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The residual effect of fish farms on the water quality of the Euphrates River, Iraq.

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ABSTRACT

This is the first study using spatial distribution maps and water level fluctuations to highlight the impact of fish farms on the water quality of the Euphrates River. Physical and chemical characteristics were estimated before, during, and after the rainy season (October – December 2018) when the water velocity and the level of the river were in fluctuation. The water depth in the study area fluctuated between 4 and 4.5 meters. Field and laboratory analyzes were carried out, obtaining the ecological indicators of Dissolve Oxygen (DO), Biological Oxygen Demand (BOD_5), Water Temperature, pH, Total Dissolved Solids (TDS), Nitrate (NO_3^-), Phosphate (PO_4^{3-}) and Turbidity (NTU). The impacts of fish farms cages on river water for (DO, BOD_5, and NO_3^-) have been determined using multi spatial distribution maps. The results showed that the increase of NO_3^- concentration within the fish cages site A is more by 51 times than its normal concentration at the point A0, whereas, the decrease in DO concentration is reached 31%. The effective contaminated distance in the direction of downstream fish farm reaches more than 60 meters. The spatial concentration rate of the nitrate enrichment with the flow direction ranges from 0.58 to 0.60 mg/L for each meter. At the same time, the amount of dilution gradient ranges from 0.30 to 0.32 mg/L/m during the monitoring period. The spatial concentration rate of BOD_5 enrichment was 0.085, 0.08, and 0.06 mg/L/m, while the amount of dilution gradient was 0.04, 0.03, and 0.06 mg/L/m during October, November, and December, respectively.

INTRODUCTION

Euphrates enters the Iraq border in a desert area within a relatively steep valley in the physiological provinces (lower valleys and Al-Jezira); then, it leaves the rocky valley and enters the plain sedimentary south of Hit city. It flows into lower locations caused by tectonic and structural movements in the region (**Fayyadh *et al*., 2016**). The importance of Euphrates is due to it constitutes a large proportion of life and is a vital source of all activities of living organisms, which has made it the most consumed resources exposed to pollution from various sources (**Awomeso., 2010; Marcin and Ireneusz., 2018; Bayan *et al*., 2020**).

Demand for marine products increased in all developed countries, with an increase reach 62% in 2003, while **Tacon and Halwar** (**2007**) predicted that fish consumption could reach about 1 million tons in 2021. Water discharges from fish farms contain solid or liquid organic pollutants, as well as the high turbidity of the flowing water changes the ecosystems of water. This causes the lives of some aquatics to be threatened by the other. The water environments, its physical, chemical, and biological properties are directly affected by the production of fish farms by pollutants (**Arisekar *et al.,* 2019; Walid *et al*., 2020**). Many ecologists have described aquaculture as an environmental disaster due to management errors. Healthy developments of fish farming require not only meeting the needs of farmed fish but also pay attention to the environment (**Tookwinas, 1996; Cripps and Bergheim, 2000; Federica *et al*., 2014; Medhat *et al*., 2020**).

Aquaculture systems in cages need further development. Fish farming in floating cages can lead to many environmental risks, such as increased plant and algae growth. A studies by (**Renato *et al*., 2006; Mcmutry *et al*., 2007**) confirmed using such water to improve the quantity and quality of plants when using it as soluble fertilizers. Another reason represented by escaping of farmed fish to the natural environment can affect on fish living in natural water as well as the inconvenience and confusion of the security of cage manufacturing and installation of terrestrial or aquatic animals in the region (**Pillay., 2004**). Fish cages are thrown out toward the deeper water and more extreme operating conditions, in order to reduce environmental impacts by increasing potential pollution (**Cremer., 2006; Lisac and Refa., 2006; Chen *et al*., 2007; Jose and Jim., 2007**). Water is considered as one of the most important factors in obtaining a good agricultural investment. Therefore, it is necessary to collect requirements to make use of available water resources to improve productivity, such as reusing water from fish ponds to irrigate various crops (**Cruz *et al*., 2000; Malik *et al*., 2017**). Nowadays, Euphrates suffers from increasing amounts of pollutants due to fish farming residues, which endanger both the aquatic environment and the farms themselves. Therefore, this paper aims to shed light on the Euphrates environment as a reference study for future research projects.

