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Maloth Mohan
College of Fishery Science-Pebbair, PVNR Telangana Veterinary University, Hyderabad, Telangana, India

Gora Shiva Prasad
Faculty of Fishery Sciences, WBUAFS, Kolkata, West Bengal, India

Rajesh Kumar Dash
ICAR- Central Institute of Fisheries Education, Versova, Mumbai, Maharashtra, India

Kakani Vijay Prakash
SMS (Animal Husbandry), Dr. KL Rao KVK, ANGRAU, Garikapadu, Andhra Pradesh, India

Nur Mohammed Mollah
ICAR- Central Institute of Fisheries Education, Versova, Mumbai, Maharashtra, India

Pabitra Barik
College of Fisheries, Kawardha, Chhattisgarh, India

Varadaraju S
College of Fisheries, Mangalore, Karnataka, India

Corresponding Author:
Maloth Mohan
College of Fishery Science-Pebbair, PVNR Telangana Veterinary University, Hyderabad, Telangana, India

Fabricated aerators influence on oxygen dissolution in pond water during day and nighttime

Maloth Mohan, Gora Shiva Prasad, Rajesh Kumar Dash, Kakani Vijay Prakash, Nur Mohammed Mollah, Pabitra Barik and Varadaraju S

Abstract
Dissolved oxygen is the single most important water quality parameter, which makes shrimp or fish survive in the water and makes aquaculture production possible with high stocking and feeding rates. The major sources of oxygen in ponds are phytoplankton photosynthesis and mechanical aeration. Aeration can increase the carrying capacity of an aquaculture system. Mechanical aeration is applied to avoid nighttime dissolved oxygen concentrations from falling below the critical level for fish of 2 mg/L. Oxygen is essential for the production of all species of fish and shellfish. The cost of the mechanical aerators is more and it requires more operational and maintenance costs. The present study few conventional aerators were designed and fabricated such as three-tier perforated tray aerator, cascading wooden plank aerator, rotating wheel aerator and vertical perforated cylindrical aerator. Using these fabricated aerators, experiments were conducted in the ponds to check their dissolution of oxygen rate during the day and nighttime. Overall, results show that in shallow ponds, aeration during the day yields better results than during the night, as it increases oxygen concentration throughout the water column.

Keywords: Dissolved oxygen, mechanical aerator, fabricated aerators

Introduction
Dissolved oxygen (DO) is the most important and critical water quality parameter for success of an aquaculture operation. Aquatic organism constantly requires DO for survival and growth. The atmosphere is the main reservoir of oxygen (21%) but as oxygen is slightly soluble in water and hence the rate of direct diffusion is very slow. Oxygen dissolves in water mainly through diffusion from the atmosphere and produced during photosynthesis by aquatic plants and algae. In natural waters DO produced usually exceeds the amount required by respiration and decomposition. However, in an aquatic pond the total biomass in the form of fishes, plants, microbes and organic matters are much higher than in natural water and oxygen is exhausted faster than it produced. Apart from above, the other environmental factors like pressure, salinity and temperature are also play important roles in dissolution of DO in water. Dissolved oxygen (DO) plays a big role in aquaculture production. Stress is indicated at 1.4 mg/L of DO (Felix, 2009) [8]. The Dissolved oxygen at 4 or 5 mg/L or greater is taken into account as ideal in aquaculture production (Robertson, 2006; Boyd, 2003) [16, 5].In general, values below 2.0 mg/L are related to restricted growth and high mortality risk (Ferreira, Bonetti, Seiffert, 2011) [9]. Low dissolved oxygen within the water can cause anoxia, slow growth, and death in shrimp and fish. Low levels of oxygen concentration are visiting be caused by reasonable reasons (Robertson, 2006; Boyd, Tucker, 1998) [16, 4]. Those are dissolved oxygen decreases with the rise of temperature and salinity, Aquatic plants die due to excessive usage of herbicides (Ferreira, Bonetti, Seiffert, 2011;Boyd, Tucker, 1998) [9, 4] and this might cause a shortage of dissolved oxygen, Dissolved oxygen normally decreases during dark. During the day, algae and plankton photosynthesize (with sunlight) and make oxygen dissolved in water. The absence of sunlight in the dark prohibits photosynthesis activities. Algae and aquatic plants' respiration continue within the dark despite the dearth of photosynthesis. This lands up in reduced oxygen levels. An analogous situation can occur on days without sunlight or with overcast weather and rain. If caused by reason, normally dissolved oxygen is increased by employing a paddlewheel aerator or aeration blower. Just in case of reason water exchange is another common practice. As mentioned in (FAO, 2019) [7]. The dissolved oxygen level of incoming water is additionally enhanced if ripples are built into gravity inflow channels and water is injected into the ponds above water level. Daily water exchange of 15–70% of pond volume traditionally has been aware of reducing BOD

