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RESEARCH ARTICLE

Application of Factor Analysis in the Assessment of Ground Water Quality in Bangalore North Taluk

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Abstract

A hydro chemical evaluation of the ground water of Bangalore north taluk was conducted using 47 samples. Electrical conductivity, temperature and pH were measured at the time of sample collection while, determination of calcium, magnesium, sodium, potassium, chloride, sulfate, bicarbonate, and nitrate. The obtained data are processed by multivariate techniques with a varimax rotation approach after standardization. The chemical data follow four factorial axes that provide a cumulative total variance explained by 60.4%. Considering the EC as an additional variable, the matrix components after varimax rotation have identified a first axis related to Permanent hardness, a second axis associated with carbonate and bicarbonate, a third axis for potassium. These variables control a significant part of the chemistry of the groundwater in the Bangalore North Taluk.

INTRODUCTION

The analysis of ground water quality is an important and sensitive issue. The anthropological Influences (i.e., urban, industrial and agricultural activities) as well as the natural processes (i.e., changes in precipitation amounts, erosion and weathering of crustal materials) degrade surface and ground water quality and impair its use for drinking, industrial, agricultural, recreational and other purposes. The application of different multivariate approaches such as factor analysis, cluster analysis and source apportionment by multiple regression on principal components are all used for the interpretation of these complex data matrices with the objective of a better assessment of the water quality and ecological status of the surface water systems (Kumru and Bakac, 2003; Lambrakis, 2004). They further allow the identification of the possible factors/sources influencing the system and offer not only a valuable tool for reliable management of water resources but also provide rapid solutions to pollution problems. (Simeonov et al, 2003).

This study attempts to implement the factor analysis method in order to identify practical pollution indicators for delineating the domestic and agricultural pollution in Bangalore north taluk located in Southern India.

Geographical location

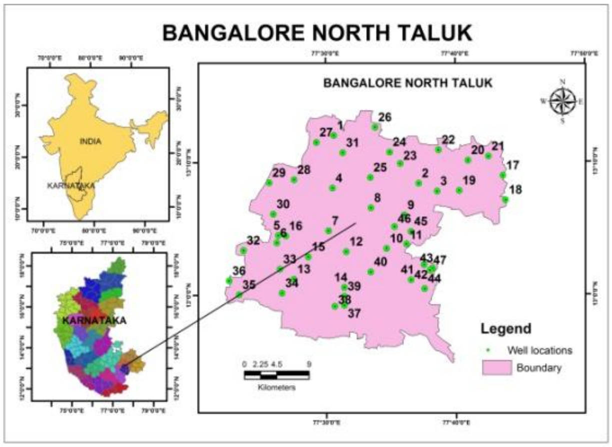

Fig: 1 Geographical location Map of study area

Materials and methods:

Factor analysis

Factor analysis is a multivariate statistical method that yields the general relationship between measured variables by showing multivariate patterns that may be help to classify the original data. It also enables the distribution of the resulting factors to be determined (Manly 1994). The first step of the analysis is to standardize the raw data. Let xi…..,xp denote P variables, each with N observations. The jth observation of the ith variable is Xij, where i=1,….,P and j=1,….,N. If x_m and Si denote the mean and standard deviation, respectively, computed from the N observations of the ith variable, then the jth observation of the ith variable is expressed in standardized units as:

In the second step of factor analysis, the correlation coefficients are evaluated and presented in a matrix format (Lewis-Beck, 1994). Factor analysis takes data contained in this correlation matrix and rearranges them in a manner that better explains the structure of the underlying system which produced the data. Therefore, the correlation coefficient measures how well the variance of each constituent can be explained by relationships with each other. The correlation coefficient is given as:

$$r(x,y) = \frac{\sum(x - x_m)(y - y_m)}{\sqrt{\sum(x - x_m) \sum(y - y_m)}}$$

In this expression, the correlation coefficients (*rx,y*) are simply the sum (over all samples) of the products of the deviations of the *x*-measurements and the *y*-measurements on each sample, from the mean values of *x* and *y*, respectively, for the complete set of samples (Liu et al, 2003).One of the most important steps of factor analysis is to determine the number of factors that need to be extracted for an accurate analysis of the data. In this regard, the rotation of the factor axis is executed to yield a “simple structure” such that factors that are somehow clearly marked by high loadings for some variables and low loadings for others, facilitating data interpretation in terms of original variables.

In order to determine the number of factors to be used, the variances and co-variances of the variables are computed. Then, the Eigen values and eigenvectors are evaluated for the covariance matrix and the data is transformed into factors (Table 1), presents the eigen value and percentages of variance associated with each factor. These values are also summed to express as a cumulative Eigen value and percentage of variance.

In 1958, Kaiser proposed to use only the factors with Eigen values exceeding one (Liu et al, 2003 Briz Kishore 1992 et al,). Parallel to his proposal, two factors explaining 60.4% of the total variance are retained in this particular study (Table1). Then, Kaisers varimax rotation scheme is implemented to evaluate factor loadings that correlate the factors and the variables(Ashley RP 1978, Massart DL 1983). The rotated factor matrix of the two factor model is created as shown in Table 2 and Fig2(a). The factor loadings are used to group the water quality parameters and represent the most important information for interpreting the data.

The next step of the analysis is to compute the contribution of each factor at every site giving the factor scores. The factor scores are projections of data onto corresponding eigenvectors. They could be considered as the actual values of station on the underlying factors. The factor scores were calculated for all 47 monitoring stations (fig 3).

