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Computer Modeling of Dissolved Oxygen Performance in Greenhouse Fishpond: An Experimental Validation

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Abstract: This study presents modeling of dissolved oxygen performance in a greenhouse fishpond. A short-term Disolved Oxygen (DO) fluctuation of a fishpond was developed by using various simple equations and continuous measurement of DO, temperature and solar intensity. Numerical computation has been performed for a typical winter day at the month of January, 2007. Components considered in the DO model include the production of DO by phytoplankton and consumption of oxygen by phytoplankton, fish, water column and sediment. Numerical equations were solved with Excel soft ware to predict DO in the pond. Initial slope (α) and P_{max} were calculated from DO production Vs. solar radiation curve. The amount and distribution of oxygen production in the water column depend on solar intensity and penetration as well as phytoplankton concentration. A parametric study has been performed to represent the effects of pond depth, SDD, extinction coefficient, water temperature and fish yield changes on DO regimes in fish pond. Dissolved oxygen concentrations in the pond varied with both pond depth and SDD. By increasing the depth of the pond and of the SDD and maintaining phytoplankton chlorophyll-a concentration at 232 μg L^{-1}, the overall oxygen production was increased. The low DO values in the shallow pond (0.5 m) with a high SDD (0.5 m) when compared to other ponds with SDD equal to their pond depths, was the result of low overall oxygen production relative to the demand by sediment and fish which were same for all depths of pond. Predicted and experimental DO concentrations exhibited fair agreement with correlation coefficient of R = 0.99 and root mean square percent deviation e = 3.73%. Such correlation between predicted and experimental data indicates that the assumption inherent in the computer model of the processes is valid for the DO production and consumption in the pond.

Key words: Dissolved oxygen, greenhouse pond, fish, sediment, plankton, solar radiation

INTRODUCTION

Dissolved Oxygen (DO) is one of the most important factors affecting most aquaculture species. For fish culture, maintaining dissolved oxygen at a level suitable for fish survival and growth does pond management. When DO levels in aquaculture ponds become low, the cultured organisms may become stressed or even die. A healthy balance pond provides a fluctuation in oxygen levels between day and night that leaves an adequate concentration of oxygen in the water that can support aquatic animal life during both day and night hours. Phytoplankton can exert a profound effect on water quality constituents, especially dissolved oxygen, by producing supersaturated concentrations during the day and reduced levels during the night due to biotic respiration and chemical oxidants result in a net loss of oxygen which can reach critically low concentrations (Muhammetoglu and Soyupak, 2000). The highest oxygen levels in a pond are usually measured on sunny afternoon when phytoplankton and

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other aquatic plants are producing oxygen through photosynthesis. The lowest level occurs just before daybreak after a night of oxygen consumption by aquatic plants and animals. Dissolved oxygen consumption and regeneration by phytoplankton is directly related to their rates of photosynthesis and respiration.

The intensity of solar radiation strongly regulates rates of photosynthesis and oxygen evolution in fishponds (Romaire and Boyd, 1979). The rate of oxygen production is a function of the concentration of algae and other forcing functions. Because the growth of algae is light and temperature dependent, hence the rate of photosynthetic oxygen production follows the same pattern. Temperature is a parameter that shows a marked seasonal and daily variation in fishponds. It influences photosynthesis, growth of algae and bio decomposition of organic matter in the pond. Other factors such as density of fish, turbidity, organic matter levels and wind velocity also greatly influence dissolved oxygen budgets for fishponds (Boyd *et al*., 1978). In ponds showing marked stratification, surface waters may be harmful to fish due to supersaturated DO conditions in combination with high temperatures, while in the same pond near anoxic conditions may exist close to the bottom (Chang and Ouyang, 1988; Losordo, 1988; Boyd, 1990).

There are several reports of DO models incorporating mechanistic characterization of the chemical, physical and biological processes in an open pond which governs the resulting DO levels (Losordo, 1988; Losordo and Piedrahita, 1991). The intent of the present study describes to develop a dissolved oxygen model using input variables in low cost greenhouse fishpond. In this study additional modification have been implemented to the predictions of DO performance in greenhouse fishpond from calculation of solar radiation falling on greenhouse canopy cover to the pond water surface. This model simulates the hourly variation of DO in a fishpond over a 24 h period as influenced by the consumption and production of oxygen by phytoplankton, fish and detritus. Measurable rates of photosynthesis and respiration are needed for proper calibration of the model. This model is neither site nor species specific and input variables can be adjusted to accommodate most pond conditions. In freshwater fishponds effects of solar radiation on temperature and oxygen variations have been described in detail (Boyd, 1979) but relatively very little is known about the effect of solar radiation on temperature and DO variations in greenhouse fishponds (Tiwari *et al*., 2006; Ghosh *et al*., 2007). The model was developed with the following objectives under consideration:

- To establish conceptual framework which unifies theories from various parameters.
- To determine components which have greatest effect on DO.
- To simulate the DO model to various alterations of pond depth and Secchi disc depth.

