J. Fish. Sci. Tech., 6(3), 149-154, 2003

JOURNAL OF
FISHERIES SCIENCE
AND TECHNOLOGY


# Characteristics of Pollutant Loads and Water Quality in Kwangyang Bay, Korea

**Dae-In Lee*, Chung-Kil Park and Hyeon-Seo Cho[1]**

*Department of Environmental Engineering, Pukyong National University, Busan 608-737, Korea*
*[1]Division of Ocean System, Yosu National University, Yeosu 550-749, Korea*

The characteristics of pollutant loads from the various sources and seawater quality in Kwangyang Bay were evaluated. Total flow rate was estimated to be 10,868,066.8 $m^3$/day with a flow rate of R21 (the Seomjin River) as the highest one. Total COD, TN and TP loads of the input rivers and the ditches were about 27,591.8, 25,029.6 and 586.4 kg/day, respectively. Wastewater discharging loads was the greatest contributors to pollutant loads in the inner part of Kwangyang Bay. COD values in the inner part of the bay was over 3.0 mg/L, which exceeded the seawater quality criteria III of Korea. The average values of DIN and DIP were 8.62 $\mu$gN/L and 1.26 $\mu$gP/L, respectively. The limiting factor for algal growth was DIN. In the total discharging loads of the watershed from unit loading estimations, BOD, TN and TP were 9,132.3, 2,727.2 and 304.2 kg/day, respectively. In addition, municipal sewage by the population as pollution sources and the city of Kwangyang as administrative district had the highest loads. For a appropriate water quality recovery of Kwangyang Bay, it is suggested that it is essential to estimate reduction rate of total pollutant loads by water quality modeling.

Key words: Pollutant load, Seawater quality, Kwangyang Bay, Wastewater discharging load, Unit loading estimation

## Introduction

Kwangyang Bay is a semi-closed coastal sea on the south coast of Korea. The Yeocheon industrial complex was built along the south coast at the end of the 1970s; the POSCO (Pohang Steel Company) was built on the north coast and the estuary of the Seomjin river in the 1980s. Topographical changes occurred when many reclamation works and new industrial facilities were built. This has created eutrophication in the study area by the increase of pollutant loads from these industrial developments. The environmental change has deteriorated the water quality and sediments and caused to red tide and heavy metal pollution (Shim et al., 1984; NFRDI, 1997; Cho et al., 2000)

To meet this problem, Kwangyang Bay is designated as a special management area under the control of coastal environmental management. It is also being studied to enhance its water quality by the control of total pollutant loads (MMAF, 2002). For the effective water quality management in the coastal areas, engineering countermeasures such as reducing pollutant loads is required. This means that not only a pollutant loads which enters the sea from pollutant sources should be investigated and monitored, but also the water quality of seawater itself should be estimated to understand the current water environment (Ellis, 1989; USEPA, 1997; Jarvie et al., 1997; Wilkinson et al., 1997; Ichiki et al., 1999; Lee and Cho, 2001; Lee and Cho, 2002). Furthermore, we need to know how pollutant loads could be reduced for the appropriate recovery of the water quality (Chua, 1999; Lee et al., 2001; Lee and Park, 2002).

From this background, in order to evaluate the characteristics of pollutant loads and seawater quality in Kwangyang Bay, we studied as follows: Firstly, we analysed flow rate and input loads of organic/inorganic matters from the point sources. Secondly, we estimated generation and discharging pollutant loadings of municipal sewage, industrial wastewater, livestock wastewater, land culture and non-point sources in Kwangyang Bay watershed. Finally, organics and nutrients of seawater were estimated to understand responses of seawater by the pollutant loads.

*Corresponding author: dilee@mail1.pknu.ac.kr

## Materials and Methods

### Field surveys

Land-based pollution sources were investigated from 33 points (R1-R33) in November 2001 (Fig. 1). Seawater samples were collected at 12 stations (1-12) in November 2000. W1, W2 and W3 are the sites of the wastewater discharge. In reference to Kwangyang Bay, the inner area bordered by the dotted line is designated as seawater quality criteria III (2-3 mg/L in COD) and the rest of the areas are seawater quality criteria II (1-2 mg/L in COD).

