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The Effects of Trout Farm Effluents on Water Quality Parameters of Zaringol Stream (Golestan, Iran) Using NSFWQI and WQI Indexes

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Abstract

Fish culture sites produce considerable volume of effluents which could have effects on water quality and downstream aquatic systems. The aim of this study was to assess the potential impacts of Trout farm effluents on water quality of Zaringol stream (Golestan, Iran) based on NSFWQI and WQI indexes. For this, physicochemical water quality parameters were measured each season from 14 stations during December 2009 to September 2010. The average value of NSFWQI was 53.21 and it showed spatial and temporal variation. The maximum value or best water quality condition (74.5) and minimum value of NSFWQI or the worst condition (50.93) belonged to stations 1 and 2 respectively. Results of seasonal variations of NSFWQI showed that the maximum and minimum values were 59.62 and 53.82 in autumn and spring respectively. Similar to the NSFWQI, the WQI index changed between different stations. Stations 2 and 8 had the lowest value (0.76), station 7 had the highest (1.01) and the mean value was 0.88. Although the temporal variations of WQI were low, the highest value was calculated for summer (0.94) and the lowest one (0.81) for autumn. According to the results of NSFWQI, WQI and physicochemical parameters, water quality condition of Zaringol stream is average and need a change in strategies of water quality management in the area. It seems that effluents entering from Trout farms in spring and summer are reasons of the decline in water quality and it is necessary to use treatment methods based on environmental standards to avoid the future risks.

Keywords: Trout farm effluent, Water quality, NSFWQI, WQI, Zaringol stream

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1. Introduction

Population growth increases the food requirement and especially protein demand (Sohrabian *et al.*, 2009). In addition, worldwide harvest of the aquatic products by fisheries is close to its maximum sustainable productivity and marine fishes are under heavy pressure of commercial fishing (Arjmandi *et al.*, 2007). That is why aquaculture is one of the promising industries. Nowadays, aquaculture supplies more than one-quarter of fish requirements, consumed by humans (FAO, 2000).

According to previous studies, aquaculture has various impacts on the surrounding environment and ecosystems (Uzbilek Kirkagac *et al.*, 2009), e.g. releasing 0.5 ton of suspended solid per 1 ton of fish cultured into the water bodies such as rivers (Costa Pierce, 2002).

Trout farm effluents are made up of three main parts: suspended solid matters such as unconsumed feed and faecal matters; dissolved matters such as nitrogen compounds (Urea and ammonium ion) and organic carbon; and chemical and pharmaceutical matters such as fungicides (Malachite green) and antibiotics (Sulfonamides) (Naderi Jelodar *et al.*, 2007). All the items have an important role in the water chemical balance disorder (Selong and Helfrich, 1998). For example, it has been reported that dissolved oxygen and pH values together with ammonia-nitrogen, total phosphorous and orthophosphate concentrations were affected by land based salmonid farms (Uzbilek Kirkagac *et al.*, 2009). Pulatsu *et al.* (2004) reported that environmental impact of aquaculture varies and includes: conflicts between the needs of different users of its products, alternation in the hydrological regime, introduction of exotic species to the wild and pollution of water resources.

There are many methods for the analysis of water quality characters. NSFWQI[1] is a general index, classifying water quality without regarding type of usage (Asadollah Fardi *et al.*, 2000) and WQI[2] is also a common index which is used for suitable management decision to reduce the water pollution. These indexes are simple and their required parameters are also available, so they are suitable for river water quality zoning (Zandbergen and Hall, 1988).

Zaringol stream with a length of 22 kilometers is one of the branches of the Gorgan-Rud River (Golestan, Iran) and it supplies water resources for agricultural, aquaculture and domestic uses (Abdoli and Rahmani, 2002). Despite the severe effects of human activities, there is no report on water quality assessment of Zaringol stream and there is only one hydrometric station along the stream, so there is not enough data for evaluating effects of human activities. Therefore, this study was carried out to assess the effects of two trout farm effluents on Zaringol stream based on NSFWQI and WQI indexes.

