ABSTRACT

Nepal has an abundant source of water and the number of farmers involved in fish farming is gradually increasing in recent years especially in the Terai region. In Nepal, fish are cultured in earthen ponds, concrete ponds and plastic ponds in intensive or semi-intensive way. Assessment of diurnal fluctuation of water quality parameters was carried out in selected 18 ponds from the tole Baidauli, Siyari Municipality of Rupandehi district, Nepal in the year 2021. The treatment consisted of pond type as between-subject factor with Six earthen nursery ponds, Six earthen production ponds and Six plastic production pond ponds. Data were taken by using Aquaread, a multi-parameter water quality testing meter, at dawn (6 AM), noon (12 PM), dusk (6 PM) and at night (2 AM), with Time as within-subject factor. Ten repeated observations were taken on Cloudy and Sunny days during three summer months viz. March, April and May. Field determination of physical (temperature and total dissolved solid) and chemical (pH, Dissolved Oxygen, Salinity, Electrical Conductivity and Oxygen Reduction Potential) properties of water of the ponds was carried out. Mean values and range were computed and data was represented graphically. Variation in each parameter at different sampling hours in three types of ponds were compared by Repeated Measures Analysis of Variance (ANOVA) using R-studio which showed that the values of water quality parameters varied with Time and Day of observation, but not with the pond type. Pairwise comparison for each significant factor explained that the parameters vary significantly between daytime and morning/nighttime. Results of T-test showed that values differ between Cloudy and Sunny days. There was a linear correlation among Temperature, pH, Dissolved Oxygen and Oxygen Reduction Potential with greater diurnal fluctuation for all ponds. Earthen Nursery Ponds had statistically higher values of Total Dissolved Solid, Electrical Conductivity and Salinity and these parameters were highly correlated. Lower Mean Absolute Percent Error for best fitted linear regression model depicted good predictability of pH, Electrical Conductivity, Dissolved Oxygen and Oxygen Reduction Potential for different time of a day. This research observed the fluctuation of water quality parameters affecting fish survival at certain time interval thus opening up the scope for improvement in water quality at local management conditions.

1. INTRODUCTION

Aquaculture has been growing as a potential source of income among farmers of Southern Nepal (FAO, 2021). Promotion of fish culture helps in attaining better nutrition, employment opportunities and global food security thus contributing towards poverty alleviation. In Nepal, fish are cultured in earthen ponds, concrete ponds and plastic ponds in intensive or semi-intensive way (Budhathoki & Sapkota, 2018). Compared to other agriculture practices, Nepalese aquaculture system faces fewer economic and environmental problems, which specially include sedimentation and water quality deterioration (FAO, 2021). Major problem of fish farming, as cited by farmers and local leaders, was found to be the sudden death of fish in large numbers due to lack of oxygen and other imbalance in water quality of the ponds. The problem is more severe during cloudy days of summer months when the temperature is high and sunlight is blocked by clouds thus reducing photosynthesis by phyto-planktons.

Density, diversity, abundance, composition and distribution of fresh water organisms is greatly affected by the water quality variables and its consequent fluctuation with time and season. Alteration of physical and chemical properties of water beyond the tolerance limit creates stress, affects the health and reduces survival rate of fishes thus decreasing production, profit and product quality. Poor pond management leads to poor water quality and causes an adverse effect on the productivity of fish. The dynamics of water quality parameters at local management system in Rupandehi district of Nepal has not been studied and analyzed.

Environmental requirements of the fish, range of water quality variables in different situation and their tolerable limits have to be well known to exploit the productivity and profitability of aquaculture enterprise. Monitoring the physicochemical parameters of pond water at regular interval can help in obtaining optimum fish growth and higher economic benefit. Instead of taking constant values, diurnal fluctuations in a certain time period of the year, acclimation with atmospheric conditions and synergism among species and their stocking rates have to be taken into consideration. Assessment of diurnal fluctuation of water quality parameters can provide valuable information to farmers regarding the cause of physiological stress and health problems in their fish. It will encourage farmers to become cautious about their pond water quality and adopt the practice of providing a stress-free environment to meet the physical, chemical and biological needs of fish for their normal health and growth performance.

