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Controls of Nutrient Availability in River Ecosystems: A Case Study of Tigris River

Batool Kadhim[1*] and Mohammed Hamdan[2]
[1,2]Department of Biology, College of Science for Women, University of Baghdad, Baghdad, Iraq.
*Corresponding Author.

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Abstract

In response to the water crisis, further research is necessary to comprehend the impact of human activities on nutrient concentrations in aquatic ecosystems, building on the extensive studies already conducted to understand these impacts on the water quality of various aquatic ecosystems. We hypothesized that human activities in the Tigris River's catchments could alter the nutrient concentrations in the water along the river. The results showed that phosphate concentration differed significantly among the studied sites due to distributed human activities, while nitrate concentration did not. Water temperature did not affect phosphate and nitrate concentrations. We concluded that human activities on the surrounding landscapes could be more essential sources for nutrients in aquatic ecosystems than the role of ongoing climate warming. Despite the role of warming in driving nutrient availability in aquatic ecosystems, our findings suggest that studies focusing on the trophic status classification of aquatic ecosystems should take into account the various activities in the surrounding catchments.

Keywords: Phosphate, Nitrate, Anthropogenic, Warming.

1. Introduction

Nutrients are the most important elements and compounds that living organisms such as plants, algae, and microbes need for growth and reproduction processes. Some of the most important nutrients in aquatic ecosystems are nitrogen, phosphorous, and silica. These nutrients have many effects, such as limiting producers' biomass, growth, and primary production, and changing the make-up of aquatic communities (1–5). This, in turn, leads to changes in the trophic levels of food webs (6–8). It is possible for nutrients to enter aquatic ecosystems naturally through weathering processes and as products from producers (9). Artificial introduction of nutrients can also occur through sewage discharges, atmospheric releases from burning fossil fuels, and runoff from areas fertilized with agricultural pesticides (10–12). Different factors influence nutrients; temperature is the primary climate factor that controls soil nitrogen and phosphorous, while warming encourages the breakdown of soil organic matter and accumulates accessible phosphorus and nitrogen (13). People use the Tigris River, one of Iraq's main rivers and a vital source of water, for recreational, industrial, agricultural, municipal, industrial, and household purposes. Most of the studies on the Tigris River focused on how nutrients affect the quantity and quality of diatoms as well as zooplankton in the river (14, 15). Additionally, it is believed that all wastewater produced by the aforementioned operations eventually ends up in the Tigris River (16). Researchers have long monitored the Tigris River and conducted numerous studies on it. Some studies have focused on the variations of chemical physical properties and nutrient concentrations in the water of the Tigris River, either monthly (17) or seasonally (18-20). The Tigris River utilizes nutrients as an indicator of water quality (21–24). We still don't fully comprehend the fluctuations in nutrient concentrations in rivers, necessitating further research. We hypothesized that human activities can significantly influence the availability of nutrients in river ecosystems, using the Tigris River as an example for our study.

2. Materials and Methods

2.1. Study site description

We conducted this study at eighteen locations in three sites along the Tigris River within Baghdad (**Figure 1**). The Tigris River enters the city of Baghdad approximately 5 km from the tourist island. The river, which flows from the north to the south, divides the city into two sections: the right (Karkh) and the left (Risafa). It has a slope of 6.9 cm per kilometer and a width that ranges from 160 meters in straight areas to more than 400 meters in twisted areas.

Climate change influences a number of variables, including temperature variance and rain frequency, that affect the Tigris River. Other factors, such as irrigation, drainage projects, and dams like the Samarra Dam, which regulate water flow and level and raise saline content when water returns from the dams to rivers, are also influenced by climate change.

We selected three sites on the Tigris River to collect water samples for our study. The estimated distance of the Tigris River between the sites is more than 10-km, with the distance from the first station to the third station being approximately 20-km. AL-Gherai'at, a permanent island on the side of Rusafa northeast of Baghdad, is known for its wild plant cover. The Tigris River in this region occurs under the influence of direct sewage discharge coming from Al-Gherai’at’s inhabited residential areas. The second area is the AL-Shuhda'a Bridge, one of Baghdad's main bridges connecting the two sides of Karkh and Rusafa. Due to overpopulation and restaurants that discharge liquid pollutants into the river, it is considered an active site. The third area is AL-Jadriyah, situated on the Rusafa side, where the Tigris River undergoes a significant turn and travels northeast. Compared to the previously described sites of rapid urbanization and residential expansion, the AL-Jadriyah region has produced a significant volume and variety of liquid waste.

