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Environmental effects of the cold water fish farms effluents on the water quality of Gamasyab River as their main source of water supply in the west of Iran

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Abstract

Rainbow trout (*Oncorhynchus mykiss*) is one of the most-widely cultivated cold fresh water fish in the world. Gamasyab River, with a length of about 200 Km, is one of the longest rivers of Iran. The aim of this research is to determine the effects of trout farm effluents on this river water. From a total of 24 trout farms in the area, four farms were randomly selected and three sampling stations were chosen at each selected farm. Measured water quality parameters were temperature (T), total suspended solids (TSS), total dissolved solid (TDS) dissolved oxygen (DO), pH, five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), ammonia-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N) and phosphates (PO_4-P). Based on the laboratory analysis, DO in the river water was more than 6 mg/l in all cases. There were significant differences in six variables of T, BOD, COD, NO_3-N, NH_4-N, and TSS of all water samples taken from the second sampling stations between dry and wet season. The DO concentration in Gamasiab River decreased between the water inlet (first stations) and outlet (second stations), but increased in third station. Trout farm effluents had significant impact on the TSS content of the river. This significant increase in TSS concentrations is expected to have occurred due to cleaning or harvesting activities on any of the farms. The results of the study showed that, in all of season, the amount of TSS in the second stations was not equal to the standards of the Department of Environment Protection (40 mg/L) for discharging into river systems.

Keyword: Aquaculture, Cold water fish culture, Gamasyab River, Rainbow trout, Water quality,

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Introduction

River water pollution is a serious problem that mainly results from the human activities within the river basin. Discharging fertilizers, pesticides and other organic and inorganic pollutants are contributed as major causes of the rivers' water quality deterioration. Reyahi Khoram and Nafea (2011). Like in many other countries, the aquaculture industry plays a significant role in the Iranian economy, in terms of employment as well as other conventional economic indicators. The main types of aquaculture activities in Iran are categorized into warm-water and cold-water aquaculure. In Iran, the sole species for cold water aquaculture is rainbow trout. Hassanpour *et al.* (2010).

Development and enhancement of the cold-water aquaculture industry has been accompanied by an increase in environmental impacts, which is mainly pollution and deterioration of the rivers' water quality. Many researchers had studied the effects of aquaculture pollution effluents on the rivers (Pulatsu *et al*., 2004; ; Tanigawa *et al*., 2007; Manoochehri *et al*., 2010; Angus Webb, 2012 ; Fadaeifard *et al*., 2012; Mirrasooli *et al.*, 2012; Saremi *et al*., 2013).

Effluents from aquaculture systems contain organic matter, nutrients, and suspended solids which directly impacts on oxygen depletion, eutrophication, and turbidity in receiving waters. Such effluents may have a serious negative impact on the quality of the receiving water when discharged untreated (Saremi *et al*., 2013).

The environmental effects of fish farms on the river systems could be the introduction of non-native fish species, changing the river course and hydrology as well as discharging polluted water. If fish farms effluents discharge into the environment without treatment, it will have undesirable and harmful effects on the environment. Fadaeifard *et al* (2012).

Regarding the environmental and economic importance of Gamasyab River, the aim of this research is to determine the physico-chemical parameters of Gamasyab River water in various regions and further determine the effects of trout farm effluents on the river water.

Materials and methods

Study area

Gamasyab River, with about 200 Km length, is one of the longest rivers in Iran. This river has a permanent regime and its average annual flow rate is about 19.14 cubic meters per second. It should be noted that during recent years, due to droughts and increased consumption of underground water sources, at least 25-30% reduction has happened in river water flow. Pollution sources that threaten the quality of water in Gamasyab River may be classified in to two sections namely non-point and point sources. Non-point sources pollution consist of agriculture-related pollutants which are drained towards the river. Point pollution sources are those wastewater which are discharged into the river from a specific point such as fish farm effluents and industrial waste water Reyahi Khoram and Nafea (2011).

