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Assessment Of Water Quality Using Multi-Variate Analysis,Water Quality Index And Geo-Statistical Analysis

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ABSTRACT

The water quality is mostly characterized by many variables (parameters) which represent a water composition in specific localities and time. Real hydrological data are mostly noisy, it means that they are not normally distributed, often co-linear or auto correlated, containing outliers or errors etc. These data sets create a n-dimensional space from which information about the water composition has to be mined. For this purpose, multivariate methods such as the Principal Component Analysis(PCA), the Factor Analysis, and the Discriminate Analysis, are used. An alternative is not to use all the quality parameters themselves, but instead of them the indexes that synthesize the typical similarities and differences between the major ions in the surface water environment. These new variables (indexes) can be easily identified by means of a factorial method. Then trends can be analyzed by a robust technique. In the present investigation, an attempt has been made to study Multi-variate statistical analysis of groundwater collected from different sampling points during different seasons. This project objective is to assess existing water quality condition and future water quality conditions for selected parameters. The basic aim is to use PCA for reducing the number of parameters without losing much information which was determined during the three season and to recognize basic feature of water quality. water quality index is one of the most effective tool to communicate the information on the quality of any water body. Geo-statistical technique, namely Ordinary Kriging is been used to enhance the water quality data prediction. This is widely and the most prominent spatial statistical analysis method in Estimation.

Keywords : PCA , WQI, Kriging, robust technique.

1 INTRODUCTION

The evaluation of water quality in developing countries has become a critical issue in recent years (Ongley, 1998), especially due to the concerned that freshwater will be a scare resource in the future. Whereas, water monitoring for different purposes is well defined (Chapman, 1992). Assessment of seasonal changes in water quality is an important aspect for evaluation of temporal variations of water pollution due to natural or anthropogenic inputs. Physical and chemical parameters of groundwater plays a significant role in classifying and assessing water quality. Presentation of chemical analysis in graphical form makes understanding of complex groundwater system simpler and quicker. Water quality indices (WQI) permit us to access changes in the water quality and to identify water trends (Chapman, 1992). A quality index is a unit less number that describe a quality value to an aggregate set of measured parameters (Yagow and Shanholtz, 1996). In the present investigation, an attempt has been made to study Multi-variate statistical analysis of groundwater collected from different sampling points during different seasons.

The Principal Component Analysis has been used to find out the hidden relationship among the variable parameter. The basic aim is to use PCA for reducing the number of parameters without losing much information which was determined during the three season and to recognize basic feature of water quality. The Present work is evaluate and assess the Water Quality Index(WQI) for the study area, as water quality index is one of the most effective tool to communicate the information on the quality of any water body. Geo-statistical technique, namely Ordinary Kriging is been used to enhance the water quality data prediction. This is widely and the most prominent spatial statistical analysis method in Estimation.

This project objective is to assess existing water quality condition and future water quality conditions for selected parameters, and evaluate best management practices for achieving Goa state water quality index, to determine water quality parameter (DO, pH, metals, conductivity, hardness, alkalinity) causing the impurities in the water bodies and to identify sub-basin and streams with good water quality.

2 METHODOLOGY

The sampling procedure was studied and strategies were made to collect the water sample from the Goa region. In the region around the river, totally 25 samples were collected according to the grid. The latitude and longitude of the location point were noted down using GPS instrument. After collecting the samples, chemical was added to the sample to arrest the reaction. The samples were taken and analysis was done in the lab. The parameters namely pH, Conductivity, Chloride, Fluoride, Hardness, Iron, Sulphate, TDS were analyzed using titration and direct instruments. The chemical content of each sample is taken down. Then a table was made Water quality is assessed using the water quality index. Using statistical analysis, correlation matrix is calculated. The next is to calculate the principal component, is calculated. Results are obtained and cross checked along with water quality index. This is done for three seasons namely pre-monsoon and monsoon and post- monsoon and graph were drawn.

