

Investigation of the Effects of Fish Farms in Bolu (Turkey) on Aquatic Pollution

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Abstract

In the present study, the inlet and exit waters of two trout farms that were situated on the 4th and the 20th km of the Abant Rivulet in Bolu (Turkey) were investigated in a 10-month period between August 2011 and May 2012 in terms of their physicochemical parameters; the results were evaluated in terms of the environmental impact that they generated. Both of these farms, entitled as A and B in the present study, produce rainbow trout. Among the significant parameters that were determined in the inlet and exit waters in farm A throughout the study period, the following values were obtained: temperature 12.7-12.4°C; pH 8.3-8.5, 8.1-8.5; conductivity 171.5-354, 170.8-353 µS/cm; turbidity 0.38-18.30, 0.13-19.15 NTU, COD 16.5-65, 32-72 mg/l; orthophosphate 1.47-19.75, 0.63-12.67 mg/l; nitrite 0.02-0.11, 0.03-0.10 mg/l; nitrate 0.83-5.5, 0.1-5.85 mg/l; ammonium 0.02-1.04, 0.13-0.99 mg/L. The values that were recorded in farm B were as follows: temperature 12.6-12.7°C; pH 7.8-8.4, 7.9-8.3; conductivity 190.3-336.7, 122-335.3 µS/cm; turbidity 0.12-47.40, 0.10-47.35 NTU, COD 21.5-78, 24-75 mg/l; orthophosphate 3.73-54.67, 1.53-20 mg/l; nitrite 0.02-0.09, 0.01-0.08 mg/l, nitrate 0.70-1.93, 0.60-9.50 mg/l, ammonium 0.09-0.88, 0.10-0.88 mg/l.

Keywords: Trout Farm, Trout farm effluents, Environmental pollution, COD

1. Introduction

Total current fish cultivation of the world is above 100 million tons. Recent studies revealed that exceeding this number would not be possible using the currently available reserves. Fish cultivation was initiated in Turkey in 1970s with the establishment of the first trout farm, and developed rapidly during the 1990s reaching the annual cultivation capacity of 100 000 ton by 2008. The total production by fish farms increased to account for 11% of the total aquatic cultivation in 2000s, whereas it could only account for 3% of the total production during 1990s. Another

important aspect of aqua culturing is that it constitutes the sole food family of animal origin that is currently being exported to the European Union countries. This sector demands the necessary attention to maintain the quality level and to expand the market (Bayram and Altuncicek, 2008).

Bolu, situated in the Western Black Sea Region, is a settlement with suitable conditions for trout farming. Specifically, the availability of sufficient water resources (under and over ground) for trout

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cultivation is an advantage. The various potential adverse effects of aqua culturing and the consequent necessity to restrict such activities in Turkey were discussed recently (Celikkale et al., 1999). Although the environmental effects of fish cultivation in cages were investigated in this regard, the environmental effects of fish farming in tanks that were situated in terrestrial areas were not thoroughly investigated.

Significant amount of waste is released into the aquatic environment during fish farming in terrestrially situated establishments or in cages. The most significant nutritional inflow is fishmeal in aqua culturing. More than 90% of the feed provided to the fish were reported to be transferred into the water and then into the sediment in the form of residual food materials and fish feces in aqua culturing (Tsutsumi, et al., 1991).

While a portion of the food materials in the discharge waters of the fish farming tanks would be absorbed by the soil, a significant portion was reported to be very suitable for organic material production. The fishmeal waste was minimized in well-organized farms (Pillay, 2004; Ayik, 2006).

Many issues need to be taken into consideration simultaneously in aqua culturing including the pollution of water resources, familiarization of exotic species in wilderness, modifications in the hydrological regime and the struggle among the needs of the end product users; all these issues were reported to constitute different aspects of the environmental impact that aqua culturing created (Midlen and Redding, 1998; Read et al., 2001). The most frequently encountered complaint was reported as the pollution of water resources by pond effluents by Boyd (2003) and the official attraction of most nations was focused on issues regarding this common complaint. An enhancement of the effluents with nutrients and solids would be observed in flow-through aqua culturing systems that discharged their water out of a series of raceways and tanks. The untreated discharge of such effluents was reported to adversely affect the quality of water into which the effluent was mixed (Forenshell, 2001; Miller and Semmens, 2002; Schulz et al., 2003). Waste management and effective feed management were the followed routes in recent years in order to reduce waste in the aqua culture industry and to implement environmentally

friendly and sustainable fish farming practices. The potential adverse effects of aqua culturing were also made to be minimized by the governments through the implementation of environmental safeguards to regulate, control and monitor the farming processes (Midlen and Redding, 1998; Henderson and Davies, 2000; Forenshell, 2001; Read et al., 2001; Bergheim and Brinker, 2003). The necessary environmental safeguard regulations would only be structured by the decision-makers and the fish farmers would adopt and develop their own waste management systems through the provision of the necessary information and the database on the environmental impact of aqua culturing including the characterization of fish farm effluents and the quantification of its environmental impact (Pulatsu et al., 2004).

The potential impact of trout farm effluents on the quality of the inlet and exit water in trout farm tanks was investigated in the present study conducted in Abant/BOLU, where the Abant Rivulet hosted two trout farms one after the other along the same water source. This situation was of particular interest in terms of evaluating the potential additive impact of farm effluents on the receiving environment.

2. Materials and Methods

2.1 Geographical Location of the Area of Study and its Borders

The research area was located in the Western Black Sea Section of the Black Sea Region in the area that is known as the “Abant territory in the city of Bolu” (Figure 1). The selected establishments were situated along the Abant Rivulet flowing towards northeast from the Abant Lake. The Abant Rivulet also forms an effluent of the Buyuksu River. The establishments were denoted as A and B in the present study. Farm A was located 5 km away from the Abant Lake and 20 km away from the Bolu D-100 motorway; situated in between the Abant Rivulet and the road to Abant. Farm B was located 20 km away from the Abant Lake and 4 km away from the Bolu D-100 motorway; situated to the west of the road. The specifications of the farms are summarized in Table 1.