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[1] National Sanitation Foundation Water Quality Index

[2] Water Quality Index

2. Material and methods

2.1. Site sampling and water quality parameter

This study was carried out in Zaringol stream located in the eastern Elburz Mountains at 54° 43' 40" to 55° 11' 36" E and 36° 43' 30" to 37° 8' 44" N. The water was sampled each season from 14 stations along the stream during December 2009 to September 2010 (Fig. 1). Two trout farms are located at stations 2 and 8 with 15 and 7 tons of actual capacities respectively.

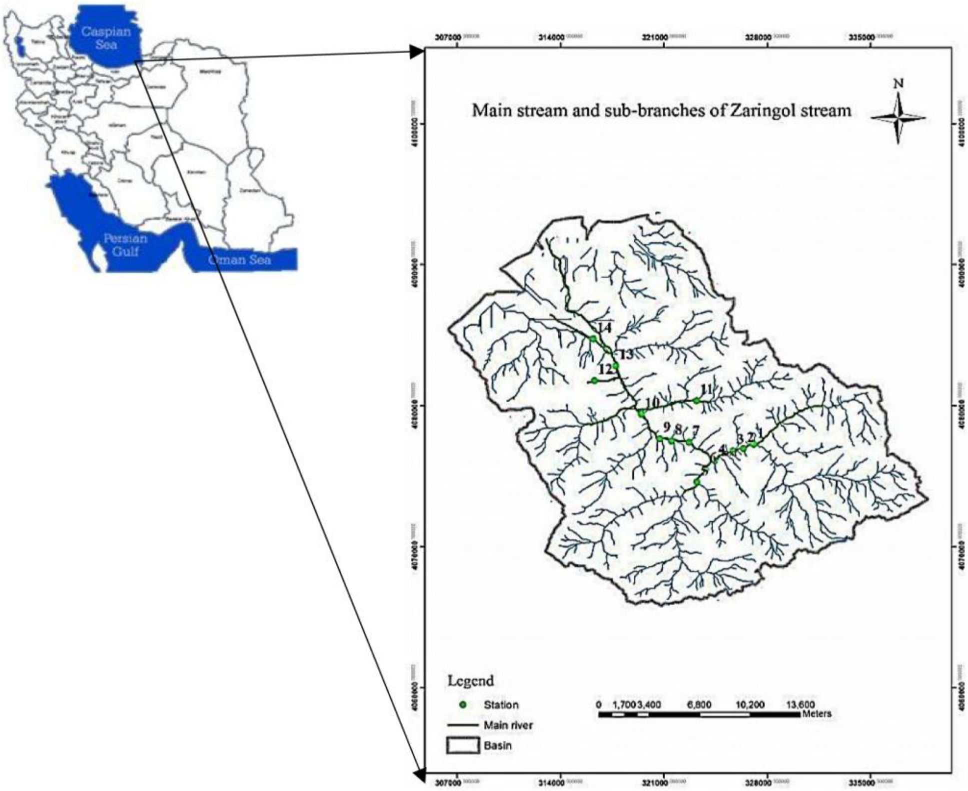

Figure 1. Site of water sampling in Zaringol stream

Different types of water quality parameters including salinity (ppt), turbidity (NTU), total suspended solid (ppm), electrical conductivity (μmoscm^{-1}), temperature (°C), total phosphate (ppm), nitrate (ppm), pH, dissolved oxygen (ppm and saturated percent), biological oxygen demand (ppm) and faecal coliforms (counts/100ml) were measured by water checker u-10 and spectrophotometer.

2.2. NSFWQI and WQI index

NSFWQI was calculated using the following equation:

$$\mathrm{NSFWQI} = \sum \mathrm{W_i Q_i}$$

Where Wi equals the weight of each water quality parameter (Tab. 1).

