Current Scenario on Application of Multivariate Statistical Analytical Techniques in Water Environment Research

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Abstract

The objective of the present study was to explore the current status on application of multivariate statistical analytical techniques, namely, cluster analysis (CA), discriminant analysis (DA), multiple linear regression analysis (MLRA) and principal component analysis/factor analysis (PCA/FA) in water environment research. For this, the research papers published recently, 2018 – 2020, on water quality assessment and monitoring were evaluated. The search for the articles revealed: 90% works employed PCA/FA, 76% applied CA, 10% used MLRA and 6% utilized DA. Most of the papers used a combination of, two or three, multivariate analytical techniques (74%). The most commonly employed multivariate statistical techniques were found to be a combination of PCA/FA and CA (62%). Furthermore, the multivariate analytical techniques have been used for both surface and ground water studies.

Keywords: Cluster analysis, Discriminant analysis, Factor analysis, Multiple linear regression analysis, Principal component analysis

Introduction

[1]Multivariate statistical analysis deals with simultaneous examination of more than two variables (Hair *et al.*, 2010; cited in Manoj and Padhy, 2014) or it is a scientific system which is concerned with simultaneous measurements on many different variables (Johnson and Wichern, 2007; Hair *et al.*, 2010; both cited in Manoj and Padhy, 2014). Multivariate statistical models are regarded as intelligent data analysis techniques which can be used in comprehensive assessment

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of water quality, and to reveal the processes which control properties of water. The application of multivariate analytical models has been advocated to be useful in designing water quality monitoring frameworks, including water pollution control measures, which is essential for sustainable management of water-based systems. Sustainable management of water resources requires continuous monitoring and assessment. This generates a large and complex database which requires sophisticated data mining tools for a complete evaluation of water quality to avoid misinterpretation of data. The branch of environmental science which deals with multivariate models is called environmetrics or chemometrics. In water quality studies the sub-branch is called hydrometrics. The information on some commonly used multivariate data techniques and their application is given in the work of Manoj and Padhy (2014). The objective of the present study was to explore the current status on application of multivariate statistical analytical techniques, namely, hierarchical cluster analysis (CA), discriminant analysis (DA), multiple linear regression analysis (MLRA) and principal component analysis/factor analysis (PCA/FA) in water environment research.

Methodology

The search for the articles, with work on multivariate statistical techniques, was made by typing statements such as "multivariate statistical techniques in water quality research", "application of multivariate statistical analytical techniques in analysis of surface water quality", "application of multivariate statistical analytical techniques in analysis of groundwater quality", "multivariate analyses and water quality data". From the randomly selected articles, four multivariate statistical techniques – CA, DA, MLRA and PCA/FA (PCA and FA were taken together in this study) – were assessed. The research papers published recently, 2018 – 2020, on water quality assessment and monitoring were only evaluated.

Discussion

Multivariate statistical analytical techniques used in various studies on water environment are presented in Table-1, Table-2 and Table-3. The study showed that multivariate data analytical techniques have been used for both surface and ground water studies. The research works on water quality were performed for characterization, classification and identification of

hidden factors responsible for controlling its quality. The papers advocated their application in sustainable management of water bodies including pollution control measures.

Table 1: Multivariate statistical techniques used in studies on water environment in 2018

Multivariate statistical technique(s)	Study area	Type of water body	Reference
CA; PCA/FA; MLRA	Ghrib Dam (Algeria)	Surface water	Hamil *et al.*, 2018
CA; PCA	Sıddıklı Dam Lake (Turkey)	Surface water	Akkan *et al.*, 2018
CA; PCA	Nainital District Lakes (India)	Surface water	Dalakoti *et al.*, 2018
CA; PCA	Bektaş Pond (Turkey)	Surface water	Uncumusaoğlu, 2018
CA; PCA	Gharaso River/ Gorgan Rod River (Iran)	Surface water	Khaledian *et al.*, 2018
CA; PCA	A Small Urban River (India)	Surface water	Dutta *et al.*, 2018
CA; PCA/FA	Maddhapara Granite Mining Industrial Area (Bangladesh)	Surface and groundwater	Howladar *et al.*, 2018
CA, PCA	Indian River Lagoon (USA)	Surface water	Zaman *et al.*, 2018
CA; PCA	Old Brahmaputra River (Bangladesh)	Surface water	Bhuyan *et al.*, 2018
CA; PCA	Paraopeba River Basin (Brazil)	Surface water	Calazans *et al.*, 2018
CA; PCA/FA; DA	Legedadie and Dire Catchments (Ethiopia)	Surface water	Anteneh *et al.*, 2018
MLRA	Bhubaneswar Temple Ponds (India)	Surface water	Harichandran *et al.*, 2018
CA	Water Treatment Plants (Iraq)	Treatment plant water	Issa and Alrwai, 2018
PCA	Santo Domingo Aquifer (Mexico)	Groundwater	Celestino *et al.*, 2018
CA; PCA	Fesdis Plain (Algeria)	Groundwater	Khelif and Boudoukha, 2018
CA; FA	Azmak Spring Zone (Turkey)	Groundwater	Acikel and Ekmekci, 2018
CA; PCA; DA	Urban Bengaluru (India)	Groundwater	Gulgundi and Shetty, 2018

