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Evaluation of Eutrophication Levels in Al-Najaf Al-Ashraf Lake, Iraq (Biological and Chemical study)

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K E Y W O R D S

Eutrophication; Carlson trophic state index (CTSI); trophic state index (TSI); Total nitrogen (TN); Total phosphorus (TP); Geographical information system (GIS).

A B S T R A C T

Within Al-Najaf lake, that is one of the important shallow lakes in Iraq, the lake facing tremendous pressure due to encroachments, discharge of untreated domestic and industrial waste, drainage water from cultivated orchards, dumping of solid waste and illegal diversion of water and currently it's still suffering from these problems and neglect. The study aimed to evaluate the eutrophication status. Eutrophication is a grave problem in lakes, a knowledge about the eutrophic state help in providing a make efficient realization of the eutrophic problem.

This study conducted to assess the Eutrophication level with a scale 0 – 100 depending on the trophic state index (TSI) and (CTSI) calculation by measuring (Chl-a), (TP), (TN) and (TSS), also measured the parameters (Tw), (Pb), (TDS), (pH), (EC), (MPN) and (COD). The least significant difference (LSD) and ANOVA analysis were performed by using the Genstat statistical program. Lake can be classified according to the Carlson index as eutrophic (CTSI > 80) most hegemony of blue-green algae, extensive macrophyte troubles. Adding, according to Trophic State Index classification (TSItotal was ranged between 88.104-89.49 depending on TP, TSS, TN, P/N and Chl-a concentrations), were classified as the lake as extremely hypereutrophic and algal scums.

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1. INTRODUCTION

Eutrophication is an accelerated growth of algae on higher forms of plant life caused by the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus and inducing an undesirable disturbance [1]. Eutrophication takes into consideration a serious dilemma in the water of the Al-Najaf lake. Knowledge about of the eutrophic status help in providing a make efficient realization to eutrophic in the lake, classification trophic level help to know extent water pollution, and is defined as turbidity in the water of the lakes and decline of (light permeability and dissolved oxygen) a result of the outright increase of several microorganisms, especially Protista that included chlorophyll-a, which are enriched by nutrients (nutrient salts) released into the environment by human activities (man-made, artificial, or cultural eutrophication) [2]. This situation causes deterioration in fineness of water that affects to harm aquatic life forms in the lake. Since the 1960-70's many studies have been made to determine eutrophic state levels [1]. Therefore, studies should be pursued to determine the water quality of the lake, especially as the status of the water in it changes according to human activities in the lake region and the quantity of rainfall and water level.

Al-Najaf lake is a depressing territory, it's a composed of a lake or marsh-like area with restricted cultivated orchards, it enclitic by vast desert or semi-desert areas. Al-Najaf lake lies in the north west-south east orientation, area of the lake about 360-750 km2 (longitude 43? 40 - 44? 25 E and latitude 31? 40 - 32? 10 N) while it is raises nearly 11msl [3].

The lake is also an important tourist region, but the authorities concerned banned the use of boats for tourism within the lake to maintain the security of the lake and protect the Al-Najaf governorate from the threat of terrorism, addition Al-Najaf lake can be considered a station for a number of migratory birds. Al-Najaf lake is a refuge for an ample variety of flora and fauna, chiefly the immigrant fowl and the rare. Figure. 1 illustrated the location of Al-Najaf lake (longitude and latitude of the lake) and its geographical location in Al-Najaf Governorate plotted by the program geographic information system (GIS).

