

Figure 3: Plots of water quality parameters as a linear regression model (A-N)

Note: Average values of the parameters on X and Y axis were taken in mg/l except for pH and EC

Principal Component Analysis

The screen plot was used to identify the number of PCs during seasonal sampling of physicochemical parameters.

The 23 physicochemical parameters were reduced to 3 main factors i.e. factor 1, 2 and 3 (Fig. 4). A pronounced change of slope was seen after the 3rd eigenvalue as the remaining 20 factors have eigenvalues of less than one and therefore not

considered significant. Loading of three retained PCs are shown in table 4. PC1 explains 59.4% of the variance and is highly contributed by variables with highest positive factor loadings (>0.90) such as WT, pH, TS, TDS, AK, AD, Cl, TH, Ca, Mg, Ni and Pb whereas DO and Mn has strong negative loadings. High positive loadings indicated strong linear correlation between the factors and water quality parameters. PC2 explains 21.5% of the variance and includes COD, EC and Cr. PC3 explains 19.1% of variance contributed to it by CO₂, NH₄-N and Cd. These high values are indicative of high agricultural runoff and erosion from surrounding hills.

A rotation of PCs can achieve a simpler and more meaningful representation of the underlying factors by decreasing contributions to PCs by variables with minor significance and increasing the more significant ones. Although rotation does not affect the goodness of fitting of principal components solution, the variance explained by each factor is modified [9]. A varimax rotation of principal components to rotated PCs (called henceforth varifactors) is presented in (Table 4). Therefore 3 varifactors (VF) were extracted, explaining 100% of the variance in data sets. It must be noted that rotation were resulted in an increase in the number of factors necessary to explain the same amount of variance in the original data set. Therefore, the VF1 (51.4%) explained less variance than shown before rotation. Similar conclusions were explained on spatial and temporal variation in water quality of Jajrood River [9]. VF1 showed high positive scores on pH, TS, TDS, Cl, TH, Ca, Mg, Ni and Pb with DO, Cd and Mn having negative load. VF2, showed 24.4% of the total variance which showed high negative loading of BOD, COD and Cr with only TSS showing strong positive loading. The increased level of BOD and COD is due to anthropogenic interference from the surroundings [7],[20]. VF3 (24.1% of variance) has a high and positive load of CO₂ whereas only ΣP has strong negative load.

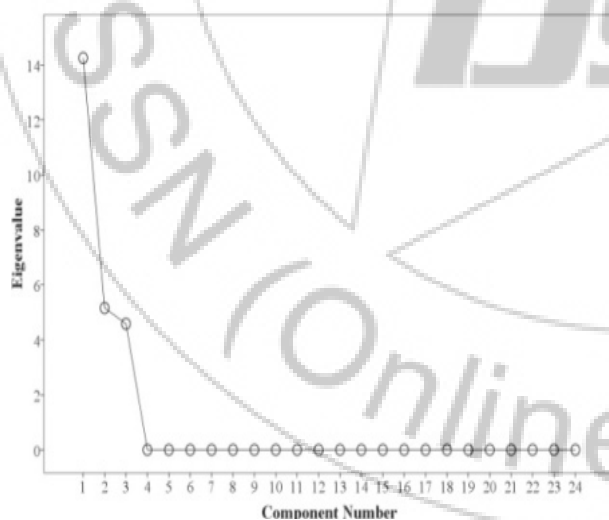


Figure 4: Scree plot of eigen values showing temporal variations

Table 4: Loadings of temporal water quality variables on principal and rotated components

	Principal Components			Rotated Components		
	PC1	PC2	PC3	VF1	VF2	VF3
WT	.942	-.015	.334	.701	.385	.600
pH	.991	.131	-.010	.911	.163	.380
BOD	-.656	.724	-.214	-.392	-.912	-.123
DO	-.786	-.605	.127	-.844	.362	-.395
COD	-.214	.954	-.208	.034	-.992	.122
EC	.515	.780	-.354	.723	-.668	.177
TS	.988	-.043	.145	.818	.368	.443
TDS	.843	.377	-.384	.971	-.216	.105
TSS	.454	-.581	.676	.038	.862	.505
CO2	.225	.514	.828	-.073	-.153	.985
AK	.932	.120	.342	.708	.262	.656
AD	.935	.089	.344	.704	.292	.647
Cl	.925	.066	-.373	.995	.094	.021
TH	.979	-.163	-.120	.904	.395	.166
Ca	.953	-.270	-.138	.872	.478	.100
Mg	.991	-.085	-.106	.919	.331	.213
Ni	.945	.326	-.020	.902	-.031	.431
NH ₄ -N	-.370	-.314	.874	-.745	.442	.500
Pb	.960	-.272	-.069	.849	.503	.161
Cd	-.649	.080	.756	-.889	-.032	.458
Cr	-.411	.910	.051	-.258	-.930	.260
Mn	-.756	.545	.363	-.751	-.604	.266
P	-.532	-.449	-.718	-.238	.039	-.970
Eigen Value	14.26	5.16	4.58	12.35	5.86	5.79
%Total Variance	59.40	21.5	19.1	51.5	24.4	24.1
Cumulative %	59.40	80.9	100.0	51.5	75.9	100.0

4. Conclusion

The present study assessed the temporal variability and water quality using multivariate statistics in the Chamera-I reservoir in Himachal Pradesh. All sampled parameters were within permissible limits of BIS. These parameters also showed a trend in seasonal variation. The higher concentration of heavy metals like Pb, Cd and Mn in the surface water can be attributed to discharge of domestic wastes from catchment area and due to natural erosion of mineral & soil deposits from the surrounding hills. A systematic correlation and regression in this study showed that there is a significant linear relationship between different pairs of water quality parameters which can be used to determine the water quality. It can be concluded that Ni and TS are the most important WQPs as they are correlated with most of the variables. Results of regression analysis also showed that during rainy season, runoff increases the concentration of most inorganic parameters. Hierarchical cluster analysis grouped the sampling seasons into 2 seasons suggesting inorganic runoff from the surrounding hills. The results from PCA also suggested that most variations in water quality are due to natural soluble salts and domestic sewage.