Figure 1: Location of sampling area Abant-BOLU/TURKEY

2.2 Analytical Methods

The temperature, pH, chemical oxygen demand (COD), ammonium-nitrogen content ($\text{NH}_4\text{-N}$), nitrite-nitrogen content ($\text{NO}_2\text{-N}$), nitrate-nitrogen content ($\text{NO}_3\text{-N}$), ortho-phosphate content ($\text{PO}_4\text{-P}$), alkalinity, hardness, electrical conductivity (EC), oxidation-reduction potential (ORP) and the turbidity analyses of the samples, which were monthly collected from the inlet and the discharge waters in the fish farms regularly, were carried out in the laboratory without any further delay. The analyses were conducted as stated in the standard methods depicted in Table 2 (APHA, 2005). COD, $\text{NH}_4\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}$, PO_4 , alkalinity and hardness were determined spectrophotometrically using pharo-100 while pH, ORP and EC were determined using WTW multi-function.

Table 1

Trout Farms and their properties

Farm	Location	Type of Fish	Capacity	Tank Volume	Water Source	Flow Rate
A	4 th km along the road to Abant	Rainbow Trout	1500 fish	26 m ³	Abant River	210 ml/sec
B	20 th km along the road to Abant	Rainbow Trout	3500 fish	45 m ³	Abant River	108 ml/sec

Table 2

Standard Methods used in Analysis

Parameter	Method
COD [#]	Standard Method 5220 B*
Ortho Phosphate [#]	Standard Method 4500 P- C*
Alkalinity [#]	Standard Method 2320 Alkalinity B*
Total Hardness [#]	Standard Method 2340 Hardness C*
Fresh water $\text{NO}_3\text{-N}$ [#]	Standard Method 4500- NO_3 B*
Fresh water $\text{NO}_2\text{-N}$ [#]	Standard Method 4500- NO_2 B*
$\text{NH}_4\text{-N}$ [#]	Standard Method 4500- NH_4 *
Turbidity	Standard Method 2130 B Nefolometric method*
EC \$	Standard Method 2510 B*
ORP\$	Standard Method 2580 B*
pH\$	Standard Method 4500 H*

#: Measured by PHARO 100 spectrophotometer, \$: Measured by WTW multiparameter

2.3 Statistical Analysis

The independent sample *t*-test was performed in order to evaluate the effect of the tank water in farms A and B. The removal efficiencies were analyzed using the independent sample *t*-test with a significance threshold of 0.05 throughout the 10 month period of monitoring for the environmental quality parameters. SPSS (PASW 18) software was used to conduct the statistical analysis. The results are presented in the following form: (*t*, *df*, *p*) where *t*= *t* value; *df*= degrees of freedom, and *p*>0.05 in the relevant parts of the Results and Discussion sections.

3. Results and Discussion

The most significant impact of fish cultivation plant effluents on the environment is the increase of nutritional elements in natural water resources. The major potential pollutants in fish farm discharge waters are nitrogen, phosphorous, organic materials and suspended solid materials, affecting the nitrogen and phosphorous levels of the aquatic environment (such as the lake, river, rivulet or the stream) causing eutrophication. In the present study, the effect of trout farms that operate on the basis of aqua cultivation in order to meet the ever increasing demand for food on the environment was investigated within the context of the environmentally significant water quality parameters. The water quality of the tank inlet (Table 3) and discharge (Table 4) waters were determined for farms A and B. Classification bylaws for terrestrial water resources based on the water quality parameters revealed that the quality of the water in both farms was of 2nd degree with respect to COD, and of 1st degree with respect to temperature and pH.

Table 3

Water Quality Parameters of Trout Farms pool inlet

Parameter	FARM A		FARM B	
	#	mean ±std. dev	#	mean ±std. dev
Temperature °C	23	12.7±0.5	23	12.4±0.4
pH	23	8,4±0,2	23	8,2±0,2
Total Alkalinity, mg CaCO ₃ /L	23	226,2±97,3	23	224,4±93,1
Total Hardness, mg CaCO ₃ /L	23	185,7±42,9	23	173,6±53,9
Turbidity, NTU	23	10,9±38,7	23	5,76±16,9
EC (20 °C) µS/ cm	23	279,2±64,2	23	260,06±69,7
COD, mg/L	22	44,04±22,2	22	41,1±21,9
NH ₄ -N, mg/L	22	0,36±0,35	23	0,33±0,28
NO ₃ -N, mg/L	23	1,44±1,4	23	1,76±1,9
NO ₂ -N, mg/L	23	0,06±0,05	23	0,04±0,03
ORP, MV	23	(-)72,5±15,8	23	(-)63,98±11,95

Table 4

Water Quality Parameters of Trout Farms pool outlet

Parameter	FARM A		FARM B	
	#	mean ±std. dev	#	mean ±std. dev
Temperature °C	23	12.6±0.5	23	12.7±0.4
pH	23	8,3±0,2	23	8,2±0,2
Total Alkalinity, mg CaCO ₃ /L	23	228,5±113,2	23	211,98±78,4
Total Hardness, mg CaCO ₃ /L	23	185,70±44,3	23	176±49,2
Turbidity, NTU	23	6,6±18,3	23	6,15±16,9
EC (20 °C) µS/ cm	23	278,9±62,1	23	257,9±66,6
COD, mg/L	22	43,7±19,4	22	41,2±20,6
NH ₄ -N, mg/L	23	0,33±0,29	23	0,41±0,27
NO ₃ -N, mg/L	23	3,03±2,71	23	2,07±2,3
NO ₂ -N, mg/L	23	0,05±0,04	23	0,03±0,02
ORP, MV	23	(-)67,59±9,65	23	(-)64,52±9,82

3.1 Monitoring of the Variation in COD

The major cause of the organic pollution that is caused by fish farms is fish feces and residual fish meal. Fish wastes such as feces and feed wastes transfer into the water through the net. The extent of defecation of the fish is closely related with the composition of the meal that they have in fish farms. Studies showed that approximately 25-50% of the fish meal was converted into feces. The dead fish depositing at the basin facilitated the increase in organic pollution as well as the blood and other bodily remains of the fish caught to be processed (Mirto et al., 2002; Wu et al., 1994). The depletion of oxygen would be observed when the amount of organic pollution exceeded the aerobic digestion capacity and ammonia and hydrogen sulfide gases would be released due to the continuous degradation of organic carbon by the sulfur reducing bacteria.

