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Water Quality Parameters for the Culture of Rainbow Trout, *Oncorhynchus mykiss* (Walbaum) in the Raceways of Kathmandu, Nepal

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Abstract

Eighteen water quality parameters (5 physical, 9 chemical, 2 climatic and 2 geographical) were investigated for the water quality assessment so as to know whether water in the raceways from spring-fed torrential stream at a high altitude was feasible and suitable for the culture of rainbow trout, *Oncorhynchus mykiss* (Walbaum) or not. Results indicated colourless, odourless, and crystal-clear water throughout the year with air temperature ranging from 11.4-26.9 (20.3±1.1^{o}C), water temperature 8.4-21.5 (16±1.1^{o}C), water velocity 1.5-3.5 (2.5±0.11m sec^{-1}), water discharge 37-92 (56±2.87L sec^{-1}), turbidity 3-19 (11± 1.04NTU), pH 6.5-8.2 (7.44±0.11), electrical conductivity 35-204 (112.13±11.2µS cm^{-1}), dissolved oxygen 5.9-10.5 (8.2±0.3mg L^{-1}), free carbon dioxide 1.4-5.1 (3.6±0.2mg L^{-1}), total alkalinity 17-97 (55.1±5.32mg L^{-1}), total hardness 11-90 (47±5.06mg L^{-1}), phosphate-P 0.01-0.50 (0.14±0.02mg L^{-1}), ammonium-N 0.09-0.91 (0.28 ±0.04mg L^{-1}), nitrate-N 0.01-0.83 (0.17±0.04mg L^{-1}), relative humidity 62.4-88.7 (75.01±1.59%), rainfall 0.0-503.4 (132.44±32.83mm), altitude 1550msl, and water resource stream-fed torrential stream. Correlation analyses of the parameters showed strongest correlation at the significance level of 0.01. All parameters were positively correlated except pH, electrical conductivity, dissolved oxygen, total alkalinity, and total hardness which were negatively correlated with rest. Parameters of the first year were slightly higher than second due to 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. Water velocity and water discharge could be maintained as per requirement of the culture. These parameters were within permissible limits being feasible and suitable for rainbow trout culture.

***Key words*:** Rainbow trout culture, raceways, water quality assessment

Introduction

Rainbow trout, *Oncorhynchus mykiss* (Walbaum) requires cold and crystal-clear running water with low water temperature, high dissolved oxygen, moderate free carbon dioxide, proper water velocity and balanced water discharge (Huet, 1975). In addition, it requires optimum pH, electrical conductivity, turbidity, total alkalinity, total hardness, NH_4, NO_3 and PO_4 (Bardach *et al*., 1972). Furthermore, its culture is to be supported by some climatic factors like relative humidity and rainfall and geographical factors like altitude andwater resource. Such condition of ever running water could be met with running water habitat of raceways if supplied with perennial and dependable water resource like spring-fed torrential stream.

Pradhan *et al*. (2007/2008) studied on water quality parameters in the raceways of Godawari, Kathmandu, Nepal. The present study aimed to assess feasibility and suitability of the water quality parameters of the raceways at Kakani, Kathmandu, Nepal for the culture of rainbow trout.

Materials and methods

Study site

The raceways supplied with perennial spring-fed torrential stream lie in Kakani, Nuwakot district, Kathmandu valley, Nepal at a high altitude of 1550msl situated at latitude of 27°48'N and longitude 85°15'E.

The study was conducted from June 2010 to May 2012 at monthly intervals representing four seasons: monsoon (June to August), autumn (September to November), winter (December to February) and summer (March to May).Water velocity was determined by recording time to travel 10 m distance using a float (an orange coloured cork) in the feeding channel of raceways (Adoni *et al*., 1985). Water discharge was determined by measuring time to fill a 100 l plastic tank. Turbidity was determined by turbidometer (model 2001A). pH and electrical conductivity were measured by pocket pH meter and conductivity meter (211–Microprocessor), respectively.

