AACL BIOFLUX

Aquaculture, Aquarium, Conservation & Legislation
International Journal of the Bioflux Society

Seasonal investigation of main physico-chemical parameters in terminal part of Gorganroud River during 2009-2010

[1,3]Sima Balaly, [2]S. Abbas Hosseini, and [2]Saeid Balaly

[1]Institute of Hydroecology and Ichthyology of SCZH of NAA, 00014, Yerevan, Republic of Armenia; [2]Faculty of Fisheries and Environment, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran;
[3]Institute of Higher Education of Loghman Hakim, Aq qala (Agh Ghala), Golestan, Iran.
Corresponding author: S. Balaly, sima_balaly@yahoo.com

Abstract. Water quality of the terminal part of Gorganroud River was investigated, during 2009-2010. Monthly values of dissolved oxygen, pH, temperature, BOD, COD, electro conductivity, mineral nitrogen, nitrate, nitrite, ammonium and ortho phosphate were measured in five stations. Despite the probability of introduction of waste waters, results show not serious problem in this part of the river, regarding to aims of the river usage.
Key words: Water quality, Gorganroud, physico-chemical parameter, nutrient loading.

کیفیت آب بخش انتهایی رودخانه گرگان رود در طول سال 2010- 2009 مورد بررسی قرار گرفت ، مقادیر ماهانه اکسیژن محلول ، pH ، دما ، BOD، COD، EC ، نیتروژن معدنی ، نیترات ، نیتریت ، آمونیوم و ارتوفسفات در 5 ایستگاه اندازه گیری شد . علارقم احتمال ورود فاضلاب ، نتایج مشکل حادی را در این بخش رودخانه با توجه به هدف استفاده از رودخانه نشان نداد.
کلمات کلیدی : کیفیت آب ، گرگان رود ، پارامترهای فیزیکی- شیمیایی ، بار مواد مغذی

Introduction. Nowadays, understanding physical and chemical factors of rivers are important aspects. In this paper the authors want to unveil mentioned factors for Gorganroud River that releases to Caspian Sea. Region of Gorganroud has been rapidly developed during the past two decades. Mentioned river is very important for local economics, irrigation seawards farm, fish migration, broodstock for valuable fish species, and place for abandon of valuable fish fingerlings (natural environment for biotic characteristics).

The massive economic growth and urban development in this region has led to excessive release of wastes into the estuarine region. Wastes in disturbed aquatic ecosystems are often dominated by anthropogenic inputs of nitrogen (N) and phosphorus (P).

Discharge of pollutants to a water resource system from domestic sewers, storm water discharges, industrial wastes discharges, agricultural runoff and other sources, all of which may be untreated, can have significant effects of both short term and long term duration on the quality of a river system (Crabtree et al 1986).

N is an important element of the ecosystem and is a key constituent of various organic and inorganic substances. Aquatic systems contain small concentrations of nitrogen in organic and inorganic forms (Ilic & Panjan 2010). Besides N, P is the second most important essential elements of primary production and is the most important nutrient which causes the eutrophication of freshwater which induces algae growth, lowers the content of diluted oxygen in the water, and reduces water clarity (Ilic & Panjan 2010).

Nitrate concentrations in rivers and groundwater continue to be a matter of concern throughout the developed world (Howden & Burt 2009). The maximum acceptable concentration in drinking water is 30 μg L^{-1}, but may only be allowed to reach up to 3 or 9 μg L^{-1}. To protect salmonids and coarse fish, respectively, typical values in unpolluted streams are generally between 1 and 3 μg L^{-1}, but may range between 8-17 μg L^{-1} in highly contaminated rivers (Hatch et al 2002).

The conversion of NH_4^+ to the intermediate NO_2^- and then through to NO_3^- by nitrifying bacteria (i.e. nitrification) is a key process which mobilize N and promotes losses to watercourses (Hatch et al 2002). The coupling of this obligatory aerobic process (nitrification) with an anaerobic process (denitrification) leads to the loss of nitrogen to the atmosphere. Therefore, nitrification is crucial to an understanding of the nitrogen cycle in aquatic systems, particularly, the river/estuarine systems. There have been many examples showing intensive nitrification in polluted rivers/estuaries that directly or indirectly (through organic nitrogen mineralization) receive large amounts of ammonium favorable to the development of nitrification. Transformation of nitrogen species from ammonia and nitrite to nitrate in river/estuaries during transportation not only modulates their relative distributions but also enhances oxygen consumption (Dai et al 2008).

The majority of P is flushed from agricultural areas into surface running waters; flushing into ground water is insubstantial. According to the EPA (1984), P losses from farming surfaces amount to 0.97–1.85kg/ha/year (Ilic & Panjan 2010).

In unpolluted freshwaters, total phosphorus (TP) concentrations are typically below 25μg P L^{-1}. In water management, it is generally assumed that concentrations above 50 μg $P1^{-1}$ are the result of anthropogenic influences. A survey of rivers in Europe revealed that a large proportion of c.1000 monitoring stations observed TP concentration exceeding 50 μg P L^{-1}. Only cca 10% of the monitoring stations reported mean TP concentrations below 50 μg P L^{-1} (Leinweber et al 2002).

In this study, N and P and some other physio-chemical factors in part of Gorganrod River were investigated; the river that use to be an important point for young fish release (for stock enhancement purposes), specially the endangered sturgeon species, and an important river for Caspian Sea's migratory fish in order to spawn.

Material and Method. This study was undertaken during the period April 2009 until March 2010, by monthly sampling of chemical factors of Gorganrod River.

Since Gorganrod is the largest river in North-East Caspian Sea, we studied only on ~50 km of it by choosing five sampling stations (Figure 1, Table 1). These stations were chosen because lands along stations 1-2 have been using for agriculture and stations 2-5 are near river mouth that are strategic points of young fish release for stock enhancement purposes. The area of investigation was shown in Figure 1. Gorganrod River can receive drainage of all flood, waste waters and runoff derived from precipitation of its huge basin; and we investigated the area after Woshmgir dam.

Samples were analyzed to determine temperature, pH, dissolved oxygen (DO), NH_4^+, NO_2^-, NO_3^{2-}, N-mineral, PO_4^{3-}, electro conductivity (EC), BOD and COD, using standard methods (Wetzell & Likens 1991).

All data were transformed to logarithm scale and then analyzed using split-plot that the seasons were assumed as main factor and the stations as plots. Duncan's test was applied to determine significant difference between all stations and season as well as their combination. Data present as mean ±SD. All analyses were performed using MSTATC software.