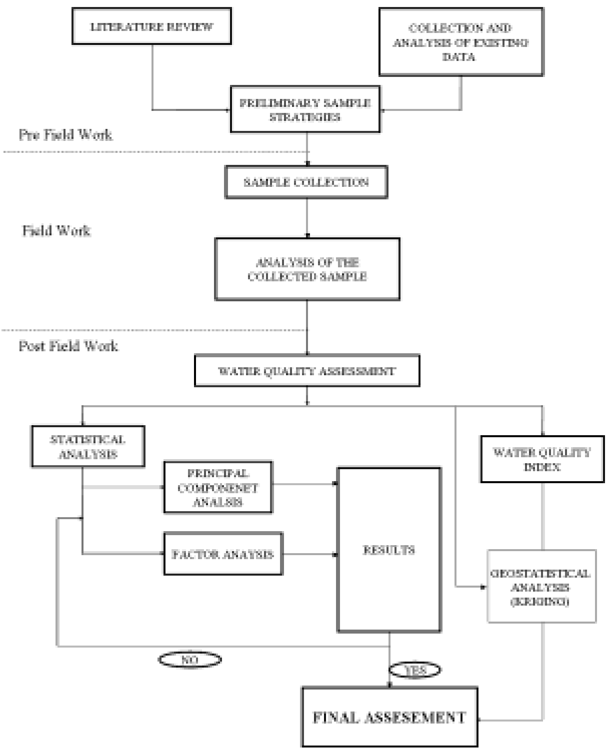

Figure 1.1: Flow chart representation of methodology

2.1 Principal Component Analysis (PCA)

Principal component analysis (PCA) involves a mathematical procedure that transforms a number of possibly co-related variables into a smaller number of uncorrelated variable called principal components. The first principal component accounts for as much of the remaining variability as possible. This technique aims to transform the observed variable to a new set of variable which are uncorrelated and arranged in decreasing order of importance. The principal aim is to simplify the problem and to find new variables (principal components) which make the data easier to understand.

2.2 Water quality index (WQI)

WQI indicates the quality of water in terms of index number which represents overall quality of water for any intended use. Its is defined as a rating reflecting the composite influence of different water quality parameters were taken into consideration for the calculation of water quality index (WQI). The indices are among the most effective ways to communicate the information on water quality trends to the general public or to the policymakers and in water quality management.

2.3 Kriging

Geostatistics is a branch of applied statistics developed by George Matheron in France. The original purpose of geostatistics centered on estimating changes in ore grade within a mine. However, the principles have been applied to a variety of areas in geology and other scientific disciplines. A unique aspect of geostatistics is the use of regionalized variables which are variables that fall between random variables and completely deterministic variables. Regionalized variables describe phenomena with geographical distribution. The phenomenon exhibit spatial continuity; however, it is not always possible to sample every location. Therefore, unknown values must be estimated from data taken at specific locations that can be sampled. The size, shape, orientation, and spatial arrangement of the sample locations is termed the support and influences the capability to predict the unknown samples. If any of these characteristics change, then the unknown values will change. The sampling and estimating of regionalized variables are done so that a pattern of variation in the phenomenon under investigation can be mapped such as a contour map for a geographical region.

3 Equations

The overall water quality index is calculated by aggregating the quality rating with the unit rate linearly.

$$WQI = \frac{\Sigma q_n w_n}{\Sigma w_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where $$q_n = \frac{100(V_n - V_i)}{(V_s - V_i)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

q_n = quality factor

V_s = standard value

V_i = ideal value.

$$W_n = \frac{K}{S_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where Wn = Unit weight of the nth parameters.

S_n = Standard value of the nth parameter.

K = Constant of Proportionality.

Principal Component Analysis (PCA) calculates the, new variables by a combination of the original variables, representing the multidimensional data structure in an optimal way. The direction of the first Principal Component (PC1) to which the studied objects are projected, is calculated in the way that the maximum variance of the studied objects is preserved.

