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ASSESSMENT OF PHYSICO-CHEMICAL PARAMETERS OF RAINBOW TROUT FARMS FOR THE EVALUATION OF POTENTIAL THREAT TO NATURAL STREAMS IN NEPAL

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Abstract

Three trout farms from Nepal were studied to investigate the changes in physico-chemical parameters and their potential threat to natural water bodies receiving the effluents. Reference and impact sites were determined in each farm so as to find out the level of impacts due to farming activities. Some of the parameters such as dissolved oxygen, turbidity, conductivity, and total dissolve solids were significantly changed in the impacted zones compared to reference sites. Similarly, concentrations of some major ions such as calcium and sodium were increased in the impacted zones. On the other hand, some of the parameters such as pH and potassium did not change in the impacted zone although their concentrations were different among farms studied. Nevertheless, the overall changes in the physico-chemical parameters did not pose health risk to the aquatic ecosystems receiving effluents from these fish farms as the concentrations were below the prescribed levels by Environmental Protection Agency (EPA) as well as Nepal Environment Statistics. This is an indication that, although fish farming activities are degrading water qualities, there is no threat to the water quality receiving the effluents yet probably due to small scale farming. The increase in number of fish farms in the same area, however might pose risk to the ecological health in the region which warrants regular monitoring.

Key words: Rainbow trout farms; physico-chemical parameters; pollution threat; Nepal

Introduction

Fish farming has been gaining popularity not only globally (Naylor et al., 1999) but also in Nepal as it contributes 62% of the total fish production (MOAD, 2013). Among different fish species Rainbow trout has been attracting many fish farmers and consumers due to various reasons like high profit margin and employment opportunities (MOAD, 2013). In addition, it has potential to be exported overseas and earn foreign currency.

Although trout farming is economically beneficial, a number of studies have concluded that trout farming affects the water physico-chemical parameters (Pulatsu et al., 2004; Noroozrajabi et al., 2013) and hence can cause negative impacts on the aquatic ecosystems (Boaventura et al., 1997; Nyström et al., 2001; Power, 1992). In most cases of fish farming, the setting of farm is such that the stream water is diverted to aquaculture facilities and the effluent from farm is discharged to downstream waters untreated. Such effluents contain suspended solids, nitrogen and phosphorous from uneaten feed and fish excreta (Naylor et al., 1999). The decomposition of the feces can further degrade water quality of the farm and downstream reaches by changing the concentrations of a range of physico-chemical parameters such as Dissolved Oxygen (DO), biological oxygen demand (BOD), nitrates and nitrites, total phosphorus (TP) and major ions (Pulatsu et al., 2004; Saremi et al., 2013) which can affect the health of other aquatic organisms (Fries and Bowles, 2002).

In Nepal, in spite of the popularity of the trout farming (MOAD, 2013), the studies of the impacts on aquatic ecosystems is very limited (Pradhan et al., 2008; Bhagat and Barat, 2015). So, better understanding of how farming practices affect the water quality and aquatic habitat is required for the effective pollution control management. Similarly, studies to assess the water quality of the trout farms of Nepal in terms of heavy metals are also very limited. Many heavy metals are known to bio-accumulate and bio-magnify due to which the concentration increases as the trophic level increases (Sharma et al., 2008). Fish is one of the main sources through which heavy metals can enter our body and can cause adverse health impacts. Since major ions and heavy metal parameters are known to cause not only environmental impacts but also have health impacts, this research attempts to study the impacts of major ions and heavy metals on water quality of trout farms.