Study Area

The study area locates at western Iraq on the coordinates (X=291249-291302; Y=3745095-3745173) (Fig 1) classified as dry climate, according to **Mather** (**1974**).
The average temperature, falling rains, and wind speed during the study period were 22.5 °C, 41 ml, 21 Km/h, respectively. The number of fish in the farms was about 50,000 fish at an average weight of 1800 g/fish. The water velocity was 0.15, 0.19, and 0.16 m/sec in November, October, and December, respectively. The depth of water was 3.7 meters in October, increased about 50 cm in November then increased 10 cm in December.

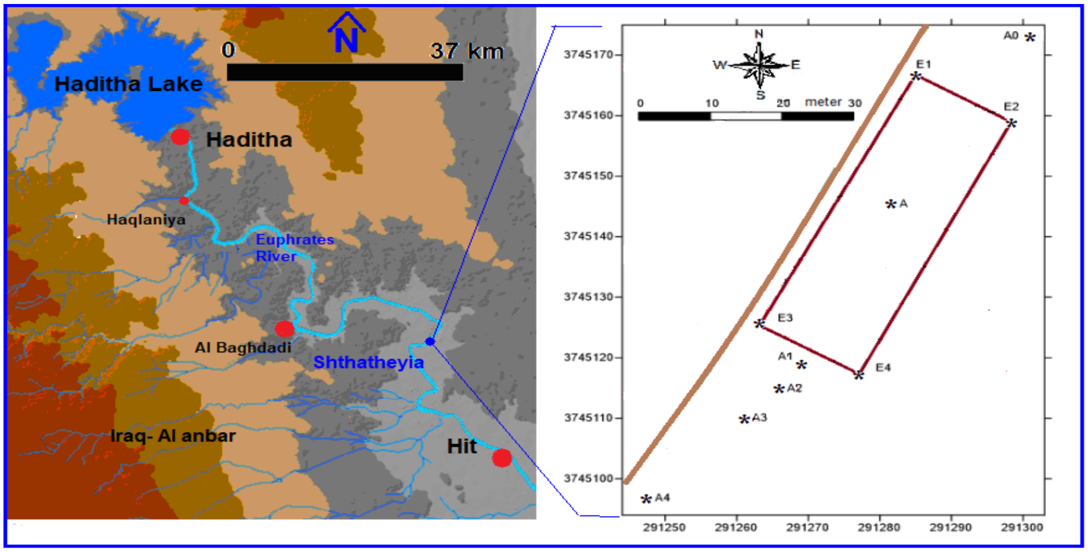

Fig. 1 A map of the study area

MATERIALS AND METHODS

The monitoring points are located using the Global Positioning System (GPS) and plotted the locations of survey networks on Geo-referenced base map using Surfer Software11 within the study area. Some studied variables (DO, BOD_5, and NO_3^-) are produced as a spatial distribution map. Five Points (A, A1, A2, A3, A4, and A5) are fixed to monitor the physical and chemical changes of river water passing through floating cages for three months (Fig 1), then, comparing the characteristics of the river water in these monitored points with the representative upstream zone at the location (A0).

Eighteen samples are collected for analysis during the monitoring period extended from October to December (2018). The samples are collected in polyethylene bottles washed by distilled and sterile water (**APHA, 1998**). The results are listed in Table 1.

Table 1 Physico-chemical analysis of Euphrates River

	Variables	**A0** Northing(X)=3745173 Easting(Y)=291301	**A** 3745146 291282	**A1** 3745119 291270	**A2** 3745115 291265	**A3** 3745110 291261	**A4** 3745097 291248
October	PH	8	8.5	7.8	7.9	7.9	7.9
	Temp °C	21	21	21	22	21	22
	Turb. NTU	3.6	10	8.7	8	5.3	3.5
	TDS mg/l	450	455	460	452	480	470
	NO_3^- mg/l	0.42	21.54	18.43	13.51	7.25	2.19
	PO_4^{3-} mg/l	0.049	0.101	0.049	0.044	0.064	0.056
	DO mg/l	9	5.6	8.1	8.5	8.4	8.6
	BOD_5 mg/l	1.2	4	2.3	2.1	2	1.5
November	PH	8.4	8.6	8.6	8.5	8.4	8.4
	Temp °C	19	19	19	19	20	19
	Turb. NTU	30	30	30.4	30.5	30.1	30
	TDS mg/l	535	535	490	490	520	530
	NO_3^- mg/l	0.35	20.58	17.72	9.50	10.26	1.81
	PO_4^{3-} mg/l	0.075	0.075	0.050	0.058	0.055	0.056
	DO mg/l	7.8	5.8	6.9	7.1	7.6	7.8

