An Application of Principal Component Analysis for the Temporal Variations in Water Quality Data of Manora Channel: Karachi

Sidrah Ghayas[1*], Junaid Sagheer Siddiquie[2], Suboohi Safdar[3], Asif Mansoor[4]

University of Karachi, University of Karachi, University of Karachi, National university of Science and Technology

Summary
The most important area of the port is the Manora channel, where the Arabian Sea is connected to the city of Karachi. The significance is in both economical and ecological means as it covers the area of 7.17 km^2. The current water quality aspects of the critical deteriorating conditions of Manora channel are due to multiple factors examples are domestic wastages, sewages effluents and industrial pollutants. This study is intended to account the temporal variations and respective conditions of the water quality of Manora channel during the time period of 1996 to 2014 for the selected certain chemical parameters BCO_3, COD, pH, Cl, NH_3, BOD and SO_4 which have been split in all four different seasons of Karachi to explore. Principal component analysis is employed to explore the dimensions responsible most for the temporal variations. This is to be done seasonal wise. Three varifactors are resulted for the summer and winter season, two varifactors are resulted for the autumn and summer season. High factor loadings of BOD and COD contributes the most in all four seasons, then NH3 and pH are responsible for the water quality variation in all seasons. In this manner, Nutrient factors and agricultural runoff and sewage effluents are the sources of pollutants in all four seasons which affects the marine ecosystems and marine lives mainly.

Key Words:
Seasonal variations, pollutants, water quality, factor analysis, industrial effluents, chemical parameters, waste water.

1. Introduction

Sea water is an imperative ecosystem which is the major concerned of both the environmental and economical agencies. The reason of contamination of such essential ecosystem is unnecessary impurities added to the sea. Variations in sea water quality are naturally occurred when the pollutants are deposited to the sea water from the very beginning. Pollution damages the water quality continuously. The process of dumping industrial toxic waste and sewage are mainly responsible for the pollution in seawater. Industries running on the sea water surfaces are dependable on the seawater quality but also massively accountable for the deterioration of the sea water. For instance, oil spilling producing pollution is very commonly observed from the ships.The environmental changes caused by the point and non point sources of water pollutants contributing towards the seawater quality damage and change of season also lead to the temporally variations in seawater quality [1,2]. The physicochemical and biological seawater quality variation parameters are a result of factors like storm water runoff, marine traffic and coastal land use conflicts other than sewage discharges and industrial dumping. Seawater quality temporal variations have been examined physical, chemical and biological parameter(s) by numerous researchers [3, 4, 5]. Many studies have shown that the changes of physico-chemical and biological seawater quality parameters are a result of sewage discharges and other factors such as storm water runoff, marine traffic and coastal land use conflicts. [6,7,8]
Multivariate techniques are not only well known to interpret the water quality parameters but also known to be expert for the spatial and temporal variations in the sea water quality.[9,10,11,12] The sea water quality holds inside it many water quality parameters, a researcher must keen to observe that among these parameters of large data sets taken for decades, which of them are contributing massively for the water quality damage. In this regard, dimension reduction techniques are found to be most suitable for the accountability of the parameters mainly contributable to the temporal variations [13,14,15].Factor analysis(FA) techniques are one of those dimension reduction techniques which are widely observed to examine the contributions of the water quality parameters, mostly factor analysis is proceeded by using principal component analysis.[16,17,18,19] Principal component analysis(PCA) derived the data sets to the linear combinations which are uncorrelated factors and explain the variations of the actual water quality parameters representing the percentages of variations.[20,21]
Factor analysis reduces the number of variables involves in a study by highlighting the contribution of key responsible variables for the variation. The variables are correlated with each other. Factor analysis turns these correlated variables into the uncorrelated variables termed as factors. The linear combination of the correlated actual variables is generated. This is accomplished by following principal component analysis. Principal component analysis establishes the principal components which are entitled to devise the fewer factors than the actual given factors of the data sets.[22]. Dimension reduction is conducted in such a way that the variance which was distributed or contributed by many provided actual data variables is explained by the new generated principal components. The first principal

Manuscript received May 5, 2019
Manuscript revised May 20, 2019

component explains the most of the variance; the second principal component explains the variance less than the first principal component and so on [23,24]. The cumulative variance is provided by the PCA technique corresponding to each principal component. Eigen values and the Eigen vectors are constructed for the correlation matrix of the actual variables. Only those principal components whose Eigen values are greater than 1 are to be chosen in the analysis. Kaiser criterion(KMO Test) is used[25,26,27]. For the adequacy to follow the principal component analysis KMO test and Bartlett's test is evaluated. KMO test observes the correlation between the variables of the actual data. The value of KMO test lies between 0 to 1 and the suggested value must be more than 0.5 which to be considered for the implication of PCA technique. Bartlett's test of sphericity is observed to figure out that the correlation matrix is an identity matrix leading with the rejection of the null hypothesis to apply the principal component analysis. (23, 28).