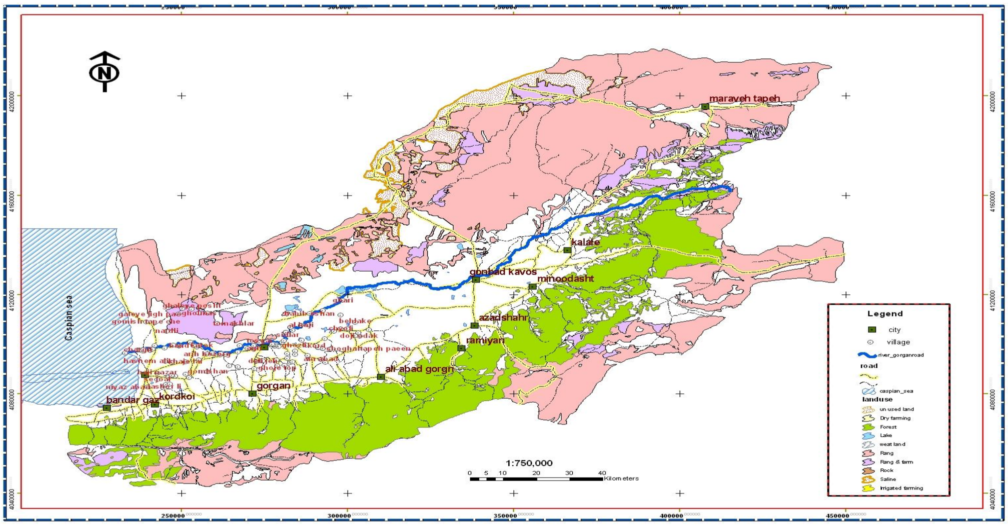

Figure 1. Position of the Gorganroud river.

Figure 2. Position of sampling stations.

Table 1

Location of the sampling stations

Station	Distance from estuary	Location
1	49679.16	Agh Ghalla
2	10547.46	Khajenafas
3	6852.22	Chargholi
4	3302.72	Lookout unit
5	0	Estuary

Results and Discussion

Temperature. Results showed that temperature values were significantly affected by the seasons, not the stations (Table 2). Figure 2 shows temperature fluctuations typically followed the years, where the lowest temperature was related to winter and highest related to summer.

Table 2

Analyze of variance for temperature values in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	8.461	2.86	11.3158	0.003
Error	8	1.994	0.249		
Station	4	0.060	0.015	0.9295	
Season*Station	12	0.28	0.023	1.4550	0.1929
Error	32	0.512	0.016		
Total	59	11.306			

Split-plot design, n=3.

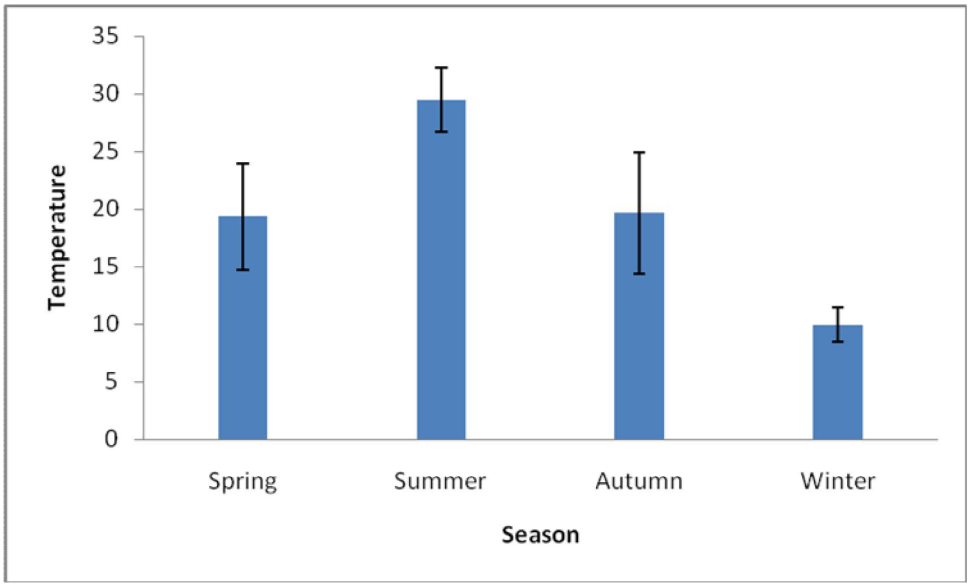

Figure 3. Seasonal changes of temperature values.

Dissolved Oxygen. Data indicated that DO levels were significantly affected by the seasons, station as well as their interaction (Table 3) (Figure 4). DO level is believed to have negative correlation with temperature. Although temperature of spring was approximately two-fold higher than winter, DO values of these two seasons were similar (Table 15). Reason of this is related to higher turbulence in spring due to more flood currents compared winter. The other reason of this might be due to daily movement local and guard of sea's boats along this part of the river. Since this part of the river has low dept (not more than 2 m), single movement of a boat might cause a wide turbulence that leads to more dissolved oxygen levels and reach near saturation levels. DO levels decreased from station 1 to 3 and then increased after station 3 and in station 5, it reached the levels similar station 1 (Table 16). It is because the station 1 and maybe 2 are affected by local waste waters station 4 and 5 are affected by estuarine currents and turbulences which in turn lead to increase in DO levels. Another reason might be related to slop of the river. The slop of the river decreases from station 3 to 5 and in turn, the rate of the river decreases in these stations that consequently leads to less turbulence compared station 1 and 2. However, station 5, and in less magnitude station 4, are affected by estuarine current which increases the turbulence of these to stations compared station 3.

Table 3

Analyze of variance for dissolved oxygen values
in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	124.3	1.041	15.4323	0.0011
Error	8	0.54	0.067		
Station	4	0.12	0.03	3.0440	0.0311
Season*Station	12	0.498	0.042	4.2240	0.0005
Error	32	0.314	0.01		
Total	59	4.96			

Split-plot design, n=3.

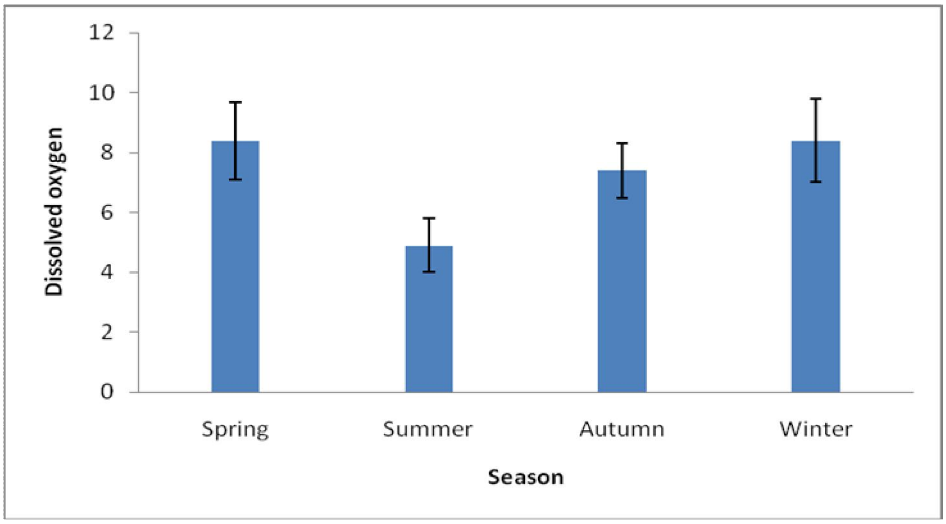

Figure 4. Seasonal changes of dissolved oxygen values.