Water samples were collected in between 8:00 a.m. to 9:00 a.m. in the morning. Dissolved oxygen, free carbon dioxide, total alkalinity, total hardness, NH_4, NO_3, and PO_4were determined by as per APHA (2005) and preserved as per Svobodova *et al.* (1993) for further analyses in the laboratory within 24 hours.

Results and discussions

Rainbow trout require water temperature 10-18°C (Yamazaki, 1991), pH 6.5-8.5, and dissolved oxygen above 8 mg l^{-1} (Huet, 1975). Water quality parameters are represented as monsoon (June to August), autumn (September to November), winter (December to February) and summer (March to May) in Table 1. All the parameters were within permissible limits for the culture of rainbow trout.

The range of air temperature and water temperature were 11.4-26.9°C and 8.4-21.5°C respectively. Monsoon was hot and winter was cold in both the years. June was the hottest and January was the coldest month. McGregor and Nieuwolt (1998) reported 0.65°C decrease in air temperature per 100m increase in altitude. Air temperature is related with water temperature and it higher than water temperature (APHA, 2005; Arain *et al*., 2009).

Water temperature was depended on air temperature (Manon and Hossain, 2011) and altitude (Jacobsen, 2008). Acherjee and Barat (2011) reported 0.6°C decrease in water temperature per 100m increase in altitude.

Water velocity and water discharge ranged 1.5-3.5 m sec^{-1} and 37-92 l sec^{-1} respectively, having maximum in monsoon and minimum in winter season. Similar seasonal trend was recorded for turbidity which ranged from 3-19. High water velocity and water discharge during monsoon and low during winter was due to rainfall (Wetzel, 2001). Acherjee and Barat (2011) reported 0.61-1.5m sec^{-1} with its lowest value in November and highest in July. Bartoli *et al*., (2007) reported 190 l sec^{-1} water discharge in rainbow trout raceways and suitable value for 10,000 incubated eggs of rainbow trout was 120 l sec^{-1}.

Table 1. Season-wise, annual and two-year data of water quality parameters of the raceways at Kakani, Kathmandu, Nepal with min, max and mean ± SE.

