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# Monitoring Pollution Indicators of the Water of the Tigris River in Tikrit and its Suburbs

**Ibrahim Abed Alwan[1], Ibrahim Omar Saeed[2, *], Mohammed ghadban Farhan[3]**
Department of Biology, College of Science, Tikrit University, Iraq
[*]**Corresponding Author: dr.ibrahim1977@tu.edu.iq**

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**ABSTRACT**

The current study involved measuring the physical and chemical characteristics of the water of the Tigris River in Tikrit and its suburbs at five different sites for a period of six months. The results indicated significant variations across the study sites: turbidity ranged from 8,437 to 16,301NTU; conductivity from 191,833 to 202.38µS/ cm; TDS from 382.77 to 412,944mg/ L, and pH from 6.040 to 6.493. Dissolved oxygen levels ranged between 9.300 and 11.53mg/ L, while biological oxygen demand varied from 2,922 to 4,016mg/ L, and total alkalinity ranged from 56,888 to 62,444mg/ L. Total hardness of the water at the sites ranged from 80,167 to 91,056mg/ L, calcium hardness from 59,222 to 64,778mg/ L, and magnesium hardness from 17,611 to 30,722mg/ L. Furthermore, phosphate concentrations ranged from 3,339 to 3,449µg of phosphate atom/ L, and silica concentrations from 3.40 to 4.58µg/ L.While nitrite values ranged from 0.467 to 0.477µg of nitrogen atom/ L. The results for monthly changes showed that the turbidity values were 4,278 to 24,644NUT, and the pH values were 5,469 to 7,250, while the dissolved oxygen values were 8.86 to 11.24mg/ L, and the biological oxygen demand value was 3,500 to 3,826mg/ L. Moreover, the results showed that the total hardness values ranged from 71,733 to 113,200mg/ L, and phosphate values ranged from 2,998 to 4,808µg of phosphate atom/ L, while nitrite values ranged from 0.454 to 0.532µg of nitrogen atom/ L.

## INTRODUCTION

Water is one of the most essential and valuable natural resources on Earth. It is considered the most important factor on which human life depends in various activities and fields. Its significance lies in its continual renewal through the hydrological cycle, and it is considered of a high importance on the Earth due to its distinction from other natural resources **(Shambara, 2021)**. All living organisms depend on water for all their activities, and wherever there is water, there is life. Seas and oceans constitute the main reservoir for water, and 97.2% of the total water is in the form of salt water. Fresh water constitutes about 2.8% of the total water on the surface of the Earth; glaciers constitute the majority of the water in the polar regions, and groundwater constitutes 97%, while lakes, rivers, and the atmosphere constitute 0.3% of fresh water **(Al-Saadi *et al*., 2000)**. The most prominent and important problem that humans face is the problem of environmental pollution, especially in third world countries. The reason for this is the lack of interest and focus on environmental issues, and when we look at Iraq and the crises, wars and difficult circumstances that the country has gone through, such as the lack of services, which led to the accumulation of waste in large quantities and types of waste- industrial, agricultural, and civil. Consequently, this waste which is carried away by floods and rainwater in addition to the discharge of commercial, industrial, civil and municipal waste into surface water and its entry into groundwater **(Al-Safawi, 2007)**. The chaos led some citizens to throw away the water from their homes' septic tanks into vertical sewers, causing the transmission of epidemics and diseases **(Al-Mandeel *et al*., 2024)**. Furthermore, the untreated discharge of industrial, civil and agricultural wastewater into the river causes major pollution to the river. There are large quantities of waste thrown into the Tigris River, and this waste causes several damages and problems, the most important of which is the emission of unpleasant odors and distorting the aesthetics of the river banks **(Al-Saffawi & Al-Taie, 2013)**. Consequently, it led to the deterioration and decline of the physical, chemical and biological properties of water, leading to its inability to eliminate or reduce these pollutants during the self-purification process. This is considered the main reason that makes the water degraded, polluted, and unfit for various uses, which led to a decrease in the level of potable water **(Mahmood *et al*., 2021)**. Therefore, public opinion monitored indicators that designate high rates of pollution and low levels of water **(Al-Saffawi, 2018)**. Hence, today the issue of environmental pollution, especially water pollution, is considered one of the most important problems that the entire world is concerned about, and it must be dealt with, with the greatest responsibility, due to the relationship of this issue to the existence of man and his economic and health condition **(AL Shanona *et al*., 2020)**. Owing to the limited studies on the Tigris River in the city of Tikrit, this study was conducted on the Tigris River.

## MATERIALS AND METHODS

### 1. Description of the study area and selected sites

The study period lasted six months, starting from October 2022 until March 2023. The process of collecting water samples began in the morning for the six sites (Fig. 1) at a rate of once a month, and began from October 2022 until the end of March 2023. The bottles were directly filled with river water with as little air space as possible to preserve the physical and chemical properties of the sample water during transportation and to perform physical and chemical tests.

#### *1.1 First site (st1)*

It is located between the University of Tikrit and the village of Al-Fandi on the left side of the river. This site is considered the control for the study area, since this site is the beginning of the entry of the waters of the Tigris River into the city of Tikrit. A lot of waste and dirt are concentrated on the edges of the river from the direction of the village of Al-Fandi since the area is considered a place of entertainment for families from nearby areas.

***1.2 Second site (st2)***

It is located between the Al-Qadisiyah area and the Al-Dibsah area. It differs from the first site in that it has trees concentrated on both sides of the banks of the Tigris River, which led to the inability of families to reach this site and it is far from the first site.

***1.3 Third site (st3)***

It is located between the presidential palaces and Al-Karaaat area under the Tikrit Bridge. It is a center linking the city of Tikrit, Al-Alam District, and other districts. Water pumps that supply tanker cars with water are concentrated in this site in addition to the residents using this site for swimming and entertainment since it is a place for families to gather.

***1.4 Fourth site (st4)***

It is located between the city of Tikrit and Al-Bu Ajil area. This site is bordered by mountains from the direction of the city of Tikrit and dense trees from Al-Bu Ajil area. This prevents residents from reaching this site. This site is some distance away from the third site.

***1.5 Fifth site (st5)***

This site is located at Al-Dour – Al-Auja crossing and is considered a tourist promenade for the neighboring areas, where large trees and green spaces are spread, and pollutants thrown away by residents are concentrated. It is considered an entertainment place for families and is a distance away from the fourth site.