Manora channel has been considered to be the study area by many researchers who has been worked on this area taking into account many water quality parameters.

Mirza et al(1992) examined the hazardous heavy metals concentrations(Pb, Zn,As, Cu and Mn) in the sampling sites of Karachi coast(Baba channel, Chari Kundi channel and Manora channel) during December 1994 to November 1985.[29] Mirza Arshad(1995) worked on pollution by industries and public emissions into the Lyari and Malir which transfer these pollutants to the sea. Ecological situations of three costal lines are considered which are exposed to manmade pollutions majorly which are Manora Chanel , Gizri Creek and the coastal line between the Gizri Creek and Manora Channel.S.I.T.E area industrial effluents and northern and central areas municipal effluents which entered to the Lyari river are directly introduced to the Manora channel affecting mangroves and marine habitats nearby Manora channel.[30], Riffat et, al(2002) observed the water quality of Baluchistan and Sindh coast (including Manora channel) during the November to December 2000 by observing pH ,E.C, Salinity and stable carbon isotope analysis[31].Mashiatullah et. Al (2009)studied physical, chemical and biological water quality parameters(pH, E.C, Turbidity, Fecal Coliform) in both low tide and high tide of Manora channel taking the samples from multiple sites of Manora channel (Lyari river out fall zone, fish harbor, KPT Shipyard, KPT Shipyard Butti, Bhaba island, Kemari Boat Basin, Bhit island , Boat Club , Pakistan Navel Academy, Manora Lighthouse)[32],Hossam et, al (2009) examined the salinity, dissolved oxygen, suspended load , organic matter and total oil and grease volume during July to November 1999 in various areas including Lyari river mouth, Korangi creek, Gizri creek, Manora channel and Karachi harbor representing the north western coastal line of Arabain sea[33]. Tahira et al(2013) using Shannon and Weaver diversity index assessed the temporal proportion of the presence of Diatoms correlating with total phytoplankton, salinity, temperature, Dissolved Oxygen, Chlorophyll, Transparency, pH in the two sampling stations of Manora channel during the year 2002 to 2003[34]. Saleem et al. (2015) used the ERICA software for the assessment and the hazard evaluation of radiological risk exposure to the marine lives including Benthic Fish, Plegic Fish and zookoplantoon[35].

In this study, we intend to examine with water quality parameters BCO_3, COD, pH, Cl, NH_3, BOD and SO_4 using PCA technique to asses seawater quality variation temporally.

This article is organized as follows: In Section 2, study area is explained, in Section 3 materials are reported, in Section 4 methods are mentioned, in Section 5 results are given and in Section 6 discussion and conclusions are described, Section 7 represent the future recommendations.

2. Study Area

The Manora channel of Karachi Sea surrounds with the Lyari River, Malir River and Creek River. All of the wastages and effluents dumped into the sea at last passing through all of these rivers. Lyari river, Malir River and creek river are enclosed by the population effluents and as well as the industrial effluents especially from the Sindh industrial trading site (S.I.T.E). Manora channel is a navigational channel composed of the two major locations: Manora harbor and Kemari fish harbor. The area of Manora channel is 7.17km^2. Manora channel linked the Arabian Sea to the Karachi port. [36,37, 38,39]

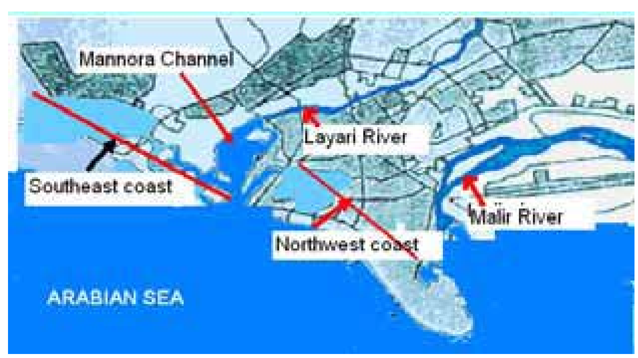

Fig. 1 MAP OF KARACHI HARBOUR

Source: Mashiatullah, A et al 2009[39]

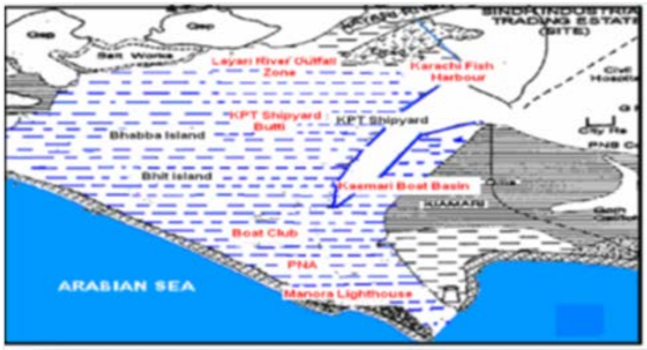

Fig. 2 VARIOUS LOCATIONS OF MANORA CHANNEL

Source: Mashiatullah, A et al 2009[39]

