Evaluation of Water Quality inTehran Urban Water Bodies

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Abstract
As cities grow, residents need more recreational facilities. Urban water bodies located in parks are a great place to spend time. However, their water quality is of particular concern due to its easy access especially for the younger generation. To prevent health problems, there is a need to continuously evaluate their water quality. Water quality indices are one of the most widely used tools for evaluating the quality of water resources. In this study, first, water quality of 13 water bodies of Tehran Metropolitan was evaluated using Iran Water Quality Index for Surface Water-Conventional Parameters ($IRWQI_{SC}$). Then, we suggest some effective strategies to improve the quality of each zone by considering their different characteristic. The results showed that most of water bodies are in poor and relatively poor-quality classes. In addition, the quality of water especially in terms of dissolved oxygen is low in almost all water bodies. As the main source of pollution into these urban artificial ponds is the surrounding environment, using methods such as Filter Strip that prevent the entry of suspended particles and pollution can be recommended as an effective strategy. However, based on the available equipment and the operating cost, “reducing the retention time by using water for irrigation” is introduced as the main remedy.

Keywords: Water Quality, Tehran Urban Water Bodies, $IRWQI_{SC}$, Improvement Strategies

Introduction
In recent years, population growth, industrialization, urbanization, and human activities have made us intervene in the water cycle, producing high loads of polluted wastewater. This caused water resources shortage and as a result less reliable resources available. Gradually, the increase of pollutant sources and amount of pollution entering water resources raised the water quality experts’ attention. Due to the complexity of determining water quality and the extent of indices used to describe water quality, it is quite difficult to provide a comprehensive and simple definition for it (Ebraheim et al., 2020). On the other hand, with the increasing demand for water and the diversity of methods for interpreting water quality data over the past century, the definition of "water quality" has continuously changed. The most appropriate definition for water quality can be said as: "Physical, chemical and biological properties provided in connection with the suitability of a water source for a particular use" (Ighalo and Adeniyi, 2020).
Many researches have provided various methods for evaluating the surface water quality around the world. Among these, water quality indices (WQI’s) are the most widely used and simplest methods (Kim et al., 2020). Given that Iran is located in an arid region, demand for water resources and improving their quality is rather high. In this regard, water quality indices can play a great role in identifying quality issues and their solutions, as they can be vastly used and explained by even non-specialists in simple and understandable way (Ebraheim et

al., 2020). Ebraheim et al. (2020) in a comparison between the National Sanitation Foundation Water Quality Index (NSFWQI) and the Iran Water Quality Index for Surface Water-Conventional Parameters ($IRWQI_{SC}$) for the Sefidrood River in northern Iran, found out that the $IRWQI_{SC}$ is more desirable for identifying maximum and minimum points. Also, Mirzaei et al. (2017) monitored the rivers of Bushehr for a period of two years from 2011 to 2013 using $IRWQI_{SC}$. Their findings showed that the studied rivers (Shapoor, Dalaki, Heleh, Mond, Bahoush and Baqan) can be used for agriculture, but they need to be treated and improved in terms of quality for drinking usages. Khalife and Khoshnazar (2018) classified the Zarinehrood River in Urmia as relatively poor, using samples from 16 points in and $IRWQI_{SC}$ Method. In another study, Aghaee et al. (2020) evaluated the quality of Chehelchai River using $IRWQI_{SC}$ using seven different stations in a period of six months on the river, which is one of the most important Gorganrood branches in Golestan Province. The results showed that the average calculated index in spring is higher than summer and the quality decreases from upstream to downstream. Talebi and Alipour (2020) calculated $IRWQI_{SC}$ for Bozhan and Kharv Rivers located in Khorasan Razavi province in a study. Their results showed that both rivers are in relatively good quality class. Using this method, they determined that there is a significantly high amount of pollutants such as iron and phosphorus, originating from the gardens of Bozhan village.
As explained, $IRWQI_{SC}$ is a good tool for assessing the quality of water bodies. Although this index (developed by the Department of Environment of I.R. Iran) is mostly used in rivers in the past studies, due to the critical role of urban water bodies on the physical and mental health of citizens, especially for the younger generation, and lack of proper indices modified for Iran's arid climate, we used it for evaluation of urban water areas in Tehran, as it is one of the main urban areas in Iran.