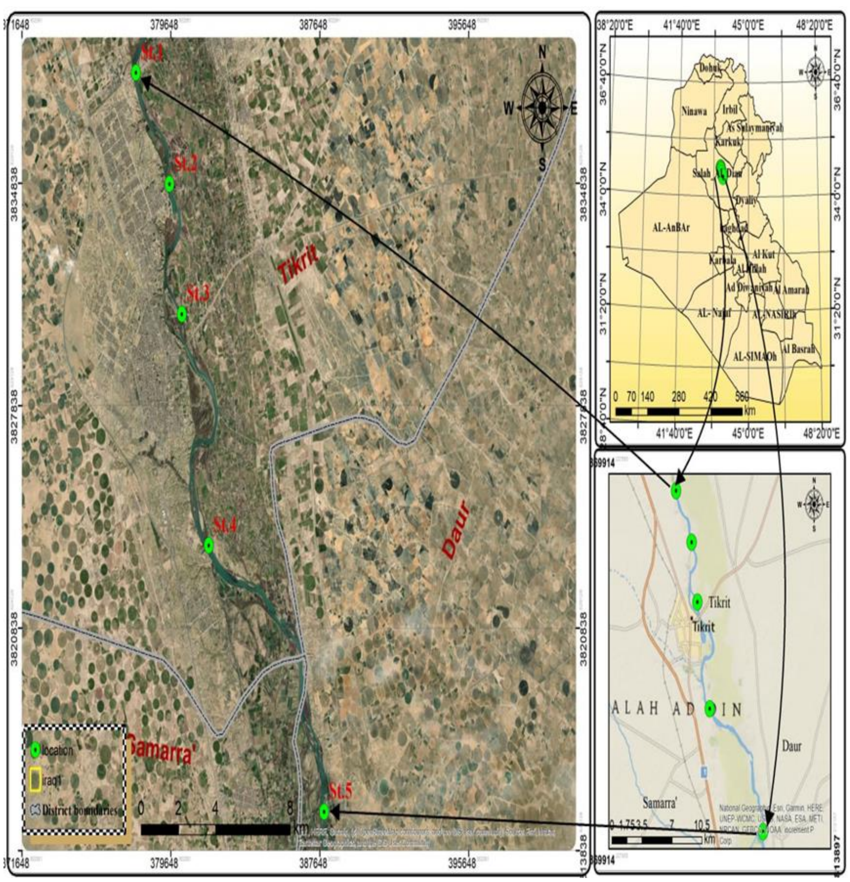


**Fig. 1.** Tigris River sites under study

All parameters were determined in the laboratory following the standards of the American Public Health Association **(APHA, 2007)**. Samples were analyzed for 11 parameters: electrical conductivity (EC), dissolved oxygen (DO), turbidity, pH, chloride (Cl-), sulfate (SO4-2), total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), chemical oxygen demand (COD), orthophosphate (PO4-3), total hardness (TH), calcium hardness (Ca H.), and magnesium hardness (Mg H.).

## 2. Physical and chemical tests

### *2.1 Physical tests*

#### 2.1.1 Turbidity

In the laboratory, the turbidity was directly measured upon arrival using a device (Turbidity meter), which indicates the amount of turbidity measured in (NTU) unit. The samples were shaken well until the sample was mixed, then the measuring cell was filled to the mark marked on it, taking into consideration the absence of bubbles and the stability of the device, in addition to wiping the measuring cell with a clean cloth so as not to leave any fingerprints.

#### 2.1.2 Electrical conductivity

The ability of water to transmit an electrical current was recorded using a conductivity meter, type Oyster, which was calibrated before use with distilled water, by measuring the electrical conductivity of the samples at a rate of three readings in terms of µmhos/ cm.

#### 2.1.3 Total dissolved solids

The dissolved solids of the samples were measured using a T.D.S meter, after calibrating it before use, with an average of three readings for each sample in mg/ L.

### *2.2 Chemical characters*

#### 2.2.1 pH

A CE CONSORT 830 multi-parameter analyzer device made by Belgium was used to measure the pH after calibrating it with buffer solutions (4, 7, 9) at the beginning of each measurement **(APHA, 1999)**.

#### 2.2.2 Dissolved oxygen (D.O) and the biological oxygen demand ($BOD_5$)

The Winkler method was used for dark and light bottles. Oxygen bottles with a size of 250ml were filled by immersing them in water, and the sample was fixed in the field by adding 2ml of manganese sulphate and shaking it two or more times to mix the sample properly, then adding 2ml of basic potassium iodide, the sample was also shaken well. After 10 minutes, 2ml of concentrated sulfuric acid was added to stabilize the dissolved oxygen. 50ml of the fixed sample was taken and titrated with 0.025N sodium thiosulphate with the addition of drops of starch as a reagent. An average of two readings was taken, and the results were expressed as mg/ L of oxygen according to the method of **Lind (1979)** and described in **APHA (1999)**.

#### 2.2.3 Biochemical oxygen demand

The biochemical oxygen demand was calculated using the dissolved oxygen measurement method, after placing the unfixed and opaque bottles at 25°C for five days, then determining the dissolved oxygen (DO5) and expressing it in mg/ L as stated in **APHA (2017)**, according to the following equation:

$BOD_5$ = DO1 – DO5 mg/l

### 2.2.4 Total alkalinity

Total alkalinity was determined according to the method described by **APHA (2017)**, and the results were expressed in mg/ L in terms of $CaCO_3$. An amount of 50ml of the sample was taken, and 3 drops of methyl orange indicator were added to it and titrated with 0.02N sulfuric acid until the color changed to reddish-orange, and an average of three readings was taken. The total alkalinity was calculated according to the equation:

Total Alkalinity mg/L = V × N × 1000 × eq.wt of $CaCO_3$/ V Sample

Where:

V = Volume of the solution

N = Normality of solution

eq.wt = Equivalent weight of calcium carbonate

### 2.2.5 Total hardness

The total hardness was measured by taking a volume of 50ml of sample water and titrating it with the standard 0.01N NazEDTA solution after raising the pH of the sample to 10 by adding 1ml of ammonia buffer solution and an appropriate amount of dry Erichrom Black-T indicator powder until the color changed to blue and taking an average of two readings. The total hardness was calculated following the method of **APHA (2017)**, according to the following equation:

V × N × 1000 × Mole - Wt T.H as $CaCO_3$ - V Sample

Since:

V = Volume of $Na_2$ EDTA titrated standard solution

N = Normality of $Na_2$ EDTA standard solution

Mole-wt = Molecular weight of $CaCO_3$

### 2.2.6 Hardness of calcium

The hardness of calcium was determined by taking a volume of 50ml of sample water and titrating it with the standard 0.01N NazEDTA solution after raising the pH level from 13- 14 by adding 2ml of 0.1N sodium hydroxide and using 0.2g Murexide dry powder as a reagent until the color changed from light pink to light violet **(APHA, 2017)**.