Table 1. Water quality parameters and their weight used in NSFWQI

Parameter	Unit	Weight
Dissolved Oxygen	Saturation (%)	0.17
Faecal coliform	counts/100ml	0.16
pH	---	0.11
BOD_5	ppm	0.11
ΔT	°C	0.1
NO_3	ppm	0.1
PO_4	ppm	0.1
Turbidity	NTU	0.08
TSS	ppm	0.07

and Q_i is the value of each water quality parameter in the 0-100 scale, obtained from conversion curve (Fig. 2).

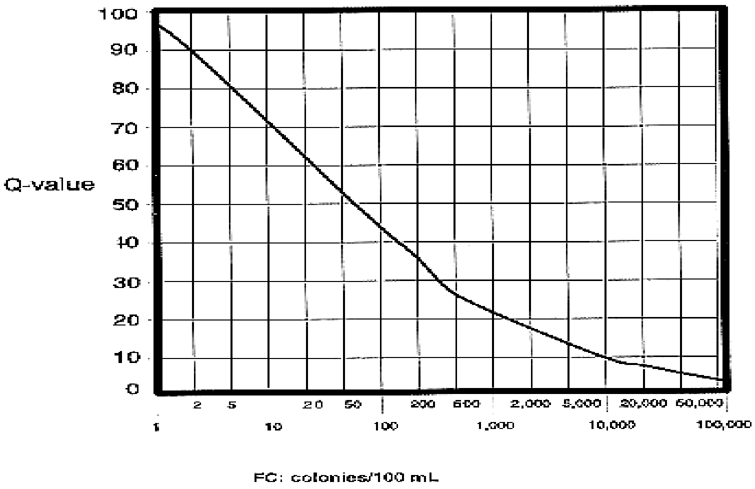

Figure 2. Conversion curve of faecal coliform

NSFWQI is a reduction index, so if the water pollution increases, NSFWQI will be decreased. It was evaluated for each season and station. Then, water quality condition was assessed according to Tab. 2.

Table 2. Classifying water quality condition based on NSFQWQI index

NSFWQI	Water quality condition
90-100	Very good
70-90	Good
50-70	Average
25-50	Bad
0-25	Very bad

To calculate WQI index, there is no need to standardize the parameters. In addition, the calculations are further simplified through the elimination of sub-indexes (Said *et al.*, 2002). The WQI index is not suitable for streams which have high amount of faecal coliform in head water because WQI is sensitive to faecal coliform value. It was calculated by following equation:

$$\mathrm{WQI} = \mathrm{Log}\left[(\mathrm{DO})^{1}.\frac{65}{50(\mathrm{TP})^{0}.5+(\mathrm{Turb})^{0}.15+0.4(\mathrm{F.Coli})^{0}.5+0.15(\mathrm{EC})^{0}.5)}\right]$$

Where DO = dissolved oxygen (% oxygen saturation), Turb = turbidity (NTU), TP = total phosphates (mg/L), F-Coli = faecal coliform (counts/100ml) and EC = electrical conductivity in (µS/cm). It should be mentioned that in this formula, the powers of the parameters were chosen for the WQI based on the effect of each parameter on water conditions. Its value ranged between 0-3 and classified water quality as Tab. 3.

Table 3. Classifying water quality condition based on WQI index

WQI	Water quality condition
2-3	Acceptable (None)
1-2	Change the strategies of management (TMDL[1])
0-1	Change the strategies of management and sanitary programs (TMDL and BMP[2])

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[1] Decrease total maximum daily load for one or more parameters in the formula

[2] Improve water quality situation for most or all the parameters in the formula

2.3. Statistical test

Data were checked for normality distribution with the Kolmogorov-Smirnov test. Spatial and temporal variations of water quality parameters were analyzed using one-way ANOVA and Duncan's post-hoc test, assuming a significant level of $\alpha=0.05$.

