



Original Article

Investigation on the Trophic Status of Ekbatan Reservoir: A Drinking Water Supply Reservoir in Iran

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ARTICLE INFORMATION

Article history:

Received: 27 July 2013

Revised: 15 September 2013

Accepted: 06 October 2013

Available online: 27 October 2013

Keywords:

Eutrophication

Nutrients

Chlorophyll-a

Iran

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ABSTRACT

Background: Eutrophication is one of the detrimental environmental problems in water reservoirs due to the irregular introducing nutrients (phosphorus and nitrogen). This study aimed to explore the eutrophication state of Ekbatan Reservoir, Hamadan, western Iran.

Methods: Monthly sampling was conducted during April 2010 to March 2011. Seven sampling stations were selected in the various locations of the reservoir and the samples were collected in the depth of 50 cm. The grab sampling of water for nitrogen, phosphorous and chlorophyll-a was carried out at all localities by Hatch sampler. The trophic state of the dam was determined by Carlson's Trophic State Index (TSI) and Chapra's classification.

Results: The highest concentrations of phosphorus and chlorophyll-a were measured in August and the lowest concentration for both of the parameters was determined in February. The TSI index according phosphorus concentration showed that the reservoir was in eutrophic status during May to November and was in mesotrophic status over November to May.

Conclusions: It seems that the eutrophication process in the lake was resulted from the rural wastewaters and agricultural fertilizers. Therefore, using long term management methods including prevent of uncontrolled discharge of agricultural wastewaters is recommended in order to reduce the eutrophication in the reservoir. Decrease of phosphorus concentration in the dam by 50% can convert the eutrophic state to mesotrophic state.

Citation: Weysi K, Nourmoradi H, Samarghandi MR, Samadi MT. Investigation on the Trophic Status of Ekbatan Reservoir: A Drinking Water Supply Reservoir in Iran. J Res Health Sci. 2014;14(1): 65-69.

Introduction

Due to the rapid population growth and agricultural and industrial development, many pollutants have introduced into the environment, particularly in water bodies¹. Eutrophication is one of the harmful environmental phenomena occurred in inland waters, mainly because of the artificially enrichment by nutrients, phosphorus and nitrogen². Discharge of municipal and industrial wastewaters into the water bodies are considered as point sources of nutrients and non-point sources of the nutrients are caused by urban and agricultural runoff³⁻⁵.

During the past 50 years, the greatest eutrophication was happened as a result of human impact in the lakes of many parts of the world⁶⁻⁸. About 54% of the lakes in Asia, for example, are eutrophic, while the same is true for 53% of the lakes in Europe, 48% of the lakes in North America, 41% of the lakes in South America and 28% of the lakes in Africa, respectively². Eutrophication can change lakes condition from transparent water to turbid water because of transforming the macrophyte governed water to phytoplankton-

dominated water. This process can result in the adverse effects on the water ecosystem and human health⁹.

Nitrogen and phosphorus are two main nutrients for algae growth⁸. On the basis of the concentration of the nutrients, the trophic condition of the water can be the oligotrophic state (low nutrient), mesotrophic state (middle nutrient) and eutrophic or hypereutrophic state (high nutrient)⁸. Algal blooms are abundantly occurred in the eutrophic or hypereutrophic waters. Cyanobacteria are one the most important algal species that increase in number in nutrients-rich waters. These algae can generate a vast diversity of toxic materials¹⁰. More than fifty species of cyanobacteriae including *Microcystis*, *Anabaena*, *Oscillatoria*, *Nostoc*, *Hapalosiphon*, etc. can produce cyanotoxin (hepatotoxin, neurotoxin and dermatotoxin) in eutrophic waters¹¹. These toxins are severe dangerous for aquatic organisms as well as human. Many deaths have been documented in human due to the utilization of water containing cyanotoxin¹¹. The removal of cyanotoxins by the conventional processes in the water treatment plant is complicated. Therefore, it is better that this

type of algae has been removed from water resources¹¹. Several direct objectionable properties such as fish kills, oxygen depletion, and loss of aesthetic quality (color, turbidity and taste and odor problems) are result from eutrophic or hyper-trophic waters^{7,12,13}.

