

Effect of the Freshwater Discharge on Seawater and Sediment Environment in a Coastal Area in Goheung County, South Korea

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Abstract : Seasonal characteristics of water and sediment qualities and potential effects of the freshwater discharge from a small tide embankment interior in a coastal area in Goheung county were investigated from May to September in 2012. Chemical oxygen demand values (COD) were mostly higher than 2 mg/L in summer ebb tide, which exceed the standard value of water quality criteria II of acceptable level for aquaculture activities. Nitrogen and phosphorus were found as the limiting nutrients for algae growth in summer and fall and in spring, respectively. Nitrogen was the limiting nutrient for diatom growth in the whole studied period. The sudden high values of COD, ammonia, dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP) were found in water sample collected from station 5 which located in front of the tide embankment sluice gate during spring ebb tide. The freshwater discharge from the tide embankment interior maybe affected the survey areas during a short time interval. Mean values of eutrophication index of the surveyed coastal region in spring, summer and fall were all bigger than 1. Water quality was mostly considered at level II which acceptable for aquaculture activities. Sediment quality in this study was generally in the range of standard for fisheries environment.

Key Words : Tide embankment, Freshwater discharge effect, Seawater quality, Sediment environment, Goheung coast

1. Introduction

Human activities such as construction of dams have changed the biogeochemistry and ecosystem structures of coastal areas on long-term scales (Li et al., 2007) and freshwater discharge is a major process that affect waer properties and community structures in coastal estuarine systems (Ramus et al., 2003). However, the direct effects of freshwater introduced from a reservoir on hypersaline water column have rarely been documented, and the potential change of water quality and sediment environment regarded to the freshwater input are limited.

In South Korea, the seasonal fluctuation of water quality and potential effects of freshwater discharge have surveyd in some coastal areas such as Muan Peninsula (Cho et al., 1998; Lee et al., 2003a) and Hechang Bay (Lee et al., 2003b). The environmental properties of well-mixed hypersaline coastal areas can be rapidly changed when a large volume of eutrophic freshwater is discharged into the ecosystem. Hence, the fluctuation of chemical environment can affects existing muscle, cockle shell aquaculture and other aquatic organisms in the coastal area around

Beakgil-do, Goheung county, which is located in a temperate region (34°40'N - 34°44'N, 127°24' - 127°28'E) and receives freshwater input from the Hodeok reservoir, located 1 km upstream from the Yeonbong tide embankment. Many coastal areas in Goheung county have experienced similar perturbations due to the effects of freshwater discharge from interior areas of tide embankments. However, no records are available for changes in the chemical properties of water and sediment environment of the Goheung coastal areas. The objective of this study, therefore, was to investigate potential impacts of freshwater discharge on the coastal area around Beakgil-do in Goheung county by monitoring spatio-temporal variations in water and sediment environment properties.

2. Materials and Methods

2.1 Study area

The study area covers a coastal area around Baekgil-do, Goheung county with east-west length of 9 km and south-north length of 3 km and has an average water deep less than 5 m during both flood and ebb tide. The Yeonbong tide embankment was constructed in the coastal region of Goheung county to

