http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS
Pakistan Journal of Biological Sciences
ISSN 1028-8880
DOI: 10.3923/pjbs.2022.776.780

Research Article
Assessment of Water Quality Index in Anzali Lagoon using Multivariate Analysis

Mehrnoush Aminisarteshnizi

Aquaculture Research Unit, School of Agricultural and Environmental Sciences, University of Limpopo, Turfloop Campus, Private Bag X1106, Sovenga 0727, South Africa

Abstract

Background and Objective: Water quality in freshwater bodies is involved with multiple aspects such as physical, chemical and biological processes and their interactions. Due to the vulnerability of water resources, quality control of surface water is one of the key issues in environmental conservation programs. The objectives of the present work were to study the water quality in the Anzali Lagoon and to study the classification of water based on the water quality index in different parts of the Anzali Lagoon. **Materials and Methods:** In this study, we sampled water from January to December, 2015 in the Anzali Lagoon. All physicochemical parameters were sampled and determined according to standard methods. **Results:** The Water Quality Index results showed the Anzali Lagoon water quality had been "medium" in site 1 and "bad" in sites 2, 3 and 4. The result showed a significant difference between sit 1 and sites 2, 3 and 4 ($p<0.05$). However, there was no significant difference between sit 2, 3 and 4 ($p>0.05$). The result showed a clear spatial separation among parts in the Anzali Lagoon. The Eastern part of the Anzali Lagoon showed lower water quality compared to the central and western stations. **Conclusion:** This study showed that the level of pollution was different on all of the Anzali Lagoons. The water of the Anzali Lagoon has different quality classes according to the aggregation methods employed. Nutrient loadings from the adjacent agricultural lands combined with high mean salinity values affect all organism conditions. The three primary sources of nutrients, including fertilizers used in agriculture, household waste and livestock waste, reduced the water quality of the Anzali Lagoon.

Key words: Water quality index, PCA analysis, physicochemical factors, Anzali Lagoon, pollution, sediments, dendrogram analysis

Citation: Aminisarteshnizi, M., 2022. Assessment of water quality index in Anzali Lagoon using multivariate analysis. Pak. J. Biol. Sci., 25: 776-780.

Corresponding Author: Mehrnoush Aminisarteshnizi, Aquaculture Research Unit, School of Agricultural and Environmental Sciences, University of Limpopo, Turfloop Campus, Private Bag X1106, Sovenga 0727, South Africa

Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The Anzali Lagoon is located on the Southern Coast of the Caspian Sea in the Guilan Province. Nineteen rivers enter the Anzali Lagoon and it is connected to the Caspian Sea from two parts[1]. These rivers pass through forests, urban and rural areas and because of that, the rivers carry a variety of organic, mineral, sedimentary materials, domestic, industrial and agricultural effluents. Water quality has drastically deteriorated due to the constant disposal of industrial, agricultural and domestic waste into the rivers, the rivers affect Anzali Lagoon ecosystems[2]. Anzali Lagoon is a significant breeding and wintering ground for numerous species of water birds and extensive reed beds, making it vital for the spawning and nursery of the Caspian fish. Then, Anzali Lagoon was considered as urgently needing conservation plans in the Montreux Record. Deteriorating water quality in the Anzali Lagoon is the effect of urbanization, agricultural drainage and sediment influx[3]. The Anzali Lagoon includes four basins, namely (1) Western, (2) Eastern, (3) Central and (4) South-West. The mentioned basins are distinguished by having different physicochemical, ecological and geographical parameters and represent diverse ecosystems[1].

Water quality in freshwater bodies is involved with multiple aspects such as physical, chemical and biological processes and their interactions[4]. Water quality indices are being developed and used worldwide due to their simplicity, adaptability and easy-to-use nature. Due to the vulnerability of water resources, quality control of surface water is one of the key issues in environmental conservation programs[5]. In recent years, the Anzali Lagoon has been exposed to numerous threats, including environmental pollutants[4]. The Water Quality Index (WQI) popularity comes from its pragmatic structure. Water plays a significant role in maintaining ecosystem health. A survey of water physicochemical factors helps to understand the ecosystem's health and all organisms living in it[5]. Understanding the Anzali Lagoon ecosystem's health is useful not only helps aquatic communities but also to all terrestrial animals, including human communities living in the area. Physicochemical factors of water such as water temperature (°C), dissolved oxygen and pH Biochemical Oxygen Demand (BOD_5), chemical oxygen demand (COD), total dissolved solids (TDS), total PO_4, NH_4, faecal coliform bacteria and turbidity show us water health rate[6].