DISSOLVED OXYGEN MODEL

The modeling of dissolved oxygen concentrations in an aquaculture pond depend upon some factors, which contributes oxygen entry into the pond, oxygen removal from the pond and oxygen exchanges within the pond. In a pond, dissolved oxygen concentrations depends on the balance between photosynthetic production, total respiration and exchanges with atmosphere (Eq. 2)

Two main hypotheses of the DO models are as follows:

- It is assumed that pond water is completely mixed.
- Biomasses and nutrients are supposed to be constant throughout the period during which the model is applied.

Under these two assumptions, the only state variable of the system is mean dissolved oxygen concentrations and the only forcing variables are solar intensity and temperature. Wind speed remains constant throughout the experiment.

The solar radiation at the surface of the water attenuates through the water column. The effective light intensity in the water column directly affects the phytoplankton population, which in turn, increases dissolved oxygen during the day via photosynthesis and utilizes oxygen at night through respiration. Decaying phytoplankton, unconsumed fish feed and fish waste products also decrease DO as represented by sediment oxygen demand. The oxygen mass balance equations are specified by the program or calculated hourly over a 24 h period.

The rate of change in DO concentration in fishpond

$$\frac{dDO_2}{dt} = P - C + E \tag{1}$$

P = DO production, C = Consumption, E = Exchanges

$$\text{or,} \quad \frac{dDO_2}{dt} = DO_{2P} - (DO_{2PR} + DO_{2FR} + DO_{2WCR} + DO_{2SR}) \pm DO_{2D} \tag{2}$$

DO_{2P} = Rate of photosynthetic production by phytoplankton.
DO_{2PR} = Rate of DO respiration by phytoplankton.
DO_{2FR} = Rate of DO respiration by fish.
DO_{2WCR} = Water column respiration.
DO_{2SR} = Sediment respiration rate.
DO_{2D} = Rate of diffusion.

As wind velocity inside greenhouse remained negligible, so exchange of oxygen in air water column through reaeration was negligible. Thus, overall equation accounting for all processes involving production and utilization of DO in greenhouse fishpond is as follows:

$$\frac{dDO_2}{dt} = DO_{2P} - DO_{2PR} - DO_{2FR} - DO_{2WCR} - DO_{2SR} \tag{3}$$

where, $DO_{2D} = 0$

Though a small shallow pond is roughly horizontally uniform (Wei and Laws, 1989), temperature and DO show a daily stratification, which is destroyed by convective heat, exchanges during the night (Chang and Ouyang, 1988).

After calculating oxygen concentration for each element at each time step, the net oxygen change is then added to or subtracted from the previous time step's oxygen concentration. DO concentrations can be calculated at any time (t) as:

$$Do_t = DO_{t-1} + (d\,DO/dt) \times dt \tag{4}$$

Do_t = DO concentration at time t
Do_{t-1} = DO concentration at time t-1
dDO_2/dt = rate of change in DO concentration during the time interval

FACTORS INFLUENCING PHOTOSYNTHETIC OXYGEN PRODUCTION

Solar Radiation

The total solar radiation reaching the earth's surface is the sum of direct solar radiation and diffuse radiation. After knowing beam and diffuse radiation on horizontal surface Liu and Jordan (1963) have given a formula to evaluate total radiation on a surface of arbitrary orientation:

$$I_t = I_b R_b + I_d R_d + \rho R_r (I_b + I_d) \quad (5)$$

I_t = Total solar radiation
I_b = Beam solar radiation
I_d = Diffuse solar radiation
R_b = Conversion factor for beam radiation
R_d = Conversion factor for diffuse radiation
R_r = Conversion factor for reflected radiation
ρ = Reflection for coefficient

$$R_b = \frac{\text{Cos}\,\theta_i}{\text{Cos}\,\theta_z} \quad (6)$$

$$\text{Cos}\,\theta_i = (\text{Cos}\,\phi\ \text{Cos}\,\beta + \text{Sin}\,\phi\ \text{Sin}\beta\ \text{Cos}\gamma)\ \text{Cos}\,\delta\ \text{Cos}\,\omega + \text{Cos}\,\delta\ \text{Sin}\,\omega\ \text{Sin}\beta\ \text{Sin}\gamma + \text{Sin}\delta\ (\text{Sin}\phi\ \text{Cos}\beta - \text{Cos}\,\phi\ \text{Sin}\beta\ \text{Cos}\,\gamma) \quad (7)$$

$$\text{Cos}\,\theta_z = \text{Cos}\,\phi\ \text{Cos}\,\delta\ \text{Cos}\,\omega + \text{Sin}\,\delta\ \text{Sin}\,\phi \quad (8)$$

$$R_d = \frac{1 + \text{Cos}\,\beta_i}{2} \quad (9)$$

$$R_r = \frac{1 - \text{Cos}\,\beta_i}{2} \quad (10)$$

β = Slope (angle between plane surface and horizontal)
θ = Angle of incidence
δ = Declination
γ = Angle of azimuth
ω = Hour angle
φ = Latitude