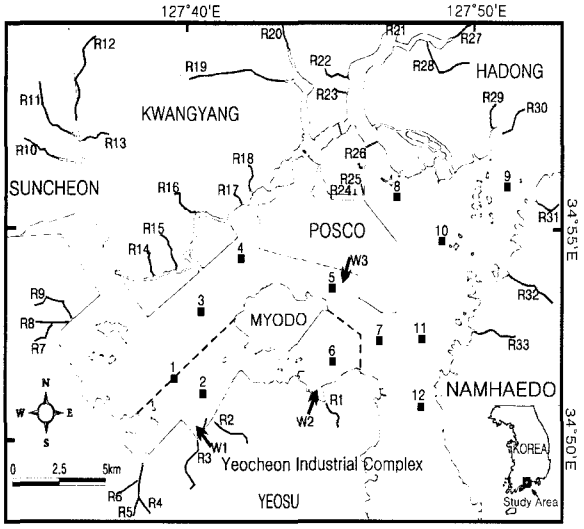


Fig. 1. Research points of land and marine in Kwangyang Bay watershed, Korea (R1-R33: Land-based pollution sources, W1-W3: Sites of wastewater discharge, 1-12: Observational stations of seawater).

### Analytical methods

An electronic flowmeter (ACM-200PC) was used to measure the flow rate at each pollution source. The COD (chemical oxygen demand), DO (dissolved oxygen), DIN (dissolved inorganic nitrogen) and DIP (dissolved inorganic phosphorus) of seawater and COD, TN (total nitrogen) and TP (total phosphorus) of pollution sources were analyzed to evaluate the loads (APHA AWWA WEF, 1995; MMAF, 1998).

### The calculation of generation and discharging pollutant loadings

The generation and discharging pollutant loads of BOD (biochemical oxygen demand), TN and TP in Kwangyang Bay was estimated by unit loading estimation included in the founding guide of total pollutant loads control system (MOE, 1999).

## Results and Discussion

### Pollutant loads from the input sources

Flow rate and pollutant loads from the various sources are shown in Fig. 2. The flow rate of rivers and ditches ranged from 63.8 to 10,368,000 $m^3$/day; with a total rate of 10,868,066.8 $m^3$/day. The site of the lowest flow rate was R16 and that of the highest flow rate was R21 (the Seomjin River). The flow rate into Kwangyang Bay was determined by the Seomjin river, but the flow rate of the Seomjin river was less than the monthly average, about 27,560,000 $m^3$/day. COD loads were from 0.14 to 26,443.69 kg/day, and the site of the highest load was at R21 with a large flow rate and a total load of approximately 27,591.77 kg/day. The R12 and R27 have high values due to large flow rates. Also, the R5, R25 and R26 have high values because their input is from municipal sewage and industrial wastewater outlets. TN loads were from 0.08 to 23,405.14 kg/day with the total load of approximately 25,029.64 kg/day. TP loads were from 0.01 to 516.51 kg/day with the total load of approximately 586.41 kg/day. Both TN and TP loads showed a similar spatial distribution with the COD.

The COD loads of W1, W2 a nd W3 were 32,000, 24,000 and 16.5 kg/day, respectively, with W1 and W2 showing the highest load in Kwangyang Bay. As a result, the flow rate inputting into Kwangwang Bay mainly depends on R21, with W1 and W2 being the main sources of pollutant loads into Kwangyang Bay.

### Characteristics of seawater quality

Distribution of COD, DO and nutrients are shown in Fig. 3. Range of COD was from 1.0 to 3.7 mg/L, and the station of the lowest value was 9 and 11. The highest COD was around the wastewater discharging area (Station 1 and 2). Average value of COD in the inner part of the bay was approximately 2.7 mg/L, which was applicable to the seawater quality criteria III, and corresponded to the results of Koo et al. (1993). Also, Fig. 3 shows the range of DO from 6.6 to 7.9 mg/L; with 11 as the station of the lowest value and that of the highest value is 2. There was little difference between them. The ranges of DO in the study area were similar to those values at Kamak Bay (MMAF, 2001).