V × N × 1000 × Mole - Wt Ca.H as $CaCO_3$= V Sample

V = Volume of $Na_2$EDTA titrated standard solution

N = Normality of $Na_2$ EDTA standard solution

Mole-wt = Molecular weight of $CaCO_3$

### 2.2.7 Hardness of magnesium

Magnesium hardness was mathematically recorded since it was estimated by the difference between total hardness and calcium hardness, as stated in the following relationship:

Mg Hardness mg/L= (Total Hardness mg/L - Hardness of Ca)

## 3. Nutrients

### *3.1 Reactive phosphate*

Reactive phosphate was measured based on the method published by **Strickl and Parsons (1972)**. A known volume of the sample, amounting to 100ml, was taken and 10ml of the mixed reagent prepared was directly added to it no later than 6 hours after the addition. It will be observed that the color changed to blue and that the intensity of the color was proportional to the phosphate concentration. After two hours, the samples were read using a spectrophotometer UV-9200 at a wavelength of 885nm, after zeroing the device and stabilizing the reading in the prepared blank, the results were expressed in terms of µg/ L.

Phosphate was calculated according to the following equation:

$PO_4 = ABS \times F$

Since F is a constant and equals 3.00

F = E Standard – E Blank

### *3.2 Nitrite*

Nitrite was measured based on the method published by **Strickland and Parsons (1972)**, where a volume of 25ml of the sample was taken, and 1ml of sulphanilamid solution was added to it while stirring. After 2- 8 minutes had passed, 1ml of N(1-Naphtyl)-Ethylenediamine dihydrochloride solution, mixed well and left for no less than 10 minutes. The intensity of the pink color was proportional to the nitrite concentration. The nitrite concentration of the samples was measured using a spectrophotometer UV-9200. At a wavelength of 543nm, the blanck value was first read to reset the device, then the samples were read, and the concentrations were recorded; the results were expressed in µg/ L. Nitrates were calculated according to the following equation:

$NO_2 = ABS \times A$

Where, A represents the dilution rate

## RESULTS AND DISCUSSION

### Physical and chemical tests

### - Turbidity (NTU) and pH

The results of Tables (1, 2) and Figs. (1, 2) indicate the presence of monthly variations in the values under study, as the highest values for the characteristics of turbidity and pH coincided with the values recorded during the month of December, reaching 7.099, 24.644mg/L, and the lowest value was for the months of March and

December, reaching 4.278, 5.469NTU, respectively. As for the sites, we noticed that the turbidity and pH values increase when the river enters the city due to the liquid waste excreted through the outfalls, which has an impact on the turbidity values in the water. Turbidity also increases when rain falls in large quantities, leading to surface runoff from the soil and its arrival into the river **(Wolde *et al*., 2020)**. The reason for the variation in pH value from one site to another is due to the rainfall and subsequent dissolved materials and torrents and their transfer to the water, which leads to a rise and fall in the pH **(Najeeb & Saeed, 2023)**. As for the rates for the months and sites, they reached 6.256, 8.887NTU for the months and 6.2223, 12.994 for the sites.

**- Electrical conductivity (EC) and total dissolved salts (TDS)**

Tables (1, 2) and Figs. (2, 3) show that the monthly rates of electrical conductivity values and dissolved solids of the Tigris River water ranged between 197.230, 382.296µmhos/ cm and mg/ L, respectively, where the variation began to increase in the third site and due to the huge amount of civil and industrial waste in this site, and the decrease in the fifth site. The results were close to the results reached by **Al-Iraqi *et al*. (2013)**, when they conducted a statistical analytical study of the water of the Tigris River, where the electrical conductivity values ranged between 337.00- 339.00µS/ cm, and total dissolved solids ranged between 196.00- 198.00, while the rates for electrical conductivity values and total dissolved solids of the Tigris River water ranged between 197.230- 397.166µS/ cm and mg/ L. During this study, it was observed that the electrical conductivity value decreased during the summer and increased during the winter. The reason may be due to the increase in liquid discharges into the river, i.e. a decrease in the dilution factor. These results are consistent with the findings of **Al-Ni'ma *et al*. (2013)**.

**- Dissolved oxygen DO and biological oxygen demand $BOD_5$**

The results in Tables (1, 2) and Figs. (4, 5) indicate that the values of DO and $BOD_5$ for the Tigris River water ranged between 9.300- 11.583mg/ L and 4.016- 2.922, respectively, with the lowest values recorded at 9.300 and 2.922mg/ L in January and October, and the highest value was 11.583 and 4.016mg/ L in November and October, respectively. Since the relationship between DO and $BOD_5$ is an inverse relationship, we noticed from Table (2) that in the fifth site there is a decrease in the values of DO and an increase in $BOD_5$ for the same site; the reason may be due to the pollutants that are thrown away by the residents since it is considered an entertainment place for families, and this is consistent with the findings in numerous studies such as **Mahmood and Saeed (2023)**. For the rates for months and sites, they reached the value of 3.703, 10.145 for the months and 3.703, 10.143 for the sites.

**Total alkalinity, total hardness, calcium, and magnesium**

The results of the current study at the Tigris River water site showed that, the values of total alkalinity ranged between 19.333- 84.266mg/ L. Tables (1, 2) and Figs. (6, 7) exhibit that the lowest value was recorded at 19.333mg/ L, and the highest value was recorded (84.266 mg/ L) in the months of October and January, respectively. It was found that the alkalinity values were low at the first site of the study, while they increased as we headed toward the city of Tikrit, especially the third and fourth sites, and they were 56.888- 62.444mg/ L, respectively (Table 2). The reason for this may be ascribed to the waste water and excreta that reach or flow into the Tigris River from the city and are considered a source of alkalinity due to the disintegration of organic materials and the production of carbon dioxide gas, and these in turn work on the formation of bicarbonates, which increases the regulatory ability of the Tigris River water to resist major changes that lead to acidity **(Mahmuad, 1988)**. After this site, the total alkalinity rates at Hammam Al-Alil site decreased to 147.6mg/ L, which may be attributed to the effects of self-purification processes of the river water **(Ostroumov, 2006; Saeed & Dawas, 2023)**.

Hardness is one of the measures of water quality, and hardness varies depending on the water source, as surface water is often less hard than groundwater, and this depends on the geological characteristic of the lands on which the water flows or passes **(Al-Safawi, 2007)**. The results of the current study showed (Figs. 1, 2, 6) that the concentration of total hardness, calcium and magnesium varies from one month to another, as well as within the Tigris River water for the studied sites. The reason for the high values of total hardness in the winter and spring months is traced back to the rise in water levels due to rainfall, which led to the drift of pollutants and flows from nearby lands into the riverbed, and thus the total hardness values increased during these months.