In order to determine total solar radiation on greenhouse cover. It is necessary to determine total solar radiation on each curved surface and wall of greenhouse by using Eq. 5. There are two walls and 6-curved surface (I = 8). Hence, total solar radiation on greenhouse canopy cover can be obtained by using expression

$$\text{Total solar radiation} = S(t) = \sum_{i=1}^{i=8} A_i\ I_i \tau_i \quad (11)$$

where A_i and I_i are an area of ith section and solar radiation available on ith section.

Total solar radiation on water surface is computed using Matlab 7.0 Programme.

Light Attenuation

Light intensity within the water column can be evaluated by Beer-Lambert law, where the light intensity is attenuated exponentially with depth. The light extinction coefficient is influenced by the absorption and scattering of light within the water column dissolved and suspended substances of biological and non-biological.

Light extinction coefficient can be calculated from relationship

$$I_z = I_o.\ e^{-KZ},\ \text{or}\ K = \ln I_o - \ln I_z/Z \tag{12}$$

I_Z = Light intensity at depth Z (Wm^{-2})
I_o = Photosynthetically active radiation just under water surface (Wm^{-2})
K = Light extinction coefficient (m^{-1})
Z = Depth of water (m)

Light attenuates faster in pond water with larger Ks. Only 46% of the total solar radiation is available for photosynthesis (Losordo, 1988).

The Photosynthetically Active Radiation (PAR) is calculated using

$$I_o = a \times I_t \tag{13}$$

a = Conversion factor from total solar radiation to PAR
I_t = Total solar radiation at water surface (Wm^{-2})

Photosynthetic Oxygen Production

In most aquaculture ponds phytoplankton provide the major source and sink for dissolved oxygen. Gross phytoplankton production rates are affected by many factors, including intensity of PAR, light attenuation in the water column, water temperature, pH and dissolved nutrients concentrations.

Numerous expressions relating photosynthetic oxygen production are available (Eilers and Peeters, 1988). Among these we have choosen the Smith (1936) and Talling (1957) widely employed expression to estimate the rate of phytoplankton oxygen production.

$$DO_{2P} = \frac{P_{max}}{KZ} \ln \left[\frac{I_k + \sqrt{\left(\frac{P_{max}}{\alpha}\right)^2 + I_k^2}}{I_k \exp(-KZ) + \sqrt{\left(\frac{P_{max}}{\alpha}\right)^2 + \left(I_k \exp(-KZ)\right)^2}} \right] \tag{14}$$

P_{max} = Maximum of DO production vs light curve (mg O_2 L^{-1} h^{-1})
I_k = Saturated light intensity (W m^{-2})
α = Initial slope of the DO production vs light carve (mg O_2 L^{-1} (W m^{-2}) h^{-1})

FACTORS INFLUENCING DO CONSUMPTION

Respiration

In an aquaculture pond after sunrise, DO increases due to photosynthesis, but at night, biotic respiration and chemical oxidants result in a net loss of oxygen, which can reach critically, low concentrations. Loss of oxygen from fishpond is due to fish respiration, plankton respiration, water column respiration and sediment respiration.

Phytoplankton Respiration

Photo respiration occurring during photosynthesis is used to oxidize organic components and is assumed to be proportional to gross photosynthesis.

The rate of Photo respiration is considered to be 10% of the rate of photosynthetic oxygen production (Losordo, 1988).

$$DO_{2pr} = 0.10\ DO_P \tag{15}$$

DO_{2pr} = Rate of Photo respiration

According to Boyd *et al*. (1978) respiration rate for phytoplankton can be calculated

$$DO_{2PR} = -1.133 + 0.0038 \times SDD + 0.000014 \times SDD^2 + 0.081 \times T_W - 0.000749 \times T_W{}^2 - 0.00035 \times SDD \times T_W \tag{16}$$

SDD = Secchi disc depth (m)
T_w = Water temperature (°C)