CA = Cluster analysis; PCA = Principal; component analysis; FA = Factor analysis; DA = Discriminant analysis; MLRA = Multiple linear regression analysis

Table 2: Multivariate statistical techniques used in studies on water environment in 2019

Multivariate statistical technique(s)	Study area	Type of water body	Reference
FA	Saraydüzü Dam Lake (Turkey)	Surface water	Kükrer and Mutlu, 2019
CA; PCA/FA	Indus River (India)	Surface water	Giri *et al.*, 2019
PCA; DA; MLRA	Tigris River (Iraq)	Surface water	Abed *et al.*, 2019
CA	Jialing River (China)	Surface water	Zhang *et al.*, 2019
CA; PCA	Pazarsuyu Stream (Turkey)	Surface water	Ustaoğlu and Tepe, 2019
PCA/FA; MLRA	Ganwol Reservoir (South Korea)	Surface water	Liu *et al.*, 2019
CA; PCA	Tuzakli Pond (Turkey)	Surface water	Uncumusaoğlu and Mutlu, 2019
CA; PCA	Coastal Aquifers in Koko Area, Western Niger Delta (Nigeria)	Groundwater	Ohwoghere-Asuma *et al.*, 2019
CA; PCA	M'sila Plain (Algeria)	Groundwater	Dougha and Hasbaia, 2019
CA; PCA	Lower Bhavani River Basin (India)	Groundwater	Sajil Kumar, 2019
CA; PCA/FA	Katedan Industrial Development Area (India)	Groundwater	Krishna *et al.*, 2019
CA; PCA/FA	Beni Mellal City (Morocco)	Groundwater	El Baghdadi *et al.*, 2019
CA; PCA	Mokopane Area (South Africa)	Groundwater	Molekoa *et al.*, 2019
CA; FA	Shilabati River Bank (India)	Groundwater	Ghosh and Mondal, 2019
FA	Rupnagar (India)	Groundwater	Chaudhry *et al.*, 2019
CA; PCA	Takelsa (Tunisia)	Groundwater	Trabelsi and Zouari, 2019
CA	Gaza Coastal Aquifer (Palestine)	Groundwater	Abu alnaeem *et al.*, 2019

CA = Cluster analysis; PCA = Principal; component analysis; FA = Factor analysis; DA = Discriminant analysis; MLRA = Multiple linear regression analysis

Table 3: Multivariate statistical techniques used in studies on water environment in 2019 – 2020

Multivariate statistical technique(s)	Study area	Type of water body	Reference
PCA	Alappuzha District Earthen Pond (India)	Surface water	Dhanya and Joseph, 2019
CA	Visakhapatnam (India)	Groundwater	Subba Rao and Chaudhary, 2019
CA; PCA/FA	Boumerzoug-El Khroub Valley (Algeria)	Groundwater	Bouteraa *et al.*, 2019
PCA; MLRA	Regina Landfill (Canada)	Groundwater	Pan *et al.*, 2019
CA; FA	Setif Area (Algeria)	Groundwater	Belkhiri *et al.*, 2018
CA; PCA	Bengal Basin (Bangladesh)	Groundwater	Islam *et al.*, 2019
CA; FA	Chavara Aquifer System (India)	Groundwater	Krishnan *et al.*, 2019
CA; PCA/FA	Guarani and Serra Geral Aquifer (Brazil)	Groundwater	Rezende *et al.*, 2019
CA; PCA	Along Urmia Lake (Iran)	Groundwater	Heydarirad *et al.*, 2019
FA	Saveh Aquifer (Iran)	Groundwater	Jalali *et al.*, 2019
CA; PCA	Gombe Area (Nigeria)	Groundwater	Kwami *et al.*, 2019
FA	Kalpakkam Coastal Region (India)	Groundwater	Prasanna *et al.*, 2019
FA	Semi-Arid Region in Central-Eastern Tunisia (Tunisia)	Groundwater	M'nassri *et al.*, 2019
CA; PCA/FA	Khibiny Alkaline Massif, Kola Peninsula (Arctic)	Groundwater	Popugaeva *et al.*, 2020
PCA	Kanavi Halla Sub-Basin (India)	Groundwater	Patil *et al.*, 2020
CA; PCA	Bafia (Cameroon)	Groundwater	Nyam *et al.*, 2020