BOD. BOD values were not affected by seasons, stations as well as their combination (Table 4). Since, BOD level is believed to mainly be related to planktonic assemblages, it is not surprising that the BOD levels were similar in different seasons and stations, because Gorganroud River has very limited planktonic assemblages due mainly to high turbidity and speed of the river.

Table 4

Analyze of variance for BOD values in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	7.972	2.657	2.4907	0.1344
Error	8	8.535	1.067		
Station	4	1.38	0.345	0.7912	
Season*Station	12	8.271	0.689	1.5810	0.1473
Error	32	13.950	0.436		
Total	59	40.107			

Split-plot design, n=3.

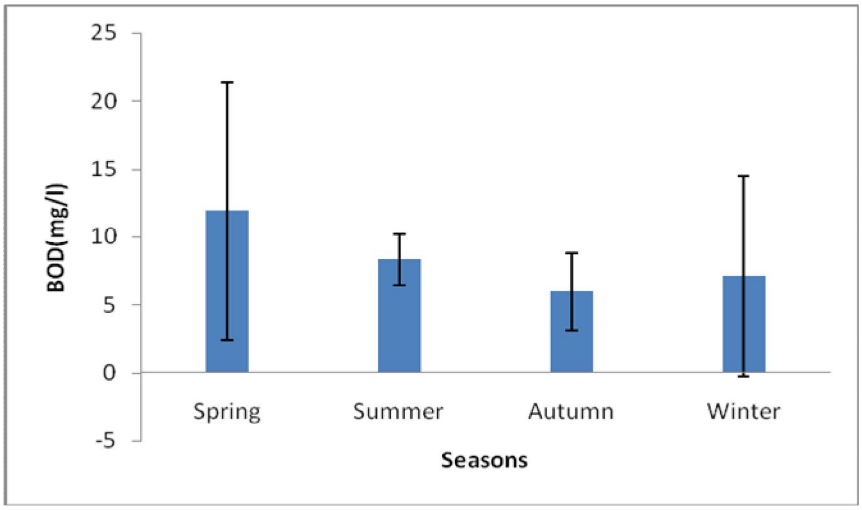

Figure 5. Seasonal changes of BOD values.

COD. While station and interaction between station and season had no effect on COD levels, season significantly affected COD levels (Table 5). Figure 4 shows COD levels of spring, summer and autumn were similar and significantly higher than the values of winter (Table 15). The reason might be due to limited microbial communications in winter due to low temperature compared to other seasons. On the other hand, similarity of the values between stations suggests that none of the stations have received organic and decomposable materials.

Table 5

Analyze of variance for COD values in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	15.596	5.199	6.7985	0.0136
Error	8	6.118	0.765		
Station	4	0.346	0.087	0.2362	
Season*Station	12	4.031	0.753	2.0520	0.0520
Error	32	11.737	0.367		
Total	59	42.828			

Split-plot design, n=3.

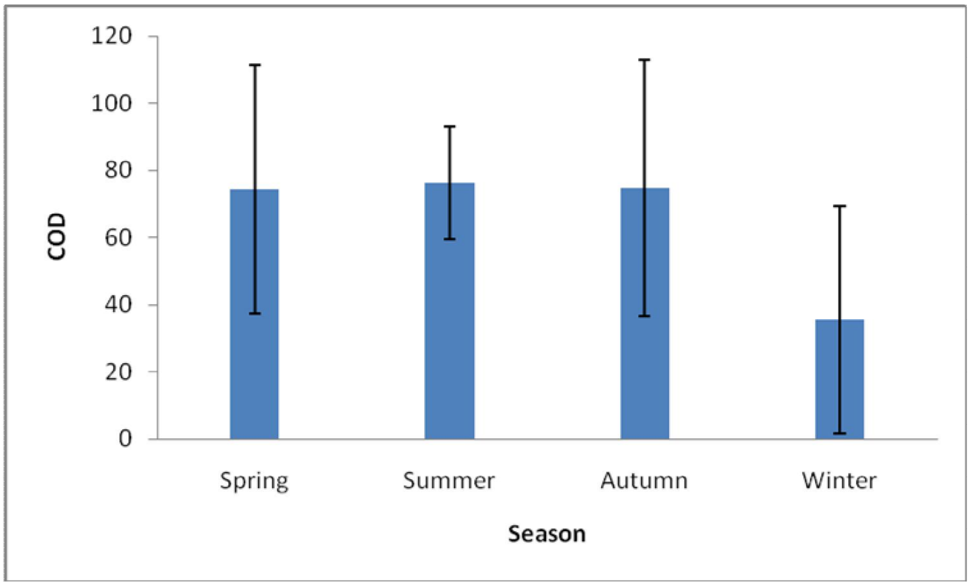

Figure 6. Seasonal changes of COD values.

pH. pH Values did not significantly change in relation to stations and seasons as well as their interaction (Table 6). Since, Gorganroud River is not exposed to different type of soils from stations 1 to 5, it was predictable that pH be stable between stations. Also, this result might suggest that the waste water and runoffs that are introduced to the river are approximately neutralized in the case of pH, or the tampon power of the river is high enough to neutralize the acidic or basic waste drainages. There is a relation between pH and photosynthesis intensity, if we dispense with waste drainages. Thus, since there is no phytoplanktonic assemblages in Gorganroud River (due to high turbulence and turbidity), it is not surprising that pH values was similar and stable during different seasons.

Table 6

Analyze of variance for pH values in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	0.025	0.008	1.4713	0.2938
Error	8	0.045	0.006		
Station	4	0.004	0.001	1.9770	0.1218
Season*Station	12	0.011	0.001	1.7435	0.1033
Error	32	0.017	0.001		
Total	59	0.102			

Split-plot design, n=3.