3. Results

3.1. Results of Water quality parameters

Data on water quality parameters of Zaringol stream are given in Tab. 4. Consider that station 1 is the first station after spring and also it is not exposed to the pollution sources, so it is considered as the test station. According to Tab. 4, most of the parameters showed significant differences between stations except for nitrate and temperature ($P<0.05$).

Table 4. Water quality parameters in different stations - Zaringol stream

Station	Salinity (ppt)	Log Turbidity (NTU)	EC (µmos/cm)	TSS (ppm)	TP (ppm)	NO_3 (ppm)	pH	T (°C)	DO (ppm)	BOD_5 (ppm)	F. coli $\times 10^5$
1	0.04^{a}	1.46^{abcd}	0.3^{a}	0.2^{a}	0.69^{a}	1.38	8.75^{b}	14	9.2^{d}	1.8^{a}	1^{a}
2	0.07^{ab}	2.37^{de}	1.59^{ab}	1.06^{ab}	1.21^{b}	2.18	8.58^{ab}	16.6	8.3^{ab}	2.7^{bcd}	2.2^{cd}
3	0.11^{b}	1.21^{a}	2.24^{b}	1.5^{b}	0.63^{a}	1.77	8.55^{ab}	12.7	8.7^{abcd}	2.5^{abc}	2.1^{bcd}
4	0.11^{b}	1.26^{ab}	2.5^{b}	1.68^{b}	0.72^{a}	1.82	8.49^{ab}	13.7	8.6^{abcd}	2.4^{abc}	1.9^{bc}
5	0.01^{a}	1.86^{abcde}	1.8^{b}	1.21^{b}	0.49^{a}	1.24	8.42^{ab}	15.5	9^{cd}	2.5^{abc}	2^{bcd}
6	0.05^{ab}	2.16^{bcde}	1.2^{ab}	0.8^{ab}	0.58^{a}	1.4	8.75^{b}	17.2	8.9^{bcd}	2.4^{ab}	2.1^{bcd}
7	0.05^{ab}	2.33^{de}	1.29^{ab}	0.87^{ab}	0.49^{a}	0.63	8.77^{b}	20.8	9.1^{cd}	2.2^{ab}	1.6^{abc}
8	0.06^{ab}	2.49^{e}	1.43^{ab}	0.95^{ab}	0.53^{a}	2	8.36^{ab}	17	8.2^{a}	2.8^{bcd}	2.8^{d}
9	0.05^{ab}	2.08^{abcde}	1.22^{ab}	0.82^{ab}	0.45^{a}	2.08	8.59^{ab}	18.7	8.5^{abc}	3.3^{cd}	2.2^{cd}
10	0.06^{ab}	2.22^{cde}	1.42^{ab}	0.95^{ab}	0.41^{a}	2.28	8.66^{b}	19.3	8.7^{abcd}	3.5^{d}	1.9^{bc}
11	0.04^{a}	2.05^{abcde}	1.26^{ab}	0.84^{ab}	0.39^{a}	1.25	8.37^{ab}	18	8.5^{abcd}	2.6^{abcd}	1.6^{abc}
12	0.05^{ab}	2.03^{abcde}	1.36^{ab}	0.91^{ab}	0.44^{a}	2.35	8.3^{ab}	19.3	8.6^{abcd}	2.6^{abcd}	1.4^{ab}
13	0.04^{a}	1.38^{abc}	1.43^{ab}	0.96^{ab}	0.61^{a}	2.65	8.6^{ab}	17.5	8.8^{bcd}	2.7^{bcd}	1.5^{abc}
14	0.06^{ab}	1.24^{a}	1.44^{ab}	0.97^{ab}	0.46^{a}	1.41	8.14^{a}	15.6	8.9^{bcd}	2.3^{ab}	1.4^{ab}

Different letters show significant differences ($P<0.05$).