loading to assist maintain appropriate DO concentrations (Hopkins *et al*., 1993) [11] Aeration has been accustomed improve water quality and increasing yields in aquaculture ponds. Aeration is a potential mechanism of aquafarming to enhance dissolved oxygen and thereby enhance growth and production of fish at higher stocking densities (Sultana *et al.*, 2017) [17]. Surface agitation by wind or other means that mixes air and water together is the most effective way to add atmospheric oxygen into the water column. Aeration may also be a suitable method for managing thermal stratification (Miles, West, 2011) [15]. Circulation of pond water by aerators also facilitates mixing of pond water and thereby reducing vertical stratification of temperature and chemical substances (Boyd, Martinson, 1984; Boyd, 1998) [2, 6]. In general aerators work mainly on two principles: (1) aeration by splashing water into air i.e. paddle wheel aerator, vertical pump, pump sprayer, gravity aerators etc. or (2) aeration by bubbling air into water i.e. propeller aspirator, diffused aeration system etc. (Kumara *et al*., 2013) [13]. Most of these aerators are operated by electricity. However, many fish culture practices are located in remote areas where there is no continuous supply of electricity and prevents the farms from the use of aerator as it needs for intensification. Hence, low cost fabricated aerator can be highly beneficial to these remote areas. In this study, the effect of daytime and nighttime aeration with low cost fabricated aerator on temperature and dissolution of dissolved oxygen concentration in ponds was analyzed and compared to results from the identical ponds without aeration.

Materials and Methods

The present research was conducted at the Research and Instructional Fish Farm of the College of Fisheries, Mangaluru. Three uniform square-shaped cement ponds of the size (5 × 5 × 1 m) were selected for conducting the experiment. Four aerator designs namely i) Three-tier perforated tray aerator, using the GI (Galvanized Iron) perforated sheets, a three-tier perforated tray aerator designed with a dimension of 85 × 85 × 5 cm were fabricated. ii) Vertical perforated cylindrical aerator, design is made from a perforated Galvanized Iron (GI) sheet of size 38 cm and diameter of 11 cm. Bottom of the design is connected to the water supply pipe with the help of an elbow and the other end of the design is closed with a sheet. iii) Rotating wheel aerator, the design was made with wooden planks of size 40 × 30 × 2 cm. Four wooden planks were fitted to GI (Galvanized Iron) pipe of diameter 1.25 cm and length of 80 cm. The two ends of the GI (Galvanized Iron) pipe were fitted with bearings for easy rotation of wooden planks and iv) Cascading wooden plank aerator, design was made with a wooden plank of size 95 × 85 × 2 cm. The rectangular shaped wooden pieces of size 85 × 2 × 7 cm were inclined in such a manner to create a cascading effect of flow of water. These four types of aerators are planned, designed, and fabricated. Each aerator design was fabricated in triplicate. These aerators were used to find out the oxygen dissolution in the pond water during the day and nighttime. The oxygen-transfer tests were performed in a pond (without a soil base). These tanks were initially drained completely and cleaned neatly the sides and bottom of the tank. These tanks were filled with fresh water up to the level of 0.5 m depth. One side of the tank is provided with an outlet for draining out the water whenever required. Before each test, the pond was deoxygenated with sodium sulfite and cobalt chloride. The chemicals were dissolved in water, splashed over the pond surface, and mixed throughout the pond volume with an aerator. Two sampling points were taken in the test basin. Sampling points are recommended at several depths (near the surface, bottom, and at mid depth) within the basin. The sampling points should be located away from the walls and floor of the tank. A greater number of sampling points may be needed for a complex aeration system (ASCE, 1983) [1]. After 20-30 minutes of mixing the DO of the tank water was measured and ensured to be less than 0.5 mg/l. The aerator is turned on to increase the DO concentration of the tank water. Then dissolved oxygen readings are taken simultaneously at regular intervals with a polarographic DO meter while the DO increases to at least 90% saturation. Three oxygen-transfer trials were conducted for each aerator. To find out the dissolution of oxygen into pond water experiments have been carried out with and without using aerators during the day and nighttime. During daytime initial temperature and dissolved oxygen concentration were measured, then the aerators are turned on. The dissolved oxygen concentration was measured simultaneously at timed intervals of (0, 30, 60, 90, 120, 150, 180, and 210 minutes). The same procedure was also followed in the evening time to find out the dissolution of oxygen in the pond water.