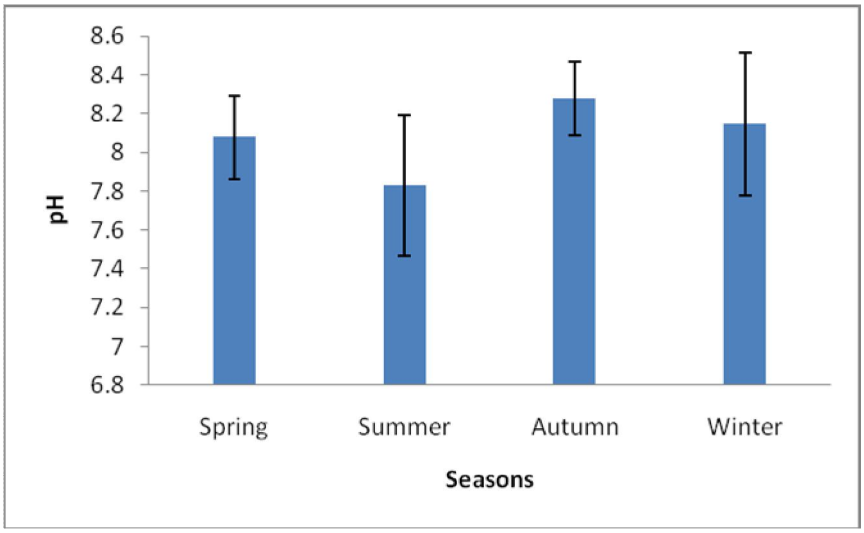

Figure 7. Seasonal changes of pH values.

Electro Conductivity. EC values were significantly affected by the stations, not the seasons and nor their interaction (Table 7). The values of the stations 1-4 were similar and significantly lower than the station 5 (Table 16). The reason is due to invert currents from sea water to the river and increase in salinity levels. Higher EC values of the station 5 can be more important in spring and summer, when the sturgeon fingerlings were released to river mouth for stock rebuilding purposes (station 4) and then migrate toward Caspian Sea. The other importance of high EC values of the station 5 might be related to aquatic plants assemblage that might be limited in the case of growth, despite of suitability of the other factors like light, temperature and nutrients. Regard to above, particular considerations are needed when fish fingerlings are released to the river mouth; the place that seems to be not favorable for this purpose.

Table 7

Analyze of variance for electro conductivity values
in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	3.667	1.226	0.5142	
Error	8	19.066	2.383		
Station	4	10.991	2.748	8.7563	0.0001
Season*Station	12	2.079	0.173	0.5521	
Error	32	10.041	0.314		
Total	59	45.853			

Split-plot design, n=3.

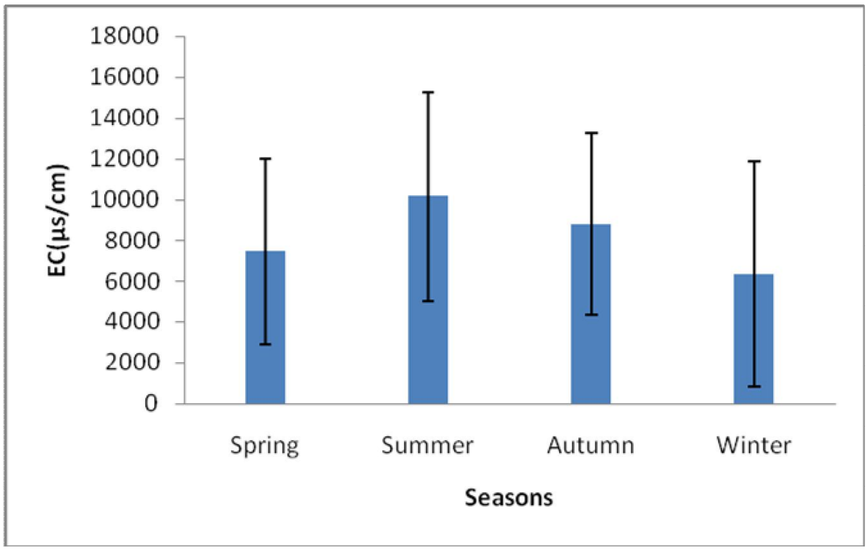

Figure 8. Seasonal changes of pH values.

PO_4^{3-}. PO_4^{3-} levels were significantly affected by season but not the station or their interaction (Table 8). Figure 5 shows the lowest values were related to spring while there was no significant difference between the other three seasons (Table 15). The low level of PO_4^{3-} might be related to more flood currents in spring that leaches PO_4^{3-} from the river (dilution) and decreasing the resident time. Although the river have been receiving the waste water from urban recourses in station 1 (City of Agh Ghalla) and agricultural recourses between station 1-2, there was no significant change between the stations (Table 8). The reasons might be related to: 1) Measuring of only one form of P (PO_4^{3-}) instead of all forms (TP, total dissolved P, organic P etc), unlike N; transformations between different forms of P might mask the change in PO_4^{3-} levels, more or less, depending on stations and seasons. 2) Instead of N, P trends to attach to suspended particle and sediment and forms complex (Vagnetti et al 2003). Since the studied part of Gorganroud River is very turbid with high fine sediment on its bottom, P might be removed from water body by attaching to the sediment and suspended materials (the effect that can be neutralized by measuring sediments' P and water TP); and 3) maybe, the introduced P in station 1-2 be absorbed by aquatic plants along the river.

Table 8

Analyze of variance for PO_4^{3-} values in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	5.512	1.837	5.5497	0.0235
Error	8	2.649	0.331		
Station	4	2.351	0.588	1.7927	0.1546
Season*Station	12	3.906	0.326	0.9930	
Error	32	10.491	0.328		
Total	59	24.909			

Split-plot design, n=3.

