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Physico-Chemical Parameters of the Raceways for the Cultivation of Rainbow Trout, *Oncorhynchus mykiss* (Walbaum), in Kathmandu, Nepal

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ABSTRACT

Altogether 18 physico-chemical parameters (5 physical, 9 chemical, 2 climatic, and 2 geographical) of the running water carried from spring-fed torrential stream and flowing in the raceways of Kathmandu, Nepal situated at an altitude of 1550msl were studied to know their suitability for the cultivation of rainbow trout, Oncorhynchus mykiss (Walbaum). Air temperature, in the vicinity of the raceways, ranged from 11.7-26.9 (20.4±1.6^{o}C). Raceway water, throughout the year, was found to be colourless, odourless, and transparent. Water temperature ranged from 8.6-21.5 (16.0±1.4^{o}C), water velocity 1.5-3.0 (2.3±0.14m sec^{-1}), water discharge 37-84 (54.17±3.91L sec^{-1}), turbidity 3-18 (10.1±1.5NTU), pH 6.5-8.1 (7.4±0.17mg L^{-1}), electrical conductivity 35-200 (107.83±16.05μS cm^{-1}), dissolved oxygen 5.9-10.3 (8.3±0.44mg L^{-1}), free carbon dioxide 1.4-4.9 (3.41±0.33mg L^{-1}), total alkalinity 17-96 (55.58±7.39mg L^{-1}), total hardness 11-88 (47.08±7.03mg L^{-1}), phosphate-P 0.01-0.26 (0.13±0.02mg L^{-1}), ammonium-N 0.09-0.91 (0.27 ±0.06mg L^{-1}), nitrate-N 0.01-0.83 (0.2±0.07mg L^{-1}), relative humidity 63.2-88.7 (75.35±2.39%), and rainfall 0.0-402.6 (116.28±41.36mm) in above mentioned altitude and water resource. All the parameters were positively correlated except pH, electrical conductivity, dissolved oxygen, total alkalinity, and total hardness which were negatively correlated with the rest. There was strongest correlation (P>0.01) in between air temperature, water temperature, turbidity, pH, electrical conductivity, dissolved oxygen, free carbon dioxide, total alkalinity, total hardness, and phosphate. Therefore, all the parameters were fluctuated due to the fluctuation in air temperature, water temperature, turbidity, pH, electrical conductivity, dissolved oxygen, free carbon dioxide, total alkalinity, total hardness, and phosphate, thus affecting each other and rest of the parameters. However, water velocity and water discharge, although higher than requirement, were maintained as per need of the cultivation. All the parameters were within permissible limits hence, suitable for rainbow trout cultivation.

Key words: *Physico-chemical parameters, raceways, cultivation of rainbow trout.*

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INTRODUCTION

Physico-chemical parameters are essential requirement for aquaculture[79]. They refer to all physical, chemical and biological parameters[21] which are highly influenced by climatic factors, geography, seasons, and environment of their origin and occurrence[75]. Fishes depend on physico-chemical parameters like water temperature (WT), turbidity (TBD), power of hydrogen ion concentration(pH), dissolved oxygen (DO), free carbon dioxide (FCO), total alkalinity (TA), total hardness (TH), and nitrate-N (NO_3)[49]. To great extent, physico-chemical parameters of the raceways determine the success or failure of rainbow trout cultivation[67].

Rainbow trout, *Oncorhynchus mykiss*[9], always requires cold, transparent and flowing water with low WT, required water velocity (WV), balanced water discharge (WD), high DO, and moderate FCO. In addition, it requires the water having optimum TBD, pH, electrical conductivity (EC), TA and TH[32]. Besides all these, it also requires suitable nutrients like phosphate (PO_4), ammonium (NH_4) and NO_3[15]. Furthermore, its cultivation is to be supported by some climatic factors like relative humidity (RH) and rainfall (RF) and geographical factors like altitude (ALT) and water resource (WR). Such condition of always flowing water can be met with raceways being supplied with permanent, perennial but dependable WR of spring-fed torrential stream.

Moogouei *et al*.[57] studied physico-chemical parameters of raceways in Iran to see effects on growth of rainbow trout. Pradhan *et al*.[68] conducted a preliminary study on water quality parameters in the raceways of Godawari, Kathmandu, Nepal. However, no detailed study on water quality parameters was done so far for rainbow trout cultivation in the raceways in Nepal. Hence, altogether 18 physico-chemical parameters (5 physical, 9 chemical, 2 climatic and 2 geographical) were investigated for the water quality assessment of the raceways. Physical parameters were air temperature (AT), WT, WV, WD, and TBD; chemical parameters pH, EC, DO, FCO, TA, TH, PO_4, NH_4, and NO_3; climatic parameters RH and RF; and geographical parameters ALT and WR.

The study was aimed to assess suitability of the physico-chemical parameters of the raceways for rainbow trout cultivation; to see fluctuations of these parameters due to climatic factors (RH and RF), geography (ALT and WR), and seasons (monsoon, autumn, winter and summer); to conclude impact of these parameters on one another; to find whether some of these parameters could be managed without impairing the environment of the raceways or not; and to know whether raceways having running water from permanent, perennial and dependable spring-fed torrential stream at a high altitude was suitable flowing water habitat for the rainbow trout cultivation or not.

MATERIALS AND METHODS

Study site and duration of the work

This study was conducted for one year from June 2010 to May 2011 on physico-chemical parameters in the farmer's raceways at Kakani, Kathmandu, Nepal (Figure-1) situated at latitude 27°48' N, longitude 85°15' E and altitude 1550msl. The whole year was represented by four seasons – monsoon (June to August), autumn (September to November), winter (December to February) and summer (March to May).