CA = Cluster analysis; PCA = Principal; component analysis; FA = Factor analysis; DA = Discriminant analysis; MLRA = Multiple linear regression analysis

The search for the articles revealed: 90% works employed PCA/FA, 76% applied CA, 10% used MLRA and 6% utilized DA (Figure-1). Furthermore, the investigation found that 26%

works employed at least one type of multivariate statistical technique, 66% utilized two types of multivariate analytical tools while 8% used three types of multivariate statistical models (Figure-2). Most of the works used a combination of, two or three, multivariate analytical techniques (74%). The most commonly employed multivariate statistical techniques were found to be a combination of PCA/FA and CA (62%).

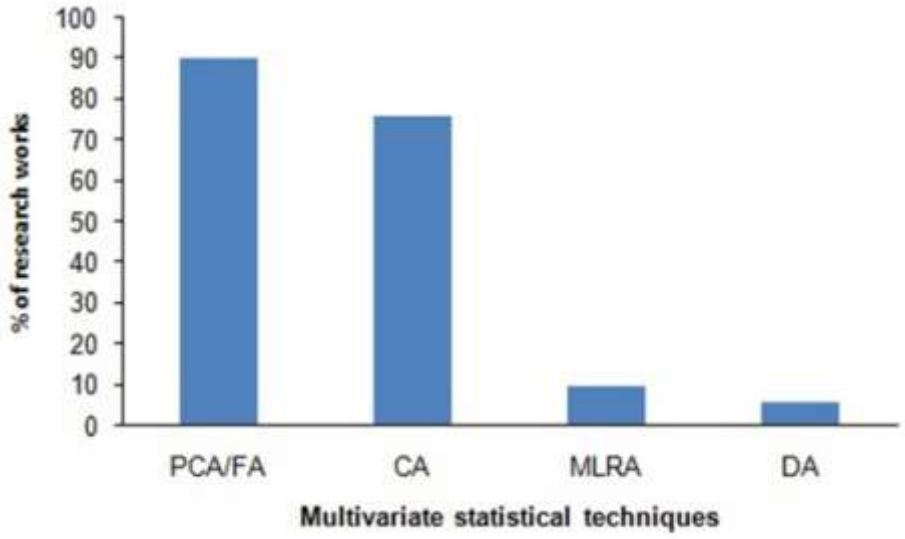

Figure -1: Individual multivariate techniques used in studies on water environment (in %)

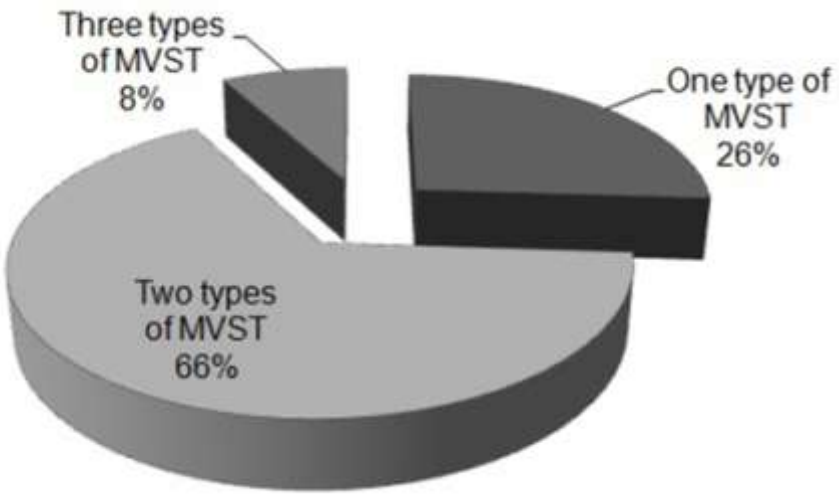

Figure-2: Number of multivariate statistical techniques (MVST) used in studies on water environment (in %)

Conclusions

The multivariate data analytical techniques have been used for the mining of large database of water quality parameters for the characterization and classification of water bodies. These analytical models have been advocated to promote protection and conservation of water bodies, including pollution control measures, essential for their sustainable management. Most of the works used a combination of multivariate data analytical models. The most preferred analyses were found to be a combination of PCA/FA and CA.

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