

Factor Analysis of the Seawater Quality of the Southern Coastal Waters of Korea

Yong-Hwan Lee*, Kyoo-Jin Jung¹ and Hak-Kook Kim²

*Department of Civil Engineering, Namdo Provincial College of Jeonnam
Jeonnam 529-851, Korea*

¹*Department of Marine Food Industry, Namdo Provincial College of Jeonnam
Jeonnam 529-851, Korea*

²*Department of Tourism Information, Namdo Provincial College of Jeonnam
Jeonnam 529-851, Korea*

On the basis of factor analysis, stations were grouped according to their similar characteristics of seawater quality. The data for factor analysis were collected from the 15 stations from Dukryang Bay to Ulsan Bay on the southern coast of Korea. The study was based on the data from 1991 to 2000. The 8 water quality items analyzed were temperature, salinity, pH, DO, COD, DIN (dissolved inorganic nitrogen), DIP (dissolved inorganic phosphorus), and SS (suspended solid). Analysis of 6 water quality items including DO with the exception of temperature and salinity showed that 15 stations were grouped into two zones, i.e., the western and the eastern coast, by the axis of Samcheonpo-Jinju Bay-south of Geoje, 3 seawater zones in all. The adjacent stations to the southward or northward but not those to the eastward or westward were classified into the same group. On the analysis of all of the 8 water quality items, the stations of Dukryang Bay and Goheung; and those of Onsan and Ulsan Bay were classified into the same group. Yeosu and Namhae stations were sectioned into 1 group on the all seawater quality items but DIP, Samcheonpo and south of Geoje stations another group on all seawater quality items but water temperature, and Masan and Busan stations in the other group on all seawater quality items but DO. The stations from Dukryang Bay through Goheung to east of Geoje were grouped together on the COD item, and this showed somewhat different tendency in other seawater quality items.

Key words: Factor analysis, South coastal area of Korea, Seawater quality

Introduction

MOE (Ministry of Environment) and NFRDI (National Fisheries Research and Development Institute) have continuously investigated the environment of ocean water quality, but academical researches of using these data have not been actively undertaken because of the limited investigation area, short period of investigation, and restricted investigation cycle.

Most researches on water quality of the southern coastal waters of Korea are data collection of its chemical and physical environment (Baek et al., 1998; Cho et al., 1998; Han et al., 1996). But Yoon (2000a,b) and Yoon et al. (2000) choose one or several investiga-

tion stations and used water quality data measured in a separate way for 1-2 years. And they analyzed environmental factors and correlation among measured items by means of correlation matrix. Investigation on one research area may indicate detailed results on the station, but it is impossible to estimate direct correlation with the adjacent stations.

The coastal water quality at a certain station is under the influence of the changes in water quality of the neighboring stations which are caused by fluid sea water. Accordingly, analysis on the correlation between water quality items of the adjacent stations should be made on the basis of data collected for a long period of time covering a wide range of investigation stations. The results drawn on this analysis will be of help to control the environment

*Corresponding author: leeyh@namdo.ac.kr

of sea water quality on the whole ocean area.

In this study, we used the statistic data on sea water quality which were collected from the 15 stations on the south coast for 10 years and grouped the stations into a small number of zones according to their similar characteristics of sea water quality, which was performed through factor analysis.

Materials and Methods

Seawater quality data

The collected data on seawater quality from 15 south coastal stations were analyzed by the analytical method of factor analysis (Alexander, 1994; Kim and Jeon, 1997) with SAS (Statistical Analysis System) 6.11. The study was based on the data from 1991 to 2000. The 8 water quality items analyzed were temperature, salinity, pH, DO, COD, DIN (Dissolved Inorganic Nitrogen), DIP (Dissolved Inorganic Phosphorus), and SS (Suspended Solid). Some of the data from 1991 to 1994 were quoted from the statistical yearbook published by MOE (MOE, 1990-1996), others from 1995 to 2000 were cited from the homepage of NFRDI, Republic of Korea (http://www.nfrda.re.kr/sitemap/technic/enviroment_1.htm, 1996-2000). The Romanization of the survey stations refers to the 2001 Annual Report of Korean Coastal Environment Monitoring by NFRDI.