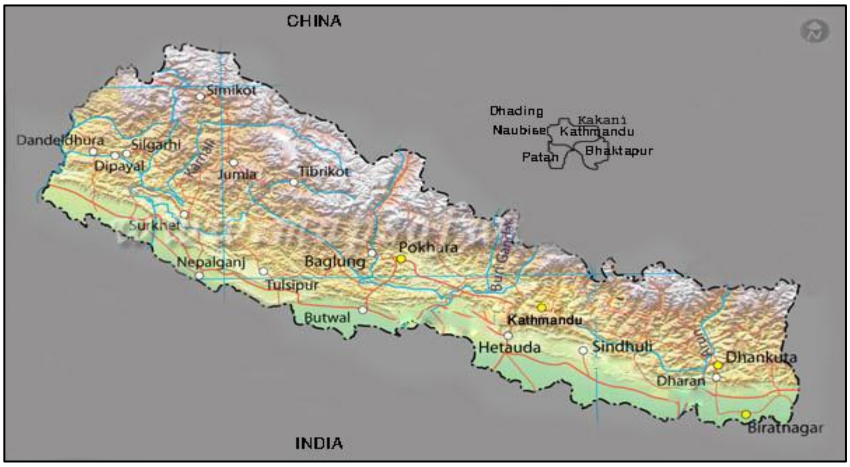

Fig. 1: Kakani, Kathmandu, Nepal

Study Criteria

Two parameters ALT and WR were measured at the beginning of the study. ALT which was measured with the help of altimeter and expressed in metre from sea level (msl) was the average of 5 locations. WR was confirmed through observation. The data for RH and RF which were respectively expressed in percent (%) and millimetre (mm) were taken from the Department of Meteorology, Government of Nepal. Rest 14 parameters were measured at the monthly intervals for 12 months.

On the Spot Measurement of Parameters

AT and WT were measured by using a calibrated Germany made standard mercury-in-glass thermometer, graduated (0-100°C) with an accuracy of 0.1°C, avoiding direct sunlight and expressed in degree Celsius ($^{\circ}$C). For AT, the thermometer was held upright in the air with the help of fingers and with the lower part exposed to the air for about 5min. For WT, the thermometer was immersed in water 6cm below the water surface and left to stabilize for about 5min. The average values of AT and WT were recorded. To measure WV, a distance of 10m at the sampling site in the feeding channel of raceways was taken. A float (an orange-coloured cork) was released at the initial position and the time taken to travel the distance was measured with the help of stopwatch[4]. It was expressed in metre per second (m sec^{-1}). To measure WD, a plastic tank of 100L in the sampling site was taken and kept below the feeding channel of the raceways to fill it up with flowing water and at the same time, the time taken to fill the water was measured with the help of stopwatch. It was expressed in litre per second (L sec^{-1}). TBD was determined by using a Hach-made turbidometer (model 2001A). It was expressed in Nephelo-turbidity unit (NTU). pH and EC were measured by Hanna-make battery operated pocket pH and conductivity meter (211–Microprocessor) and expressed in numerical (1-14) and micro-Siemens per centimetre (µS cm^{-1}) respectively.

On the Spot Water Sampling

Water samples were collected in a 1L sampling bottle. Generally, collections were carried out in between 8:00 a.m. to 9:00 a.m. in the morning. Collections were done at 5 different locations in raceways – at the entry point, at the outlet, and at 3 locations in between these two, so as to get an average. The sampling bottles were immersed below the water surface and filled to capacity, brought out of the water and properly closed. Fixing of DO and FCO were carried out in required capacity bottles which were flushed several times until all air bubbles escaped. For DO, 2ml $MnSO_4$ sol^n and another 2ml KI + NaOH sol^n was added ina1L capacity clean oxygen bottle using a pipette. The bottle was closed and thoroughly shaken to ensure proper mixing. A brown precipitate was formed at the bottom of the bottle after the process. The bottle was then, transported to the laboratory for further analysis. For FCO, few drops of H_2SO4 sol^n were added in a1L capacity clean bottle using a pipette. The bottle was closed and thoroughly shaken to ensure proper mixing. The bottle was then, transported to the laboratory for further analysis. Water samples for TA, TH, PO_4, NH_4 (treated with 1ml H_2SO_4 and 3ml $CHCl_3$ L^{-1}) and NO_3 (treated with 1ml $H_2SO_4L^{-1}$) were collected in acid washed 250ml glass bottles and all samples were preserved in ice-box[80] for further analyses in the laboratory within 24 hours following Standard Methods[8], except NO_3[85].

Laboratory analyses

Samples fixed for DO and FCO were determined following Standard Winkler's method (titration with sodium thiosulphate sol^n to a colour end point) and Nassler's method (titration with NaOH sol^n to a phenolphthalein or methyl orange end point) respectively and expressed in milligram per litre (mg L^{-1}). Samples of water collected for the determination of TA, TH, and PO_4were determined in the laboratory following Standard Methods (APHA)[8] and expressed in milligram per litre (mg L^{-1}). Samples for NH_4 and NO_3 which were also fixed on the spot were determined following Standard Methods (APHA)[8] and expressed in milligram per litre (mg L^{-1}).