Eutrophication also could indirect undesirable impacts on the lakes function including recreational and commercial activities, fisheries, boating, swimming and travel industry^{7,14}. The Carlson's index ranges of 0–30, 30–50, 50–60, 60–70, and 70–100 are applied to explain oligotrophic, mesotrophic, eutrophic, hypertrophic, and dystrophic conditions, respectively¹⁵. Three parameters of chlorophyll-*a*, Secchi depth, and total phosphorus are applied to determine the Carlson's index^{3,16}. The Chapra's method is also used to show the trophic state of surface water bodies on the basis of total phosphorus, chlorophyll-*a* and subsurface oxygen¹⁷. Many studies have been conducted on the trophic state of lakes and reservoirs by this procedures¹⁸⁻²¹. In Iran, many studies reported that eutrophication has been occurred in various lakes and reservoirs^{22,23}.

The aim of this study was to investigate the trophic state of the reservoir.

Methods

Study location

This study was conducted on the Ekbatan Reservoir, western Hamadan (Iran) in 2010-2011. Hamadan City is located in the west of Iran. The reservoir was constructed on the Yalfan and Abaroo rivers, located in 10 km distance from Hamadan City with coordinates of 45°34'N and 36°48'E (Figure 1). Ekbatan Reservoir was constructed in 1963 for the purposes of drinking water supply of Hamadan City and agricultural water for the surrounding areas. The physical characteristics of the Ekbatan Reservoir are shown in Table 1.

Table 1: Principal Morphometric and hydrological characteristics of reservoir²⁴

Item	Value
Watershed area (km ²)	213.00
Mean Surface area (Mm ²)	1.34
Dam crest length(m)	637.00
Mean depth (m)	30.00
Mean Volume (Mm ³)	20.46
Hydraulic retention time (years)	0.39
Mean flow (Mm ³ /yr)	52.00
Mean Altitude (m)	1955.00
Mean total phosphorus (mg/l)	0.06

Water sampling and data analysis

Monthly sampling was conducted during April 2010 to March 2011. As seen in Figure 1, seven sampling stations in the outlet (station No. 1), center (station No. 2-5) and inlet (station No. 6 and 7) of the reservoir were selected in order to determine of trophic state of the dam. Samples were collected in the depth of 50 cm. The grab samplings of water for nitrogen, phosphorous and chlorophyll-*a* were carried out at all locations by the Hatch sampler². The samples were placed in 1000 ml plastic containers and transferred to the laboratory at 4 °C for chemical analyses²⁵. The chemical analyses were carried out spectrophotometrically according to the standard methods²⁵. The trophic state of the dam was

specified by Carlson's Trophic State Index (TSI) and Chapra's classification^{16,17}. Two parameters of chlorophyll-*a* and total phosphorus were used to determine the index. Eq. 1 and 2 were used to calculate the Carlson's index and the concentration of these parameters is measured on the basis of microgram per liter^{5,16}.

$$TSI (chl a) = 10 \left(6 - \frac{2.04 - 0.68 \ln chl a}{\ln 2} \right) \quad (1)$$

$$TSI (TP) = 10 \left(6 - \frac{48}{TP \cdot \ln 2} \right) \quad (2)$$

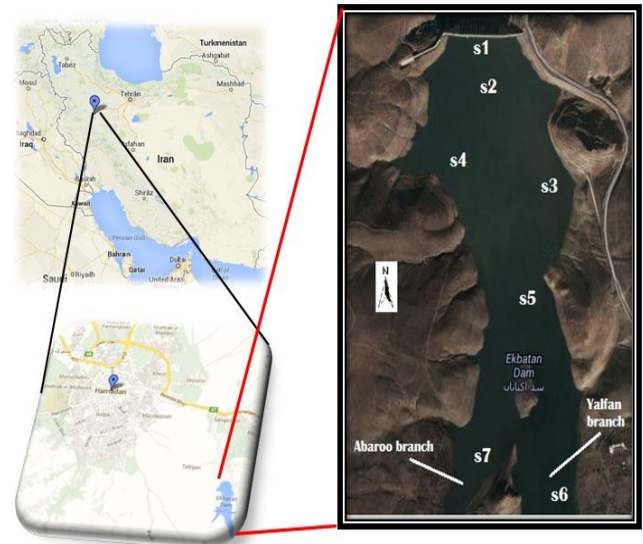


Figure 1: Location of Ekbatan reservoir and the sampling points

The Chapra's classification (Table 2) is applied to illustrate the trophic state of surface water bodies¹⁷. To determine the eutrophication condition, the data obtained was fitted by this classification.