	BOD_5 mg/l	2.5	3.9	3.6	3.7	3.8	2.4
December	PH	8	8.4	7.9	7.9	8.1	8
	Temp °C	17	18	18	19	18	18
	Turb. NTU	4.4	6	6.1	5.7	4.9	4.1
	TDS mg/l	490	491	525	530	520	515
	NO_3^- mg/l	0.37	21.21	17.93	10.91	8.29	3.25
	PO_4^{3-} mg/l	0.059	0.095	0.050	0.041	0.040	0.046
	DO mg/l	8.2	5.8	8	8.3	8.1	8.1
	BOD_5 mg/l	1.8	3.8	2.6	2.7	2.2	1.8

RESULTS

According to the statistical correlation of Spearman coefficient (rs) = $1 - 6 \sum di^2 / n (n^2 - 1)$, comparisons are carried out between the chemical and physical variables versus DO and NO_3^-; where, $d_i = x_i - y_i$ represents the difference in ranks for the i-th individual and n denotes the number of individuals (**Helsel and Hirsch., 2002**).

The analysis has shown a positive correlation with some variables and a negative one with the others (Table 2). The DO is one of the most important parameters of the aquaculture environment. Thus, it regulates the metabolic processes as well as being one of the most important elements that create good environmental conditions for various neighborhoods (**Eric *et al*., 2016**). Table 2, shows reverse relation between DO and the studied variables except for the water temperature shown weak linear positive relation with DO. The reverse relation of DO with pH values is originated from the presence of nitrogen as (NH_3) in a reduction environment, which converted to a high concentration of NO_3^- according to the oxidation-reduction reactions (**Stumm and Morgan., 1981**). Another reverse correlation is observed between DO and TDS originated in the precipitation of specific ions due to the oxidation reaction of different ions.

Table 2 Statistical correlations according to the results of Spearman Rank Coefficient

Parameters	DO	NO_3^-	Temp	pH	BOD_5	PO_4^{3-}	TDS
DO	1.0						
NO_3^-	-0.5511	1.0					
Temp	0.3457	0.1011	1.0				
pH	-0.7688	0.1847	-0.1935	1.0			
BOD_5	-0.8808	0.7048	-0.1021	0.6542	1.0		
PO_4^{3-}	-0.5536	0.1259	0.0206	0.5087	0.4417	1.0	
TDS	-0.3725	-0.0737	-0.5407	0.3214	0.3869	0.0877	1.0

The dispersion of DO, BOD_5 and NO_3^- was monitored and detected by spatial distribution maps before, within and after fish farms (floating cages) with an area of 720 meters. Figures 1-A, 1-B and 1-C showed that DO concentration inside (A) the cages is stable at a value ranged between 5.6 and 5.8 mg/L during the study period. Figure 2-A shows that the highest concentration of DO in October is observed at the end of the farm rather than in the middle (point A). This is due to the decline in water level by 3.7 m at a water velocity of 0.15 m/sec. In Figures 2-B and 2-C, the highest concentration of DO value is observed to be in a different location in the farm (middle). Then, the dilution starts directly until reaching a concentration of 8 to 8.1 mg/L at point A1. The DO saturation rate is 7.8 mg/L in November; this decrease is observed due to the thrived suspended organic matters carried by the floods during the rainy season (November) (**Amirkolaie, 2008**).

The water recovers its normal state after 60 meters distance at point A4 due to the high water velocity, which reduced the time of dilution. In December and October, the water needs further distance than A4 to recover DO concentration to its normal state (A0). The study model indicates that DO concentration should be monitored continuously when the water level fluctuates. The lowest water temperature (17 °C) is recorded during the monitoring period in December, yet no changes observed in the concentration of DO (Figure 4) despite the low temperature should help to maintain a greater amount of oxygen (**Nyanti *et al*., 2018**). This behavior was neutralized since the fluctuation of the river level changed its properties.