Table-1: Physico-chemical parameters of the raceways at Kakani, Kathmandu, Nepal during June 2010 to May 2011

Parameters		June 2010	July 2010	Aug 2010	Sep 2010	Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011	Mar 2011	Apr 2011	May 2011
Physical	AT	26.9	26.5	26.3	25.7	21.8	16.8	12.4	11.7	13.9	18.2	21.1	23.4
	WT	21.5	21.3	21.2	20.7	16.9	13.1	9.1	8.6	10.5	13.8	16.5	18.2
	WV	2.7	2.9	3.0	2.8	2.1	1.8	1.5	2.1	2.2	1.9	2.3	2.5
	WD	60	67	84	66	48	41	37	44	50	43	51	59
	TBD	14	17	18	15	12	4	3	5	6	7	9	11
Chemical	pH	6.7	6.8	6.9	7.1	7.6	7.8	7.8	7.9	7.7	7.5	7.2	7.1
	EC	35	51	72	103	137	166	172	200	149	98	61	50
	DO	7.2	7.3	7.4	7.5	9.3	9.8	10.1	10.3	9.5	9.4	8.1	7.6
	FCO	4.9	4.6	4.4	3.9	3.5	2.9	1.8	1.4	2.3	3.1	3.9	4.2
	TA	17	26	38	53	67	80	82	96	69	65	53	21
	TH	11	20	31	42	58	70	71	88	57	60	42	15
	PO_4	0.018	0.022	0.026	0.020	0.015	0.007	0.004	0.008	0.001	0.009	0.012	0.018
	NH_4	0.041	0.033	0.029	0.021	0.012	0.020	0.010	0.016	0.009	0.030	0.014	0.037
	NO_3	0.023	0.040	0.083	0.038	0.005	0.002	0.001	0.003	0.006	0.004	0.010	0.019
Climatic	RH	71.1	83.9	88.7	84.6	80.7	79.7	73.8	76.5	69.9	65.8	63.2	66.3
	RF	145.4	342.8	402.6	272.8	31.6	0.0	0.0	5.2	50.0	8.3	68.3	68.4

Statistical analyses

Data provided were the average of five. Physico-chemical parameters were first tabulated and then analyzed. Correlations between parameters were calculated following Karl Pearson's Method and the corresponding significance tests were done using SPSS statistical software version 20. The values of these parameters were compared to the standard literatures cited.

RESULTS AND DISCUSSION

AT ranged from 11.7-26.9 with the range of 15.2, amplitude 19.3, median 21.45, standard deviation (SD) 5.67, and mean with standard error (SE) 20.39±1.64°C. Monsoon was hot and winter cold (Table-2). June was hottest month and January coldest (Table-1). Acherjee and Barat[2] reported similar findings. McGregor and Nieuwolt[51] reported 0.65°C decrease in AT per 100m increase in ALT. In the present work, AT varied considerably throughout the year [49] due to high ALT. AT has close relation with WT as it controls WT's physiological behaviour[8,11] and is always higher than WT (Figure-2). Similar results were shown in the present study.

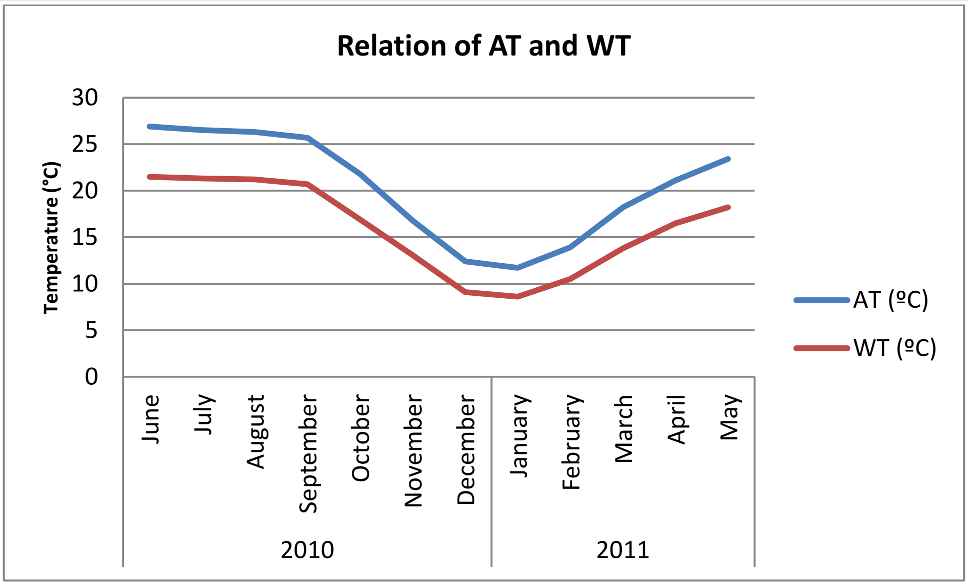

Fig. 2: AT and WT

WT ranged from 8.6-21.5 with the range of 12.9, amplitude 15.05, median 16.7, SD 4.85, and mean with SE 15.95±1.40°C (Table-2) due to WR from spring-fed torrential stream at high ALT of 1550msl. Winter showed cold WT and monsoon hot (Table-2). January exhibited coldest WT and June hottest (Table-1). Acherjee and Barat[2] showed similar results and also investigated 0.6°C decrease in WT per 100m increase in ALT. These results confirmed WT depended on AT[49] and ALT[35] thus, varying considerably throughout the year[49] (Table-1). Suitable WT for rainbow trout culture is 10-18°C[91], hatching temperature 8-14°C and table fish production WT 14-20°C. Hence, WT was suitable for rainbow trout cultivation in the present study. WT has close relation with AT and is always lower than it. Similar results were found in the present study (Figure-2). Rawat *et al.*[73], Wetzel[89] and Ayoade[12] found significant positive correlation of WT with AT and was so in the present study (Table-3).

WV ranged from 1.5-3.0 with the range of 1.5, amplitude 2.25, median 2.25, SD 0.47, and mean with SE 2.32±0.14m sec^{-1}. Monsoon had more velocity and winter less (Table-2). August showed more velocity and December 2010 less (Table-1). Acherjee and Barat[2] obtained 0.61-1.5m sec^{-1} of WV with its lowest value in November and highest in July and having low range in winter and high in monsoon, however, in the present study, it is more with lowest range in December and highest in August and with similar seasonal value like above. This might be due to high ALT in the present work. WV increases due to RF[16] and that high WV during monsoon and low during winter is due to RF[89]. Same trend was seen in this research. Anonymous[10] described that as a rule of thumb, the current should be sufficient to provide at least one complete change of water $hour^{-1}$ and in the present study the velocity, i.e., current was capable to do so.