A variation in COD levels was observed in the inlet waters of farm A and a decrease in COD concentration was observed during the winter months (Figure 2).

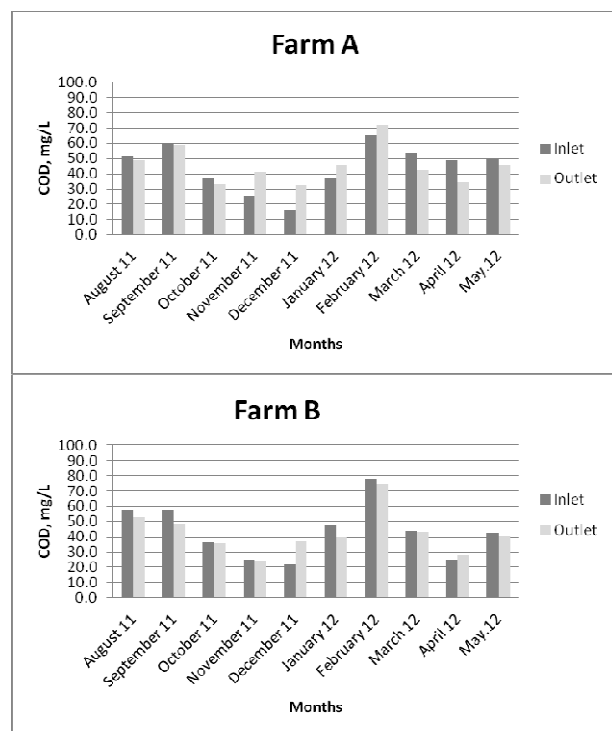


Figure 2: Monthly Change of COD for Farm A and Farm B

The variation in COD in farm A indicated a minimum value of 16.5 mg/L in December 2011 and a maximum value of 65 mg/L in February 2012 for the inlet waters and a minimum value of 28 mg/L in April 2012 and a maximum value of 72 mg/L in February 2012 for the discharge waters. The COD measurements in farm B indicated a minimum value of 21.5 mg/L in December 2011 and a maximum value of 78 mg/L in February 2012 for the inlet waters and a minimum value of 24 mg/L in November 2012 and a maximum value of 75 mg/L in February 2012 for the discharge waters. February 2012, for which the maximum COD values were recorded for the inlet waters, was the month with highest precipitation with a value of 85.7 kg/m² as reported by the Bolu division of DMI (Turkish State Meteorological Service). The Abant Rivulet was thought to incorporate more organic material along with precipitation and this was thought to cause the increase in COD levels in the inlet water taken from the rivulet. The minimum values were measured during heavy snow and the maximum values were obtained towards the end of March when the snow melted. The maximum COD value for the discharge waters was measured in February

2012 when the average air temperature was -0.6°C. The optimal temperature for trout cultivation is an annually non-fluctuating value that would not exceed 20°C. The increase in COD in the discharge waters was thought to occur due to elevated number of fish deaths in the very cold weather. The Turkish Water Pollution Control Bylaws state that the COD parameter should not exceed 50 mg/l for 2 hour composite samples and 30 mg/l for 24 hour composite samples in discharge waters of aqua culturing farms. Additionally, international legal regulations disregard COD as a parameter for the evaluation of discharge water quality (Yildirim and Pulatsu, 2011). The inlet and the discharge waters of the fish tanks were classified as 2nd degree quality as indicated by the Terrestrial Water Pollution Classification Criteria.

The difference in the COD levels of the inlet and the discharge waters in farm A was statistically insignificant ($t=-0.202$, $df=9$, $p=0.844$, $p>\alpha$, $\alpha=0.05$). Similarly, the difference in the COD levels in the inlet and the discharge waters in farm B was also statistically insignificant ($t=0.536$, $df=9$, $p=0.605$, $p>\alpha$, $\alpha=0.05$). The difference in the COD levels in the inlet waters of farm A and farm B was also statistically insignificant ($t=0.128$, $df=18$, $p=0.900$, $p>\alpha$, $\alpha=0.05$) since both farms use the same water resource as their inlet water. The investigation of the discharge waters did not reveal a statistically significant difference either ($t=0.475$, $df=18$, $p=0.641$, $p>\alpha$, $\alpha=0.05$).

3.2 Monitoring the Variation in NH₄-N /NO₂-N and NO₃-N

The nitrogen content of the feed, with its crucial role in the nutrition of all organisms, varies depending on the nutritional content of the feed. Nitrogen, which constitutes 15-18% of the protein content of the feed, is also present in the structure of the lipids. Approximately 20-30% of the nitrogen taken in fish meal is withheld in the system of the fish, the amount varying depending on the species, and the remaining 70-80% is discharged in to the water. Nitrogen in the form of urea and ammonium accelerates the development of phytoplanktons causing eutrophication (Bayram and Altunciciek, 2008). Although the recommended limit for salmonid waters (0.04 mg NH₄/L) was exceeded in the maximum measurements made throughout the period, the maximum allowable limit of 1 mg/l (NWPCB, 2008) was not exceeded

even in the Abant River (Boaventera et al., 1997).

