P) developed

$$I = 2P/(R+C)$$

The biological index of pollution is even easier, taken only relative numbers of chlorophytes (A) and achlorphyllous organisms(B) to define this index

$$BIP = 100.B/ (A+B)$$

(v) Species deficit method

This method for biological quality of water based extensively on the number of species of microorganisms present in the environment. The method is named as Species deficit method Artenfelhlhetrag technique. The assessment of water is based on hieneman's "basic biocoentic law". The more varying the conditions of life in a place the greater are the numbers of species in the community. This also indicate optimal condition of physicochemical factors in water, becomes poorer in species composition. The problem is associated with organism's standard mark reference numbers for comparision in upstream and downstream of the river. The species deficit (SD) can be calculated on the basis of the number of species at the reference site (So) and the number of species at any locality (Sx) downstream of So. The result is expressed as a percentage. SD= 0 means that there is no loss of species. While SD=100% corresponds to complete obliteration. The formula used for calculation is as fallows

$$SD = \frac{So - Sx}{So} * 100$$

(vi) Macrophytes as indicators of the ecochemical composition of freshwaters

High indicator values for macrophytes in evaluating the water quality of the littoral zones of standing and flowing waters has been demonstrated, Water mosses and algae *Potamogeton pectinatus*, *Elodea Canadensis*, *Chara* sp. *Zannichellia palustris* (fam.- Characeae possess this attribute). Macrophytes provide information on the chemistry of the water and soil [14].

EUTROPHICATION

Natural eutophication is the enrichment of water body in nutrients, the nutrients that enters in the atmosphere, rivers, from catchment areas, soil erosion and run off and fertilizers [15]. In the water body, increase of organic matter leading to eutrophication as a result algal bloom reported. The effect of eutrophication leads to changed species composition in increased growth of phytoplankton, benthos and fish at moderate eutrophication. [16].

Consequently mortality of animals somehow prevented by general reduction of nutrients (phosphorus, nitrogen, silicon, trace elements as well as organic carbon). In ecological term, the mathematical models reliable enough to estimate dose effect relationship. Human activities such as salmon (or fish) farming and the blooms of toxic algae, change in N:P:Si ratio may also cause a shift in species composition in pelagic and benthic communities [17].

TROPHIC STATE

Oligotrophic lakes generally host very little or no aquatic vegetation and are relatively clear, while eutrophic lakes appeared turbid and tend to host large quantities of organisms. Oligotrophic, mesotrophic and eutrophic class supports different types of fish and other organisms, as well. If the algal biomass in a lake or other water body reaches too high a concentration (say <80 TI), massive fish die-offs may occur due to algal blooms and deoxygenated water.

Carlson's Trophic State Index

Carlson's index is one of the more commonly used trophic indices, and is the trophic index used by the USEPA [18]**.** The *trophic state* is defined as the total weight of biomass in a given water body at the time of measurement. The Carlson index uses the algal biomass as an objective classifier of a lake or other water body's trophic status. According to the US EPA, Index should be used with lakes that have relatively few rooted plants and non-algal turbidity sources (Table-4).

Index variables

Three independent variables chlorophyll pigments, total phosphorus and Secchi depth correlation used in Carlson Index (Carlson, 1977). This relationship is expressed in the following equation:

Carlson's TSI = (TSI (SD) + TSI (CA) + TSI (TPI))/3

TSI = Trophic State Index

SD = Secchi depth

CA =chlorophyll pigments

TPI = total phosphorus

Indicators of the Salinity of Inland water

Salt pollution is classified under halobic system based on certain salinity levels and their impact and in fact trace amount of organic compounds and toxic substances that degrade slowly or not at all. In halobic system, depletion of communities of organisms is indicative of varied salt concentration rather than salt pollution generally is comes from leaching of minerals from water bottom substrates. The more importance is given rather assessment of the degree of salinity of inland waters to thalassogenic waters i.e. those are influenced by marine waters. This is due to the fact completely different hydrographic and population conditions than saline inland waters. Freshwater characterized above all by the a predominance of calcium bicarbonate $Ca(HCO_3)_2$. At low calcium bicarbonate concentrations, the pH level additionally influences the composition of biological community. Halobes are indicator organisms capable of providing information of certain salinity ranges for inland waters. Diatoms have been observed particularly indicative of contamination of salt type.