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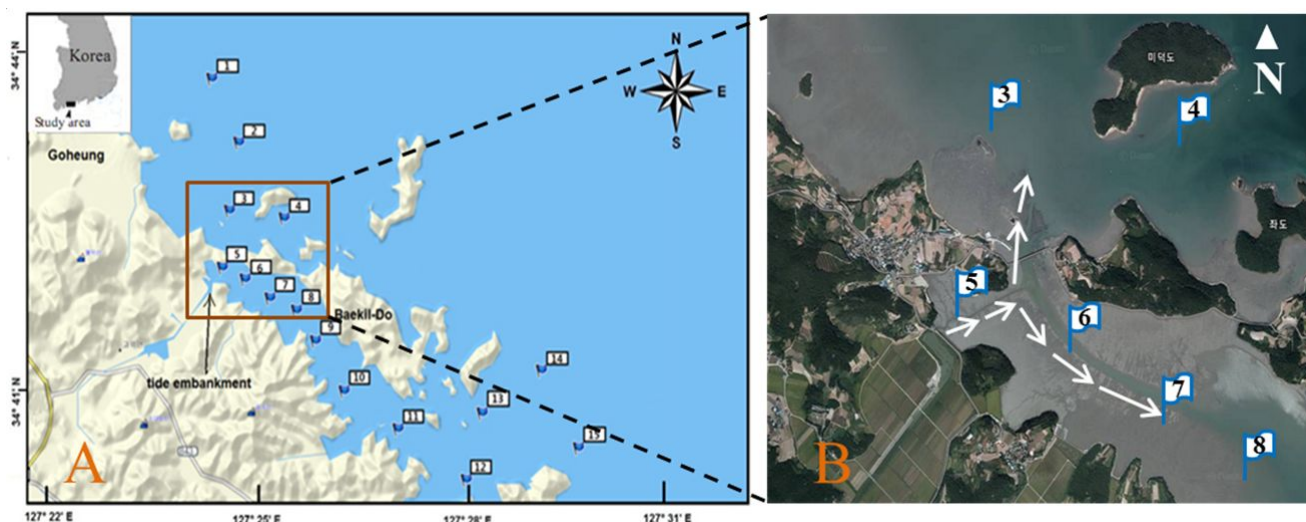


Fig. 1. Map showing 15 sampling stations in the surveyed coastal region in Goheung County (A) and the sampling stations in the station group 1 (B). White arrows are the pathway directions of freshwater discharge

prevent seawater intrusion into the rice fields in the basin of the Hodeok reservoir, which has the total area of 1.6 hectare and mean water deep of 2 m. Hodeok reservoir is artificial reservoir used to supply freshwater for agricultural areas belonged to Hodeok and Yoendeung villages. Freshwater discharge from the Hodeok reservoir occurs throughout the year. When the reservoir water level peaks, freshwater is discharged into the coastal region at low tide (ebb tide) through the opening of the tide embankment sluice gate. The tides in the coastal region are generally semidiurnal with tidal range of 2 - 3 m.

2.2 Sampling station

Fifteen sampling stations located along the freshwater discharge pathways which are possibility affected by the freshwater discharge were sampled in spring (May 28), summer (July 21) and fall (September 15) in 2012 (Fig. 1). Water samples were taken in both flood tide (before the sluice gate opens) and ebb tide (after the sluice gate opens). Out of 15 sampling stations, 3 groups of sampling site were separated by distance from sampling stations to the tide embankment marked as D including group 1 ($D < 2$ km), group 2 ($D = 2 - 5$ km) and group 3 ($D > 5$ km). Group 1 includes stations 5, 6, 7, 8, 3 and 4. Group 2 includes stations 9, 10, 11, 1 and 2 and group 3 includes stations 12, 13, 14 and 15.

2.3 Sampling and analytical methods

Surface water samples collected by a bucket and sediment samples (2 cm surface layer) collected by a Van Veen grab were kept in icebox filled with dry ice until analysis. Temperature ($^{\circ}\text{C}$), salinity (psu), dissolved oxygen (DO, mg/L) and pH were directly measured by a YSI[®]-600XL (Yellow Spring Instrument Inc., USA).

Suspended particle matter (SPM), chemical oxygen demand (COD), total nitrogen (TN), total phosphorus (TP), ammonium ($\text{NH}_4^+\text{-N}$), nitrate ($\text{NO}_3^-\text{-N}$), nitrite ($\text{NO}_2^-\text{-N}$), silicate ($\text{Si}(\text{OH})_4\text{-Si}$) of water samples and ignition loss (IL), COD, acid volatile sulfide (AVS) of sediment samples were analyzed based on the Standard Test for Marine Environment Process (Korea Ministry of Land, Transport and Maritime Affairs, 2010).