The ammonium ion is generally not highly toxic for aquatic life. NH_4^+ is detected at very low concentrations in clean and well oxygenated waters. This waste by aquatic organisms is in turn reabsorbed by the organisms. It was reported that NH_4^+ would be directly taken in by many algae and higher plants (Cirik and Cirik, 1999).

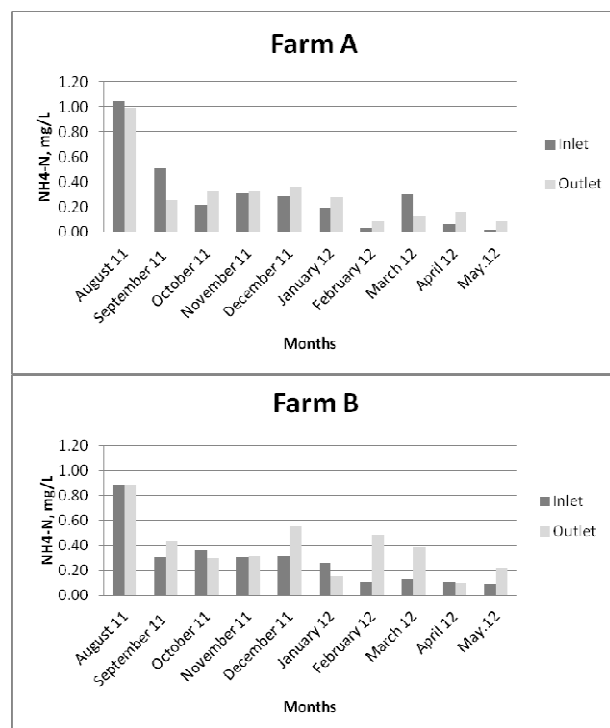


Figure 3: Monthly Change of $\text{NH}_4\text{-N}$ for Farm A and Farm B

Throughout the period of investigation, the variation in $\text{NH}_4^+\text{-N}$ in farm A indicated a minimum value of 0.02 mg/L in May 2012 and a maximum value of 1.04 mg/L in August 2011 for the inlet waters and a minimum value of 0.09 mg/L in February 2012 and a maximum value of 0.99 mg/L in August 2011 for the discharge waters. The variation in $\text{NH}_4^+\text{-N}$ in farm B indicated a maximum value of 0.88 mg/L in August 2011 and a minimum value of 0.09 mg/L in May 2012 for the inlet waters and a minimum value of 0.10 mg/L in April 2012 and a maximum value of 0.88 mg/L in August 2011 for the discharge waters. The monthly variation of $\text{NH}_4^+\text{-N}$ is displayed in Figure 3 for farms A and B. The presence of ammonium in water is an indicator of water pollution. The ammonium concentration should not exceed 1mg/L as

stated in the Water Pollution Control Bylaws. The measured values were all determined to be below this upper limit. The difference in the $\text{NH}_4^+\text{-N}$ concentrations in the inlet and the discharge waters in farm A was statistically insignificant ($t=-0.076$, $\text{df}=9$, $p=0.941$, $p>\alpha$, $\alpha=0.05$). Similarly, the difference in the $\text{NH}_4^+\text{-N}$ concentrations in the inlet and the discharge waters in farm B was also statistically insignificant ($t=-2.121$, $\text{df}=9$, $p=0.063$, $p>\alpha$, $\alpha=0.05$). The difference in the $\text{NH}_4^+\text{-N}$ concentrations in the inlet waters of farm A and farm B was also statistically insignificant ($t=0.144$, $\text{df}=18$, $p=0.887$, $p>\alpha$, $\alpha=0.05$) since both farms use the same water resource as their inlet water. The investigation of the discharge waters did not reveal a statistically significant difference either ($t=-0.741$, $\text{df}=18$, $p=0.469$, $p>\alpha$, $\alpha=0.05$).

Nitrite is an intermediate product in the nitrogen cycle. Nitrites contribute to plankton development as in the case of the nitrates. Concentrations exceeding 1 mg/l of NO_2 was reported to be an indicator of pollution in water (Nisbet and Verneaux 1970). The nitrite concentration of natural waters is usually much lower. However, higher concentrations may be reached in areas of high organic pollution and low oxygen availability. The rate of nitrification-denitrification was reported to be affected by the oxygen saturation, nutrient concentration (from the soil or by feed), fish production capacity (kg-ton/m^2), conductivity, temperature and the pH of the aqueous environment (Yildirim and Pulatsu, 2011).

Nitrite concentration was measured as 0.02, 0.06, 0.04 and 0.04 mg/l in the inlet waters Farm A during summer, spring, fall and winter, respectively and as 0.01, 0.06, 0.03 and 0.04 mg/l in the discharge waters. The nitrite concentration was lower when the rate of nitrification-denitrification was high and it was higher when this rate was low. A natural consequence of this variation in the rate of the cycle was the accumulation of intermediates in the environment for longer periods when the rate of the cycle was slow. Nitrite concentration was measured as 0.02, 0.05, 0.04 and 0.04 mg/l in the inlet waters Farm B during summer, spring, fall and winter, respectively and as 0.03, 0.07, 0.04 and 0.06 mg/l in the discharge waters. These values varied within the following confidence intervals $0.01\pm0.02\text{mg/l}$, $0.06\pm0.02\text{mg/l}$, $0.03\pm0.02\text{mg/l}$, $0.04\pm0.02\text{mg/l}$ (Figure

4). Nitrite concentration remained below the upper limit concentration of 1mg/l in both farms throughout the period of investigation without imposing any threats on the aquatic environment.