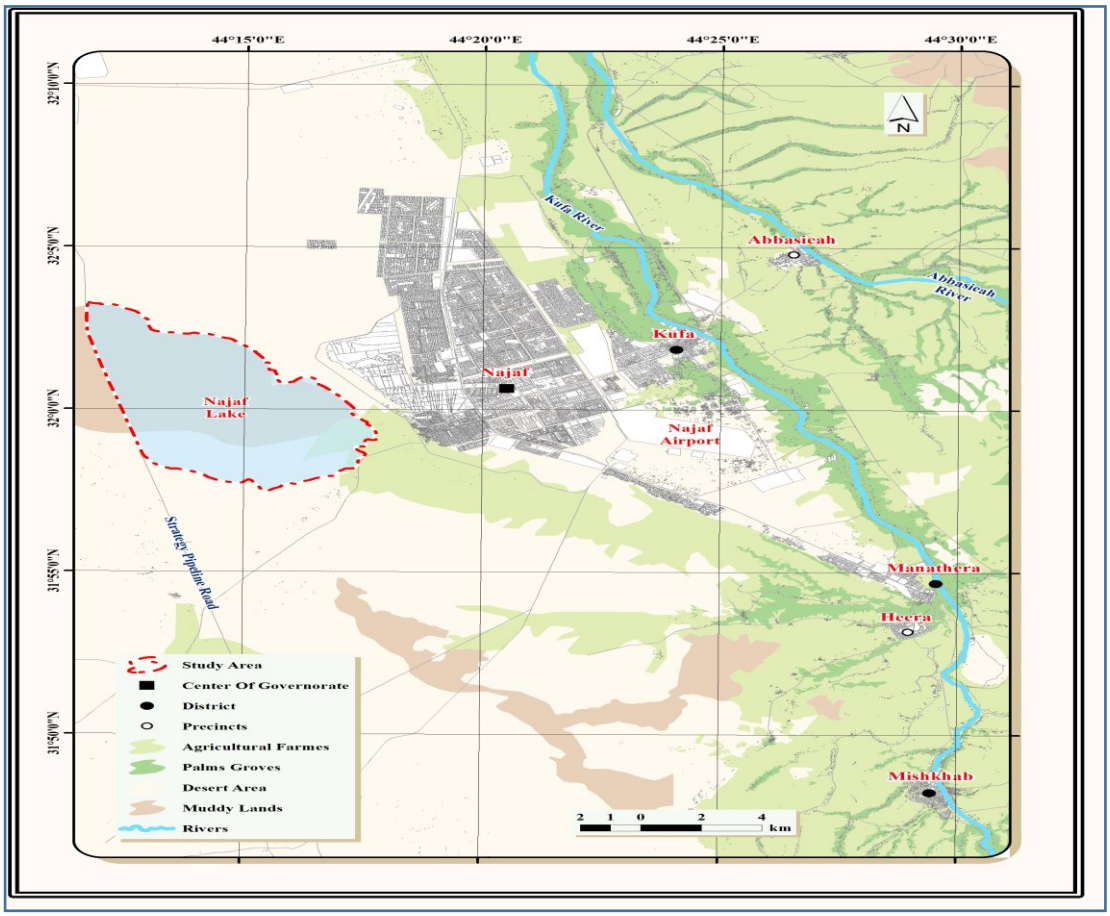


Figure 1: GIS map illustrated the location of Al-Najaf lake

Eutrophication status in AL-Najaf lake was assessed during the period (December 2018 to March 2019) by measuring a number of physical, chemical, and microbiological parameters which are important in determining water quality and evaluated eutrophication of the lake, this includes water temperature (Tw), chlorophyll-a (Chl-a), total phosphorus (TP), total nitrogen (TN), lead (Pb), total suspended solids (TSS), total dissolved solids (TDS), hydrogen ion concentration (pH), electrical conductivity (EC), most probable number (MPN) and chemical oxygen demand (COD), these parameters were related together statistically by using Genstat statistical program.

2. MATERIALS AND METHODS

In advance, the steps of the program were drawn up as the ultimate goal for tested relationships, hypotheses, forecasts, analytical methods, and accuracy required, the definition of the target group, characterization of the sampling unit, development of a sampling framework, According to [4]. To be able to draw an accurate picture of the monitoring status of eutrophication and observe the temporal and spatial changes of the lake during the study period, seven monitoring sites were chosen in Al-Najaf lake as shown in Figure, 2.