Analyzing the water quality index helps understand the ecosystem's health system in the Anzali Lagoon. Therefore, the Anzali Lagoon ecosystem health benefits aquatic communities and terrestrial animals. Besides, human communities living in the area will be benefited. Additionally, understanding the water quality situation in the Anzali Lagoon is very significant for water management. This study aims were (1) To investigate the water quality index in different parts of the Anzali Lagoon and (2) Division of different parts of the lagoon based on the water quality index.

MATERIALS AND METHODS

Study area: In this study, three localities were used, namely site 1 (GPS coordinates: 37°47'026.42"N and 49°34' 307.12"E) and site 2 (GPS coordinates: 37°41'2998.45"N and 49°41' 6902.1"E), site 3 (GPS coordinates: 37°44'2998.45"N and 49°44' 6902.1"E and site 4 (GPS coordinates: 49°23' 9446.43"N and 37°25' 9944.18"E). The study was carried out at fish biology laboratory Anzali, Iran, from January to December, 2015.

Determination of physiochemical parameters: The samples were collected three times per month for 12 months. The water samples were stored and refrigerated at 4°C for later laboratory analysis. Carried out all the sampling trips were between 8:00 am and 12:00 noon, local time. All physicochemical parameters were sampled and determined according to standard methods. The water temperature (°C), dissolved oxygen and pH were measured *in situ*, using the calibrated multi-parameter meter (Multiprobe, Hach HQ40d). The water samples were collected using Nalgene bottles (1000 mL). The other parameters like Biochemical Oxygen Demand (BOD_5), chemical oxygen demand (COD), total dissolved solids (TDS), total PO_4, NH_4, faecal coliform bacteria and turbidity were analyzed in the laboratory as per the standard procedure of APHA[7].

Water Quality Indices (NSFWQI): In this study, for the calculation of the water quality index, we used the NSFWQI, an internationally recognized WQI. Values were obtained by multiplying the respective weight factor by an appropriate quality value for each water quality variable[8]. This WQI consists of nine water quality variables listed in Table 1[9]. The water quality variables' respective values to obtain a general index

Table 1: Weights of parameters in NSFWQI index

Parameters	Weight
Dissolved oxygen	0.17
Fecal coliform bacteria	0.16
Biochemical oxygen demand	0.11
pH	0.11
Temperature change	0.10
Phosphates	0.10
Nitrates	0.10
Turbidity	0.08
Total solids	0.07

ranging from 0 to 100. According to this calculated index, the water quality is then assigned to one of five possible categories (Table 2)[10]:

$$NSFWQI = \Sigma W_i I_i$$

WQI is the Water Quality Index, I_i is sub-index I and W_i is the weight given to sub-index I. Finally, after calculating water quality indices, the water quality of the Anzali Lagoon was compared based on four Anzali Lagoon sites.

Statistical methods: Data were tested for normal distribution using the Shapiro-Wilk test for normality before applying the parametric tests. To detect the site's effects on Physico-chemical variables, the General Linear Model (GLM) under ANOVA was applied[11]. A pairwise comparison based on the Tukey's method was used[12].

Principal component analysis (PCA) was performed utilizing a two-way table of water quality index[13] and sites. During this analysis, principal components (PCs) with eigenvalues greater than one were retained as those explaining the highest total water quality variability. Biplots for the first two components were constructed out of the resulting scores and loadings to provide an overall view of the multivariable relations within months[14]. These multivariate ordination analysis were carried out with XLSTAT2020 software.

RESULTS

Water quality index: The values of NSFWQI are presented in Table 3. According to the classification shown in Table 2, the Anzali Lagoon water quality had been "medium water quality" in site 1 and "bad water quality" in sites 2, 3 and 4. The result showed a significant difference between sit 1 and sites 2, 3 and 4 ($p<0.05$). However, there was no significant difference between sit 2, 3 and 4 ($p>0.05$).

