

*Original Article*

***Assessment of Carson trophic index in Dam lake: a case study of Ekbatan Dam***

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***Abstract***

***Background and purpose:*** The study aimed to investigate the trophic state of Ekbatan Dam Lake. In the current research, the quality of water behind the dam was studied during the months July and January in order to compare the trophic state and zonation of the reservoir in two different seasons (dry and wet).

***Materials and Methods:*** 15 stations were selected in different points of Ekbatan Dam Lake and sampling was accomplished in July and January. To determine the rate of eutrophication in the reservoir, 30 samples (15 in July and 15 in January) were taken from the reservoir. In this study, secchi disk, nitrate, phosphate and chlorophyll-A were measured. Then, using Carlson's Trophic State Index, the rate of eutrophication was estimated for all points. Also, using GIS zoning of water quality parameters, TSI (Trophic State Index) value was evaluated in two different seasons.

***Results:*** The findings of the current study showed that TSI varied between 35.7 and 50.7 in different stations of the lake in July. At the same time, it was documented to vary between 55.13 and 58.6 at different points in January. Also, the results revealed that the trophic state of the lake is oligotrophic to eutrophic in different stations in July while it was eutrophic for all points in January.

***Conclusion:*** Based on the estimated values of this index, the stations located at the entrance of the lake showed more eutrophic situation in July. Also, phosphorous was revealed to be the limiting nutrient in this system. The current research showed that eutrophication is a serious problem in Ekbatan reservoir.

***Key Words:*** Carlson Index; Ekbatan Dam; Eutrophication; TSI; Water Quality

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## **1. Introduction**

Natural lakes and dam lakes are more exposed to pollution as a result of their geometry and their stream characteristics. Many studies have been accomplished on reservoir eutrophication. Such studies are mainly the primary steps of water quality monitoring in these systems that could finally result in practical strategies to improve the quality of these resources (1).

Eutrophication limits the application and consumption of water. Algae clog, the filtration equipment and suction pipes in refineries, change the taste and odor of water and even cause some diseases (2, 3). Also, excessive growth of algae and water plants reduces the amount of dissolved oxygen (DO) and causes fish death (4, 5). Nitrogen (N) and Phosphorus (P) are the main nutrients to affect the growth of algae and chlorophyll-a augmentation directly (4). Based on the ratio of eutrophication in a water body, N or P could be the limiting factor. Many researchers have studied eutrophication phenomenon and nutrients interaction with phytoplanktons (6, 7). Investigating the TSI (Trophic State Index) of Mansi Ganga Lake in India revealed that the rate of water quality degradation is high in this lake (8). This lake was oligotrophic in 2006 and changed to meso-trophic in 2008. The trophic state of 11 subtropical reservoirs in Fujian province was also studied in the summer 2010 (9). All 11 reservoirs showed eutrophic state.

Not only the trophic state of a reservoir might change from year to year but also it can show significant changes from season to season (10). Trophic state of a lake from oligotrophic to meso-trophic and eutrophic is a gradual progress, and it is necessary to monitor this

state in a long term. However, sometimes the trophic state of a lake changes from month to month (11).

Many studies have been accomplished in Iran about the eutrophication of lakes, ponds and reservoirs (12-14). Ekbatan dam as a resource of potable water of Hamedan city is exposed to the same problem (15), and the concentration of nutrients is found to be considerable in this reservoir (16). The aim of this study was then to investigate the state of eutrophication in Ekbatan Dam Lake.

## **2. Materials and Methods**

Hamedan is a mountainous city located in the west of Iran. It is the centre of Hamedan Province. The city is located in the hillside of Alvand Mountain in 1800 masl and has a cold climate. Abshine River originates from Alvand Mountain and flows towards Ekbatan Dam Lake. Ekbatan Dam is located in south west of Hamedan on Abshine River where two branches of Yalfan and Abru join together. This Dam is located between 34° 45' 24" N and 48° 36' 10". The area of the reservoir lake is 1.75 km<sup>2</sup> at normal level. The primary structure of this dam was first built in 1963 to supply the agriculture and potable water for Hamedan. Then, the height of dam was increased to 79 m in 2008.