Salinity had limited changes and ranged from 0.01 (station 5) to 0.11 ppt (point 3 and 4). The highest value was measured in station 3 and 4. Turbidity increased after fish farms in stations 2 and 8. Maximum value of turbidity belonged to station 8. After these stations it showed a declining trend. Electrical conductivity and total suspended solid variations in different stations indicated an increase in severity after test station.

Total phosphate is another parameter that showed the same changes. It varied from 0.39 to 1.21 ppm. There is no significant difference between stations except in station 2. Total phosphate increased significantly in station 2.

Nitrate did not show significant differences but increased from station 1 to 2 and 7 to 8, especially after station 7.

Since Zaringol stream is a mountainous stream, concentration of dissolved oxygen had limited changes (8.2-9.2 ppm) and saturated in most of the stations. However, it decreased in stations 2 and 8 after fish farms. Biological oxygen demand (BOD_5) is a parameter which related to dissolved oxygen. The minimum level of BOD_5 was registered in station 1 due to less water pollution. After this station it increased and reached 2.7 (ppm).

According to Tab. 4, faecal coliform increased after trout farms. Minimum and maximum values are 100000 and 280000 counts per 100ml which were measured in stations 1 and 8, respectively.

Comparison of water quality parameters between different seasons showed significant increase in salinity, electrical conductivity, total suspended solid, nitrate and faecal coliform in summer but showed a decrease in pH level. Concentration of total suspended solid and biological oxygen demand increased in spring (Tab. 5; $P<0.05$).

Table 5. Water quality parameters in different seasons - Zaringol stream

Parameter/ Season	Spring	Summer	Autumn	Winter
Salinity (ppt)	0.04^{a}	0.07^{b}	0.07^{b}	0.04^{a}
Log Turbidity (NTU)	1.88^{a}	1.79^{a}	1.45^{a}	2.35^{b}
EC (µmos/cm)	1.38^{ab}	1.90^{b}	1.71^{b}	0.85^{a}
TSS (ppm)	0.93^{a}	1.28^{b}	1.15^{b}	0.57^{a}
T.PO_4 (ppm)	0.77^{b}	0.59^{ab}	0.49^{a}	0.46^{a}
NO_3 (ppm)	1.66^{b}	2.42^{c}	2.48^{c}	0.41^{a}
pH	8.51^{b}	8.21^{a}	8.66^{b}	8.7^{b}
T (°C)	23.4^{d}	19.5^{c}	10.8^{a}	13.8^{b}
DO (ppm)	8.3^{a}	8.9^{b}	8.7^{b}	8.8^{b}
BOD_5 (ppm)	2.9^{b}	2.6^{b}	2.8^{b}	2.1^{a}
F. coli$\times 10^5$ (counts/100ml)	2.4^{c}	1.9^{b}	1.6^{ab}	1.5^{a}

Different letters show significantly differences ($P<0.05$).

3.2. Results of NSFWQI and WQI indexes

The average NSFWQI index was 53.21 and ranged from 50.93 to 74.5. Results showed that most of the stations have average water quality condition except for the station 1 (Tab. 6).

The NSFWQI index declined after station 2 and reached 50.93 that indicate average water quality condition becoming bad. After this station, the index improved along the stream, as in the last stations (13 and 14) it reached over 60.

The value of NSFWQI index varied in different seasons. It was calculated 53.82, 57.54, 59.62 and 57.61 in spring, summer, autumn and winter respectively and annual water quality condition was average. Although seasonal indexes showed average conditions, the minimum value and the worst condition referred to the spring and the best condition was estimated for autumn.

Table 6. Value of NSFWQI index in different stations - Zaringol stream

Station	NSFWQI index	Water quality condition
1	74.5	Good
2	50.93	Average
3	58.78	Average
4	57.72	Average
5	55.85	Average
6	53.96	Average
7	54.5	Average
8	56.67	Average
9	55.96	Average
10	55.99	Average
11	57.49	Average
12	58.16	Average
13	60.22	Average
14	64.94	Average

WQI index variations in different seasons and stations were calculated (Tab. 7). According to the table, the average value of WQI is less than 1 in most of the stations and different seasons except for the stations 1 and 7 which had better condition; So Zaringol stream needs more attentions to improve its water quality condition.