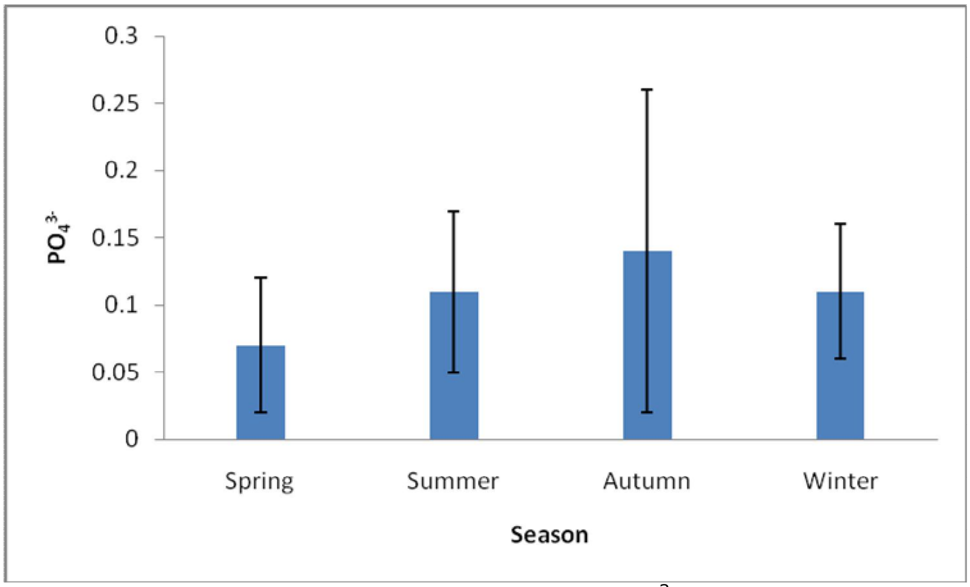

Figure 9. Seasonal changes of PO_4^{3-} values

Nitrogen. Results showed the main form of N-Min was related to NO_3^{2-} which was not surprising considering high levels of DO in all stations and seasons (Tables 13-14). Lack of significant changes in NH_4^+ levels in stations and season (Table 10) (Figure 13) is due to the high levels of DO, too. Major portion of N-Min was related to NO_3^{2-}. Similarly, Abdel-satar (2005) reported major portion of N-Min was NO_3^{2-} in Nile River which had high measured DO levels. N-Min levels were significantly affected by stations and interaction between seasons and stations (Table 9). In the case of stations, N-Min levels significantly decreased from station 1 to 5 that is believed to be related to absorption by aquatic plants and transformation to organic N. However, station 1 and 5 showed pattern during the seasons compared the other stations (Figure 10). In station 1-4, N-Min levels decreased from spring to summer and then increased until winter, exception of station 1 that had same levels of N-Min in autumn and winter (Figure 10). However, in station 5, N-Min levels was similar in season spring and summer, followed by decrease and increase in autumn and winter, respectively (Figure 10). Decrease in N-Min levels in summer compared to spring in station 1-4 is believed to be due to development in aquatic plant communities in summer and absorption of NO_3^{2-} which is the main form of N-Min in the river. Abdel-satar (2005) reported decrease in NO_3^{2-} when phytoplanctonic communities developed in Nile River. These stations showed similar pattern in the case of NO_3^{2-} levels in different seasons (Figure 11). However, since station 5 has been placed in river mouth, aquatic plants communities could not be developed due to hard environmental conditions (mainly due to high salinity and sever salinity fluctuations); therefore, NO_3^{2-} and, in turn, N-Min levels did not change in summer compared spring (Figures 10-11). NO_3^{2-} and N-Min levels increased in stations 1-4 (Figure 10). In this case, increase in NO_3^{2-} and N-Min levels in stations 1-4 is related to crash in aquatic plants communities due to lack of suitable environmental conditions (mainly light and temperature) in autumn. Abdel-satar (2005) mentioned increase in NO_3^{2-} levels in cold season was due to crash in planktonic communities and conversion of ammonium to nitrate in Nile River. However, station 5 showed decrease in N-Min levels while NO_3^{2-} levels were approximately unchanged (Figure 11). Decrease in N-Min levels in this season was related to decrease in NO_2^- levels (Figure 12). There is no strong reason for decrease in N-Min levels in autumn in station 5, but, it might be related to precipitation or invert currents from the sea to the river that cause water dilution. In all stations, N-Min levels increase from autumn to winter, exception station 1 (Figure 10). Increase in NO_3^{2-} and N-Min levels in stations 2-5 in winter might be related to more flood current in winter and slightly late autumn that have been led to increase in leach of N from lands (fertilizers that have been applied for agricultural purposes) to river. However, lack of change in N-Min in station 1, seems to be due to higher levels of NO_2^- in autumn (Figure 12) that has been led to increase in N-Min levels in autumn and in turn, no change in winter. Low values of NO_2^- in all stations and seasons compared to other forms of N is due to high DO levels and fast conversion to NO_3^{2-} (Abdo 2004). Since, DO levels of the station 1 in autumn is high, it seems the increase in NO_2^- levels in this season might be related to introduction of pollutant to river rather than transformation on NO_3^{2-} to NO_2^-, in this station.

Table 9

Analyze of variance for N-Mineral values in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	11.134	3.711	1.54	0.2776
Error	8	19.280	2.410		
Station	4	9.645	2.411	7.3137	0.0003
Season*Station	12	8.554	0.713	2.1621	0.0407
Error	32	10.55	0.330		
Total	59	59.164			

Split-plot design, n=3.

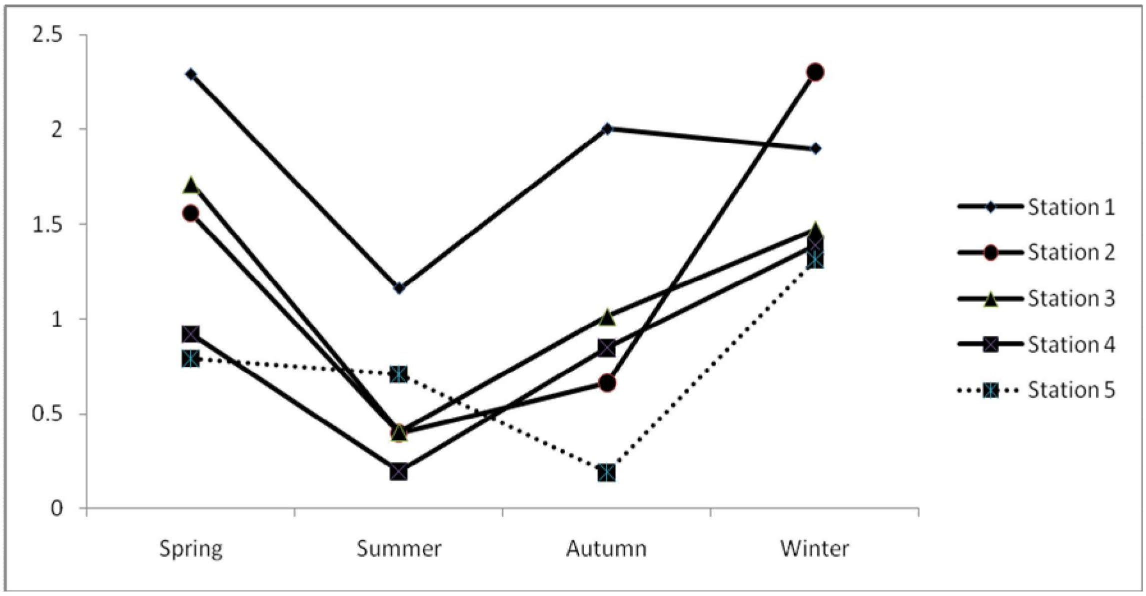

Figure 10. Change pattern of N-Mineral levels during different season in the stations.

Table 10

Analyze of variance for NH_4^+ values in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	66.945	22.315	2.9379	0.0991
Error	8	60.764	7.596		
Station	4	1.192	0.298	0.1805	
Season*Station	12	16.098	1.341	0.8124	
Error	32	52.841	1.651		
Total	59	197.839			

Split-plot design, n=3.