Fish Respiration

The oxygen consumption of fish is affected by many factors, including water temperature and oxygen content, carbondioxide level, size of fish, activity and photoperiod. Using respiration flasks, researchers have been able to establish relationships among various factors and minimum dissolved oxygen requirements are known for many fish species (Davis, 1975). Andrews and Matsuda (1975) studied the effect of water temperature, fish weight and dissolved oxygen on fish respiration; Boyd (1979) performed a multiple regression and developed an equation for catfish respiration using average fish weight, water temperature and dissolved oxygen as variables. These equations are:

$$DO_{2F} = F_R \times F_b \tag{17}$$

(Losordo, 1988) where

$$F_R = (10^{(X)}) \times 1000$$

(Boyd, 1990) where

$$x = -0.999 - 9.57 \times 10^{-4} \times wt + 6.0 \times 10^{-7} \times (wt)^2 + 3.27 \times 10^{-2} \times T_W - 8.7 \times 10^{-6} \times (T_W)^2 + 3 \times 10^{-7}\, wt \times T_W$$

$$F_b = \frac{F_W}{(A \times Z)} \tag{18}$$

F_w = Total fish biomass (kg)
F_b = Av. Fish biomass concentration (kg m^{-3})
A = Area of pond (m^2)
F_R = Fish respiration (mg O_2/kg/h)
wt = Av. wt. of fish (g)

Water Column Respiration

The water column respiration rate in the current model includes respiration of the phytoplankton, zooplankton respiration and respiration by suspended bacteria. Losordo (1980) found that water column respiration accounted for on average; about 60% of the overnight DO decrease in the Auburn pond could be attributed to the plankton respiration rate.

Water column respiration is calculated as:

$$DO_{2\ WCR} = DO_{2\ WCRM} \times 1.049^{(T_w - T_m)} \times 1000 \quad (19)$$

DO_{2WCRM} = Measured water column respiration rate (mg O_2 L^{-1} h^{-1})
T_m = Temperature (°C) at which water column respiration rate was measured

Sediment Respiration Rate

Sediment respiration in the DO model includes decaying phytoplankton; unconsumed fish feed and fish waste products, which require oxygen to decompose. The night dissolved oxygen decline estimation for water column respiration rates are considered to include that respiration exhibited by the pond bottom sediments as well. When dissolved oxygen fall below a certain threshold value (1.0 mg L^{-1}) sediment respiration was assumed to decline to zero.

Sediment respiration is calculated as (Losordo, 1988)

$$DO_{2SR} = (DO_{2MSR} \times 1.065^{(T_w - T_m))/T_{hs}} \quad (20)$$

DO_{2MSR} = Measured sediment respiration rate at measured temp (mg O_2 L^{-1} h^{-1})
T_{hs} = Thickness of sediment (m)

MATERIALS AND METHODS

Experimental Greenhouse

The experiment was conducted in a low cost Quonset shape greenhouse (modified IARI model) having length 4.5 m, width 3.0 m and central height of 2.0 m. The effective floor area of greenhouse enclosure is 13.5 m^2. The total surface area of UV stabilized canopy cover (0.2 mμ) is about 38 m^2. The orientation of the greenhouse was from east to west direction in order to allow maximum solar radiation inside greenhouse during winter season. The volume of the greenhouse enclosure was 19 m^3. The frame of the greenhouse was constructed from Aluminum flat and is covered by UV stabilized low density polythene film.

Experimental Set Up

The experiment was carried out at Solar Energy Park, IIT Delhi (Latitude - 28°35′, Longitude- 77°12′E and an altitude of 216 m above mean sea level). One rectangular low cost pond of size (4×2 m) was constructed having a surface area of 8 m^2 and an average depth of 1m. The effective water volume is 8 m^3 with water depth level maintained at 1 m. The pond was filled with oxygenated ground water. Aeration was not provided during the study period. The pond was prepared as per the recommended practices (APHA, 1992). For healthy phytoplankton production 8 g/8 m^3 single super phosphate was added to both the ponds every fortnightly. The pond was stocked with 40 No. Indian Major Carp such a *Catla catla* (av. wt. 2.45±0.27 g; av. length 74±3 mm) and *Labeo rohita* (av.wt. 2.53±0.19 g; av. length 76±2 mm) in the ratio of 3:1 in each pond. The fish were fed primarily with supplementary feed (ground nut oil cake 50 and rice bran 50%) at the rate of 2% live fish biomass twice a day throughout the 150 days experimental period. Water samples were analyzed by standard methods (APHA, 1992). The fish sampling was done once in 15 days interval throughout the experimental period to measure length and weight for each species.