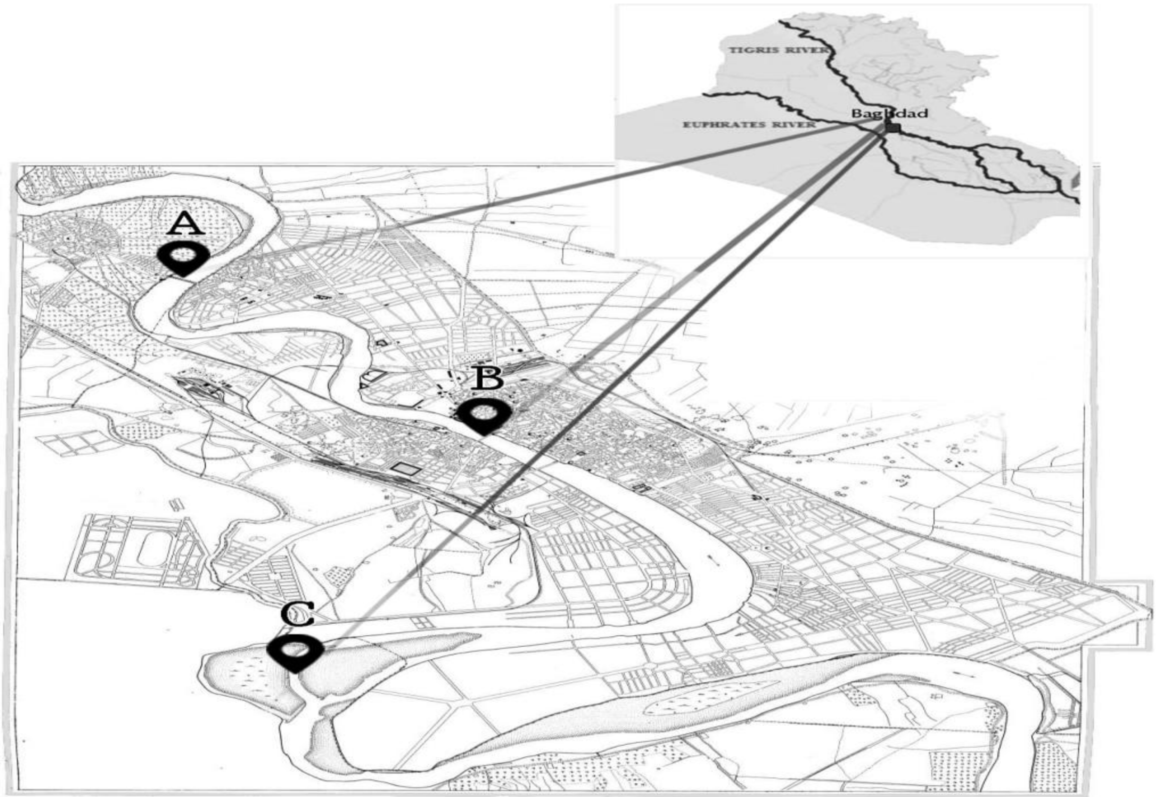

Figure 1. Map of the studied sites (A-C) on the Tigris River in Baghdad. A) AL-Gherai'at (44°20'11.2 "E, 33°23'11.1 "N), B) AL-Shuhda'a Bridge (44°23'10.0 "E, 33°20'18.9 "N), and C) AL-Jadriyah (44°23'07.4 "E, 33°17'26.5 "N).

2.2. Measuring nutrient availability and temperature

We measured all parameters using the standard methods outlined in (25). Water temperature (°C) was measured by an AL-Hana portable pocket thermometer. For nitrate (NO_3), 50 ml of water sample is taken. 1ml of HCl (1N) was added for each sample, then measured by using a spectrophotometer for two wavelengths (220 nm). For reactive phosphate (PO_4), the ascorbic acid method described in (26) was used. In this method, we add 8 ml of a compound solution containing ascorbic acid, sulfuric acid, antimony potassium tartrate, and ammonium molybdate to 50 ml of the filtered sample, then dilute it to 50 ml with distilled water to form a blue complex solution. Next, we measured the complex solution's optical absorption at a wavelength of 860nm.

2.3. Statistical analysis

All variables underwent statistical analysis in SPSS 20. T *tests* estimated the differences in variables between specific locations. A one-way ANOVA test was used to show if the variables were significantly different between the different locations. Person´s correlation coefficient (*r*) was used to show the correlation between water temperature and nutrient concentrations. Linear regression was used to show if the correlations were significant or not. As well, we found the mean and the standard divisions for all measured parameters.