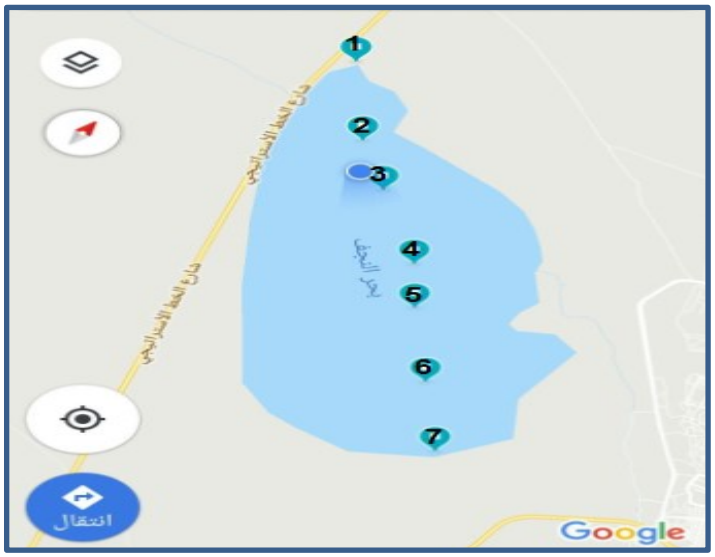


Figure 2: Geographical location of seven sampling stations in the Al-Najaf lake from Google Erath.

It is important to keep in mind that algae uptake of nutrients is greatest during the productive summer era, causing lower nutrient concentrations; therefore, the decisive concentrations of nutrients should be measured during the winter or spring era. So that samples were collected at a weekly rate during the study period (for two seasons), winter and spring by using a boat to obtain two samples from two depths, the first is a superficial sample at a depth of 10 cm and the second at a depth of at least 50 cm at the middle of the lake approximately, from seven stations in the lake to the purpose of measure the parameters; (Tw), (Chl-a), (TP), (TN), (Pb), (TSS), (TDS), (pH), (EC), (MPN) and (COD), with different methods and tools depending on the type of the sample and the purpose of it, and all vials carry identification numbers for the sample inside it, and it had been sent to the examination and testing centers. The physical and chemical tests were conducted in two stages, the first stage of sampling directly measured in the field such as water temperature and pH. The second stage in a laboratory where the parameters were examined in the laboratories University of Kufa/ College of Agriculture/ Department of Soil Chemistry Sciences, and laboratories Environmental Directorate of Al-Najaf Governorate / Division of Environmental Analysis, and laboratories Environmental Research Center / University of Technology, were analyzed according to procedures given by [4].

Carlson index [5] was used to the classified level of trophic in the lake, calculated trophic state index (TSI) by using the subsequent Equations [6]:

$$(\text{TSI}) \text{ for } (\text{Chl-a}) = (9.81^* \text{ Ln } (\text{Chl-a})) + 30.6 \quad (1)$$

$$(\text{TSI}) \text{ for } (\text{SD}) = 60 - (14.41^* \text{ Ln } (\text{SD})). \quad (2)$$

$$(\text{TSI}) \text{ for } (\text{Tp}) = (14.42 * \text{Ln } (\text{TP})) + 4.15. \quad (3)$$

$$\text{Carlson's Trophic Status Index } (\text{CTSI}) = \text{average of the total TSI(TP)+TSI(Chl-a)+TSI(SD).} \quad (4)$$

Chl-a: Chlorophyll-a, µg/l

SD: Secchi disk, m.

Tp: Total phosphorous, µg/l.

Furthermore, each parameter was measured appraisal based on the obtainable thresholds for eutrophication of lakes belonging to Japan's [7] and China's ambiance [8]. The standards can display in Table 1.

TABLE I: Standard of the trophic index. (trophic state index) for TSS, TN, and Chl-a parameters.

Water body class (TSI range (unit less))	TSS (mg/l)	TN (mg/l)	Chl-a (µg/l)	TSI
Oligotrophic (0-30)	0.04	0.01	0.1	0
	0.09	0.02	0.26	10
	0.23	0.04	0.66	20
	0.55	0.079	1.6	30
Lower-meso trophic (30-40)	1.3	0.16	4.1	40
Mesotrophic (40-50)	2.1	0.31	10	50
Upper-meso trophic (50-60)	7.7	0.65	26	60
Eutrophic (60-70)	19	1.2	64	70
Hyper eutrophic (70-80)	45	2.3	160	80
Extremely hyper eutrophic (80-100)	108	4.6	400	90
	260	9.1	1000	100

TSI values for P/N and TP were calculated by Equation (5) and Equation (6), respectively [9].

$$\text{TSI(P/N)} = 9.81 \text{ Ln } (10)\text{P/N} + 30.6 \quad (5)$$

$$\text{TSI(TP)} = 4.15 + 14.42 \text{ (Ln (TP))} \quad (6)$$

P/N: phosphorus/nitrogen concentration, mg /l.

