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Original Article

Water Quality Assessment of the Zarivar Lake Using Physico-chemical Parameters and NSF-WQI Indicator, Kurdistan Province-Iran

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ABSTRACT

The Zarivar Lake a freshwater lake in west of Kurdistan Province is home for large number of native plant and animal species therefore water quality and health of the lake are vital for conservation of these species. The present study aimed at evaluation of the Zarivar Lake using NSF- WQI as an indicator of water quality. WQI is a suitable tool to examine and classify spatial and temporal variations in water quality and pollution loads in a water body. Seven sites were selected in different parts of the lake for sampling. Water samples were taken and placed in dark bottle, kept in ice box to prevent any change in chemical properties of samples prior to transportation to the lab for further analyses. Nitrite, Nitrate, Orthophosphate, NH_4^+, NH_3, Iron, salinity, Electron Conductivity (EC) and pH were measured in all sites. Electron Conductivity was 295- 426 $\mu S.cm^{-1}$ and pH varied between 7.28- 8.35. Concentrations of examined chemicals were PO_4^{3-}: 0.019-1.45 mg l^{-1}، NO3-:0.6 mg l^{-1}، NO2: 0.001-0.011 mg l^{-1}، NH_4^+ :< 0.11-11.33 mg l^{-1} which indicated trophic status of the lake. Water quality assessment was carried out based on values obtained for nine factors including dissolved oxygen (DO), Fecal Coliform, BOD, pH, water temperature (°C), Phosphate, Nitrate, Total Suspended Solid (TSS) and turbidity. The highest value was recorded for Nitrate and lowest for fecal coliform. The study showed based on WQI indicator the Zarivar Lake is a low or slightly polluted basin with an average water quality.

Keywords: Zarivar Lake, water pollution, water quality, NSF- WQI indicator

Introduction

The availability of good quality water is a necessary feature for preventing diseases and improving quality of life (Oluduro and Aderiye, 2007).Water is a necessary element for endurance of living on earth, which contains minerals, essential for humans as well as for earth and aquatic life (Versari *et al*., 2002). Lakes have long been at the center of human attention. Several cities, industrial infrastructures and agriculture complexes have been built up in vicinity of rivers and other water bodies. Development of human communities and increase in irresponsible use of water resources has deteriorated river and lake water qualities (Sanchez, 2007). Population growth and pollution caused by toxic waste water, surface water runoffs from municipal, industrial and agricultural sources have increased pollution load and further limited healthy water resources (Siemonov, 2003) and surface water quality management. Bearing the idea in mind it is inevitable to understand quality of surface water for various purposes such as use for drinking, industries and agriculture. Knowledge on point sources of pollution and pollutants in the region are prerequisite for appropriate use of water (Siemonov, 2003). Monitoring and control of surface water is critical to guaranty high quality water for various applications (Bollinger *et al*., 1999). Lakes and surface water reservoirs are the planet's most important freshwater resources and provide numerous benefits. They are used for domestic and irrigation purposes, and provide ecosystems for aquatic life especially fish, in that way functioning as a source of essential protein, and for significant elements of the world's biological diversity. They have important social and economic benefits as a result of tourism and recreation, and are culturally and aesthetically important for people throughout the world. They also play an equally important role in flood control (An *et al*., 2002). However, the remarkable increase in population resulted in a considerable consumption of the water reserves world wide (Ho *et al*., 2003). The quality of surface water is mainly affected by natural processes (weathering and soil erosion) as well as anthropogenic inputs (municipal and industrial wastewater discharge). The anthropogenic discharges represent a constant polluting source, whereas surface runoff is a seasonal phenomenon, mainly affected by climatic conditions (Singh *et al*., 2004). The serious environmental problems have been faced in developing as well as developed countries (Listori, 1990). Dissolved constituents of water bodies are often determined as a major component for baseline Limnological studies. Water quality monitoring has a high priority for the determination of current conditions and long term trends for effective management. The supply of clean and safe water has a significant effect on the expectation of water transmissible diseases (Lerda and Prosperi, 1996). The abundance of organic compounds, radio nuclides, toxic chemicals, nitrites and nitrates in water may cause unfavourable effects on the human health especially cancer, other human body malfunctions and chronic illnesses (Ikem *et al*., 2003). Therefore, it is necessary to frequently monitor water quality, used for drinking purposes. National Sanitation Foundation Water Quality Index (NSF WQI) is an effective tool to collect and process data on water resources at any given ecosystem to improve management activities. United State National Sanitation Foundation (UNNSF) has proposed nine factors including dissolved oxygen (DO), Fecal Coliform, BOD, pH, water temperature (^oC), Phosphate, Nitrate, Total Suspended Solid (TSS) and turbidity which are suitable for use in temperate regions for WQI assessment (Princy *et al*, 1999). The index uses water properties as measurable quality values to calculate total water quality index (Qram, 2010, Brown *et al*., 1970). To use WQI in an ecosystem four samplings required on at least four factors and maximum values should not be used for evaluation. Considering the importance of the Zarivar Lake, monitoring and control of pollution load into this ecosystem is essential to preserve high water quality and improve management policies. In Iran, drinking water comes from groundwater and surface water including rivers, lakes and reservoirs (Dehghan *et al*., 2010). The present investigation involves the analysis of water quality in relation to physico- chemical parameters.