Sampling procedure

This research was carried out during 2012 to 2013 in Nahavand Township. Gamasyab River provides the water supply of many fish farms along its course. Four trout farms were randomly selected from a total of 24 trout farms located in this river's basin (Fig. 1). These trout farms receive their required water from Gamasyab River and discharge their effluent directly into the river without any treatment. Three sampling stations were chosen at each selected farm. The first stations were located 50 m upstream from the farms which represents the normal conditions of the river. The second stations were the effluents discharge point of each farm to the river. The third stations were located 200 meters downstream in the river and away from the second stations. The selected farms included Ghezel Danesh Farm (farm 1) at Varayaneh village, Ghezel Zagros farm (farm 2) in Sorkh Kand village, Amiri farm (farm 3) at Moradabad village, and Heidari farm (farm 4) at Dehno Sofla village lands. Sampling was performed three times for each station during dry and wet seasons. On this basis, we had a total number of 12 sampling stations and a total of water 72 samples were taken by grab sampling method for this study.

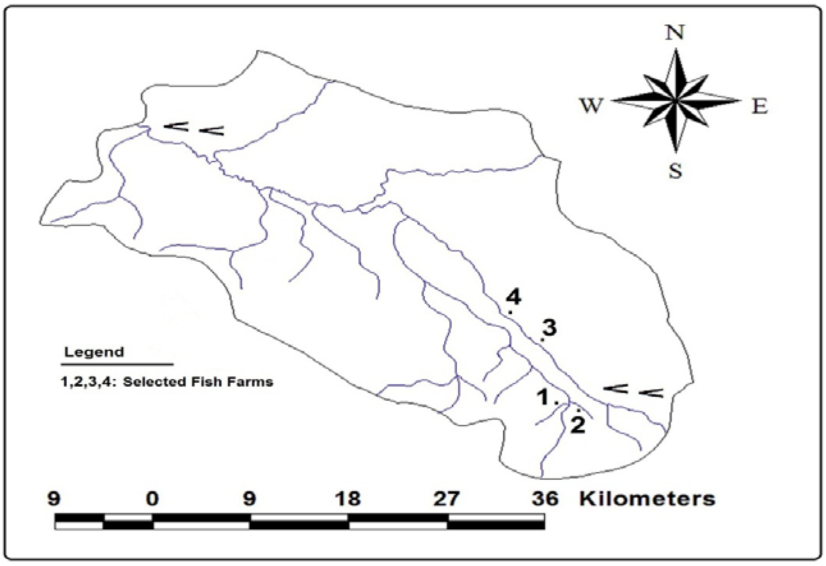

Figure 1: Location of four trout farms were randomly selected on the Gamasyab River in Nahavand Township in Iran.

Experimental methods

Measured physico-chemical water quality parameters were temperature (T), total suspended solids (TSS), total dissolved solids (TDS) dissolved oxygen (DO), pH, five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), ammonia-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N) and phosphates (PO_4-P).

Temperature, dissolved oxygen and pH were measured in situ. The other analyses were conducted according to standard methods APHA (2005). All measurements were replicated three times. Water samples were collected for analysis using clean polyethylene bottles, chilled to 1-4°C in the dark and transported to the laboratory within 6 hours.

The data collected from this research was statistically analyzed using SPSS (version 19). Also, excel software was used for drawing graphs. The Kolmogorov-Smirnov test (KS-test) is one of the useful and general nonparametric methods for comparing two samples. It can be used to study the effect of seasonal variation on water samples that are taken from designated stations. Other comparisons were made using non-parametric Kruskal-Wallis tests. We considered all differences with $p \leq 0.05$ to be statistically significant. Linear relationship between variables was investigated using Pearson correlation coefficient.

Results

Based on field surveying and laboratory analysis the amounts of physicochemical parameters of Gamasyab River water were determined at 12 stations. Average values of the parameters are given in Table 1.