3. Materials

3.1 Biochemcial Oxygen Demand

BOD means biochemical oxygen demand; it is the natural degradation process of oxygen in the domestic effluents of food wastages by the bacteria and fungi. Manora channel gains BOD every day by both of the domestic and industrial wastages of the food processing industries in Karachi.[40]**BOD** is noticed with the 268.74 mg/l highest in spring season where as minimum in autumn season with the amount of 258.72 mg/l on average.

3.2 Chloride

Chloride ions are found abundant in seawater; but there are human made resources responsible for the chloride ions in the seawater also. Chloride is introduced to the water in industries in order to treat them. Consequently increases the levels of chloride in water. Rock salts also enormously increases the chloride levels in the water, these are hazardous for the seaweeds and mangroves lives in seawater[41].The deicers processes also introduce the chloride levels in the rivers and groundwater which are lastly enter to the sea[42] .chloride levels increases the salinity of the water. Chloride is found to be recorded on the highest average of 329.02482 mg/l in autumn and on the lowest average of 317.15246 mg/l in winter season.

3.3 Chemical Oxygen Demand

Oxidization of organic materials from water is required equivalent number of oxygen which is termed as chemical oxygen demand**.COD** is measured by observing the excessive oxidizing agent remains in the sample after the introduction of oxidant like permanganate or dichromate in the water when $FeSO_4$ used as a titrant[43].**COD** is noticeable with the highest mean 649.6 mg/l in spring season and lowest mean of 622.2 mg/l in autumn season.

3.4 Ammonia

Ammonia is the unionized form of a nutrient which is composed of hydrogen and nitrogen. Increased in Ammonia levels are highly toxic for the aquatic lives of fishes specially [44] .ammonia levels are toxic to photosynthetic processes as well as high salinity and high pH values introduces great ecological imbalances to the marine lives [45].When it is excreted by plants and animals, it actually introduces nitrogen in the water bodies which is a sign of increased growth of algae. The source of emission of ammonia can be sewage effluents as well as the industrial effluents of fertilizers mainly [46].**NH_3** is computed on average of 9.064mg/l at greatest in spring and 8.641 mg/l minimum in summer.

3.5 Bicarbonates

BCO_3 shows the presence of bicarbonates in the water.**BCO3** are the commonly bicarbonates of calcium, Magnesium, sodium ions[47].**BCO_3** is reported at the maximum amount of 305.37 mg/l in spring and minimum amount of 292.02 mg/l in summer.

3.6 Sulphate Ion

The sources of pollutants of **SO_4** to the sea water is sewage effluents and as well as industrial effluents. The waste water treatment also produces the sulphate ion in the water, the sulphate deteriorates the marine life and brings massive ecological disturbances [48,49]. SO_4 is found to be maximum on average in the season of winter with 141.84 mg/l and minimum on average in the season of summer with 139.29mg/l.

3.7 Potential Hydrogen

Effects of the pollutants in seawater, deteriorates the ph of seawater. **pH** is chemical property of seawater which is mainly responsible for the pure ecosystems; it effects the marine life, aquatic microorganisms, chemical reactions occurring in the sea and other balances of ecosystems. Decrease in **pH** values are termed as acidification of seawater. Decrease in pH values are observed due to the transfer of fossil fuel CO_2 [50,51].The emissions of fossil fuel CO_2 are increasing day by day. Uses of natural gas, cement production emissions and the use of gas flare which involves the consumption of gases for petroleum refineries, chemicals and processing plants of natural gas [52]. Decrease in **pH** values are hazardous for many species in the seawater like sea urchin (psammechinus miliaris), marine copepods (acrtia steueri and acartia erythraea) , lamellibranch mollusc. And bivalve Mytilus edulis [53,54,55,56]. The pH values are maximum in autumn season on average of 7.32 and minimum in summer season on average of 7.19.

4. Methods

- Monthly data is recorded for the variables **BCO_3, COD, pH, Cl, NH_3, BOD** and **SO_4** from the year January 1996 to December 2014 by following the APHA(American Public Health Association) guidelines.
- According to the climate of Karachi, data sets are divided into four seasons: Spring, Summer, Autumn and Winter [57], the descriptive statistics are reported in Table(1).
- To make dimensionless measurements before factor analysis, it is important to first standardized the parameters using Rank based inverse normal transformations[58]
- To check adequacy of PCA, KMO Test and Bartlett's Test are assessed(Table (2))
- If the KMO and Bartlett's Test allow the implication of PCA, then evaluate rotated component using Varimax rotation for parameters with four temporal datasets[59].(Table (3) to Table(6)).
- Statistical analysis is carried out by using IBM SPSS 20.0

5. Results

Chemical parameters are examined season wise, descriptive statistics of parameters are computed for every season for the years January 1996 to December 2014 as shown in table(1).