Fifteen stations were surveyed (Fig. 1), in which the place names are shown in Table 1(a) and 1(b). The arithmetical mean of the data collected from several stations were used with the exception of deficient measured values.

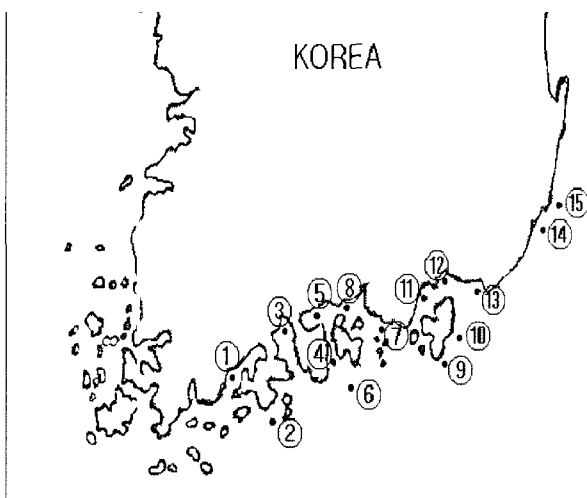


Fig. 1. Map of survey stations.

Results and Discussion

Statistical Description

Basic statistical description is shown in Table 1 (Smith, 1986) and each extreme value on each item is represented in the bold cells.

The stations, the months, and the years showing maximum and minimum values in Table 1 are represented in Table 2.

Yeosu, Busan, and Ulsan stations compared to other stations seen to show relatively small change of seawater quality in that the three stations did not show extreme values on the 8 water quality items (Table 1 and 2). Masan Bay station, however, marked maximum values on pH, DO, and COD items, and the last two items showed a wider range of change than those of other stations (See standard deviation). Focusing on the frequency of maximum and minimum values, as shown in Table 2, we can find that the high frequency of maximum value was marked at Namhae and Masan Bay stations.

Partial Correlation Analysis

Partial correlation coefficient was calculated to analyze the true correlation of the only 2 stations for each seawater quality item (Lee et al., 1998; Richard and Dean, 1992).

The seawater quality items scoring interstation partial correlation coefficient over 0.5 were described in Table 3, in which the names of localities are shown in Table 1(a) and 1(b). The symbols used in Table 3 were indicated in Table 4. The right side of the diagonal line is indicative of positively correlated stations, and the left side negatively correlated ones in Table 3.

In Table 3, the seawater zones Dukryang Bay-Goheung, Yeosu-Gwangyang Bay, Samcheonpo-Jinju Bay, south of Geoje-east of Geoje, Jinhae Bay-Masan Bay, and Onsan-Ulsan Bay can be grouped together and they show high interstation correlation.

Factor analysis

Factor analysis was performed on the 8 water quality items inclusive of water temperature between stations. Four factors were set for the statistical factors. As a result of analysis, MSA (Measure of Sampling Adequacy) scored all over 80%, so that the number of factors can be said sufficient enough (Lee and Kim, 1997), and MSA marked lower than 50% represents lack of the number of variables.

Factor rotation used the VARIMAX solution of orthogonal solutions. As a consequence of factor