PCA and dendrogram analysis: Principal component analysis's performance between sites and Water Quality Index (WQI) results indicate that our set of variables explained 99.64% of the variability with the first two axes (Fig. 1). The

Table 2: National Sanitation Foundation Water Quality Index (NSFWQI)

Water quality index value	Rating of water quality
91-100	Excellent water quality
71-90	Good water quality
51-70	Medium water quality
26-50	Bad water quality
0-25	Very bad water quality

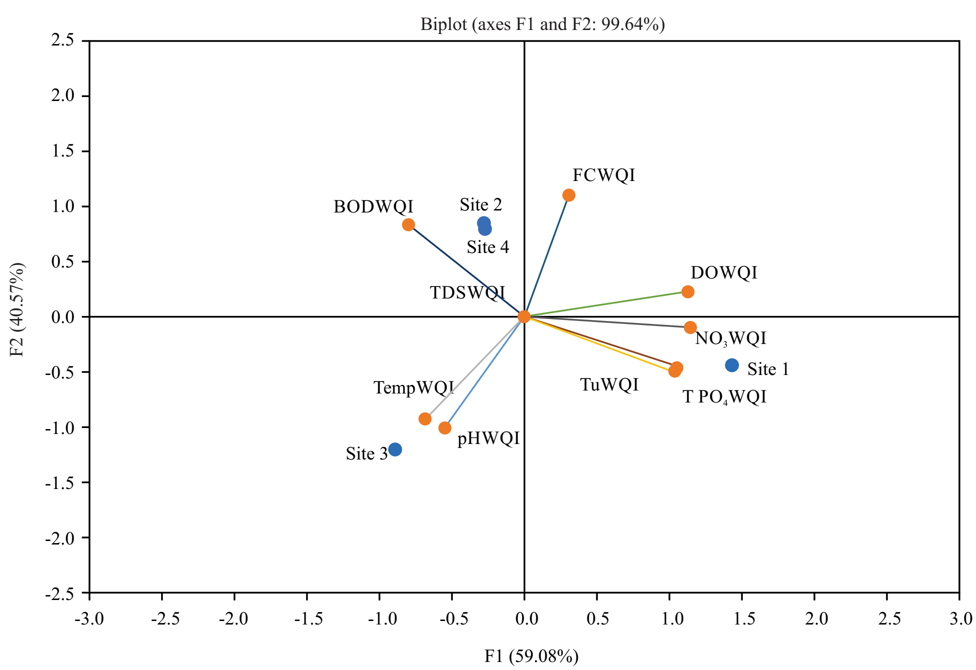

Fig. 1: Diagram of the principal components analysis results based on water quality indices, sampled in 4 sites

TempWQI: Water temperature quality index, DOWQI: Dissolved oxygen water quality index, TuWQI: Turbidity water quality index, BODWQI: Biochemical oxygen demand water quality index, T PO_4WQI: Total phosphate water quality index, TDSWQI: Total dissolved solids water quality index, NO_3WQI: Nitrate water quality index, pHWQI: pH water quality index and FCWQI: Fecal coliform water quality index

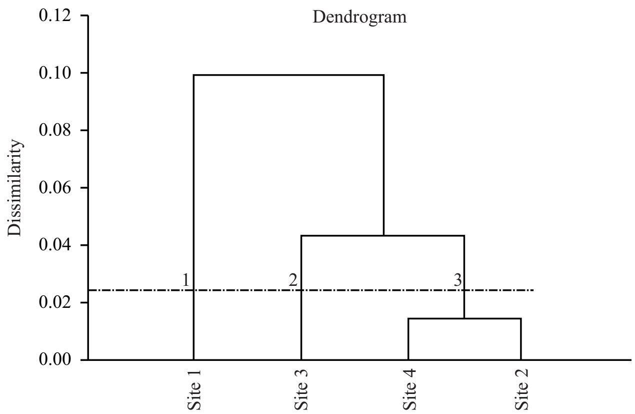

Fig. 2: Cluster analysis of sampling sites based on water quality indices (mean values) during the study period

Table 3: Comparison of environmental parameters and the mean value of water quality indices (Mean±SE)

Water quality indices	Site 1	Site 2	Site 3	Site 4
Fecal coliform (MPN/100 mL)	42±3	50±6	30±3	47±4
Turbidity (F.T.U)	86±8	48±5	54±6	48±5
Temperature (°C)	22±2	22±0.8	24±0.9	22±.9
pH	68±4	67±2	77±3	66±2
Dissolved oxygen (ppm)	90±7	66±1.5	50±1.5	67±3
Biochemical oxygen demand$_5$ (ppm)	51±2	55±4	53±1.1	55±1.2
Total phosphate (ppm)	97±9	31±1.9	40±3	34±1.1
Nitrates (ppm)	97±8	65±4	56±2	63±4
TDS (mg L^{-1})	20±1	20±1	20±0.9	20±0.8
NSFWQI	65±2[a]	50±2[b]	45±1[b]	49±3[b]