DO in the river water was more than 6 mg/L in all sampling dates (Table 1). The minimum value of DO measured in Gamasyab River still exceeded the upper limit of DO concentration (5 mg/L or more for DO) that is recommended by the Global Aquaculture Alliance (Boyd and Gautier, 2000).

In dry Season, differences among the stations were significant for BOD and TSS (Kruskal Wallis tests, $p<0.05$), but not for T, pH, COD, TDS, DO, NO_3-N, NH_4-N and PO_4-P concentrations. The results indicate that in dry Season, trout farms had a significant impact on the BOD and TSS concentrations of Gamasyab River ($p<0.05$) but changes in T, pH, COD, TDS, DO, NO_3-N, NH_4-N and PO_4-P concentration were not significant ($p>0.05$) (Table 2).

In wet season, differences among the stations were significant for BOD, COD, NH_4-N, pH and TSS (Kruskal Wallis tests, $p<0.05$), but not for T, TDS, DO, NO_3-N, and PO_4-P concentrations. This means that in wet season, trout farms' effluents had a significant impact on the BOD, COD, NH_4-N, pH and TSS concentrations of Gamasyab River but changes in T, TDS, DO, NO_3-N, and PO_4-P concentrations were not significant (Table 3).

Throughout the year, differences among the stations were significant for BOD and TSS (Kruskal Wallis tests, $p<0.05$), but not for T, pH, COD, TDS, DO, NO_3-N, NH_4-N and PO_4-P concentrations.

Table 1: Parameters of Gamasyab River water quality.

Time	St. No.	n	S.P.	pH	T^0C	DO Mg/L	BOD_5 Mg/L	COD Mg/L	TSS Mg/L	TDS Mg/L	NH_4-N Mg/L	NO_3-N Mg/L	PO_4-P Mg/L
During dry season	1	12	M	7.84	12.75	7.75	6.50	42.60	29.16	278.41	0.18	1.10	0.33
			S	0.07	2.50	1.87	3.37	4.38	9.00	122.65	0.10	0.31	0.35
	2	12	M	7.81	12.79	7.38	20.08	44.10	56.66	274.43	0.20	1.35	0.35
			S	0.09	2.32	1.21	4.16	6.80	7.78	122.71	0.10	0.54	0.35
			M	7.83	12.92	7.79	14.25	42.50	41.66	281.95	0.16	0.99	0.38
			S	0.07	2.30	1.14	3.74	4.95	5.77	126.52	0.08	0.41	0.35
During wet season	1	12	M	7.82	8.08	6.56	5.33	11.32	77.91	224.83	0.09	0.70	0.35
			S	0.06	1.18	0.89	1.07	2.42	11.21	43.02	0.07	0.23	0.31
			M	7.88	8.11	6.27	7.91	19.10	97.50	236.50	0.14	0.73	0.29
			S	0.07	1.18	1.07	0.90	2.74	16.15	49.01	0.04	0.35	0.28
	3	12	M	7.81	8.12	6.50	6.25	12.82	84.66	239.75	0.12	0.65	0.38
			S	0.07	1.23	1.01	0.96	2.09	13.72	39.92	0.05	0.42	0.35
			M	7.83	10.42	7.16	5.91	26.96	53.54	251.62	0.13	0.90	0.34
			S	0.07	3.06	1.56	2.51	16.34	26.81	93.96	0.10	0.34	0.32
			M	7.85	10.45	6.83	14.00	31.60	77.08	255.46	0.17	1.04	0.32
			S	0.09	2.99	1.25	6.87	13.74	24.26	93.41	0.08	0.55	0.31
			M	7.82	10.52	7.14	10.25	27.66	63.16	260.85	0.14	0.82	0.38
			S	0.07	3.04	1.24	4.88	15.61	24.25	94.25	0.07	0.44	0.34

F. C. No. : Fish Culture Number
St. No. : Station Number
n: number of sample
S.P.: statistical parameter
M: Mean
S: Standard Deviation

Table 2: Results of Kruskal-Wallis tests comparing water quality parameters among different stations of the river during the dry season.