2.4 Statistical analysis

Levene's test in independence sample test was performed by SPSS[®] ver. 16 to observe possible differences between the 3 sampling groups on selected analyzing items. Principal component analysis (PCA) with Varimax rotation method and Kaiser normalization were also applied on various data sets of analyzed parameters in water and in sediment samples from 3 sampling station groups by SPSS[®] ver. 16 to classify groups of sampling stations with similar values of analyzed parameters in water and sediment samples.

Table 1. Range and mean values of analytical parameters in seawater in coastal region around Baekil-do, Goheung County (flood tide)

Parameters	May		July		September	
	Range	Mean	Range	Mean	Range	Mean
Temp.(°C)	20.04~25.23	21.95	25.18~28.27	26.29	23.85~24.39	24.27
Sal. (psu)	33.28~34.68	33.62	29.41~32.22	30.65	27.12~27.79	27.34
pH	7.99~8.19	8.12	8.10~8.48	8.24	8.10~8.52	8.40
SPM (mg/L)	38.28~228.50	68.79	35.57~77.00	48.73	24.00~59.20	43.09
DO (mg/L)	5.97~8.12	7.17	8.11~14.07	10.70	6.40~8.20	7.40
COD (mg/L)	0.99~2.47	1.44	0.25~4.21	2.29	1.05~2.49	1.82
NH ₄ ⁺ -N(μg-at/L)	0.36~2.73	0.83	0.04~2.96	0.43	0.08~2.77	0.47
NO ₃ ⁻ -N(μg-at/L)	0.08~1.83	0.31	0.01~5.80	0.48	0.42~45.95	5.97
NO ₂ ⁻ -N(μg-at/L)	0.03~0.22	0.09	0.02~1.56	0.28	0.15~1.58	0.64
DIN (μg-at/L)	0.52~3.08	1.14	0.06~7.91	0.91	0.42~22.60	3.30
DIP (μg-at/L)	0.01~0.39	0.10	0.06~0.66	0.19	0.23~0.37	0.30
N/P ratio	3.95~544.00	70.20	0.16~11.98	2.95	1.45~66.47	10.01
Si/N ratio	1.48~28.14	13.66	4.09~160.43	68.62	2.15~43.29	15.27
TN (mg/L)	0.46~1.24	0.83	0.58~3.32	1.28	0.25~1.04	0.76
TP (mg/L)	0.01~0.07	0.03	0.01~0.15	0.04	0.03~0.06	0.04
Si (OH) ₄ -Si (μg-at/L)	4.02~22.09	11.98	6.93~73.32	15.08	11.57~48.63	20.36
Eutrophication index	0.49~4.22	2.40	2.11~7.88	4.10	0.26~6.50	1.14

3. Results and Discussions

3.1 Spatio-temporal variation of water quality

The range and mean values of water quality parameters in both ebb tide and flood tide separated by sampling seasons were shown in Table 1 and Table 2. Seawater temperature was ranged from 20.04 °C to 28.27 °C. In spring, the water temperature in stations 3, 5, 6 and 7 (station group 1) nearing the tide embankment were higher than 24 °C while the mean values of water temperature in sampling station group 2 and 3 were approximately 22°C and 21°C, respectively. This was may be caused by an effect of the disparity between temperature of freshwater discharge and seawater temperature of stations 3, 5, 6 and 7 at the sampling time. However, in summer and fall, the temperature of seawater in 3 sampling station groups was identical as nearly 26 °C in summer and 24 °C in fall. The salinity was ranged from 25.89 psu to 34.68 psu. Highest salinity was observed in spring (mean = 33.62 psu in flood tide) and lowest salinity was found in fall (mean = 27.34 psu in flood tide).

pH values were ranged from 7.99 to 8.52, the highest mean value of pH was found in fall of 8.40 and lowest pH values was found in spring of 8.12. There were no significant different between pH values in flood tide and ebb tide. The range of SPM in the sampling period was 24.00 to 228.50 mg/L. The mean value of SPM peaked in spring ebb tide (87.55 mg/L).

