Assessment of Tigris River Water Quality for Drinking Purposes in Baghdad City, Iraq

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ABSTRACT

The Tigris River, a crucial water source for Baghdad City, has faced increasing pollution due to industrialization, agricultural runoff, and population growth, necessitating regular water quality assessments. This study evaluated the physicochemical characteristics of the river in Baghdad's Al-Zafraniya district to determine its suitability for drinking. Over six months, water samples were analyzed for key parameters (e.g., temperature, turbidity, pH, electrical conductivity, total dissolved solids, major ions, and nutrients) using standard methods. Results revealed seasonal variations, with higher dissolved constituents during dry periods and dilution effects during rains. While most parameters met permissible standards, electrical conductivity, total dissolved solids, total hardness, and calcium hardness exceeded acceptable limits. Although no critical pollution was detected, anthropogenic factors (fertilizers, waste disposal) and natural processes (rainfall, erosion) likely influenced water quality. Continuous monitoring is essential to mitigate potential public health risks, particularly for communities directly dependent on river water.

1. INTRODUCTION

Water quality is affected by climate change and pollution from human activities, significantly influencing ecosystems and human health [1]. Moreover, surface water quality is more vulnerable to anthropogenic contaminants than to natural ones [2]. Consequently, the challenge for decision-makers is to attain sustainable management of water resources, particularly in developing nations [3]. Rivers are dynamic ecosystems that play a pivotal role in maintaining ecological balance, providing a habitat for diverse species, and serving as a vital source of freshwater for humans and natural systems. River water pollution can harm living beings and make water unsuitable for various needs [4].

Tigris River has a variety of physicochemical characteristics that can affect its quality and suitability for different uses. The need to assess and understand the physicochemical parameters within this ecosystem has become increasingly evident in light of the growing human impact on the environment [5].

The variability of physicochemical parameters in an aquatic environment is influenced by the varying levels of anthropogenic activities. Therefore, ongoing biomonitoring of aquatic environments is essential for evaluating the effects of human activities on water bodies and their implications for public health [6]. In Baghdad, especially in industrial areas like Al-Zafraniya, local pollution sources such as untreated industrial wastewater from small and medium-sized factories, discharge from dyeing workshops, tanneries, and domestic sewage are major contributors to water pollution. These discharges often lack any form of pretreatment, directly entering the Tigris River, affecting water chemistry and public health [7]. Additionally, airborne industrial particulates and heavy metal-laden dust in urban districts like Al-Zafraniya have been identified as contributors to the chemical burden of surface water, further degrading river quality [8]. Agricultural runoff enriched with nitrates and phosphates from surrounding fields exacerbates the problem by stimulating eutrophication and altering nutrient dynamics, recent studies also report high levels of electrical conductivity and heavy metals in urban stretches of the river, underscoring the need for policy-level interventions [9].

The objective of this study is to evaluate the temporal variations in the physicochemical characteristics of Tigris River water in the Al-Zafraniya area of Baghdad during the monitoring period from December to May, which partially encompasses transitions between wetter and drier conditions, given its role as a major source for drinking water supply projects in the city.

2. MATERIALS AND METHODS

2.1 Study station

Tigris River is regarded as the second-longest river in Southwestern Asia, and it's one of the major rivers in Iraq. It is roughly 1800 km long and 1500 Km long inside Iraq, Tigris River supplies water for the Baghdad City's drinking, agriculture, and trade [10]. The water sample was taken from Tigris River in Al-Zafraniya district of Baghdad city (see