[a]Mean superscripted letter showed a significant difference between site 1 and sites 2, 3 and 4 ($p<0.05$) and [b]Mean superscripted letter there was no significant difference between site 2, 3 and 4 ($p>0.05$)

first principal component (F1) explains 59.08% of the total variance. F1 was positively correlated to DO (0.98), total PO_4 (0.91), NO_3 (0.99). The second principal component, F2, explains 40.57% of the variance (Fig. 1). The F2 was positively correlated to fecal coliform (0.95) and BOD (0.72) and negatively correlated with water temperature (-0.8) and pH (-0.87). The results for the water quality index show a clear spatial separation among sites. Site 2 and 4 were similar together but site 1 and 3 was separated (Fig. 1). According to Fig. 2, three statistically significant clusters are formed: Cluster 1 corresponds to site 1 in the lagoon's western part. Cluster 2 corresponds to site 3 in the eastern of the lagoon. Cluster 3 consisted of sites 2 and 4, located in the Central and Southwest of the Anzali Lagoon.

DISCUSSION

The results showed DO and BOD_5 were high in site 1, that was shown the situation of site 1 was much better than the other sites. Site 1 was more depth, giving suspended matter more time to settle, resulting in higher turbidity. However, we had higher TDS in site 1. It can be due to saline water's entry from the Caspian Sea to the western part (site 1) of Anzali Lagoon[4].

High levels of total dissolved solids (TDS) were observed in all four sites. It showed that plant communities' deaths, including phytoplankton communities, due to the Azolla, plant and animal communities in water were high[15] and because of that, the BOD_5 was so high. The other reason for the high TDS level was industrial activities and land clearance in the forested area[16]. During past decades, the sedimentation surveys in the Anzali Lagoon showed significant increases (implying mounting erosion in the watershed). The erosion was partly responsible for the higher level of TDS in all sites too[17].

A complete quality assessment of the lagoons does not exist and different indicators provide different information. Nevertheless, the Water Quality Index (WQI) has proved to be easily applicable and can provide consistent water quality assessments[18]. Additionally, the general approach of WQI allows the comparison among lagoons belonging to the same or different typological classifications[19]. In this study, the Anzali Lagoon had low water quality in all 4 sites but in the western part of the Anzali Lagoon (site 1), water quality showed a better situation. Pollution at the eastern part (site 3) was worse than at any other parts. The situation in sites 2 and 4 were almost similar. Fallah and Zamani-Ahmadmahmoodi[2] conducted similar studies on the Anzali Lagoon. Their results showed that the lagoon's water quality could be classified into the "medium" and "bad" classes. Studies by the Japan International Cooperation Agency showed that the lagoon's condition was critical[4]. The main reason was domestic sewage, adjacent residential areas, food industry effluents and livestock entering to Anzali Lagoon without treatment.

Because of land-use change around the Anzali Lagoon, organic and inorganic materials enter the lagoon, which is one of the most important reasons for reducing the water quality of the Anzali Lagoon and intensifying the process of nutrition. Nutrient loadings from the adjacent agricultural lands (especially nitrates and ammonium) combined with high mean salinity values affect all organism conditions of the Anzali Lagoon. The three primary sources of nutrients, including fertilizers used in agriculture, household waste and livestock waste, reduced the water quality of the Anzali Lagoon.

CONCLUSION

This study showed that the level of pollution was different on all the Anzali Lagoons. Considering the results of the measured water quality index results, agriculture and urban land use were the most contributing factors to the pollution of sites 2, 3 and 4. However, the western part (site 1) of the Anzali Lagoon was in a better situation because the western part was more affected by the Caspian Sea but eastern and central parts (sites 2, 3 and 4) were more effect by rivers. Industrial activities should also be closely monitored to reduce their possible impact on the level of heavy metal pollution.

SIGNIFICANCE STATEMENT

This study discovered the water quality in the Anzali Lagoon that can be beneficial for aquatic ecology and management. In addition, this study will help the researchers uncover the critical areas of pollution and the good or bad quality of water in the Anzali Lagoon that many researchers could not explore.

ACKNOWLEDGMENT

The author thanks the University of Limpopo, South Africa.