Parameters	n	Mean (mg/L) (Excluding pH)			Chi-Square	Asymp. Sig.
		ST1	ST2	ST3		
pH	12	7.84	7.81	7.83	0.28	0.867
T	12	12.75	12.79	12.92	0.24	0.884
DO	12	7.75	7.38	7.79	1.02	0.599
BOD	12	6.50	20.08	14.25	25.37	0.001*
COD	12	42.60	44.10	42.50	1.66	0.434
TSS	12	29.16	56.66	41.66	25.05	0.001*
TDS	12	278.41	274.43	281.95	0.05	0.972
NH_4-N	12	0.17	0.20	0.16	0.91	0.634
NO_3-N	12	1.10	1.35	0.99	4.53	0.103
PO_4-P	12	0.33	0.35	0.38	0.034	0.982

* Significant; $p<0.05$

Table 3: Results of Kruskal-Wallis tests comparing water quality parameters among different stations of the river during the wet season.

Parameters		Mean (mg/L) (Excluding pH)			Chi-Square	Asymp. Sig.
	n	ST1	ST2	ST3		
pH	12	7.82	7.88	7.81	6.32	0.042*
T	12	8.08	8.11	8.12	0.05	0.970
DO	12	6.56	6.27	6.50	1.35	0.508
BOD	12	5.33	7.91	6.25	20.84	0.001*
COD	12	11.32	19.10	12.82	22.94	0.001*
TSS	12	77.91	97.50	84.66	9.11	0.010*
TDS	12	224.83	236.50	239.75	1.72	0.423
NH_4-N	12	0.09	0.14	0.12	8.44	0.014*
NO_3-N	12	0.70	0.73	0.65	0.85	0.651
PO_4-P	12	0.35	0.29	0.38	0.825174	0.661

* Significant; $p<0.05$

These results indicate that during the year, trout farms discharged effluents had a significant impact on BOD and TSS concentrations of Gamasyab River water but changes in T, pH, COD, TDS, DO, NO_3H, NH_4-N and PO_4-H concentrations were not significant ($p>0.05$) (Table 4).

In water samples taken from all of the first stations, there were significant differences in six variables: T, DO, COD, NO_3-N, NH_4-N, and TSS between dry and wet seasons among these sampling stations (two-sample Kolmogorov–Smirnov test, $p=0.05$), while there were no significant differences in pH, BOD, TDS and PO_4-P between dry and wet seasons (Table 5).

Table 4: Results of Kruskal-Wallis tests comparing water quality parameters among different stations of the river.

Parameters		Mean (mg/L) (Excluding pH)			Chi-Square	Asymp. Sig.
	n	ST1	ST2	ST3		
pH	24	7.83	7.85	7.82	2.47	0.289
T	24	10.42	10.45	10.52	0.07	0.964
DO	24	7.16	6.83	7.14	1.12	0.570
BOD	24	5.91	14.00	10.25	28.47	0.001*
COD	24	26.96	31.6	27.66	4.61	0.099
TSS	24	53.54	77.08	63.16	8.36	0.015*
TDS	24	251.62	255.46	260.85	0.26	0.875
NH_4-N	24	0.13	0.17	0.14	4.22	0.120
NO_3-N	24	0.90	1.04	0.82	2.08	0.351
PO_4-P	24	0.34	0.32	0.38	0.44	0.798

* Significant; $p<0.05$

Table 5: Results of the two-sample Kolmogorov-Smirnov test performed on the data obtained from 12 sampling stations located 50 m upstream from the farms (first stations) in the study area.

Variables	n	Mean (mg/L) (Excluding pH) Dry season	Monsoon season	Z value	*p*-value
pH	12	7.84	7.82	0.40	0.997
T	12	12.75	8.08	2.24	0.001*
DO	12	7.75	6.56	1.42	0.033*
BOD	12	6.50	5.33	1.02	0.245
COD	12	42.60	11.32	2.44	0.001*
TSS	12	29.16	77.91	2.44	0.001*
TDS	12	278.41	224.83	1.22	0.097
NH4-N	12	0.179	0.09	1.42	0.033*
NO3-N	12	1.11	0.70	1.83	0.002*
PO4-P	12	0.33	0.35	0.61	0.840

* Significant; $p<0.05$.