Materials and Methods

Various uses can benefit from determining the quality of surface water, such as indicating measures to minimize impacts to these water resources, zoning the pollution and providing a holistic status of the surface water quality, in addition to increasing public awareness in maintaining the health and quality of these water zones. These provide consensus among decision-makers to control direct or indirect environmental impacts (Ebraheim et al., 2020). The purpose of an index is to summarize the process and provide a summary of the possible information that will lead to the measures. We can evaluate water quality data in a variety of methods. One of the simplest methods that does not involve mathematical and statistical complexities, is using WQI's. Indices, by simplifying and downsizing the amount of data which cannot be understood easily, in addition to evaluating water quality, can indicate the trend of its qualitative changes over time and space (Ebraheim et. al, 2020).
In this study, we evaluated the quality status of 13 water zones located in parks in Tehran. Figure 1 shows the distribution of these parks in the metropolitan. As shown, we chose water zones in a way that they cover different parts of the city. The surface characteristics of the parks and their water zones are in Table 1. Accordingly, Azadegan Park, located in District 15 of Tehran with an area of about 112 hectares and a water zone of about 48,000 cubic metres, is the largest area under study. The smallest selected park is the Eshraq Cultural Centre with an area of about 8 hectares in the District 4 and the smallest water area with an area of 533 square meters is in the Andisheh Park in the District 7. The highest ratio of water levels to the total level is Al-Mahdi Park in District 9. On average, water zones cover 4.1% of the area of these parks. The total storage volume of these water areas is more than 240,000 cubic meters, among which Azadegan Park has the highest volume of 71,847 cubic meters. Also, the smallest volume of water zone belongs to Andisheh Park by 426.4 cubic meters. The source

of these water areas is groundwater aquifers through wells, their main use being as Aesthetic landscape views. It is worth mentioning that despite the dense vegetation of these parks (such as grass, shrubs and forest tree species), these water reservoirs do not irrigate the surroundings.

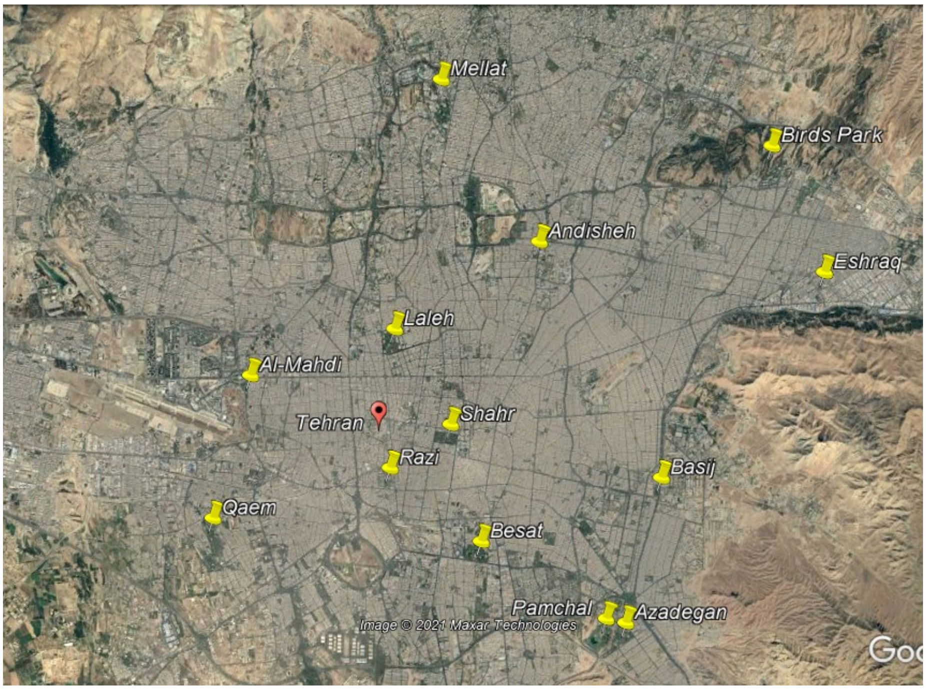

Figure 1: Location of Selected Parks

Table 1. Surface Characteristics of Study Area Parks and Water Zones (by Ratio of Water Zone to Total)