Table 1: Summary Statistics

Spring

Parameters	minimum	maximum	Mean	Standard deviation
BOD	191.88	380	268.74	59.769
COD	239.95	952.72	649.6	202.63
pH	6.34	8.32	7.25	0.4
NH_3	6.66	11.07	9.064	1.05
SO_4	99.76	186.02	141.46	27.481
BCO_3	149.7	478.26	305.37	85.134
CHILORIDE	201.46	560.23	326.86825	100.08908

Summer

Parameters	minimum	maximum	Mean	Standard deviation
BOD	191.86	360	261.8	56.225
COD	239.72	979.35	632.22	198.26
pH	6.13	8.45	7.19	0.44
NH_3	6.07	10.42	8.641	1.071
SO_4	95.09	191.14	139.29	29.053
BCO_3	151.71	474.77	292.02	78.827
CHILORIDE	198.45	561.54	319.17228	103.05494

Autumn

Parameters	minimum	maximum	Mean	Standard deviation
BOD	191.98	369.31	258.72	53.477
COD	207.7	951	622.2	196.19
pH	6.52	8.43	7.32	0.4
NH_3	6.45	10.33	8.948	0.977
SO_4	99.23	191.1	140.69	29.066
BCO_3	147.45	482.2	304.84	81.648
CHILORIDE	201.03	567.5	329.02842	102.93196

Winter

Parameters	minimum	maximum	Mean	Standard deviation
BOD	193	376	262.98	59.027
COD	207.28	981.3	643.3	203.68
NH_3	6.3	10.51	8.962	1.02
pH	6.37	8.47	7.28	0.4
SO_4	100.46	192.27	141.84	28.846
BCO_3	143.08	483.45	300.21	87.652
CHILORIDE	189.3	567.15	317.15246	96.929531

Sea water quality variations are observed season wise. For the application of principal component analysis Kaiser Mayer Measure Of Adequacy and Bartlett's test is evaluated, the results shows the adequate application of PCA on the data sets for each season: summer, spring , winter and autumn. In table (2) Kaiser Mayer Measure Of Adequacy is greater than 0.5 for all seasons and significant Bartlett's test of spherecity imply the suitability of the principal component analysis for seasonal wise approach for the contribution of variation in water quality from the selected chemical parameters.

Table 2: Kaiser Mayer Measure Of Adequacy and Bartlett's Test

Seasons	Kaiser Mayer	Measure Of Adequacy	Bartlett's Test	Conclusion
SPRING	0.626	>0.5	0.000	significant
SUMMER	0.665	>0.5	0.000	significant
AUTUMN	0.716	>0.5	0.000	significant
WINTER	0.625	>0.5	0.000	significant

5.1 Spring Season Analysis

Spring seasons variation is split into two components by PCA as shown in table(3). Component1 explains the variance by 33.104% with high factor loadings of **BOD** and **COD**. Component1 is due to the nutrient effluent as the BOD is the amount of oxygen demand in degradation processes of food wastages of both domestic and industrial food wastages by bacteria and fungi. Similarly COD describes the oxidization of organic material from water required equivalent number of oxygen. So both COD and BOD imbalances, disturbs the level of oxygen in the water ecosystem which is very harmful for marine lives.Componnet2 explains the 23.056 % with high loadings of **Cl** and **SO_4**.component 2 shows the increased influence of the treated waste water entrance in the sea as chloride ions and sulphate ions are used and the byproduct of waste water treatment respectively, mainly describes sewage and industrial effluents.

Table 3: Varimax factors for spring season analysis

PARAMETERS	Varimax factor1	Varimax factor2
BOD	0.826	
COD	0.815	
PH	0.680	
NH_3	0.666	
SO_4		0.879
BCO_3	0.204	0.528
CHILORIDE	0.152	0.766
% of variance explained	**33.104**	**26.056**

5.2 Summer Season Analysis

Summer season shows the three Varimax components as shown in table (4), contributing 28.431% of total variance described by the component 1 with the high factor loadings of **BOD** and COD. It shows the effect of nutrient effluents on seawater quality. 23.215% of total variance described by the component 2 with high factor loadings of **pH** and **NH3**. It majorly explains the agricultural and industrial effluents. 21.765% of total variance explained by the component3 with high factor loadings of **Cl** and **SO_4**. It describes the industrial and sewage effluents and treatment of waste water.