The BOD_5 concentration maps (Fig. 3-A, 2-B and 3-C) revealed that the BOD_5 plumes were located in the center of the cages, specifically at point A. In addition, there was a difference in the distribution behavior observed during the October, November and December periods. The highest BOD_5 concentration is found in point A (4, 3.9 and 3.8 mg/L) in the monitoring months respectively, with an enrichment gradient coefficient of 0.085, 0.08 and 0.06 mg/L/m from point A0. The dilution gradient coefficient is 0.04, 0.03 and 0.060 mg/L/m after point A and towards point A4. The difference between dilution and enrichment concentration mechanisms is due to the increase of organic matter and nutrients as well as water velocity, where dilution of chemical ions is strongly influenced by river flow (**Pasquini and Sacchi., 2012**).

Figure 3-A (October) shows that the water passing cages need more distance from the cages to recover its normal state as in point A0, where relative high temperatures (Fig 4), low water level and high enrichment led to decrease the dilution rate. This led to an increase in DO consumption by fishes let to high BOD_5 concentration. The DO associate with photosynthesis and respiration is a major cofactor affecting the acidic function (**Wetzel, 1983; François and Janet., 1993**). The results obtained from Figure (4) showed an alkaline condition (pH) at point A during the study period, where the DO concentration is decreased accompanied by increasing in nitrogen concentration due to the fish wastes, during October and December. However, the water outflow from the fishery farm is recovered at a distance of 27.5 m (point A1), while the alkaline water effect continued to point A3 in November.