Figure 1), which is situated southeast of Baghdad between latitude (33°13′46″N) and longitude (44°28′45″E). It shares borders with Sadr City to the northeast and the communities of Al-Jadriya, Al-Doura, and Al-Karada to the north and west. Its residential districts, marketplaces, and industrial zones it is regarded as one of Baghdad's most important locations [8]. The Al-Zafraniya site was strategically selected due to its proximity to multiple anthropogenic activity zones, including residential neighborhoods, industrial workshops, and agricultural runoff areas. This location represents a typical urban-rural interface with high environmental stress, making it a priority area for water quality assessment. While this study focuses on a single location, the findings provide valuable insight into pollution dynamics within a critical segment of the Tigris River in Baghdad. It is acknowledged that this site alone cannot represent the full spatial variability of the river system. Future research should consider integrating multiple upstream and downstream points to enable a more comprehensive spatial analysis and better assess cumulative pollution loads across Baghdad's river stretch.
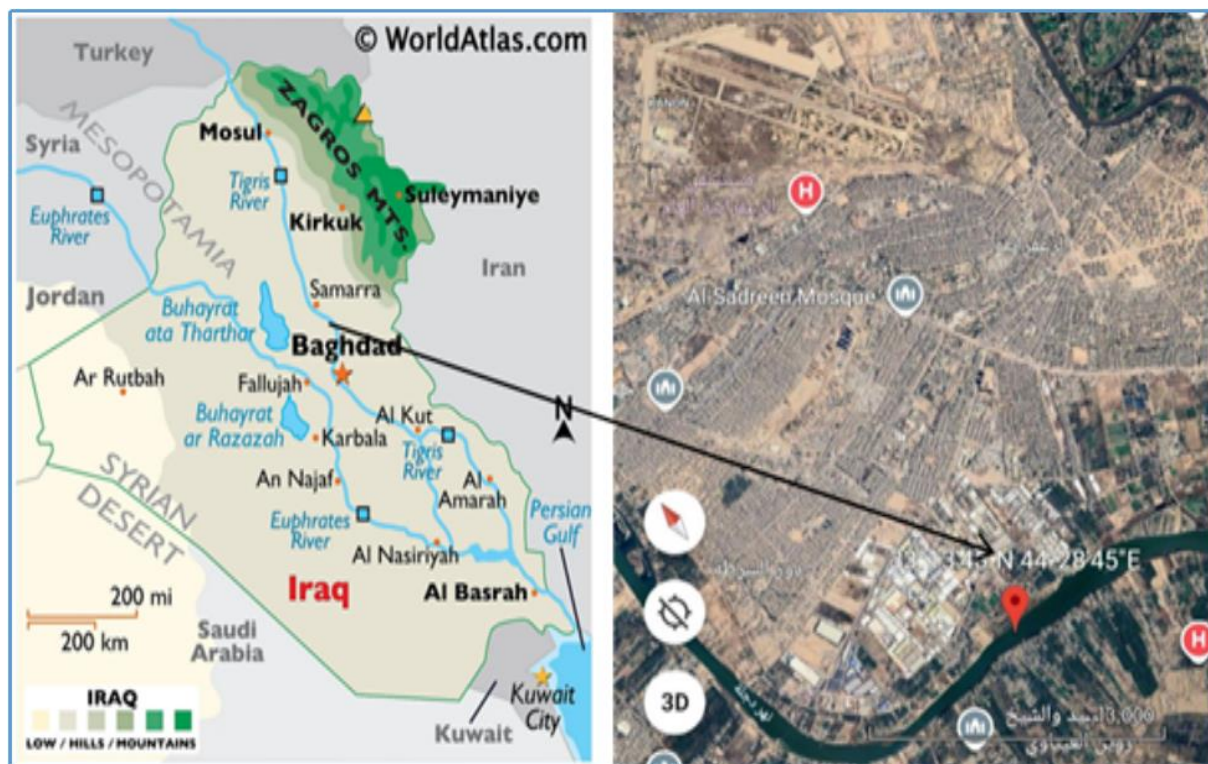

Figure 1. Maps of the study area in Baghdad city

Table 1. Physicochemical analysis techniques utilized for measurements

No.	Water Parameters	Unit	Device or Tool	Reference
1	Air & water temperature	°C	Digital thermometer	-
2	Turbidity	NTU	Turbidity-meter	-
3	Electrical conductivity	µS/cm	Multi-parameter analyzer EC, TDS meter, HANNA instruments	-
4	Total dissolved solids	mg/L		-
5	pH	-	pH-meter HANNA Instruments	-
6	Chloride	mg/L	Titration with $AgNO_3$	[11]
7	Total hardness, Ca & Mg H.	mg/L as $CaCO_3$	Titration with Na_2EDTA	[11]
8	Sulfate (SO_4)	mg/L	Turbidimetric method	[11]
9	Nitrite (NO_2)	µg/L	Cadmium column, spectrophotometer model (CE 1011 CECIL) at wavelength 543 nm	[12]
10	Nitrate (NO_3)	mg/L	Spectrophotometer model (at 543 nm)	[12]
11	Phosphate (PO_4)	µg/L	Ascorbic acid reduction method was used, spectrophotometer model (at 880 nm)	[11]
12	Silica (SiO_2)	mg/L	The molybdo-silicate method, spectrophotometer (at 885 nm)	[11]

2.2 Sample collection

Samples were collected monthly for 6 months, from December 2023 until May 2024. Using a polyethylene bottle that had been cleaned twice with water sampling before being filled, water samples were taken for physicochemical examination. The temperature of the air and water, as well as the pH, have been measured in the field. Before use, laboratory equipment was calibrated [11].