Materials and methods

Study area

The study was conducted in three trout farms; two farms from Kaski district and a farm from Nuwakot district of Nepal (Fig. 1). Machhapuchchhre Trout Farm (Farm-A hereafter) is located in Puranchaur VDC of Kaski district (28°19’40.20” N and 83°59’13.27” E; 1281 m asl) covering an area of 3 ropanis (Fig. 2). Gandaki Trout Farm (Farm-B hereafter) is located in Sardikhola VDC of Kaski district (28°19’44.19” N and 83°58’41.46” E; 1220 m asl) covering an area of 2 ropanis (Fig. 3). The main source of water for both Farm-A and Farm-

B is a stream called Bhurjung Khola. In addition, Farm-B also receives water from a spring source nearby. The third fish farm is Fall and Trout Farm (Farm-C hereafter) located in Kakani (Fig. 4), Nuwakot district (27º48′50.07″ N & 85 º 30′30.97″ E; 1620 m asl). The main source of water to this farm is spring water from the forest area.

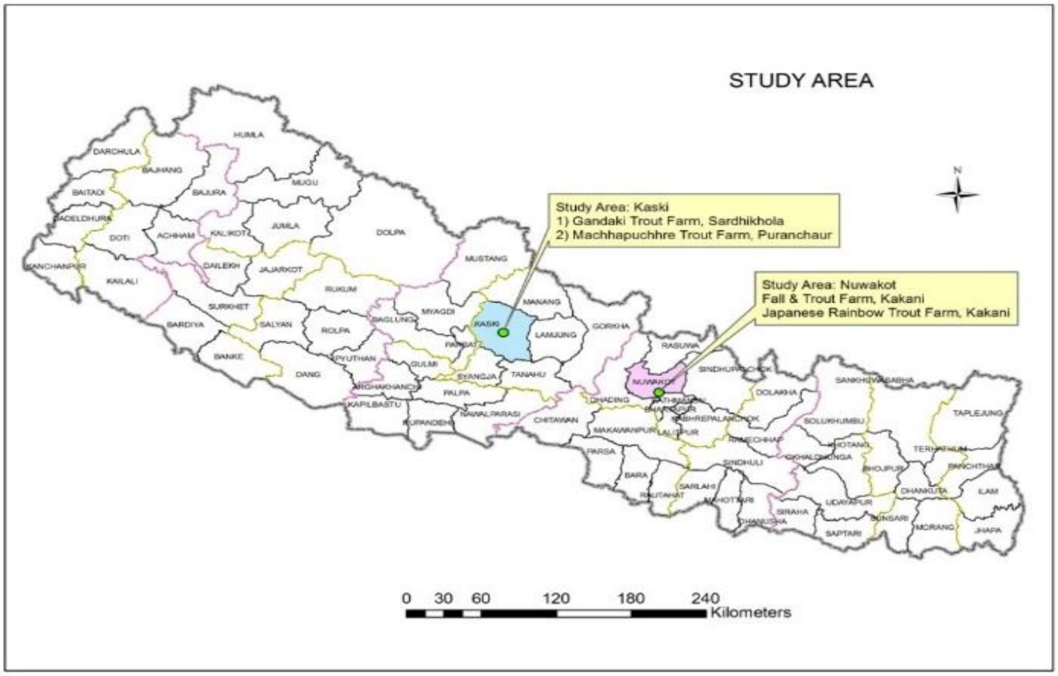

Fig. 1: Study sites in Kaski district (Farm-A and Farm-B) and in Nuwakot district (Farm-C).

Sampling

Sampling was carried out in mid-June 2016. Samples were collected from the upstream and inlets (reference site) of the trout farms and raceways (where trouts were reared) and the outlets (from where water enters the natural streams). Two different zones: viz., reference and impacted zones were studied in the present research. Reference zone included where the impacts of fish farming was minimal. Impacted zone included the raceways and the outlets.

In Farm-A, a total of seven samples were taken (Fig. 2). Two samples were taken from reference sites at 100 m interval (MSP1a and MSP1b) and five samples were taken from the raceways and ponds (two samples from the second site: MSP2a and MSP2b).