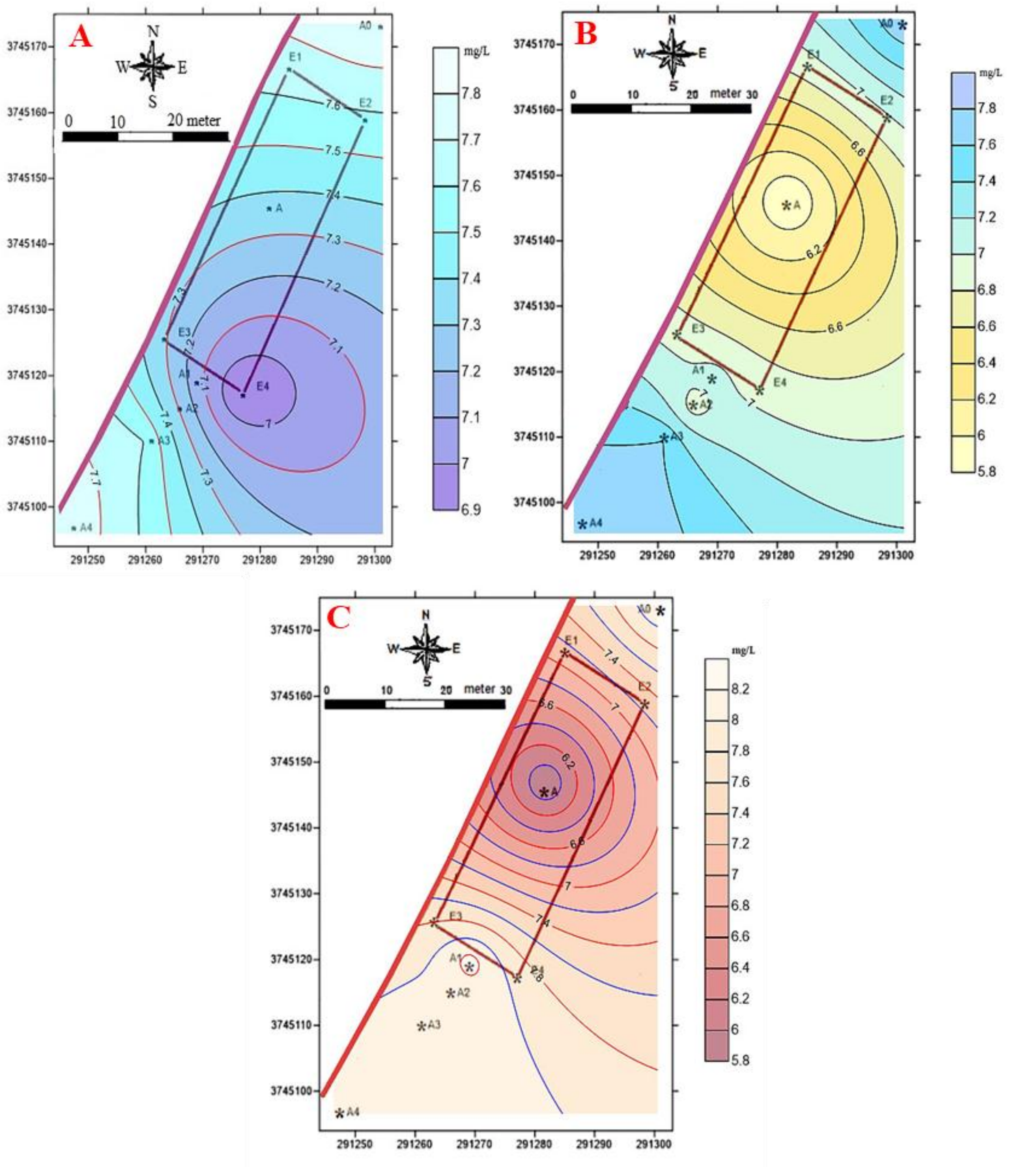

Fig. 2. DO concentration at (A) October, (B) November and (C) December

The seasonal rain period in the study area (western Iraq) begins in the end of October. There are many valleys, such as (Horan and Hijlan) flow to the Euphrates in the rainy season (**Fayyadh *et al.*, 2016**). The drafted rainwater carries the content of the soils represented by ions, causing an increase in the concentration of TDS (Table 1). Meanwhile, in November, the turbidity of Euphrates water reached high value (30 NTU) at the upstream zone of Cages (Fig 4). The high value of water discharge eliminated the impact of a fish farm on the value of turbidity at the monitored points (A-A4). However, there is a noticeable effect of the floating cages on the turbidity in October and December, where the high value reaches 10 and 6.0 NTU at A in comparing to the zone upstream Cages (A0) 3.6 and 4.4 NTU respectively. Finally, the turbidity is recovered to the normal state (A0) at A4.

