Interrelationships among Water Quality Parameters in Recirculating Aquaculture System

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Abstract

The study was conducted to investigate the relationships among important water quality parameters in Recirculating Aquaculture Systems (RAS) and hence predicts equation for determining some of the parameters in RAS. Wastewater was obtained from integrated pond of the University of Ibadan Fish farm and passed through bio-filtration treatment at different drying times: 24, 72 and 144hours. The filtrates that were analyzed for using standard procedure included Temperature, pH, Dissolved oxygen, Total ammonia-nitrogen, Nitrite-nitrogen and Nitrate-nitrogen. Statistical analysis (Correlation and Regression) was used to determine the relationships among the water quality parameters and predict equation. Some of the water quality parameters were significantly interdependent. Temperature had significant relationship with all the dependent parameters but with low co-efficient of determination except with DO where the co-efficient of determination is high (R^2=0.502) and prediction equation D.O=26.469-0.784T. Temperature and pH used together had significant relationship with strong co-efficient determination (0.514 and 0.405) in relation to DO and Nitrite-nitrogen respectively with prediction equations D.O=20.547-0.787T+0.821pH and NO2-N=0.478+0.035T-0.188pH. Though temperature is a good predictor of other water quality parameters, it is encouraged to use Temperature and pH for a more reliable prediction.

Keywords: Bio-filtration, Nitrogenous wastes, Physico-chemical, Water re-use system.

INTRODUCTION

The development of Recirculating Aquaculture System (RAS) has contributed immensely to the growth experienced in Nigeria aqua-cultural sector as it encouraged urban and peri-urban aquaculture. This is due to its perceived advantages which includes reduction in land and water quantity requirements as well as feasibility of locating production very close to markets (Dunning *et al*., 1998), most especially in the production of fish seed (Fingerlings and juveniles). The epileptic power supply situation in Nigeria has made its use for grow-out production questionable due to the high cost of alternative power supply.

A major challenge to aquaculturists is maintaining system water quality suitable for the crop throughout the culture process. In recirculating aquaculture system, deterioration of the water quality constitutes a major disadvantage, if the treatment of water within the system is not properly controlled. It can have adverse effect on the growth of the fish, increase the chance of disease infestation, stressing of the stocked fish and so many other problems that are associated with water quality which may eventually lead to poor health for the fish and ultimately loss of the entire production (Timmons *et al*. 2002). There are different factors affecting water quality in RAS and the most important among them, being the source of the water, the level of recirculation, the species of fish cultured and the type of waste water treatment process within the system (Sanni and Forsberg 1996, Losordo *et al*., 1999). The use of RAS requires frequent monitoring of water quality because degradation of water quality can result in loss of the whole stock within a short period of time. According to Akinwole and Adeola (2012), water quality criteria are scientific and technical information provided for a particular water quality constituent in the form of numeric data or narrative description of its effect on the sustainability of water for a particular use or on the health of aquatic ecosystems. Water quality is determined by various physico-chemical and biological factors, as they may directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Nwakwo, 1998). Although, there are many water quality parameters in an aquatic environment, only a few normally play an important role (Boyd 1979). In RAS, the major water quality problems experienced can be associated with low dissolved oxygen and high concentrations of fish metabolic waste in the culture water (Sanni and Forsberg 1996). Waste metabolites productions that are of major concern include Total Ammonia Nitrogen (TAN), un-ionised ammonia (NH_3-N), nitrite (NO_2-N) and nitrate (NO_3-N) (Hagopian and Riley 1998). Maintenance of good water quality is important in all aquaculture systems in order to ensure survival, fast growth and high yield while that of re-circulating system requires more diligence owing to high level of loss that can arise within a very short period of time as a result of deterioration in water quality and upset in water chemistry. Fish farmers are expected to measure, record and manage the water quality all through the growing season, as this will serve as guide for managing the fish culture systems so that conditions that can adversely affect the growth of fish can be avoided (Akinwole and Adeola, 2102). The commonly measured water quality parameters that are important to fish culturists especially in recirculating tanks includes Temperature; pH, Salinity, Disolved Oxygen and Nitrogenous wastes (Ammonia, Nitrite and Nitrate). These parameters are measured with different methods and techniques such as titrimetric procedure requiring chemical reagents, bottles and glass wares which include beakers, burette and conical flasks, D.O bottles, calorimeters as well as use of meters like digital thermometer, pH meter, D.O. meter, spectrophotometer and portable test kits. Whichever method is used the measure of this water quality parameters are usually technical, time demanding and associated with high cost that may be unbearable for peasant farmers dominating the farming community in Nigeria. According to Akinwole and Adeola (2012), the development of theoretical or numerical and analysis that tends to utilize easily measured parameters like pH and Temperature to estimate the level of other important water quality parameters will be appreciated. This will ease the problems of averagely trained fish farmers in terms of time and money for the analysis and purchase of test kit. This study therefore investigated the relationship among important water quality parameters and hence predicts equation for estimating some of the water parameters in recirculating aquaculture system.

