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Computer Program for Predicting and Managing Water Quality Parameters for Aquacultural Production

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Abstract: The success of aquacultural production depends to a large extent on the water quality parameters. Maintaining water quality of aquacultural systems through adequate monitoring is paramount for increasing production. However, the cost of laboratory analysis involved discourages farmers from proper water quality monitoring, hence the deterioration of the fish environment and subsequent decrease in production. This study therefore developed a computer program which will be used in predicting and take management decisions for parameters such as un-ionized ammonia (UIA), dissolved oxygen (DO) and carbon-dioxide (CO_2) whose laboratory analysis are time consuming and expensive. The interrelationships between the water quality parameters were established mathematically and written in C#. The developed model was validated with experimental data, to ascertain the suitability of the model. The mean observed values of UIA, DO and CO2 were 0.03995, 7.641 and 5.72 mg/L, respectively which showed a strong relationship with the predicted ones 0.0412, 7.53943 and 5.9095 mg/L.

Key words: Aquacultural waste water · DO, UIA, $CO_{2,}$ Prediction

INTRODUCTION

A suitable environment is necessary for any organism to survive, since life depends on the continuance of a proper exchange of essential substances, energies between the organism and its surroundings [1]. The culture of aquatic animals are fundamentally different from most conventional forms of animal agriculture. This is because of the peculiar physical and chemical properties of water (the environment of aquatic life), which have significant effect on survival, growth and reproductive behavior of the aquatic animals. Environmental quality is therefore very important in a culture system. This is because the feed, dissolved oxygen and metabolic wastes are transmitted through the liquid phase. Hence, to produce fish in a cost effective manner, aquaculture production systems must maintain good water quality during periods of fish growth.

As common with all animals, waste is produced by these metabolic processes and ammonia is the principal waste product excreted by fish. In trace amounts, ammonia is odorless and colorless, so the only way it can be detected is through water test [2]. According to [2], of all the water quality parameters that affect fish, ammonia is the most important after oxygen, especially in intensive systems. Fish consume oxygen and excrete ammonia and carbon dioxide. Metabolic carbon dioxide reduces the ambient pH of the water and changes the ionization fraction of unionized ammonia and carbon dioxide [3]. Hence, the importance of water quality monitoring.

Total ammonia nitrogen is the sum of free or unionized ammonia (NH_3) and ionized-ammonia (NH_4^+) of reduced inorganic nitrogen which exist in equilibrium depending upon the pH and temperature of the waters. The free or unionized ammonia form is considerably more toxic to organisms such as fish and, therefore, the toxicity of ammonia is usually expressed in the unionized form. As a by-product of protein metabolism, ammonia is primarily excreted across the gill membrane with only a small amount excreted in the urine. Hence, more attention is paid to its relative concentration in fish tank. In small amounts, ammonia causes stress and gill damage and fish exposed to low levels of ammonia over time are more susceptible to bacterial infections and have poor growth [2].

Each individual environmental parameter is important, but it is the aggregate and interrelationship of these parameters that influence the health and growth rate of

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the fish. Parameters such as pH and temperature are driving variables because they affect and determine the amount of the state variables such as ammonia, CO_2 etc. [4]. Hence, keeping the driving variables within recommended standards will make aquacultural system safe and healthy.

Fish production is closely correlated with the biological production which in turn depends upon the environmental conditions of water body. In view of this, a water quality analysis is paramount for successful aquacultural production. However most of these analysis are time consuming and expensive. This study, therefore, aimed at developing *C#* based model that will predict the amount of un-ionized ammonia (UIA), dissolved oxygen (DO) and carbon dioxide (CO_2) in aquacultural system given the driving variables.

MATERIALS AND METHODS

C#, a simple, modern, object-oriented and type-safe programming language derived from C and C++ developed by Anders Hejlsberg of Microsoft especially for the NET platform and Scott wiltamuth was used to develop a computer model for predicting ammonia, DO and CO_2. The model was validated with experimental data to ascertain its suitability for water quality management.