In water samples taken from the second stations; there were significant differences in six variables: T, BOD, COD, NO_3-N, NH_4-N, and TSS between dry and monsoon seasons among these stations (two-sample Kolmogorov–Smirnov test, $p=0.05$), but no significant differences were observed in pH, DO, TDS and PO_4-P (Table 6).

In water samples taken from the third stations, there were significant differences in four variables: T, BOD, COD and TSS between dry and wet seasons among these stations (two-sample Kolmogorov–Smirnov test, $p=0.05$), but there were no significant differences in pH, DO, TDS, NO_3-N, NH_4-N and PO_4-P (Table 7).

There was a significant correlation at $p<0.001$ between T and TSS (r=0.661), and between T and NH_4-N (r=0.657). There were also a significant correlation at $p<0.001$ between COD and BOD (r=0.618), and between COD and TSS (r=0.747). DO is vital for the aquatic life, and it is also accepted that, DO levels in cold water are actually higher than warm water. Table 5, 6 and 7 showed that, the concentration of DO in water samples were not consistent with water temperature.

In order to evaluate this finding, a multiple linear regression analysis was performed, with DO as dependent variable and TSS, TDS, pH, T, BOD_5, COD, NH_4-N, NO_3-N and PO_4-P as independent variables.

The obtained results showed that the (R-squared) coefficient was 0.51 at 0.001 significance level. This means that the change in dissolved oxygen of the Gamasyab River water is influenced by these 9 variables. On the other hand, approximately 51 percent of changes in DO variation in this river were explained by these variables and about 49 percent remained unexplained.

Table 6: Results of the two-sample Kolmogorov-Smirnov test performed on the data obtained from 12 stations located before the point that river water and farm effluent join together (second stations) in the study area.

		Mean (mg/L) (Excluding pH)		Kolmogorov-	Asymp. Sig.
Variables	**n**	**Dry season**	**Monsoon season**	**Smirnov Z**	**(2-tailed)**
pH	12	7.81	7.88	1.02	0.248
T	12	12.79	8.11	2.44	0.001*
DO	12	7.38	6.27	1.22	0.099
BOD	12	20.08	7.916	2.44	0.001*
COD	12	44.10	19.10	2.44	0.001*
TSS	12	56.66	97.50	2.44	0.001*
TDS	12	274.43	236.50	1.02	0.248
NH4-N	12	0.20	0.14	1.42	0.033*
NO3-N	12	1.35	0.73	1.63	0.009*
PO4-P	12	0.35	0.29	0.40	0.996

* Significant; $p<0.05$.

Table 7: Results of the two-sample Kolmogorov-Smirnov test performed on the data obtained from 12 stations located 200 meters away from the second stations (third stations) in the study area.

		Mean (mg/L) (Excluding pH)		Kolmogorov-	Asymp. Sig.
Variables	**n**	**Dry season**	**Monsoon season**	**Smirnov Z**	**(2-tailed)**
pH	12	7.83	7.81	0.40	0.996
T	12	12.92	8.12	2.44	0.001*
DO	12	7.79	6.50	1.22	0.099
BOD	12	14.25	6.25	2.24	0.001*
COD	12	42.50	12.82	2.44	0.001*
TSS	12	41.66	84.66	2.44	0.001*
TDS	12	281.95	239.75	1.22	0.099
NH4-N	12	0.16	0.12	1.02	0.248
NO3-N	12	0.99	0.65	1.02	0.248
PO4-P	12	0.38	0.38	0.40	0.996

* Significant; $p<0.05$.

Table 8: Pearson Correlation coefficient (r) matrix of parameters related to Gamasiab River water quality.