Although the sampling period was limited to six

consecutive months (December 2023 to May 2024), this timeframe was strategically selected to capture transitional climatic phases in central Iraq, particularly from the peak of the wet season to the early onset of dry conditions. This interval aligns with periods of heightened hydrological variability, influenced by seasonal rainfall, runoff, and rising temperatures. While the sampling does not cover a full annual cycle or extreme summer conditions, it provides representative insight into water quality dynamics during a critical transitional phase. The design acknowledges limitations such as the absence of high-temperature stress events or peak evaporation periods, which may influence parameters like salinity or dissolved solids. However, the chosen duration was also logistically constrained by field accessibility and academic timelines. Future work is recommended to extend monitoring to include hotter and drier months to provide a more complete seasonal representation.

2.3 Physical and chemical analysis

The parameters were measured in Ecology and Pollution Laboratory at Tikrit University College of Science. Table 1 lists the techniques used to analyze these factors.

2.4 Statistical analysis

Program [13] was used to detect the effect of different groups (patients and controls) on study parameters. Duncan's and /Least Significant difference were used to significantly compare between means. Estimate of the correlation coefficient between variables in this study.

3. RESULTS AND DISCUSSION

3.1 Air and water temperature

The results of this study indicate that air temperature varied from 12.9°C to 36.3°C, while water temperature ranged from 12.3°C to 22.8°C. Water temperature reflected seasonal variations throughout the monitoring period (see Table 2).

The statistical analysis indicated significant temporal variations in air temperature during the initial four months of the study (December-March), with a notable difference (P ≤ 0.05) identified between April and May. The Pearson correlation coefficient in Table 3 indicated a positive correlation between air and water temperature (r = 0.950) at a significance level of P ≤ 0.05. Differences in air temperature are attributed to the water temperature change, which is a significant seasonal variance. Because solar radiation raises the temperature of surface water, elevated water temperatures are expected during dry months. Accordingly, heavy precipitation is blamed for lower water temperatures during rainy months [14, 15].

Table 2. Duncan's test for multiple variables in the study site

Sample of Tigris River	Parameters														
	Air Temp.	Water Temp.	Turb.	EC	TDS	pH	Cl-	Total Hard.	Ca. Hard.	Mg. Hard.	SO_4^{-2}	NO_2^{-2}	NO_3^-	PO_4^{-3}	SiO_2^{-2}
December	15.2 c	15 b	27.3 b	1150 a	1150 a	7.1 b	36.5 a	210 a	122.5 cd	87.5 a	19.3 bc	88.3 a	11.4 a	26.3 a	2.6 a
January	16.3 c	12.3 b	22.0 b	1115 a	1122 a	8.3 a	18.3 c	215 a	170.3 ab	44.7 b	23.2 a	20.7 b	11.2 a	24.1a b	2.85 a
February	12.9 c	12.5 b	10.5 c	1011 a	1013 ab	8.3 a	25 b	218 a	140.8 bc	77.2 a	22.0 ab	20.5 b	11.5 a	22.1 b	1.21 b
March	14.9 c	13.9 b	23.0 b	1122 a	1128 a	7.5 ab	25.5 b	212 a	133.4 bc	78.6 a	19.0 bc	80.3 a	9.11 b	23.3a b	3.1 a
April	25.3 b	19.5 a	44.0 a	850 b	930 bc	8.5 a	20.1 bc	230 a	190.1 a	39.9 bc	17.5 c	24.0 b	9.1 b	23.9a b	2.6 a
May	36.3 a	22.8 a	51.5 a	820 b	840 c	7.9 ab	20.0 bc	120 b	91.2 d	28.8 c	18.9 c	25.1 b	7.9 b	23.5a b	1.6 b
L.S.D.	4.922 *	4.317 *	12.84*	174.37 *	162.98 *	0.992 *	5.52 *	42.57 *	37.87 *	13.68*	3.59 *	12.92 *	1.44 *	3.19 *	0.882 *
Means with the different letters in same column differed significantly. * (P ≤ 0.05). Duncan's test															