No.	District	Name	Area (Hec.)	Area of Water Zone	Volume of Water Zone	Ratio of Water Zone to Total
1	9	Al-Mahdi	6.55	1082	15706.6	18.4
2	11	Razi	25.8	26328	39492	10.2
3	14	Basij	13.3	9626	14439	7.2
4	16	Besat	53	36477	40124.7	6.9
5	15	Azadegan	112	47898	71847	4.3
6	3	Mellat	34	13508	17560.7	4
7	12	Shahr	25	7004	10506	2.8
8	18	Qaem	50	9183	13774.5	1.8
9	7	Andisheh	3.2	533	426.4	1.7
10	6	Laleh	28	4243	3818.7	1.5
11	4	Birds Park	22	3213	3410	1.5
12	15	Pamchal	54	7769	8545.9	1.4
13	4	Eshraq	8	766	689.4	1

The water quality data observed in stations are the basis of evaluation in WQI methods. The data varies depending on the type of index and its goals. However, these data should represent the chemical, physical and biological characteristics of water. The $IRWQI_{SC}$ quantifies all of these characteristics and their status modified for the region of Iran. This method makes the data understandable as it is graphical and classified. In fact, the $IRWQI_{SC}$ combines different water quality parameters to provide the final index value and the class the water body fits for (Hashemi et. al, 2011). The calculation process of this index is shown in Figure 2. In this method, after selecting the parameters using Table 2, we convert the concentration of dissolved oxygen, which is in mg/L, to the percentage of saturated oxygen if necessary. Then we calculate the weight of each parameter using Table 2 and the index value of each parameter with ranking curves. Guide for Calculating the $IRWQI_{SC}$ presents the ranking curves. Using these curves, we can calculate the value of the index based on Equation 1 (Hashemi et. al, 2011).

$$IRWQI_{sc} = \left[\prod_{i=1}^{n} I_i^{w_i} \right]^{\frac{1}{\gamma}} \quad (1)$$