Tp: Total phosphorous, mg /l.

Eventually, Eq. (7) and Eq. (8) were used to compute eutrophication index for all parameters of the trophic state [1].

$$\text{TSI}_i = ((\text{TSI}_{i,\,k-1}) + |(C_i\text{-}S_{i,\,k-1}) \,/\, (S_{i,\,k}\text{-}S_{i,\,k-1})| \times (\text{TSI}_{i,\,k} - \text{TSI}_{i,\,k-1})) \quad (7)$$

$$\text{TSI}_{\text{total}} = \Sigma \text{TSI}_i \times W_i \quad (8)$$

Where, $\text{TSI}_{i,\,k}$ and $\text{TSI}_{i,\,k-1}$ are the k-th and (k−1) th levels of the i-th indicator; and $S_{i,\,k}$ and $S_{i,\,k-1}$ are assessment standards of the k-th and (k−1) th levels of the i-th indicator. C_i represents the concentration of i-th indicator including TN, TSS and Chl-a; $\text{TSI}_{\text{total}}$ is the calculated total trophic level, W value was considered as 1/n for each parameter, where n is the number of employed parameters.

In the management of surface water resources, eutrophication status is considered as the farthest substantial issue that impacts the quality of water in lakes [10]. The excrescent input of nutrients (such as total nitrogen and total phosphorus) to the water of the lake leads to the increment biomass growth of the prime producers [11], thence causes numerous troubles like shortage in water dissolved oxygen and water fineness, in addition, to release an odor and bad taste. These conditions

and deterioration of the water state lead to the demise of fish or reduce their kinds to one type of fish, which tolerates saltwater of the Al-Najaf lake and resulting pernicious impacts on human and animal health. The job of phosphorus and its effects has been studied by [12]. Reference [13] indicated that a pronounced decrease in Secchi's depth transparency with the increase in phosphorus and chlorophyll-a concentrations