Table 2: Chapra's classification for trophic state of water bodies¹⁷.

Parameter	Oligotrophic	Mesotrophic	Eutrophic
Total phosphorus (mg/m ³)	<10	10-20	>20
Chlorophyll- <i>a</i> (mg/m ³)	<4	4-10	>10
Subsurface oxygen saturation (%)	>80	10-80	<10

Vollen Weider's diagram is also used to determine the eutrophication conditions on the basis of phosphorus loading into lakes and reservoirs¹⁷. Equation 3 to 5 was used to calculate the phosphorus loading¹⁷. The data of Table 1 was applied to calculate the parameters of the following Equations.

$$\frac{H}{T_w} = \frac{HQ}{HA_s} = \frac{Q}{A_s} \quad (3)$$

$$T_w = \frac{V}{Q} \quad (4)$$

$$L_p = \frac{Q \times P_m}{A_s} \quad (5)$$

Where; the parameters of H, T_w and V are the average reservoir depth (m), the average water residence time (yr) and the average volume of water (Mm³), respectively. A_s is the reservoir surface (Mm²) and Q is also average input flow (m³/yr). L_p and P_m are the average phosphorus loading (g P/m².yr) and the average phosphorus concentration (mg/l), respectively¹⁷.

Results

Figure 2 shows the average concentration of phosphorus, nitrogen and chlorophyll-*a* in the different sampling months and locations. As seen from Figure 2a, the highest phosphorus and chlorophyll-concentrations were measured in August and the lowest concentrations for both the parameters were determined in February. These results indicated that the concentration of chlorophyll-*a* was depended on the phosphorus concentration. The concentration of nitrogen in August and January was also in maximum and minimum values, respec-

tively (Figure 2a). The trend of nutrients fluctuations (nitrogen and phosphorus) in the reservoir in the sampling months was approximately similar. Figure 2b also showed that the highest and lowest chlorophyll-*a* concentration were occurred at stations No. 6 and No. 1, respectively. Figure 2b specified that the highest and lowest nitrogen concentration was acquired at sampling station No. 6 and No. 4, respectively. These results indicated that the Yalfan River, as the one of two input branches into the dam, has inserted the most of nitrogen and phosphorus pollution in the reservoir.

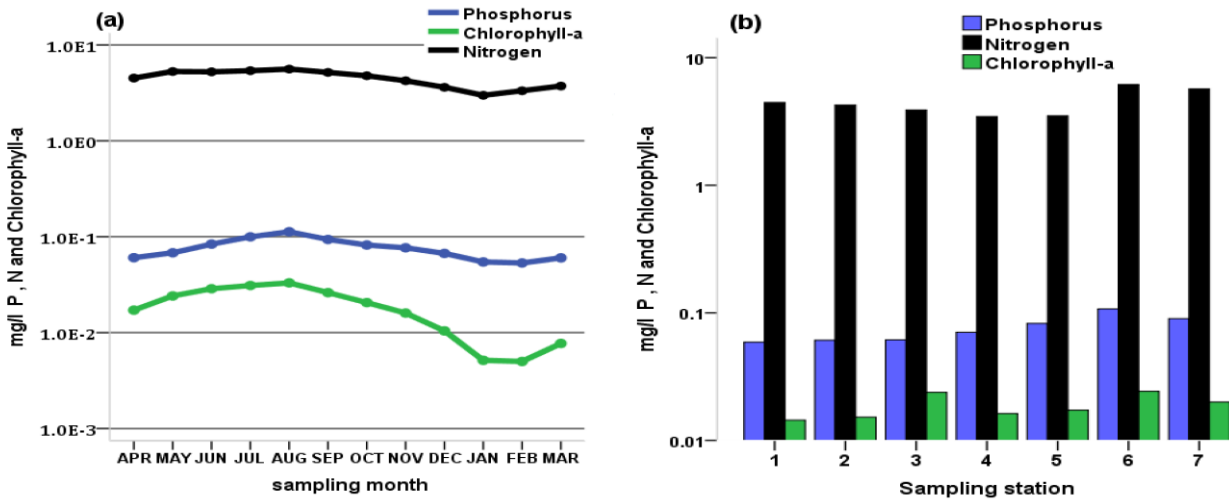


Figure 2: Concentration of phosphorus nitrogen and chlorophyll-*a* (a) in the various months and (b) at the different locations