REFERENCES

1. Aminisarteshnizi, M., 2021. Length-weight relationship and Fulton's condition factor of *Macrobrachium nipponense* (De Haan, 1849) in Siah Darvishan River, Iran. Egypt. J. Aquat. Biol. Fish., 25: 551-560.
2. Fallah, M. and R. Zamani-Ahmadmahmoodi, 2017. Assessment of water quality in Iran's Anzali Wetland, using qualitative indices from 1985, 2007 and 2014. Wetlands Ecol. Manage., 25: 597-605.
3. Yancheshmeh, R.A., A.R. Bakhtiari, S. Mortazavi and M. Savabieasfahani, 2014. Sediment PAH: Contrasting levels in the Caspian Sea and Anzali Wetland. Mar. Pollut. Bull., 84: 391-400.
4. Fallah, M., A.R.P. Zefrehei and S.A.A. Hedayati, 2018. Evaluation of water quality of the Anzali international wetland using TOPSIS method. Iran. J. Health Environ., 11: 225-236.
5. Kannel, P.R., S. Lee, Y.S. Lee, S.R. Kanel and S.P. Khan, 2007. Application of water quality indices and dissolved oxygen as indicators for river water classification and urban impact assessment. Environ. Monit. Assess., 132: 93-110.
6. dos Santos Simões, F., A.B. Moreira, M.C. Bisinoti, S.M.N. Gimenez and M.J.S. Yabe, 2008. Water quality index as a simple indicator of aquaculture effects on aquatic bodies. Ecol. Indic., 8: 476-484.
7. Young, J.C., L.S. Clesceri and S.M. Kamhawy, 2005. Changes in the biochemical oxygen demand procedure in the 21st edition of standard methods for the examination of water and wastewater. Water Environ. Res., 77: 404-410.
8. Oliver, S., J. Corburn and H. Ribeiro, 2019. Challenges regarding water quality of eutrophic reservoirs in urban landscapes: A mapping literature review. Int. J. Environ. Res. Public Health, Vol. 16. 10.3390/ijerph16010040.
9. Tyagi, S., B. Sharma, P. Singh and R. Dobhal, 2013. Water quality assessment in terms of water quality index. Am. J. Water Resour., 1: 34-38.
10. Uddin, M.G., S. Nash and A.I. Olbert, 2021. A review of water quality index models and their use for assessing surface water quality. Ecol. Indic., Vol. 122. 10.1016/j.ecolind.2020.107218.
11. Elias, J.D., 2021. Effectiveness of macroinvertebrate species to discern pollution levels in aquatic environment. Open J. Ecol., 11: 357-373.
12. Kwok, K.W.H., K.M.Y. Leung, G.S.G. Lui, V.K.H. Chu and P.K.S. Lam *et al*., 2007. Comparison of tropical and temperate freshwater animal species' acute sensitivities to chemicals: Implications for deriving safe extrapolation factors. Integr. Environ. Assess. Manag., 3: 49-67.
13. Basatnia, N., S.A. Hossein, J. Rodrigo-Comino, Y. Khaledian, E.C. Brevik, J. Aitkenhead-Peterson and U. Natesan, 2018. Assessment of temporal and spatial water quality in international Gomishan Lagoon, Iran, using multivariate analysis. Environ. Monit. Assess., Vol. 190. 10.1007/s10661-018-6679-2.
14. Jabbar, F.K. and K. Grote, 2019. Statistical assessment of nonpoint source pollution in agricultural watersheds in the Lower Grand River watershed, MO, USA. Environ. Sci. Pollut. Res., 26: 1487-1506.
15. Dey, S., S. Botta, R. Kallam, R. Angadala and J. Andugala, 2021. Seasonal variation in water quality parameters of Gudlavalleru Engineering College pond. Curr. Res. Green Sustainable Chem., Vol. 4. 10.1016/j.crgsc.2021.100058.
16. McGlathery, K.J., K. Sundbäck and I.C. Anderson, 2007. Eutrophication in shallow coastal bays and lagoons: The role of plants in the coastal filter. Mar. Ecol. Prog. Ser., 348: 1-18.
17. Abbasi, S., S.S. Fakhradini, N. Jaafarzadeh, P. Ebrahimi and S.Y. Ashayeri, 2022. Eutrophication and sediment-water exchange of total petroleum hydrocarbons and heavy metals of Hashilan Wetland, a national heritage in NW Iran. Environ. Sci. Pollut. Res., 29: 27007-27025.
18. Alobaidy, A.H.M.J., H.S. Abid and B.K. Maulood, 2010. Application of water quality index for assessment of Dokan Lake Ecosystem, Kurdistan Region, Iraq. J. Water Resour. Prot., 2: 792-798.
19. Christia, C., G. Giordani and E. Papastergiadou, 2014. Assessment of ecological quality of coastal lagoons with a combination of phytobenthic and water quality indices. Mar. Pollut. Bull., 86: 411-423.