3. Results

Average (±1 *SD*) of water temperature among the studied sites ranged between (15.5±0.1) and (15.9±0.02) (˚C). Water temperature did not differ between the sampling sites **(Table 1).** Water temperature did not show effects on nutrient concentrations during the study (r = 0.58, p = 0.10 and r = 0.37, p = 0.32) for PO_4 and NO_3, respectively (**Figure 2a, b)**.

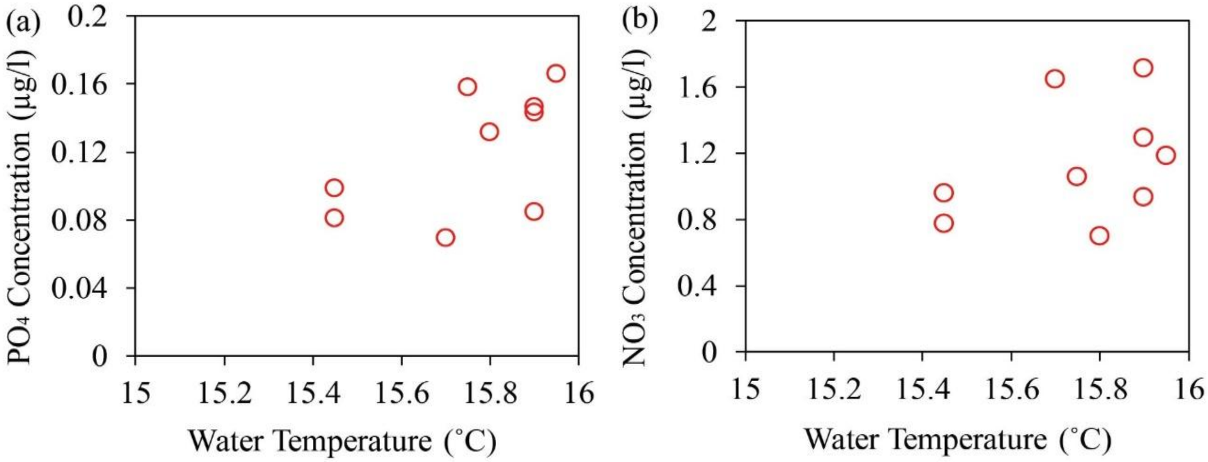

Figure 2. Relationships between water temperature and phosphate (PO_4) concentration (a) and nitrate (NO_3) concentration.

PO_4 concentration differed among the studied sites **(Table 1)**. Average (±1 *SD*) of phosphate concentration was ranged from the lowest value (0.08±0.01 µg/l) in Al-Gherai´at site to the highest value (0.15±0.02µg/l) in AL-Jadriyah **site (Figure 3a).** There were significant differences in phosphate concentration between some specific sites (*t-test*: $df = 5$, $t = -1.77$, $p = 0.04$ and df = 5, $t = -5.21$, $p = 0.001$), respectively, between Al-Gherai´at and Al-Shuhda´a Bridge; Al-Gherai´at and AL-Jadriyah, while it did not show a significant difference between Al-Shuhda´a Bridge and AL-Jadriyah (*t-test*: $df = 5$, $t = -1.11$, $p = 0.15$) **(Figure 3a).**
NO_3 concentration did not show significant differences among the studied sites (**Table 1**). Average (±1 *SD*) of NO_3 concentration was ranged from the lowest value (0.87±0.27 µg/l) in Al-Shuhda´a Bridge site to the highest value (1.40±0.77µg/l) in AL-Jadriyah site (**Figure 3b**).