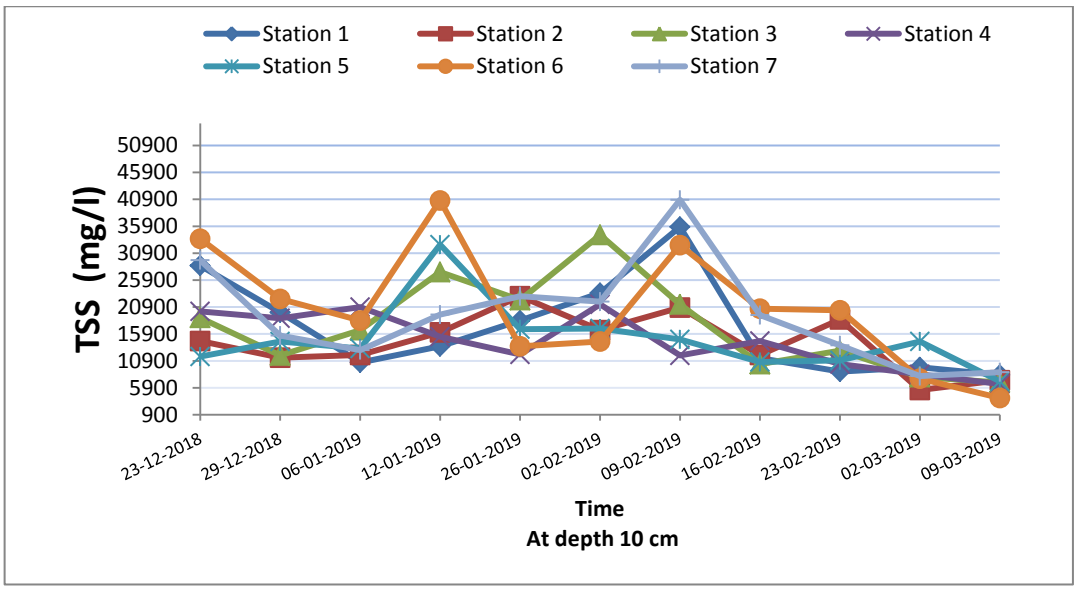
3. RESULTS AND DISSECTION

During the last years close to the present time, the number of studies touching eutrophication status in the water of lakes has increased in Iraq and evaluated according to many classifications. The study of Al-Najaf lake for the trophic status in water to record and evaluate the temporary variation (according to seasons as a result of successive dilution and evaporation) and locative variation (by dividing Al-Najaf lake into seven portions) to calculate the eutrophic status index via determining the class and level of eutrophic, through physical, chemical and biological analysis to the water of the lake. Furthermore, the results recovered from this study of the Al-Najaf lake to the observed seasonal variation of the parameters that calculated. The trophic state index value was calculated for chlorophyll-a (Chl-a), and trophic state index for total phosphorus (TP) with trophic state index for (TSS). Were there some spatial and temporal differences for TSI of the lake. Al-Najaf lake classifies as extremely hypereutrophic and algal scum condition. The maximum, minimum and average of physiochemical parameters with (± standard deviation) for station seven, at 50 cm depth were: 10-27 (16.5) ±4.16, 21000- 73000 (55427.27) ±18567.28, 20200-79900(42718.18) ±22702.85, 3-28.7 (11.57) ±9.88, 0.018-0.283 0.0969) ±0.0935, 0.52-5.56 (2.41) ±1.85, 7.31-8.63 (7.93) ±0.45, 4600 - 84800 (30663.63) ±27027.47, 114 - 154 (130.63) ±12.73, 0.17 - 0.38 (0.2963) ±0.0721, for parameters Tw(C°), EC (µs/cm), TDS (mg/l), TN(mg/l), pb(mg/l), TP(mg/l), pH, TSS(mg/l), COD (mg/l) and Chl-a (mg/l) respectively. According to the value of parameters that were measured, the worst condition was observed at stations 6 and 7 because of the entry of the Al- Bedeiryi River carries muds and salts that it transports during its passage in the semi-desert areas and then the agricultural areas near the lake. Also, that river carries untreated sewage with it from Al-Najaf City, which is thrown into the river (where the water was turned gray). In addition to the Ghazi River and Abu Jadoua, which also carries muds and salts and drainage water from the orchards and agricultural land near the lake as the main input for the lake. Moreover, there was a movement of groundwater towards the lake because it is located in a very low area compared to the lands around it and this groundwater reaches very high levels that reach the dumping of residential areas near the lake.

To evaluate the state eutrophication of Al-Najaf lake, TSI calculated by utilizing the results gained along with the duration of the study through the laboratory analysis of the parameters. Figure 3 illustrates diagram parameters average reading measured according to stations and the time of the test, and the values above the limits.

Water state parameter maps of the Al-Najaf lake were plotted by using the Arc GIS method. Figure 4 provides an obvious picture of the values of readings for the various parameters obtained during the study period of the lake by using Arc GIS.

Precipitation on the depressed area where the lake located, considered an important exporter of surface water and groundwater in the district. Results show a high increase in EC values to 73900 (µs/cm), and TDS values to 79900 (mg/l) in December 2018, the lower value pH to 6.7 in January 2019 when increased to 8.91in February while COD, Pb TN, TP, TSS values reached a maximum in January. This indicates the occurrence of organic pollution and a decline in the healthy quality of the Al-Najaf lake. Increasing temperature lead to depletion in oxygen concentration, then results in higher phosphorus concentration (TP) in the water [14]. Reference [15], indicated that the onset of increasing biological activity in spring triggered the release of some of the phosphorus retained during the winter. Accordingly, it was noticed that TP increased during winter while it decreased in the spring because of the fast-growing of producers in addition to increasing productivity. The highest values of TSI based on total phosphorus concentration were recorded in winter, while the lowest values were in spring. These results agree with those of [16] for shallow water, and that agrees with [12]. It should be noted that the eutrophication state is closely related to photosynthesis, which is the active force for seasonal variation of several physiochemical parameters and biotic activity [17].