Water Quality Predicting Model: Mathematical relationships from related literatures were used in writing the algorithm. The equations for each of the parameters are as presented below:

DO was calculated using [5] Oxygen solubility equation:

$$O_S = 14.652 - 0.41022T + 0.00799910T^2 - 0.000077774T^3 \quad (1)$$

Where T is the temperature of the system
The algorithm is presented in Figure 1.
UIA is calculated using the equation given by [6]

$$UIA = \frac{TAN}{1 + 10^{(0.0902 - pH) + \left(\frac{2730}{(273.2+T)}\right)}} \quad (2)$$

Where TAN is total ammonia nitrogen.
Figure 2 presents the algorithm for UIA
CO_2 is calculated using [7] equation which is given as:

$$CO_2 = Alkalinity \times {}^{44}\!/_{50} \times 10^{(6.36 - pH)} \quad (3)$$

The flow chart is presented in Figure 3.

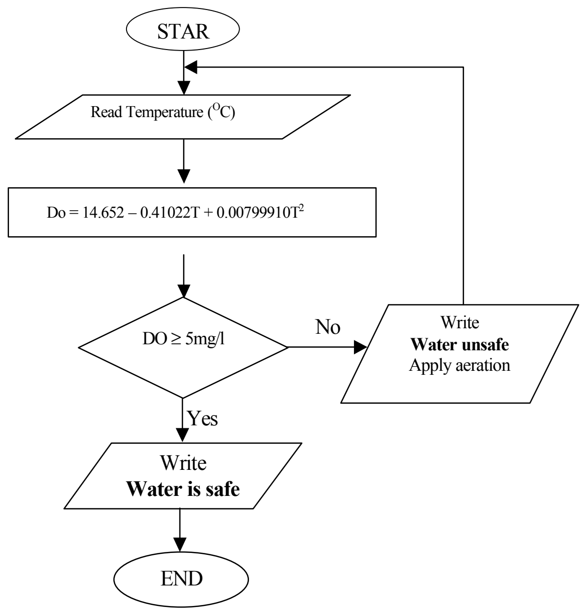

Fig. 1. Flow chart for Dissolved Oxygen

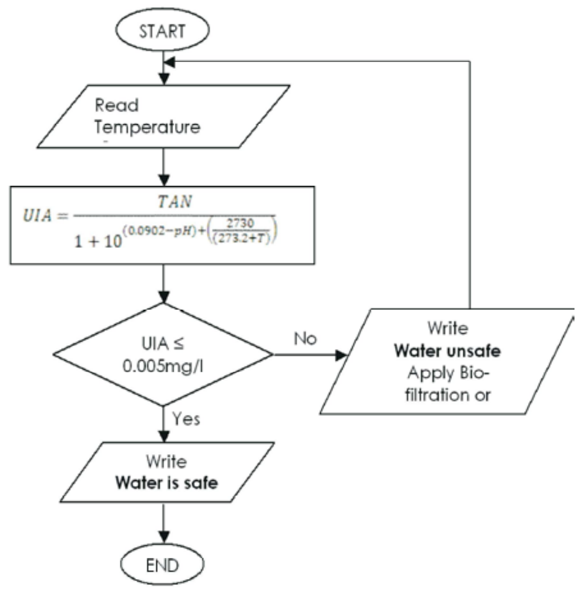

Fig. 2: Flow chart for unionized ammonia (UIA)

Experimental Work: Juvenile catfish (*clarias gariepinus*) of about 6cm length and 15g weigh were used. The fish were weighed and separated into nine rectangular plastic tanks of 50cm x 30cm x 30cm, filled with 30litres of water. The tanks were stocked at densities of 7, 14 and 21 fingerlings, each of three replicates. The fish were fed daily at 5% body weight with 40% crude protein pelleted feed for 4weeks. The culture tanks' water were sampled and water quality parameters such as temperature, dissolved oxygen (DO) and pH were monitored weekly

