Biological Water Quality Assessments and Criteria in Korea

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Abstract

The attainment of sustainable water environment is not enough with only the clean water, but it should sustain healthy and diverse aquatic life. Aquatic life is affected by various factors such as physical habitat conditions, water chemistry, and biological interactions, and thus good condition of both physical and chemical water quality is prerequisite for sustaining healthy organisms. Therefore, biological assessment, along with other physical and chemical assessments, is crucial for evaluating the health of a water body. Biological assessments in Korea were just formalized in the national 10 year master plan (2006-2015), named as “the basic plan for water environment management” with the adoption of narrative biological criteria in the law of water quality and aquatic ecosystem conservation in 2006. These efforts have resulted in a significant change of a paradigm in the management of water environment, and a shift away from a sole reliance on regulatory and administrative activities as the principal measures of success to the inclusion of measures based on environmental results. We expect that integrating biological assessments into existing assessment programs will provide the information critical to protect and restore aquatic ecosystems.

1. Introduction

Water bodies exhibit various physical, chemical, and biological characteristics, but their conditions are expressed as a water quality as a whole. Thus, water quality largely focused on the chemical measurements, and their conditions, resulting in ignoring an ecological concept in the water quality program. Current programs are not protecting rivers or their biological resources because our laws of water conservation and management are being implemented as if crystal clean water running down concrete conduits were the goal. In this conjunction, our policies of conservation and restoration of aquatic systems have been focused on a narrow array of factors, mostly related to chemical pollution. As such, assessments of water quality are being implemented to attain only clear water.

Water resources are not simply the water; however, their value as resources is beyond the water alone. They also depend on biological components (species) and the underlying biological processes that sustain those species. Only clean water is not enough for sustainability of water resources (Karr, 1995), and thus, sustainable aquatic system should support diverse and healthy organisms. Because aquatic biota are affected by not only chemical water quality but also habitats and risks, good water quality based on both physical and chemical aspects is prerequisite for supporting healthy organisms. Therefore, the true health of aquatic environments is reflected by the biological communities that reside within them (US EPA, 2002).

Since 1980s, some development countries started to understand a sustainability of aquatic environment in conjunction with attaining ecosystem health. Biological assessments have been developed in that context, and now are being implemented (EEA, 1996; US EPA 1999). The concept of ecological integrity (i.e., ecosystem health) has been introduced for the conservation and management of aquatic ecosystems (rivers) in Korea. After the three-year (2004-2006) pioneer research, Korean government is now to formalize an ecosystem health concept in the related regulations. Biological assessment tools are also being developed and tested with a tentative bioassessment program on rivers across the whole country. The purpose of this paper is to introduce current status and development of a biological assessment program in Korea.

2. Conceptual background of bioassessments for water quality

Bioassessment is a primary tool to assess biological condition in a water body, and consist of survey and other direct measurements of aquatic life; algae and aquatic vegetation, macroinvertebrates, fishes, etc. Bioassessment, along with physical and chemical assessments, are critical for evaluating the health of a water body, and in turn, their results are essential to provide the information of disturbed systems to be restored. Aquatic life integrates the cumulative effects of diverse stressors such as excess nutrients, toxic chemicals, increased sediment loadings, and habitat destructions. Therefore, bioassessments allow measuring the aggregate impacts of the stressors, and this, in turn, emphasizes that a conceptual framework of a comprehensive assessment of aquatic environment needs to include ecological integrity (biological health) responding to all existing stressors interrelated (Figure 1).

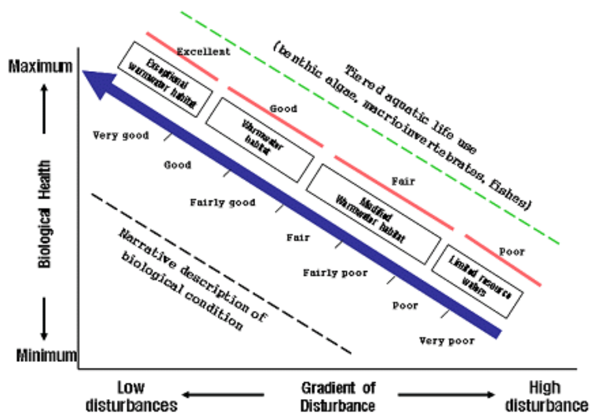

Figure 1. A framework for using biological assessments and criteria to set aquatic life use (Source: US EPA, 2002).