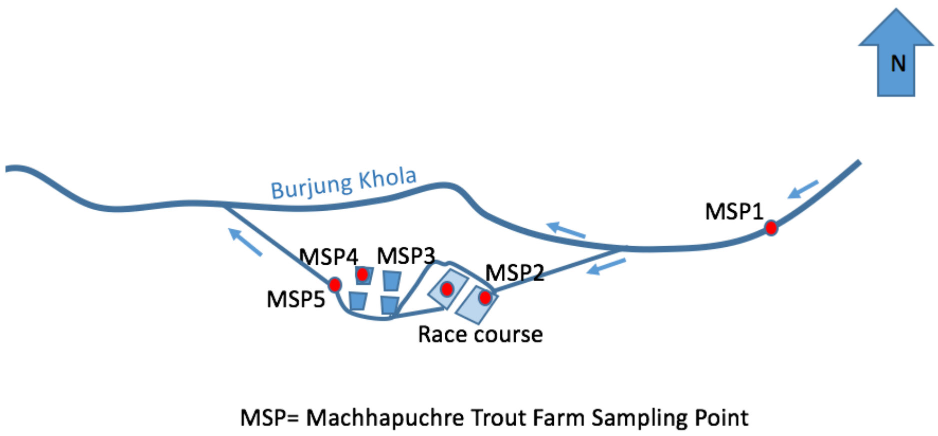

Fig. 2: Sampling sites on Farm-A. MSP1 and MSP2 contain two sampling sites each making a total of seven sites.

In Farm-B, a total of ten samples were taken (Fig. 3). Two samples were taken from the reference sites, one from the (GSP1) and another from the stream (GSP2). Eight samples (GSP3 to GSP10) were taken from the impact zone which included raceways, ponds and outlets.

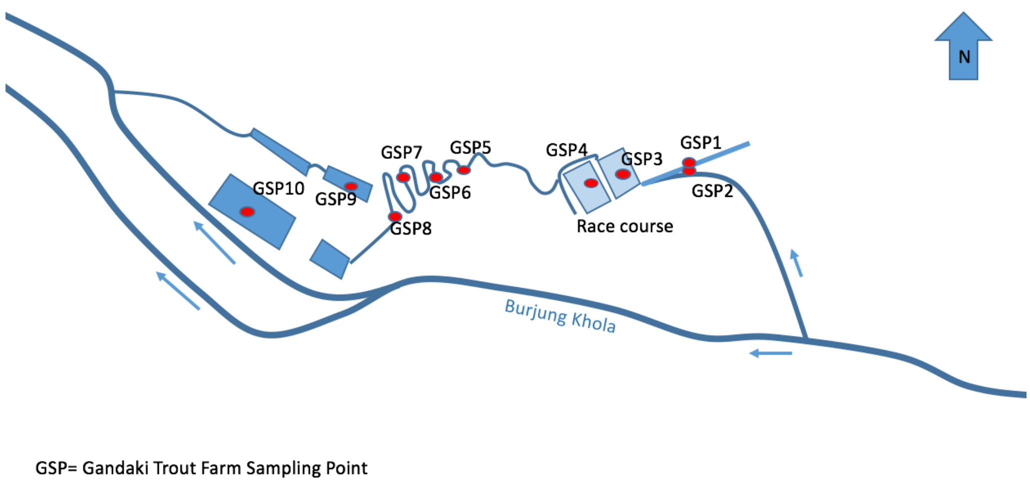

Fig. 3: Sampling sites at Farm-B. First two sampling sites (GSP1 and GSP2) represent the reference zone

In Farm-C, a total of nine samples were taken (Fig. 4), two from as the reference sites (FSP1a and FSP1b) and seven from the impacted zone such as raceways (FSP2 to FSP7) and outlet (FSP8).