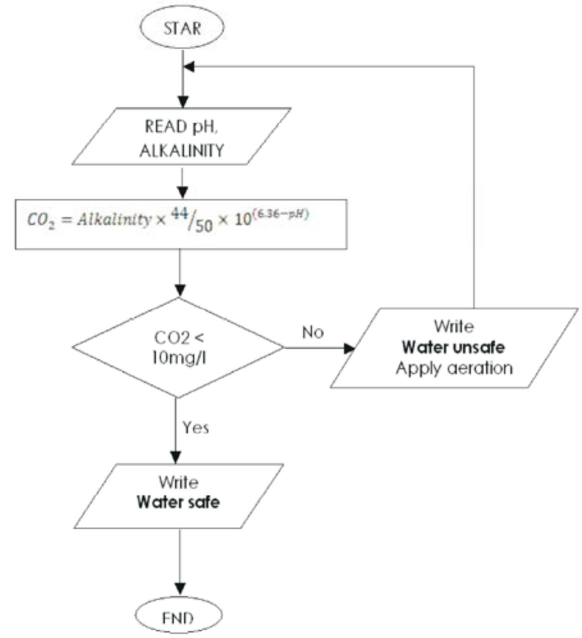

Fig. 3: The flow chart for carbon dioxide

with a digital thermometer, DO meter and pH meter respectively. Total ammonia nitrogen (TAN), unionized ammonia (UIA), Alkalinity and Carbon dioxide (CO_2) were also monitored [8].

RESULT AND DISCUSSION

The experimental results of the water quality analysis are presented in Table 1.

The experimental data generated were used to validate the developed model, whose computer interface are presented in Figure 4, 5 and 6.

If the value of dissolved oxygen (DO) output is = 5 mg/L, it writes water safe but if <5 mg/l, it writes water not safe, apply aeration.

If the CO_2 output is < 10 mg/L, it writes water safe but if >10 mg/L, it writes water unsafe, apply CO_2 removal process.

The results of the model output and the observed data are presented on Table 2. Simple statistics was used to calculate the average means of the observed field work and computer predicted data. The observed and predicted average means were found to be relatively close. The mean value of UIA observed was 0.03995 while UIA predicted was 0.0412. The DO observed and predicted were 7.641 and 7.53943 respectively, while a mean of 5.72 observed and 5.9095 predicted were recorded for CO_2. Furthermore, the graphs (Figure 7, 8 and 9) of the observed parameters with the predicted took a similar trend, with a little margin between DO observed and

Table 1: Water quality laboratory analysis during 25/10 to 13/11/2010

Water Quality Parameter	25/10/10	1/11/2010	7/11/2010	13/11/10
Temperature (°C)	29.5	28	29	31.1
pH	8	8.3	7.2	6.5
Alkalinity	160	120	60	15
Total ammonia nitrogen(TAN) (mg/L)	1.2	1.4	0.6	1
Dissolved oxygen (DO) (mg/L)	7.6	7.81	7.71	7.4
Unionized ammonia (UIA) (mg/L)	0.071	0.12	0.002	0.001
Carbon dioxide (CO2) (mg/L)	2.93	1.32	8.1	8.6

Table 2: The model output and the observed data during 25/10 to 13/11/2010

	25/10/10		1/11/2010		7/11/2010		13/11/10	
Water Quality Parameter	PRE.	PRE.	PRE.	OBS.	PRE.	OBS.	PRE.	OBS.
Temperature (OC)	29.5	29.5	28	28	29	29	31.1	31.1
pH	8	8	8.3	8.3	7.2	7.2	6.5	6.5
Alkalinity	160	160	120	120	60	60	15	15
Total ammonia nitrogen(TAN) (mg/L)	1.2	1.2	1.4	1.4	0.6	0.6	1	1
Dissolved oxygen (DO)(mg/L)	7.508	7.508	7.723	7.81	7.579	7.71	7.284	7.4
Unionized ammonia (UIA) (mg/L)	0.08662	0.08662	0.1719	0.12	0.007064	0.002	0.002736	0.001
Carbon dioxide (CO2) (mg/L)	3.2255	3.2255	1.21245	1.32	7.63192	8.1	9.5626	8.6