$$\gamma = \sum_{i=1}^{n} W_i \quad (2)$$

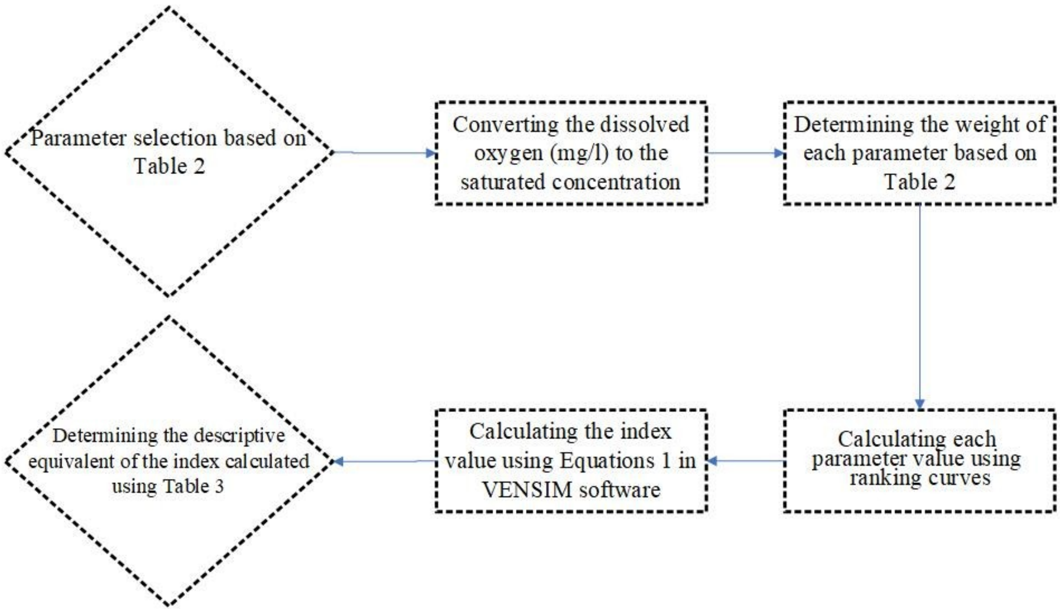

Figure 2: Flow Chart of Calculating $IRWQI_{SC}$

Table 2: Parameters and Weights

No.	Parameter	Weight	Description
1	Fecal coliform	0.140	MPN/100ml
2	BOD5	0.117	mg/L
3	Nitrate	0.108	mg/L
4	Dissolved oxygen	0.097	Saturation (%)
5	EC	0.096	µS/cm
6	COD	0.093	mg/L
7	Ammonium	0.090	Total Ammonium
8	Phosphate	0.087	mg/L
9	Turbidity	0.062	NTU
10	Total hardness	0.052	mg/L of Sodium Carbonate
11	pH	0.051	Standard Scale

Where W_i is the weight of the parameter i, N is the number of parameters and I_i is the index value for the parameter i of the ranking curve. In order to determine the descriptive equivalent of the calculated index, we use Table 3 for the index classification.

Table 3: Descriptive Equivalent of the Index

Index Value	Descriptive Equivalent
Less than 15	Very Poor
15 to 29.9	Poor
30 to 44.9	Relatively Poor
45 to 55	Moderate
55.1 to 70	Relatively Good
70.1 to 85	Good
More than 85	Very Good

Selection of sampling stations was according to hydraulic conditions, volume, water source, aquatic animals, minimum and maximum water zones depth and water retention time. We have also determined sampling time and frequency according to seasonal conditions, reservoir retention time, dewatering time, and operation conditions. After sampling, we performed the procedure of data pre-processing and checked their accuracy according to the conditions and test results of other points.

In this study, in order to calculate $IRWQI_{SC}$, we used VENSIM software to develop a mathematical model. Figure 3 shows the developed model to calculate the index.