The results of the current study are consistent with many studies that indicated high values of total hardness in Iraqi water, including **Al-Lami *et al*. (1999)**, **Al-Douri (2000)**, **Al-Saffawi *et al.* (2006)** and **Al-Shindah (2008)**.

**- Phosphates, silica and nitrates**

The results of studying the values of phosphate, silica, and nitrate (Tables 1, 2 & Figs. 8, 9, 10), during the study period in the Tigris River water sites showed a clear change, as the time of recording the highest values of phosphate and silica coincided with the month of February, and it was 26.60, 4.80mg/ L, respectively, the increase in concentrations may be attributed to the rainfall and rising water levels, which lead to the washing away plant nutrients and fertilizers added to agricultural lands adjacent to the river in addition to the rise in the values of the biological oxygen demand resulting from the increased decomposition of sedimented organic materials carried by torrential rains **(Al-Saffawi *et al*., 2006)**. This result is consistent with those of **Al-Douri (2005)** and **Al-Shindah (2008)** who reported that, the highest value recorded of nitrate for the month of November was 0.532mg/ L. As for these sites, the lowest value was recorded at 0.469mg/ L in the third and fourth sites, this decrease in phosphate values may have resulted from the lack of pollutants released into the Tigris River before it entered the city of Mosul or due to the consumption of phosphate by plants and aquatic organisms **(Al-Eryani, 2005)**, while the highest value was recorded at 0.477mg/ L for the second site. The monthly variables for the monthly rates ranged from 0.467, 46.84, 3.34 to 0.467, 7.94, 3.430mg/ L.

## CONCLUSION

From the results obtained during the study period, it was noted that, there was an increase in the values of turbidity and pH for all sites. It was also noted that most of the physical and chemical characteristics of the water of the Tigris River at the study site within the city of Tikrit, which are sources of raw water for liquefaction water stations, were within the permissible limits and had good ventilation, accompanied by an increase in the concentration of dissolved oxygen with a decrease in the values of $BOD_5$, nitrates and phosphates. These characteristics decrease after passing through the city of Tikrit due to the river's natural purification capacity, coupled with the reduced volume of waste entering the river in this area.

**Table 1. Values of in site changes for physical and chemical tests of Tigris River water**

| FACTOR / Station | Sit 1 | Sit 2 | Sit 3 | Sit 4 | Sit 5 | Men |
|---|---|---|---|---|---|---|
| Turb. (NTU) | 11.435 | 14.981 | 16.301 | 13.818 | 8.437 | 8.887 |
| PH | 6.040 | 6.254 | 6.191 | 6.138 | 6.493 | 6.223 |
| EC ( µmhos/cm) | 200.66 | 196.278 | 202.38 | 195.000 | 191.833 | 197.230 |
| T.D.S. (mg/L) | 392.111 | 400.555 | 397.444 | 412.944 | 382.777 | 397.166 |
| DO (mg/L) | 11.583 | 9.850 | 9.633 | 9.300 | 10.361 | 10.145 |
| $BOD_5$ (mg/L) | 2.922 | 4.016 | 3.550 | 3.922 | 4.105 | 3.703 |
| Alkalinity (mg/L) | 59.111 | 58.888 | 62.444 | 56.888 | 58.888 | 59.243 |
| T.H. (mg/L as $CaCO_3$) | 85.833 | 80.167 | 90.000 | 85.667 | 91.056 | 86.544 |
| Ca.H. (mg/L as $CaCO_3$) | 64.778 | 62.556 | 59.333 | 63.000 | 59.222 | 61.777 |
| Mg.H. (mg/L as $CaCO_3$) | 21.056 | 17.611 | 30.722 | 22.667 | 29.400 | 24.291 |
| $Po^{-3}$ (mg/L) | 3.425 | 3.422 | 3.399 | 3.449 | 3.459 | 3.430 |
| Silica (mg/L) | 4.58 | 3.40 | 3.71 | 4.19 | 3.82 | 7.94 |
| $NO_3$ (mg/L) | 0.453 | 0.477 | 0.469 | 0.469 | 0.470 | 0.467 |

**Table 2. Monthly sites changes values for the Tigris River water**

| Factor / SAMPLING | Oct. | Nov. | Dec. | Jan. | Feb. | March | Men |
|---|---|---|---|---|---|---|---|
| Turb. (NTU) | 24.644 | 14.254 | 6.812 | 4.278 | 12.217 | 15.762 | 12.994 |
| pH | 7.099 | 7.250 | 6.493 | 5.656 | 5.573 | 5.469 | 6.256 |
| EC ( µmhos/cm) | 212.93 | 196.06 | 187.20 | 223.80 | 182.80 | 180.60 | 197.231 |
| T.D.S. (mg/L) | 433.46 | 390.26 | 385.60 | 433.46 | 359.00 | 381.00 | 382.296 |
| DO (mg/L) | 8.086 | 11.05 | 11.24 | 10.813 | 10.18 | 9.493 | 10.143 |
| $BOD_5$ (mg/L) | 3.500 | 4.080 | 3.586 | 3.566 | 3.826 | 3.660 | 3.703 |
| Alkalinity (mg/L) | 72.933 | 19.333 | 20.133 | 84.266 | 79.866 | 77.866 | 59.066 |
| T.H. (mg/L as $CaCO_3$) | 113.200 | 75.467 | 72.133 | 71.733 | 93.067 | 93.667 | 77.544 |
| Ca.H. (mg/L as $CaCO_3$) | 67.333 | 58.933 | 46.667 | 64.600 | 67.400 | 65.733 | 61.777 |
| Mg.H. (mg/L as $CaCO_3$) | 45.867 | 16.467 | 25.467 | 7.133 | 25.933 | 24.880 | 24.291 |
| $Po^{-3}$ (mg/L) | 2.698 | 2.855 | 2.711 | 2.715 | 4.808 | 4.799 | 3.430 |
| Silica (mg/L) | 4.84 | 4.34 | 3.59 | 26.60 | 4.01 | 4.26 | 46.84 |
| $NO_3$ (mg/L) | 0.460 | 0.532 | 0.467 | 0.454 | 0.460 | 0.432 | 0.467 |

