II－573 IMPLEMENTATION OF PRINCIPAL COMPONENT ANALYSIS AND DISCRIMINANT ANALYSIS TO THE HYDROCHEMICAL STUDY OF A ROCKFILL DAM

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1.INTRODUCTION

In this work, application of principal component analysis (PCA) and discriminant analysis to the hydrochemistry study of groundwater, reservoir water and all related water around a rockfill dam is reported.

The statistical procedures used in this study constitute a quantitative mean for differentiating waters according to hydrochemistry.

The dam is a rockfill dam, located in Kyushu Island. Sampling have been started from 1989. Fig 1 shows plan of the dam including sampling points. The authors reported the initial estimation of seepage through the dam, from the similarities of the reservoir water with groundwater point in the right abutment of the dam.

In this work, the results of hydrochemical analysis of the year 1992 is used to clarify the source of some unknown points and to get more detail information of seepage path.

2. Numerical Analysis

Principal component analyses and cluster analyses were utilized to classify the water stations with different sources, and discriminant analysis was used to find out about the source of some unknown points.

2.1 Principal Component Analysis

A total number of six ions was taken into account for data analysis. Direct concentrations of the ions were used as input data. The correlation matrix for July 1992 is given in Table 1, the coefficients of PC1 and PC2, the correlation between the original variables and PC in Table 2. From Table 1 it can be seen that the chemical ions are positively correlated with each other (except K with Mg) and from Table 2 that the correlation between the original variables and PC1 are of positive sign and are high for EC, Na^+, Ca^{2+}, SO_4^{2-}. The PC2 is correlated with K^+ and Mg^{2+} and shows that these ions behave independently of the other constituents in the system.

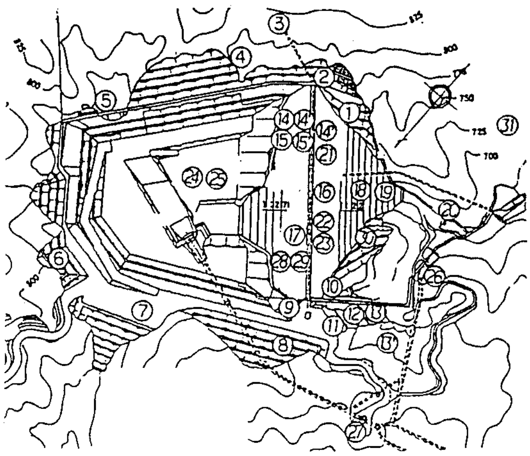

Fig 1 Plan of the dam including sampling stations

The PC1 accounts for 56% of the total variability and PC2 for 23%. As the proportion of variance accumulated by the first two factors was greater than 75%, two factors were chosen. Fig 2 shows the PC1 and PC2 scores.

Table 1 Matrix of correlation coefficients between the chemical variables

	EC	Na^+	K^+	Mg^{2+}	Ca^{2+}	SO_4^{2-}
EC	1					
Na^+	0.738	1				
K^+	0.277	0.775	1			
Mg^{2+}	0.642	0.174	−0.151	1		
Ca^{2+}	0.839	0.726	0.355	0.336	1	
SO_4^{2-}	0.564	0.502	0.205	0.207	0.458	1

To investigate the similarity of the points, PC1 and PC2 were analyzed using cluster analysis.

The analytical data show a variety of water types. In general the groups did not differ much compared to the previous years.

The sampling points located in 5 different groups which in most cases are matched with their sources. High concentration of K^+ in point 22 is attributed to the schisty rocks that exist in this part. Point 14 which is a seepage point does not have a stable condition, the reason of which was clarified by direct mixing of a groundwater point and the nearest seepage point to the point 14 and is explained in the next section.

2 Discriminant analysis

The results of hydrochemistry during year 1991 were utilized for performing discriminant function. On the basis of cluster analysis results and also the information of sampling location, the water stations were classified into three groups, namely groundwater, seepage through rock part, and seepage through dam .

On the basis of the variation in the 8 hydrochemistry parameters, the overall percentage of correct classification is 95%.

To clarify the source of some unknown points, groundwater and seepage points were mixed with different proportion, and to investigate the effect of dissolution of core materials on water quality parameters dissolution test was performed using groundwater and reservoir water as solvents and core aggregate as materials. The mixed waters and solvents resulted from dissolution tests were analyzed for water quality parameters. These parameters were substituted into discriminant functions. The results are given in Table 3.

The results revealed that point 19 that is designates seepage through rock part is a seepage through dam. Also points 14 which is a seepage point are affected by groundwater and based on amount of in flow, it does not show stable condition.

Table 2 Principal component analysis of raw water quality data

	EC	Na^+	K^+	Mg^{2+}	Ca^{2+}	SO_4^{2-}
PC1	0.503	0.490	0.302	0.299	0.473	0.359
PC2	0.263	−0.308	−0.633	0.654	0.053	0.061
CR−PC1	0.927	0.903	0.556	0.459	0.871	0.661
CR−PC2	0.308	−0.360	−0.790	0.765	0.062	0.071

PC1, PC2: Coefficients of principal components 1 and 2 (coordinates of eigenvectors of the correlation matrix in Table 1); CR−PC1, CR−PC2: Correlation between the initial variables and the PC1 and PC2.

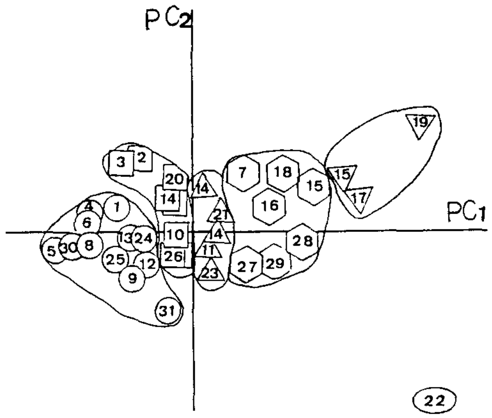

Fig 2 Plot of sampling stations on the plane associated with the first two principal components

Results

Multivariate statistical techniques were used as analytical tools to reduce and organize hydrochemical data into groups with similar characteristics in a rockfill dam. Also it was possible to characterize the source of some unknown points using discriminant analysis.The results also revealed that point 7 can be considered as the other probable seepage path and in the left abutment of the dam, there is a flow from rock mass.

Table 3 Discrimination of mixed waters

Mixed Proportion	First Discriminant Function: Distance from centres 1	2	3	Group
16*	2.136	0.972	2.032	2
1 : 9	1.816	1.292	2.352	2
3 : 7	1.060	2.048	3.109	1
5 : 5	0.487	2.621	3.682	1
7 : 3	0.008	3.100	4.161	1
9 : 1	0.930	4.038	5.099	1
1*	1.365	4.473	5.533	1
18*	3.093	0.015	1.075	2
1 : 9	3.309	2.088	0.860	2
3 : 7	3.566	1.056	0.602	2
5 : 5	3.810	0.184	0.358	3
7 : 3	4.392	1.254	0.223	3
9 : 1	4.620	2.680	0.452	3
15*	5.196	3.464	1.027	3
15*	5.196	2.088	1.027	3
1 : 9	4.164	1.056	0.005	3
3 : 7	2.924	0.184	1.245	2
5 : 5	1.854	1.254	2.315	2
7 : 3	0.428	2.680	3.741	1
9 : 1	0.356	4.473	4.525	1

* Sampling locations

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