Table 7. Variation of WQI index - Zaringol stream

Station / season	Spring	Summer	Autumn	winter	Total	Water quality condition
1	1.04	1.02	0.9	1	0.99	TMDL
2	0.74	0.75	0.80	0.80	0.76	TMDL and BMP
3	0.75	0.85	0.75	0.86	0.79	TMDL and BMP
4	0.80	0.82	0.75	0.91	0.81	TMDL and BMP
5	0.92	0.89	0.77	0.92	0.87	TMDL and BMP
6	1.03	0.88	0.70	0.89	0.88	TMDL and BMP
7	1.18	1.04	0.82	0.94	1.01	TMDL
8	0.67	0.84	0.76	0.79	0.76	TMDL and BMP
9	0.83	1.00	0.77	0.92	0.88	TMDL and BMP
10	0.90	1.01	0.82	0.97	0.93	TMDL and BMP
11	0.87	1.12	0.84	0.81	0.92	TMDL and BMP
12	0.95	1.01	0.89	0.95	0.95	TMDL and BMP
13	0.87	1.03	0.92	0.93	0.93	TMDL and BMP
14	0.91	1.01	0.96	0.94	0.95	TMDL and BMP
Total	0.88	0.94	0.82	0.90	0.88	TMDL and BMP

4. Discussion

The effect of fish farm effluents on receiving waters depends on local condition such as volume and concentration of substances, flow rate of water and time of effluent discharge (Pillay, 2004).

Results of NSFWQI index in different stations and seasons showed spatial and temporal variations. Maximum value or best water quality condition was observed in station 1 located after spring. The NSFWQI index decreased in Station 2, located after a trout farm which had 15 tons of actual production capacity. According to Tab. 4 and field observation, other parameters were similar in stations 1 and 2. However, after station 2, the NSFWQI values increased, and water quality condition was average. Since self-purification power of the stream carries and dilutes the pollution, the NSFWQI value improved along the stream but agricultural plans prevent the water quality trend to become better. Station 8 located after a trout farm with 7 tons of actual production capacity and the NSFWQI declined.

Seasonal variations in NSFWQI index values showed that minimum value was in spring. Because agricultural activity and reproduction period of trout farm begins in spring and continues in summer, this trend seems quite reasonable. The NSFWQI index of winter was estimated lower than autumn because of its high turbidity. It may refer to flood occurrence in winter. Zaringol is usually flooded in winters.

Karimian *et al.* (2009) reported that agricultural effluents effects on water quality of Zohreh River (Khuzestan, Iran) and decreased the value of NSFWQI and reached 33 in downstream. Mirzaei *et al.* (2006) who classified water quality condition of Jajrud River based on NSFWQI index reported that entering of pollution from urban areas around the river decreased water quality condition by increasing total dissolved solid and microbial counts. They observed that autumn had better condition than summer due to less population living in the vicinity in those times.

There are many reports on aquaculture effects on environment (Manoochehri *et al.*, 2010; Uzbilek Kirkagac *et al.*, 2009; Pulatsu*et al.*, 2004; Mmochi *et al.*, 2002) which confirm that effluent impacts on water quality condition.

Naderi Jelodar *et al.* (2007) suggested that dissolved oxygen is one of the physicochemical parameters which are affected by aquaculture effluents. They reported that it decreased after fish farm and ranged from 8.7 to 10.2 ppm. Also they reported it depends on water temperature and BOD_5 value as it reached 7.6 in summer.