Data Collection

During the experimentation solar radiation (total and diffuse) on a horizontal water surface on an hourly basis was measured by a dataloger model R10 (least count ±10 W m^{-2}) provided with probes. The data loger was fitted with IBM type PC for further processing using MATLAB 7 software. The average radiation based on 10 h duration sunshine was taken into consideration. Water temperature at surface (0 to 4 cm) was measured with the help of calibrated thermocouples on an hourly basis. Dissolved oxygen was measured at hourly intervals from sunrise to next day until after sunrise (Until DO started to increase) from four sites in the water column. DO was measured using an YSI model 54 oxygen meter (least count ±0.1 mg L^{-1}) with a field probe with stirrer. The wind velocity inside greenhouse was measured with a portable digital anemometer with least count is 0.1 m sec^{-1}. Data were analyzed using the Statistical Analysis System (SAS) package (1982). Secchi disc transparencies were estimated with a 20 cm diameter disk with alternate black and white quardrants. The measurements were taken between 8:00 and 8:30 h and adjusted to midday values with a correction factor computed from data presented by Almazan and Boyd (1978). The Secchi disc is lowered to the point where disappears and rose until it just reappears. The average of those two depths is called Secchi disc depth (SDD). Once a day at 11:00 h a water sample was taken from pond for measurement of chlorophyll-a. The absorbance of the chlorophyll-a extract was read on a Beckman DU-7 spectrophotometer. From absorbance chlorophyll-a was estimated by Jeffrey and Humphrey (1975). Water samples were poured into 300ml BOD bottles (three replicates) and incubated in the dark for 4 h. Respiration rate was calculated by measuring oxygen levels before and after incubation for a known period of time. DO was measured using a YSI model 54 oxygen meter with a BOD probe equipped with a stirrer.

The sediment cores with overlying water are collected in glass tubes with rubber corks and their oxygen contents measured. After a given period of incubation, the oxygen levels are again measured and the differences between the two indicate the sediment oxygen consumption rates. All experimental data (water temperature, solar radiation, dissolved oxygen, secchi disc depth, phytoplankton biomass and chlorophyll-a content) were measured from four sides of the ponds and taken average value.

Statistical Analysis

Coefficient of Correlation (R)

When predicted values are validated with the experimental data then correlation between predicted and experimental values is presented with a coefficient known as coefficient of correlation. The coefficient of correlation can be evaluated with the following expression (Chapra and Canale, 1989).

$$R = \frac{N\sum x_i y_i - \sum(x_i)\sum(y_i)}{\sqrt{N\sum x_i^2 - \left(\sum x_i\right)^2}\sqrt{N\sum y_i^2 - \left(\sum y_i\right)^2}} \quad (21)$$

R = Coefficient of correlation

Root Mean Square of Percent Deviation (e)

The prediction is done with the help of thermal modeling. The predicted values are validated with experimental data. The closeness of predicted values and experimental data can be presented in terms of root mean square of percent deviation. The expression used for this purpose is as follows (Chapra and Canale, 1989).

$$e = \sqrt{\frac{\sum(e_i)^2}{n}} \quad (22)$$

where,
$$e_i = \frac{X_{pred} - Y_{exp}}{X_{pred}}$$

e = Root mean square of per cent deviation

RESULTS AND DISCUSSION

The developed Dissolved oxygen model has been solved with the help of a computer program based on Excel software. To verify the accuracy of the developed model, experimental validations were conducted for a typical winter day, 10th January, 2007. The hourly variation of total solar radiation, dissolved oxygen, phytoplankton concentrations, temperature and secchi disc depth were used as inputs to calibrate the DO model. The coefficients and constants were used during model calibration are presented in Table 1. The equations describing solar radiation Eq. (5-11) are based in theoretical and experimental basis and it has been applied to calculate total solar radiation falling on greenhouse fishpond water surface.

From the Fig. 1 it is seen that maximum solar radiation occurs at 12.00-13.00 h. The photosynthetic oxygen production is plotted against PAR of the greenhouse pond during sunshine hours in Fig. 2.

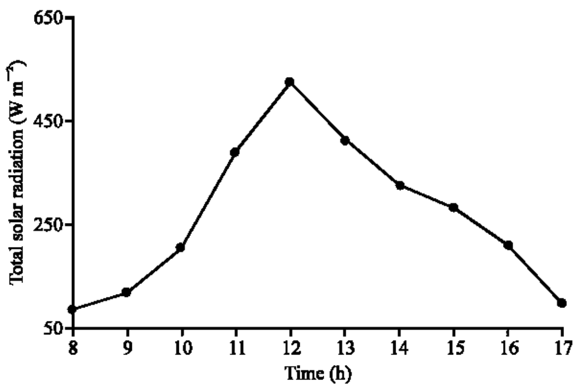

Fig. 1: Hourly variations of total solar radiation (W m^{-2}) during sunshine hours in pond water surface