Table 4: Varimax factors for summer season analysis

PARAMETERS	Varimax factor1	Varimax factor2	Varimax factor3
BOD	0.919	0.163	0.123
COD	0.924	0.156	0.156
PH	0.337	0.746	-2.11
NH_3	-0.31	0.748	0.132
SO_4	-0.23	0.224	0.825
BCO_3	0.271	0.632	0.388
CHILORIDE	0.321	-.097	0.769
% of variance explained	**28.431**	**23.215**	**21.765**

5.3 Autumn Season Analysis

Analyzing the autumn season's factors contributing toward maximum variance explained, it splits the data sets into two components as shown in table(5). Component1 with high factor loadings of **BOD, COD and pH.** It described the 37.133% of total variance. Component 1 explains clearly nutrient and industrial effluent impacts on seawater quality variations and changes in level of pH. Decreased or increased oxygen levels due to BOD and COD and pH levels imbalances are the major factors which destroy the water quality. Component 2 describes the 23.754% of the total variance explained with high factor loadings of **Cl** and **SO_4**.treament of wastewater and other impacts of sewage and industrial waste shows the variation in water quality explained by component 2.

Table 5: Varimax factors for Autumn season analysis

PARAMETERS	Varimax factor1	Varimax factor2
BOD	0.806	0.268
COD	0.751	0.278
PH	0.733	-1.44
NH_3	0.596	.299
SO_4		0.798
BCO_3	0.650	0.353
CHILORIDE	0.252	0.802
% of variance explained	**37.133**	**23.754**

5.4 Winter Season Analysis

Varimax rotation divided the factors into three components for winter season as shown in table(6). Maximum variance is described by the factors **BOD** and **COD** with 28.419 % of variance explained that is it describes the nutrient effluents. Component 2 explains the 23.402% of the variance described by the **pH** and **NH_3** shows impacts of agricultural effluents and the component 3 explains 14.688% of the variance described by **SO_4** shows the waste water treatment and industrial effluents.

Table 6: Varimax factors for winter season analysis

PARAMETERS	Varimax factor1	Varimax factor2	Varimax factor3
BOD	0.914	0.226	
COD	0.873	0.311	0.114
PH	0.210	0.865	
NH3	0.128	0.721	0.199
SO4			0.915
BCO3	0.233	0.412	0.582
CHILORIDE	0.525	-0.216	0.568
% of variance explained	**28.419**	**23.402**	**14.688**

6. Conclusion

Seasonal analysis of seawater quality parameters are described with high factor loadings and Varimax factors in table 7.

Table 7: seasonal Varimax factors analysis of parameters

parameters	**Effluent sources**	**High factor loadings Seasons**	**Component number**
BOD	**Nutrient effluent**	**Spring, summer, winter, autumn**	**varifactor1**
COD	**Nutrient effluent**	**Spring, summer, winter, autumn**	**varifactor1**
NH_3	**Agricultural effluent**	**Spring , summer, winter**	**varifactor1 in spring , varifactor2 in winter and summer**
pH	**Industrial effluent**	**Spring ,summer, winter, autumn**	**Varifactor1 in spring and autumn. Varifactors 2 in winter and summer**
CL	**Industrial effluent**	**Spring, summer, winter**	**Varifactors 2 in spring and autumn, varifactors 3 in summer.**
SO_4	**Industrial effluent**	**Spring, summer, winter, autumn**	**Varifactors 2 in spring and summer , varifactors 3 in winter and autumn**

The **BOD** and **COD** are found to be the greatest responsible factors which contribute to the maximum of total variance among all four seasons, highlighting the high factor loadings at the principal component factor 1 among all four seasons. It indicates that among all four seasons the nutrient waste factor dominates. pH shows dominant loadings in all four season but at different varifactors. It shows the pH levels disturbances due to industrial effluents of cement production, petroleum refineries, chemical and processing plants of natural gas.NH3 shows high loadings in spring, summer and winter season because of excessive introduction of nitrogen to the water body by biological excretion and fertilizer making industries. Cl and SO4 shows high factor loadings in spring, summer &winter, and only SO4 in autumn defining the waste water treatment. Increasing Cl to the seawater increase salinity of water.BCO3 does not shows any high factor loadings in all four seasons, so the water quality does not effected by bicarbonates of calcium, magnesium and sodium .overall, nutrient effluents, industrial effluents and agricultural run-off deteriorates the water quality.

7. Future Work

Further this work can be proceeded with the extraction of principal components(PCs) from Principal Component Analysis and using these PCs for the prediction of water quality parameters by using Neural Network techniques.

References

[1] Abdullah, Mohd Harun, Ramzah Dambul, Maryati Mohamed, and Sahana Harun. (2014) Spatial and seasonal variations in surface water quality of the Lower Kinabatangan River Catchment, Sabah, Malaysia. Journal of Tropical Biology and Conservation 11: 117-131.

[2] Arora, Neetu, Amarpreet Singh Arora, Siddhartha Sharma, and Akepati S. Reddy. (2014).Use of Cluster Analysis-A Data mining tool for improved water quality monitoring of River Satluj. International Journal of Advanced Networking & Applications 63-68.