15 points were determined for sampling at Ekbatan reservoir. Coordinates of all points were determined using GPS (Model Garmin eTrex 20). These points were located in different parts of the lake. Figure 1 shows the location of these points for summer and winter sampling, respectively. Summer sampling was accomplished in July and winter sampling was done in January.



**Figure 1.** The location of sampling points

Also, the characteristics of sampling points for July and January are shown in Table 1.

**Table 1.** Characteristics of sampling points for summer (January)

Characteristics of sampling points in January			Characteristics of sampling points in July		
Station No.	Long	Lat	Station No.	Long	Lat
1	48° 35' 54.6"	34° 45' 15.48"	1	48° 36' 4.32"	34° 45' 15.48"
2	48° 35' 57.12"	34° 45' 7.56"	2	48° 36' 12.24"	34° 45' 12.96"
3	48° 36' 2.16"	34° 45' 6.12"	3	48° 36' 12.24"	34° 45' 10.08"
4	48° 36' 4.68"	34° 45' 5.04"	4	48° 36' 3.96"	34° 45' 10.08"
5	48° 36' 7.92"	34° 45' 4.32"	5	48° 35' 56.4"	34° 45' 10.08"
6	48° 36' 11.16"	34° 45' 4.32"	6	48° 36' 12.96"	34° 45' 6.48"
7	48° 36' 13.68"	34° 45' 4.32"	7	48° 36' 1.08"	34° 45' 5.4"
8	48° 36' 14.4"	34° 45' 5.4"	8	48° 35' 58.56"	34° 45' 19.08"
9	48° 36' 12.6"	34° 45' 10.44"	9	48° 35' 55.68"	34° 45' 17.28"
10	48° 36' 5.4"	34° 45' 14.76"	10	48° 36' 0.72"	34° 45' 21.96"
11	48° 36' 2.52"	34° 45' 12.24"	11	48° 36' 9.0"	34° 44' 57.48"
12	48° 36' 3.24"	34° 44' 48.48"	12	48° 36' 9.0"	34° 44' 49.92"
13	48° 36' 3.96"	34° 44' 43.08"	13	48° 36' 14.04"	34° 44' 43.08"
14	48° 36' 11.16"	34° 44' 48.84"	14	48° 36' 1.44"	34° 44' 42."
15	48° 36' 12.96"	34° 44' 51.36"	15	48° 36' 5.4"	34° 44' 35.16"

Sampling was accomplished from the surface of water and in 30 cm depth using one liter of poly-ethylene bottle. Secchi disk, total phosphate (TP), total nitrate (TN) and chlorophyll-a were studied in this research. Hence, a total of 30 samples (15 samples in the July and 15 samples in January) were taken from the reservoir in the present study. Secchi disk was determined using a 20 cm black and white metal disk. TP was measured using Standard method 4500-P-PHOSPHORUS (D.stannous chloride Method). Also, TN was measured using Standard method-4500-NO3-B-Ultraviolet (spectrophotometric screening Method). The concentration of chlorophyll-a was also determined using NMM method. In this method, acetic acid fiber filter and 90% ethanol is used to determine chlorophyll-a concentration. In the current research, Carlson eutrophication index was also used to determine the trophic state of the lake. TSI is calculated using three parameters of water, such as chlorophyll-a (Chl a), TP and Secchi disk (SD) based on equations 1 to 3:

$$TSI_{chl}=9.81 \ln (chl) + 30.6 \quad (1)$$

$$TSI_{SD}= 60- 14.4 \ln (SD) \quad (2)$$

$$TSI_{TP}=14.42 \ln TP+ 4.15 \quad (3)$$

The unit of Chl a and TP is  $\mu\text{g l}^{-1}$  and the unit of SD is m.