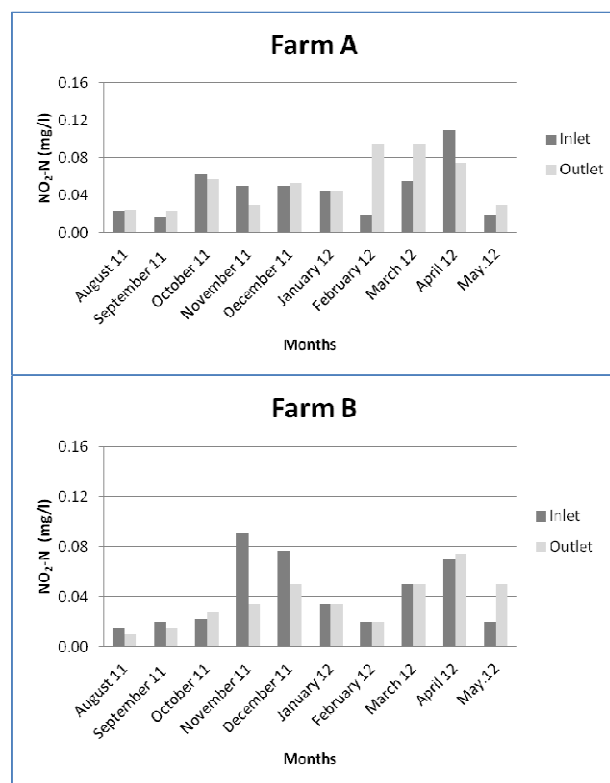


Figure 4: Monthly Change of NO₂-N for Farm A and Farm B

The difference in the NO₂-N concentrations in the inlet and the discharge waters in farm A was statistically insignificant ($t=-0.916$, $df=9$, $p=0.384$, $p>\alpha$, $\alpha=0.05$). Similarly, the difference in the NO₂-N concentrations in the inlet and the discharge waters in farm B was also statistically insignificant ($t=0.696$, $df=9$, $p=0.504$, $p>\alpha$, $\alpha=0.05$). The difference in the NO₂-N concentrations in the inlet waters of farm A and farm B was also statistically insignificant ($t=0.238$, $df=18$, $p=0.814$, $p>\alpha$, $\alpha=0.05$) since both farms use the same water resource as their inlet water. The investigation of the discharge waters did not reveal a statistically significant difference either ($t=1.413$, $df=18$, $p=0.177$, $p>\alpha$, $\alpha=0.05$).

Nitrate is the common form of nitrogen in oxygen rich waters and is a significant factor that could limit or enhance algal growth. NO₃ concentration was reported to remain low in surface waters,

usually not exceeding 1 mg/l although it may reach values as high as 5 mg/l (Anonymous, 1981). The nitrogen content of oligotrophic waters is very low, whereas that of eutrophic waters is very high. Nitrate was reported to have a toxic effect on aquatic life at concentrations above 80 mg/l (Svobodá et al., 1993).

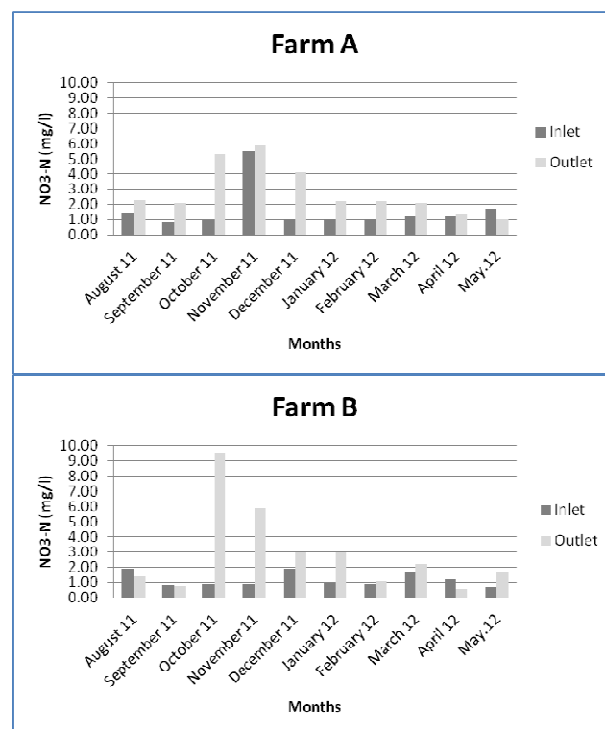


Figure 5: Monthly Change of NO₃-N for Farm A and Farm B

NO₃-N concentration followed its natural course throughout the conducted analysis. Nitrate concentration was measured as 1.50 ± 0.63 mg/l, 2.43 ± 0.63 mg/l, 1.00 ± 0.63 mg/l and as 1.37 ± 0.63 mg/l, in the inlet waters during summer, spring, fall and winter, respectively and as 2.27, 4.41 ± 1.14 mg/l, 2.83 ± 1.14 mg/l and as 1.78 ± 1.14 mg/l in the discharge waters (Figure 5). The NO₃-N concentration of the water decreased during the summer months parallel to the decrease in the amount of precipitation. However, NO₃-N concentration increased with increasing precipitation in October and November. Ammonium that is not utilized by the phytoplanktons is readily oxidized first to nitrite and then to nitrate. The main source of nitrate and nitrite in water was reported as organic materials, nitrogenous fertilizers and some minerals in soil (Yaramaz, 1992). As discussed above, the NO₃-N

concentration of the rivulet was observed to increase during the periods when $\text{NO}_3\text{-N}$ salts in soil were carried into the aquatic environment along with rainwaters in fall and along with melting snow. The seasonal averages for summer, spring, fall and winter were 1.90 mg/l, 0.89 mg/l, 1.26mg/l and 1.20mg/l in the inlet waters and 1.37mg/l, 5.36mg/l, 2.33mg/l and 1.50mg/l in the discharge waters. A considerable difference could not be observed between the two farms. Farm B would be classified as having water quality of the 1st degree as indicated by the Terrestrial Water Pollution Classification Criteria of the Water Pollution Control Bylaws displayed in Table 1. The temporary seasonal increase in $\text{NO}_3\text{-N}$ concentration in farm B in November would still not adversely affect the environment with regards to this parameter.