3. Development of biological assessment tools in Korea

Broad scale preliminary biosurvery should be conducted for the development of bioassessments and biocriteria for a country and in this case regional differences, such as ecoregion, should be fully considered. In Korea, the biocriteria are under development, and remains to complete with more data in spatially broader scale. At the initial stage, however, a narrative biological classification system has been proposed; 4-tired system including categories of excellent (A class), good (B class), fair (C class), and poor (D class). Indicator species including fishes and macroinvertebrates also were designated to each class. The numeric biocerteria are also under developing, using tiered use of fish, macroinvertebrates and benthic algae. Values of numeric indices were tried to discriminate the indices at 4-tiered classes, as mentioned above. To the selected biological assemblages, various numerical indices were considered in order to get the best candidate for Korean rivers. Values of indices were discriminated at 4 classes, in supportive of the proposed narrative biocriteria.

There exist a quite few number of numeric indices for the assessment of water quality using benthic diatoms (e.g., Descy, 1979; Watanebe *et al.*, 1986; Kelly and Whitton, 1995). All of them followed the format of the saprobic index, first proposed by Zelinka and Marvan (1961), to assess organic pollution of the water. We finalized two indices reflecting organic pollution (Diatom Assemblage Index of Organic Water Pollution: DAIpo, Watanabe et al., 1986) as well as nutrient enrichment (Trophic Diatom Index: TDI, Kelly and Whitton, 1995). Parameters consisting of the indices were tried to amend for Korean environment.

A numeric index, named as Korea Saprobic Index (KSI), to evaluate saprobicity of the water body was developed using DIN 38410 (1990), based on the formula of Zelinka and Marvan (1961), and the method of calculating weighting value proposed by Yoon et al. (1992). Our fish multimetric model to evaluate water biological water quality principally followed the multimetric model of IBI (Index of Biological Integrity) invented by Karr (1981). Originally, Karr’s model was consisting of 12 metric. However, we modified the metrics to fit Korean environment, river structure and species, and finally made the model with 8 metrics.

A classification of biocriteria can be varied with management purposes in countries, and the level of class is usually ranged from four to seven. We finalized with 4 class system, form A class to D class (Table 1). When classifying the values of numerical indices of the considered biota into 4 levels, BOD water quality parameter in the same study sites were compared. Several representative indicator species for macroinvertebrates and fishes were included in the classification system, although the standard for the bioindicator remains to be questionable. Thus, the classification according to the indicator species needs to be revised with the accumulated survey data.

Table 1. Biocriteria based on the model values and bioindicators of macroinvertebrates, benthic diatoms along with BOD in Korean Streams

Class and narrative description	Numerical indices				Trophic status	BOD	Indicator species	
	BM* KSI	Diatoms		Fish IBI			Macroinvertebrates	Fish
		TDI	DAIpo					
A (Excellent)	0-1.0	0-40	100-85	36 - 40	Oligo trophic	< 1	*Plecoptera* *Gammarus*	*Zacco temmincki* *Rhynchocypris kumgangensis*
B (Good)	1.0-2.4	40-55	85-60	28 - 34	Oligo-Mesotrophic	1-4	Potamanthidae *Semisulcospira.*	*Coreoleuciscus splendidus* *Microphysogobio yaluensis*
C (Fair)	2.4-3.6	55-70	60-40	18-24	Meso-Eutrophic	3-8	*Radix auricularia* *Orthetrum*	*Zacco platypus* *Hamibarbus labeo*
D (Poor)	3.6-5.0	70-100	40-0	≤ 14	Eu – Hyper trophic	>7	*Limnodrilus gotoi* *Physa acuta*	*Carassius auratus* *Cyprinus carpio*

* BM: Benthic macroinvertebrates

4. Results of biological water quality assessments using tiered use of aquatic life

Using diatom indices, TDI evaluated the water quality of the studied river sites to be worse than DAIpo (Figure 2). With this result it is implied that the studied river appears to be more affected by nutrients than organic matters. Overall, a pattern of variation in biological water quality and agrees with chemical water quality (BOD) with in a broad range. However, both diatom indices showed a considerable variation even within the very similar BOD levels. This result emphasizes that biological water quality evaluated by benthic diatoms is affected various parameters.