Table 1(a). Water quality parameters from Dukryang Bay to Ulsan

Items	Values	Dukryang Bay①	Goheung ②	Yeoja Bay ③	Yeosu ④	Gwang-yang Bay⑤	Namhae ⑥	Samcheonpo ⑦
Temperature (°C)	Max	28.0	28.0	30.0	31.0	31.0	32.0	28.0
	Min	5.3	1.0	4.2	2.0	3.0	3.0	6.1
	Mean	16.6	16.3	16.7	16.1	17.0	16.7	16.4
	SD	7.0	6.9	7.5	7.3	7.7	6.9	6.3
Salinity (‰)	Max	33.71	33.92	34.10	34.50	34.70	40.82	36.80
	Min	20.70	20.40	22.00	23.40	22.84	24.00	23.70
	Mean	30.00	30.07	29.15	29.73	29.23	30.68	32.12
	SD	2.58	2.77	2.64	2.83	2.91	3.30	2.55
pH	Max	8.37	8.34	8.36	8.57	8.40	8.60	8.52
	Min	6.90	7.00	6.90	7.60	7.70	7.70	7.80
	Mean	8.01	8.01	7.99	8.09	8.12	8.11	8.14
	SD	0.25	0.22	0.27	0.18	0.17	0.17	0.15
DO (mg/L)	Max	11.93	11.51	13.30	11.51	12.10	11.50	11.90
	Min	6.38	5.88	5.90	4.68	5.86	4.91	4.97
	Mean	8.88	8.69	8.73	8.73	8.82	8.56	8.20
	SD	1.34	1.36	1.68	1.72	1.75	1.760	1.38
COD (mg/L)	Max	2.41	2.20	3.42	3.41	3.49	3.04	2.71
	Min	0.69	0.71	0.58	0.98	1.20	0.29	0.46
	Mean	1.50	1.39	1.70	1.56	2.12	1.26	1.39
	SD	0.340	0.31	0.53	0.45	0.42	0.41	0.46
DIN (mg/L)	Max	0.422	0.405	0.421	0.712	0.786	0.456	1.491
	Min	0.014	0.017	0.011	0.014	0.015	0.016	0.016
	Mean	0.159	0.151	0.187	0.187	0.224	0.143	0.502
	SD	0.112	0.097	0.113	0.117	0.135	0.092	0.438
DIP (mg/L)	Max	0.077	0.052	0.092	0.079	4.657	0.034	0.045
	Min	0.000	0.003	0.002	0.004	0.009	0.001	0.000
	Mean	0.014	0.014	0.021	0.029	0.211	0.016	0.015
	SD	0.014	0.009	0.020	0.018	0.800	0.008	0.011
SS (mg/L)	Max	30.50	45.43	44.40	21.18	39.77	24.13	27.57
	Min	1.60	2.00	4.07	2.40	3.00	2.30	1.60
	Mean	9.79	11.55	15.92	8.91	12.54	7.03	6.78
	SD	6.01	6.94	8.57	4.62	6.93	4.38	4.81

The values in the boxes represent extreme values on each statistical values.

Table 1(b). Water quality parameters from Dukryang Bay to Ulsan

Items	Values	Jinju Bay ⑧	South of Geoje ⑨	East of Geoje ⑩	Jinhae Bay ⑪	Masan Bay ⑫	Busan ⑬	Onsan ⑭	Ulsan ⑮
Temperature (°C)	Max	28.0	28.0	28.0	29.0	29.0	25.0	26.0	26.0
	Min	5.8	5.0	5.0	5.0	5.0	8.0	5.0	5.0
	Mean	16.2	16.5	16.6	16.1	16.5	16.2	16.2	16.3
	SD	6.5	5.4	5.2	6.5	6.8	4.6	4.7	4.7
Salinity (‰)	Max	35.60	35.30	35.30	35.50	39.20	35.20	34.80	34.80
	Min	17.09	28.79	29.00	24.08	21.36	28.20	27.00	28.30
	Mean	31.17	32.58	32.80	31.76	30.32	32.65	32.70	32.63
	SD	3.86	1.75	1.73	2.52	3.49	1.92	1.98	1.78
pH	Max	8.55	8.40	8.46	8.90	9.10	8.48	8.60	8.56
	Min	7.59	7.80	7.80	7.24	7.80	7.71	7.70	7.20
	Mean	8.10	8.14	8.17	8.22	8.29	8.17	8.16	8.09
	SD	0.19	0.16	0.17	0.25	0.30	0.17	0.17	0.24
DO (mg/L)	Max	11.60	10.33	10.50	12.70	15.90	10.20	12.50	10.60
	Min	5.08	5.51	6.16	3.98	4.18	6.01	5.97	6.13
	Mean	8.06	8.09	8.18	8.45	8.42	7.91	8.51	8.26
	SD	1.51	1.05	0.91	1.89	2.63	0.88	1.15	0.96
COD (mg/L)	Max	3.31	3.00	3.00	3.40	8.10	2.80	2.90	2.82
	Min	0.80	0.57	0.70	1.08	0.80	1.00	0.90	1.18
	Mean	1.45	1.21	1.28	2.03	3.83	1.75	1.81	1.80
	SD	0.51	0.46	0.45	0.55	1.58	0.47	0.58	0.35
DIN (mg/L)	Max	1.476	1.262	1.262	1.633	2.543	1.734	2.724	2.111
	Min	0.029	0.047	0.033	0.042	0.123	0.084	0.070	0.098
	Mean	0.596	0.490	0.520	0.644	1.019	0.723	0.857	0.959
	SD	0.446	0.398	0.376	0.477	0.534	0.460	0.629	0.486
DIP (mg/L)	Max	0.075	0.035	0.060	0.097	0.257	0.106	0.195	0.101
	Min	0.003	0.000	0.000	0.005	0.010	0.004	0.001	0.004
	Mean	0.020	0.013	0.014	0.025	0.066	0.032	0.025	0.024
	SD	0.015	0.010	0.013	0.027	0.054	0.023	0.036	0.021
SS (mg/L)	Max	20.30	15.63	13.75	30.60	20.00	14.93	19.10	17.70
	Min	1.50	0.95	1.40	1.00	1.80	1.50	0.90	1.38
	Mean	8.69	5.27	4.87	5.54	7.38	6.74	5.56	6.64
	SD	5.00	3.35	2.92	4.80	3.87	3.65	3.34	3.54