2. METHODOLOGY

Rupendehi district has lower tropical, upper tropical and sub-tropical climatic zone ranging at an elevation from below 300 to 2000 m above sea level. The hot and dry spring season occurs during March-May while the rainy season is between June to August. It receives a mean annual rainfall of 1174 mm and the mean monthly temperature is generally high (maximum 43.4ºC, minimum 18.2ºC).

Samples were determined based on the type of fishing ponds used in the fish farming area. 18 ponds containing water from the same source with uniform area and water depth were used in the study which included 6 ponds having plastic at the base and dike area, used for production of saleable fish (Plastic Production Pond/PPP) while the others were 6 earthen ponds used for fish production (Earthen Production Pond/EPP) and 6 ponds for stocking small fingerlings (Earthen Nursery Ponds). Variables were measured at a depth of 15 cm (epilimnion) at the same relative location (opposite side of the water inlet region) in each pond by grab sampling method. Special attention was given that sampling would not be taken when it is raining, but only after 72 hours of rain when it has returned to normal conditions.

The area under water surface of the sampled ponds was 5±0.5 Kattha. Before stocking, ponds were drained and limed with CaO at a rate of 5 kg per 100 sq.m area. Production ponds housed uniform sized fish of 7 species (Silver carp, Bighead carp, Common carp, Rohu, Naini and Mrigal) used as carp polyculture in the area at the stocking rate of 300 per kattha while nursery ponds were stocked with 500 fingerlings per kattha area. Fish were fed at constant daily feeding rate of 5% of their body weight to simulate the farmers general feeding practice. Rice bran and mustard oil cake, being the major ingredient of home-made feed in Nepal (Giri, 2017), were mixed in equal ratio to make balls and were sun-dried. Fertilizer and cow-dung were applied, according to farmers practice, at uniform rate in all ponds during the weekend between two water quality sampling days. Water depth was regularly monitored and maintained constant (1.5m) to avoid the fluctuations due to the effect of water levels and subsequent light penetration to the pond bottom.

3. TREATMENT DETAILS

Between Subject Factor: Pond Type [Earthen Nursery Pond – 6 ENP, Earthen Production Pond – 6 EPP, Plastic Production Pond – 6 PPP]

Within Subject Factor: Time of Day [T1- Dawn (6 AM), T2 – Noon (12 Noon), T3 – Dusk (6 PM), T4 – Night (2 AM)]

Repeated Observations: Day of Observation [5 cloudy days and 5 sunny days in March, April and May]

Weather information was obtained from Power NASA to define the date of observation as "Cloudy" and "Sunny" Days. The days with fair weather and normal summer temperature was assigned as sunny days while those with cloudy weather were taken as cloudy days.

Table 1: Weather Information on days of water quality observation at Siyari Nepal, 2021

Sunny days	16-Mar (S1M1)	31-Mar (S2M1)	6-Apr (S3M2)	16-May (S4M3)	23-May (S5M3)
Day	Mainly fair (30-32 ºC)	Mainly fair (36-38ºC)	Mainly fair (33-35ºC)	Mainly fair (38-40ºC)	Mainly fair (31-33ºC)
Night	Mainly fair (14-16ºC)	Mainly fair (35-37ºC)	Mainly fair (16-18ºC)	Partly Cloudy (23-25ºC)	Mainly fair (24-26ºC)
Cloudy days	23-Mar (C1M1)	21-Apr (C2M2)	30-Apr (C3M2)	5-May (C4M3)	11-May (C5M3)
Day	Partly Cloudy (35-37ºC)	Generally Cloudy (38-40ºC)	Partly Cloudy (36-38ºC)	Generally cloudy (31-33ºC)	Generally cloudy (32-34ºC)
Night	Partly Cloudy (16-18ºC)	Generally Cloudy (18-20ºC)	Partly Cloudy (25-27ºC)	Generally cloudy (23-25ºC)	Partly Cloudy (23-25ºC)