The total amount of TSI is the mean of these three parameters, and the value of TSI varies between 1 and 100. Based on Carlson's Trophic State Index, the state of the lakes is categorized to oligotrophic, meso-trophic, eutrophic and hyper-eutrophic. The higher the values of Carlson index, the worse the situation of water quality. Oligotrophic means that the algae production and nutrient concentration of a

water body is low. Also, Mesotrophic shows that the production and concentration of nutrients is normal. Hence, when the concentration of nutrients and algae production is high, the state of water body is called eutrophic. Table 2 shows this classification (8).

**Table 2.** Classification of TSI

The state of eutrophication	TSI Range
Oligotrophic	TSI<40
Mesotrophic	40<TSI<50
Eutrophic	50<TSI<70
Hypereutrophic	70<TSI<100

There are other classifications based on this value which categorize a water body into seven classes (17) in a more accurate classification (Table 3):

**Table 3** Classification of TSI

The state of eutrophication	TSI Range
Oligotrophic	0<TSI<30
Low Mesotrophic	30<TSI<40
Mesotrophic	40<TSI<50
High Mesotrophic	50<TSI<60
Eutrophic	60<TSI<70
Hypereutrophic	80<TSI<100

In the current research, SD, chlorophyll-a concentration, and TP were used to calculate the value of TSI at different sampling points for two seasons, the findings of which are shown in results section.

### 3. Results

After analyzing the samples, the value of TSI was determined based on the three parameters of chlorophyll-a, TP, and SD. It was documented that the value of TSI for different sampling points varied between 35.7 and 50.7 in July, and between 53.48 and 58.6 in January.

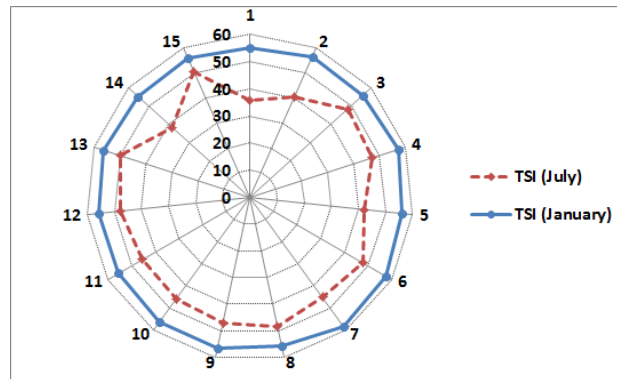
Table 4 shows column graph for TSI values in July and January. It shows that the lake was eutrophic in January, and the value of TSI for different sampling points varied between 35.7 and 50.7 in July. Also, the TSI values varied between 55.1 and 58.6 in January.