DIN ranged from 3.72 to 11.74 $\mu$gN/L. It is clear that DIN is high in the inner part of the bay and relatively low in the outer part of the bay. This range

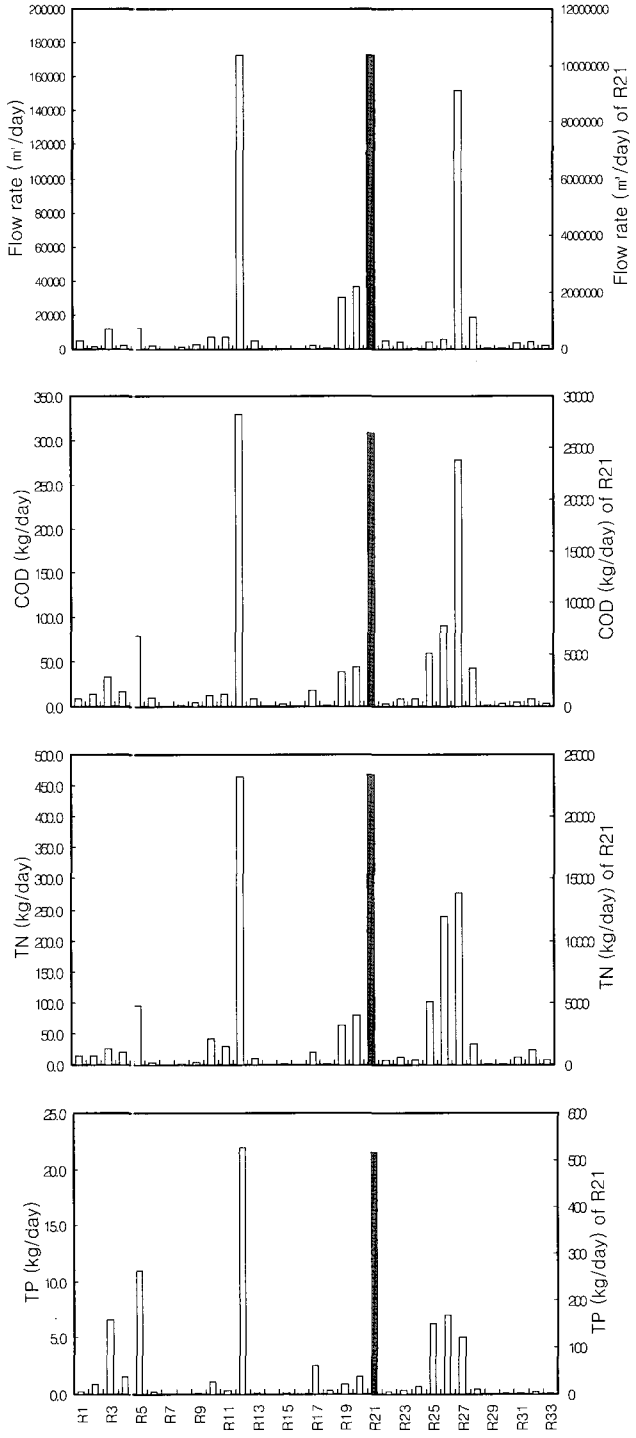


Fig. 2. Flow rate, COD, TN and TP loads of each input sources in Kwangyang Bay watershed (Values of R21 was scaled separately at the right y axis).

was lower than that (11.43-36.21 μgN/L) observed at Kamak Bay (MMAF, 2001). Moreover, DIN in the inner part of the bay showed a higher value than

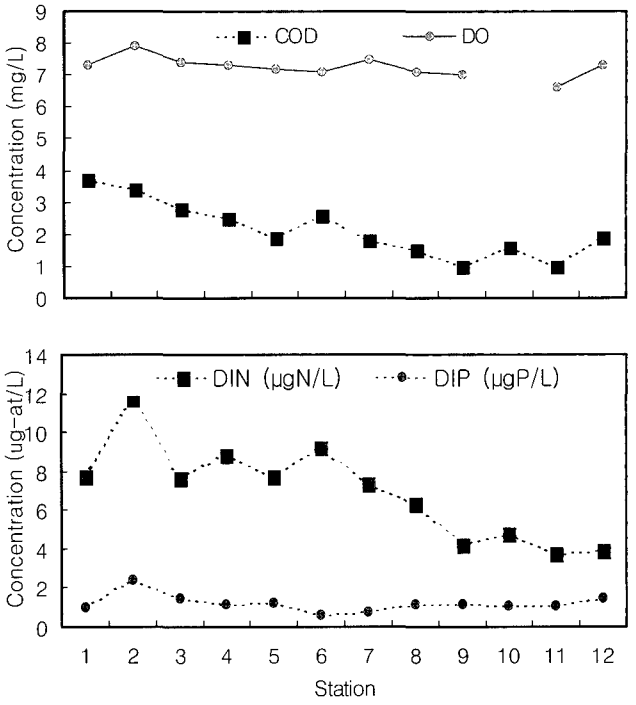


Fig. 3. COD, DO, DIN and DIP distribution in Kwangyang Bay, Korea.