Table 11

Analyze of variance for NO_2^- values in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	1.834	0.611	0.7043	
Error	8	6.943	0.868		
Station	4	7.271	1.818	3.8524	0.0115
Season*Station	12	17.224	1.435	3.0418	0.0059
Error	32	15.1	0.472		
Total	59	48.371			

Split-plot design, n=3.

Table 12

Analyze of variance for NO_3^{2-} values in different stations and seasons

Source	DF	SS	MS	F	P
Season	3	33.710	11.237	4.3944	0.0418
Error	8	20.456	2.557		
Station	4	14.186	3.547	9.5632	0.0000
Season*Station	12	15.132	1.261	3.4002	0.0028
Error	32	11.867	0.371		
Total	59	95.351			

Split-plot design, n=3.

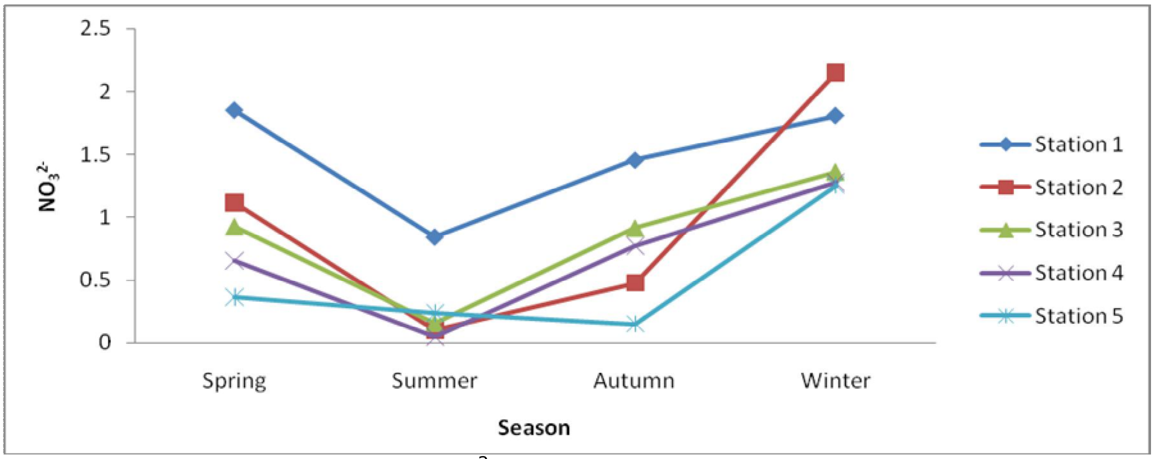

Figure 11. Change pattern of NO_3^{2-} levels during different seasons in the stations.

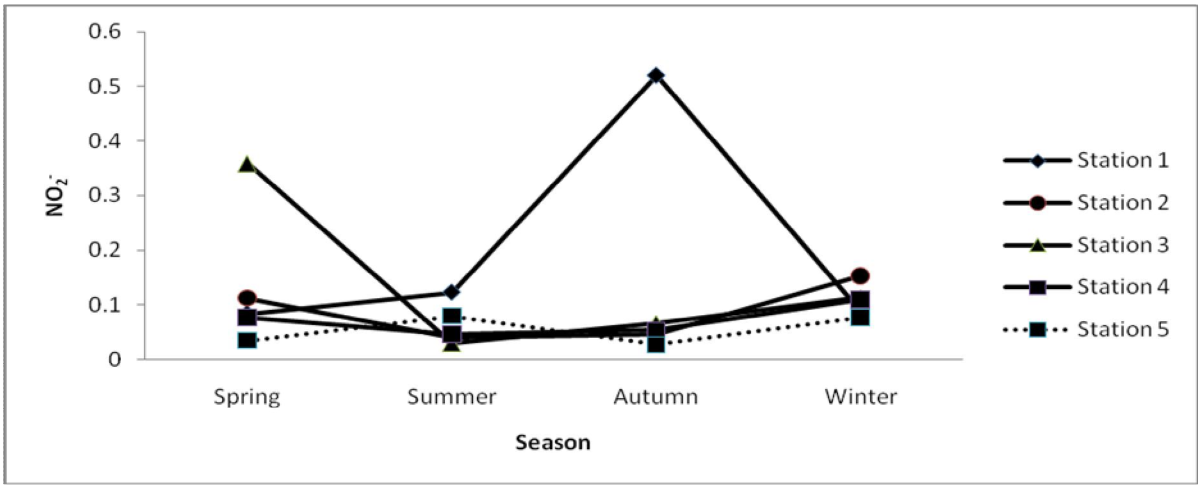

Figure 12. Change pattern of NO_2^- levels during different seasons in the stations.

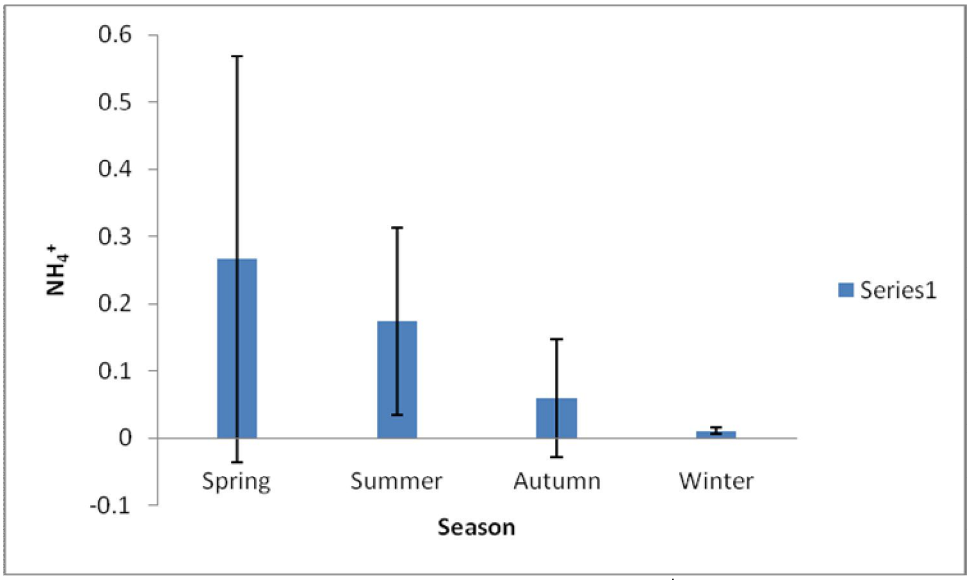

Figure 13. Seasonal changes of NH_4^+ values.