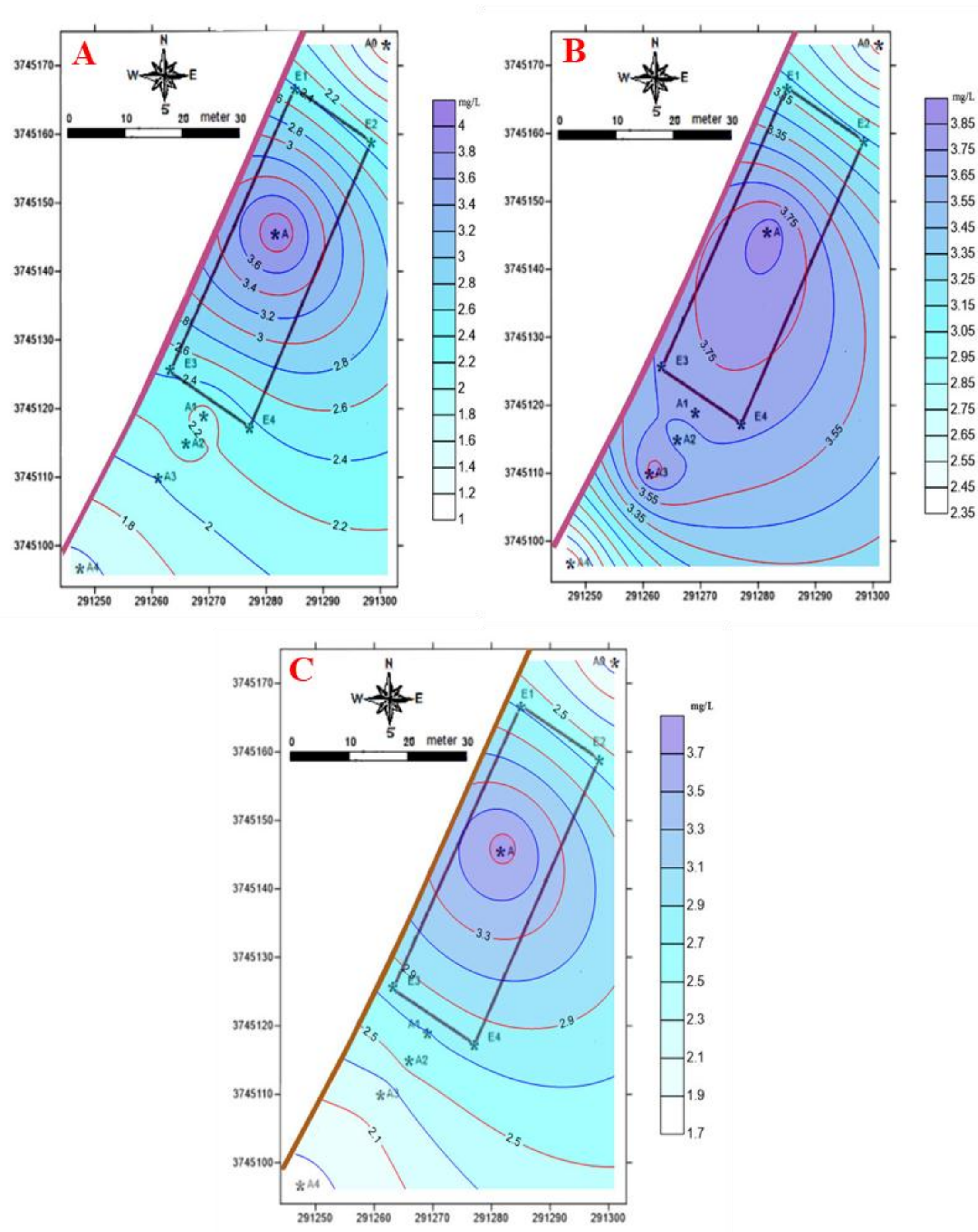

Fig. 3 BOD_5 concentration at (A) October, (B) November and (C) December

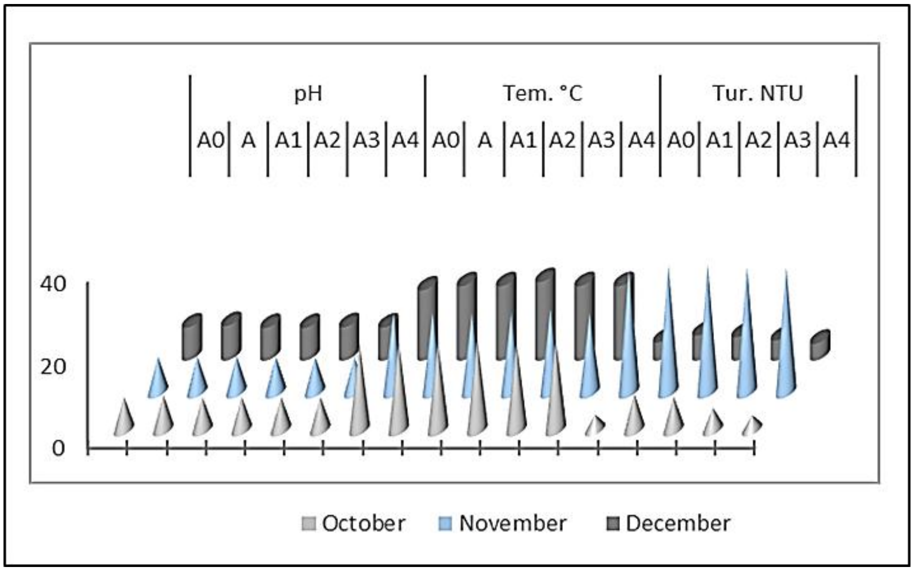

Fig. 4 Values of pH, Temp., and Tur., at the monitored water points

The increase of NO_3^- concentrations within the fish farm at point A is 51.2 times than A0; hence it is classified as a polluted aquatic life (**Costa-Pierce *et al*., 2005**). Table 1 shows that NO_3^- highest concentration is recorded at the point A0 during October. Which coincides with the low Euphrates water level and accompanied by groundwater flow as seepages (**Hussien *et al*., 2011**). This indicates that part of the slight increase in NO_3^- concentration of the Euphrates is due to the effect of groundwater.