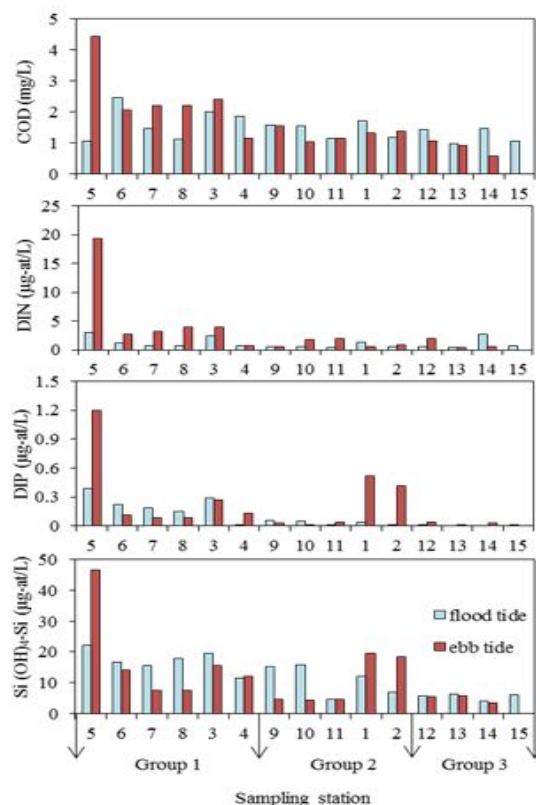


Fig. 2. The variation of COD, DIN, DIP and silicate distribution in water samples from the coastal area in Goheung County in spring flood tide and ebb tide.

Table 2. Range and mean values of analytical parameters in seawater in coastal region around Baekil-do, Goheung County (ebb tide)

Parameters	May		July		September	
	Range	Mean	Range	Mean	Range	Mean
Temp. (°C)	20.65~25.63	22.75	25.54~28.20	26.65	23.42~24.53	24.26
Sal. (psu)	33.46~34.55	33.68	29.15~31.20	30.37	25.89~28.08	27.36
pH	7.99~8.20	8.11	8.22~8.36	8.26	8.35~8.47	8.41
SPM (mg/L)	41.42~183.75	87.55	34.71~73.25	47.00	27.28~72.80	46.75
DO (mg/L)	5.26~7.65	6.19	8.68~10.61	9.42	6.33~8.61	7.57
COD (mg/L)	0.59~4.43	1.67	1.17~2.81	1.90	1.69~3.77	2.53
NH ₄ ⁺ -N (µg-at/L)	0.29~3.69	1.74	0.04~0.92	0.17	0.04~1.24	0.36
NO ₃ ⁻ -N (µg-at/L)	0.10~11.34	1.31	0.02~1.05	0.17	0.12~8.57	2.80
NO ₂ ⁻ -N (µg-at/L)	0.02~0.86	0.17	0.03~0.98	0.42	0.10~1.45	0.82
DIN (µg-at/L)	0.39~19.38	3.08	0.07~1.12	0.32	0.20~9.82	3.23
DIP (µg-at/L)	0.01~1.20	0.21	0.06~0.39	0.18	0.23~0.31	0.14
N/P ratio	1.17~184.00	36.84	0.29~3.33	1.84	0.80~32.73	9.33
Si/N ratio	1.87~31.98	8.57	13.21~263.86	76.07	3.02~84.85	16.76
TN (mg/L)	0.45~1.35	0.77	0.20~3.28	1.25	0.57~2.41	1.07
TP (mg/L)	0.03~0.18	0.05	0.01~0.05	0.03	0.03~0.05	0.04
Si (OH) ₄ -Si(µg-at/L)	3.59~46.47	12.12	8.10~38.65	13.58	10.50~29.67	20.44
Eutrophication index	0.58~4.00	2.60	1.90~4.18	3.12	0.17~3.08	1.18