Table 13

Values (mean±SD) of temperature (T; °C), pH, dissolved oxygen (DO; mg L^{-1}), NH_4^+, NO_2^- and NO_3^{2-} in different stations and seasons

Station	Season	T	pH	DO	NH_4^+	NO_2^-	NO_3^{2-}
1	1	18.0±5.0^{b}	8.02±0.16	8.23±1.32^{abc}	0.35±0.31	0.08±0.07^{bcdef}	1.85±1.72^{ab}
1	2	30.0±3.0^{a}	7.75±0.42	4.70±0.80^{gh}	0.19±0.11	0.12±0.01^{abcd}	0.84±0.09^{abc}
1	3	19.6±7.6^{b}	8.19±0.16	8.50±0.34^{ab}	0.04±0.01	0.520±0.42^{a}	1.45±1.17^{abc}
1	4	8.30±2.0^{d}	8.29±0.61	9.17±1.52^{a}	0.009±0.004	0.08±0.02^{abcde}	1.80±1.26^{ab}
2	1	18.3±5.0^{b}	8.01±0.19	7.97±1.11^{abcd}	0.21±0.18	0.11±0.05^{abcde}	1.11±0.74^{abc}
2	2	28.7±4.2^{a}	7.93±0.54	4.50±0.30^{h}	0.25±0.17	0.04±0.02^{def}	0.10±0.06^{fg}
2	3	18.7±6.5^{b}	8.49±0.32	7.93±0.90^{abcd}	0.15±0.17	0.046±0.005^{bcdef}	0.47±0.30^{cde}
2	4	10.0±1.7^{cd}	7.92±0.23	8.23±2.22^{abcd}	0.007±0.005	0.15±0.07^{abc}	2.15±1.42^{a}
3	1	19.3±6.1^{b}	8.13±0.23	9.10±0.47^{a}	0.16±0.12	0.36±0.48^{ab}	0.92±0.42^{abc}
3	2	29.7±3.2^{a}	7.72±0.32	3.77±0.32^{i}	0.22±0.24	0.03±0.01^{ef}	0.15±0.10^{fg}
3	3	20.0±6.0^{b}	8.20±0.16	6.63±0.47^{de}	0.04±0.01	0.067±0.015^{bcdef}	0.91±0.85^{abcde}
3	4	10.7±1.5^{c}	8.00±0.15	8.57±1.07^{ab}	0.009±0.007	0.11±0.12^{bcdef}	1.36±1.44^{abc}
4	1	20.7±7.0^{b}	8.07±0.26	8.07±1.27^{abcd}	0.20±0.23	0.07±0.06^{bcdef}	0.65±0.53^{bcde}
4	2	28.7±2.1^{a}	7.79±0.29	5.43±0.58^{fg}	0.10±0.03	0.04±0.01^{bcdef}	0.04±0.01^{g}
4	3	19±5.6.0^{b}	8.25±0.03	6.77±1.06^{cde}	0.03±0.01	0.053±0.015^{bcdef}	0.77±0.67^{abcde}
4	4	10.0±1.0^{cd}	8.02±0.16	8.13±2.15^{abcd}	0.010±0.003	0.10±0.08^{abcde}	1.27±0.53^{abc}
5	1	20.3±2.5^{b}	8.14±0.31	9.07±2.54^{ab}	0.39±0.60	0.03±0.03^{f}	0.36±0.36^{def}
5	2	30.3±3.5^{a}	7.94±0.44	6.17±0.64^{ef}	0.10±0.04	0.08±0.03^{bcdef}	0.23±0.13^{ef}
5	3	20.7±5.7^{b}	8.25±0.04	7.37±0.55^{bcde}	0.02±0.01	0.026±0.005^{cdef}	0.15±0.15^{fg}
5	4	10.7±0.6^{c}	8.48±0.39	8.07±0.74^{abcd}	0.014±0.004	0.07±0.03^{bcdef}	1.25±1.56^{abcd}

Different letters above the values show significance ($p<0.05$), Duncan's test; n=3

Table 14

Values (mean±SD) of N-Mineral (N-Min), PO_4^{3-}, BOD, COD and electro conductivity (EC) in different stations and seasons

Station	Season	N-Min	PO_4^{3-}	BOD	COD	EC
1	1	2.28 ± 2.06^{ab}	0.093 ± 0.097^{cd}	9.90±3.73	75.0 ± 35.0^{ab}	6849 ± 5239^{bcde}
1	2	1.16 ± 0.19^{abcde}	0.166 ± 0.025^{abcd}	8.16±3.40	76.6 ± 10.4^{ab}	6494 ± 4902^{bcde}
1	3	2.00 ± 1.56^{abcd}	0.256 ± 0.251^{abcd}	5.90±3.02	70.0 ± 36.1^{ab}	4447 ± 3183^{e}
1	4	1.89 ± 1.28^{abc}	0.170 ± 0.010^{abc}	11.03±12.09	43.3 ± 49.1^{b}	4355 ± 4249^{e}
2	1	1.55 ± 0.78^{abc}	0.063±0.049cd	10.16±1.52	60.0 ± 30.0^{c}	6190 ± 4281^{bcde}
2	2	0.40 ± 0.20^{efg}	0.076 ± 0.030^{abcd}	7.86±2.07	63.6 ± 7.8^{ab}	10183 ± 3160^{abcd}
2	3	0.66 ± 0.46^{cdef}	0.083 ± 0.025^{abcd}	6.63±2.92	53.3 ± 12.6^{c}	7703 ± 1260^{abcde}
2	4	2.3 ± 1.147^{a}	0.156 ± 0.011^{abc}	8.26±9.28	43.3 ± 45.4^{ab}	4996 ± 5135^{cde}
3	1	1.71 ± 0.15^{ab}	0.056 ± 0.005^{bcd}	8.56±4.47	61.7 ± 17.6^{b}	5836 ± 3968^{bcde}
3	2	0.40 ± 0.15^{defg}	0.070 ± 0.040^{abcd}	9.63±1.00	76.7 ± 23.1^{ab}	10106 ± 3181^{abcd}
3	3	1.01 ± 0.89^{abcde}	0.146 ± 0.032^{abc}	5.70±2.40	63.3 ± 20.8^{ab}	7700 ± 1405^{abcde}
3	4	1.47 ± 1.57^{abcde}	0.103 ± 0.025^{abcd}	7.30±4.20	40.0 ± 25.0^{ab}	4421 ± 4272^{de}
4	1	0.92 ± 0.83^{abcde}	0.073 ± 0.040^{abcd}	11.23±7.76	70.0 ± 36.1^{b}	7438 ± 6139^{bcde}
4	2	0.20 ± 0.05^{fg}	0.096 ± 0.023^{abcd}	7.00±1.32	70.0 ± 17.3^{ab}	7170 ± 6026^{bcde}
4	3	0.84 ± 0.70^{g}	0.096 ± 0.037^{abcd}	5.20±2.40	80.0 ± 36.1^{ab}	7650 ± 1384^{abcde}
4	4	1.38 ± 0.62^{abcd}	0.083 ± 0.005^{abcd}	7.06±7.18	44.0 ± 37.3^{b}	4980 ± 5217^{cde}
5	1	0.79 ± 1.01^{defg}	0.043 ± 0.020^{d}	19.53±20.44	106.6 ± 66.6^{a}	10936 ± 4522^{abc}
5	2	0.70 ± 0.56^{bcde}	0.133 ± 0.110^{abcd}	8.93±0.90	93.3 ± 15.3^{ab}	16750 ± 2015^{a}
5	3	0.20 ± 0.15^{abc}	0.106 ± 0.005^{abcde}	6.46±5.08	106.7 ± 66.6^{ab}	16510 ± 176^{a}
5	4	1.31 ± 1.60^{abcde}	0.056 ± 0.025^{cd}	1.76±2.21	7.3 ± 6.8^{c}	12916 ± 6316^{ab}

Different letters above the values show significance ($p<0.05$), Duncan's test; n=3.

