Exergy analysis as a measure of ecosystem health in the lower part of Nakdong River

Jwa Kwan Kim* Sven Erik Jorgensen[1]
Dept. of Environmental management, Jisan College
[1]Section of Environmental Chemistry, Royal Danish School of Pharmacy, Denmark

1. Introduction

More and more environmental managers want to include ecological considerations in their management strategy and they have therefore asked the following question to ecologists: How can we express and measure that ecosystem is ecologically sound? Costanza (1992) summarizes the concept definition of ecosystem health as follows : health as 1) homeostasis; 2) absence of disease; 3) diversity or complexity; 4) stability or resilience; 5) vigor or scope for growth; and 6) balance between system components. He emphasizes, that it is necessary to consider all or least most of the definitions simultaneously. Consequently, he proposes an overall system health index, HI=V·O·R, where V is system vigor (e.g. scope for growth), O is the system organization index, and R is the resilience index (stability, a system's ability to maintain structure and patterns of behavior in facing disturbance). We intend to examine the ecological health condition of the Nakdong River (Mulgum) by the application of exergy, specific exergy, exergy ratio between two species (phytoplankton and zooplankton) on Nakdong River (Mulgum) as ecological indicators.

2. Exergy and specific exergy

Exergy is defined as the amount of work a system can perform when it is brought to thermodynamic equilibrium with its environment. 'The environment' or reference state could be defined as the inorganic soup of the system without life. With this reference state the exergy measures directly the distance between the present state of the considered ecosystem and the thermodynamic equilibrium. Therefore, it can be shown possible (Jorgensen 1995, 1998) to calculate a relative exergy contribution of biomass and information to an ecosystem as:

$$Ex = \sum_{i=o}^{i=n} Wi \cdot Ci \text{ , } \text{---------------------------(1)}$$

where Ci is the concentration of the ith state variables and Wi is the information stored in the ith state variable.

Specific exergy (in other words, stuctural exergy) is defined as the exergy divided by the biomass. If the total biomass in the ecosystem remains constant through time, then the variation of exergy will be a function of only the structural complexity of the biomass or, in other words, of the information embedded in the biomass. A very eutrophic ecosystem has a very high exergy due to the high concentration of biomass, but the specific exergy is low, as the biomass is dominated by algae with low Wi-values. Specific exergy is exergy calculated relatively to the total biomass as follows:

$$\text{Specific exergy} = \sum_{i=o}^{i=n} Wi \cdot (Ci/Ct) \text{ ----------(2)}$$

The combination of exergy and specific exergy indices gives usually a more satisfactory description of the health of an ecosystem than the exergy index alone, because it considers diversity and the life conditions for higher organisms.

3. Results and conclusion

Exergy values (on average, 1,181 J/l) by phytoplankton concentrations are more higher than those of zooplankton (on average, 442.8J/l), which might be concluded that the study site (Mulgum) has, from ecological point of view, an unbalanced structure between two organisms. considering both the 'Lindeman's efficiency (10% ecological efficiency in food chain) and 10 times-gap for weighting factors together, it might be concluded that this site has an unbalanced structure between two organisms in terms of organization index of ecosystem, as a measure of ecological health.

Exergy increases with phytoplankton biomass because more biomass existing in the form of phytoplankton, which is the result of eutrophication, contributes to exergy values. Therefore, exergy can used as a measure for ecosystem health given in the introduction, e.g. system vigor(scope for growth) and the resilience (stability) indices. However, in case of specific exergy, this parameter decreases with eutrophication, In this case, specific exergy shows, to a certain extent, a transition zone (approximately, 60 - 85 ug/l of chl-a), along with increasing eutrophication. Specific exergy accounts for the information content of the ecosystem per unit of biomass (in other words, the ability of the system to utilize the available resources. Also, the level of organization and balance between phytoplankton and zooplankton biomass are, in terms of ecosystem health, better covered by the specific exergy. Therefore, the meaning of decreasing specific exergy with eutrophication is strongly related to lower level of organization and unbalanced structure in ecosystem.

Consequently, considering all the results by application of the concepts, exergy, specific exergy, and exergy ratio, it might be concluded that these three concepts, in this case, cover satisfactorily some of ecosystem health indices defined by Costanza (1992).

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