Results and discussion

	Eigenvalue	Variability (%)	Cumulative %
F1	5.866	48.887	48.887
F2	1.383	11.528	60.415
F3	0.583	4.858	65.273
F4	0.360	3.001	68.275
F5	0.230	1.916	70.190

Table 1: cumulative eigen value and percentage of variance.

Variables	F1	F2	F3
Sp cond	**0.954**	-0.045	0.132
TDS	**0.968**	0.223	0.116
TH	**0.857**	0.191	-0.185
Ca^{2+}	**0.851**	-0.163	-0.410
Mg^{2+}	**0.767**	-0.167	-0.008
Na^{+}	**0.661**	0.395	0.259
K^{+}	0.158	-0.123	**0.427**
CO_3^{-}	-0.160	**0.476**	-0.044
HCO_3^{-}	0.326	**0.767**	-0.031
Cl	**0.819**	-0.428	0.240
SO_4^{-}	**0.771**	-0.232	-0.199
NO_3^{-}	**0.334**	0.130	-0.009

Table 2: Factors loadings

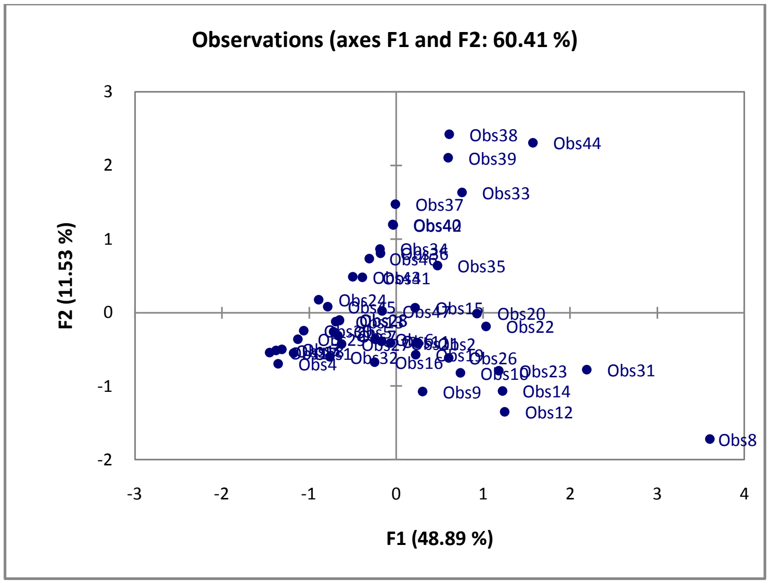

Fig 2(a). Factors pattern with variables

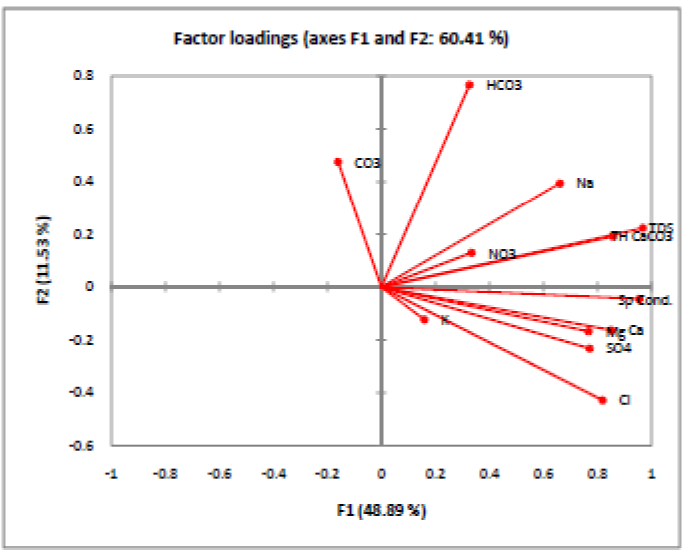

Fig 3: Ploting of factors scores with observations

The Eigen values, the percentages of variance, and the cumulative percentage of variance presented at Table 2 reveal that first two factors explain approximately 60.40% of total variance. This value corresponds to a relatively high representation of the variables by the two factor model. Factor 1 explains 48.88% of the total variance (Table 1). It is clearly seen from Table 2 that factor 1 has strong positive loadings for specific conductivity, sulfate, sodium and nitrate. These high loadings represent a relative high correlation between each other. This finding reflects a negative influence on surface water quality by agricultural discharges and hence could be considered as “inorganic contamination”. On the other hand, Factor 2 explains the 11.5% of the total variance (Table 1) with strong absolute loadings on Carbonate and Bicarbonate.

The high scores for Factor 1 are observed at sample stations 8, 12,14,22,23 and 31 indicating Inorganic with nitrate pollution. Similarly, the high scores for Factor 2 are observed at sample stations 33, 37,38,39,40 and 44 and are representative of carbonate and bicarbonate.

Multivariate statistical analyses are applied to evaluate the chemistry of groundwater samples in the Bangalore North Taluk. The multivariate analysis with varimax rotation revealed that the variables responsible for the mineralization of groundwater fall into two factorial axes, explaining 60.4% of the total cumulative variance. The ionic associations, cations and anions are characteristics of the factorial axes F1 and F2, respectively; for factorial axes F3, explained by potassium, respectively. Indeed, the two associations are linked to minerals, such as halite and gypsum, which are widespread in the region. HCO_3^- comes from the carbonate rocks, while NO_3^- originates as a result of to pollution and extensive agriculture activity. The mapping of factorial axes spatially locates the sources of these hydro chemical variables and their contributions, which are of definite interest for the sustainable management of this type of environment while providing useful information for water quality assessment.

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