3.2 Air and water temperature

The results of turbidity ranged between 10.5 and 51.5 NTU in February and May, respectively Table 2. According to the World Health Organization, the recommended turbidity level for drinking water should not exceed 5 NTU. Therefore, all observed values in this study substantially surpass this guideline, particularly during the rainy season. While these levels may be typical for running surface water, such deviations indicate potential risks for conventional water treatment systems, as elevated turbidity can shield pathogens and reduce disinfection efficiency. However, it is important to note that this water originates from a river system and is expected to undergo sedimentation processes in drinking water treatment plants. These engineered treatment steps, such as coagulation, flocculation, and settling, are specifically designed to reduce turbidity-causing particles, including suspended solids and organic matter. As a result, the measured turbidity values, although elevated in raw water, do not necessarily represent a direct health risk, provided effective treatment is in place. The increase in turbidity during rainy months may be attributed to the influx of suspended solids, sediments, organic debris, and other particulate matter resulting from surface runoff and episodic flooding events [16, 17].

3.3 Electrical conductivity (EC) and total dissolved solids (TDS)

EC values ranged between (820-1150) µS/cm, whereas TDS values ranged 840-1150 mg/L. The majority of results for electrical conductivity (EC) and total dissolved solids (TDS) exceeded the permissible limits for drinking water, which are set at a maximum of 1000 µS/cm for EC and 500 mg/L for TDS [18]. The elevated electrical conductivity observed during the rainy season may result from the increased water levels and the influx of nutrients from the runoff of inorganic fertilizers from adjacent irrigated agricultural areas

surrounding the river, coupled with the reduced evaporation rate that further elevates water levels during this period (January to March). Consequently, the conductivity of the water is contingent upon the concentration of ions and the nutrient composition present [19, 20]. On the other hand, the rises and falls of electrical conductivity values were consistent with the values of total dissolved solids during the study period in Figure 2, this was confirmed by the correlation coefficient shows a positive correlation (r=0.880) at $P \leq 0.01$ (see Table 3), this was confirmed by Srishylam et al. [21].

3.4 pH

The pH levels of water ranged from 7.1 in April to 8.5 in December over the research period. The water samples are almost neutral to sub-alkaline in nature. In Iraq, the pH of water exhibits an alkaline shift from neutrality, attributable to the region's geological composition, predominantly consisting of $CaCO_3$ [22], and this may be related to the soil and watershed characteristics of the study area. Consequently, water that has interacted with limestone for a relatively brief duration is expected to exhibit a low pH, and conversely [23, 24].
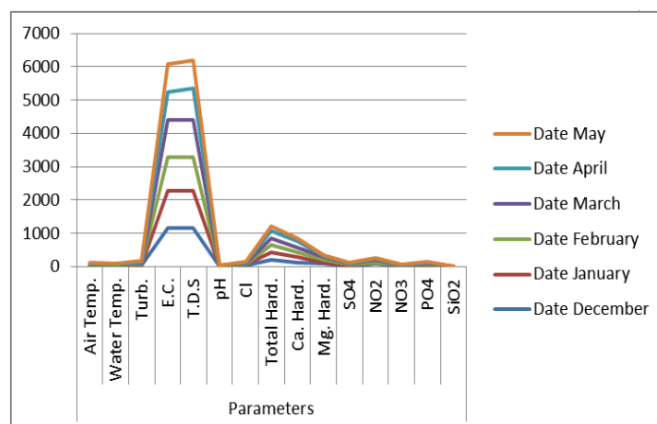

Figure 2. Monthly variations of parameters for water in the studied station

Table 3. Correlation coefficient between different parameters study of Tigris River