Note: C – Cloudy Day, S – Sunny Day, M1 – March, M2 – April, M3 - May

4. DATA AND DATA ANALYSIS

Aquaread, a digital, portable and multi-parameter testing equipment, was used as the water quality meter for data collection. Field determination of physical (Temperature and Total Dissolved Solid) and chemical (pH, Dissolved Oxygen, Salinity, Electrical Conductivity and Oxygen Reduction Potential) properties of water of the ponds was carried out.

Variation in each parameter at different sampling hours in 3 types of ponds were compared by using Repeated Measures Analysis of Variance (ANOVA) followed by post-hoc mean comparison using Tukey. Mean values were computed and compared with the acceptable range of values suggested by Water Quality Standards Handbook (EPA, 1994) and Nepal Water Quality Guidelines for Aquaculture (CBS, 2019).

Variables under test had values which were not normally distributed, as indicated by Shapiro Wilk test (P-value<0.001) and had outliers (Figure 1). Oberfeld & Franke (2013) have recommended to conduct larger number of trials per subject in such case so that the sample mean can be considered normally distributed, according to central limit theorem. Similarly, Schielzeth et al., (2020) have explained the robustness of Linear Mixed Effects Model for a quite severe violation of assumptions of normality thus providing confidence in analysis of complex datasets with repeated observations. The data was analyzed using the function lmer from Lme4 package for unstructured residual variance covariance matrix, as recommended by Ozenne (2018) and explained by Kuznetsova, Brockhoff, & Christensen (2017); then following the procedures given in the web by RExRepos ("Mixed-Effects Models for Repeated-Measures ANOVA," n.d.).

In analysis for each variable, the significance for main effect was further interpreted by simultaneous test for general hypothesis using multiple comparison of means: Tukey contrasts and adjusted by Bonferroni method using 'glht' function in R. Significant interaction among factors, Time and Pond, was analyzed by making the pairwise comparison by Tukey but the test on interaction on Day and Pond/Time was a quite difficult task. Hence, the observation under Day, were further classified as "Cloudy" and "Sunny" Day to perform paired t-test in interaction with Pond and Time consecutively.

Pearson correlation coefficient for each pair was determined using excel, and variables showing strong and significant correlation were subjected to linear regression to obtain an equation for each day. Values of dependent variables for other observations were predicted, based on the equations with higher coefficient of determination, to obtain Mean Absolute Percentage Error as also conducted by Xu & Boyd (2016).

$$MAPE = \frac{100}{n}\sum_{t=1}^{n}\frac{(A-P)}{A}$$

Where,

MAPE = Mean Absolute Percentage Error, n = Number of observations, A = Actual Value, P = Predicted Value

5. RESULTS AND DISCUSSION

5.1 Range of values

The mean values of Temperature, pH, Dissolved Oxygen, Total Dissolved Solid, Electrical Conductivity, Salinity and Oxygen Reduction Potential obtained from all observations were 21.88ºC, 8.035, 7.365 mg/l, 291.5 mg/l, 447 mV, 0.13 PSV and 42.13mV respectively. Temperature reached above the acceptable range in summer season during the daytime (12 Noon and 6:00 PM) in all types of ponds. Highest temperature was found to be 34.83ºC at 6:00 PM in Earthen Nursery Pond, 34.95ºC at 12 noon in Earthen Production Pond and 36.68ºC at 12 Noon in Plastic Production Pond.