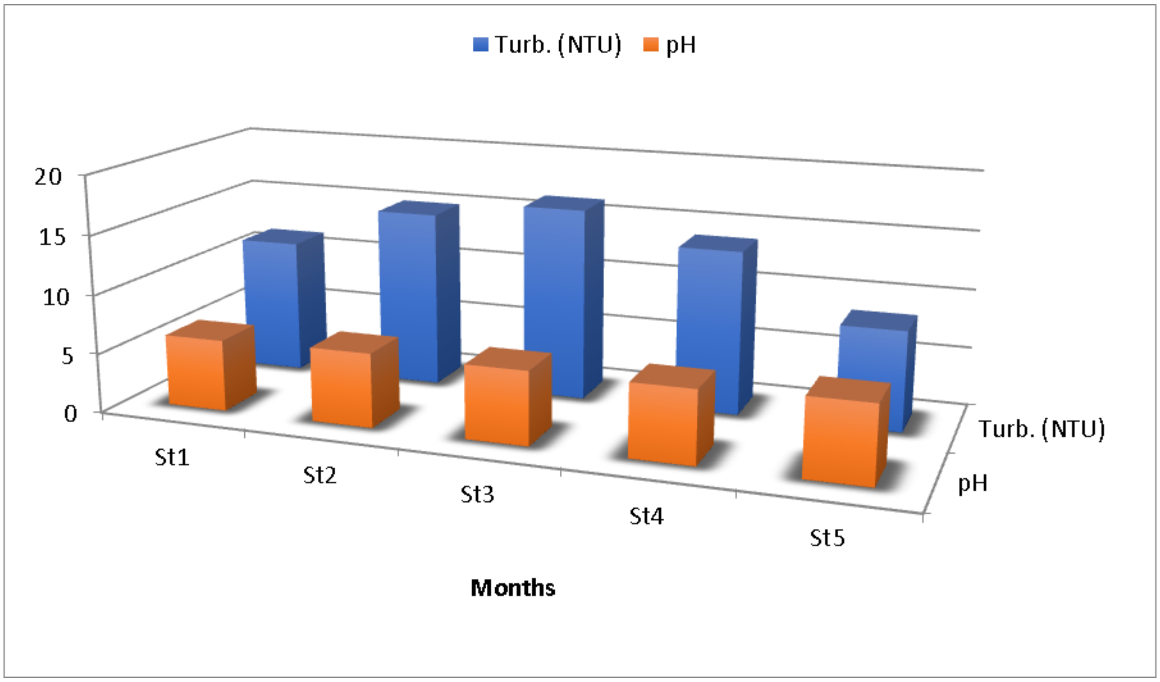


**Fig. 1.** Turb. (NTU) and pH at the study location

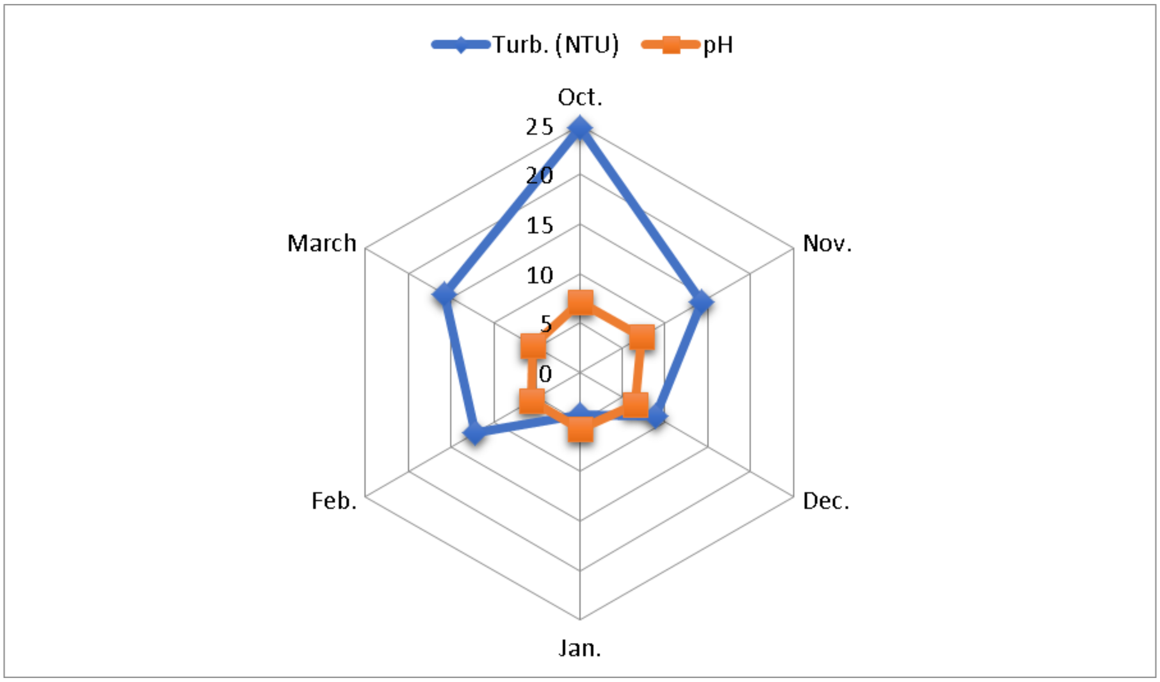


**Fig. 2.** Turb. (NTU) and pH at the study location

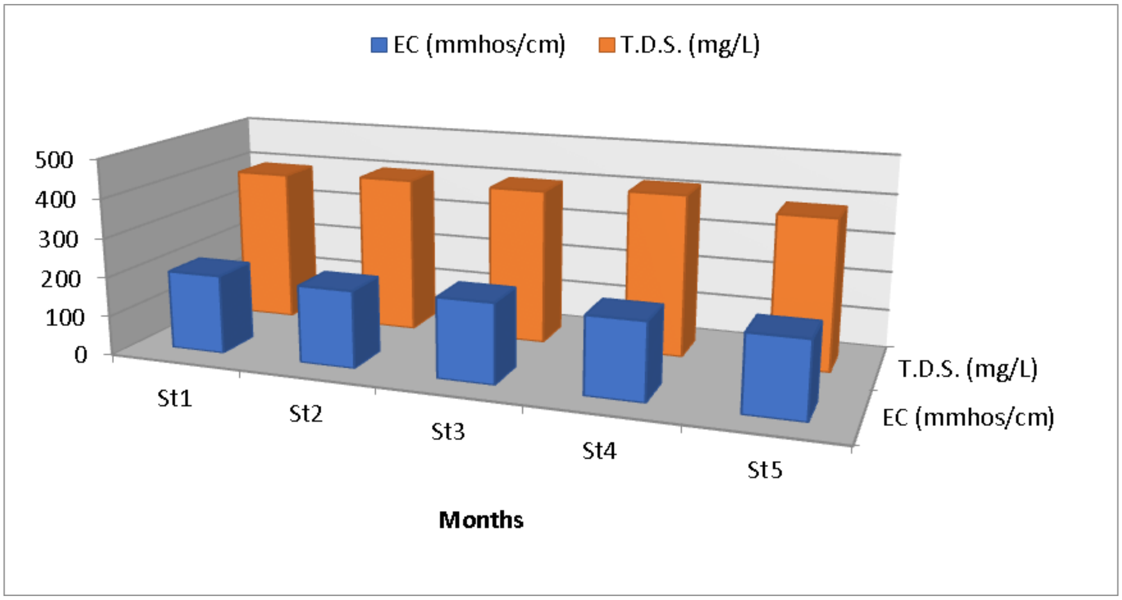


**Fig. 3.