The results of KSI using macroinvertebtates at study sites also showed the similar trend of variation to BOD changes with a broad spatial range (Figure 2), as shown in the diatom result. However, the variation of KSI was relative small. A major reason of this variation was evaluated to be habitat destruction. If biological water quality is assessed to be worse than chemical one, there may be possibilities of physical disturbance (e.g., destruction of river bed and siltation) and unknown toxic material. Excepting for some river site with physically disturbed condition, KSI agreed with BOD in most cases, and showed a justification to apply KSI to other sites.

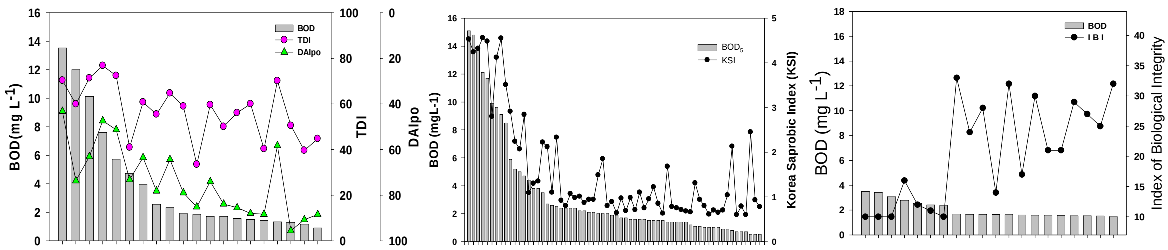

Figure 2. Comparison of BOD and numerical indices of diatom (DAIpo and TDI), macroinvertebrates (KSI), and fish (IBI) at the study sites of Seomjin and Youngsan Rivers.

Although chemical conditions, based on BOD values, indicated a good water quality, biological water quality using the biological integrity (IBI) was frequently more deteriorated than expected in the aspect of water chemistry (Figure 2). Those impacted sites were mainly due to habitat simplifications such as sand or silt depositions and channel modifications by various constructions in bank area. These activities usually cause modification of fish habitat providing nursery area and refugee. Accordingly, water quality evaluation using only chemical parameters usually overestimate actual ecosystem health. The same implication also was supported by the results of diatoms and macroinvertebrates.

5. Implementation and perspective of biological assessment program in Korea

Our next step is to establish a national bioassessment monitoring network (> 1000 sites in 5 major river watersheds) for throughout the country. The plan is supposed to be launched in the early 2007. A tentative bioassessment program was named as, "Korea River Monitoring Network for the Evaluation of Ecosystem Health," and summarized as Table 2.

In Korea, the concept of bioassesssment was just formalized in the regulation of water quality management. It provided us with a comprehensive perception of how we deal with water quality, why ecosystem health is important, why we expand the meaning of the pollution and risk, and how we attain the sustainable water resources (Karr, 1995). Because we are at the beginning stage in the development and implementation of biocriteria program, there are still many things to be completed in the program, such as the establishment of bioassessment monitoring network, development of numerical biocriteria, implantation of biocriteria into the broad range of water resource management program. Related with the biocriteria program, the government is trying to integrate an ecological concept into the ecosystem restoration in the amend of the related regulations. Bioassessment is not only the most basic but also an essential process to provide the goal to restore disturbed ecosystems.

Table 2. A tentative biomonitoring program in Korea.

Code name	Name of the program	Parameters of assessment	Survey interval	Survey frequency	Geographical coverage	Reporting
KR-Ref	Bioassessment of reference streams	-Chemical water quality -Habitat -Benthic diatoms -Macroinvertebrates -Fish	Every year	Two times (spring, fall)	Started with 50 streams: increasing step by step	-Report -DB
KR-RH						
KR-R1	Bioassessment of streams	-Chemical water quality -Habitat -Benthic diatoms -Macroinvertebrates -Fish	Every year	Two times (spring, fall)	> 1,000 sites: need to be fixed	-Report -DB -Mapping
KR-R2						
KR-R3						

Note; KR: Korea, Ref: Reference stream, R: River, H: Habitat

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