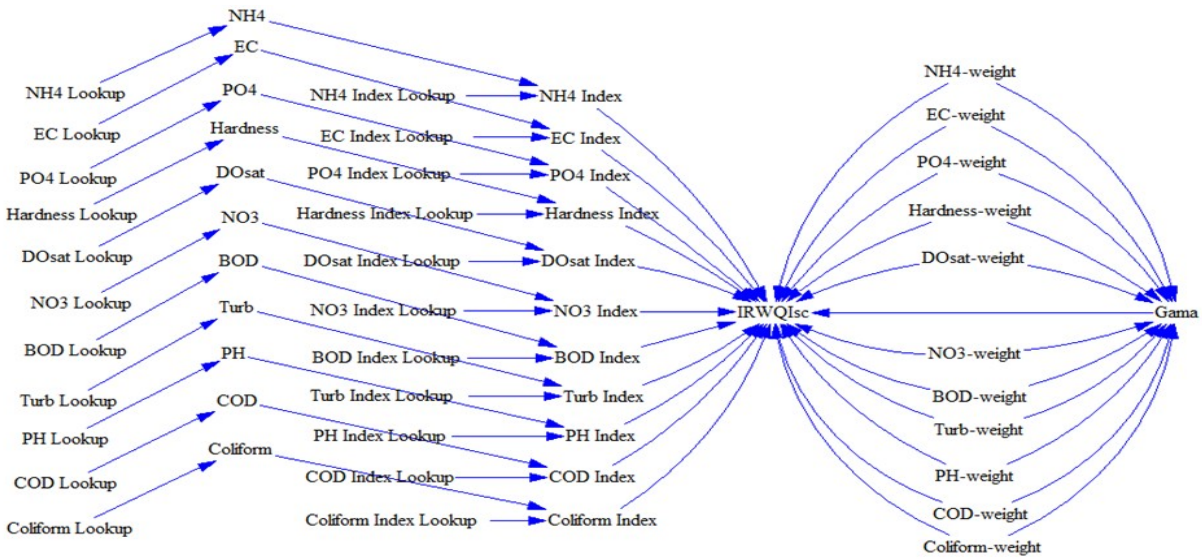

Figure 3: Index Model Calculation Diagram

Results and discussion

In order to calculate the $IRWQI_{SC}$ in the first stage, we calculated the average of the sampling results for each study area. Then, by applying the ranking curves, we calculated the weight of the parameters and the structure of the equations in the VENSIM software, the value of the $IRWQI_{SC}$. Table 4 shows the results of the average of the sampling results and the calculated values of the index. As shown, the parks of Mellat, Al-Mahdi and Azadegan are in poor quality class. Razi, Shahr and Basij parks are on the border of poor and relatively poor classes, and their tendency to be in the class of poor is obvious. The Bird Garden, Laleh, Qaem, Andisheh and Besat parks are in a relatively poor-quality class with slight differences. Finally, we can classify Eshraq Cultural Centre as the only water area as moderate.

Table 4: Mean Values of Quality Parameters for Each Park

Qualitative Parameter	Unit	Al-Mahdi	Razi	Basij	Besat	Azadegan	Mellat	Shahr	Qaem	Andisheh	Laleh	Birds	Pamchal	Eshraq
NH_4	mg/l	3.37	1.29	1.41	1.44	0.81	0.98	1.36	0.36	0.85	1.24	2.09	0.39	0.21
BOD_5	mg/l	46.52	29.70	21.32	19.10	56.70	50.27	28.14	15.48	10.15	23.75	16.78	18.90	7.40
COD	mg/l	71.72	49.49	53.08	27.56	90.08	79.75	44.58	24.46	18.33	38.08	24.46	25.74	10.20
Coliform	MPN/100ml	56.20	4.67	6.50	2.00	5.00	9.00	9.00	23.00	2.00	2.00	9.00	2.00	2.00
DO	mg/l	1.32	1.68	1.85	1.64	1.54	1.90	2.02	3.24	2.75	2.96	2.11	2.01	3.03
Turbidity	NTU	4.82	14.74	22.46	0.42	51.01	6.93	33.92	0.31	2.89	1.45	3.44	0.21	5.22
NO3	mg/l	13.90	21.10	17.58	14.47	21.95	20.72	19.72	17.03	19.70	21.00	14.75	13.75	25.20
pH	-	7.98	7.98	8.32	8.16	8.62	8.27	8.60	7.93	8.31	8.16	7.60	7.79	8.05
Hardness	-	257.99	162.66	88.54	200.24	74.86	109.2	92.72	155.13	231.02	34.22	149.31	231.4	185.10
EC	µS/cm	1157.6	902.4	795.4	918.67	1329.5	864.7	1269.6	921.5	1134.5	862.5	1207.5	959.5	593.00
T	°C	25.08	25.02	25.54	24.53	24.98	24.98	24.86	25.70	25.15	25.35	25.03	24.65	25.20
TP	mg/l	0.10	0.07	0.06	0.08	0.07	0.09	0.05	0.06	0.09	0.04	0.21	0.06	0.10
$IRWQI_{SC}$	-	22.93	29.69	19.30	39.07	21.07	22.70	28.97	41.20	39.24	33.61	36.96	41.65	45.81

According to Figure 4, most of the water zones in the studied parks are evaluated as poor and relatively poor. The reasons for this are large time span of water retention, lack of proper aeration, high nutrients, high solid and animal waste entering water areas. Obviously, improvement of each water zone requires its own solution. Table 5 shows the most suitable solutions for each water zone. In selecting the proposed solutions, we considered factors such as available facilities, available space, pollution intensity and source, area, population and usages. As all water zones lack dissolved oxygen concentration, the aeration option is one of the proposed solutions in all cases due to its ease of implementation and maintenance. On the other hand, chemical processes can eliminate dissolved oxygen depleting agents and improve this fundamental problem.