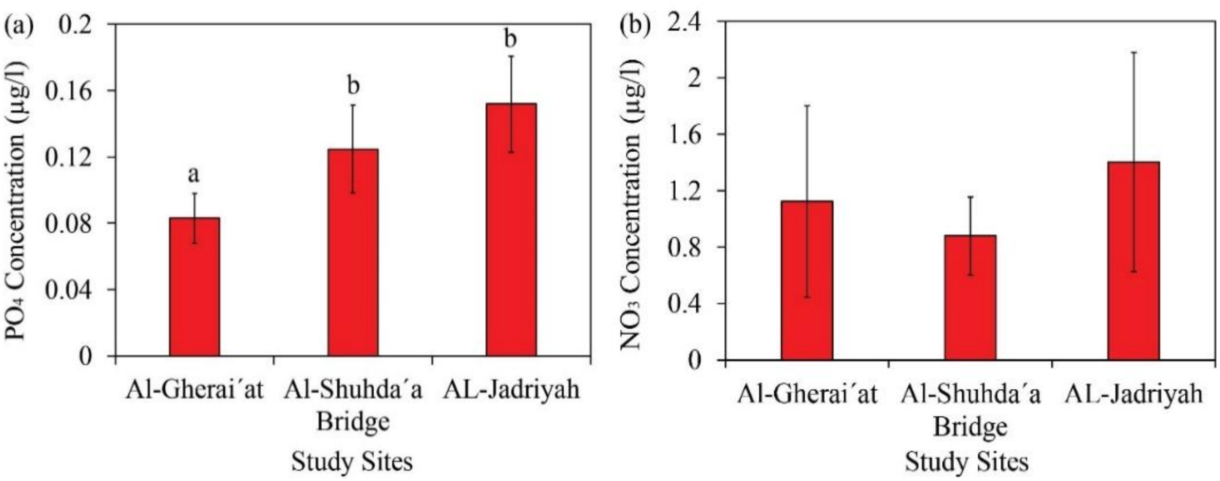

Figure 3. Nutrient concentrations of the different studied sites, a) Phosphate (PO_4) concentration and b) Nitrate (NO_3) concentration. The different letters on the error bars mean significant differences at the significant level (p-value <0.05).

Table 1. One-way ANOVA statistics results showing changes of studied variables during the study.

Variable	*df*	*F*-value	*p*-value
Water Temperature	(2, 17)	0.014	0.98
PO_4	(2, 17)	5.59	0.01
NO_3	(2, 17)	0.89	0.42

Significant level at p-value <0.05.

4. Discussion

Phosphate concentration demonstrated significant differences among the studied sites, while nitrate concentration did not differ significantly. The changes in phosphate concentration were not attributed to impacts of water temperature. Different human activities in the surrounding catchments of aquatic ecosystems can influence phosphate concentration more than nitrate, according to these findings. Some studies have revealed that water temperature significantly affects nutrients, as warming enhances the release of nutrients from sediments (27–30). Microorganisms carry out increased mineralization processes in tandem with the positive relationship between increased water temperature and released nutrients (31). While our results did not show significant correlations between water temperature and nutrient concentrations that supports our hypothesis that human activities are the main drivers of nutrient concentrations in some aquatic ecosystems, especially those close to urbanization areas. The main inorganic phosphorus component in water is active phosphate (32). Natural water often has low phosphate levels, as observed (33; 34). We would expect low phosphate concentrations because soil particles could absorb it and remelt it easily (35). The abundance of aquatic species, the composition of soil and rocks, and other variables can affect phosphate, an essential element of all biological aquatic systems and processes (36). We can attribute the differences in phosphate concentration along the studied sites to phosphate inputs from industrial waste, sewage, and detergents (37–40). Further, the changes in phosphate concentration along the river are due to the run-off of fertilizers used in agriculture (2). Conversely, we can attribute the variations in phosphate concentration across the studied sites to varying population densities and heightened urbanization near the river. For instance, the existence of restaurants may contribute to an increase in the direct disposal of waste materials such as food waste and detergents like soap into the river. Research has shown that the presence of detergent, particularly dishwashing detergent, in urban areas along riverbanks could serve as a primary source of phosphate in aquatic ecosystems (41-43). On the other hand, nitrate in aquatic ecosystems is the main form of inorganic nitrogen (44), and it is a product of the biological breakdown of organic nitrogen molecules, whether they are in their native or contaminated forms. Many studies showed that human activities like using fertilizers in agriculture have an effect on nitrate concentrations in aquatic ecosystems (45-48). While our results did not reveal significant differences in nitrate concentration among the studied sites along the Tigris River, this could be because different locations receive the same amounts of nitrate from urbanization areas, such as restaurants or residential areas. However, reclaimed land for agriculture is rare around the studied sites, despite nitrate being a crucial component of chemical nutrients used in agriculture. For agriculture, the farmers always use ammonia (NH_4) as chemical nutrients that will be transformed by bacteria into nitrate, while phosphorous is an important component of domestic detergents (49). These factors may contribute to an increase in phosphate levels, but not nitrate levels.

5. Conclusion

Overall, our results revealed that warming does not influence nutrient concentration clearly, whereas phosphate concentration could be impacted by urbanization areas around the aquatic ecosystems more than nitrate. We can conclude that anthropogenic activities have a greater impact on nutrient concentration in aquatic ecosystems than climate warming does. Therefore, we recommend considering the various human activities in the surrounding aquatic ecosystem.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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