Parameters	**June 2010 to May 2011**				
	Monsoon (June 2010 to August 2010)	**Autumn (September 2010 to November 2010)**	**Winter (December 2010 to February 2011)**	**Summer (March 2011 to May 2011)**	**Annual (June 2010 to May 2011)**
Air temperature	26.3-26.9 26.57±0. 18	16.8-25.7 21.43± 2.58	11.7-13.9 12.67± 0.65	18.2-23.2 20.9± 1.5	11.7-26.9 20.4± 1.6
Water temperature	21.2-21.5 21.33±0. 09	13.1-20.7 16.9± 2.19	8.6-10.5 9.4±0. 57	13.8-18.8 16.17± 1.28	8.6-21.5 16.0± 1.4
Water velocity	2.7-3.0 2.87±0. 09	1.8-2.8 2.23±0. 30	1.5-2.2 1.93±0. 22	1.9-2.5 2.23±0. 18	1.5-3.0 2.32±0. 14
Water discharge	60-84 70.33± 7.13	41-66 51.67± 7.45	37-50 43.67±3.76	43-59 51± 4.62	37-84 54.17± 3.91
Turbidity	14-18 16.33± 1.20	4-15 10.33± 3.28	3-6 4.67± 0.88	7-11 9± 1.16	3-18 10.08± 1.50
pH	6.5-6.8 6.63±0. 09	7.1-8.0 7.57±0. 26	7.9-8.1 8.0±0. 06	7.0-7.8 7.33±0. 24	6.5-8.1 7.38±0. 17
Electrical conductivity	35-72 52.67±1 0.71	103-166 135.33± 18.21	149-200 173.67± 14.75	50-98 69.67± 14.52	35-200 107.83± 16.05
Dissolved oxygen	5.9-7.2 6.63±0. 38	8.5-9.8 9.2±0. 38	9.5-10.3 9.97±0. 24	6.5-8.4 7.37±0. 54	5.9-10.3 8.29± 0.44
Free carbon dioxide	4.4-4.9 4.63±0. 14	2.9-3.9 3.43±0. 29	1.4-2.3 1.83±0. 26	3.1-4.2 3.73±0. 33	1.4-4.9 3.41± 0.33
Total alkalinity	17-38 27± 6.08	53-80 66.67± 7.80	69-96 82.33± 7.80	21-65 46.33± 13.13	17-96 55.58± 7.39
Total hardness	11-31 20.67± 5.78	42-70 56.67± 8.11	57-88 72± 8.96	15-60 39± 13.08	11-88 47.08± 7.03
Phosphate-P	0.18-0.26 0.22±0.0 2	0.07-0.20 0.14±0.0 4	0.01-0.08 0.04±0.0 2	0.09-0.18 0.13±0.0 3	0.01-0.26 0.13±0.0 2
Ammonium-N	0.29-0.91 0.51±0. 20	0.12-0.21 0.18±0.0 3	0.09-0.16 0.12±0.0 2	0.14-0.37 0.27±0. 07	0.09-0.91 0.27±0. 06
Nitrate-N	0.23-0.83 0.49±0. 18	0.02-0.38 0.15±0. 12	0.01-0.06 0.03±0.0 1	0.04-0.19 0.11±0.0 4	0.01-0.83 0.20±0. 07
Relative humidity	71.1-88.7 81.23±9 5.25	79.7-84.6 81.67± 1.50	69.9-76.5 73.4± 1.92	63.2-66.3 65.1± 0.96	63.2-88.7 75.35± 2.39
Rainfall	145.4-402.6 296.93± 77.71	0.0-272.8 101.47± 86.15	0.0-50.0 18.4± 15.87	8.3-68.4 48.33± 20.02	0.0-402.6 116.28± 41.36