Dissolved Oxygen was critically low during the dawn (6:00 AM), with minimum values of 1.58 mg/l, 2.09 mg/l and 3.65 mg/l, and at night (2:00 AM), with minimum values of 2.32 mg/l, 2.55 mg/l and 3.22 mg/l, in Earthen Nursery Pond, Earthen Production Pond and Plastic Production Pond respectively. Following high temperature during the day, the Dissolved Oxygen peaked up to 15.1 mg/l, being highly saturated. Values of parameters, pH, Total Dissolved Solid, Electrical Conductivity and Oxygen Reduction Potential remained within the acceptable range throughout the research period. On an assessment of water quality in integrated livestock fish ponds during a 3 years Animal-Fish Project conducted in Philippines (Hopkin, Inocencio, & Cruz, 2009), the maximum morning pH values were found to be around 8.5 to 9 and the temperature ranged from 24 to 30ºC. Early morning pH did not drop below neutral in any of the ponds and the overall pH values revealed the alkalinity of ponds which is due to sufficient liming practice adopted by farmers. A marginal variation in temperature, pH and dissolved oxygen could be observed at monthly intervals from November to April with pH values ranging from 5.63-8.5 and Dissolved Oxygen between 6.5-8.5 mg/l (Mishra, Rath, & Thatoi, 2008). The pH values were inconsistent with the data obtained in Bangladesh by Khanom et al. (2014) where pH ranged from 6.88 to 7.4 and Electrical Conductivity ranged from 653.3 to 7933.3 µs/L during the winter season, which might be due to seasonal fluctuation.

Maximum Salinity was higher than the normal range for freshwater ponds (0.0 – 0.1) and Oxygen Reduction Potential attained a positive value. Salinity as low as 0.3%, observed in the present findings are not detrimental to fish (Peterson & Meador, 1994). ORP attained a positive value range similar to a saline recirculating aquaculture system (190-240mV) in China (Ye et al., 2017) in contrast to negative values (-10 to -77 mV) observed in 8 ponds having pH value of range 6.41 to 8.7, which were assessed for drinking water and irrigation quality standards at Varanasi city, India in 2012-13 (Mishra et al., 2008). The positive values indicate that the pond water was in oxidizing state.

Table 2: Range of water quality parameters observed in sampled earthen nursery ponds at Siyari Nepal, 2021

Earthen Nursery Pond	Unit	6:00 AM	12 Noon	6:00 PM	2:00 AM
Temperature	⁰C	22.45 - 30.83	24.05 - **34.18**	23.95 - **34.83**	22.53 - 30.21
Dissolved Oxygen	mg/l	**1.58** - 7.88	**4.88 - 14.76**	6.72 - **15.1**	**2.32** - 8.51
pH		7.21 - 8.67	7.68 - 9.64	7.74 - 9.21	7.12 - 8.63
Total Dissolved Solid	mg/l	205 - 397	202 - 392	193 - 386	198 - 389
Electric Conductivity	µs/s	316 - 618	311 - 605	295 - 597	302 - 600
Salinity	PSV	0.1 - **0.25**	0.1 - **0.25**	0.09 - **0.25**	0.09 - **0.3**
Oxygen Reduction Potential	mV	9.6 - 184.1	21.7 - 143	19.1 - 157.1	24.5 - 149.6
Earthen Production Pond	**Unit**	**6:00 AM**	**12 Noon**	**6:00 PM**	**2:00 AM**
Temperature	⁰C	21.88 - 30.72	23.15 - **34.95**	23.9 - **34.02**	22.46 - 30.24
Dissolved Oxygen	mg/l	**2.09** - 7.67	6.04 - **14.87**	7.16 - **13.89**	**2.55** - 9.21
pH		7.24 - 9.13	7.47 - 9.18	7.56 - 9.1	7.19 - 8.69
Total Dissolved Solid	mg/l	226 - 553	221 - 551	212 - 541	216 - 555
Electric Conductivity	µs/s	295 - 853	289 - 848	282 - 836	281 - 846
Salinity	PSV	0.11 - **0.36**	0.1 - **0.35**	0.1 - **0.35**	0.1 - **0.36**
Oxygen Reduction Potential	mV	18.8 - 131	14.8 - 123.7	15.2 - 130.3	33.2 - 94
Plastic Production Pond	**Unit**	**6:00 AM**	**12 Noon**	**6:00 PM**	**2:00 AM**
Temperature	⁰C	22.65 - 30.3	24.98 - **36.68**	24.08 - **34.46**	22.56 - 30.13
Dissolved Oxygen	mg/l	**3.65** - 7.59	5.64 - **13.57**	5.67 - **13.26**	**3.24** - 8.75
pH		7.37 - 9.08	7.64 - 9.35	7.59 - 8.94	7.04 - 8.96
Total Dissolved Solid	mg/l	203 - 398	200 - 405	196 - 403	200 - 402
Electric Conductivity	µs/s	312 - 613	308 - 624	308 - 620	310 - 622
Salinity	PSV	0.1 - **0.26**	0.1 - **0.26**	0.1 - **0.26**	0.1 - **0.26**
Oxygen Reduction Potential	mV	29.1 - 129.6	24.9 - 174	32.7 - 119.1	29.8 - 118.7