References

- [1] A.H. Pejman, G.R.N. Bidhendi, A.R. Karbassi, N. Mehrdadi, M.E. Bidhendi, "Evaluation of spatial and seasonal variations in surface water quality using multivariate statistical techniques," International Journal of Environmental Science and Technology, 6(3), pp. 467-476, 2009.
- [2] APHA, AWWA, & WEF, Standard methods for the examination of water and wastewater (21st ed.),

- Washington, DC: American Public Health Association, 2005.
- [3] B. Helena, R. Pardo, M. Vega, E. Barrado, J.M. Fernandez, L. Ferná'Ndez, "Temporal evolution of groundwater composition in an alluvial aquifer (Pisuerga river, Spain) by principal component analysis," *Water Research*, 34, pp. 807-816, 2000.
- [4] BIS (Bureau of Indian Standards), Indian standards specification for drinking water, India, IS 10500:1991, 2-4
- [5] C.W. Liu, K.H. Lin, Y.M. Kuo, "Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan," *Science of the Total Environment*, 313(1-3), pp. 77-89, 2003.
- [6] D. M. Joshi, N.S. Bhandari, A Kumar, N. Agrawal, "Statistical analysis of physicochemical parameters of water of river Ganga in Haridwar District," *Rasayan Journal of Chemistry*, 2(3), pp.579-587, 2009.
- [7] F. Zhou, Y. Liu, H. Guo, "Application of Multivariate Statistical Methods to Water quality assessment of the watercourses in Northwestern New Territories, Hong Kong," *Environmental Monitoring and Assessment*, 132, pp. 1-13, 2007.
- [8] H. Boyacioglu, H. Boyacioglu, "Water pollution sources assessment by multivariate statistical methods in the Tahtali basin, Turkey," *Environmental Geology*, 54, pp. 275-282, 2008.
- [9] H. Razmkhah, A. Abrishamchi, A. Torkian, "Evaluation of spatial and temporal variation in water quality by pattern recognition techniques: A case study on Jajrood river (Tehran, Iran)," *Journal of Environmental Management*, 91, pp. 852-860, 2010.
- [10] H.K. Sharma, P.K. Rana, "Assessing the impact of Hydroelectric Project construction on the Rivers of District Chamba of Himachal Pradesh in the Northwest Himalaya, India," *International Research Journal of Social Sciences*, 3(2), pp.21-25, 2014.
- [11] I. Donohue, D. Style, C. Coxon, K. Irvine, "Importance of spatial and temporal patterns for assessment of risk of diffuse nutrient emissions to surface waters," *Journal of Hydrology (Amsterdam)*, 304, pp. 183-192, 2006.
- [12] K.P. Singh, A. Malik, D. Mohan, S. Sinha, "Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India) - a case study," *Water Research*, 38 (18), pp. 3980-3992, 2004.
- [13] K.P. Singh, A. Malik, S. Sinha, "Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques- a case study," *Analytica Chimica Acta*, 538 (1-2), pp. 355-374, 2005.
- [14] L. Muthulakshmi, A. Ramu, N. Kannan, A. Murugan, "Application of correlation and regression analysis in assessing ground water quality," *International Journal of ChemTech Research*, 5(1), pp.355-361, 2013.
- [15] M. Vega, R. Pardo, E. Barrado, L. Deban, "Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis," *Water Research*, 32, pp. 3581-3592, 1998.
- [16] P. Palma, P Alvarenga, V.L. Palma, R.M. Fernandes, A.M.V.M Soares, I.R.Barbosa, "Assesment of anthropogenic sources of water pollution using multivariate statistical techniques: a case study of the Alqueva's reservoir, Portugal," *Environmental Monitoring and Assessment*, 165, pp.539-552, 2010.
- [17] P. Simeonova, V. Simeonov, G. Andreev, "Water quality study of the Struma river basin, Bulgaria (1989-1998)," *Central European Journal of Chemistry*, 2, pp. 121-136, 2003.
- [18] R. Reza, G. Singh, "Heavy Metal Contamination and its Indexing Approach for River Water," *International Journal of Environmental Science and Technology*, 7(4), pp. 785-792, 2010.
- [19] S. Shrestha, F. Kazama, T. Nakamura, "Use of principal component analysis, factor analysis and discriminant analysis to evaluate spatial and temporal variations in water quality of the Mekong River," *Journal of Hydroinformatics*, 10(1), pp. 43-56, 2008.
- [20] S. Shrestha, F. Kazama, "Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan," *Environmental Modelling & Software*, 22, pp. 464-475, 2007.
- [21] T. Kowalkowski, R. Zbytniewski, J. Szejna, B. Buszewski, "Application of chemometrics in river water classification," *Water Research* 40, pp.744-752, 2006.
- [22] W.D. Alberto, D.M.D. Pilar, A.M.Valeria, P.S. Fabiana, H.A. Cecilia, B.M. De Los Angeles, "Pattern recognition techniques for the evaluation of spatial and temporal variations in water quality. A case study: Suquia river basin (Cordoba, Argentina)," *Water Research*, 35(12), pp. 2881-2894, 2001.
- [23] Y. Ouyang, P Nekdi-Kizza, Q.T. Wu, D. Shinde, C.H. Hang, "Assessment of seasonal variations in surface water quality," *Water Research*, 40, pp. 3800-3810, 2006