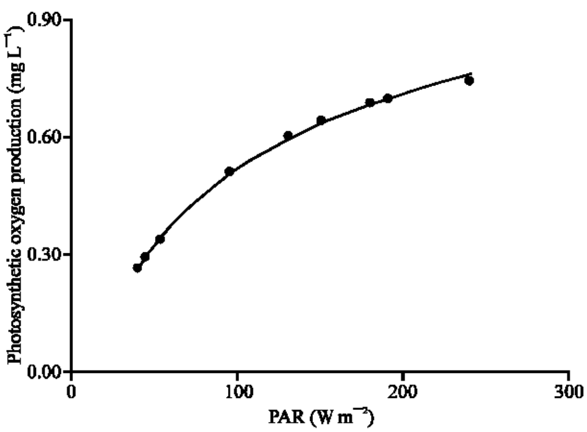

Fig. 2: Relation between photosynthetic oxygen production and photoactive solar radiation (PAR, W m^{-2}) during sunshine hours

Table 1: Model parameters used for computation

Parameters	Value	Parameters	Value
Modeling date	10th January, 2007	I_k	80 (W m^{-2})
A	8 (m^2)	T_w	19.4°C
Z	1 (m)	Wind speed	Negligible
Chl-a	232 (μg L^{-1})	Initial DO	6.32 (mg L^{-1})
SDD	0.31 (m)	wt	18.47 (g)
K	0.88 (m^{-1})	Fw	0.761 (kg)
PHY	15.51 (mg L^{-1})	γ	0.46
Initial slope (α)	0.0085 (mg O_2 L^{-1}(W m^{-2}) h^{-1})	τ	0.65
P_{max}	0.78 (mg O_2 L^{-1} h^{-1})		

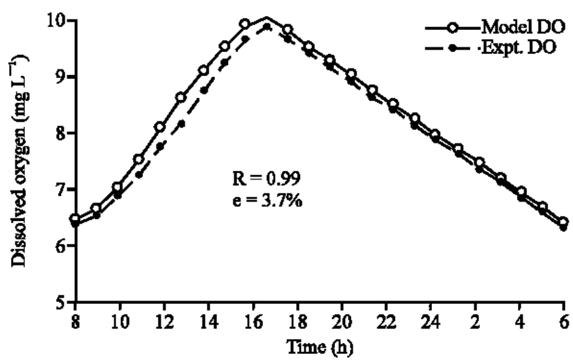

Fig. 3: Predicted model and experimental dissolve oxygen profiles in greenhouse fishpond

Linear regression analysis showed that the model derived from Smith (1936) and Talling (1957) fitted the experimental data very well with coefficients of determination. It was positively correlated with solar radiation and maximum production was at higher solar intensity. The pond DO concentration increases as the phytoplankton produce more oxygen through photosynthesis than is consumed through respiration and decay. The phytoplankton photosynthesis decreases as the intensity of the solar radiation decreases in the late afternoon. Algae respond to the daily solar radiation and will reach their maximum rate of photosynthesis at a light intensity, which is a function of the daily solar radiation (Iohimura, 1960).

From the Fig. 3, it is noted that the DO reaches its maximum between 15:00 to 17:00 of sunshine hours, while the minimum values were observed at dawn between 5:00 to 7:00 h. The hourly predictions of DO concentrations are very close to the experimental values. The predicted DO exhibited good agreement with the values of coefficient of correlation r = 0.99 and root mean square percent deviation e = 3.73%. In the morning hours the pond DO is falling due to the phytoplankton, fish respiration and detrital decay.

The model output has good correlation with the experimental data at a correlation coefficient of (0.98). Such an agreement of the predicted model data and that of the actual experimental data indicate that the rates and constants used in the development of the model are valid for a description of the processes of utilization and production of DO (Fig. 4).

Simulations were carried to present the effect of pond depth such as 0.5, 1.0 and 1.5 m and SDD of 0.5, 1.0 and 1.5 m on DO production with constant phytoplankton Chl-a concentration of 232 μg L^{-1}. For the pond with the simulated depth of 0.5m where SDD is 0.25 m produces better results in terms of maximum DO production compared to 0.5 m SDD during 24 h cycles (Fig. 5). Increasing the SDD resulted in a drop in phytoplankton concentration and overall drop in DO production. Therefore, DO concentrations in the 0.5 m deep pond with a SDD of 0.5 m were lower than 0.25 m SDD (Fig. 5).