[3] Damotharan, P., N. Vengadesh Perumal, M. Arumugam, S. Vijayalakshmi, and T. Balasubramanian. (2010) Seasonal variation of physicochemical characteristics in point calimere coastal waters south east coast of India. Middle-East J. Sci. Res 6(4): 333-339.

[4] Fatema, Kaniz, WO Wan Maznah, and Mansor Mat Isa. (2014) Spatial and Temporal Variation of Physico-chemical Parameters in the Merbok Estuary, Kedah, Malaysia. Tropical life sciences research 25(2): 1.

[5] Ouyang, Y., P. Nkedi-Kizza, Q. T. Wu, D. Shinde, and C. H. Huang. (2006) Assessment of seasonal variations in surface water quality. Water research 40(20) : 3800-3810.

[6] Razmkhah, H., Abrishamchi, A., & Torkian, A. (2010). 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(4), 852-860.

[7] Hai, X. U., Lin-Zhang, Y. A. N. G., Geng-Mao, Z. H. A. O., Jia-Guo, J. I. A. O., Shi-Xue, Y. I. N., & Zhao-Pu, L. I. U. (2009). Anthropogenic impact on surface water quality in Taihu Lake region, China. Pedosphere, 19(6), 765-778.

[8] Simeonov, V., Stratis, J. A., Samara, C., Zachariadis, G., Voutsa, D., Anthemidis, A., ... & Kouimtzis, T. (2003). Assessment of the surface water quality in Northern Greece. Water research, 37(17), 4119-4124

[9] Panigrahi, S., Wikner, J., Panigrahy, R. C., Satapathy, K. K., & Acharya, B. C. (2009). Variability of nutrients and phytoplankton biomass in a shallow brackish water ecosystem (Chilika Lagoon, India). Limnology, 10(2), 73-85.

[10] Qadir, A., Malik, R. N., & Husain, S. Z. (2008). Spatio-temporal variations in water quality of Nullah Aik-tributary of the river Chenab, Pakistan. Environmental Monitoring and Assessment, 140(1-3), 43-59.

[11] Tariq, S. R., Shah, M. H., Shaheen, N., Khalique, A., Manzoor, S., & Jaffar, M. (2006). Multivariate analysis of trace metal levels in tannery effluents in relation to soil and water: A case study from Peshawar, Pakistan. Journal of Environmental Management, 79(1), 20-29.

[12] Wang, Y., Wang, P., Bai, Y., Tian, Z., Li, J., Shao, X., ... & Li, B. L. (2013). Assessment of surface water quality via multivariate statistical techniques: a case study of the Songhua River Harbin region, China. Journal of hydro-environment research, 7(1), 30-40

[13] Alkarkhi, Abbas FM, Anees Ahmad, Norli Ismail, Azhar mat Easa, and Khalid Omar. (2009) Assessment of surface water through multivariate analysis. Journal of sustainable development 1(3):27.

[14] González, Soledad Oliva, César A. Almeida, Sylvia Quintar, Miguel A. Mallea, and Patricia S. González. (2011) Application of multivariate statistical techniques to evaluate organic pollution on a river in Argentina. Ambiente e Agua-An Interdisciplinary Journal of Applied Science 6(3): 27-42.

[15] Jiang-Qi, Qu, Zhang Qing-Jing, Liu Pan, Jia Cheng-Xia, and Yang Mu. (2013) Assessment of water quality using multivariate statistical methods: A case study of an Urban Landscape Water, Beijing. International Journal of Bioscience, Biochemistry and Bioinformatics 3(3):196.

[16] Liou, S. M., Lo, S. L., & Wang, S. H. (2004). A generalized water quality index for Taiwan. Environmental Monitoring and Assessment, 96(1-3), 35-52.

[17] Chenini, I., & Khemiri, S. (2009). Evaluation of ground water quality using multiple linear regression and structural equation modeling. International Journal of Environmental Science & Technology, 6(3), 509-519.

[18] Han, S., Kim, E., & Kim, S. (2009). The water quality management in the Nakdong River watershed using multivariate statistical techniques. KSCE Journal of Civil Engineering, 13(2), 97-105.

[19] Zhang, Q., Li, Z., Zeng, G., Li, J., Fang, Y., Yuan, Q., ... & Ye, F. (2009). Assessment of surface water quality using multivariate statistical techniques in red soil hilly region: a case study of Xiangjiang watershed, China. Environmental monitoring and assessment, 152(1-4), 123.

[20] Sheldon, Fran, and Christine S. Fellows. (2010) Water quality in two Australian dryland rivers: spatial and temporal variability and the role of flow. Marine and Freshwater Research 61(8): 864-874.