Materials and Methods

Study area

The Zarivar Lake is a freshwater basin located 3 km northwest of Marivan- Kurdistan Province, 1284 als. It has 830ha area with maximum depth of 5-6 m (ASARAB Consulting Co., 2008). It is surrounded by aquatic plants e. g. *Typha sp.* (common bulrush) and *Phragmites sp.* (common reed) except for eastern part covering an average area of 1200 ha. Precipitation in the forms of snow and rain (14 mil.m^3) groundwater springs (11 mil.m^3), surface waters (32 mil.km^3) with total input of 57 mil.m3 and diverting weir (47 mil.m^3) are water sources of the lake (ASARAB Consulting Co., 2008).

Sampling

In this study 7 sampling sites were sampled for NSF- WQI assessment, which are shown in Figure 1. Sampling sites 1, 2 and 3 were selected in open water area, site 4 at the entrance of water from the Ghezelche Soo diverting dam, sites 5 and 6 in Bulrush covered areas and site 7 near the dyke of the lake in southern parts. Dissolved oxygen was measured by portable Oxygen meter (Sension 6- HACH), EC and total suspended solids Sension 5 TDS and EC meter; pH by Sension1 pH meter. Nitrate and Phosphate were determined by standard methods with the aid of UV visible spectrophotometer (Shimadzo UV- Visible Pharma Spect) in the range of 220 and 680nm. Turbidity was measured by HACH 2100N turbidity meter. Fecal coli forms were counted with standard method using membrane filters, vacuum pumps (Millipore) and microbial culture incubator (WTE Binder Model) at 100ml of samples. Biological Oxygen Demand was measured by BOD incubator model WTW TS606/2-I. Total solid was determined at 103- 105^{o}C (APHA, 1998).

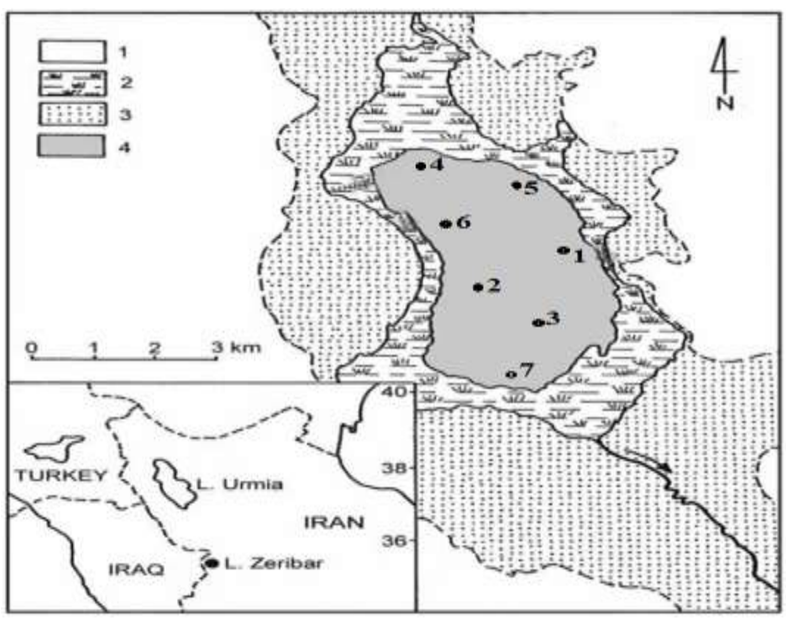

Figure 1. Sampling sites of Zarivar Lake (1- mountain ridges, 2 – mires, 3 – alluvial fens, 4 – lake)