High values of SPM (> 50 mg/L) were found in stations 5, 6, 7, 8 and 3 in both ebb tide and flood tide in spring. The range of DO was from 5.26 to 14.07 mg/L and sufficient for aquaculture activities standard released by Marine Environmental Policy Bureau of Korea (2011). The range of COD in spring, summer and fall flood tide were 0.99 - 2.47 (mean = 1.44 mg/L), 0.25 - 4.21 (mean = 2.29 mg/L) and 1.05 - 2.49 (mean = 1.82 mg/L), respectively. The highest level of COD (4.43 mg/L) was found in station 5 in spring ebb tide during the freshwater discharging. This value is generally two times higher than that in other sampling stations collected in spring. COD levels were mostly higher than 2 mg/L in summer ebb tide, which exceed the standard value of water quality criteria II of acceptable level for aquaculture activities (Marine Environmental Policy Bureau of Korea, 2011).

Dissolved inorganic nitrogen (DIN) values varied from 0.06 to 22.60 µg-at/L. The mean values of DIN in flood tide in spring, summer and fall were 1.14, 0.91 and 3.30 µg-at/L, respectively. Especially, the DIN value found in station 5 in spring ebb tide (19.38 µg-at/L) was 4 - 5 times higher than that in other stations in group 1 and over 10 times higher than that in other stations in groups 2 and 3. In addition, ammonia concentration in sampling station 5, 6, 7, 8 and 3 in spring ebb tide were 4 - 8 times higher than that in other stations. Dissolved inorganic phosphorus (DIP) values varied from 0.01 to 1.20 µg-at/L. The mean values of DIP in flood tide in spring, summer and fall

were 0.10, 0.19 and 0.30 µg-at/L, respectively. Similar to DIN, the DIP value found in station 5 in spring ebb tide (1.2 µg-at/L) were 6 - 8 times higher than that in other stations in group 1 and approximately 9 times higher than that in other stations in stations groups 2 and 3. The TN value was ranged from 0.20 to 3.32 mg/l. The mean values of TN in spring, summer and fall blood tide were 0.83, 1.80 and 0.76, respectively. The TP value was ranged from 0.01 mg/L to 0.18 mg/L. The TP concentration observed in station 5 (0.18 mg/L) in spring ebb tide was also 3 - 4 times than that in other stations. This suggests that the freshwater discharge has not only affected to dissolved inorganic phosphorus concentration but also effect the organic phosphorus concentrations of seawater in station 5 in spring ebb tide.

Silicate concentrations were ranged from 3.59 to 73.32 µg-at/L. The mean values of silicate in flood tide in spring, summer and fall were 11.98, 15.08 and 20.36 µg-at/L, respectively. In the spring ebb tide, the sudden increasing of silicate concentration in sampling station 5 in a comparison with other sampling stations was also found. The silicate concentration determined in station 5 in spring ebb tide of 11.98 µg-at/L was approximately 2 times higher than that observed in other sampling station in both spring flood and ebb tide. Especially, the disparities of silicate concentration in station 5 in summer flood time (73.32 µg-at/L) and that in other sampling stations were mostly 3 - 4 times. The variations of

COD, DIN, DIP distribution in water sample collected in spring ebb tide were showed in Fig. 2.