Figures 5-A, 5-B and 5-C show that the concentration of NO_3^- increased significantly within the fish farm during the study period (October – December). NO_3^- level at point A reached 20.5 to 21.5 mg/L compared to 0.35 to 0.42 mg/L at the upstream zone (A0). The concentration rate of NO_3^- enrichment with the flow direction is ranged between 0.58 and 0.60 mg/L for each meter, while the amount of dilution gradient varies from 0.30 to 0.32 mg/L/m during the monitoring period. The significant increase of NO_3^- concentration is caused by the disposal ammonia introduced by fish as well as the amount of nitrogen produced by protein degradation from fish feeding. The concentration of NO_3^- began to decrease from point A. Nonetheless, the river water at point A4 cannot recover the concentration since it needs a longer distance than 60 m, especially during October and December due to the accumulation of the nitrate source from groundwater and fish farm.

The phosphate is considered as one of the essential nutrients for algae in the aquatic environment. Phosphate analysis of the studied aquatic environment (Figure 6) showed that the fish farm caused a small increase in phosphate concentration. The highest concentration was found at point A during October and December. Then, it faded at the other points A1, A2, A3 and A4. During November, flow velocity and rainfall intensity caused the concentration of PO_4^{3-} to stabilize before the fish farm (A0) and the other points (A-A4).