The values in the boxes represent extreme values on each statistical values.

Table 2. Maximum and minimum values of the 8 water quality items

Items	Max value				Min value			
	Value	Station	Year	Month	Value	Station	Year	Month
Temperature (°C)	32.0	Namhae	1992	Aug.	1.0	Goheung	1991	Feb.
Salinity (‰)	40.82	Namhae	1997	Feb.	17.09	Jinju Bay	1999	Aug.
pH	9.10	Masan Bay	1994	Aug.	6.90	Dukryang Bay, Yeoja Bay	1991	Nov.
DO (mg/L)	15.90	Masan Bay	1996	May	3.98	Jinhae Bay	1997	Aug.
COD (mg/L)	8.10	Masan Bay	1994	May	0.29	Namhae	2000	Feb.
DIN (mg/L)	2.724	Onsan	1995	Aug.	0.011	Yeoja Bay	2000	Feb.
DIP (mg/L)	4.657	Gwangyang Bay	1991	Feb.	0.000	Samcheonpo	1991	Feb., May, Aug., Nov.
SS (mg/L)	45.43	Goheung	1997	Feb.	0.90	Onsan	1999	Aug.

Table 3. Partial correlation coefficient over 0.5

Station Number	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮
①		B,D, F,G	A,D							G					
②				G,H		F						G			
③					F,H										
④					B,C,E, F,H	A,D							C		
⑤						D		B							
⑥														H	
⑦								A,B,C, D,G,H	C,H		B,H		B,G		
⑧		G										B,G		G	B
⑨	G	H								A,B,C, D,E,G, H					
⑩															D
⑪								B				A,B,C			
⑫							B						B		G
⑬			B		C			B,G						G	B
⑭							G					C			A,C,D, F,G
⑮								B					B		

Table 4. Symbols of water quality used in Table 3

Symbols	A	B	C	D	E	F	G	H
Items	Temperature (°C)	Salinity (‰)	DO (mg/L)	pH	COD (mg/L)	DIN (mg/L)	DIP (mg/L)	SS (mg/L)
Positive correlation	6/0	12/6	7/2	8/0	2/0	5/0	12/4	8/1
Negative correlation								

analysis on the seawater quality items, the stations showing similar variational characteristics are grouped together as in Fig. 2. MSA is illustrated in Table 5, and all the scores of MSA over 50% mean that there were no seawater quality items lacking of the number of the variables. Table 6 shows factor communality, whereupon each station of measuring seawater quality was grouped.

Analysis of seawater quality items with the exception of water temperature and salinity (Fig. 2a,b) showed that 15 stations were grouped into 2 seawater zones, i.e., the western and the eastern coast, by the axis of Samcheonpo-Jinju Bay-south of Geoje. The adjacent stations to the southward or northward but not those to the eastward or westward were classified into the same group (Fig. 2c-h).