Calculation of NSF-WQI

Values of Q for each factor were determined utilizing histograms supplied by Qram, 2010. These values were then multiplied by weight factor to obtain final figure for each of them. WQI was calculated using modified model of O-Yang (1990), where Wi is weight factor and Qi is the obtained value for variable i. Guidelines for quality classes and water pollution are presented in Table 1 and 2 (USM, 1995).

$$WQI = 0.1\times [\sum WiQi]^{1.5}$$

Table 1. Mean values of River water quality index to be used for calculation of NSF-WQI (USM, 1995)

Range of WQI	0-20	20-50	50- 70	70-90	90-100
Quality	Very Poor	Poor	Average	Good	Excellent

Table 2. Ranges of WQI as indicator of water quality (USM, 1995)

WQI index	**Pollution rate**
81- 100	Clean water
60 – 80	Slightly polluted water
0- 59	Heavily polluted water

Result and Discussion

Assessment of physical and chemical parameters of the lake

The physical and chemical factors investigated in this research have been used to assess the water quality of some African reservoirs (Nhiwatiwa and Marshall, 2007; Mustapha, 2008).The physico-chemical parameters obtained from analysis of water samples were presented in Table 3. The average value of pH was 7.94 ±1.07 with the lowest and highest values of 7.28 and 8.33 at sampling sites. Based on the given facts pH of the lake is suitable for fish at present time. The present results obtained for pH are similar to the results obtained by Adefemi *et al*. (2007); Adefemi and Awokunmi (2010). pH below 4.8 and above 9.2 are deleterious for aquatic organisms specially for fish. Asaolu (1997) also obtained similar results in water samples from Ondo State coastal water. The temperature ranged between 3.5-30 °C with an average value of 19.29 ± 26.5°C. The temperature of water sample from Zarivar Lake is higher than those obtained from wells. This could be due to increase in rate of chemical reaction and nature of biological activities, since temperature is one of the factors that govern the assimilative capacity of the aquatic system (EPA, 1976; Forstner and Wittlman, 1979). The temperature variations in the lake were normal for metabolic activities of organisms such as fish as reported by Boyd and Lichtkoppler (1979) and will not affect the water quality for drinking or fish production. Dissolved oxygen (DO) is essential for water quality, ecological status, productivity and health of a lake. This is due to its importance as a respiratory gas, and its use in biological and chemical reactions (Mustapha, 2008). Depending upon water temperature and salinity, saturation rate DO varied between 5- 9 $mg.lit^{-1}$. Oxygen demand for decomposition of materials results in depletion of DO in water and threatens aquatic life and water quality. Mean DO of the Zarivar Lake was 7.293± 8.53 $mg.lit^{-1}$. The mean value of DO was 7.293± 8.53 $mg.lit^{-1}$, and with lowest and highest values of 2.65 - 11.193 at sampling stations. Temperature is a measurement of the intensity of heat stored in a volume of water (RISC 1998). High water temperatures increase the metabolic oxygen demand, which in conjunction with reduced oxygen solubility, impact many species (RISC 1998). Temperature strongly influences dissolved oxygen as oxygen solubility decreases with increasing water temperature. The amount of dissolved oxygen in a lake is also related to photosynthesis and respiration rates as well as mechanical actions such as wind. Photosynthesis releases oxygen in the day light hours and the consumption of oxygen during the night results in lower pre-dawn levels. As a lake becomes more eutrophic, the diurnal fluctuation in dissolved oxygen concentration becomes more extreme. Dissolved oxygen concentration greater than 100% saturation occurs in areas of rapid photosynthesis and below 100% where respiration is dominant. Inputs into the lake from sewage and manure can reduce dissolved oxygen levels due to the decomposition process and the demand for oxygen (Urban Systems 2001). The conductivity of water is a measure of capacity of a solution to conduct electrical current through it and depends on the concentration of ions and load of nutrients. As most of the salts in water are present in ionic forms, they make water capable for conducting current. The conductivity, thus serves as a good and rapid measure of the total dissolved solids in water (Srivastava *et al*., 2011). The conductivity was found in all the water samples between (295-426.9) $\mu S.cm^{-1}$ with an average value of 357.7±131.2 $\mu S.cm^{-1}$. Using electrical conductivity as water quality index (Moore, 1989), the lake has good water quality. Its range 80.40–178.80 $\mu S.cm^{-1}$ will protect diverse species of organisms. Dumont (1999) observed that species number decreases in water with high conductivity. The Turbidity of any water sample is the reduction of transparency due to the