Selected physico-chemical parameters such as temperature, dissolved oxygen (DO), pH, conductivity, turbidity and total dissolved solids (TDS) were measured on site using portable kit (WagTech). Water samples for heavy metals and metalloids [Mercury (Hg), Lead (Pb), Cadmium (Cd) Manganese (Mn) and Arsenic (As)] analyses were preserved with nitric acid. For this, 500 ml of water samples were collected in polyethylene bottles. The bottles were washed and rinsed thoroughly with the water from the sampling sites. Water samples were collected approximately 20 cm below the surface with the open mouth facing slightly downwards towards the current. The samples were fixed with concentrated HNO_3. All the samples were stored in an ice box for transport. Once the samples were collected, samples were stored in a box and stored in cool place.

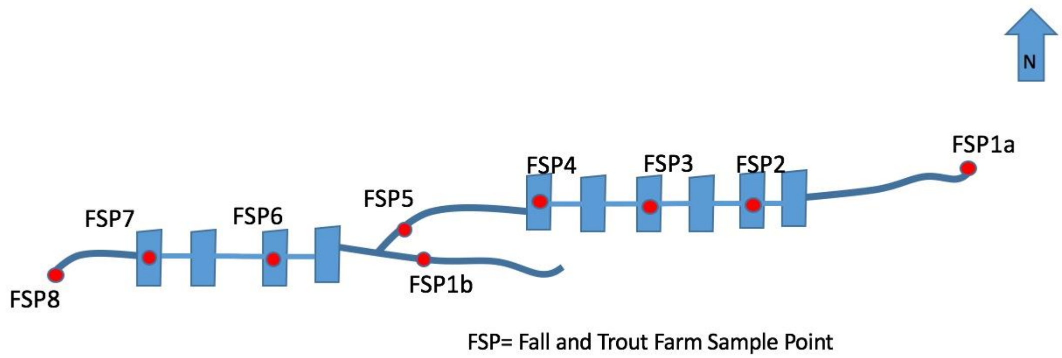

Fig. 4: Sampling sites on Farm-C. There are two different sources as the reference sites (FSP1a and FSP1b).

Water samples for major ions (cations: Na^+, K^+, Ca^{2+} and Si^{4+}; anions: SO_4^{2-}, NO_3^-, PO_4^{3-} and Cl^-) were collected in 500 ml plastic bottles and kept in ice box until they were brought to the laboratory for further analyses.

Laboratory and data analysis

Laboratory analysis of major ions, heavy metals and metalloids were analyzed following the standard procedures (APHA, AWWA, WEF, 2012) in Environment and Public Health Organization (ENPHO) laboratory, Nepal. Data entry, processing, statistical analysis and comparison were conducted using Sigma Plot 12.3 software. Most of the data were skewed, therefore, non-parametric methods (Kruskal-Wallis One Way Analysis of Variance on Ranks and Mann- Whitney Rank Sum Test) were used for comparisons at the significance level of $p < 0.05$.

Results and discussion

No statistical significant difference of DO was found among studied trout farms. However, significant difference in DO concentrations was observed between reference and impacted zones in pooled data (t = 2.125; p 0.039). Table 1 also gives comparison of DO concentrations in references and impacted zones separately. In Farm-B and Farm-C, concentration of DO decreased at impact zone as compared to reference (Table 1) contrary to higher concentration of DO at the outlet of Farm-A. This indicates that the DO is affected by trout farming. The higher DO concentration at the outlet of Farm-A could be attributed to turbulence of the water. Similar observations were also accounted by Mirrasooli et al. (2012) in Iran, Pulatsu et al. (2004) in Turkey and Tovar et al. (2000) in Arizona where DO concentrations were lower in outlets.

Although the trend of turbidity in Farm-A and Farm-C gives an indication that outlets are having higher values (Table 1), there was no significant difference between the reference and impacted sites. Higher concentration at outlets could be resulted due to flushing of uneaten feeds and fish excreta without treatment. Farm-C effluents showed comparatively greater impact on water Turbidity (1.69 NTU). However, statistical analysis showed no significant difference in turbidity between farms.

Table 1: On-site physico-chemical parameters at different trout farms. (R) indicates reference sites and (I) indicates impacted sites.