WD ranged from 37-84 with the range of 47, amplitude 60.5, median 52, SD 13.53, and mean with 54.17±3.91L sec^{-1}. Winter had less discharge and monsoon more (Table-2). December had less discharge and August more (Table-1). WD depends on WV and fluctuates due to RF. It increases due to high WV and RF. In the present study, it was 37-92L sec^{-1}. Bartoli *et al.*[14] reported 190L sec^{-1} of WD in rainbow trout raceways which was quite higher than the present study. The suitable range of WD for 10,000 incubated eggs of rainbow trout is 0.5L sec^{-1}, for 1-2g fingerlings 0.67L sec^{-1} and for 4-5g fingerlings 0.83L sec^{-1}. The same range in the present investigation could be managed as per requirement. Wedemeyer[88] found direct correlation of WD with PO_4, NH_4, and NO_3 and was so in this study (Table-3).

TBD ranged from 3-18 with the range of 15, amplitude 10.5, median 10, SD 5.18, and mean with SE 10.08±1.5NTU. Monsoon exhibited more turbidity than winter (Table-2). December showed clear water and August turbid (Table-1). TBD was less in spring-fed WR due to absence of silt. If water contains abundant silt or clay particles with planktons then it is 20-25NTU[42] and its level of 26NTU is lethal to fish[49]. High WV[42], WD[88] and RF[44] increase turbidity. Higher the TBD lower is the DO and lower the TBD vice-versa[44] (Figure-3). Similar results were obtained in the present study. Higher TBD can cause damage to gills[88];[83]. Hence, TBD of 3-18NTU in the present study seemed to be suitable.

pH ranged from 6.7-7.9 with the range of 1.2, amplitude 7.3, median 7.35, SD 0.43, and mean with SE 7.34±0.12. Winter had more pH and monsoon less (Table-2). January showed more pH and June less (Table-1). pH is affected by WT[71]. Variations in the pH values are due to changes in the values of FCO, carbonate and bicarbonate in water[6,8,37,39,69]. pH below 8.3, converts carbonates into bicarbonates[40]. It increases with increased FCO and is affected by TA, surface runoff (due to RF) and WD[44]. FCO influences pH of water[20]. It is affected by WR[27] and RF[78]. Its suitable range for fish farming is 6.7-8.4[26]; 6.5-9.0[82]; 6.5-8.5[80]; 6.5-9.0[45]; 7.4-8.3[61]; 6.8-8.7[72]; 7.0-8.1[84]; neutral or slightly alkaline[49] and 7.3-8.3[2]. Its maximum value of 8.2 in January and minimum value of 6.6 in June in the present study was different from maximum value of 7.8 in July and minimum value of 6.9 in March of river Buriganga, Bangladesh[33] and that of maximum value of 8.3 in May and minimum value of 7.3 in September[2]. Its maximum value of 8.1 and 8.2 in December and January respectively in the present study coincides with the maximum value of 8.2 and 8.3 in July and August respectively[61]. It is highest in winter, higher in summer and monsoon[39,2] but in the present study, it is highest in winter, higher in summer, high in autumn and low in monsoon (Figure-3). Gupta *et al.*[29] showed positive correlation of pH with EC and TA just like this study (Table-3).

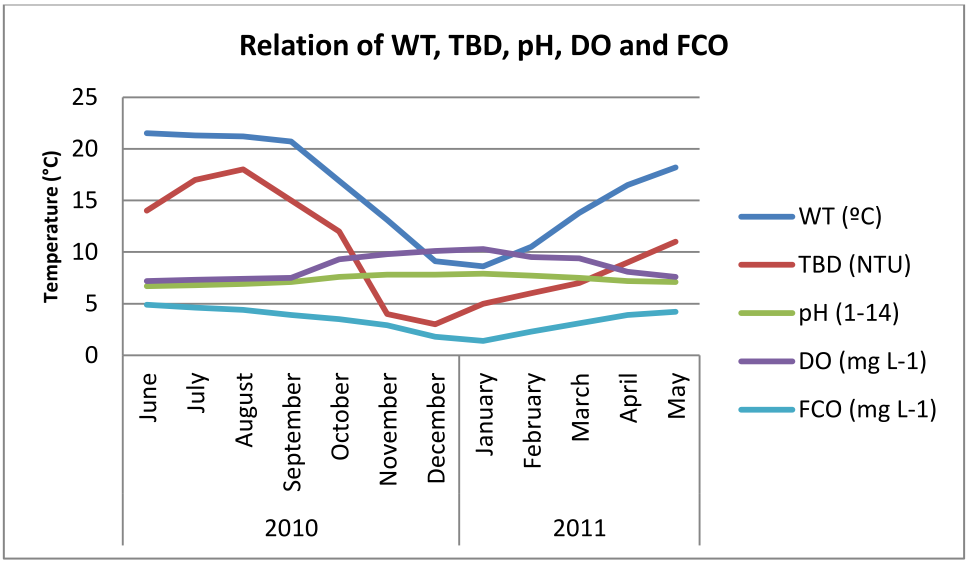

Fig. 3: WT, TBD, pH, DO and FCO

EC ranged from 35-200 with the range of 165, amplitude 117.5, median 100.5, SD 55.61, and mean with SE 107.83±16.05µS cm^{-1}. Winter showed more conductivity and monsoon less (Table-2). January exhibited more conductivity and June less (Table-1). EC is affected by WT as the values increases from 2-3% per $1^{o}C$[44]. Same trend is seen in the present study. Its range of 40-204µS cm^{-1} in the present study is higher than those reported for other studies[62,43,30] and lower (52-99 µS cm^{-1}) than reported by Acherjee and Barat[2]. According to Acherjee and Barat[2], it is lowest in July and highest in May and that it is lowest during monsoon and highest during pre-monsoon, however in the present study, it is lowest in June and highest in January and that it is lowest during monsoon and highest during winter. Lower water volume during winter is the cause of high EC and higher water volume during monsoon due to RF is the cause of low EC[3,54]. Patil *et al*.[64] obtained significant correlation of EC with WT, pH, TA and TH. Mariappan and Vasudevan[50], Mondal[56] and Acherjee and Barat[2] also obtained significant positive correlation of EC with DO, pH, TA and TH (Table-3).