With regard to the trophic classification (Carlson's index), the data obtained from chlorophyll-*a* concentration showed that the reservoir was categorized within hypertrophic zone during May to October. The best quality of water on the basis of chlorophyll-*a* concentration was obtained over December to Mars. The eutrophic state was also occurred throughout October to December and March to May (Figure 3a). The TSI index according phosphorus concen-

tration (Figure 3a) also showed that the reservoir was eutrophic during May to November and was mesotrophic over November to May. Figure 3b specified that the eutrophic condition according to chlorophyll-*a* content was governed in all the sampling stations and mesotrophic situation for phosphorus concentration was found in all stations except to stations No. 5-7.

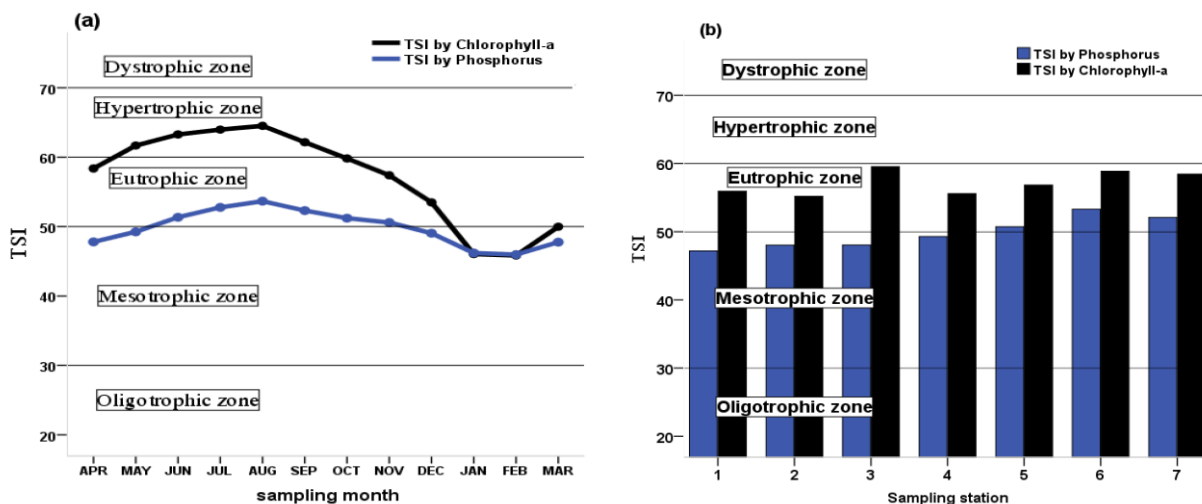


Figure 3: The trophic state of the reservoir (a) in the various months and (b) at the various sampling stations

The data was fitted with Vollen Weider's diagram and the trophic state of the lake was marked with asterisk (Figure 4). As seen, according the diagram, the condition of the reservoir was eutrophic (dangerous).

Discussion

As seen in Figure 2, phosphorus concentration during summer and winter was in the maximum and minimum lev-

els, respectively. Agricultural activities, irregular use of chemical fertilizers and lack of rainfall during warm seasons can lead to reduce the water flow entering the lake and then increase the phosphorus concentration during summer season. The watershed of the lake, especially around the Yalfan River, has also been considered as a recreational and tourist area with villa buildings that the area was populous over summer. Therefore, the rate of municipal wastewater enter-