Parameters	Farm-A (R)	Farm-A (I)	Farm-B (R)	Farm-B (I)	Farm-C (R)	Farm-C (I)
DO (mg/L)	9.2± 1.32	9.91±0.70	10.8±0.28	8.97±0.73	11.2±0.84	9.32±0.93
Turbidity (NTU)	0.31 ± 0.22	0.72±0.34	1.29±1.04	1.21±0.65	0.51±0.03	1.69±1.65
pH	8.15±0.08	8.17±0.21	7.99±0.08	7.97±0.10	7.60±0.12	7.34±0.26
Conductivity (µS/cm)	134.2±1.60	145.49±12.05	207.5±0.70	208.58±21.59	38.7±1.69	46.78±7.59
Temperature (ºC)	21.61±2.60	20.3±0.44	18.15±0.07	19.15±0.93	18.36±0.83	18.81±1.73
TDS (ppm)	67.16±1.70	73.88±6.43	109.5±7.77	101.88±2.53	19.45±0.77	23.34±3.72

Conductivity and TDS were found maximum at impact sections of Farm-A and Farm-C which might be due to increased dissolved salt concentrations from the feeds. Farm-B had the highest concentration which could be because of the source of water from springs and streams. Conductivity increases with increase in number of dissolved salts and thus TDS also increases (Lawson, 1995). Also, there is a statistically significant difference between farms ($H=28.405$, $P = <0.001$) which could be due to difference in amount of uneaten feeds, fish excreta and other mineral salts (Naylor et al., 1999). Lawson (1995) states that dissolved solids could directly influence water conductivity, the higher the dissolved solids the higher the conductivity. But Noroozrajabi et al. (2013) mentioned that total amount of dissolved solid differs from place to place because of natural differences and anthropogenic sources.

pH values in all the farms were alkaline and pH differed significantly between the farms ($H = 20.791$, $P = <0.001$). It could be due to different sampling time in farms as pH in pond water is lowest during sunrise and increases with light intensity with CO_2 consumption and reaches peak value during afternoon (FAO, 2007). Contrary to this, increasing acidity was observed in downstream by Tovar et al. (2000) in Spain. The pH in the impact zone of all the farms lie between 7.3 to 8.4 which falls within the good water quality criteria (6.5-9.5) given by Environmental Protection Agency (EPA, 2001).

In all of the farms, temperature was higher in the impact zones. Also, there is a statistically significant difference between the farms ($H = 13.613$; d.f.= 2; $P = 0.001$). Since temperature is known to have diurnal variation (Wetzel, 2001), it may be possible reason for the difference in temperature in the sampling sites and the farms as sampling was done at different time of the day in all the farms. According to Lawson (1995), the temperatures observed in the farms lie within the acceptable range for survival, metabolism and physiology of aquatic organisms including trout.

Although water quality parameters differ among different sites in the study area and shows impacts of trout farming, the overall values were below the limits of Nepal Environmental Statistics (CBS, 2016). This is an indication that Trout farming were being practised in small scale and shows small impacts compared to other parts of the world.

The concentration of measured cations in reference of Farm-A, Farm-B and Farm-C was in the order: $Ca^{2+}>Si^{4+}>K^{+}>Na^{+}$, $Ca^{2+}>Si^{4+}>K^{+}>Na^{+}$ and $Si^{4+}>Ca^{2+}>K^{+}>Na^{+}$, respectively. The order of these cations in impact site of Farm-A, Farm-B and Farm-C was $Ca^{2+}>Si^{4+}>Na^{+}>K^{+}$, $Ca^{2+}>Si^{4+}>Na^{+}>K^{+}$ and $Si^{4+}>Na^{+}>Ca^{2+}>K^{+}$. There was slight increase Ca^{2+} and Na^{+} in impact site of all farms and the concentration of K^{+} was similar in inlet and outlet of three farms. The concentration of total Si^{4+} in impact site increased in Farm-A and Farm-B but decreased in Farm-C. Si^{4+} is known to be higher in concentration in spring water than other fresh water bodies (Davis, 1964). This explains the higher concentration of Si^{4+} in Farm-C as the source of water was spring water.