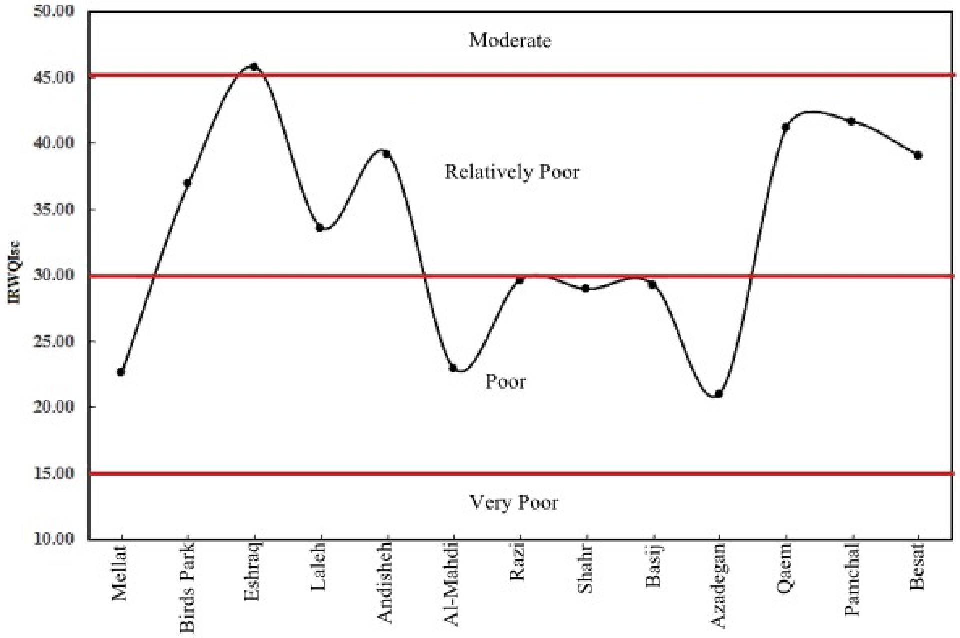

Figure 4: Calculated Values of $IRWQI_{SC}$ for the Water Zones of the Studied Parks

Table 5: Proposed Solutions for Improving the Quality of Water Zones

No.	Name	Water Dilution and Drainage	Surface Aeration	Deep Aeration	Artificial Rotation	Retention Time Control	Sand and Carbon Filters
1	Al-Mahdi		*		*	*	*
2	Razi	*	*	*		*	*
3	Basij	*	*			*	*
4	Besat	*	*		*		*
5	Azadegan	*	*		*		*
6	Mellat	*	*			*	*
7	Shahr		*	*			
8	Qaem	*	*			*	*
9	Andisheh		*			*	
10	Laleh		*			*	
11	Birds Park	*	*		*		
12	Pamchal		*	*			
13	Eshraq		*			*	

Conclusion

In this study, we studied water quality of some urban water bodies in Tehran. The results showed that the water quality of almost all these ponds is classified as poor or relatively poor. Thus, we proposed solutions to improve their quality. Reducing the retention time by using water for irrigation is recommended as the main solution due to the available equipment and the low cost. Surface aeration is the second effective and optimal method that can be installed and operated. The study showed that the concentration of dissolved oxygen is low in water bodies and the surrounding environment is the main cause of reducing the water quality in artificial ponds. Therefore, to sustainably improve the water quality, there is a need to focus on using methods such as Filter Strip that prevent the entry of suspended particles and pollution. Finally, improving water quality of these urban ponds reduces risks of health problems and can lead to less water use by decreasing groundwater withdrawal.

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