The difference in the $\text{NO}_2\text{-N}$ concentrations in the inlet and the discharge waters in farm A was statistically insignificant ($t=-2.755$, $df=9$, $p=0.844$, $p>\alpha$, $\alpha=0.022$). Likewise, the difference in the $\text{NO}_2\text{-N}$ concentrations in the inlet and the discharge waters in farm B was statistically insignificant ($t=-1.510$, $df=9$, $p=0.165$ $p>\alpha$, $\alpha=0.05$). The difference in the $\text{NO}_2\text{-N}$ concentrations in the inlet waters of farm A and farm B was also statistically insignificant ($t=0.842$, $df=18$, $p=0.418$ $p>\alpha$, $\alpha=0.05$) since both farms use the same water resource as their inlet water. The investigation of the discharge waters did not reveal a statistically significant difference either ($t=1.175$, $df=18$, $p=0.255$, $p>\alpha$, $\alpha=0.05$).

3.3 Variation in $\text{PO}_4\text{-P}$ Concentration

Phosphorous is the most important nutritional mineral affecting the productivity of natural waters. It is detected in the form of dissolved organic and inorganic phosphate as well as organic phosphate particles in lakes and streams. Phototrophic producers would take dissolved inorganic phosphate up and they would bind this phosphate organically including it in the food chain (Schworbel, 1987). Phosphate is mixed up with water through the degradation of organic materials, washing away of the agricultural fertilizers, and discharge or seeping of domestic and industrial waste waters into the aquatic environment. Phosphorous was reported to be the most important element in aquatic eutrophication (Harper, 1992). It would be present in trace amounts in unpolluted waters and it would determine the productivity of

lakes (Tepe and Boyd, 2003). It has a limiting effect on the growth of specifically photosynthetic autotrophic and heterotrophic organisms. The total concentration of phosphorous in natural waters varies depending on the morphometric values of the basin, the chemical content of the geological architecture of the region, the presence of any organic material and especially domestic wastes including detergents seeping into the water and on the organic metabolism of the water environment. Nisbet and Verneaux (1970) reported that the productivity of waters with a phosphate content of 0.15-0.30 mg/l would be high, whereas water would be considered as polluted if this limit was exceeded. Phosphate content higher than 50 mg/l was reported to be an indicator of excessive pollution and eutrophication in water (Tas et al., 2010).

The effect of phosphorous would be the excessive lowering of oxygen content in water as a result of a series of bacteriological events taking place. This causes changes in aquatic life and in the number of the organisms.

Phosphorous and nitrogen are the two major constituents affecting the environment in fish farms. The impact of these materials on the environment depends on the physical and the chemical specifications of the fish meal that is used and on the management of the feeding process. Development of new strategies based on the applied system of production is required in order to be able to lower the concentration of these materials, which would lower the quality of water, in the discharge waters. Phosphorous is also an essential element for fish and nearly 80-90% of the element is present in the structure of the fish bones and teeth.

Throughout the period of investigation, the variation in $\text{PO}_4^{+}\text{-P}$ in farm A indicated a minimum value of 2 mg/L in May 2012 and a maximum value of 19.72 mg/L in November 2011 for the inlet waters and a minimum value of 0.63 mg/L in August 2011 and a maximum value of 12.67 mg/L in December 2011 for the discharge waters. The variation in $\text{PO}_4^{+}\text{-P}$ in farm B indicated a maximum value of 54.67 mg/L in December 2011 and a minimum value of 2.1 mg/L in March 2012 for the inlet waters and a minimum value of 2.1 mg/L in April 2012 and a maximum value of 20 mg/L in November 2011 for the discharge waters.

The monthly variation of $\text{PO}_4^{+}\text{-P}$ is displayed in Figure 6 for farms A and B.

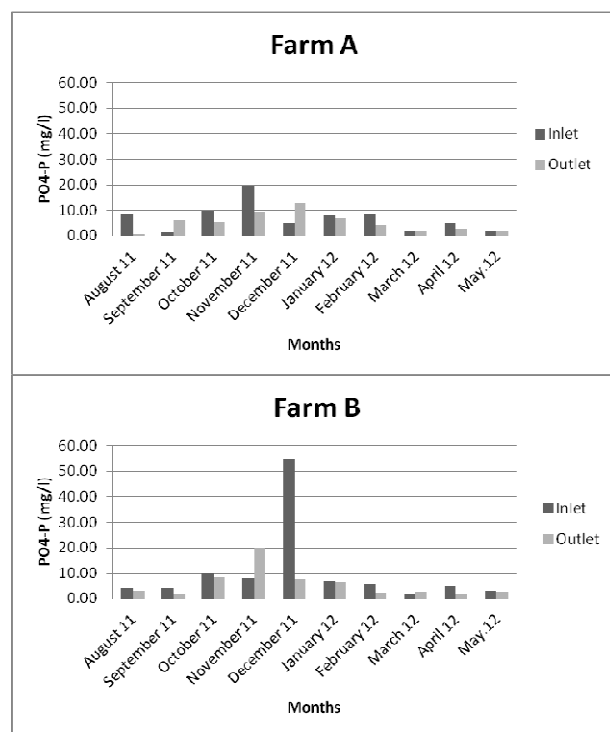


Figure 6: Monthly Change of $\text{PO}_4\text{-P}$ for Farm A and Farm B

Generally, an increment was observed in phosphorous concentration during the winter months. This was thought to stem from the increase in the amount of sediment and fertilizers that were dragged down from the mountain villages into the rivulet causing the phosphorous content of the tanks to peak. Additionally, the phosphorous in the fish feed was also thought to contribute to the accumulation of phosphorous in the tank water.