CONCLUSION

The flowing water , natural state productivity is defined as plant life is usually at a minimum level. This is reference to upper courses of rivers, stream etc. These zones largely populated by heterotrophs derived the energy from organic matter. Allochthonous with its saprobity level is naturally greater in down stream then upstream correspondingly to decomposing organic matter. Microorganisms can reproduce at a faster rates occupy more space and induce further changes in the ecosystem. The cycle starts oxygen utilized by microorganisms for using decaying organic matter and release decay products e.g. organic acids, CH_4, CO_2, H_2O, at the same time decomposer is food for numerous consumers. The increasing amount of nutrients is released utilized by autotrophic organisms in the water bodies.

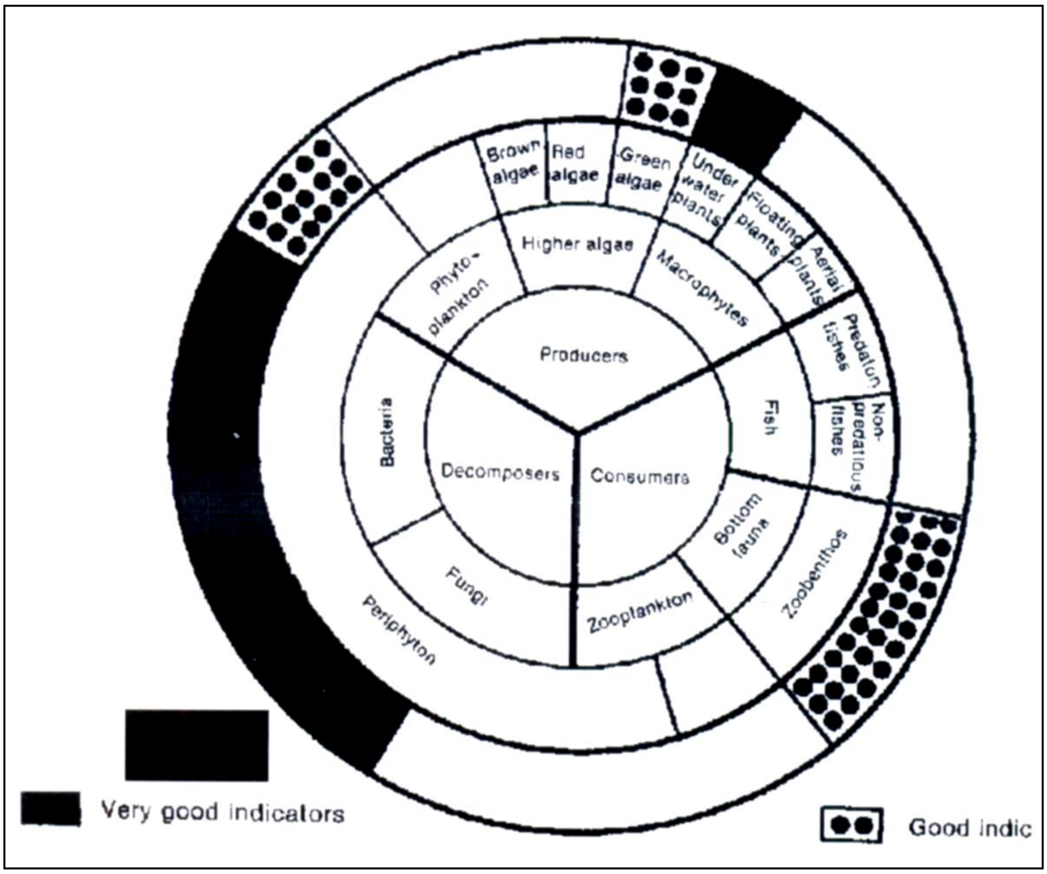

Fig. 1: Schematic of a flowing-water biocoenosis

Table-1:Saprobic index and indicative weightage of planktonic organisms. Source-Hermann ellenberg et al. (1991)

Sr. No.	Phytoplanktonic Organisms	Saprobic Index (s)	Indicative weightage(g)
1	*Achnanthes lanceolata*	1,2	4
2	*Amphora ovalis*	1,8	2
3	*Ceratoneis arcus*	1,0	5
4	*Cladophora sp.*	1,8	2
5	*Cocconeis pediculus*	1,8	3
6	*Cymatopleura salea*	2,3	2
7	*Cymbella ventricosa*	1,5	3
8	*Diatoma vulgare*	1,9	2
9	*Euglena viridis*	3,4	2
10	*Gamphonema olivaceum*	1,9	2
11	*Melosira varians*	1,9	2
12	*Meridion circulare*	1,1	5
13	*Navicula accommoda*	2,9	5
14	*Navicula avenacea*	2,0	2