On the analysis of all of the 8 water quality items, the stations of Dukryang Bay and Goheung; and those of Onsan and Ulsan Bay were classified into the same group, respectively. The stations from Dukryang Bay through Goheung to east of Geoje were grouped together on the COD item, and this showed somewhat different tendency among other seawater quality items.

As a result of the analysis, we can draw some conclusions.

1. Analysis of 6 water quality items including DO with the exception of water temperature and salinity showed that 15 stations were grouped into 2 zones, i.e., the western and the eastern coast, by the axis of Samcheonpo-Jinju Bay-south of Geoje, 3 seawater zones in all. The adjacent stations to the southward or northward but not those to the eastward or westward were classified into the same group.
2. On the analysis of all of the 8 water quality items, the stations of Dukryang Bay and Goheung and those of Onsan and Ulsan Bay were classified into the same group.
3. Yeosu and Namhae stations were sectioned into one group on the all seawater quality items exclusive

of DIP, Samcheonpo and south of Geoje stations another group on all seawater quality items exclusive of water temperature. Masan and Busan stations the other group on all seawater quality items exclusive of DO.

4. The stations from Dukryang Bay through Goheung to east of Geoje were grouped together on the COD item, and this showed somewhat different tendency among other seawater quality items.

From these conclusions, we can cope effectively with the seawater quality variation by grouping the stations sharing similar seawater quality variation characteristics on seawater quality items into one seawater zone. The seawater showing similar variation characteristics on the seawater quality items are sectioned into the same zone. Controlling seawater quality on a zoned basis make it possible to predict and to cope effectively with the seawater quality variation on the coastal area. Regression Analysis drawn on between the weather factor and the seawater quality factors may have an effect of reducing the number of survey stations, but also of reducing the number of stations. In addition, it will be of some help to predict that the seawater quality variation at a certain station is correlated with that at the other stations within the same seawater zone which shares similar variation characteristics.

References

- Alexander B. 1994. Statistical factor analysis and related method. John Wiley & Sons, Inc. New York, N.Y., pp. 120-130.
- Baek, C.I., P.Y. Lee, Y.S. Kang and J.S. Park. 1997. Examination of seawater pollution and red tide. SSFRI. NFRDI., 73-119. (in Korean)
- Cho, Y.C., W.J. Ko, S.S. Kim and K.A. Jeon. 1995. Investigation of oceanographic data in the offshore Korea. SSFRI. NFRDI., 120-139. (in Korean)
- Han, S.B., Y.H. Ahn, Y.S. Seo, K.A. Jeon, H.K. Jin and