4 Results and Analysis

Table 1.1: Standard Values And Unit Weight

Parameters	Standard Value (Sn)	Unit Weight(Wn)
pH	7	0.2190
EC	300	0.371
TDS	500	0.0037
A	120	0.0155
H	300	0.0662
Cl	250	0.00074
N	45	0.0412
S	150	0.01236
DO	5	0.3723

Notes:-EC- Electric Conductivity ; TDS-Total Dissolved Solid; A-Alkalinity; H -Hardness; Cl-Chlorine Content;F-Fluoride Content; S -Sulphate; DO-Dissolved Oxygen; Fe-Iron Content.

The PCA was used with the objective of establishing the associations between the physico-chemical variables of the waters and to note any correlations between them.

For the monsoon season, samples were collected in 25 location and 8 physico- chemical variable were analysed. The Results of the data set were normalized and correlation between the variable was found out using correlation matrix. With the help of correlation matrix , Eigenvalue and Eigenvector was found using MATLAB7 and Eigenvalue >1 was chosen and two principal component namely PC1 and PC2 was extracted. PCA of the studied 25,34 and 26 (respectively monsoon, post-monsoon and pre-monsoon) natural mineral water samples was performed in order to get an overall impression about assembling the samples in a multidimensional space defined by the chosen physical and chemical variables. A matrix composed of 25X12, 34X13 and 26X12 (respectively monsoon, post-monsoon and pre-monsoon) elements was created for the studied problem. The original data were pre-processed using auto-scaling of the data. With this procedure, the mean of the column elements is subtracted from all individual elements and divided by the column standard deviation. Consequently, each auto-scaled column has a zero mean and a unit variance. The percentage of the total variance, corresponding to the resulting eigenvalues and indicating information content of the individual PCs.

This study has attempted to predict the spatial distribution and uncertainty of surface water Ordinary kriging, a type of geostatistical techniques, is applied to the groundwater chemicals data for a distribution map. Geostatistics provided the tools to describe spatial and temporal behavior of hydrochemical parameters. Surfacewater Chemicals concentrations were log normally distributed. The spherical model is found to the best model representing the spatial variability of surfacewater chemicals concentrations. The average value of the variograms for the spatial analysis was approximately 33 km in the Spherical model.

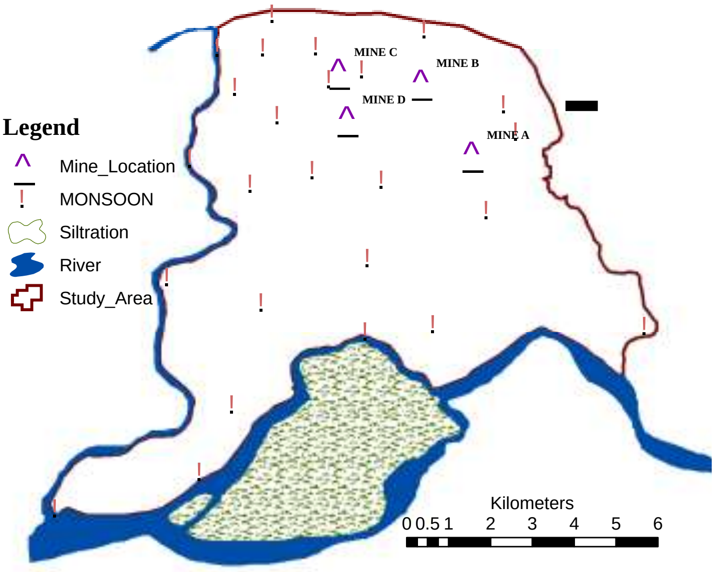

Figure 4.2: Sampling Points and Mine Location in the study area During Monsoon Season

Semi-Variogram:

