論 文

부영양화된 해양환경의 수질개선을 위한 해양생태계모델링의 적용 ; 한국의 진해만

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Application of ecosystem modeling for the assessment of water quality in an eutrophic marine environment; Jinhae Bay

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ABSTRACT : *This study focused on water quality response to land-based pollution loads and the appropriate pollutant load reduction in Chinhae Bay using an eco-hydrodynamic model. Land-based discharge from urban areas, industrial complex and sewage treatment plant was the greatest contributor to cause red-tide blooms and summer hypoxia. Tidal currents velocity of the ebb tide was about 10 cm/s stronger than that of the flood tide. A residual current was simulated to have a slightly complicated pattern with ranging from 0.1 to 2.7 cm/s. In Masan Bay, pollutant materials cannot flow from the inner to the outer bay easily because of residual currents flow southward at surface and northward at the bottom. The simulation results of COD distribution showedhigh concentrations over 3 mg/L in the inner part of Masan Bay related pollutant discharge, and lower levels less than 1.5mg/L in the central part of Chinhae Bay. For improvement water quality in Chinhae Bay, it is necessary to reduce the organic and inorganic loads from point sources by more than 50% and ameliorate severe polluted sediment.*

KEY WORDS : *Automatic Identification System, Marine Accidents, Vessel Traffic Service, Ship's Collision, Communication*

1. Introduction

Eutrophication, the biological response of aquatic systems to anthropogenic nutrient enrichment, is now a widespread phenomenon in lakes, rivers and coastal systems (M□nesguen, 1990). Increased nutrient loading to the sea is responsible for overproduction of marine algae, either macroalgae proliferation in very shallow areas like sandy beaches, or red tides due to phytoplankton blooms in deeper areas, associated with endemic bottom hypoxia. Such events may lead to dramatic benthic invertebrate and fish morality due to anoxia as in New York bight (Ryther & Dunstan, 1971; Falkowski et al., 1980), in Chesapeake Bay (Taft et al., 1980; Kemp et al., 1992), in the Baltic Sea (Richardson, 1990) or in the north of the Adriatic Sea (Degobbis, 1989).

Chinhae Bay is a semi-enclosed coastal sea on the south-eastern coast of Korea, includes several small bays such as Masan Bay, Haengam Bay, Chindong Bay, Dangdong Bay, Wonmoon Bay and Kohyun Bay. It has a total area of 637 km^2, and water depths ranging from 5 to 20 m with its mouth opening to the Korean Strait. There are strong semidiurnal currents with speeds of approximately 50 cm/s along the deep channel at the mouth, while very weak currents of less than 5 cm/s are observed in the inner bay. The Bay supports one of the greatest concentration of heavy industry, large population, the port, and the intensive mariculture activities. Rapid urbanization and industrialization of the Bay, which include the cities of Masan, Changwon, Chinhae and Kohyun, have imposed severe problems on the water quality of coastal areas resulting in damaged marine resources and human health. Red-tide outbreaks and summer hypoxia are appeared every year and become socio-economical problems.

It is very important to regulate land-based pollutant loads within environmental carrying capacity for improvement water quality in eutrophic coastal areas. One of the methods to evaluate plans for water quality management is the use of simulation models.Water quality can be predicted using models based on the environmental variation in coastal areas (Mark & Bunch, 1992; Chau & Jin, 1998), and pollutant load reduction plans can be based on a target water quality (Cerco, 1995).

The aim of this study is to describe water quality parameters response to land-based pollution loads and to elucidate the effective method for nutrient load reduction to achieve the target seawater quality in Chinhae Bay.

2. Materials and Method

2.1 Field surveys

Land-based pollution loads (streams and ditches) were investigated at 50 points monthly in 2002 and seawater samplers were collected at 7 stations seasonally for 1999-2002. The basic data in sewage treatment plant for the simulation of the model has been obtained from the Ministry of Maritime Affairs and Fisheries, Korea (MOMAF, 2002). The water temperature, salinity, COD, DO, POC, DOC, DIN, DIP and Chl-a of seawater and COD, DO, TN and TP of the pollution sources were analyzed to evaluate the characteristics of seawater quality and pollutants loads.