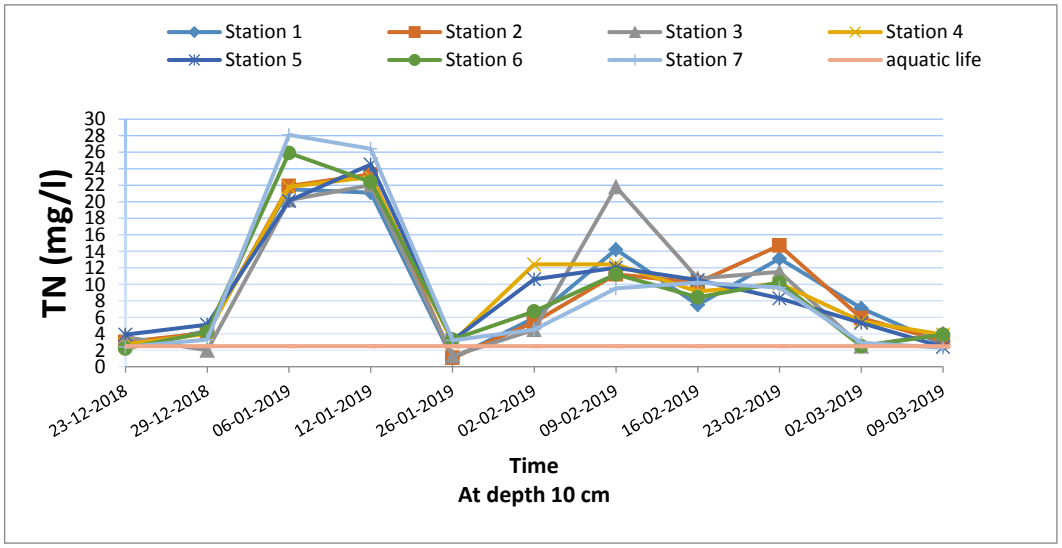
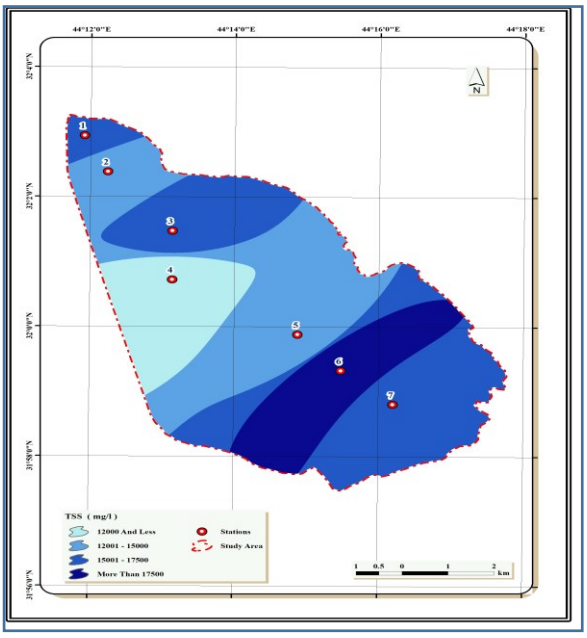
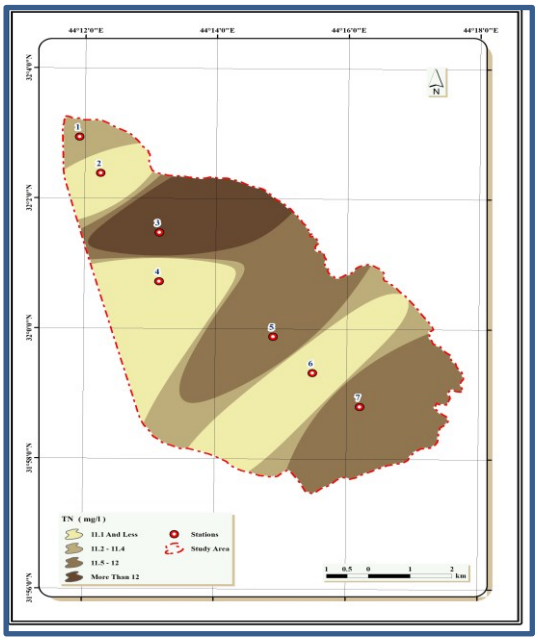


Figure 3: The average values TSS and TN respectively of water sampling stations in Al-Najaf lake.