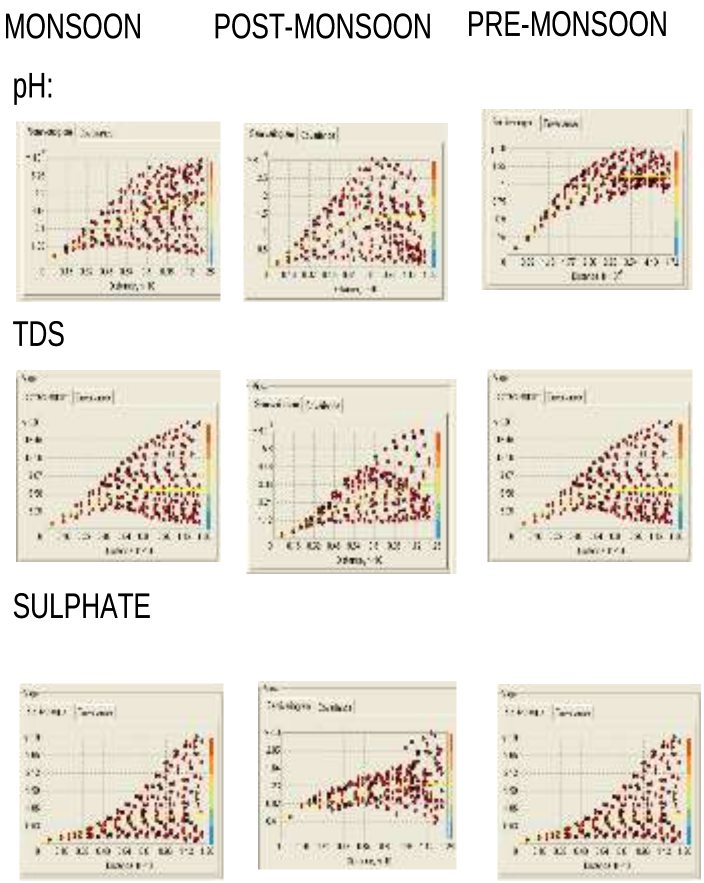

Figure 5.14: Graphic representation of Semi-variogram of pH, TDS, and S.

Table 1.2: Principal Component Analysis

	Monsoon	
	PC1	**PC2**
pH	-0.80851	-0.7514
C	**1.668748**	**4.66175**
DO	-0.57667	-1.241
S	0.454649	**4.0733**

Fe	**1.100497**	-1.5403
Cl	-0.08555	-0.5579
H	0.639185	-1.1793
A	-0.33893	**5.21861**
TDS	-0.28648	-0.5675

Table 1.3: Principal Component Analysis

	Post-Monsoon	Post-Monsoon	Post-Monsoon	Post-Monsoon
	PC1	PC2	PC3	PC4
pH	**2.19766**	-0.14987	-0.18226	**4.218819**
C	-0.72487	-0.26729	**1.43986**	**4.097936**
DO	0.384076	**1.149749**	**1.32299**	**4.094549**
S	-1.50923	0.863745	0.37117	**2.96285**
Fe	-1.13254	1.711606	-1.50826	-1.62174
Cl	-0.35325	-1.55572	0.41968	-2.44797
H	**4..47671**	-1.7232	-0.57541	0.239941
A	-1.29464	0.334018	-1.06336	-1.98617
TDS	3.083611	0.665112	-1.76011	-0.82508

5 CONCLUSION

The project consists of collecting water samples for three season namely monsoon, pre-monsoon and post monsoon at 30 sampling stations under the study area and then analyzing the water quality assessment for each season. We calculated around 13 parameters of each water samples and found out water quality index, principal component analysis and geo statistical anylysis. The high value of Nitrate and Sulphate indicate anthropogenic additions from minor industrial waste discharges, boat traffic and ship building activities along the river banks, which contaminate the river waters as seen from the PCA analysis of the data. The spherical model is found to the best model representing the spatial variability of surfacewater chemicals concentrations. The average value of the variograms for the spatial analysis was approximately 33 km in the Spherical model. The modeling results indicate that the kriged surfacewater physio-chemicals concentrations satisfactorily matched the observed surface water physio-chemicals concentrations.

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