2.2 Hydrodynamic model

Hydrodynamic model simulates the three-dimensional physical field in the coastal bay and predicts the long-term variability of flow field, salt and heat transport. The numerical development and algorithm of the hydrodynamic model were described by Nakata et al.(1983a). Briefly, the model includes time-dependent tidal forcing, surface wind and local density gradients together with the realistic coastal topography and bathymetry. Model equations are based on the equation of motion, continuity, conservation of heat and salt. The vertical mixing process is parameterized with a turbulence model of second moment closure, which determines local distributions of the turbulent kinetic energy, k, by means of well established k-equations (SGS equation. Mamayev, 1958).

2.3 Ecological model

Ecological model simulates the flux of carbon, nitrogen and phosphorous elements plus mechanism of oxygen production and consumption in the pelagic system from the viewpoint of being plankton-based. The model applied to our present work is essentially the same as the one well described by Nakata & Taguchi (1982) and Nakata et al. (1983b). It was developed to evaluate the physical-biological interactions and water quality in an estuarine and coastal ecosystem. The model contains eight state variables called "compartment": four organic compartments expressed in carbon stock (phytoplankton, zooplankton, detritus and dissolved organic matter), two nutrients (phosphate, nitrogen) plus dissolved oxygen (DO) and chemical oxygen demand (COD).

3. Results

To evaluate water quality response to nutrient loadsreduction, we have categorized into 4 major regionsrelated to wastewater flowing loads; Masan Bay neighbors (R1), Jindong Bay neighbors (R2), Gohyun Bay neighbors (R3), and Dukdong sewage treatment plant (R4) (Fig. 1). We simulated the water quality parameters according to 30~90% pollution load reductions from pollution sources. In case of the 90% reduction in the pollutant loads from all sources, it is possible to decrease COD value to below 2 mg/L, levels conforming to seawater water quality grade Ⅱ. But, this is non-realistic countermeasure. A reduction of organic and inorganic loads from R1 to R4 discharge by 50% resulted in sharply decreasing concentrations of COD, Chl-a and DIN in Masan Bay, especially. A reduction of inorganic pollutant loads from R1 and R4 by 50% was less effective than that of organic and inorganic sources. This suggests that a reduction in the total loads of organic and inorganic materials will be necessary for successful water quality management. Expansion of water treatment facilities to remove organics and inorganics by chemical and biological processes was considered for the purpose of load reduction.

4. Conclusion

The dominant pollution sources effecting water quality in Masan Bay was to be land-based waste discharge from urban areas and Dukdong sewage treatment plant. The average COD was below 2 mg/L in the Chinhae Bay and over 3 mg/L in Masan and Haegam Bay, especially.

The residual current simulated by hydrodynamic model had a complicated flow pattern with ranging from 0.1 to 2.7 cm/s. The distribution water quality patterns and absolute values of COD and DIN in the study area were fairly good reproduced. A reduction of organic and inorganic loads from all pollution sources by 50% resulted in sharply decreasing concentrations of water quality parameters in Masan Bay, especially. For improvement water quality in the Chinhae Bay, It is very important to set up reasonable plan for integrated coastal zone management and to control point and non-point sources within environmental carrying capacity.