Parameters	Water Temp.	Tur.	EC	TDS	pH	Cl⁻	Total Hard.	Ca. Har.	Mg. Hard.	SO₄⁻²	NO₂⁻²	NO₃⁻	PO₄⁻³	SiO₂⁻²
Air Temp.	0.95 **	0.93 **	-0.85 **	-0.87 **	0.19	-0.36	-0.62 *	-0.23	-0.71 **	-0.40	-0.28	-0.73 **	-0.04	-0.28
Water Temp.	-	0.96 **	-0.63 *	-0.64 *	0.07	-0.22	-0.59 *	-0.32	-0.57 *	-0.61 *	-0.22	-0.76 **	0.06	-0.24
Turb.		-	-0.65 *	-0.52 *	0.06	-0.21	-0.41	-0.19	-0.63 *	-0.59 *	-0.17	-0.60 *	0.21	-0.06
E.C.			-	0.88 **	-0.43	0.35	0.35	0.04	0.55 *	0.37	0.52 *	0.59 *	0.26	0.37
T.D.S.				-	-0.38	0.53 *	0.52 *	0.17	0.43	0.29	0.43	0.59 *	0.20	0.52 *
pH					-	-0.62 *	0.17	0.51 *	-0.41	0.26	-0.82 **	-0.06	-0.52 *	-0.27
Cl -						-	0.19	-0.34	0.63 *	-0.17	0.75 **	0.34	0.41	0.09
Total Hard.							-	0.59 *	0.40	0.18	0.15	0.42	0.07	0.33
Ca. Hard.								-	-0.12	0.10	-0.22	0.26	-0.06	0.21
Mg. Hard.									-	0.12	0.52 *	0.40	0.19	0.12
SO₂										-	-0.24	0.54 *	-0.24	-0.17
NO₂											-	0.09	0.38	0.32
NO₃												-	0.21	-0.02
PO₄													-	0.32

3.5 Chloride Cl⁻

Chloride values ranged 20-36.5 mg/L in May and December respectively, chloride was within the permissible limits of 250 mg/L during the study period [18]. These results agree with these studies [16, 20, 21].

3.6 Total hardness, Ca, and Mg hardness

Total Hardness was recorded 120-230 mg/L as $CaCO_3$, and Ca hardness values of the current study ranged between 91.2 and 190.1 mg/L as $CaCO_3$ in April and December, respectively, while the Mg Hardness values ranged 28.8-87.5 mg/L as $CaCO_3$ in May.

In general, the water of Tigris River is considered, according to the results of total hardness, to be very hard in most cases (the results were found to cross the standard limits > 180 mg/L as $CaCO_3$ [18], the reason for the high values of total hardness during the study period, especially in the first months of study is may be because 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 [25, 26].

The statistical analysis showed the presence of positive correlation between total hardness and Ca, TDS, Mg, and EC at $P \leq 0.05$ (r=0.590, r=0.520, r=0.400, and 0.350), respectively (see Table 3).

3.7 Sulfate SO_4^{-2}

Sulfate in most of the samples was found within a limited standard of 250 mg/L [18]. SO_4 was recorded (17.5 -23.2) mg/L, it can be created by fertilizers or by the dissolution of rocks like gypsum rocks [20].

3.8 Nitrite NO_2^{-2}

The results of nitrite concentrations ranged between 20.5 and 88.3 μg/L in February and December, respectively. NO_2 concentrations are expected to be significantly lower than those of nitrates; all nitrite levels in this investigation complied with WHO standards for drinking water, which stipulate levels below 0.2 mg/L (200 μg/L) [18]. The present work aligns with several investigations that have documented exceedingly low levels of nitrite, including those by Ahmed and Al-Shandah [27].

3.9 Nitrite NO_3^-

Nitrate values ranged of 7.9- 11.5 mg/L in May and February respectively, these values are within study [18] recommended standards for drinking water (< 50 mg/L). This reduction in nitrate concentrations is crucial for human health, as elevated levels of nitrate in drinking water can have severe and potentially fatal consequences for infants aged from birth to three months [28]. The cause of the NO_3 concentration decrease during this study may have been consumed by plants and algae [24, 29].

3.10 Reactive phosphate (PO_4^{-3})

Typically, water exhibits minimal phosphorus levels due to the limited solubility of indigenous phosphate minerals and the capacity of soils to retain phosphate [11], which aligns with the low phosphate concentrations seen in this study. The phosphate concentrations measured were 22.1 μg/L in February and 26.3 μg/L in December, respectively.