DO ranged from 7.2-10.3 with the range of 3.1, amplitude 8.75, median 8.7, SD 1.21, and mean with SE 8.63±0.35mg L^{-1}. Winter exhibited more oxygen and monsoon less (Table-2). January showed more oxygen and June less (Table-1). DO depend on WT[20,49,71]. High WT decreases DO[42,44,90] and less WT vice-versa[41,58,59]. Suitable DO for rainbow trout culture in raceways is 8mg L^{-1} (Huet[32]). It increases gradually from September reaching maximum in December-January[7,25,33,34,39] and then decreases in July-August[2,7,25,28,33,34,49,86]. Same result is found in the present study – highest in January and lowest in July. High values seen in winter and low in monsoon in the present study exactly resembles to that reported by Acherjee and Barat[2]. Its high value in winter is possibly due to low WT and RF[31,49,55] and low value during monsoon is due to cloudy days and heavy rain[47]. Shastri and Pendse[76] showed significant positive correlation of DO with pH (Figure-3). Rawat *et al.*[73], Agarwal and Thapaliyal[5], Joshi *et al*.[37] and Acherjee and Barat[2] showed significant negative correlation of DO with WT and FCO. Palatsu *et al*.[63] showed significant correlation (P>0.05) of DO with nitrate and total phosphorus in rainbow trout farm (Table-3). Similar correlation was obtained in the present study.

FCO ranged from 1.4-4.9 with the range of 3.5, amplitude 3.15, median 3.7, SD 1.22, and mean with SE 3.41±0.33mg L^{-1}. Winter exhibited less CO_2 than monsoon (Table-2). January had less CO_2 and July more (Table-1). High FCO decreases DO and low FCO vice-versa[44]. It showed seasonal changes being high in summer and monsoon and low during autumn and winter[2,20,33]. Similar result is obtained in the present study. It is double during July than in January[20]. Higher the TBD, lower is the FCO and lower the TBD, vice-versa[44]. According to Acherjee and Barat[2], its lowest value is in January and highest in September but in the present study, it is lowest in January and highest in July. Its lower value in lotic habitats is due to its escape in atmosphere due to rapid flow[60]. Acherjee and Barat[2] showed significant positive correlation of FCO with WT and WV and significant negative correlation of FCO with pH (Figure-3) and TA. Dhanze *et al*.[24] also showed significant negative correlation of FCO with pH and TA. Boyd and Tucker[20] also showed significant negative correlation (P>0.05) of FCO with DO (Table-3).

TA ranged from 17-96 with the range of 79, amplitude 56.5, median 59, SD 25.6, and mean with SE 55.58±7.39mg L^{-1}. Monsoon had less alkalinity and winter more (Table-2). June exhibited less alkalinity and January more (Table-1). TA at the range of 30-400 mg L^{-1} acts as buffer because it prevents large variations in pH[44] and less than 20mg L^{-1} has low buffering and is vulnerable to fluctuations in pH creating stress in fish[19]. Its acceptable range for fish and shrimp production is 30-500mg L^{-1}(1,52) and for fish production is50-100mg L^{-1}(52). Fish mortality occurs at 250-500mg L^{-1}(26). Its suitable range is 80mg L^{-1}(13,18). According to Chakraborty[22] and Mishra *et al*.[53], it is lowest in July and highest in January. According to Acherjee and Barat[2], it is lowest in July and highest in January and that it is high in winter and low in monsoon but in the present study, it is lowest in June and highest in January and that it is high in winter and low in monsoon. Low TA in monsoon is due to dilution[17,76].

TH ranged from 11-88 with the range of 77, amplitude 49.5, median 49.5, SD 24.37, and mean with SE 4708±7.03mg L^{-1}. Winter showed more hardness and monsoon less (Table-2). January had more hardness and June less (Table-1). TH is due to Ca and Mg. Calcareous water is more preferable by rainbow trout in raceways[46]. Fishes spend more energy in water with TH of 200mg L^{-1} but less energy in 30 mg $L^{-1(78)}$. Its suitable range for growing fish in farming system is 100 mg $L^{-1(78)}$. TH >20mg L^{-1} is satisfactory for productivity of water body and helps to protect fish against harmful effects of metal ions and pH fluctuations[19]. It ranges from 110.75-120.91mg $L^{-1(39)}$, 18.4-27.1mg $L^{-1(2)}$. According to Acherjee and Barat[2], its lowest value is in July and highest in January and that it is low in monsoon and high in winter. According to Mishra *et al*.[54], it is low in monsoon and high in winter. In the present study, it is lowest in June and highest in January and that it is low in monsoon and high in winter. Low value of TH in monsoon is due to dilution[66,74]. Acherjee and Barat[2] obtained significant positive correlation with pH, EC, NO_3, Cl^- and TA and significant negative correlation with WT, WV and FCO (Table-3)

PO_4 ranged from 0.001-0.026 with the range of 0.025, amplitude 0.0135, median 0.0135, SD 0.008, and mean with SE 0.013±0.002mg L^{-1}. Monsoon showed more phosphate and winter less (Table-2). August had more phosphate and February less (Table-1). PO_4 dissolves in water[52]. Its maximum value which is harmful to fish is more than 0.7mg $L^{-1(18)}$ however; its suitable range is 0.200-0.308mg $L^{-1(39)}$ and 0.006-0.033mg $L^{-1(2)}$. It is suitable in the present study. According to Acherjee and Barat[2], its lowest value is in January and highest value in September and that it is low in winter and high in monsoon. In the present study, its lowest value is in February and highest value in August and that it is low in winter and high in monsoon. High value of PO_4 in monsoon is due to surface runoff[23]. Venkateshraju, *et al*.[87], Patra *et al*.[65] and Acherjee and Barat[2] had shown significant positive correlation of PO_4 with NO_3 (Table-3).