The N/P ratio in flood tide of the sampling region in spring, summer and fall were range from 3.95 - 544.00 (mean = 70.20), 0.16 - 11.98 (mean = 2.95) and 1.45 - 66.47 (mean = 10.01), respectively. Based on the comparison with Redfield N/P ratio of 16:1, the limiting nutrient for algae growth in the study area was mostly nitrogen (average N/P ratio < 16) in summer and fall, however phosphorus in spring. The range of Si/N ratio in flood tide of surveyed area in spring, summer and fall were 1.48~28.14 (mean = 13.66), 4.09~160.43 (mean = 68.62) and 2.15~43.29 (mean = 15.27). The Si/N ratio which indicates for potential nutrient limitation, peaked in the summer. In addition, the Si/N ratios determined in all sampling stations and sampling periods were higher than the Brzezinski ratio for Si:N (0.95:1) (Brzezinski, 1985). This suggested that nitrogen is the limiting nutrient for diatom growth in the investigated coastal region.

Eutrophication Index (EI) was calculated based on the research of Primas et al. (2010). In this study, the mean values of EI in the surveyed area in spring, summer and autumn were all bigger than 1. It is therefore the surveyed area was considered in the eutrophication condition according to the requirements of European Water Framework Directive (EC, 2000). However, Druon et al. (2002) has built a simplified concept of various parameters affecting the eutrophication status of shallow marine waters such as the surveyed coastal region in this study. Druon et al. (2002) has showed the relations of 3 main factors affecting eutrophication status including high nutrient concentration, high phytoplankton biomass, oxygen deficiency and 2 supporting factors of surface layer physics and bottom layer physics. Hence, the physics of surface and bottom layer such as tidal characteristics in a shallow coastal area of this study must be taken in a consideration to release the right evaluation of eutrophication status and vulnerability (Druon et al., 2002).

3.2 Sediment environment

The spatio-temporal variation of IL, AVS and COD in the sediment quality was shown in Fig. 3. The range of IL was 4.15 to 7.64%. The mean values of IL in spring, summer and fall were 6.63, 5.63 and 5.85%, respectively. No statistically difference in IL values between 3 sampling site groups in spring, summer and fall was observed. The AVS value was

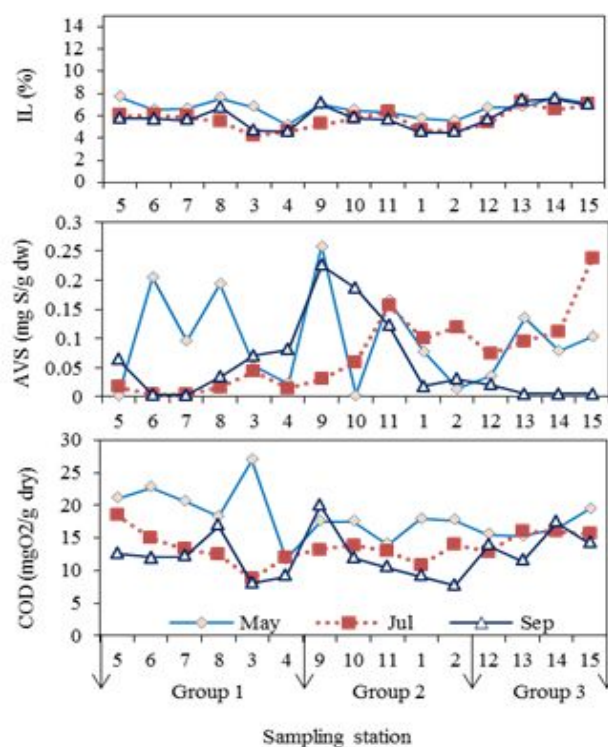


Fig. 3. The variation of IL, AVS and COD distribution in sediments samples from the coastal area in Goheung County.

ranged from 0.002 to 0.259 (mg S/g dry weight). The mean values of AVS in spring, summer and fall were 0.096, 0.072 and 0.058 mg S/g dry weight. The COD value varied from 7.64 to 27.91 mg O₂/g dry weight and mean values of COD in spring, summer and fall were 18.18, 13.69 and 12.43 mg O₂/g dry weight. The effects of freshwater input on the IL, AVS and COD distribution were not obvious compared to those of other analyzed parameters in water environment. The sediment environment parameters in this study were mostly lower than the standard for fisheries environment which recommend the limit values of IL, AVS and COD for fisheries environment as 13%, 0.2 mg S/g dry weight and 20 mg O₂/g dry weight (dw), respectively (Japan Association of Fisheries Resource Preservation, 1980).