June 2011 to May 2012					Remarks
Monsoon (June 2011 to August 2011)	**Autumn (September 2011 to November 2011)**	**Winter (December 2011 to February 2012)**	**Summer (March 2012 to May 2012)**	**Annual (June 2011 to May 2012)**	**Two years (June 2010 to May 2012)**
25.7-26.1 25.9±0. 12	19.4-24.8 21.83± 1.58	11.4-13.2 12.57±0. 84	17.1-23.4 20.47± 1.83	11.4-26.1 20.18± 1.55	11.4-26.9 20.3± 1.1
21.1-21.3 21.2±0. 06	12.2-20.1 17.33± 2.57	8.4-9.9 9.03±0. 45	13.4-18.2 16.13± 1.42	8.4-21.3 16.05± 1.47	8.4-21.5 16± 1.1
3.2-3.5 3.33±0. 09	1.8-3.0 2.37±0. 35	1.6-2.5 2.17±0.2 9	2.0-2.8 2.43±0. 23	1.6-3.5 2.61±0. 18	1.5-3.5 2.5±0. 11
69-92 77.67± 7.22	42-62 50.67± 5.93	39-53 47.67±4.3 7	45-59 53± 4.16	39-92 57.42± 4.32	37-92 56± 2.87
15-19 17.33± 1.20	5-16 11.33± 3.28	4-7 5.67± 0.88	9-11 10± 0.6	4-19 11.17± 1.48	3-19 11±1 .04
6.7-7.2 6.9±0. 15	7.4-7.9 7.6±0. 15	8.0-8.2 8.1±0. 06	7.2-7.6 7.4±0. 1	6.7-8.2 7.5±0. 14	6.5-8.2 7.44±0. 11
40-80 62± 11.72	121-172 147.67± 14.77	157-204 181.33± 13.59	52-109 74.67± 17.46	40-204 116.42±1 6.23	35-204 112.13± 11.2
6.1-7.1 6.5±0. 31	8.2-9.5 8.87±0. 38	9.0-10.5 9.83±0. 44	6.6-8.0 7.2±0.4 2	6.1-10.5 8.1±0 .43	5.9-10.5 8.2± 0.3
3.8-5.1 4.57-0.39	2.9-3.5 3.2±0. 17	2.5-3.7 2.97±0. 37	4.2-4.5 4.37±0. 09	2.5-5.1 3.78±0. 24	1.4-5.1 3.6±0. 2
20-41 29.67± 6.12	55-82 69± 7.81	75-97 87.67± 6.57	22-44 32± 6.43	20-97 54.58± 7.98	17-97 55.1± 5.32
13-34 23± 6.08	45-75 60± 8.66	65-90 78± 7.23	16-37 26.33-6.07	13-90 46.83± 7.59	11-90 47± 5.06
0.19-0.50 0.32±0. 09	0.04-0.21 0.11±0. 05	0.01-0.09 0.04±0.0 2	0.07-0.14 0.11±0.0 2	0.01-0.50 0.15±0.0 4	0.01-0.50 0.14±0. 02
0.23-0.80 0.47±0. 17	0.21-0.27 0.24±0.0 2	0.16-0.22 0.18±0.0 2	0.21-0.37 0.28±0. 05	0.16-0.80 0.29±0. 05	0.09-0.91 0.28±0. 04
0.21-0.45 0.32±0. 07	0.03-0.24 0.12±0. 06	0.02-0.10 0.06±0.0 2	0.04-0.18 0.11±0.0 4	0.02-0.45 0.15±0. 04	0.01-0.83 0.17±0. 04
77.8-85.4 82.53± 2.38	74.0-84.8 78.17± 3.35	68.2-75.1 71.93± 2.01	62.4-66.3 64.4±1. 13	62.4-85.4 74.68± 2.20	62.4-88.7 75.01±1.5 9
256.0-503.4 404.67± 75.66	6.8-294.1 108.63±92 .89	0.0-42.2 23.03± 12.34	19.4-86.4 50.07± 20.02	0.0-503.4 148.6± 52.43	0.0-503.4 132.44± 32.83

Table 2. Pearson correlation coefficient along with significance (two-tailed) of physico-chemical parameters of the raceways at Kakani, Kathmandu, Nepal

Parameters	AT	WT	WV	WD	TBD	pH
Air temperature	1					
Water temperature	0.999** 0.000	1				
Water velocity	0.777** 0.000	0.799** 0.000	1			
Water discharge	0.772** 0.000	0.787** 0.000	0.925** 0.000	1		
Turbidity	0.921** 0.000	0.928** 0.000	0.886** 0.000	0.890** 0.000	1	
pH	-0.931** 0.000	-0.933** 0.000	-757** 0.000	-0.736** 0.000	-0.854** 0.000	1
Electrical conductivity	-0.850** 0.000	-0.850** 0.000	-678** 0.000	-0.638** 0.001	-0.711** 0.000	0.910** 0.000
Dissolved oxygen	-0.845** 0.000	-0.848** 0.000	-741** 0.000	-0.678** 0.000	-0.746** 0.000	0.915** 0.000
Free carbon dioxide	0.827** 0.000	0.829** 0.000	0.701** 0.000	0.637** 0.001	0.750** 0.000	-0.864** 0.000
Total alkalinity	-0.848** 0.000	-0.852** 0.000	-0.718* 0.000	-0.658** 0.000	-0.739** 0.000	0.912** 0.000
Total hardness	-0.853** 0.000	-0.858** 0.000	-0.715** 0.001	-0.659** 0.001	-0.744** 0.003	0.917** 0.000
Phosphate-P	0.771** 0.000	0.782** 0.000	0.818** 0.000	0.903** 0.000	0.853** 0.000	-0.667* 0.010
Ammonium-N	0.557** 0.005	0.555** 0.005	0.489* 0.015	0.378 0.069	0.480* 0.018	-0.661** 0.000
Nitrate-N	0.704** 0.000	0.708** 0.000	0.721** 0.000	0.884** 0.000	0.797** 0.000	-0.689** 0.000
Relative humidity	0.425* 0.038	0.433* 0.035	0.439* 0.320	0.558** 0.005	0.563** 0.004	-0.303 0.149
Rainfall	0.758** 0.000	0.773** 0.000	0.862** 0.000	0.932** 0.000	0.886** 0.000	-0.711** 0.004