**Table 4.** TSI values for July and January sampling

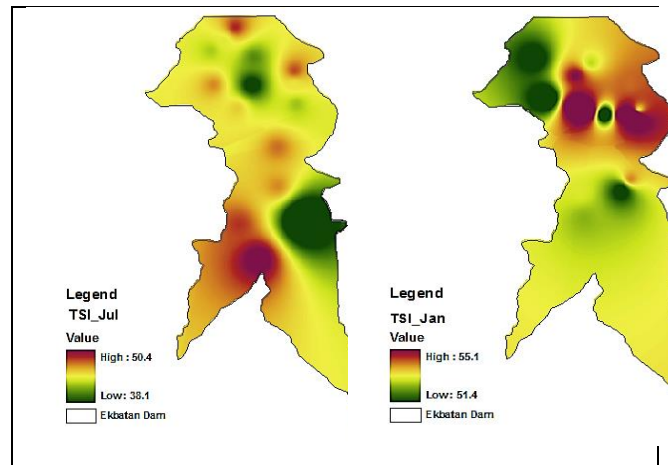
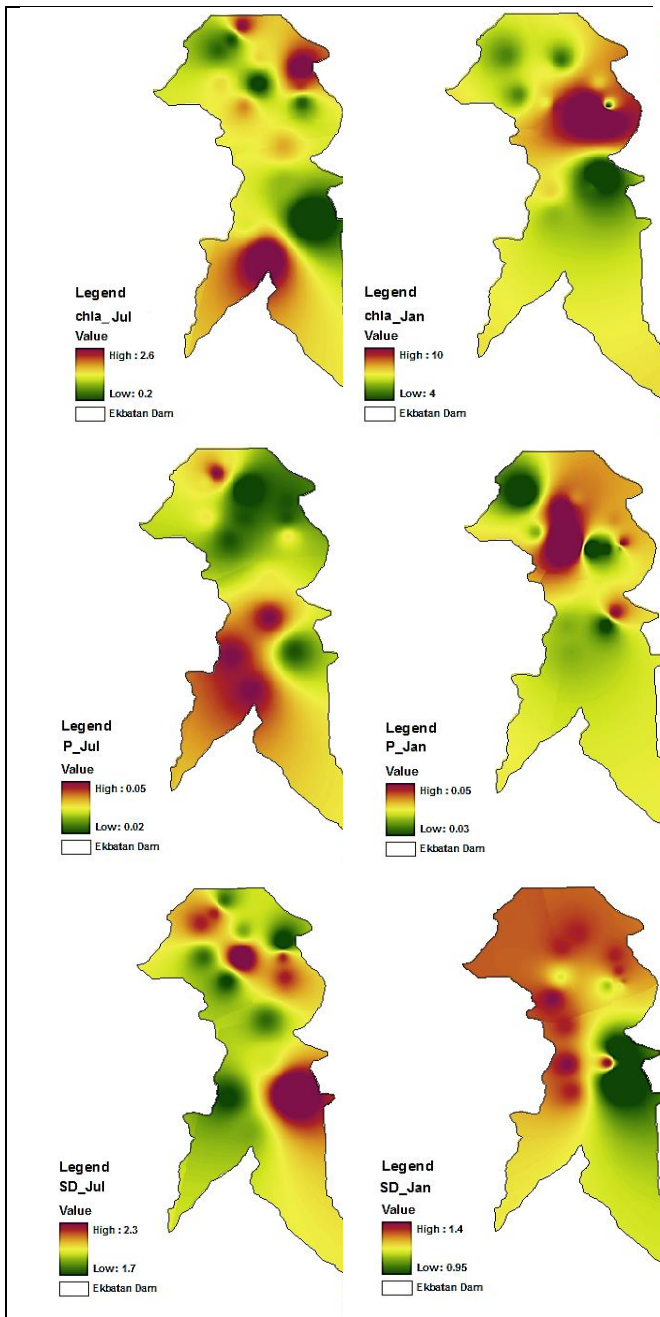
Sampling Points	TSI (July)	TSI (January)
1	35.66	55.13
2	40.31	55.1
3	48.43	58.60
4	47.13	56.55
5	41.99	54.68
6	47.76	55.74
7	45.31	56.25
8	48.55	54.38
9	46.95	54.79
10	46.06	54.21
11	45.59	54.89
12	47.76	54.38
13	50.01	54.15
14	38.21	55.48
15	50.69	54.68

Radar graph of TSI values at sampling points for July and January is shown in Figure 2. The comparison of trophic state is very easy using this graph. It is clearly shown that Ekbatan Dam Lake showed trophic state in January, while only one station showed trophic state (point 15) in July.

Based on the average value of total TSI for the Lake in July and January, the state of the lake was mesotrophic in July and eutrophic in January in spite of the fact that in summer environmental factors have a positive influence on eutrophication rate. At the same time, the volume of water in the lake was 17.7 and 5.3 MCM in July and January, respectively.