15	*Navicula gracilis*	1,7	2
16	*Navicula gregaria*	2,2	3
17	*Nitzschia acicularis*	2,7	4
18	*Nitzschia linearis*	1,5	3
19	*Nitzschia sigmoldea*	2,0	4
20	*Phormidium antumnale*	2,0	2
21	*Rhoicosphenia curvata*	1,9	2
22	*Surirella angulata*	2,2	3
23	*Surirella ovala*	1,9	2
24	*Synedra ulna*	2,0	2
25	*Uronema marinum*	3,3	4
26	*Vorticella campanula*	2,2	3
27	*Vorticella convaluria*	2,9	5
28	*Vorticella microstoma*	4,0	5
29	*Vorticella striata*	2,7	1

Saprobic weightages of genera not mentioned as above are: *Achnanthes* sp. *Fragillaria* sp. *Microspora* sp. *Maugeotia* sp. *Navicula* sp. *Nitzschia* sp. *Pinnularia* sp.,*Oedogonium* sp. *Oscillatoria* sp. *Ulothrix* sp. *Voucheria* sp. *Vorticella* sp.

Table 2: aquatic community and saprobic zones of polluted to recovery zone. Source (Round, 1965)

Zone-I	The caprozoic zone –algae absent a: The bacterial community b: the bodo community c: both communities
Zone-II	The α- Polysaprobic zone 1. the *Euglena* community; 2: the Rhodo-thiobacteria community 3:the pure chlorobacteria community
Zone-III	The β-polysaprobic zone 1: the *Beggiatoa* community; 2. The *Thiothrix nivea* community 3: the *Euglena* community
Zone-IV	The γ-poly saprobic zone 1: the *Oscillatoria chorina* community 2: the *Sphaerotilus natans* community
Zone-V	The α-mesosaprobic zone a: the *Ulothrix zonata* community b:the *Oscillatoria benthonicum* community c: *Stigocloneum tenue* community
Zone-VI	The β-mesosaprobic zone a:the *Cladophora fracta* community b: the *Phormidium* community
Zone-VII	The γ-mesosaprobic zone a: the Rhodophyta community(*Batrachospermum vagum* or *Lamanea fluviatilis*); b:the chlorphyta community (*Cladophora glomerata* or *Ulothrix zonata*) the type of pure water
Zone-VIII	The oligosaprobic zone a: the chlorophyta community(*Draparnaldia gromerata*); b: the Rhodophyta community (*Lemanea annulata*, *Batrachospermum moniliforme* or *Hildenbrandia rivularia* d: the *Vaucheria sessilis* community e: the *Phormidium innudatum* community
Zone-IX	The Katharobic zone; a: the chlorophyta community (*Chlortylium-cataractum* and *Draparnaldia plumosa*): b: the rhodophyta community (*Chautransia chalybea* or *Rhodochorton* sp. And *Hildenbrandia rivularia* c: the encrustina algal communities (*Chamaesiphon popnius* and different *calothrix* sp.

Table-3 Comparison of biocoenotic and chemical parameters corresponding to the individual quality classes and saprobic levels

Quality class	Extent of organic pollution	Saprobic level	Saprobic index	Chemical parameters		
				BOD 5^+	NH_4-N^+	O_2 minimal
I	Unpolluted to very slightly polluted	oligosaprobic	1,0<1,5	1	Traces	>8
I-II	Slightly polluted	Transition between oligosaprobic and β-meso saprobic	1,5-<1,8	1-2	Approx. 0.1	>8
II	Moderately polluted	β-meso saprobic	1,8-<2,3	2-6	<0,3	>6
II-III	Critically polluted	α-β meso saprobic transitional zone	2,3-<2,7	5-10	<1	>4
III	Heavily polluted	α-meso saprobic	2,7-<3,2	7-13	0.5 to Several mg/l	≥2
III-IV	Very heavily polluted	Transition between α-mesosaprobic and poly saprobic	3,2-<3,5	10-20	Several mg/L	<2
IV	Grossly polluted	Poly saprobic	3,5-<4,0	>15	Several mg/L	<2

Table-4: Relationships between Trophic Index (TI), chlorophyll (Chl), phosphorus (P,both micrograms per litre), Secchi depth (SD, millimeters), and Trophic Class (after Carlson,1996)

TI	Chl	P	SD	Trophic Class
<30—40	0—2.6	0—12	>8—4	Oligotrophic
40—50	2.6—7.3	12—24	4—2	Mesotrophic
50—70	7.3—56	24—96	2—0.5	Eutrophic
70—100+	56—155+	96—384+	0.5—<0.25	Hypereutrophic

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