NH_4 ranged from 0.009-0.041 with the range of 0.032, amplitude 0.025, median 0.0205, SD 0.011, and mean with SE 0.023±0.003mg L^{-1}. Winter showed less ammonium and monsoon more (Table-2). June exhibited more ammonium and February less (Table-1). NH_4 varies due to WT, DO and pH[49] and ranges from 0.25-0.35mg $L^{-1(22)}$ and 0.008-0.028mg $L^{-1(2)}$. It is suitable in the present study. According to Acherjee and Barat[2], its lowest value is in January and February and highest value is in September and that it is low in winter and high in post-monsoon. According to Chakraborty[22], it is 0.035, 0.025 and 0.030mg L^{-1} in pre-monsoon, monsoon and post-monsoon respectively. In the present study, it is lowest in February and highest in June and that it is low in winter and high in monsoon. Jana and Barat[36] and Acherjee and Barat[2] found significant positive correlation of NH_4 with NO_2 and NO_3 and significant negative correlation of NH_4 with DO (Table-3).

NO_3 ranged from 0.001-0.083 with the range of 0.082, amplitude 0.042, median 0.008, SD 0.024, and mean 0.0195±0.007mg L^{-1}. Monsoon had more nitrate and winter less (Table-2). August exhibited more nitrate and December less (Table-1). NO_3 over 5mg L^{-1} indicates pollution and becomes toxic at 30mg L^{-1}. DO decreases slightly as it decreases[44]. Its suitable range is 0.30mg $L^{-1(88)}$ and maximum acceptable limit is 1.36mg $L^{-1(37,45)}$. It is suitable in the present study. According to Acherjee and Barat[2], its lowest value is in January and highest in November and that it is low in winter and high in post-monsoon but in the present study, it is lowest in December and highest in August and that it is low in winter and high in monsoon.

RH ranged from 63.2-88.7 with the range of 25.5, amplitude 75.95, median 75.15, SD 8.29, and mean with SE 75.35±2.39%. Monsoon showed more humidity and summer less (Table-2). August exhibited more humidity and April less (Table-1). RH contains dissolved DO, FCO, NO_3 and PO_4[44]. It is governed by seasons[48,70]. Its range from 62.4-88.7% in the present study is probably due to low AT and high ALT.

RF ranged from 0.0-402.6 with the range of 402.6, amplitude 201.3, median 59.15, SD 143.29, and mean with 116.28±21.36mm. Winter had less rain and monsoon more (Table-2). August showed more rain and December no rain (Table-1). RF range of 0.0-503mm in the present study is due to high ALT. It is also affected due to the geographic location of valley where RF is always more than high mountains and plain terai. It increases TBD[44].

ALT was 1550msl. It was directly affecting AT and WT and indirectly WV and WD. ALT directly affects AT and WT. If ALT is high then AT and WT low and if ALT low then vice-versa.

WR was permanent, perennial and dependable spring-fed torrential stream. It had less turbidity. It was directly supplying the main feeder channel of the raceways. WR affects WT, WV, DO, TBD and WD. Spring-fed torrential stream which is perennial has DO range of 6.8-11.6mg L^{-1}[77].

Investigations of this study indicated that all the physico-chemical parameters of the raceways were within permissible limits suitable for rainbow trout cultivation (Table-1 and Table-2) being dependent on one another as shown during discussions. Correlation analyses of the parameters which were computed in Table-3 showed strong and significant correlation ($P>0.01$) among one another. The parameters were correlated either positively or negatively. Parameters like pH, EC, DO, TA and TH were negatively correlated with rest of the parameters. Among all the parameters, WT was highly correlated with AT, WV, WD, TBD, pH, EC, DO, FCO, TA, TH, PO_4, NH_4, NO_3, and RF, whereas RH was least correlated with TH, NH_4, TA, EC, FCO, and pH (Table-3). The parameters except ALT and WR were fluctuated according to seasons and put their impact on one another. When 0.900 (90%) correlation was taken as standard measurement to show strongest correlation then AT was seen correlated with WT, TBD, pH, DO, FCO and PO_4; WT with AT, TBD, pH, DO, FCO and PO_4; WV with WD and TBD; TBD with AT, WT, WV, WD, and PO_4; pH with AT, WT, EC, DO, FCO, TA, and TH; EC with pH, DO, FCO, TA, and TH; DO with AT, WT, pH, EC, FCO, TA, and TH; FCO with AT, WT, pH, EC, DO, TA, and TH; TA with pH, EC, DO, FCO, and TH; TH with pH, EC, DO, FCO, and TA; PO_4 with AT, WT, and TBD; NH4 with none; NO_3 with WD; RH with none; RF with WD and NO_3. When parameters like AT, WT, WV, WD, TBD, FCO, PO_4, NH_4, NO_3, RH and RF increased then pH, EC, DO, TA and TH decreased but when pH, EC, DO, TA and TH increased vice-versa. Parameters like AT, WT, WV, WD, TBD, FCO, PO_4, NH_4, NO_3, RH and RF were highest during monsoon, higher during summer, low during autumn, and lowest during winter season. Parameters like pH, EC, DO, TA and TH were highest during winter, higher during autumn, low during summer and lowest during monsoon season (Table-1 and Table-2). Parameters were such due to the fluctuation in temperature, velocity and discharge, relative humidity, and rainfall influenced by climatic factors, geography, seasons, and environment of the origin and occurrence of the water resource, thus affecting rest of the parameters. Parameters like WV and WD were managed as per rainbow trout cultivation. Raceways having water from the perennial and dependable WR having spring-fed torrential stream at a high ALT of 1550msl were suitable running water habitats for rainbow trout cultivation.