** Ec(µmhos/ cm) and TDS (mg/ L) at the study location

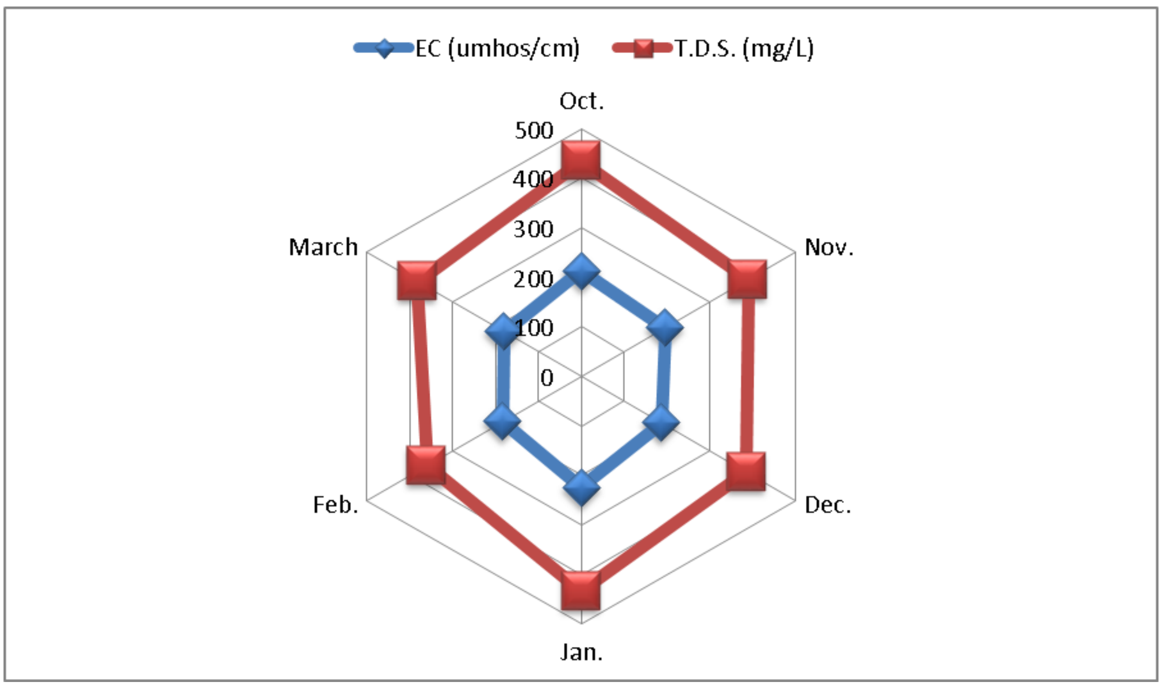


**Fig. 4.** Ec(µmhos/ cm) and TDS (mg/ L) at the study location

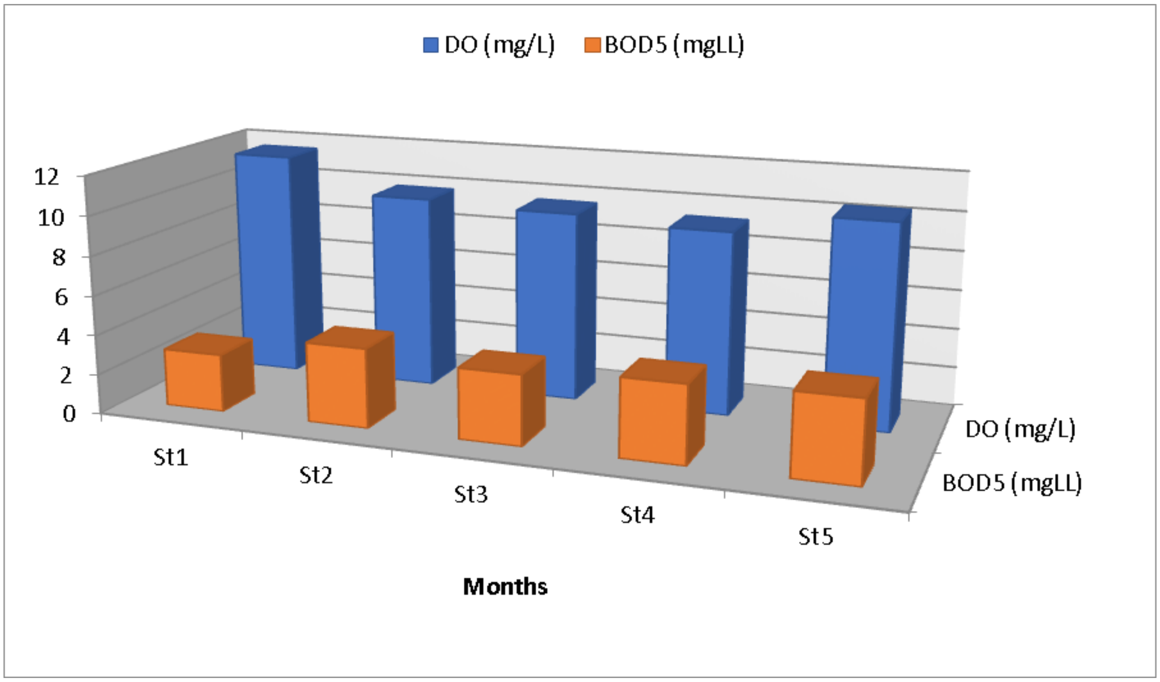


**Fig. 5.** DO and TDS (mg/ L) at the study location

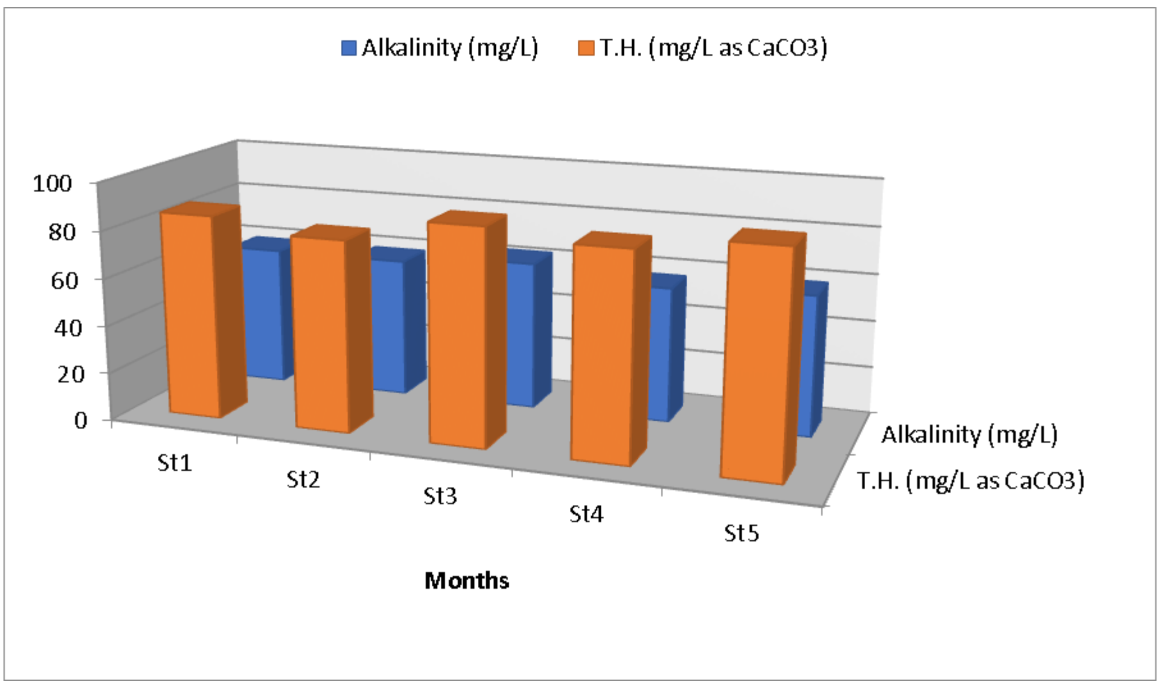