EC	DO	FCO	TA	TH	PO_4	NH_4	NO_3	RH	RF
1									
0.975** 0.000	1								
-0.885** 0.000	-0.915** 0.000	1							
0.968** 0.000	0.970** 0.000	-0.904** 0.000	1						
0.966** 0.001	0.965** 0.000	-0.901** 0.000	0.997** 0.000	1					
-0.585** 0.003	-0.616** 0.001	0.535** 0.007	-0.585** 0.003	-0.579** 0.003	1				
-0.589** 0.002	-0.688** 0.000	0.660** 0.001	-0.632** 0.001	0.612** 0.000	0.358 0.086	1			
-0.535** 0.007	-0.539** 0.007	0.539** 0.007	-0.536** 0.015	-0.540** 0.006	0.741** 0.000	0.283 0.179	1		
0.16 0.630	0.018 0.934	0.085 0.692	-0.037 0.864	-0.046 0.830	0.583** 0.003	0.108 0.616	0.630** 0.001	1	
-560** 0.004	-610** 0.002	0.580** 0.003	-0.580** 0.003	-0.585** 0.003	0.891** 0.000	0.418* 0.042	0.847** 0.000	0.700** 0.000	1

Winter had maximum pH, electrical conductivity and dissolved oxygen than monsoon season that ranged 6.5-8.2, 35-204 µS cm $^{-1}$ and 5.9-10.5 mg l^{-1} respectively. However, free carbon dioxide, PO_4, NH_4, and NO_3 was maximum during summer and minimum during winter that ranged 1.4-5.1 mg l^{-1}, 0.01-0.50 mg l^{-1}, 0.09-0.91 mg l^{-1}, and 0.01-0.83 mg l^{-1} respectively. pH was affected by water temperature. Variations in the pH values were due to changes in the values of free carbon dioxide, carbonate and bicarbonate in water (APHA, 2005). Dissolved oxygen was depended on water temperature (Boyd and Tucker, 1998; Manon and Hossain, 2011). High water temperature decreased dissolved oxygen and vice-versa (Lawson, 2011, Kataria et al., 1996). According to Huet (1975) suitable dissolved oxygen for rainbow trout culture in raceways was above 8 mg l^{-1}. High free carbon dioxide decreased dissolve oxygen and vice-versa (Lawson, 2011). It showed seasonal changes being high in summer and monsoon and low during autumn and winter (Boyd and Tucker, 1998). Total alkalinity and total hardness was maximum during winter and minimum during summer that ranged 17-97 mg l^{-1} and 11-90 mg l^{-1}respectively.

NH_4 varied due to water temperature, dissolved oxygen and pH (Mannon and Hossain, 2011) and ranged from 0.25-0.35mg l^{-1} (Chakraborty, 1998) and 0.008-0.028mg l^{-1} (Acherjee and Barat, 2011). NO_3 over 5mg l^{-1} indicated pollution and became toxic at 30 mg l^{-1} (Lawson, 2011). Suitable range of PO_4 was 0.200-0.308mg l^{-1} (Kalwale and Savale, 2012), however, more than 0.7mg l^{-1} PO_4 was harmful to fish (Boaventura *et al*., 1997).

Range of relative humidity (62.4-88.7) and rainfall (0.0-503.4 mm) was maximum in monsoon and minimum in winter season. Correlation coefficient (r) analyses of all the parameters are computed in Table 2. Parameters of the first year were slightly higher than second due to 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. Water velocity and water discharge were maintained as per requirement of the culture.

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