	Parameter	DO mg/L	T	pH	BOD mg/L	COD mg/L	TSS mg/L	TDS mg/L	NH_4-N mg/L	NO_3-N mg/L	PO_4-P mg/L
Pearson Correlation	DO	1									
	T	-0.022	1								
	pH	0.120	-0.289*	1							
	BOD	0.077	0.569*	-0.130	1						
	COD	0.406*	0.750*	0.004	0.618*	1					
	TSS	-0.329*	-0.661*	0.132	-0.227	-0.747*	1				
	TDS	0.068	0.359*	-0.117	0.138	0.228	-0.150	1			
	NH_4-N	-0.085	0.657*	-0.326*	0.381*	0.349*	-0.220*	0.234*	1		
	NO_3-N	0.156	0.469*	-0.089	0.349*	0.449*	-0.313*	0.268*	0.401*	1	
	PO_4-P	-0.279*	0.121	0.093	0.062	-0.068	-0.043	0.038	0.212	0.128	1

Table 8 Continued:

Parameter	DO mg/L	T	pH	BOD mg/L	COD mg/L	TSS mg/L	TDS mg/L	NH_4-N mg/L	NO_3-N mg/L	PO_4-P mg/L
DO	.									
T	0.850	.								
pH	0.315	0.014	.							
BOD	0.520	0.001	0.278	.						
COD	0.001	0.001	0.975	0.001	.					
TSS	0.005	0.001	0.268	0.055	0.001	.				
TDS	0.573	0.002	0.328	0.248	0.054	0.210	.			
NH_4-N	0.479	0.001	0.005	0.001	0.003	0.063	0.047	.		
NO_3-N	0.190	0.001	.459	0.003	0.001	0.007	0.023	0.001	.	
PO_4-P	0.018	0.312	0.437	0.606	0.568	0.727	0.749	0.074	0.284	.

*Correlation is significant at the 0.05 level.

Table 9: Multi Regression Analysis results on the effect of DO on different independent variables related to Gamasiab River water quality.

Independent variable	β	T	Sig	R	R2	F
T	-1.079	-5.208	0.001*	0.714	0.510	7.162
pH	-0.034	-0.312	0.756			
BOD	-0.011	-0.078	0.938			
COD	0.793	3.504	0.001*			
TSS	-0.355	-1.978	0.052			
TDS	0.148	1.502	0.138			
NH_4-N	0.230	1.710	0.092			
NO_3-N	0.087	0.821	0.415			
PO4-P	-0.171	-1.700	0.094			

* Significant; $p<0.05$

Discussion

During the course of this study, trout farm effluents did not have any significant impact on the pH of Gamasiab River water quality. However, the minor increase or decrease in pH was not statistically significant (Table 1 to 7). The measured pH downstream of our last station was still within the acceptable limits of 6.5–9.5 proposed by different standard organizations (Boyd and Gautier 2000;, 1993).

The changes in the BOD of Gamasiab River water were mainly due to the output of organic matter produced by trout farming activities, were also statistically proved to be significant. This can be explained in this way that, at the third sampling stations, the BOD was almost less than that of effluent discharges from the farms (Tables 2, 3 and 4), which could be related to the self-purification ability of the river. Increases in BOD were also found to be more observed in dry months, which is most likely due to the rising of water temperature and higher feeding rates applied by fish farmers. Higher feeding levels increase the output of organic matter from fish farms as faeces or uneaten feed which results in significant elevation in the

BOD of receiving water (Pulatsu *et al.*, 2004).

A same trend was observed for COD by Fadaeifard *et al*. (2012) which was related to the aquaculture activities. But in the present study, the increase in COD values in the effluent compared to the receiving water was not found statistically significant ($p>0.05$) (Table 4).