3.3 Statistical results

The Levene's test results showed no significant difference between 3 groups of sampling station in most of analyzed parameters in both water and sediment samples in spring, summer and fall. This suggests that the freshwater discharge

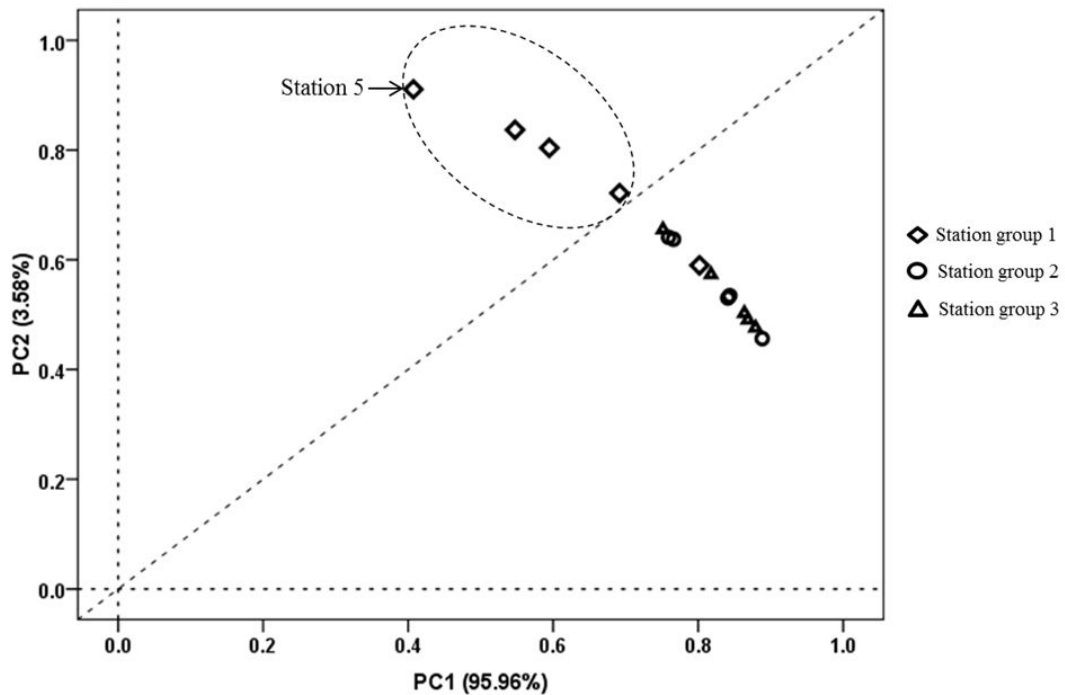


Fig. 4. Plot of PCA scores coordinate for the two principal components (PC) of all analyzed parameters from water samples collected in spring ebb tide in the coastal area in Goheung County

from the tide embankment interior may be affected the surveyed area during a short time interval after the sluice gate opened.

Except water samples in spring ebb tide, the patterns of principal component analysis on water and sediment samples collected in other periods were mostly identical. It is observed that the first principal components accounts for more than 95 % (percentage of variance), whereas the other components explain parts of the remaining variation (Fig. 4). The first component had a large positive loading for all sampling stations. Regardless to stations 5, 6, 7 and 3 belonged to station group 1, the loading degree of other sampling station on component 1 were ranged from 0.751 (station 15) to 0.888 (station 12). The loading degree of station 5 on component 1 was only 0.407. This is can used to perform the sudden high concentration of COD, ammonia, DIN, DIP, silicate and TP of water sample collected in station 5 in spring ebb tide when these values were compared with those found in other sampling stations.