7.14 μgN/L. This is the DIN concentration which can cause the outbreak of the red tide (JFRCA, 1972). DIP ranged from 0.63 to 2.42 μgP/L. This range was slightly higher than that (0.90-2.03 μgP/L) observed at Kamak Bay (MMAF, 2001). In reference to the red tide outbreak possibility concentration (0.48 μgP/L) as suggested by JFRCA (1972), all stations showed higher values. The ratio of DIN to DIP was below 16 which means DIN was the limiting factor for algal growth in Kwangyang Bay (Redfield et al., 1963).

**The generation and discharging pollutant loadings of the Kwangyang Bay watershed**

As shown in Table 1, BOD generation pollutant loadings were 25,817.3 kg/day. Pollutant loadings were 35.8% by population, 34.2% by non-point sources and 25.9% by stockbreeding. In case of TN, the values were 7,436.3 kg/day with 29.9% by population, 46.5% by non-point source, and 21.1% by stockbreeding. In case of TP, the generation pollutant loadings were 1,188.8 kg/day with 20.6% by population, 28.5% by non-point sources and 47.5% by stockbreeding. Approximately, 35.4% in the total BOD generation loadings were discharged with 36.7% in TN and 25.6% in TP.

From four BOD discharging pollutant loads in the

Table 1. Generation and discharging pollutant loadings of Kwangyang Bay watershed

| Pollutant loadings | Population (kg/day) | Stockbreeding (kg/day) | Industry (kg/day) | Non-point (kg/day) | Land culture (kg/day) | Total (kg/day) |
|---|---|---|---|---|---|---|
| BOD generation | 9,241.6 | 6,679.1 | 593.2 | 8,839.1 | 464.4 | 25,817.3 |
| BOD discharging | 6,295.7 | 76.9 | 85.6 | 2,209.8 | 464.4 | 9,132.3 |
| TN generation | 2,225.5 | 1,565.4 | 98.0 | 3,454.6 | 92.9 | 7,436.3 |
| TN discharging | 1,642.0 | 41.3 | 87.4 | 863.6 | 92.9 | 2,727.2 |
| TP generation | 245.3 | 565.2 | 14.6 | 338.9 | 24.8 | 1,188.8 |
| TP discharging | 172.6 | 11.4 | 10.7 | 84.7 | 24.8 | 304.2 |

Table 2. Discharging pollutant loadings of administrative district in Kwangyang Bay watershed

| Administrative district | BOD (kg/day) | TN (kg/day) | TP (kg/day) |
|---|---|---|---|
| Yeosu | 1,112.1 | 626.5 | 72.6 |
| Kwangyang | 7,237.7 | 1,709.2 | 185.6 |
| Suncheon | 297.8 | 136.2 | 19.9 |
| Hadong | 688.0 | 407.7 | 46.5 |
| Total | 9,132.3 | 2,727.2 | 304.2 |

administrative district of Kwangyang Bay, Table 2 and Fig. 4 demonstrate that a load by the city of Kwangyang is the highest (79.3%) with Yeosu, Hadong and Suncheon showing loads of 12.2, 7.5 and 3.3%, respectively. The city of Kwangyang and Suncheon showed 62.7% and 23.0% in TN with TP being 61% and 23.8%, respectively. Therefore, as an administrative district, the city of Kwangyang showed the highest loads, and in terms of pollution sources, municipal sewage by the population was the largest source.