Note: Bold values represent values beyond acceptable range

Temperature, Dissolved Oxygen and pH showed a typical inverted U-shaped curve from 6:00 AM at dawn to 2:00 AM at night, however the pattern of fluctuation of Oxygen Reduction Potential was not distinguishable. Total Dissolved Solid, Electrical Conductivity and Salinity showed lesser fluctuation with Time of Day (Figure 1).

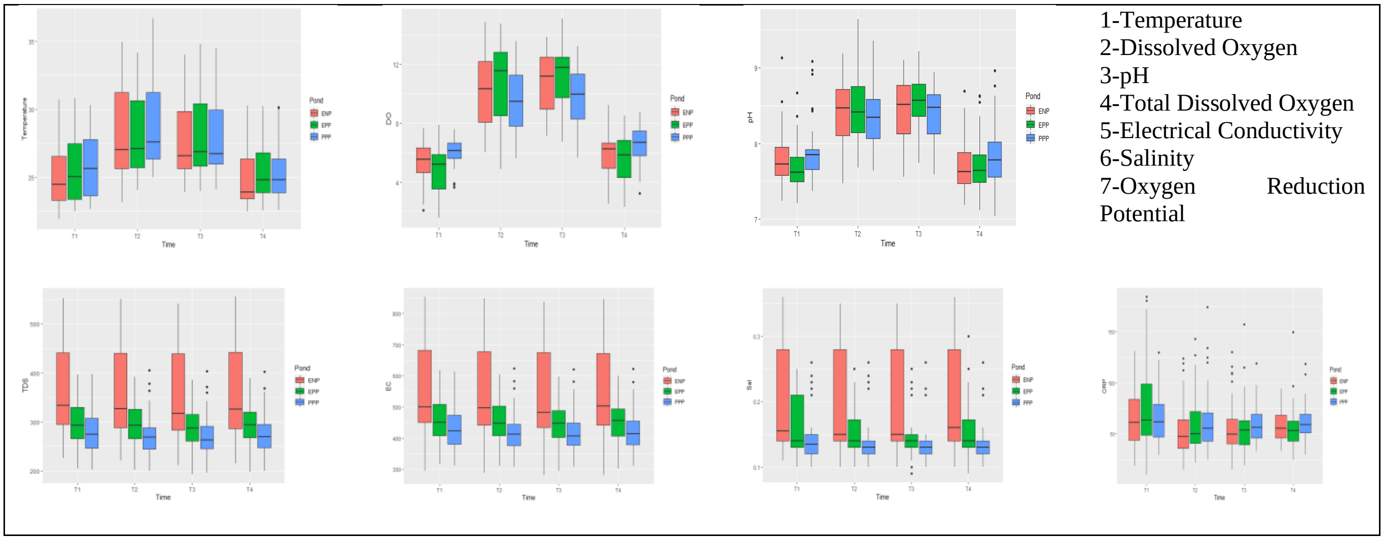

Figure 1: Boxplot for water quality parameters vs. time of day for sampled ponds at Siyari Nepal, 2021