The difference in the $\text{PO}_4\text{-P}$ concentrations in the inlet and the discharge waters in farm A was statistically insignificant ($t=1.082$, $df=9$, $p=0.307$, $p>\alpha$, $\alpha=0.05$). Likewise, the difference in the $\text{PO}_4\text{-P}$ concentrations in the inlet and the discharge waters in farm B was statistically insignificant ($t=-0.933$, $df=9$, $p=0.375$, $p>\alpha$, $\alpha=0.05$). The difference in the $\text{PO}_4\text{-P}$ concentrations in the inlet waters of farm A and farm B was also statistically insignificant ($t=0.619$, $df=18$, $p=0.544$, $p>\alpha$, $\alpha=0.05$) since both farms use the same water resource as their inlet water. The investigation of the discharge waters did not reveal a statistically significant difference either ($t=-0.238$, $df=18$, $p=0.814$, $p>\alpha$, $\alpha=0.05$).

3.4 Variations in Turbidity

Turbidity stems from suspended clay, silica, organic materials and microscopic organisms, as well as from calcium carbonate, ammonium hydroxide, iron hydroxide and similar precipitates in waters spared for trout cultivation. The size of these materials varies from colloidal particles up to coarse particles. Turbidity was reported to cause a decrease in the light transmittance of water (Sam-sunlu 1999). Additionally, increase in nutrients and organic materials, benthic enrichment, bacterial variations were also reported to lower water quality by causing changes in turbidity (Boaven-tura et al., 1997). Since turbidity is caused by the suspended solid materials (SSM), the two parameters could be associated with each other. Factors affecting the amount of suspended solid materials in water are the intensity of the phytoplankton population and the flood waters reaching the lake. Over-increasing of the SSM was reported to cause harm for sensitive structures like gills in fish causing tiddler and roe deaths (Alabaster and Lloyd, 1980). SSM is carried into aquatic environments through domestic and industrial waste waters. The turbidity of the water increases as a result and causing increased opacity, which would adversely affect photosynthesis. The substrate of the benthic organisms living on the basin is also affected adversely as a result of the sedimentation. The SSM concentrations ranging between 25 and 80 mg/l are considered to fall within the limits, whereas concentrations above 80 mg/l were reported to be unfavorable for aquatic life.

The maximum turbidity was observed during the winter months in the inlet and exit waters of farm A. Heavy precipitation during the period carrying particles from the soil into the water increased turbidity. Showers were very effective in November when the highest turbidity value was measured. The turbidity value of the inlet water was measured as 1.03 NTU, 6.86 NTU, 1.31 NTU, 22.04 NTU in summer, fall, winter and spring, respectively whereas that of the discharge water was measured as 0.79NTU, 7.20NTU, 1.32 NTU, 11.20 NTU.

The change in the variation in the turbidity in the waters of farm B also was at its maximum during spring months as it was the case for farm A. Rain caused the carryover of soil particles into the stream. The turbidity was observed to vary

between 1.43 ± 7.8 NTU and 1.72 ± 7.9 NTU in the remaining periods. Since the tanks of both farms are fed from the same water resource, both tanks underwent similar seasonal exposures. Due to this reason, the inlet water turbidity was at its highest in April when the soil and silica mixture was at its highest concentration. Values in neither of the farms would impose any threat of the viability of the fish in the tanks (Figure 7).

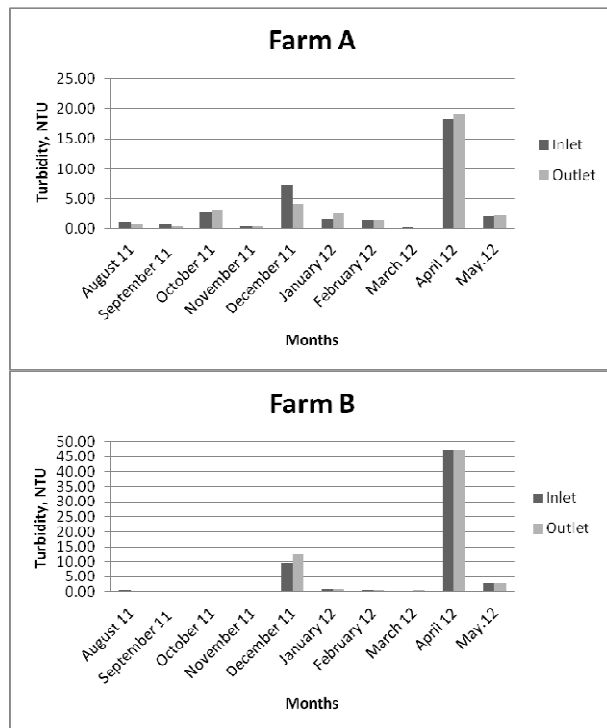


Figure 7: Monthly Change of Turbidity for Farm A and Farm B

The difference in the turbidity of the inlet and the discharge waters in farm A was statistically insignificant ($t=0.997$, $df=17$, $p=0.335$, $p>\alpha$, $\alpha=0.05$). Similarly, the difference in the turbidity of the inlet and the discharge waters in farm B was also statistically insignificant ($t=-1.117$, $df=17$, $p=0.280$, $p>\alpha$, $\alpha=0.05$). The difference in the turbidity of the inlet waters of farm A and farm B was also statistically insignificant ($t=0.533$, $df=18$, $p=0.600$, $p>\alpha$, $\alpha=0.05$) since both farms use the same water resource as their inlet water. The investigation of the discharge waters did not reveal a statistically significant difference either ($t=0.620$, $df=18$, $p=0.543$, $p>\alpha$, $\alpha=0.05$).