Table 15

Changes in temperature, dissolved oxygen, PO_4^{3-}, NO_3^{2-} and COD values during different seasons

	T	DO	PO_4^{3-}	NO_3^{2-}	COD
Season 1	19.33 ± 4.6^{b}	8.4 ± 1.3^{a}	0.07 ± 0.05^{a}	0.98 ± 0.93^{b}	74.3 ± 36.8^{a}
Season 2	29.46 ± 2.8^{a}	4.9 ± 0.9^{c}	0.11 ± 0.06^{b}	0.27 ± 0.31^{d}	76.1 ± 16.8^{a}
Season 3	19.63 ± 5.3^{b}	7.4 ± 0.9^{b}	0.14 ± 0.12^{b}	0.75 ± 0.76^{c}	74.7 ± 38.0^{a}
Season 4	9.93 ± 1.5^{c}	8.4 ± 1.4^{a}	0.11 ± 0.05^{b}	1.57 ± 1.15^{a}	35.6 ± 33.9^{b}

Table 16

Changes in dissolved oxygen, NO_2^{-}, NO_3^{2-}, N-mineral and electro conductivity in different stations

	DO	NO_2^{-}	NO_3^{2-}	N-Min	EC
Station 1	7.6 ± 1.9^{b}	0.20 ± 0.25^{a}	1.49 ± 1.07^{a}	1.83 ± 1.25^{a}	5536 ± 3819^{a}
Station 2	7.1 ± 1.9^{ab}	0.08 ± 0.06^{ab}	0.96 ± 1.06^{b}	1.23 ± 1.08^{b}	7268 ± 3785^{a}
Station 3	7.0 ± 2.2^{a}	0.14 ± 0.25^{ab}	0.83 ± 0.87^{b}	1.15 ± 0.93^{b}	7016 ± 3651^{a}
Station 4	7.1 ± 1.6^{ab}	0.07 ± 0.05^{b}	0.63 ± 0.62^{bc}	0.83 ± 0.69^{c}	6809 ± 4472^{a}
Station 5	7.6 ± 1.6^{b}	0.05 ± 0.03^{b}	0.50 ± 0.83^{c}	0.75 ± 0.94^{d}	14278 ± 4276^{b}

Conclusion. Gorganrod River is used for different aims such as local economic, irrigation seawards farm, fish migration, broodstock for valuable fish species, place for fingerling stocking of valuable fish species and natural environment for spawning. Time of releasing sturgeon fingerling fishes would be from end of April to middle of July, and there is not any inlet current water in the river. Of course, inlet waters were limited at this period and wastes were introduced to the river, however, examined parameters did not show critical point and no serious problems seems to be existed in the aspect of the water quality.

References

Abdo M. H., 2004 Environmental studies on the River Nile at Damietta Branch region, Egypt. J Egypt Acad Soc Environ Develop (D-Environmental Studies) **5**:85-104.

Abdel-satar A. M., 2005 Water quality assessment of river Nile from Idfo to Cairo. Egyptian Journal of Aquatic Research **31**(2):200-223.

Crabtree R. W., Cluckie I. D., Forster C. F., 1986 A comparison of two quality models. Wat Res **20**:53-61.

Dai M., Wang L., Guo X., et al, 2008 Nitrification and inorganic nitrogen distribution in a large perturbed river/estuarine system: the Pearl river estuary, China, Biogeosciences **5**:1227-1244.

EPA, 1984 Environmental Protection Agency: Fluvial transport and processing of sediments and nutrients in large agricultural river basins, EPA 600/53-85-054: U.S. Environmental Protection Agency, 1984.

Hatch D., Goulding K., Murphy D., 2002 Agriculture, Hydrology and Water Quality, Chapter 1, Nitrogen. CABI Publishing, Wallingford, UK.

Howden N. J. K., Burt T. P., 2009 Statistical analysis of nitrate concentrations from the rivers Frome and Piddle (Dorset, UK) for the period 1965-2007. Ecohydrol **2**(1):52-55.

Ilic D., Panjan J., 2010 Nitrogen and phosphorus amounts in the Ledava river before and after its outflow into lake Ledava. BALWOIS, 25-29 May, pp.1-11.

Leinweber P., Turner B. L., Meissner R., 2002 Agriculture, Hydrology and Water Quality, Chapter 2, Phosphorus. CABI Publishing, Wallingford, UK.

Vagnetti R., Miana P., Fabris M., Pavoni B., 2003 Self-purification ability of a resurgence stream. Chemosphere **52**:1781–1795.

Wetzell R. G., Likens G. E., 1991 Limnological Analyses. Springer Verlag, New York.

Received: 11 January 2011. Accepted: 01 March 2011. Published online: 25 April 2011.

Authors:
Sima Balaly, Institute of Hydroecology and Ichthyology of SCZH of NAA, 00014, Yerevan, P. Sevaki 7, Republic of Armenia; e-mail: Sima_balaly@yahoo.com
Second address: Institute of Higher Education of Loghman Hakim, Khoramshar St. Shahid Fahmide Ave, Aq qala (Agh Ghala) city, Golestan province, Iran, post code: 49318-37453.
Seyed Abbas Hoseini: P.O.Box: 386, Beheshti St., Faculty of Fisheries and Environment, University of Agricultural Science & Natural Resources, Gorgan – Iran; e-mail: Hoseini_abbas@yahoo.com
Saied Balaly: P.O.Box: 386, Beheshti St., Faculty of Fisheries and Environment, University of Agricultural Science & Natural Resources, Gorgan – Iran; e-mail: saeed_balali85@yahoo.com

How to cite this article:
Balaly S., Hoseini S. A., Balaly S., 2011 Seasonal investigation of main physico-chemical parameters in terminal part of Gorganroud River during 2009-2010. AACL Bioflux **4**(3):368-381.