Results of dissolved Oxygen concentration revealed a reduction past trout farm outlets. It decreased from 9.12 to 8.25 (station 1 to 2) and 9.1 to 8.16 (station 7 to 8). Also, it showed seasonal changes as the minimum value belonged to the summer. Considering that the fry rearing time is in the end of May and the period of production lasts about 5-6 months, it seems that the decline relies on fish farms activities. Limited value of dissolved oxygen concentration is 6 ppm for rivers (EPA[1], 1996). In the present study, the lowest value still exceeds the allowed concentration.

Results of BOD_5 variations showed biological oxygen demand increased in spring and after the outlet of trout farms. Increasing of organic matters led to increase in oxygen demand for aerobic decomposition. So, when organic matter increased, BOD_5 value increased. Although decomposition of trout farm effluents have important role in oxygen consumption, increase of BOD_5 indicates positive effect of their effluent on decrease of dissolved oxygen. EPA reports BOD_5 range between 0-2, 3-5 and > 5 ppm, for clear, relatively polluted and polluted water, respectively. According to this classification, Zaringol stream is relatively polluted except in station 1.

Phosphate ion is a water quality parameter that had high correlation with geology and it is usually less than 0.4 ppm in rivers (EPA, 1996). Mean total phosphate concentration showed that its value in spring exceeds the standard value especially in stations 2, 3, 4. Probably one of the reasons is effluent of trout farm and agricultural runoff into the stream, although geology and slope are effective.

Costa Pierce (2002) reported that production of 1 ton of fish produced 510 kg of solid matters, 108 kg Nitrogen and 19 kg Phosphorous in the environment. Our results confirm that nitrate and turbidity increased in stations 2 and 8. Standard value of NO_3 in the surface water is less than 1 ppm (EPA, 1996). Hence, the mean concentration of the NO_3 shows it is higher than the standard level in the present study.

Electrical conductivity represents power of water electricity transmission and amount of dissolved ions, approximately (Allan, 1995). Electrical conductivity variations depend on effluent entrance, erosion of riverbed, riversides and dissolved ions. Results show that it increases at the outlets of fish farms, too.

Naderi Jelodar *et al.* (2007) studied the effects of trout farm effluents on water quality parameter of Haraz River and represented turbidity, BOD_5, TSS and NH_4 increased significantly. Pulatsu *et al.* (2004) assessed the impact of Rainbow trout farm effluents on water quality of Karasu Stream (Turkey) and found that DO decreased and turbidity, NO_2, NO_3, total phosphorus, TSS and NH_4 increased in downstream. Ghanea Sasan Saraei *et al.* (2006) studied effect of three trout farms on water quality of Haraz River and reported dissolved oxygen decreased and pH, EC, BOD_5, NO_3 and NH_4 increased in downstream significantly. Our results are like theirs.

Results of WQI index revealed that similar to average value of NSFWQI, Zaringol water quality is not good and we need to take management strategies and

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[1] - United State Environmental Protection Agency

even sanitary programs. The worse condition was related to the station 8 in spring (0.67) and confirmed our pervious findings clearly.

In summary, the worst condition was estimated for stations 2 and 8 (after fish farms) and it suggested the need to pay more attention to control environmental effects of aquaculture. Since some parameters are higher than standard values (PO_4, NO_3 and BOD_5), it is necessary to manage the production rate and use methods of wastewater treatment to avoid future risks.

Regular monitoring can help us to assess the effects of pollutants on water quality and NSFWQI and WQI are two simple indexes that can describe water quality condition and help us make better decision.

5. Conclusion

Our results confirmed that trout farm effluents impacted negatively on water quality parameters such as DO, BOD_5, turbidity, EC, total PO_4 and significantly on faecal coliform and decreased water quality condition. This result was supported by the NSFWQI clearly. Also, the effluents affected on water quality condition in spring and summer more than other seasons. Based on WQI, we found it necessary to take management strategies and even sanitary programs to avoid future risks. Our basic suggestion is treatment of effluents based on environmental standards.

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