Reactive phosphate levels in the current study increased in December and January; these elevated concentrations are primarily attributed to drainage water enriched with phosphorus compounds [30]. Additionally, low phosphate levels may be linked to plants' and phytoplankton's propensity to collect high levels of phosphate in their bodies [31]. This is further corroborated by statistical analysis, which indicates a positive correlation between PO_4 and NO_2, NO_3 (r= 0.380 and R=0.210) respectively.

The PO_4 concentrations were within the prescribed limits (maximum permissible phosphate content of 0.25 mg/L) [18]. The statistical study revealed that, according to the analysis of variance for reactive phosphate, there were no significant temporal differences.

3.11 Reactive silicate (SiO_2^{-2})

Reactive silicate values ranged from 1.21 to 3.1 mg/L in February and March, respectively. The results indicated consistently low silicate concentrations during the study period, potentially attributable to silicate uptake by phytoplankton, particularly diatoms, which are the only freshwater organisms that utilize silica in substantial amounts

and are prevalent in the Tigris River [32, 33]. Additionally, the slow regeneration rate of silicate from sediments may also contribute to this phenomenon. All silica levels were under the acceptable limit (10 mg/L) established by the World Health Organization [18] for drinking water.

4. THEORETICAL FRAMEWORK: LINKING PHYSICOCHEMICAL QUALITY AND PUBLIC HEALTH

According to the WHO Water Safety Framework, physicochemical parameters serve as early warning indicators of potential waterborne health risks. High turbidity can shelter microbial pathogens and reduce the effectiveness of disinfection. Nitrate levels exceeding safe thresholds are particularly dangerous for infants, causing methemoglobinemia or "blue baby syndrome." Elevated electrical conductivity and TDS may signal the presence of dissolved ions, heavy metals, or industrial waste, compromising water safety.

Furthermore, extreme pH values can lead to corrosion in distribution systems, increasing the risk of toxic metal leaching. Total hardness may affect not only palatability but also cause scaling in plumbing, indirectly affecting sanitation. Elevated phosphate levels can accelerate eutrophication, leading to harmful algal blooms and microbial contamination.

In the context of this study, several measured values deviated from WHO-recommended guidelines, emphasizing the need to integrate continuous water quality surveillance with preventive control measures. This approach aligns with WHO multi-barrier strategy, which advocates for risk assessment, source protection, treatment optimization, and regulatory enforcement to ensure public health safety [18].

5. CONCLUSION

The physical and chemical parameters of the Tigris River water in the Al-Zafraniya region during the six-month monitoring period showed notable seasonal variations. While several parameters remained within the permissible limits for drinking water, others—such as turbidity, total hardness, and electrical conductivity—exceeded the recommended thresholds. Accordingly, the water may be used for drinking purposes only after proper sedimentation, filtration, and disinfection.

Given that this river segment serves as a major water source for drinking water projects in Baghdad, it is crucial to implement enforceable environmental policies. These should include mandatory industrial wastewater pretreatment, periodic inspections of effluent discharge, and penalties for unauthorized direct disposal of waste into the river. Such measures would mitigate the deterioration of river water quality and protect public health.

It is important to highlight that this study focused solely on physicochemical parameters due to methodological and resource limitations. Critical factors such as microbial contaminants (e.g., fecal coliforms) and heavy metals were not assessed and are recommended for inclusion in future investigations to ensure a more comprehensive evaluation of public health risks.

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NOMENCLATURE

Air Temp.	Air Temperature °C
Water Temp.	Water Temperature °C
Turb.	Turbidity
NTU	Nephlometric Turbidity Unit
EC	Electrical Conductivity µS/cm
TDS	Total Dissolved Solids mg/L
pH	Hydrogen Ion Concentration (pH)
Cl^-	Chloride Ion Concentration mg/L
Total Hard.	Total Hardness (as $CaCO_3$) mg/L
Ca.H	Calcium Hardness (as $CaCO_3$) mg/L
Mg.H	Magnesium Hardness (as $CaCO_3$) mg/L
SO_4^{2-}	Sulfate Ion Concentration mg/L
NO_2^{2-}	Nitrite Concentration µg/L
NO_3^-	Nitrate Concentration mg/L
PO_4^{3-}	Reactive Phosphate Concentration µg/L
SiO_2^{2-}	Reactive Silicate Concentration mg/L