Usually, DO concentration is expected to decrease after fish farm, but in the present study, the increase or decrease in DO was not statistically significant (Tables 2, 3 and 4). High population of fish or higher fish biomass and also intensive feeding could increase the DO need of a farm and result in higher DO intake from the feeding water (Midlen and Redding, 1998). In addition, the minimum value of DO found in Gamasiab River water is still greater than the upper limit of DO concentration (5 mg/L) which is recommended by the Global Aquaculture Alliance (Boyd and Gautier, 2000). In the studied area, applied Mechanical aeration and oxygenation of the receiving water can increase the concentration of DO in the farms up to 15 to 20 mg/L. The DO concentration in Gamasiab River decreased between the water inlet (first stations) and outlet (second stations), but increased in third station. It should be due to self-purification ability or high river flows (up to 13 cubic meters per second) of Gamasiab River.

Trout farm effluents have significant impact on the TSS of Gamasiab River water quality (Tables 2, 3 and 4). This significant increase in TSS concentration was expected to have occurred due to cleaning or harvesting activities on any of the farms. Total suspended solid in second stations were more than the first stations which could be attributed to fish feces, colloid particles, natural sludge, other compounds and left over foods. This causes increasing turbidity too (Fadaeifard *et al*., 2012). The results of this study showed that, in all seasons, the amount of TSS in the second stations were not equal to the standards of DoE (40 mg/L) for discharging into rivers and lakes (Table 2, 3, 4 and 6).

In water there is equilibrium between the concentrations of ammonium ion (NH_4-N) and ammonia (NH_3-H). This relation depends on the pH. The sum of NH_3-N and NH_4-N is known as the Total Ammonia Nitrogen (TAN). But ammonia is the more toxic substance for fish. In aquaculture it is often necessary to reduce the concentration of ammonia in the water, because it is toxic for the fish (Pillay and Kutty, 2005). Ammonia is present in all natural waters but, acute toxicity of ammonia to fish increases with low DO concentrations. Based on the literature review, at a pH range of 7-8 up to 90 percent of TAN is in the ammonium ion (NH_4-N) form Pillay and Kutty (2005). Thus, the TAN concentration of Gamasiab River water during this study (Table 2 to 7) remained less than the maximum allowable level of 2 mg/L recommended by the Global

Aquaculture Alliance (Boyd and Gautier, 2000).

During our study, the trout farms' effluents did not have any significant impact on the temperature of Gamasiab River water. However, the minor increase or decrease in temperature was not statistically significant (Table 1 to7).

Based on standards provided by the Department of Environment (DoE) of Iran, the temperature of effluents discharged into the river and other receiving water should not increase or reduce temperature of receiving water more than 3 centigrade, in a radius of 200 meters from the effluent entry point into the river (DoE, 2004).

TDS consist of both organic and inorganic molecules and ions that are present in true solution in water. Dissolved solid and suspended solid are two forms of metabolic waste in most fish farms. Dissolved solids are the major component of total solids. It mostly comes in the form of BOD and COD. On the other hand, organic portion of the TDS, generally occurs in the forms of ammonia, nitrite, nitrate and phosphorus (Miller and Semmens, 2002). In the present study, the fluctuation of TDS in the stations was not statistically significant (Table 2, 3 and 4).

NO_3-N compound are harmless in the recirculating systems. Even in prolonged exposures in culture systems, no toxic effects have been reported below 100 mg/L. The NO_3-N may be further combined with ions in water to form salts or reduced to nitrogen gas through a denitrification process Pillay and Kutty (2005). In the present study, NO_3-N concentration of Gamasiab River water was negligible as compared to the total amount of BOD or COD (Table 2 to 7). Similar studies were also reported by Pulatsu *et al*. (2004)

Phosphorus is closely related to metabolism, especially in bone formation and the maintenance of acid-base equilibrium. Fish can obtain phosphorus from food and also from the environment. It means that, phosphorus has to come mainly from food, as both fresh and salt waters are generally deficient in PO_4-P (Pillay and Kutty, 2005). The PO_4-P content gradually increased downstream from the trout farms, which has been reported by other authors (Boaventur *et al.*, 1997). Based on the results of the present study, the PO_4-P concentration increased after fish farm, but this increase was not statistically significant (Tables 2, 3 and 4).

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