5.2 Analysis of variance

All the observed water quality parameters were significantly influenced by Time of observation and Day of observation (except TDS) but type of Pond was not found to be a significant factor influencing water quality (Table 3). DO, pH and Salinity were varied with the dual interaction between Time and Pond while Temperature, DO and pH were significantly influenced by interaction of Time and Day of observation. ORP varied significantly with the Time : Day and Pond : Day interaction. The triple interaction among Time, Day and Pond showed a significant variance in Temperature and Salinity.

Table 3: Repeated Measures ANOVA table for Temperature of pond water at Siyari Nepal, 2021

Source of interaction	Temperature	DO	pH	TDS	EC	Sal	ORP
Time	***	***	***	***	***	***	***
Pond	***	***	***	**	***	**	***
Day	ns	ns	ns	ns	ns	ns	ns
Time:Pond	***	**	**	ns	*	**	***
Time:Day	ns	*	*	ns	.	*	ns
Pond:Day	***	***	***	ns	.	.	***
Time:Pond:Day	ns	ns	ns	ns	ns	ns	*
Total observation	720	720	720	720	720	720	720
[1]Conditional R^2	NA	0.913	0.872	0.976	0.981	0.96	0.73
[2]Marginal R^2	0.958	0.778	0.616	0.286	0.267	0.252	0.347
[3]Adjusted ICC	NA	0.606	0.668	0.966	0.974	0.947	0.587
[4]Conditional ICC		0.135	0.257	0.69	0.714	0.708	0.383

Note: * significant at 5%, *** significant at 0.1%

[1] R^2: Regression coefficient – obtained %variance was explained by the random effects (Subject) and fixed effects viz. Time, Pond and Day
[2] Marginal R^2 – obtained % variance was explained by fixed effects
[3] ICC: Intra-Class Correlation Coefficient – measurements in the same group of fixed effects resemble each other with obtained % strength
[4] Conditional ICC – measurements in the same group for random and fixed effects resemble each other with obtained % strength

Temperature was found to be significantly affected by Time and Day of observation, which is obvious because water temperature varies depending on the meteorological conditions (Raskovic, Poleksic, Zivic, & Spasic, 2010). Temperature was found above the acceptable range during daytime in the month of May. In tropical ponds, thermal stratification becomes distinct at daytime (Bartram & Ballance, 1996) and fish may survive high temperature by staying in the sub-surface layer while at night, the upper layer cools to same temperature as the lower one (Boyd, 1984).
The variation in Dissolved Oxygen concentration was similar to a comparative analysis of water quality in Nile Tilapia monoculture and polyculture which showed significantly lower dissolved oxygen concentration during midnight and pre-dawn hours than in morning, afternoon and pre-sunset period and temperature was higher during afternoon (Shoko, Limbu, Mrosso, & Mgaya, 2014).
Though non-significant, the statistically higher values of Total Dissolved Solid, Electrical Conductivity and Salinity in Earthen Nursery Ponds might be due to higher stocking density. Temperature, Transparency, DO and pH did not differ significantly in 3 ponds with increasing stocking density of mirror carp spawn, however with a significantly higher productivity (Samad, Khatun, Reza, Asrafuzzaman, & Ferdaushy, 2016).

5.3 Pairwise Comparison

Pairwise comparison for all pairs of Time factor have been shown with the mean difference in values of water quality parameters (Table 4). Temperature, DO and pH at dawn were significantly different than the values obtained at noon and dusk but similar with values at night. Temperature at noon differed significantly with Temperature at night. The values of TDS, EC and Salinity were significantly different between noon and dusk and dusk and night. ORP at dawn was significantly different from ORP at dusk and night.