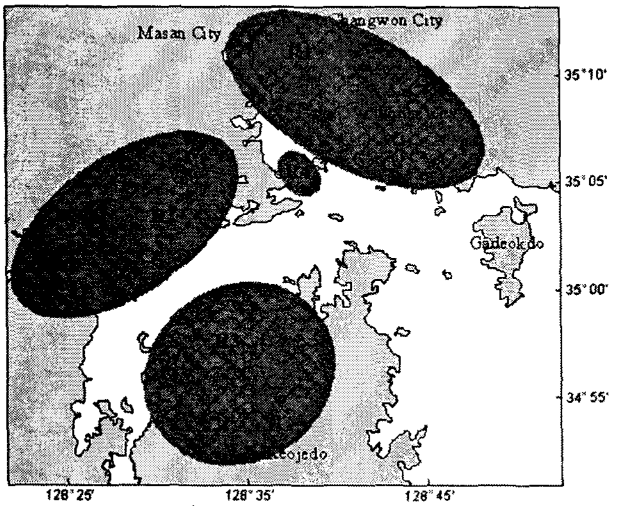

Fig. 1. Categorization of 4 major regions where pollutant loads flowing into Chinhae Bay.

References

[1] Cerco C. F., 1995: Response of Chesapeake Bay to nutrient load reductions. *Journal of Environmental Engineering*, 121, 549-557.

[2] Degobbis D., 1989: Increased eutrophication in the northern Adriatic Sea. Second act. *Marine Pollution Bulletin*, 20, 452-457.

[3 Falkowski P. G., Hopkins T. S. and Walsh J. J., 1980: An analysis of factors affecting oxygen depletion in the New York bight. *Journal of Marine Research*, 38, 479-505.

[4] Kemp W. M., Sampou P. A., Garber J., Tuttle J. and Boynton W. R., 1992: Seasonal depletion of oxygen from bottom waters of Chesapeake Bay: roles of benthic and planktonic respiration and physical exchange processes. *Marine Ecology Progress Series*, 85, 137-152.

[5] Mamayev, O.I. 1958. Influence of stratification on vertical turbulence mixing in the sea. Izvestiya Akademii nauk SSSR, ser. Geofizika, 7, 494~497.

[6] Mark D. J., Bunch B. W., 1992: Hydrodynamic and water quality modeling of Lower Green Bay. *Estuarine & Coastal Modeling, In: Proceedings of the Second International Conference*, ASCE 1992, 657-668.

[7] Ménesguen A., 1990: Eutrophication along the French coasts. In *Eutrophication-related Phenomena in the Adriatic Sea and in other Mediterranean Coastal Zones*(Barth, H. & Fegan, L., eds). Water Pollution Report 16, 63-82.

[8] Ministry of Maritime Affairs & Fisheries (MOMAF), 2002: Development of Integrated Environmental Management System for the Coastal Area of Korea, 322~323.

[9] Nakata, K. and Taguchi K., 1982:Numerical simulation of eutrophication process in coastal bay by eco-hydrodynamic model. (2) Ecological modeling. *Bull. Natl. Res. Inst. Pollut. Resour.*, 12, 17~36.

[10] Nakata, K., Horiguchi F., Taguchi K. and Setoguchi Y., 1983a: Three-dimensional tidal current simulation in Oppa Bay. *Bull. Natl. Res. Inst. Pollut. Resour.*, 12, 17~36.

[11] Nakata, K., Kishi M.and Taguchi K., 1983b: Eutrophication model in coastal bay estuary. *Dev. Ecol. Environ. Quality.*, 2, 357~366.

[12] Richardson K., 1990: Eutrophication in the Baltic Sea. An overview of the problem. In *Eutrophication-related Phenomena in the Adriatic Sea and in other Mediterranean Coastal Zones* (Barth, H. & Fegan, L., eds). Water Pollution Report 16, 149-167.

[13] Ryther J. H., Dunstan W. M., 1971: Nitrogen, phosphorous and eutrophication in the coastal marine environment. *Science*, 171, 1008-1113

[14]Taft J. L., Taylor W. R., Hartwig E. O. and Loftus R., 1980: Seasonal oxygen depletion in Chesapeake Bay. *Esturies*, 3, 242-247.

[15] Taguchi, K and K. Nakata, 1998: Analysis of water quality in lake Hamana using a coupled physical and biochemical model, *Journal of Marine Systems*, Vol. **16**, 107-132.