**Fig. 6.** Alkalinity (mg/ L) and TH (mg/ L) at the study location

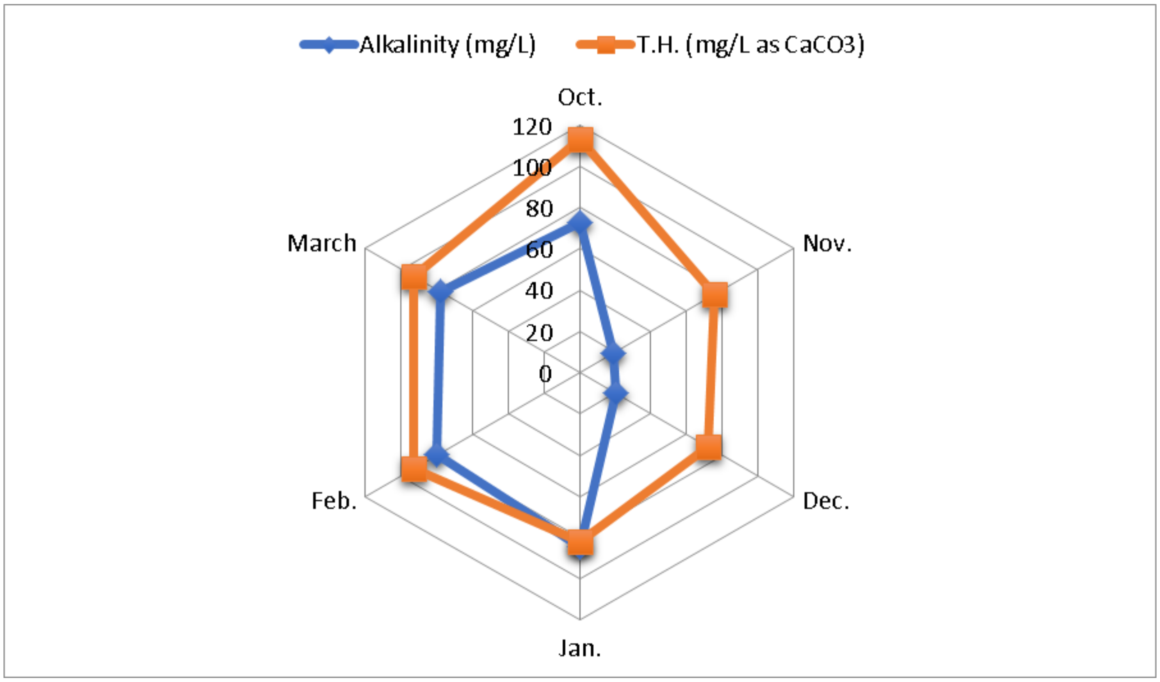


**Fig. 7.** Alkalinity (mg/ L) and TH (mg/ L) at the study location

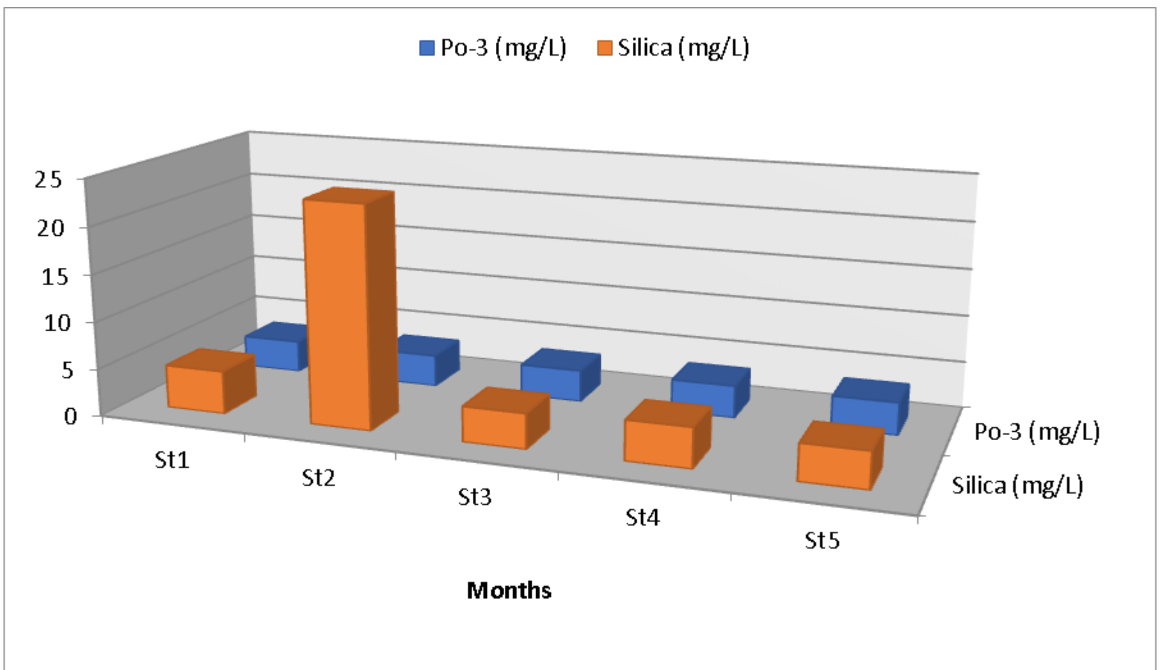


**Fig. 8.** $Po_4^{-3}$ (mg/ L) and silica (mg/ L) at the study location

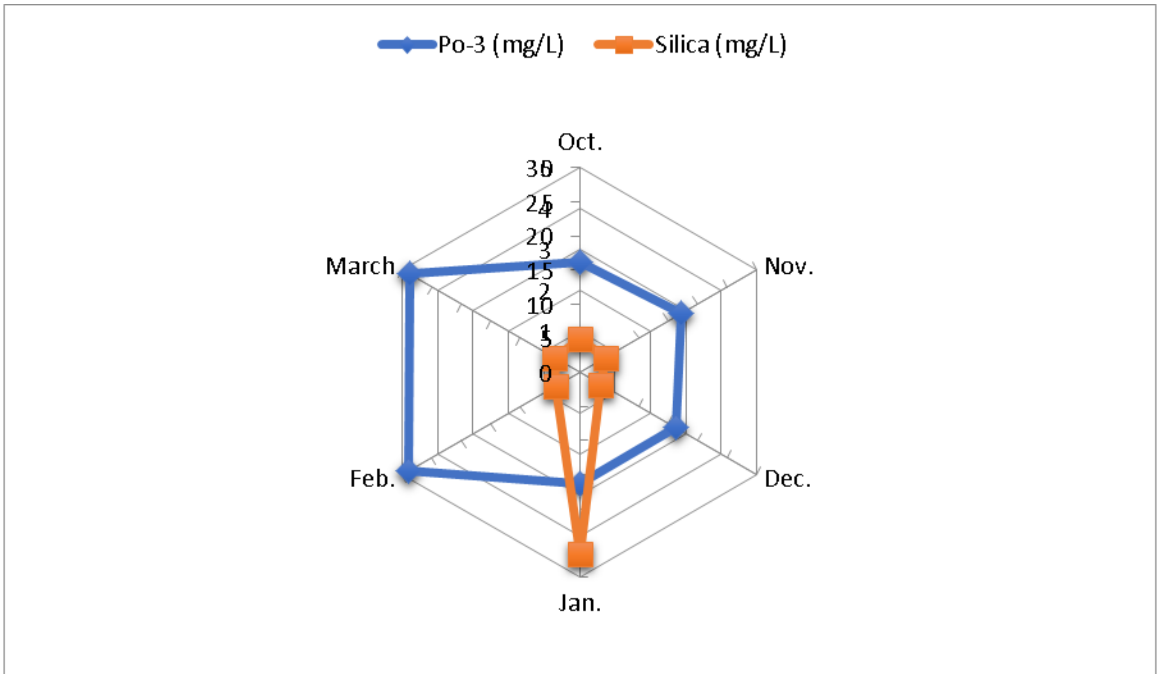