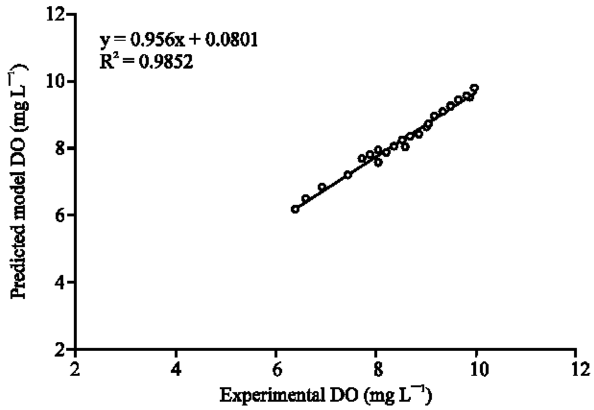

Fig. 4: Linear regression analysis of experimental and predicted model DO for greenhouse fishpond

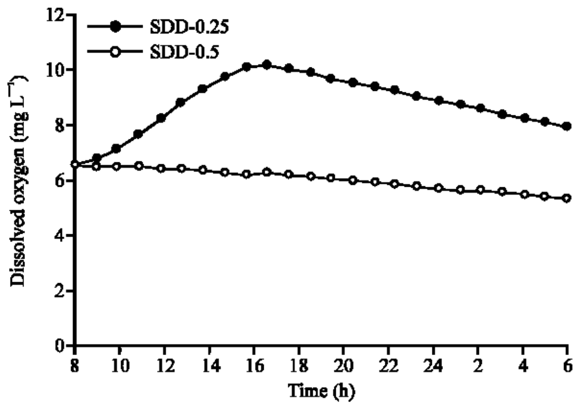

Fig. 5: Effect of SDD on dissolved oxygen in greenhouse pond of 0.5 m depth

For the pond of simulated depth equal to 1.0 m and SDD of 0.25 m yields most satisfactory DO concentration than 0.5 m and 1.0 m SDD. For 0.25 m SDD dissolved oxygen difference between sunshine hours and off sunshine hours is comparatively more than 0.5 m and 1.0 m SDD. Dissolved oxygen concentrations in the 1.0 m pond was lowest for 0.5 m SDD and enhanced slightly when SDD increases to 1.0 m (Fig. 6). Increase in DO production caused by the rise in light penetration with the same phytoplankton concentrations of 232 μg L^{-1} Chl-a and with same fish and sediment respiration in both the ponds.

Dissolved oxygen production in the 1.5 m pond was lower throughout the 24 h cycles for all SDD (0.5, 1.0 and 1.5 m) values due to low phytoplankton Chl-a concentration (Fig. 7). DO concentration was not reached above 7.5 mg L^{-1} and drops to 6.3 mg L^{-1} at the end of the 24 h simulation. The low DO values in the shallow pond (0.5 m) with a high SDD (0.5 m) when compared to other ponds with SDD equal to their pond depths (Fig. 6 and 7), was the result of the low overall oxygen production relative to the sediment and fish respiration.

It can be shown from Fig. 8 that with increase of light extinction (0.25, 0.50, 1.0 and 1.5) coefficient, pond DO production level also decreases.

The effect of water temperature (10, 15, 20 and 25°C) on DO level (Fig. 9) shows that during sunshine period there was a slight DO difference observed but off sunshine period significant DO difference prevailed due to higher respiration rate. Respiration rate increases with increase in water temperature.

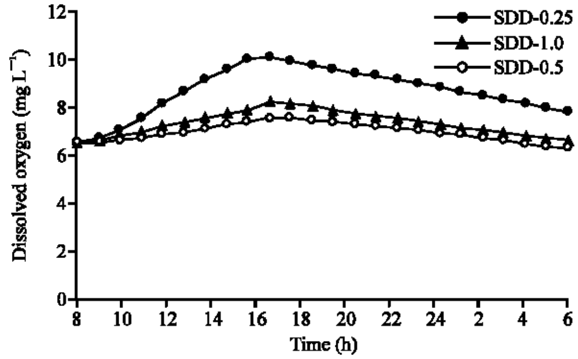

Fig. 6: Effect of SDD on dissolved oxygen in greenhouse pond of 1.0 m depth

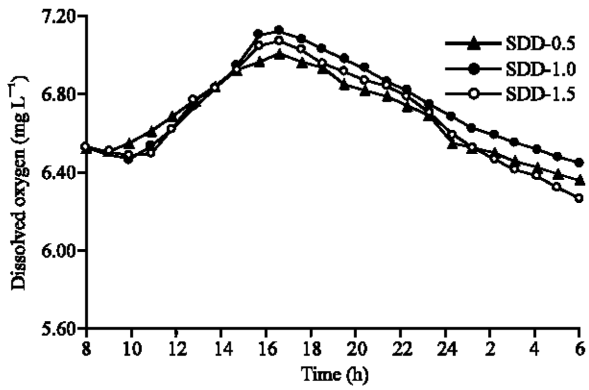

Fig. 7: Effect of SDD on dissolved oxygen in greenhouse pond of 1.5 m depth

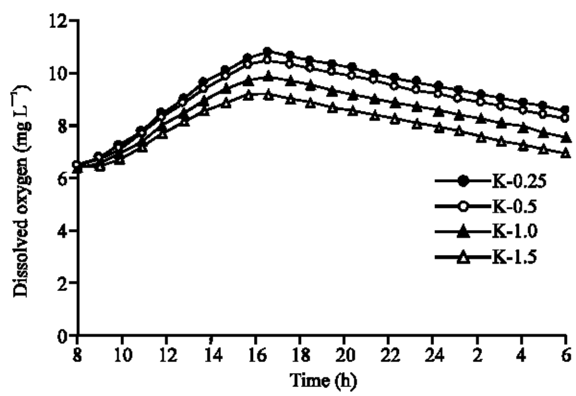

Fig. 8: Effect of Extinction coefficient (K) on DO level in greenhouse pond

Figure 10 represents that pond DO level reduces with increase of fish yield due to increase of respiration rate by fish.