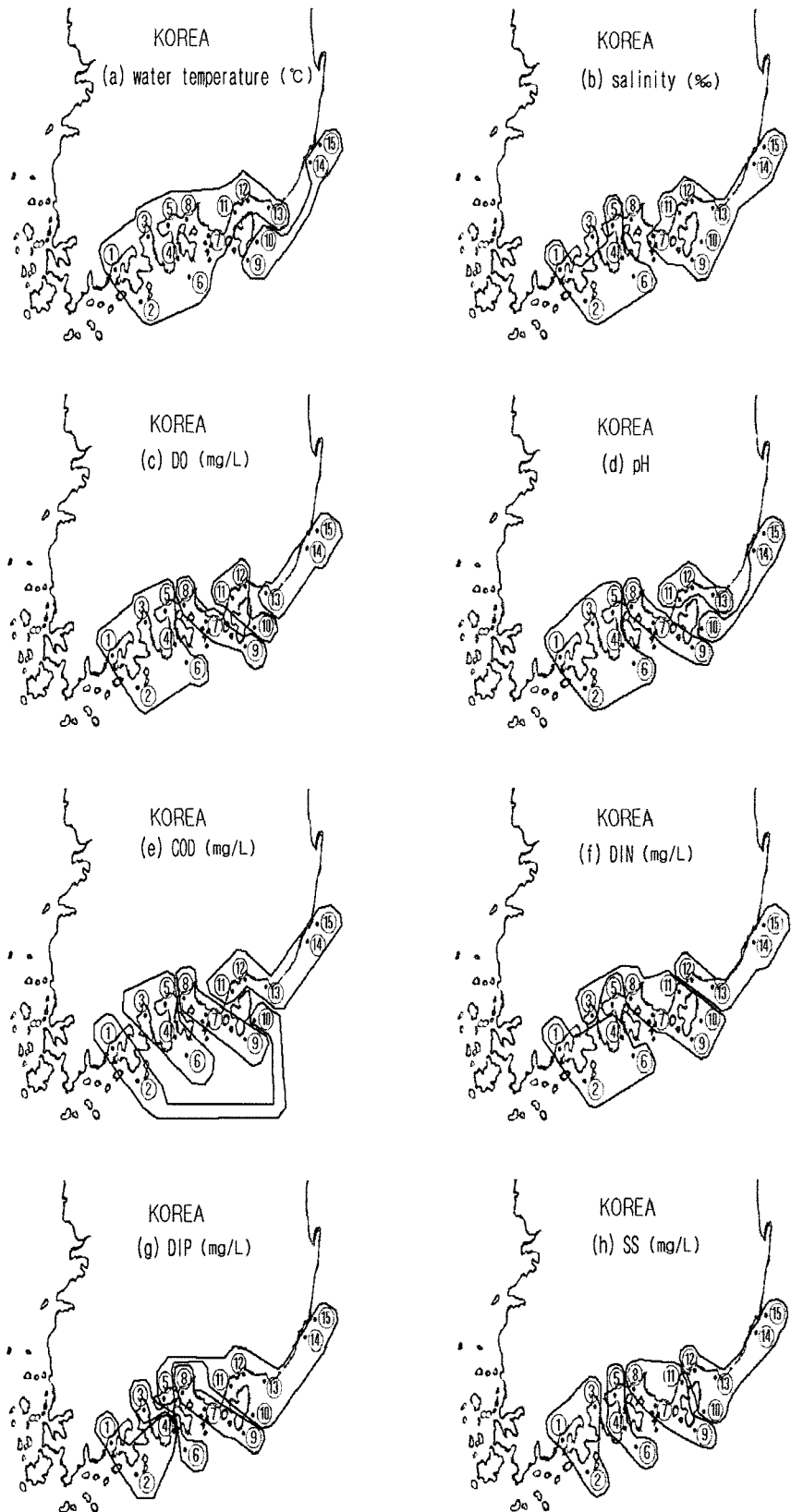


Fig. 2 Illustration of factor analysis.

Table 5. MSA of 8 water quality items

Items	Temperature (°C)	Salinity (‰)	DO (mg/L)	pH	COD (mg/L)	DIN (mg/L)	DIP (mg/L)	SS (mg/L)
MSA	0.9019	0.7220	0.7851	0.6839	0.5854	0.9005	0.6118	0.5612