MATERIALS AND METHODS

The experiment was carried out between January and March 2013 in the laboratory of the Department of Aquaculture and Fisheries Management, University of Ibadan, Ibadan. Waste water was collected from the integrated pond of University of Ibadan Fish farm and run through a bio-filtration treatment and water that supposed for fish culture tank was collected for the analysis.

Description of biofilter units

The filter housing is made of150mm diameter, 3mm thick, and 1,200mm highPolyvinylchloride (PVC) pipe. The bottom is made of solid PVC end plug piece drilled with 20mm holes. A plastic funnel was attached to the bottom end of the housing to collect the filtrate into a plastic container placed under the funnel and a wooden frame was constructed to hold the filter housing. The housing was filled with 40mm diameter gravel up to 150mm height in line with Akinwole (2005) and polypropylene bioblock was cut to fit into the housing unit up to height of 600mm with volume 0.00924m^3 was used as biofilter media.

Aquaculture wastewater

Aquaculture effluents wereobtained from University of Ibadan, Fish farm integrated pond. Thewastewater samples was collected between 0800 to 0900 hours of the day using four pieces of twenty five litres plastic containers for each batch. The pond contain 1, 120 pieces of *Clarias gariepinus* of14 weeks, 857 strands of rice of 17 weeks and 10 pigs of 28 weeks whose pens are located adjacent to the pond and its waste flushed into the pond once in a week. The fish are fed sinking pellets of 28% Crude protein twice daily and volume of water in the pond was 150.84m^3

Experimental procedure

The biofilter media was inoculated using the wastewater from the aquaculture system before applying for treatment after 24 hours (drying time) of inoculation. The wastewater samples were poured into an open container (bowl) to allow more dissolution of oxygen at the water-air interface in order to increase the dissolved oxygen content so as to enhance the performance of the aerobic bacteria. 5 litres of the wastewater was measured out and poured into the filter column. The filtrate was collected in plastic container and 100cl of the filtrate was collected for the analysis of the selected water quality parameters. The experiment was repeated for three drying times; 24 hours, 72 hours and 144 hours drying time and each of the experiment were done in triplicates.

Water quality analysis

The filtrates were examined for the following parameters; Dissolved oxygen (DO), Total Ammonia Nitrogen (TAN), pH, Temperature, Nitrate-nitrogen and Nitrite-nitrogen. Temperature was measured with mercury in glass thermometer, the thermometer was inserted into the water sample and left for two minutes before the reading was taken. DO was determined using winklers method in line with Mackereth (1963), pH was measured using a HANNA probe pH meter. Total ammonia nitrogen (TAN) was determined colourimetrcally using Merck (2011) test kit, Nitrite-nitrogen (NO_2-N) was determined using Merck (2010) test kit. Nitrate-nitrogen (NO_3-N) was determined colourimetrically using HAGEN (2008), test kit. Procedures for analysis was done according to standard methods (APHA1995).

Statistical and data analysis

Mean and standard deviation of theselected water quality parameters were determined in both the influent and the filtrate, Pearson correlation analysis was used to determine interdependence among the water quality parameters in the filtrates, single linear and multi-linear regression analysis was used to determine the interrelationship among the water quality parameters and hence predict equation. The regression equation is expressed as $Y= a + bX$ where Y is dependent variable, X is independent variable, a = intercept and b = slope of the regression. Temperature and pH which are easier and less difficult to measure compare to other were used as the independent variables while the D.O, TAN, Nitrite-nitrogen and Nitrate-Nitrogen that are more difficult to measure were used as dependent variable. The statistical analysis was done using IBM SPSS version 20.