Table 4: Pairwise comparison of water quality parameters for significant Time factor at Siyari Nepal, 2021

	T1/T2	T1/T3	T1/T4	T2/T3	T2/T4	T3/T4
Temperature	4.473***	3.033***	0.891	**-1.44 ** **	**-3.581*** **	**-2.141*** **
Dissolved Oxygen	**5.158 *** **	**5.308*** **	0.64	0.15	**-4.515*** **	**-4.665 *** **
pH	**0.628 *** **	**0.617 *** **	0.063	-0.011	**-0.565 *** **	**-0.553*** **
Total Dissolved Solid	16.833	-7.833	-5.667	**-24.667** **	**-22.5 ** **	2.167
Electrical Conductivity	**24.833* **	-10.333	-8.333	**-35.167 *** **	**-33.667** **	1.5
Salinity	0.0183.	-0.0067	-0.005	**-0.025 ** **	**-0.0233 ** **	0.0017
Oxygen Reduction Potential	24.55	**44.767 *** **	**33.617** **	20.217	9.067	-11.15

Note: Values denote the mean difference. Symbols have their usual meaning

The mean difference of water quality parameters is presented in Table 5, which shows no significant differences among Earthen Nursery Pond, Earthen Production Pond and Plastic Production Pond.

Table 5: Pairwise comparison of water quality parameters for significant Pond factor at Siyari Nepal, 2021

Pond Type		Mean Difference						
		T	DO	Ph	TDS	EC	Sal	ORP
EPP	ENP	0.145	-0.255	-0.0517	-48.17	-72.83	-0.0317	-6.083
PPP	ENP	0.388	0.323	-0.035	-69.17	-107	-0.0483	-3.233
PPP	EPP	0.243	0.578	0.017	-21	-34.17	-0.0167	2.85

Note: Symbols have their usual meaning

For comparing the differences in water quality parameters with significant influence of Day factor, means and standard deviation of Cloudy days and Sunny days were calculated and t-test was carried out. Results of t-test for each Time factor (Table 6) shows that all water quality parameters varied between Cloudy day and Sunny Day at each Time of observation except pH at 6:00 AM, 6:00 PM and 2:00 AM and ORP at 6:00 PM and 2:00 AM.

Similarly, the results for each Pond factor shows that pH of Earthen Nursery Pond and Earthen Production Pond and ORP of all ponds were similar between Cloudy day and Sunny day while other parameters were different.

Table 6: Mean comparison (t-test) of water quality parameters between cloudy and sunny day for different pond and time of day at Siyari Nepal, 2021

Time of observation	Temperature	DO	pH	TDS	EC	Sal	ORP
6:00 AM	***	***	ns	***	***	**	**
12:00 PM	***	***	**	**	**	**	*
6:00 PM	***	***	ns	**	**	*	ns
2:00 AM	***	***	ns	**	**	*	ns
Pond Type	Temperature	DO	pH	TDS	EC	Sal	ORP
Earthen Nursey Pond	***	***	ns	***	**	***	ns
Earthen Production Pond	***	***	ns	***	**	***	ns
Plastic Production Pond	***	**	**	*	*	*	ns

5.4 Regression Analysis

Correlation matrix of water quality parameters for each Pond type on each Days of observation was carried out and significant correlation among Temperature, pH, DO and ORP, among TDS, EC and Salinity and among pH, TDS and EC was further analyzed by linear regression of dependent variables (ORP, DO, pH and EC) against independent variables (Temperature, DO, pH and TDS).
Regression equations with highest Regression Coefficient (R^2 value) for each significant correlation coefficient is listed in Table 7 along with the calculated Mean Absolute Percent Error (MAPE). Best prediction model (MAPE < 10) was generated for pH against Temperature and TDS, and for EC against TDS, while regression equation for EC against pH had a good predictive capacity (MAPE = 10-20) for cloudy days. Prediction for ORP against DO and pH, and DO against temperature and pH were reasonably sound (MAPE = 20-50). However, the MAPE value for ORP against DO and DO against Temperature was high despite a good regression coefficient value.