**Figure 2.** Radar Graph of TSI values for sampling points in July and January



**Figure 3.** Zonation of water quality parameters for Ekbatan Dam Lake in July and January

Also, zonation of main variables and TSI was accomplished using GIS and IDW method. Figure 3 demonstrates the zonation of chlorophyll-a, SD, TP, and TSI. It shows that the distribution of water quality parameters in the lake in July is different from that in January. In addition, it shows that the quality of water in terms of TSI value is the worst in July in the left entrance of the lake and next to the dam structure. However, the quality of water in January in the middle part of the lake is worse than other regions.

#### 4. Discussion

Ekbatan reservoir dam is a resource of potable and agriculture water for Hamedan city. The reservoir has shown symptoms of eutrophication in recent years. Hence, this study evaluated the trophic state of Hamedan Dam Lake using Carlson's trophic state index. Summer and winter were chosen as two different seasons which are representative of dry and wet seasons, respectively. More light and higher temperature is available in summer which can increase the rate of eutrophication. The Carlson' TSI is useful for comparing lakes within a region and between the regions. Also, it is helpful for assessing changes in trophic state over time. As a result of comparing and ranking the reservoirs and lakes, managers would be able to identify the lakes that need restoration and conservation (13). The results of the present study revealed that Ekbatan reservoir had a serious problem of eutrophication and P was the limiting nutrient of this system. Only one station in the lake was eutrophic (TSI= 50.7), and the other points were mesotrophic in July, whereas all points were eutrophic in January. The Trophic state of Ekbatan Dam Lake had also been investigated in 2010 (18), with a TSI value of about 52 in July and 46 in January (19). Also, the year 2010 was classified as a hydrologic wet year. Total amount of precipitation was 469 mm during this year, which was above the average. The findings of the present study were consistent with the results of a study conducted on Gilarlo Reservoir Dam (northeast of Iran), in which the researchers concluded that it was mesotrophic in August and eutrophic in October (20). The main reason of water quality reduction in the Gilarlo Dam could be associated with the water mixing process. Water overturn and subsequently release of phosphorous from the reservoir bed resulted in increasing algal growth which intensified eutrophication in October. It should be noted that Algae growth was highly dependent on Phosphorous. Released Phosphorous from the bottom of the lakes and reservoirs play an

important role in controlling the quality of reservoir water. Dredging a reservoir leads to the removal of sludge containing nutrients. In the year 2009, sediment was removed from Ekbatan Reservoir. Therefore, the nutrients concentration of water did not increase during water overturn in the winter 2010 (21), and consequently, the state of eutrophication was not intensified. Beside this fact, the year 2010 was a hydrologic wet year, while the current study was accomplished in a hydrologic dry year. The volume of water in Ekbatan reservoir was about 17 MCM (million M<sup>3</sup>) and 5 MCM in July and January, respectively. As a result, the amount of available nutrients and the rate of eutrophication increased in water body with overturn in January. On the other hand, the results of the present study were not consistent with the research conducted on Dez, Karaj, Latian and Taleghan dams (12-14). For instance, the result of a study on Dez Dam showed that this reservoir was mesotrophic in spring and eutrophic in summer and autumn (12). Another study on the trophic state of Karaj Dam lake in 2010 (13) revealed a link between the density of phytoplankton and nutrients in different depths of the lake. The study showed that the maximum amount of phytoplankton in July was related to surface. One other investigation estimated the amount of chlorophyll in Karaj, Latian, and Taleghan dam lakes during 2011 (14). Based on the results, the highest concentration of chlorophyll-a was observed in summer and the lowest concentration amount was observed in autumn for all three dams. The limiting nutrient in Ekbatan reservoir was corresponded to the findings of the present study (19, 22), which was not similar to the result from a study on Latian dam (19), where N was the limiting Factor in Latian reservoir. Overall, the results of the current study showed that eutrophication could be a serious problem of Ekbatan Dam Lake, and a strict water quality monitoring is necessary to avoid a more declined quality of water in this reservoir.

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### Conflict of interest

The Authors have no conflict of interest

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