RESULTS AND DISCUSSION

Water quality parameters

The water quality parameters reported in the filtrates were temperature (27.35±0.83 ^{0}C), DO (5.04±0.91 mg/L), pH (7.32±0.12), TAN (0.47±0.13 mg/L), Nitrite-nitrogen (0.05±0.06 mg/L) and Nitrate-nitrogen (7.22±12.79 mg/L) as shown in Table 1. All the water quality parameters reported in the filtrates were normal for fish culture and within the range recommended Akinwole and Adeola (2012). The difference between the values of influents and filtrates though are very small but it showed that the biofilter performed as it is evident in reduction of TAN and increase in Nitrate-nitrogen.

Table 1.Mean Values±SD of selected water quality parameters and ranges for fish culture

Parameters	Mean value in influent	Mean value in filtrate	*Optimum level for fresh water fish culture
Temperature ^{0}C	27.33±0.50	27.35±0.83	26-32
Dissolved oxygen (mg/L)	3.67±0.50	5.04±0.91	>5.0
pH	7.60±0.17	7.32±0.12	6.5-8.5
TotalAmmonia-nitrogen (TAN) mg/L	0.80±0.00	0.47±0.13	<8.0
Nitrite-nitrogen (mg/L)	0.06±0.07	0.05±0.06	<1
Nitrate-nitrogen (mg/L)	6.67±10.00	7.22±12.79	< 250

* Adapted from Akinwole and Adeola (2012)

Interdependence among water quality parameter during the study period

According to data in Table 2, temperature had significant correlation with DO (r = -0.709), Nitrite-nitrogen (r = 0.494) and Nitrate-nitrogen (r = 0.398) .The Dissolved oxygen had significant correlation with Nitrite-nitrogen (r =-0.665) and Nitrate-nitrogen (-0.621). The pH only had a significant relationship with Nitrite-nitrogen (r = -0.388), while TAN had no significant correlation with any of the parameters, Nitrite-nitrogen also showed a significant correlation with Nitrate-nitrogen (r = 0.481). The correlation with DO was strong but negative; this indicated that increase in temperature may lead to decrease in dissolved oxygen. This is in line with the report of Fakayode (2005) and may be due to reduction in dissolution of oxygen at the air-water interface as the temperature increases. The temperature also had positive correlation with Nitrite-nitrogen and Nitrate-nitrogen, this can be associated with increase in decomposition of Ammonia-nitrogen at high temperature and hence increase in the oxidation product of the decomposition which is the Nitrate-nitrogen and the intermediate product which is Nitrite-nitrogen (Al-Hafedh *et al*. 2003).

The Dissolved oxygen had significant, strong but negative relationship with Nitrite-nitrogen and Nitrate-nitrogen, this suggested that increase in dissolved oxygen may lead to decrease in Nitrate nitrogen and Nitrite-nitrogen. pH had significant but negative correlation with Nitrite-nitrogen, this is indicated that increase in pH may lead to decrease in Nitrite-nitrogen and can be linked to the fact that nitrifying bacteria are pH sensitive and at a level above 8 will be inhibited (Michael *et al*. 1995) and not be able to remove any toxic nitrogenous waste, hence decrease in nitrite-nitrogen which is an intermediate product of TAN degradation. Nitrite-nitrogen has significant and positive relationship with Nitrate-nitrogen and this can be associated with the fact that they are both biodegradation products of TAN (Summerfelt and Sharrer 2004).

Table 2. Interdependence among water parameters during the period of study

	Temperature	D.O	pH	TAN	Nitrite-nitrogen	Nitrate-nitrogen
Temperate	1	-0.709**	0.026	0.324	0.494**	0.398*
D.O	-0.709**	1	0.090	-0.289	-0.665**	-0.621**
pH	0.026	0.090	1	-0.006	-0.388*	-0.099
TAN	0.324	-0.289	-0.006	1	0.115	-0.066
Nitrite-nitrogen	0.494**	-0.665**	-0.388*	0.115	1	0.481**
Nitrate-nitrogen	0.398*	-0.621**	-0.099	-0.066	0.481**	1