3.5 Variation in pH

The pH of streams that are not polluted in one way or another varies between 6 and 9. Many fish species were reported to develop well in a pH range of 6.5 to 8.5 (Arrignon, 1976, Dauba, 1981). Water pH level that was higher than 10.8 and lower than 5.0 was reported to have a detrimental effect on cyprinidae (Svobodá et al., 1993). On the other hand, alkaline waters are more suitable for trout cultivation. Although the trout can survive in a pH range of 4.5-10, the most suitable pH range was reported as 7.5-8.0 (Ozdemir, 1994). At a pH lower than 5.5, the regular spawning process would be disturbed and at pH values lower than 4.5, spawning would be suspended indefinitely exposing the species to the risk of becoming extinct. Snow would increase the acidity of the stream and the tank water causing an acid shock for the trout. An increase in the acidity of the water would disrupt the well-adjusted internal balance of the fish. It would cause the removal of calcium from the bone structure causing serious malformations including hunchbacks in fish. Additionally, it would also affect the birds and the mammals feeding on these fish.

The average pH of the inlet and discharge waters in farm A was determined as 8.4 ± 0.07 , 8.3 ± 0.11 and in farm B as 8.2 ± 0.16 , 8.2 ± 0.11 , respectively, during the 10 month period of study (Figure 8). These values were observed to fall within the limits that would be suitable for trout cultivation.

The difference in the pH of the inlet and the discharge waters in farm A was statistically significant ($t=2.333$, $df=9$, $p=0.045$, $p<\alpha$, $\alpha=0.05$). However, the difference in the pH of the inlet and the discharge waters in farm B was statistically insignificant ($t=-0.338$, $df=9$, $p=0.743$, $p>\alpha$, $\alpha=0.05$). The difference in the pH of the inlet waters of farm A and farm B was observed to be statistically significant ($t=3.067$, $df=18$, $p=0.009$, $p<\alpha$, $\alpha=0.05$) since both farms use the same water resource as their inlet water. The investigation of the discharge waters did not reveal a statistically significant difference ($t=1.711$, $df=18$, $p=0.104$, $p>\alpha$, $\alpha=0.05$).

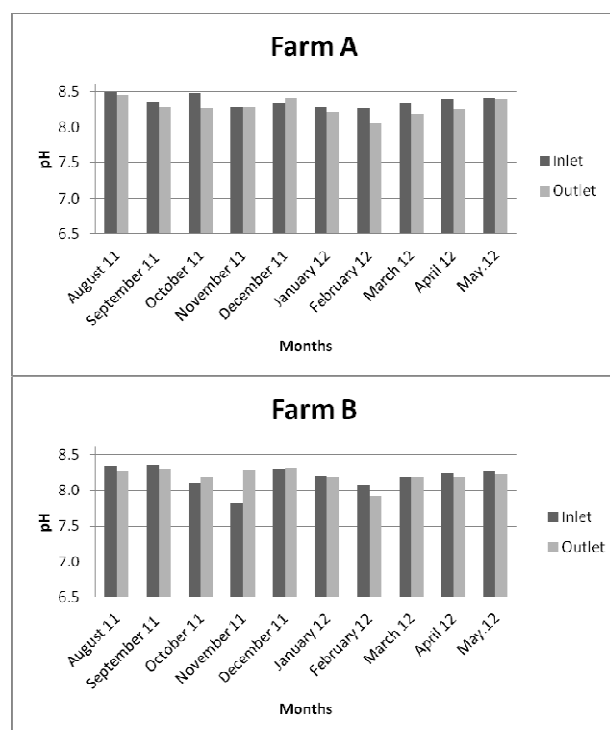


Figure 8: Monthly Change of pH for Farm A and Farm B

3.6 Temperature

The appetite of the rainbow trout is optimal if the water temperature falls within the range of 7–18°C. Falling short of or exceeding these temperatures would cause the fish to lose their appetite and this would in turn result in them ceasing to feed themselves. The uptake of food from the environment increases as the temperature of the environment increases until the temperature reaches approximately 18°C above which both the appetite and the food intake of the fish decrease, rapidly ceasing to a halt. Another important issue to be discussed is the inverse correlation between the extent of feeding and the utilization of the feed that would be consumed. Although the rainbow trout feeds intensively at temperatures near 18°C, it can digest less of the feed that they intake. An optimum balance between the two concepts is established in the temperature range of 13°C to 15°C for different trout species and the rainbow

trout was reported to be no exception to that (Hoitsy G and Poulsen T.M, 2011).

The temperature of the tank inlet and discharge waters in farm A was determined as $16.6 \pm 4.36^\circ\text{C}$, $16.9 \pm 4.40^\circ\text{C}$ and in farm B as 8.2 ± 0.16 , 8.2 ± 0.11 , respectively. These measured temperature values were observed to fall within the limits that would be suitable for fish cultivation.

4. Conclusion

The following results were obtained through the investigation of the quality of inlet and exit waters to the tanks in 2 trout farms along the road to Abant.

- The investigated parameters were determined as follows in farm A: temperature $12.7\text{--}12.4^\circ\text{C}$; COD 16.5–65, 32–72 mg/l orthophosphate 1.47–19.75, 0.63–12.67 mg/l; nitrite 0.02–0.11, 0.03–0.10 mg/l; nitrate 0.83–5.5, 0.1–5.85 mg/l; ammonium 0.02–1.04, 0.13–0.99 mg/l. Taking the water pollution regulations into consideration, the quality of the inlet water to farm A would not be expected to affect fish farming adversely and in return, the discharge waters from the farm tanks to the Abant Rivulet were determined not to impose any threat on the water quality of the rivulet.
- The parameters were determined as follows in farm B: temperature $12.6\text{--}12.7^\circ\text{C}$; COD 21.5–78, 24–75 mg/l; orthophosphate 3.73–54.67, 1.53–20 mg/l; nitrite 0.02–0.09, 0.01–0.08 mg/l, nitrate 0.70–1.93, 0.60–9.50 mg/l, ammonium 0.09–0.88, 0.10–0.88 mg/l. Similar conclusions could be drawn for farm B as those of farm A.

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