Table 7: Regression equation and Mean Absolute Percent Error for different water quality parameters observed at Siyari Nepal, 2021

Linear regression (Cloudy Days)	R^2 value	Equation (Y = a + bx)	MAPE
Oxygen Reduction Potential against Dissolved Oxygen	0.374	Y = 91.943 -4.189x	36.31
Dissolved Oxygen against Temperature	0.738	Y = -240.908 + 0.828x	28.76
Electric Conductivity against pH	0.322	Y = 1116.601 -82.786x	15.3
Electric Conductivity against Total Dissolved Solid	0.997	Y = -10.127 + 1.582x	1.76
pH against Total Dissolved Solid	0.312	Y = 9.797 -0.006x	6.06
pH against Temperature	0.574	Y = -57.155 + 0.219x	5.86
Oxygen Reduction Potential against pH	0.314	Y = 142.66 -10.90x	29.52
Linear regression (Sunny Days)	R^2 value	Equation (Y = a + bx)	MAPE
Oxygen Reduction Potential against Dissolved Oxygen	0.474	Y = 86.439 -4.205x	28.38
Electric Conductivity against pH	0.349	Y = 906.997 -60.977x	15.14
Electric Conductivity against Total Dissolved Solid	0.999	Y = -4.972 + 1.56x	1.46
pH against Total Dissolved Solid	0.371	Y = 10.348 -0.008x	6.44
pH against Temperature	0.785	Y = -61.982 + 0.231x	10.77
Oxygen Reduction Potential against pH	0.412	Y = 210.96 -19.6721x	26.5

Strong diurnal variations and a significant positive linear correlation between pH and DO was observed in aquaculture water while a weak or no correlation at all was found between pH, DO and chlorophyll a during summer and autumn on a comparative study made by Zang et al. (2011). pH value was found to differ significantly with season suggesting the effect of temperature on pH through photosynthetic activities of phyto-planktons (Abdel-Wahed, Shaker, Elnady, & Soliman, 2018). The findings on correlation between ORP and pH and ORP and DO

could be supported with the study done by Lytle, Copeland, & James (2004), ORP value increased with increasing dissolved oxygen concentration at constant pH but the magnitude decreased with change in pH from 7 to 8 and 9. Significant Negative relationship between water pH and redox potential and a positive linear relationship between pH and Electrical Conductivity was observed by Datta et al. (2008) while Das, Bhattacharya, & Goswami (2020) reported positive relationship of pH with Temperature.
The relationship of increasing dissolved oxygen, decreasing solubility of carbon dioxide and ultimate increase in pH during the daytime was explained by Hargreaves & Brunson (1996) and Wurts & Durborow (1992). The relationship of DO with TDS, EC and Salinity was not found to be significant. Hopkin et al. (2009) had also found no relationship between Secchi disk visibility and dissolved oxygen.

6. CONCLUSION

Water quality parameters vary between cloudy and sunny days during summer season with time of day as the major factor for affecting fluctuation in values. Pond water does not differ with respect to water quality among earthen production pond, earthen nursery pond and plastic production pond. Temperature, pH and Dissolved Oxygen follow an inverted U-shaped curve throughout the day; Total Dissolved Solid, Electrical Conductivity and Salinity remain constant while Oxygen Reduction Potential follows a more or less irregular pattern. Water quality parameters like Temperature, Dissolved Oxygen and pH goes above the acceptable range during daytime in summer season (especially in the month of May) in Rupandehi, a Terai district of Nepal. The parameters have a strong relationship with each other and were found to have good predictability of values at a time for a certain pond type based on observation at other time of the same day.

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