Interrelationship among the selected water quality parameters

The regression analyses showed the interrelationship among the water quality parameters.In the simple regression (Table 3),temperature had significant interrelationship with all the dependent variables with R^2 value of 0.502, 0.105, 0.244 and 0.158, for DO, TAN, NO_2-N and NO_3-N respectively. The co-efficient of determination was only strong with dissolved oxygen where the prediction equation was DO = 26.469 – 0.784T (Table 3). The pH only had significant relationship with Nitrite-nitrogen where the co-efficient of determination (R^2) was 0.150 and the prediction equation was NO_2-N = 1.378 - 0.182pH (Table 3). In the multi-linear regression, the predictors (Temperature and pH) showed significant relationship with DO and Nitrite-nitrogen, the DO had R^2 of 0.514 with prediction equation D.O = 20.547 - 0.787T + 0.821pH and Nitrite-nitrogen had R^2 of 0.405 with prediction equation of NO2-N = 0.478 + 0.035T - 0.188pH (Table 4). The study revealed that temperature alone is a good predictor in recirculating system contrary to Akinwole and Adeola (2012), who reported that the single predictor was not significant in earthen pond and concrete tank, temperature had a significant interrelationship with all the dependent variables (DO, pH, TAN, Nitrite-nitrogen and Nitrate-Nitrogen) though the Co-efficient of determinations were relatively low except with dissolved oxygen where R^2 = 0.502.

The pH cannot be used as a single predicting variable in recirculating system because it has no significant relationship with the dependent variables (DO, Total ammonia nitrogen, and Nitrate-nitrogen) except with Nitrite-nitrogen. The multi-linear regression showed significant relationship with DO and Nitrite-nitrogen with relatively fair co-efficient of determination (R^2), this is in agreement with Akinwole and Adeola (2012), who also reported higher R^2 for the multiple predictors.

Table 3. Interrelationship among water quality parameters (Simple linear regression)

Y	X	Prediction equation	Coefficient of determination (R^2)	F value
Dissolved oxygen mg/L	Temperature ^{0}C	D.O=26.469-0.784T	0.502	34.324*
Dissolved oxygen mg/L	pH	D.O=0.065+0.680Ph	0.008	0.276
Totalammonia-nitrogen (NH_4-N) mg/L	Temperature ^{0}C	NH_4-N=0.897+0.050T	0.105	3.979*
Total ammonia-nitrogen (NH_4-N) mg/L	pH	NH_4-N=4.744-0.288pH	0.002	0.083
Nitrite-Nitrogen(NO_2-N) mg/L	Temperature ^{0}C	NO_2-N=-0.879+ 0.034T	0.244	10.991*
Nitrite-Nitrogen (NO_2-N) mg/L	pH	NO_2-N=1.378-0.182pH	0.150	6.016*
Nitrate-nitrogen (NO_3-N) mg/L	Temperature ^{0}C	NO_3-N=-161.166+6.157T	0.158	6.400*
Nitrate-nitrogen (NO_3-N) mg/L	pH	NO_3-N=83.736-10.458pH	0.010	0.335

* Regression is significant at P<0.05

Table 4. Interrelationship among water quality parameters (Multi-linear regression)

Y	X	Prediction equation	Coefficient of determination (R^2)	F value
Dissolved oxygen (D.O)(mg/L)	Temperature ^{0}C & Ph	D.O=20.547 - 0.787T + 0.821pH	0.514	17.459*
Ammonia-nitrogen (NH_4-N) mg/L	Temperature ^{0}C & pH	NH_4-N=-0.785+ 0.050T -0.016pH	0.105	1.935
Nitrite-Nitrogen (NO_2-N) mg/L	Temperature ^{0}C & pH	NO_2-N=0.478+0.035T-0.188pH	0.405	11.230*
Nitrate-nitrogen (NO_3-N) mg/L	Temperature ^{0}C & pH	NO_3-N=-77.709+ 6.202T - 11.572pH	0.170	3.388

*Regression is significant at P<0.05

CONCLUSION

The study revealed that some water quality parameters in the recirculating system are interdependent and also have strong interrelationships. Temperature was revealed to be of high importance because of its tendency to affect so many other parameter and ability to give information on other important water quality parameters whose measure may be time taking and a bit difficult. However it is more reliable and encouraged to use temperature with pH in predicting equation for Dissolved Oxygen, Total Ammonia-nitrogen, Nitrite-nitrogen and Nitrate-nitrogen for a high level of reliability because a single variable may be sometime deceptive. Finally it is worthy of note that this method is not suggested to replace standard analytical methods but can serve for preemptive purpose.

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