The relation between oxygen production and consumption with the increase in Chl-a concentration show that the production and consumption of oxygen were linearly correlated with the increase in Chl-a concentration (Fig. 11). This model predicts that intermediate algal densities

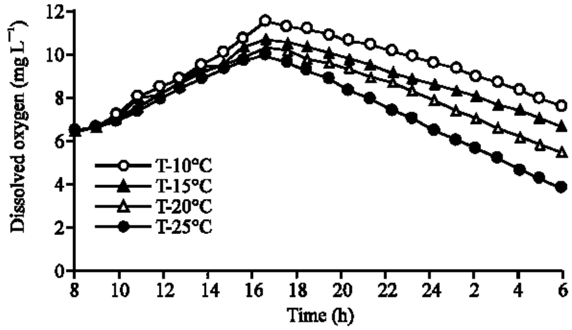

Fig. 9: Effect of water temperature on DO level in greenhouse pond

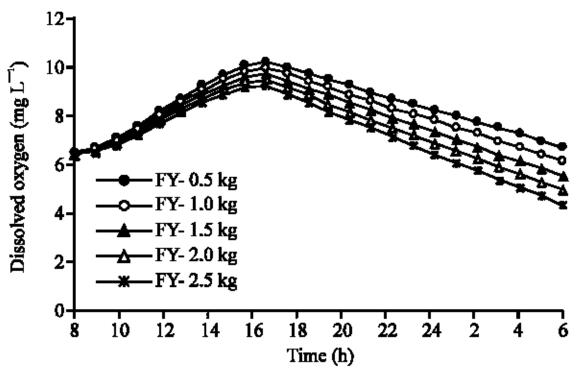

Fig. 10: Effect of dissolved oxygen on fish yield in greenhouse pond

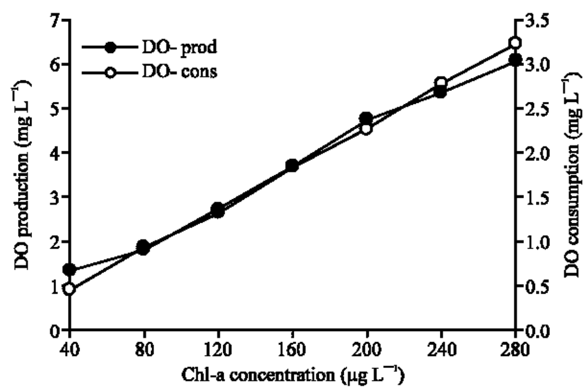

Fig. 11: Relation between oxygen production and oxygen consumption with chlorophyll-a concentrations

(232 μg L^{-1} Chl-a) produce the highest levels of DO at dawn. Romaire and Boyd (1979) reported intermediate algal densities i.e., 250 mg m^{-3} Chl-a produce the highest levels of DO at dawn. The average concentrations of phytoplankton algal biomass in greenhouse pond was 15.51 mg L^{-1}. Based on DO model, the computed value of DO produced 0.35 mg DO/mg dry algae, which is equivalent to

23.15 mg DO/mg Chl-a. This parameter helps an aquaculturist to determine DO from dry weight or Chl-a. Kayombo *et al.* (2000) obtained a rate of DO production 1.59 mg mg^{-1} of dry algal biomass in waste stabilization pond.

CONCLUSIONS

On the basis of the present study it can be concluded that the developed computer model in this study is quite simple and reliable to predict the DO concentrations for greenhouse pond. This model is valid for new greenhouse pond, but it may be extended to old greenhouse pond. Solar radiation sub model provides an effective means of using limited data to estimate total solar radiation in greenhouse system. It may suggest that for a balanced system, the amount of DO produced by the photosynthesis process is enough to keep the system healthy. Oxygen was utilized mainly due to plankton respiration. Model outputs resulted simple changes in pond management parameters such as pond water depth and secchi disc depth. DO concentrations in the pond varied with both pond depth and SDD. Dissolved oxygen calculation method is relatively simple and easy to couple with a water quality model. Overall, this model is very useful to determine DO concentrations from algal photosynthetic performance in different pond conditions.

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