The concentration of measured anions in reference sites of Farm-A, Farm-B was in the order $NO_3^{-}> PO_4^{3-}>SO_4^{2-}$ and $PO_4^{3-}>SO_4^{2-}>NO_3^{-}$ respectively (Table 2). In reference of Farm-C, NO_3^{-} and SO_4^{2-} were below detection limit. The concentration of anions in impact site was $NO_3^{-}>PO_4^{3-}>SO_4^{2-}$ in all three farms. The concentration of NO_3^{-} increased in impact site of Farm-B and Farm-C but decreased in impact site of Farm-A. The concentration of PO_4^{3-} and SO_4^{2-} were similar in reference and impact site of all farms.

Table 2: Physico-chemical parameters (mean ± SD) at reference (R) and impacted (I) sites at three trout farms

Parameters (mg/L)	Farm-A (R)	Farm-A (I)	Farm-B (R)	Farm-B (I)	Farm-C (R)	Farm-C (I)
Calcium	15	15.4±0.5	23.5±2.1	23.8±1.1	2.4	2.85±0.4
Nitrate	3.3±2.8	1.88±1.0	1.4±0.1	2.58±1.3	ND (<0.2)	1.92±0.7
Phosphate	0.07	0.07	0.05	0.11	0.28	0.3
Total Silica	6±1.4	7.1±3.0	2.5±3.5	8.83±0.7	37	28.42±10.4
Sodium	1.2	1.14	1.3±0.1	1.38	4.3	4.40±0.1
Potassium	1.3	1.3	1.4 ±0.1	1.48	0.85	0.82
Sulfate	ND (<1)	ND (<1)	ND (<1)	ND (<1)	ND (<1)	ND (<1)

There was no significant difference in major ions in inlet and outlet of Farm-A and Farm-C. However, there was significant difference in concentration of Phosphate ($T=10$, $n_1=4$, $n_2=8$, $P=0.004$), Sodium ($T=14$, $n_1=4$, $n_2=8$, $P=0.048$) and Potassium ($T=14$, $n_1=4$, $n_2=8$, $P=0.048$) in inlet and outlet of Farm-B.

Since trout fish requires Na in their diets (Hasan, 2001), we can conclude that input of Na^+ as trout feed have increased the Na^+ concentration in water of Farm-B. When discharged, water containing high concentration of Na^+ from outlets of fish farm is used for agricultural purposes it can have a negative effect on soil structure which affects plant growth. Sodium, a positively charged cation (Na^+), interacts with negatively charged layers of clay particles and increase in its concentration causes impact on soil permeability (Halliwell et al., 2001). Also, it can cause reduction of hydraulic conductivity of soil which can impact water infiltration into soil profile thus reducing the water availability to irrigated crops (Toze, 2006). Difference in concentration of phosphate in outlet of Farm-B may be due to fish excreta (Schendel et al., 2004). According to EPA (2001), the maximum concentration of PO_4^{3-} for surface water is 0.2 mg/L. The levels of phosphate in all of the sampling sites were below 0.2 mg/L indicating least impact of PO_4^{3-} in the fish farms. Similarly, the change in K^+ concentration in outlet could be attributed to uneaten trout feeds. Since, more amount of trout feed was used in Farm-B than Farm-A and Farm-C (Pers. Comm. with trout farm owners), there was significant difference in reference and in impact site of Farm-B but not in Farm-A and Farm-C.