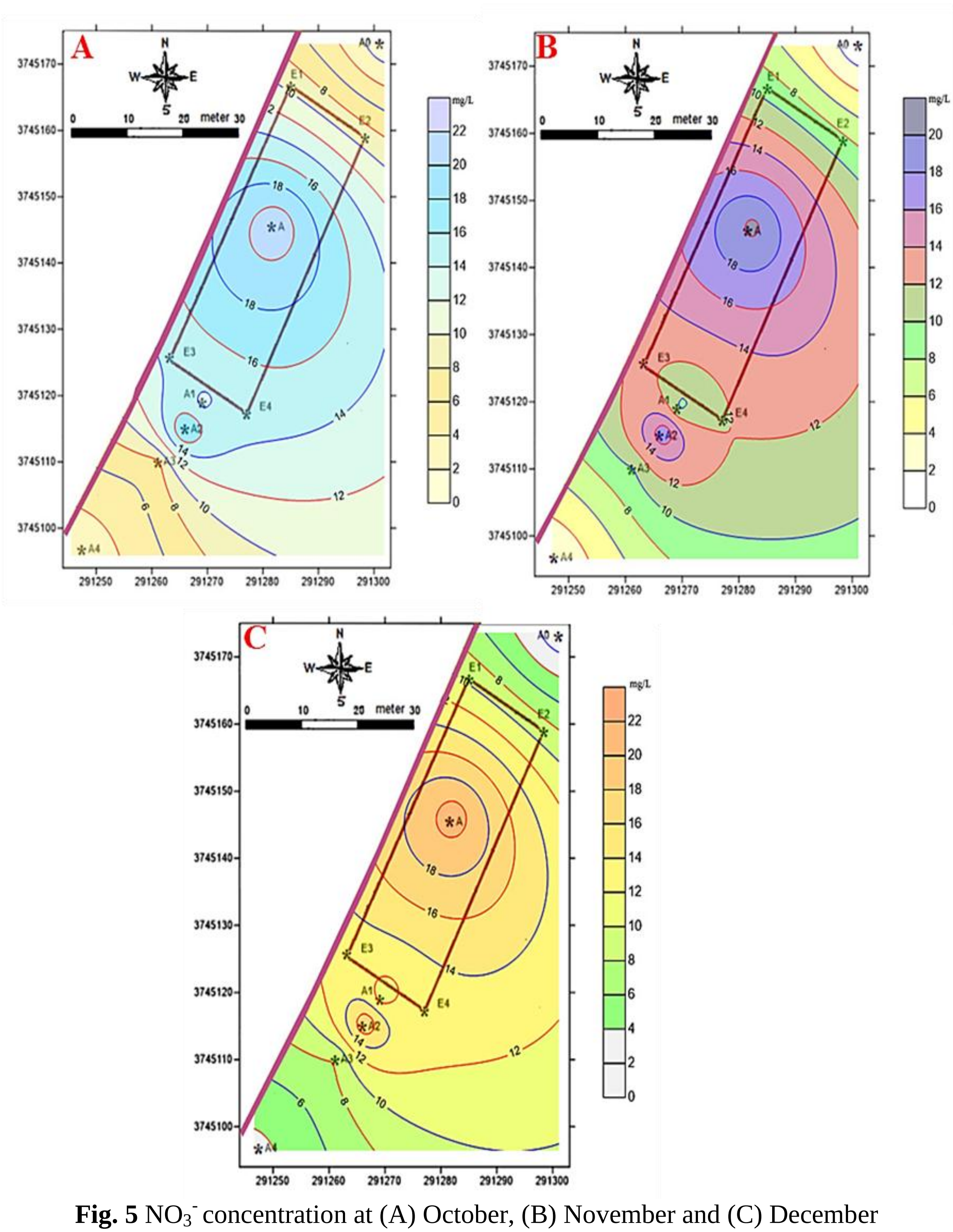

Fig. 5 NO_3^- concentration at (A) October, (B) November and (C) December

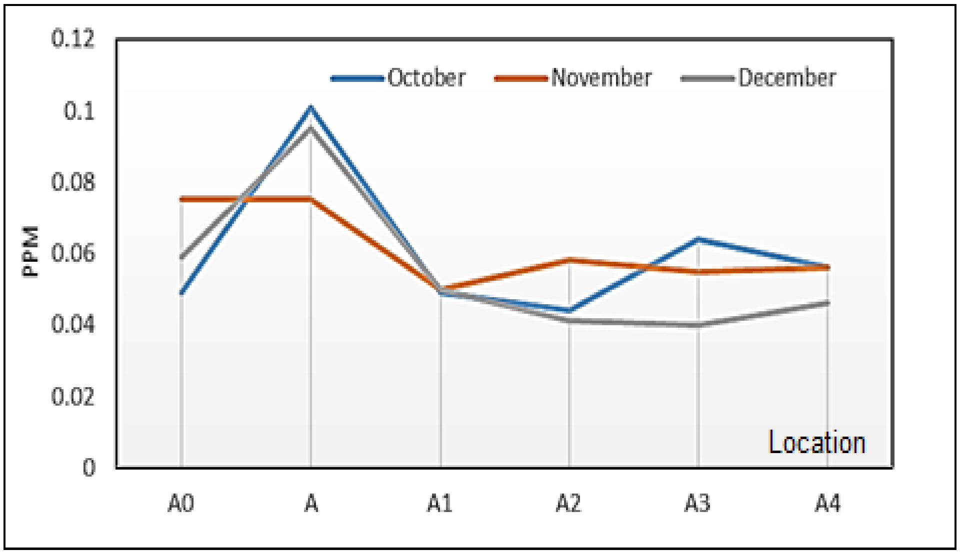

Fig. 6 PO_4^{3-} concentration in October, November and December

CONCLUSION

The floating cages of fish farms in Euphrates have a variable effect on the aquatic environment. This effect was associated with fluctuating river levels throughout the year. The decline in the Euphrates water level led to enriching its water with a considerable amount of NO_3^- and PO_4^{3-} concentration with the direction of the water flow line.

The fish farms in the form of floating cages must be separated from each other at a distance, not less than 100 meters. The spatial distribution of water quality parameter plumes indicates that the polluted zone was clearly detected in the central zone of fish floating cages extends to more than 60 meters, whereas the recovery zone is detected after the last monitored water points. The experiments on the fish culture in cages installed within the river water proved that the flow velocity affects fish culture in cages. The abundance of nitrogen and phosphorus in the wastewater of the fish farms makes this water suitable for agricultural purposes (irrigation use) instead of industrial fertilizers, and also this process plays a role in mitigating the river pollution caused by fish farms.

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