presence of particulate matter such as lay or slit, finely divided organic matter, plankton and other microscopic organisms (Srivastava *et al*., 2011). In the present study, the range of turbidity fluctuated between 0.763- 3.987 NTU. Therefore, it may be said that river water turbidity is well within the prescribed limits. Srivastava *et al*. (2011) also obtained similar results in water samples from Ramganga River at Moradabad. In the present study, the range of total suspended solids for study period is 141.9 to 201.7 mg/L with an average value of 179.7±59.8 mg/L. The suspended solids determination is particularly useful in the analysis of sewage and other waste waters and is as significant as BOD determination. It is used to evaluate the strength of domestic wastewaters and efficiency of treatment units. Suspended solids are objectionable in aquatic systems for many reasons. Suspended Solids containing much organic matter may cause putrefaction and consequently the stream may be devoid of dissolved oxygen. BOD is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in given water sample at certain temperature over a specific time period and considered as an important water quality indicator. The average BOD of the lake was 6.057 ppm. Mean phosphate concentration was 0.15± 0.64 $mg.lit^{-1}$. Assessing the level of nutrients is a main feature in determining lake productivity. Lake water quality is extremely influenced by the relative abundance of nutrients. A moderate amount of nutrients enhances the lake ecosystem by providing a food source for aquatic organisms. Nutrients can transfer into the lake from surface runoff as well as groundwater inflows. Phosphorus is usually the most limiting nutrient for plant and algae growth in lakes and is measured in its dissolved form. Total phosphorus levels include all forms of organic and inorganic phosphorus. Portions of this phosphorus component are not immediately biologically available (RISC 1998). Forms of phosphorus that are biologically available for plant growth include total dissolved phosphorus, ortho-phosphorus and soluble reactive phosphorus and therefore are better indicators of trophic status within the lake. Increased levels of phosphorus are generally associated with increasing levels of eutrophication. Soil types and land use inputs influence phosphorus levels and potential sources include storm water runoff, agriculture, golf courses and wastewater systems. Groundwater phosphorus concentrations can become elevated when the soil phosphorus holding capacity is exceeded. Nitrogen is a limiting nutrient especially at higher N/P and considered as an essential factors for water quality assessments. Different forms of N such as Nitrate, Nitrite, N-$NO_{3'}$ and N- $NH4^{+}$ are determined in a water body. The amount of N-NH_3 in the lake was 0.021mg.lit^{-1}. Use of Nitrogen fertilizers in agriculture fields and effluents from domestic wastes increase Nitrate contents of the lake which was 0.6mg.lit^{-1}. N-$NH4^{+}$ is easily utilized by plants and mean N-NH_4+ of the lake was 0.42. Chemical oxygen demand (COD) varied between 9.1 mg/L and 93.1 mg/L with a mean range 37.4 + 84. The mean range of chemical oxygen demand for (1.2 mg/L – 2.6 mg/L) fell within acceptable level for drinking water and fish production (Hach, 2003). APHA (1998), however, recommended COD levels of < 2 mg/L in drinking water. High COD has been linked with pollution (Tepe *et al*., 2005). The high COD level at Zarivar Lake may be occurred due to high rate of organic decomposition resulting from human activities which produce sewage and agricultural run-offs into the lake and this have negative impact on the water quality. In the present study, the range of total alkalinity for study period is 89 to 121.3 mg/L with an average value of 110.8 ± 32.3 mg/L. The total alkalinity of the lake is an indication of its carbonates and bicarbonate contributes (Wetzel, 2001) with the possibility of silicates and phosphates contributing to it. Higher concentration of total alkalinity in the Zarivar Lake could be due to higher carbon dioxide concentration and release of bicarbonates ions by sediments. The mean range of the total alkalinity (30–55 mg/L) compared favourably well with the range given for lakes by USEPA (1976), and is an indicator to the good quality of the reservoir water. Sugunam (1995) reported that total alkalinity above 40 mg/L is indicative of high productivity. Thus the lake will maintain good fish production. Alkalinity is also a buffer for pH changes that helps stabilizing the pH of the lake. Based on our results the Zarivar Lake can be classified in average quality class and slightly polluted water body (Table 4). Individual results on quality indicators showed that the Zarivar Lake is in bad condition as long as Coli form and BOD concerned but other factors are in better condition (Figure 3).