Comparisons of three farms showed significant difference ($P<0.05$) in all major ions except NO_3^-. As mentioned earlier, the difference in Ca^{2+} and Si^{4+} between Farm-B and Farm-C is due to difference in geology. There was difference in Ca^{2+} concentration between Farm-B and Farm-C and trout farm but not between Farm-A & Farm-B and Farm-A & Farm-C. Since, the source of water for Farm-B was both stream and spring, the concentration of Ca^{2+}

was higher in Farm-B than other two farms. There was significant difference in total Si^{4+} concentration of Farm-C with Farm-A and Farm-B; and there was no significant difference between Farm-A and Farm-B since both farms are from same geological region. PO_4^{3-} concentration was significantly different in all the farms. The concentration of PO_4^{3-} was higher in Farm-C than in Farm-A and Farm-B. The source of PO_4^{3-} is mainly from fish excreta and the regular cleaning of raceways and ponds can change the concentration of PO_4^{3-} in trout farms. There was difference in Na^+ concentration among three farms. There was significant difference between Farm-C & Farm-A and Farm-C & Farm-B.

A number of studies have shown that trout farms have a significant impact on EC, PO_4^{3-}, NO_3^-, NO_2, DO and pH concentrations in the water (Mirrasooli et al., 2012; Pulatsu et al., 2004; Boaventura et al., 1997) while some study has shown no impact of trout farm effluents on water quality (Pradhan et al., 2008; Noroozrajabi et al., 2013; Fadaeifard et al., 2012). Overall, the concentration of all the measured major ions were low in concentration and can be considered safe for aquaculture purposes according to EPA (2001). The concentrations of the parameters fall within those prescribed by Environmental Statistics of Nepal (CBS, 2016). Studies by Noroozrajabi et al. (2013) and Pradhan et al. (2008) concluded the impacts depend on production and management of the trout farms. Since, the production of trout of these farms was relatively lower than international farms, the impact due to trout farms on outlet is not of major concern.

The concentration of heavy metals in all the sampling sites were not detected (Table 3). There is natural source of Arsenic in different parts of Terai region of Nepal, due to which there is presence of Arsenite in the ground water of Terai region (Dahal et al., 2008a; 2008b). The anthropogenic source of heavy metals in aquatic bodies are mining, heavy metals processing, agricultural activities, industrial activities, (Duruibe et al., 2007; Alptekin and Yuce, 2016; Chowdhury and Maiti, 2016). The concentration of heavy metals in trout farms depends on the type of feed provided, use of anti-fouling agents as well as the environmental conditions present in the vicinity of the farms (Kempf et al., 2002; Schendel et al., 2004; Salazar and Saldana, 2007; Kalantzi et al., 2013). Apart from these, absence of industrial activities and absence of such elements in the catchments; use of locally prepared fish feeds lacking heavy metals (Pers. Comm. with trout farm owners) may be the possible reasons for the undetectable concentrations of these elements.

Table 3: Heavy metals detection in trout farms (*Not detected)

Heavy Metals	mg/L
Mercury	ND* (<0.001)
Arsenic	ND* (<0.005)
Lead	ND* (<0.01)
Cadmium	ND* (<0.003)
Manganese	ND* (<0.05)

Conclusion and recommendations

The concentrations of the different physico-chemical parameters in the fish farms were varied significantly except those of the NO_3^-. The concentrations of the heavy metals were not detected and the concentrations of all the parameters were below the prescribed limits of Nepal Environment Statistics (CBS, 2016) indicating the absence of the impacts of trout farming

The present study focused mainly on the concentrations of selected physico-chemical parameters, major ions and heavy metals in water. Though concentrations of all the parameters were below the standard given by EPA (2001) and Nepal Environment Statistics (CBS, 2016), it is essential to study microbial community to fully comprehend the water quality of trout farms. Similarly, slight change in water quality can influence the biological assemblages such as macroinvertebrate and other communities (Iliopoulou et al., 2003; Gautam et al., 2014), so it is also necessary to assess the pollution of aquatic body due to trout farming in depth using biological indicators. Future studies should include comparison of water quality parameters in different seasons to determine effects of seasonal variation on water quality due to trout farms effluents.

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