[21] Alberto, W. D., del Pilar, D. M., Valeria, A. M., Fabiana, P. S., Cecilia, H. A., & de los Ángeles, B. M. (2001). Pattern Recognition Techniques for the Evaluation of Spatial and Temporal Variations in Water Quality. A Case Study::

Suquía River Basin (Córdoba–Argentina). Water research, 35(12), 2881-2894.
[22] Li, Y., Xu, L., & Li, S. (2009). Water quality analysis of the Songhua River Basin using multivariate techniques. Journal of water resource and protection, 1(2), 110.
[23] Finkler, Nícolas Reinaldo, Taison Anderson Bortolin, Jardel Cocconi, Ludmilson Abritta Mendes, and Vania Elisabete Schneider. (2016) Spatial and temporal assessment of water quality data using multivariate statistical techniques. Ciência e Natura 38(2):577
[24] Nasir, M. F. M., Samsudin, M. S., Mohamad, I., Awaluddin, M. R. A., Mansor, M. A., Juahir, H., & Ramli, N. (2011). River water quality modeling using combined principle component analysis (PCA) and multiple linear regressions (MLR): a case study at Klang River, Malaysia. World Applied Sciences Journal, 14, 73-82.
[25] Mahmud, R., Inoue, N., & Sen, R. A. N. J. I. T. (2007). Assessment of irrigation water quality by using principal component analysis in an arsenic affected area of Bangladesh. J Soil Nat, 1(2), 8-17.
[26] Oketola, A. A., Adekolurejo, S. M., & Osibanjo, O. (2013). Water quality assessment of River Ogun using multivariate statistical techniques. Journal of Environmental protection, 4(05), 466.
[27] Alberto, W. D., del Pilar, D. M., Valeria, A. M., Fabiana, P. S., Cecilia, H. A., & de los Ángeles, B. M. (2001). Pattern Recognition Techniques for the Evaluation of Spatial and Temporal Variations in Water Quality. A Case Study:: Suquía River Basin (Córdoba–Argentina). Water research, 35(12), 2881-2894.
[28] Wang, X., Cai, Q., Ye, L., & Qu, X. (2012). Evaluation of spatial and temporal variation in stream water quality by multivariate statistical techniques: A case study of the Xiangxi River basin, China. Quaternary International, 282, 137-144.
[29] Beg, M. A. A., Mahmood, S. N., & Yousufzai, A. H. K. (1992). Heavy metals pollution in the coastal environment of Karachi. Pakistan Journal of Marine Sciences, 1(2), 117-126.
[30] Beg, M. A. A. (1995). Ecological imbalances in the coastal areas of Pakistan and Karachi Harbour. Pakistan Journal of Marine Sciences, 4(2), 159-174.
[31] Qureshi, R. M., Mashiatullah, A., Fazil, M., Ahmad, E., Khan, H. A., & Sajjad, M. I. (2002). Seawater pollution studies of the Pakistan coast using stable carbon isotope technique. Science Vision, 7(3-4), 224-229.
[32] Mashiatullah, A., Qureshi, R. M., Ahmad, N., Khalid, F., & Javed, T. (2009). Physico-chemical and biological water quality of Karachi coastal water. The Nucleus, 46(1-2), 53-59.
[33] Zaqoot, H. A., Khan, S. H., Ansari, A. K., & Qureshi, K. (2009). Assessment of water quality in the coastal environment of Karachi bordering northern Arabian Sea. Journal of Flood Engineering, 1(1), 5-19.
[34] Naz, T., Burhan, Z., Munir, S. O. N. I. A., & Siddiqui, P. J. A. (2013). Seasonal abundance of diatoms in correlation with the physico-chemical parameters from coastal waters of Pakistan. Pak. J. Bot, 45(4), 1477-1486
[35] Saleem, S., Mashiatullah, A., Asma, M., Yaqoob, N., & Khan, M. S. (2015). Radiological Risk Assessment to Marine Biota Along Manora Channel Karachi Coast Pakistan. Iranica Journal of Energy and Environment, 6(3), 212-216.
[36] Akhtar, W., Ali, I., Zaidi, S.S.H. and Jilani, S., (1997) The state of pollution levels of Karachi Harbour and adjoining coastal water. Water Air Soil Poll. 94(1-2):99-107.
[37] Beg, M.A.A. Ecological imbalances in the coastal areas of Pakistan and Karachi Harbour. (1995) Pakistan Journal of Marine Sciences 4(2):159-174.
[38] Mashiatullah, A., Javed, T., Chaudhary, M.Z., Fazil, M. and Qureshi, R.M. (2010) Stable carbon isotope ratio (δ13 c) of shallow marine bottom sediment as evidence of pollution in manora channel, karachi, pakistan. Nucleus, 47(3):233-238
[39] Mashiatullah, A., Qureshi, R.M., Ahmad, N., Khalid, F. and Javed, T. (2009) Physico-chemical and biological water quality of Karachi coastal water. Nucleus, 46(1-2):53-59
[40] Gerlach, S.A., Domestic Effluents, in Marine Pollution. (1981), Springer. p. 6-36.
[41] Aziz, Irfan, and M. Ajmal Khan. (2001) Experimental assessment of salinity tolerance of Ceriops tagal seedlings and saplings from the Indus delta, Pakistan. Aquatic Botany 70(3): 259-268.
[42] Ramakrishna, Devikarani M., and Thiruvenkatachari Viraraghavan. (2005) Environmental impact of chemical deicers–a review. Water, Air, and Soil Pollution 166(1-4): 49-63.
[43] Latif, Usman, and Franz L. Dickert. (2015) Chemical Oxygen Demand In Environmental Analysis by Electrochemical Sensors and Biosensors, Springer New York pp. 719-728.
[44] Fivelstad, Sveinung, Jannie Schwarz, Hildegunn Strømsnes, and Anne Berit Olsen. (1995) Sublethal effects and safe levels of ammonia in seawater for Atlantic salmon postsmolts (Salmo salar L.). Aquacultural Engineering 14(3): 271-280.
[45] Bower, Carol E., and Joseph P. Bidwell. (1978) Ionization of ammonia in seawater: effects of temperature, pH, and salinity. Journal of the Fisheries Board of Canada 35(7): 1012-1016.
[46] Knoph, M. B., and K. Thorud. (1996) Toxicity of ammonia to Atlantic salmon (Salmo salar L.) in seawater—Effects on plasma osmolality, ion, ammonia, urea and glucose levels and hematologic parameters. Comparative Biochemistry and Physiology Part A: Physiology 113(4): 375-381.
[47] Nyende J, van Tonder G, Vermeulen D (2014). Hydrochemical Characteristics of Ground and Surface water under the influence of Climate variability in Pallisa District, eastern Uganda. Int. J. Environ. Sci. Toxic. Res. Vol. 2(4):90-107
[48] Silva, A. J., M. B. Varesche, E. Foresti, and M. Zaiat. (2002) Sulphate removal from industrial wastewater using a packed-bed anaerobic reactor. Process Biochemistry 37(9): 927-935.
[49] Geurts, Jeroen JM, Judith M. Sarneel, Bart JC Willers, Jan GM Roelofs, Jos TA Verhoeven, and Leon PM Lamers. (2009) Interacting effects of sulphate pollution, sulphide toxicity and eutrophication on vegetation development in fens: a mesocosm experiment. Environmental Pollution 157(7):2072-2081.
[50] Marion, G. M., F. J. Millero, M. F. Camões, P. Spitzer, R. Feistel, and C-TA Chen. (2011) pH of seawater. Marine Chemistry 126(1): 89-96.
[51] Knutzen, Jon. (1981) Effects of decreased pH on marine organisms. Marine Pollution Bulletin 12(1): 25-29.
[52] Marland, Gregg, Tom A. Boden, Robert J. Andres, A. L. Brenkert, and C. A. Johnston. (2003) Global, regional, and