ing the lake during the summer is higher than of other seasons. For these reasons, the Yalfan branch (station No. 6) had the maximum level of the nutrients over the sampling period. During winter season because of the high rainfall and absence of agricultural activities and the absence of tourists in the area, phosphorus content in the lake was reduced to lowest level. The trend of chlorophyll-*a* concentration in the lake was also corresponded to phosphorus content. As known, phosphorus is one of the main nutrients for algae. The high content of chlorophyll-*a* in water over summer season can be due to the high concentration of phosphorus and as well as high temperature of the water. Increasing the water temperature can accelerate the algal activity and subsequently high algal reproduction^{26,27}. The lake, on the basis of chlorophyll-*a* concentration, was in dangerous state except in January to May months (mesotrophic state). According to Wetzel's classification, water overturn in northern hemisphere lakes (i.e. Ekbatan Lake, Iran) was occurred during winter season. Therefore, in this season, the eutrophication state is in the lowest level due to the water temperature and unfavorable condition for algal activity²⁷. The content of chlorophyll-*a* (0.0238 mg/l) was also high in the station No. 3 (Figure 1) that this can be because of the proximity with forest cover around this station. The presence of algae in the lake can lead to increase the suspended material, taste and odor and algal metabolites in water. Therefore, the remove of these impurities in polluted water is complicated and the cost of the treatment is increased²⁸. The data obtained from Figure 3a showed that the lake was in mesotrophic state during the cold season (Dec to Mar) and was in eutrophic and hypertrophic state over May to November. Shamlou et al. (2004) reported that the Gilarlo Reservoir Dam (located in northeast of Iran) was in mesotrophic and eutrophic state during the August and October, respectively. The main factor of water quality reduction in the Gilarlo Dam associated to the water mixing process. Shamlou et al. (2004) also expressed that the water overturn and subsequently resuspend of the precipitates from the dam bed can result in increasing algal growth and eutrophication²⁹. Our results were not similar to the Shamlou et al. study. This can be resulted from the sediment removal (dredging) in the Ekbatan Reservoir that had been carried out one year before our study. Dredging the dam can lead to remove the sludge containing the nutrients. Therefore, the nutrients concentration of the water was not increased during water overturn. With regard to N/P ratio of 10/1, the limiting factor of eutrophication in the Ekbatan Dam was found phosphorus. Our results were corresponded to the Parham et al. study³⁰.

With regard to the data obtained from Carlson's, Chapra's and Vollen Weider's index, the Ekbatan Reservoir in the most of sampling months and locations was in the dangerous trophic state. As seen from the above mentioned tables (Results section), the phosphorus content in the reservoir water was the most important factor of the eutrophication. Application of the management strategies are required to decrease this problem. Therefore, it is essential that the educational and cultural plans must have been provided by the associated organizations to farmers and orchardists in order to correct use of phosphate chemical fertilizers and pesticides. Other management procedures including water filtration at inlet of the reservoir (e.g. planting the straws), avoid the discharge of untreated wastewaters into the rivers, fish harvesting (to diminish the algal biomass and chlorophyll), artificial mixing, sediment removal, hypolimnetic water disposal and lake

flushing are also proposed to reduce the nutrients in the dam^{8,31,32}. It is expected that these methods successfully lead to reduce the suspended solids, phosphorus and nitrogen of the dam. These solutions must be conducted and monitored in long-term by regular management.

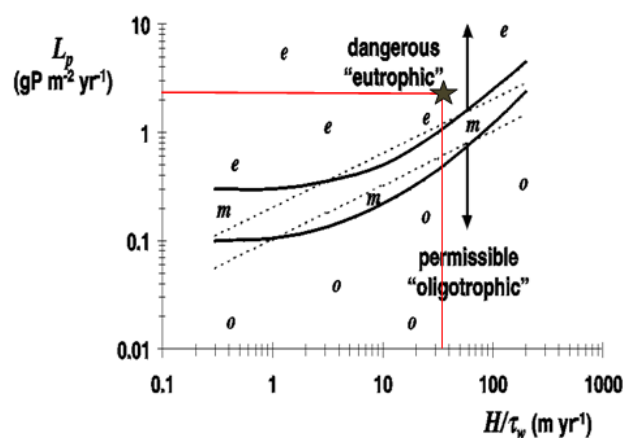


Figure 4: The trophic state of the reservoir according to Vollen Weider's diagram¹⁷

Conclusions

The condition of the reservoir in the most sampling months was in eutrophic and hypertrophic state. The concentration of the nutrients at sampling stations No. 6 and No. 7 (inlet branches of the lake) was higher than center and outlet of the reservoir. With regards that there was no industrial area in the watershed to enter the phosphorus and nitrogen into the dam; it seems that the rural and agricultural wastewaters were the main reason of eutrophication process in the lake. Therefore, using long term management methods above mentioned are recommended for decrease the eutrophication in the dam. Diminish the phosphorus concentration to the 50% of present content in the reservoir can result in convert the eutrophic state to mesotrophic state.

Acknowledgments

The authors thank the Regional Water Organization and Water and Wastewater Organization of Hamadan for cooperation in this study.

Conflict of interest statement

There was no conflict of interest in this paper.

Funding

This study was a part of MSc thesis, Grant No. 162393, and supported by the Vice Chancellery for Research of Hamadan University of Medical Sciences, Iran.

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