Table-2: Seasonal and annual data of physico-chemical parameters of the raceways of Kakani, Kathmandu, Nepal with their minimum (Min), maximum (Max), range (Range), amplitude (Amplitude), median (Median), mean (Mean), standard deviation (SD), and standard error (SE) during June 2010 to May 2011

Seasons	Parameters	AT	WT	WV	WD	TBD	pH	EC	DO	FCO	TA	TH	PO_4	NH_4	NO_3	RH	RF
Monsoon (June 2010 to August 2010)	Min	26.3	21.2	2.7	60	14	6.7	35	7.2	4.4	17	11	0.018	0.029	0.023	71.1	145.4
	Max	26.9	21.5	3.0	84	18	6.9	72	7.4	4.9	38	31	0.026	0.041	0.083	88.7	402.6
	Range	0.6	0.3	0.3	24	4	0.2	37	0.2	0.5	21	20	0.008	0.012	0.06	17.6	257.2
	Amplitude	26.6	21.35	2.85	72	16	6.8	53.5	7.3		27.5	21	0.022	0.035	0.053	79.9	274
	Median	26.5	21.3	2.9	67	17	6.8	51	7.3	4.6	26	20	0.022	0.033	0.04	83.9	342.8
	Mean	26.57	21.33	2.87	70.33	16.33	6.8	52.67	7.3	4.63	27	20.67	0.022	0.03	0.049	81.23	296.9
	SD	0.31	0.15	0.15	12.34	2.08	0.1	18.56	0.1	0.25	10.54	10.02	0.004	0.006	0.031	9.10	134.6
	SE	0.18	0.09	0.09	7.13	1.20	0.06	10.71	0.06	0.15	6.08	5.78	0.002	0.004	0.018	5.25	77.71
Autumn (September 2010 to November 2010)	Min	16.8	13.1	1.8	41	4	7.1	103	7.5	2.9	53	42	0.007	0.012	0.002	79.7	0
	Max	25.7	20.7	2.8	66	15	7.8	166	9.8	3.9	80	70	0.020	0.021	0.038	84.6	272.8
	Range	8.9	7.6	1	25	11	0.7	63	2.3	1	27	28	0.013	0.009	0.036	4.9	272.8
	Amplitude	21.25	16.9	2.3	53.5	9.5	7.45	134.5	8.65	3.4	66.5	56	0.014	0.017	0.02	82.15	136.4
	Median	21.8	16.9	2.1	48	12	7.6	137	9.3	3.5	67	58	0.015	0.02	0.005	80.7	31.6
	Mean	21.43	16.9	2.23	51.67	10.33	7.5	135.3	8.87	3.43	66.67	56.67	0.014	0.018	0.015	81.67	101.5
	SD	4.46	3.8	0.51	12.90	5.69	0.36	31.53	1.21	0.50	13.50	14.05	0.007	0.005	0.02	2.59	149.2
	SE	2.58	2.19	0.30	7.45	3.28	0.21	18.21	0.70	0.29	7.80	8.11	0.004	0.003	0.012	1.50	86.15
Winter (December 2010 to February 2011)	Min	11.7	8.6	1.5	37	3	7.7	149	9.5	1.4	69	57	0.001	0.009	0.001	69.9	0
	Max	13.9	10.5	2.2	50	6	7.9	200	10.3	2.3	96	88	0.008	0.016	0.006	76.5	50
	Range	2.2	1.9	0.7	13	3	0.2	51	0.8	0.9	27	31	0.007	0.007	0.005	6.6	50
	Amplitude	12.8	9.55	1.85	43.5	4.5	7.8	174.5	9.9	1.85	82.5	72.5	0.005	0.013	0.004	73.2	25
	Median	12.4	9.1	2.1	44	5	7.8	172	10.1	1.8	82	71	0.004	0.01	0.003	73.8	5.2
	Mean	12.67	9.4	1.93	43.67	4.67	7.8	173.7	9.97	1.83	82.33	72	0.004	0.012	0.003	73.4	18.4
	SD	1.12	0.99	0.38	6.51	1.53	0.1	25.54	0.42	0.45	13.50	15.52	0.004	0.004	0.003	3.32	27.49
	SE	0.65	0.57	0.22	3.76	0.88	0.06	14.75	0.24	0.26	7.80	8.96	0.002	0.002	0.002	1.92	15.87
Summer (March 2011 to May 2011)	Min	18.2	13.8	1.9	43	7	7.1	50	7.6	3.1	21	15	0.009	0.014	0.004	63.2	8.3
	Max	23.4	18.2	2.5	59	11	7.5	98	9.4	4.2	65	60	0.018	0.037	0.019	66.3	68.4
	Range	5.2	4.4	0.6	16	4	0.4	48	1.8	1.1	44	45	0.009	0.023	0.015	3.1	60.1
	Amplitude	20.8	16.0	2.2	51	9	7.3	74	8.5	3.65	43	37.5	0.014	0.026	0.012	64.75	38.35
	Median	21.1	16.5	2.3	51	9	7.2	61	8.1	3.9	53	42	0.012	0.03	0.01	65.8	68.3
	Mean	20.9	16.17	2.23	51	9	7.27	69.67	8.37	3.73	46.33	39	0.013	0.027	0.011	65.1	48.33
	SD	2.61	2.22	0.31	8	2	0.21	25.15	0.93	0.57	22.74	22.65	0.005	0.012	0.008	1.66	34.67
	SE	1.50	1.28	0.18	4.62	1.16	0.12	14.52	0.54	0.33	13.13	13.08	0.003	0.007	0.004	0.96	20.02
Annual (June 2010 to May 2011)	Min	11.7	8.6	1.5	37	3	6.7	35	7.2	1.4	17	11	0.001	0.009	0.001	63.2	0
	Max	26.9	21.5	3.0	84	18	7.9	200	10.3	4.9	96	88	0.026	0.041	0.083	88.7	402.6
	Range	15.2	12.9	1.5	47	15	1.2	165	3.1	3.5	79	77	0.025	0.032	0.082	25.5	402.6
	Amplitude	19.3	15.05	2.25	60.5	10.5	7.3	117.5	8.75	3.15	56.5	49.5	0.014	0.025	0.042	75.95	201.3
	Median	21.45	16.7	2.25	50.5	10	7.35	100.5	8.7	3.7	59	49.5	0.014	0.021	0.008	75.15	59.15
	Mean	20.39	15.95	2.32	54.17	10.08	7.34	107.83	8.63	3.41	55.58	47.08	0.013	0.023	0.02	75.35	116.28
	SD	5.67	4.85	0.47	13.53	5.18	0.43	55.61	1.21	1.13	25.6	24.37	0.008	0.011	0.024	8.29	143.29
	SE	1.64	1.4	0.14	3.91	1.5	0.12	16.05	0.35	0.33	7.59	7.03	0.002	0.003	0.007	2.39	41.36