4. Conclusions

The results obtained from this study are summarized as the following points:

- 1) Water quality in front of the sluice gate (station 5) was suddenly changed worse after the gate opened.
- 2) The freshwater discharge from the tide embankment interior maybe affected the survey areas during a short time interval.
- 3) Nitrogen and phosphorus were the limiting nutrient for algae growth in summer and fall and in spring, respectively. Nitrogen was the limiting nutrient for diatom growth in the whole sampling period.
- 4) Mean values of eutrophication index of the surveyed coastal region in spring, summer and fall were all bigger than 1.
- 5) Water quality was mostly considered at level II in standard scale of Marine Environmental Policy Bureau of Korea, 2011 which acceptable for aquaculture activities.
- 6) Sediment quality in this study was generally in the range of standard for fisheries environment of Japan.

Further studies should focus on the current characteristics of the present investigated coastal region and discharge rate and pollutant loads from the tide embankment interior to release more sufficient evaluations in terms of possibility effects of freshwater discharge to water and sediment quality in this area.

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References

- [1] Brzezinski, M. A.(1985), The Si:C:N ratio of marine diatom: interspecific variability and the effect of some environmental variables, *Journal of Phycology* 21, pp. 347-357.
- [2] Cho, H. S., G. H. Lee and M. O. Lee(1998), Seasonal fluctuations of water quality and effect of small tide embankment in coastal water around Muan Peninsula of Korea. *Proceedings of the Korean Society for Marine Environmental Engineering* (Fall), pp. 213-219 (In Korean).
- [3] Druon, J. N., W. Schimpf, S. Dobricic and A. Stips(2002), The physical environment as a key factor in assessing the eutrophication status and vulnerability of shallow seas: PSA and EUTRISK (v1.0), Project "COAST" EUR 20419 EN, European Commission Joint Research Center.
- [4] EC(2000), Directive of the European Parliament of the Council 2000/60/EC establishing a framework for community action in the field of Water Policy *Journal of the European Communities*, Brussels L 327, pp. 1-72.
- [5] Japan Association of Fisheries Resource Preservation(1980), p. 552 (In Japanese).
- [6] Korea Ministry of Land, Transport and Maritime Affairs (2010), Standard examination process for marine environment, p. 461 (In Korean).
- [7] Lee, D. I., H. S. Cho, G. H. Lee and M. O. Lee(2003a), Temporal and spatial fluctuations of coastal water quality and effect of small tide embankment in the Muan Peninsula of Korea. *Journal of the Korean Society for Marine Environmental Engineering*, Vol. 6, No. 4, pp. 24-26 (In Korean).
- [8] Lee, D. I., H. S. Cho and M. O. Lee(2003b), Effect of the freshwater discharge on water quality variation and in Haechang bay, Korea. *Journal of Environmental Impact Assessment*, Vol. 12, No. 5, pp. 341-348 (In Korean).
- [9] Li, Y., D. J. Li, J. L. Tang, Y. M. Wang, Z. G. Liu, P. X. ding and S. Q. He(2007), Phytoplankton distribution and variation in the Yangtze River Estuary and its adjacent sea. *Environmental Science* 28, pp. 719-729.
- [10] Marine Environmental Policy Bureau of Korea(2011), Framework Act on Environmental Policy (In Korean).
- [11] Primpas, I., G. Tsirtsis, M. Karydis and G. D. Kokkoris (2010), Principal component analysis: Development of a multivariate index for assessing eutrophication according to the European water framework directive. *Ecological Indicators* 10, pp. 178-183.
- [12] Ramus, J., L. A. Eby, C. M. McClellan and L. B. Crowder (2003), Phytoplankton forcing by a record freshwater discharge event into a large lagoonal estuary. *Estuaries* 26, pp. 1344-1352.

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