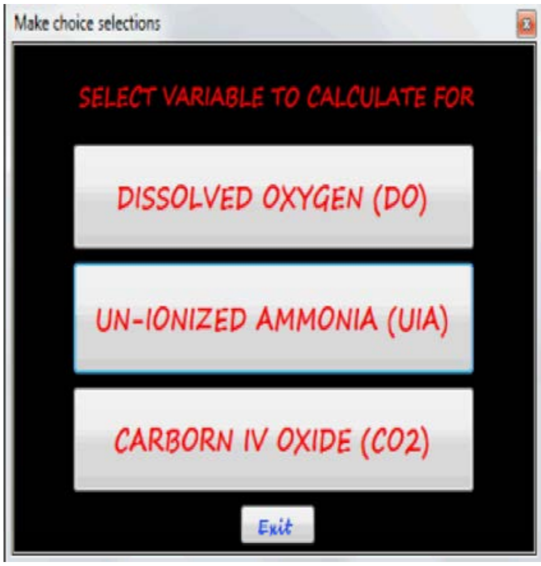

Fig. 4: Interface for selecting the parameter to be calculated

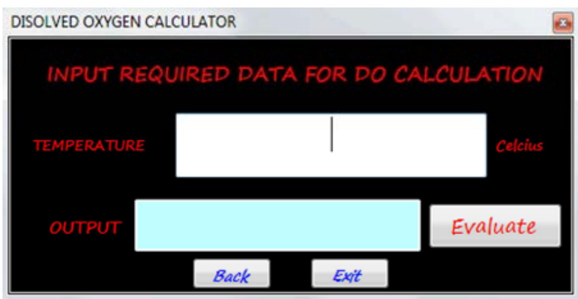

Fig. 5: Computer interface for DO prediction at a particular temperature input

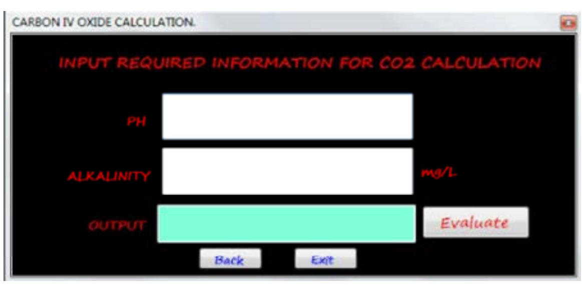

Fig. 6: Computer interface for predicting CO_2 at a given pH and alkalinity

predicted. The graph of UIA observed and predicted vary a little at first but were at the same point as the third and fourth week. The graph of CO_2 observed and CO_2 predicted coincided at the same point.

The observed and predicted data were compared graphically in figures 7, 8 and 9.

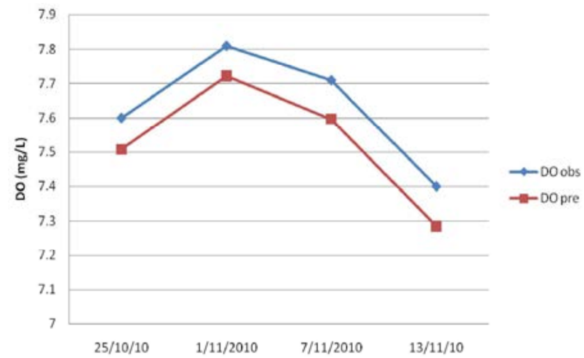

Fig. 7: The graph of DO observed versus DO predicted

Fig. 8: The graph of UIA observed versus UIA predicted

Fig. 3.6: The graph of CO_2 observed versus CO_2 predicted

CONCLUSION

Water quality parameters are interrelated, the interdependent parameters shown in the mathematical expression were used to develop a program or model which can be used to predict some state variables given the driving variables like temperature and pH. These state variables such as DO, UIA and CO_2 which are very important in water quality management can easily be monitored using the developed model. This will enhance water quality monitoring. Maintaining water quality parameters within recommended standards through proper monitoring will produce a successful and healthy aquacultural production system. Hence, the development of a computer based model that estimates major water quality parameters given the driving variables, does not only save time and cost involved in water quality monitoring, it also improves fish production.

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