Table 3. Result of physiochemical parameters in Zarivar Lake

Factor	SD	Max	Min	Mean
Water Temperature	26.5	30	3.5	19.29
pH	1.07	8.33	7.28	7.94
Dissolved Oxygen (mg/l)	8.53	11.193	2.65	7.293

Dissolved Oxygen (%)	67.48	97.46	29.89	80.03
NH_3^{2+}(mg/l)	0.113	0.114	0.001	0.021
NH_4^+(mg/l)	1.22	11.33	0.11	0.43
Nitrite (mg/l)	0.01	0.011	0.001	0.006
Phosphate (mg/l)	0.64	0.68	0.04	0.15
Total phosphate(mg/l)	1.431	1.45	0.019	0.47
EC (µS/cm)	131.2	426.9	295	357.7
TDS (mg/l)	59.8	201.7	141.9	179.7
TSS (g/l)	0.0504	0.1149	0.0645	0.145
Turbidity (NTU)	3.224	3.987	0.763	1.623
Alkalinity (mg/l)	32.3	121.3	89	110.8
COD (mg/l)	84	93.1	9.1	37.4
BOD_5 (mg/l)	9.6	12.8	3.2	6
TOC (mg/l)	10.73	14.73	3.97	8.96
Fecal Coliform (MPN/100ml)	1278	1278	0	211.25

Table 4. Values calculated of Q and WQI for quality factors in Zarivar Lake

Factor	**Factor value**	**Q_i**	**W_i**	**$W_i \times Q_i$**
Dissolved Oxygen	80.03%	87	0.17	14.79
Fecal Coliform	211.25	37	0.16	5.92
pH	7.94	86	0.11	9.46
BOD	6	51	0.11	5.61
Temperature	3.5- 30	79	0.10	7.9
Total Phosphate	0.15	94	0.10	9.4
Nitrate	0.6	96	0.10	9.6
Turbidity	1.623	94	0.08	7.52
TSS	0.145	79	0.07	5.53

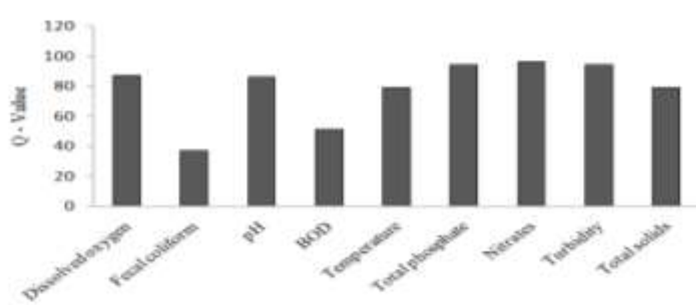

Figure 3. Value of WQI index for each water quality factor

National Sanitation Foundation Water Quality Index (NSF WQI) used for rating of water quality in Zarivar Lake indicates that the quality of water is slightly polluted (WQI= 65.9). It is almost always endangered or deteriorated. The condition in it usually diverges from normal levels and the water is not able to protect or support plenty aquatic life. Phosphorus, dissolved oxygen, total alkalinity and total solids are the main factors responsible for determination of the lake water quality. These parameters need to be modified to maintain the quality of water for further use. NSF-WQI is an excellent management and general administrative tool in communicating water quality information. This index has been widely field tested and applied to data from a number of different geographical areas all over the world in order to calculate Water Quality Index(WQI) of various water bodies critical pollution parameters were considered.

$$WQI = 0.1\times [\sum WiQi]^{1.5} \rightarrow WQI = 65.9$$

Conclusion

Assessment of the Zarivar Lake by WQI revealed that the lake is slightly polluted and could be placed in average quality class but the trend and hierarchy of the events threatens the lake. Pollutants and pollution load is ever increasing and with the present pace of pollution load the lake water will not be suitable for large number aquatic organisms anymore and eventually will result in extinction of large number of plant and animal species in the near future. Dissolved oxygen (DO), Phosphate, Alkalinity and total suspended solids as dominant factors influencing lake water quality assessment should be managed. Finally an effective and responsible ecosystem based management measures should be taken to control pollution loads and save life of the Zarivar Lake. Nutrient enrichment is a concern to residents residing along Zarivar Lake along with its implications on the long-term aquatic health of the system. Continued monitoring is required to develop a dataset to reflect the natural variations and land use implications on water quality within Zarivar Lake. A community based monitoring program will capture valuable data and increase awareness within the local population on water quality and shoreline issues. Findings from these studies are important tools to land planners in determining future development possibilities within the area.

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