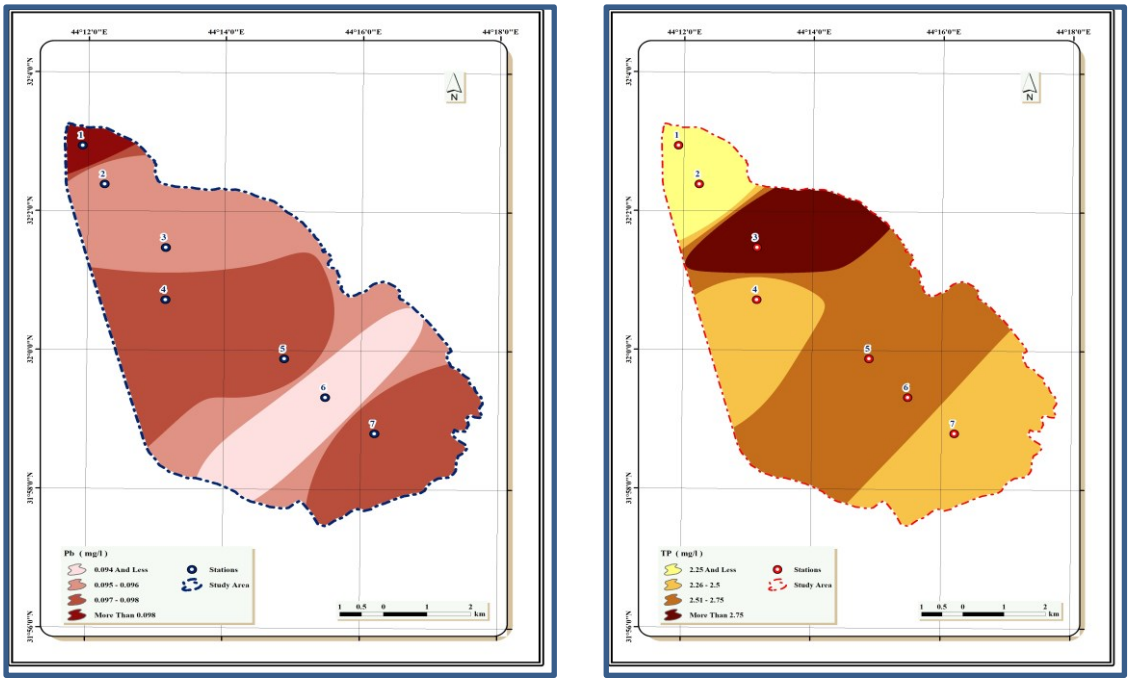


Figure 4: Spatial distribution of the average values TSS, TN, Pb and TP respectively of water sampling stations in Al-Najaf lake.

According to the results of the Al-Najaf lake, can be classified as eutrophic (by calculating Carlson eutrophication index) with algal scum, summer fish kills, few macrophytes, extensive macrophyte problems. Besides, the valuation of each parameter was carried out based on the useable frontiers for eutrophication of the lakes associated with Japan's [7] together with China's environment [8]. Standards are visible in table Table1, thus calculated the trophic state index for (TP), (Chl-a), and (TSS) to the lake, therefore the lake classifies as extremely hypereutrophic and algal scums.

4. CONCLUSIONS

The results acquired from the current study evidenced:

1) Dilapidation of water state and occurrence of eutrophication in Al-Najaf lake.
2) Some temporal and spatial mutation was observed for TSI value in the seven stations of the Al-Najaf lake.
3) Depending on maximum and minimum values of parameters (observed in winter season and spring season), the increased value of TSS consequent of dilution process by rainfall as well as the increasing water level of input rivers, especially it received drainage water from agricultural lands surrounding the lake, that had a great effect on the trophic state index (TSI) value during the spring season.
4) The substantial parameter in deciding the trophic status of the lake was total phosphorus concentration.
5) Considering the locative variation, the worst zone in the lake was observed at stations that close to the paramount input to the lake, (one of the provenances of pollution the lake).
6) LSD and ANOVA analysis results showed that there was no significant difference between the parameters during the same week. But there is a significant difference between the weeks. This confirms the validity of laboratory values for the measured parameters.
7) Concentration of nutrients in Al-Najaf lake was high as compared to the critical values as a function of both natural and epidermal activities such as agriculture, on top of that deterioration of the fed rivers.
8) The results showed Al-Najaf lake can be classified as eutrophic with algal scum, summer fish kills, few macrophytes, extensive macrophyte problems while the value of the trophic state index (CTSI) > 80. Moreover, the assessment of each parameter was performed based on the trophic state index classification for eutrophication.

9) Results of TSI were ranged between 88.104 to 89.485, thus can be classified Al-Najaf lake as extremely hypereutrophic and algal scums (80-100).

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