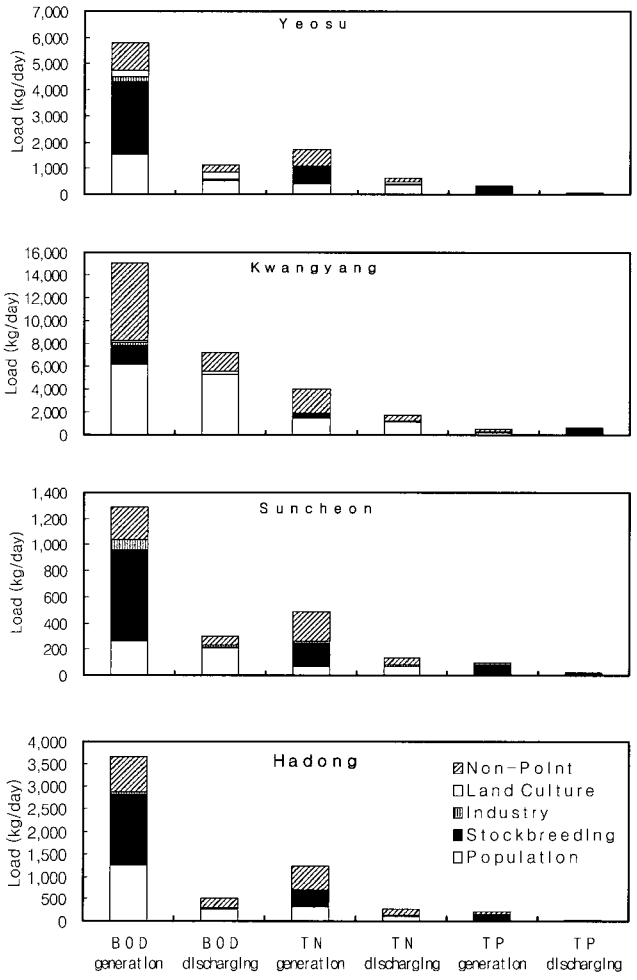


Fig. 4. Pollutant loadings of administrative district in Kwangyang Bay watershed.

## Comparison and estimation of each loads

The total loads of COD, TN and TP of Kwangyang Bay through a river and ditch were calculated to be approximately 27,591.77, 25,029.64 and 586.41 kg/day, respectively. Especially, COD, TN and TP loads of the wastewater discharges were even higher than R21 (the Seomjin River) which currently has the highest river loads. Therefore, the most important factor for water quality management in Kwangywang Bay is both strict treatment of sewage/wastewater and regulation of the permitted discharging criteria.

The non-point sources contribute 24.2% in BOD, 31.7% in TN, and 27.8% in TP in terms of the discharging pollutant loadings. These are crucial factors in accessing water quality management (Burroughs, 1993). Also. Lately, in water quality management of coastal areas the benthic flux from the polluted sediment is considered as an important source.

In comparison to the discharging pollutant loadings by unit loading estimations, Fig. 5 demonstrate that BOD, TN and TP discharging pollutant loadings in Masan Bay surpass those of Kamak Bay or Kwangyang Bay (MMAF, 2001, 2002). In this study area, it was estimated that BOD was higher and TP

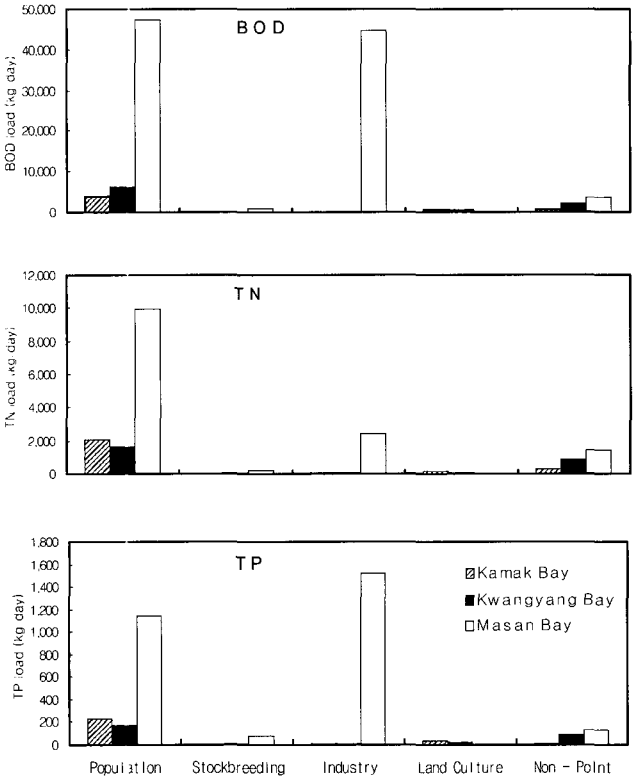


Fig. 5. Comparison of discharging loads in the other bays in Korea.

waslower than that observed at Kamak Bay. To manage a water quality in Kwangyang Bay effectively, a control measure of discharging pollutant loadings must be implemented.