**Fig. 9.** $Po_4^{-3}$ (mg/ L) and silica (mg/ L) at the study location

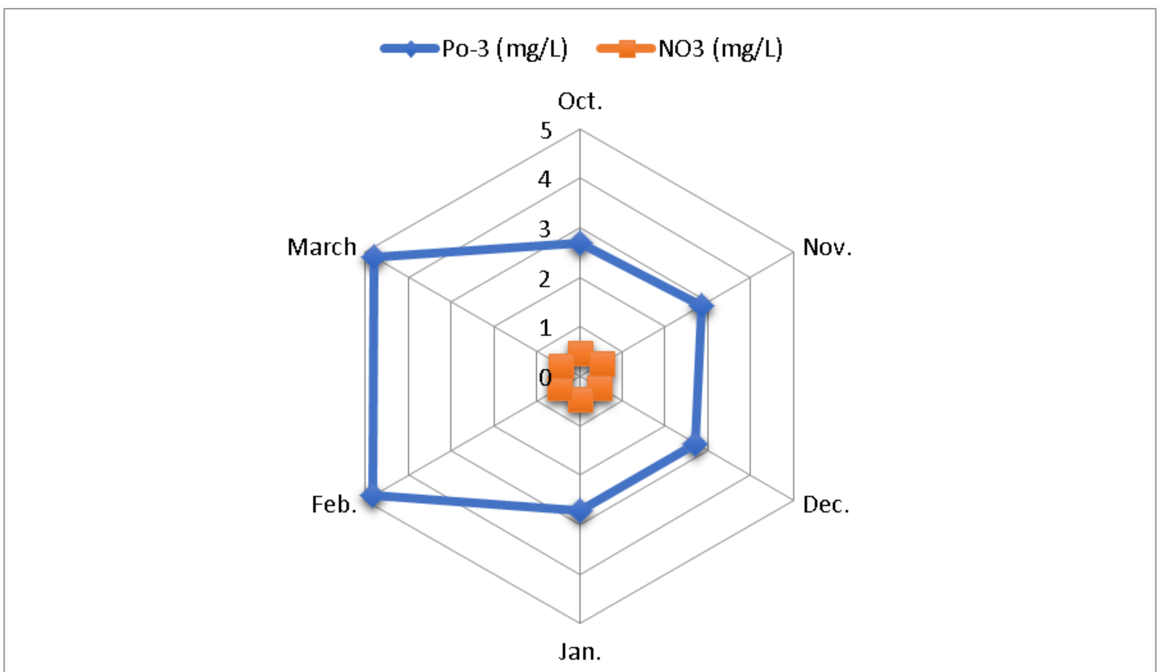


**Fig. 10.** $Po_4^{-3}$ (mg/ L) and $NO_3$ (mg/ L) at the study location

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