national fossil fuel CO2 emissions. Trends: A compendium of data on global change 34-43.

[53] Bamber, R. N. "The effects of acidic seawater on three species of lamellibranch mollusc. (1990) Journal of Experimental Marine Biology and Ecology 143(3): 181-191.

[54] Berge, John Arthur, Birger Bjerkeng, Oddbjørn Pettersen, Morten T. Schaanning, and Sigurd Øxnevad. (2006) Effects of increased sea water concentrations of CO 2 on growth of the bivalve Mytilus edulis L. Chemosphere 62(4): 681-687

[55] Kurihara, Haruko, Shinji Shimode, and Yoshihisa Shirayama. (2004) Effects of raised CO 2 concentration on the egg production rate and early development of two marine copepods (Acartia steueri and Acartia erythraea). Marine Pollution Bulletin 49(9): 721-727.

[56] Kurihara, H., and Y. Shirayama. (2004) Effects of increased atmospheric CO2 on sea urchin early development. Marine Ecology Progress Series 274 :161-169.

[57] Nergis, Yasmin, Mughal Sharif, Afzal Farooq Choudhry, Ahmed Hussain, and Jawad Abdullah Butt. (2012) Impact of industrial and sewage effluents on Karachi coastal water and sediment quality. Middle-East Journal of Scientific Research 11(10):1443-1454.

[58] Solomon, Shira R., and Shlomo S. Sawilowsky. (2009) Impact of rank-based normalizing transformations on the accuracy of test scores. Journal of Modern Applied Statistical Methods, 8(2):448 – 462

[59] Rizvi N, Katyal D, Joshi V. (2015) A Multivariate Statistical Approach for Water Quality Assessment of River Hindon, India. World Academy of Science, Engineering and Technology, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering. 1; 10(1):6-11.