## Acknowledgements

This study was part of the environment improvement research project for environment management area of the Ministry of Marine Affairs & Fisheries, Korea.

## References

APHA AWWA WEF. 1995. Standard Methods for the Examination of Water and Wastewater. 19th ed. Washington, D.C., American Public Health Association, pp. 2/46-5/20.

Burroughs, R.H. 1993. Non-point sources as external threats to coastal water quality: lessons from park service experience. Coast. Manage., 21, 131-142.

Cho, Y.G., C.B. Lee and C.H. Koh. 2000. Heavy metals in surface sediments from Kwangyang Bay, south coast of Korea. J. Kor. Soc. Oceanogr., 5, 131-140.

Chua, T.E. 1999. Marine pollution prevention and management in the East Asian Seas: A paradigm shift in concept, approach and methodology. Mar. Poll. Bull., 39, 80-88.

Ellis, J.B. 1989. The management and control of urban runoff quality. J. Inst. Wat. Environ. Manage., 3, 116-124.

Ichiki, A. and K. Yamada. 1999. Study on characteristics of pollutant runoff into Lake Biwa, Japan. Wat. Sci. Tech., 39, 17-25.

JFRCA (Japan Fisheries Resource Conservation Association). 1972. Water quality criteria of fisheries environment. JFRCA, Japan, 1-24.

Jarvie, H.P., C. Neal and A.D. Tappin. 1997. European land-based pollutant loads to the North Sea: an analysis of the Paris Commission data and review of monitoring strategies. Sci. Total Environ., 194, 39-58.

Koo, J.K., Y.R. Kim, H.B. Mun and W.B. Lee. 1993. The estimation of unit COD discharge rate from non-point source by the BOX Model in Kwangyang Bay Basin. J. Kor. Soc. Wat. Qual., 9, 122-130.

Lee, D.I. and C.K. Park. 2002. The modelling of winter water quality in the estuary of the Nakdong river. J. Kor. Soc. Wat. Qual., 18, 449-460.

Lee, D.I., C.K. Park and H.S. Cho. 2001. Water quality management of Kwangyang Bay by point pollution source control. J. Kor. Soc. Mar. Environ. Eng., 4, 28-39.

Lee, D.I. and H.S. Cho. 2002. A study on the characteristics of pollutant loads in Kamak Bay watershed. J. Environ. Sci., 11, 945-954 (in Korean).

Lee, S.H. and W.S. Cho. 2001. A study about the influence of pollutant load on water quality in a small stream watershed. Kor. Soc. Environ. Impact Assess., 10, 9-19.

MOE (Ministry of Environment). 1999. Founding guide of total pollutant loads control (Notification No 143). MOE, Seoul, Korea, 86 pp.

MMAF (Ministry of Marine Affairs and Fisheries). 1998. Standard methods of marine environment. MMAF, Seoul, Korea, 5-58.

MMAF (Ministry of Marine Affairs and Fisheries). 2001. Establishment of action plans for coastal environmental management areas. MMAF, Seoul, Korea, 496 pp.

MMAF (Ministry of Marine Affairs and Fisheries). 2002. Establishment of action plans for coastal environmental management areas. Seoul, Korea, 658 pp.

NFRDI (National Fisheries Research and Development Institute). 1997. Recent red tides in Korean costal waters. NFRDI, Busan, Korea, 280 pp.

Redfield, A.C., B.H. Ketchum and F.A. Richards. 1963. The influence of organisms on the composition of seawater. In: The Sea, Vol. 2, M.H. Hill, ed. Wiley, New York, pp. 26-77.

Shim, J.H., Y.K. Shin and W.H. Lee. 1984. On the phytoplankton distribution in the Kwangyang Bay. J. Kor. Soc. Oceanogr., 19, 172-186.

USEPA (United States Environmental Protection Agency). 1997. Technical guidance manual for developing total maximum daily loads, Book 2: Streams and rivers, Part 1: Biochemical oxygen demand/Dissolved oxygen and Nutrients/Eutrophication. EPA 823-B-97-002, USEPA, Office of Water, Washington, DC.

Wilkinson, W.B., G.J.L. Leeks, A. Morris and D.E. Walling. 1997. Rivers and coastal research in the land ocean interaction study. Sci. Total Environ., 194, 5-14.

(Received May 2003, Accepted September 2003)