Table-3: Pearson's correlation coefficient along with significance (two-tailed or one-tailed*) of physico-chemical parameters of the raceways of Kakani, Kathmandu, Nepal during June 2010 to May 2011 (12 months)**

Parameters	AT	WT	WV	WD	TBD	pH	EC	DO	FCO	TA	TH	PO_4	NH_4	NO_3	RH	RF
AT	1															
WT	0.999** 0.000	1														
WV	0.846** 0.001	0.856** 0.000	1													
WD	0.810** 0.001	0.822** 0.001	0.946** 0.000	1												
TBD	0.933** 0.000	0.937** 0.000	0.928** 0.000	0.917** 0.000	1											
pH	-0.930** 0.000	-0.931** 0.000	-0.871** 0.000	-0.820** 0.001	-0.881** 0.000	1										
EC	-0.863** 0.000	-0.853** 0.000	-0.720** 0.008	-0.659* 0.020	-0.741** 0.006	0.936** 0.000	1									
DO	-0.943** 0.000	-0.944** 0.001	-0.899** 0.000	-0.849* 0.018	-0.888** 0.007	0.978** 0.000	0.917** 0.000	1								
FCO	0.973** 0.000	0.969** 0.000	0.784** 0.003	0.739** 0.006	0.856** 0.000	-0.937** 0.000	-0.930** 0.000	-0.937** 0.000	1							
TA	-0.875** 0.000	-0.868** 0.000	-0.774** 0.003	-0.718** 0.009	-0.782** 0.003	0.944** 0.000	0.951** 0.000	0.933** 0.000	-0.924** 0.000	1						
TH	-0.874** 0.000	-0.869** 0.000	-0.777** 0.003	-0.722** 0.008	-0.779** 0.003	0.942** 0.000	0.946** 0.000	0.942** 0.000	-0.923** 0.000	0.996** 0.000	1					
PO_4	0.919** 0.000	0.921** 0.000	0.865** 0.000	0.879** 0.000	0.946** 0.000	-0.850** 0.000	-0.721** 0.008	-0.862** 0.008	0.840** 0.001	-0.754** 0.005	-0.740** 0.006	1				
NH_4	0.691* 0.013	0.684* 0.014	0.586* 0.045	0.529 0.077	0.575 0.051	-0.762* 0.017	-0.756** 0.004	-0.699* 0.009	0.728** 0.007	-0.806* 0.002	0.761** 0.015	0.656* 0.021	1			
NO_3	0.707* 0.010	0.723** 0.008	0.834** 0.001	0.960** 0.000	0.838** 0.001	-0.716* 0.010	-0.531 0.076	-0.728** 0.007	0.623* 0.031	-0.578* 0.049	-0.577* 0.050	0.834** 0.001	0.457 0.136	1		
RH	0.324 0.305	0.348 0.267	0.413 0.182	0.520 0.083	0.506 0.093	-0.162 0.615	0.134 0.679	-0.183 0.569	0.155 0.630	0.003 0.993	0.001 0.997	0.508 0.092	0.003 0.993	0.623* 0.030	1	
RF	0.759** 0.004	0.777** 0.003	0.885** 0.000	0.940** 0.000	0.890** 0.000	-0.774** 0.003	-0.566 0.055	-0.781 0.003	0.665* 0.018	-0.614* 0.034	-0.619* 0.032	0.836** 0.001	0.444 0.149	0.946** 0.000	0.657* 0.020	1

**Correlation is significant at the 0.01 level (2-tailed) *Correlation is significant at the 0.05 level (2-tailed)

CONCLUSION

These parameters were within permissible limits being suitable for rainbow trout cultivation. The parameters showed strong correlation (P>0.01) with one another. All the parameters were positively correlated except pH, EC, DO, TA, and TH which were negatively correlated with the rest. There was strongest correlation (P>0.01) in between AT, WT, TBD, pH, EC, DO, FCO, TA, TH, and PO_4. Therefore, all the parameters were fluctuated due to the fluctuation in AT, WT, TBD, pH, EC, DO, FCO, TA, TH, and PO_4, thus affecting each other and rest of the parameters. Therefore, WT, TBD, pH, DO, and FCO were governing parameters among the rest. WV and WD were managed as per requirement of the rainbow trout culture.

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