Table 6. Factor communality

Items	Factor	Station Number (factor communality)
Temperature (°C)	Factor 1	①(0.878), ②(0.826), ③(0.879), ④(0.793), ⑤(0.798), ⑥(0.746), ⑦(0.749), ⑧(0.770), ⑨(0.768), ⑩(0.818), ⑪(0.694)
	Factor 2	⑨(0.708), ⑩(0.803), ⑭(0.879), ⑮(0.859)
	Factor 3	-
	Factor 4	-
Salinity (‰)	Factor 1	⑦(0.713), ⑨(0.869), ⑩(0.881), ⑪(0.822), ⑫(0.712), ⑬(0.923), ⑭(0.925), ⑮(0.921)
	Factor 2	①(0.940), ②(0.951), ④(0.930), ⑤(0.858), ⑥(0.924)
	Factor 3	⑧(0.937)
	Factor 4	③(0.855)
DO (mg/L)	Factor 1	①(0.814), ②(0.847), ③(0.866), ④(0.846), ⑤(0.904), ⑥(0.731)
	Factor 2	⑦(0.861), ⑧(0.842), ⑨(0.798)
	Factor 3	⑩(0.616), ⑪(0.787), ⑫(0.842)
	Factor 4	⑬(0.545), ⑭(0.960), ⑮(0.908)
pH	Factor 1	①(0.831), ②(0.794), ③(0.807), ④(0.838), ⑤(0.867), ⑥(0.855)
	Factor 2	⑦(0.898), ⑧(0.938), ⑨(0.703)
	Factor 3	⑩(0.824), ⑫(0.864), ⑬(0.678)
	Factor 4	⑭(0.890), ⑮(0.738), ⑯(0.586)
COD (mg/L)	Factor 1	⑩(0.875), ⑫(0.453), ⑬(0.768), ⑭(0.758), ⑮(0.776)
	Factor 2	③(0.551), ④(0.872), ⑤(0.823), ⑥(0.742)
	Factor 3	⑦(0.698), ⑧(0.771), ⑨(0.830)
	Factor 4	①(0.738), ②(0.715), ⑩(-0.804)
DIN (mg/L)	Factor 1	⑫(0.627), ⑬(0.617), ⑭(0.896), ⑮(0.856)
	Factor 2	①(0.849), ②(0.847), ④(0.763), ⑥(0.802)
	Factor 3	③(0.640), ⑦(0.636), ⑧(0.723), ⑨(0.644), ⑩(0.641), ⑪(0.680)
	Factor 4	⑤(0.819)
DIP (mg/L)	Factor 1	⑤(-0.225), ⑩(0.649), ⑪(0.845), ⑫(0.667), ⑬(0.891), ⑭(0.897), ⑮(0.820)
	Factor 2	⑦(0.903), ⑧(0.897), ⑨(0.819)
	Factor 3	①(0.896), ②(0.811), ④(0.599),
	Factor 4	③(0.721), ⑥(0.695)
SS (mg/L)	Factor 1	⑩(0.755), ⑫(0.573), ⑬(0.677), ⑭(0.871), ⑮(0.729)
	Factor 2	⑦(0.920), ⑧(0.565), ⑨(0.756), ⑪(0.794)
	Factor 3	①(0.774), ②(0.751), ③(0.945)
	Factor 4	④(0.747), ⑤(0.598), ⑥(0.899)

- S.H. Ha. 1995. Investigation the changes and prediction of oceanographic data in the offshore Korea. NFRDI., 22-39. (in Korean)
- Kim, K.Y. and M.S. Jeon. 1997. Multivariate statistical analysis, Free Academy, Seoul, Korea, pp. 145-153. (in Korean)
- Lee, K.H. and Y.H. Kim. 1997. Statistical Data Analysis, Free Academy, Seoul, Korea, pp. 427-468. (in Korean)
- Lee, Y.H., K.W. Baek, K.Y. Han and J.W. Song. 1998. Characteristics of precipitation and river water-quality variation by the factor analysis method. J. Civil Eng., KSCE, 18, 263-276. (in Korean)
- MOE (Ministry of Environment). 1990-1996. Statistical Yearbook of Environment, Seoul, Korea. (in Korean)
- NFRDI. 1996-2000. http://www.nfrda.re.kr/sitemap/technic/enviroment_1.htm, Busan, Korea. (in Korean)
- Richard, A.J. and W.W. Dean. 1992. Applied Multivariate Statistical Analysis, Prentice Hall, New Jersey, pp. 250-275.
- Smith, G.N. 1986. Probability and Statistics in Civil Engineering, William Collins, Sons & Co. Ltd., London, UK, pp. 132-140.
- Yoon, Y.H. 2000a. A study on the distributional characteristic of organic matters on the surface sediments and its origin in Keogeum-sudo, southern part of Korean Peninsula. J. Kor. Environ. Sci. Soc., 9, 137-144. (in Korean)
- Yoon, Y.H. 2000b. Variation characteristics of water quality and chlorophyll a concentration in the northern Kamak Bay, southern Korea. J. Kor. Environ. Sci. Soc., 9, 429-436. (in Korean)
- Yoon, Y.H., J.S. Park and N.P. Ko. 2000. The variational characteristics of water quality and chlorophyll a concentration in Kogum-sudo, southern part of Korean Peninsula. J. Aquacult., 13(1), 87-99. (in Korean)

(Received November 2002, Accepted September 2003)