Statistical analysis

The data obtained from this research work were analysed statistically using Microsoft Excel, 2016. The linear regression was used to determine the slope of the K_La value of aerators Microsoft corporation, WA.

Experimental results

Plants growing in water produce oxygen by photosynthesis and thru daytime plants in aquaculture, ponds often produce oxygen so fast that DO concentration in water rises above saturation. Water also may contain less DO than expected at saturation. At night, respiration by fish, plants, and other pond organisms causes DO concentrations less. With this background, the experiment has been disbursed to review the dissolution of oxygen within the pond water during the day and nighttime.

Dissolution of oxygen without using aerator during daytime

At the beginning of the experiment dissolved oxygen content of water was 6.95 mg/l, 6.19 mg/l, and 7.15 mg/l in ponds W_1, W_2, and W_3 respectively. The dissolved oxygen content of the pond water increased slowly during the experiment and eventually it reached the value of seven.6.3 mg/l, 7.26 mg/l, and 7.76 mg/l within the above ponds. An increase in dissolved oxygen content of the pond water is shown in Fig.1.

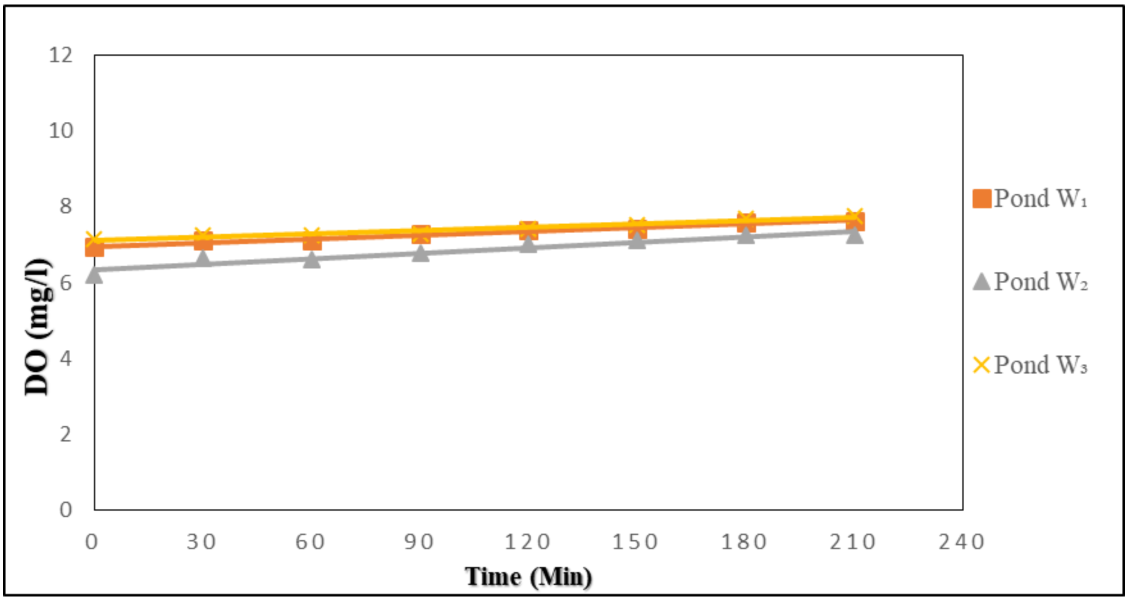

Fig 1: Increase of dissolved oxygen content during daytime (Without using aerators)

Dissolution of oxygen without using aerator during nighttime

The dissolved oxygen content in the ponds water measured in the beginning of the experiment were 8.43 mg/l, 8.58 mg/l and 8.73 mg/l in ponds W_1, W_2 and W_3 respectively. The dissolved oxygen content gradually decreased until it reaches the final values of 7.08 mg/l, 6.99 mg/l and 7.17 mg/l in the above ponds respectively. Dissolved oxygen content decreases in the pond water shown graphically in the Fig.2.

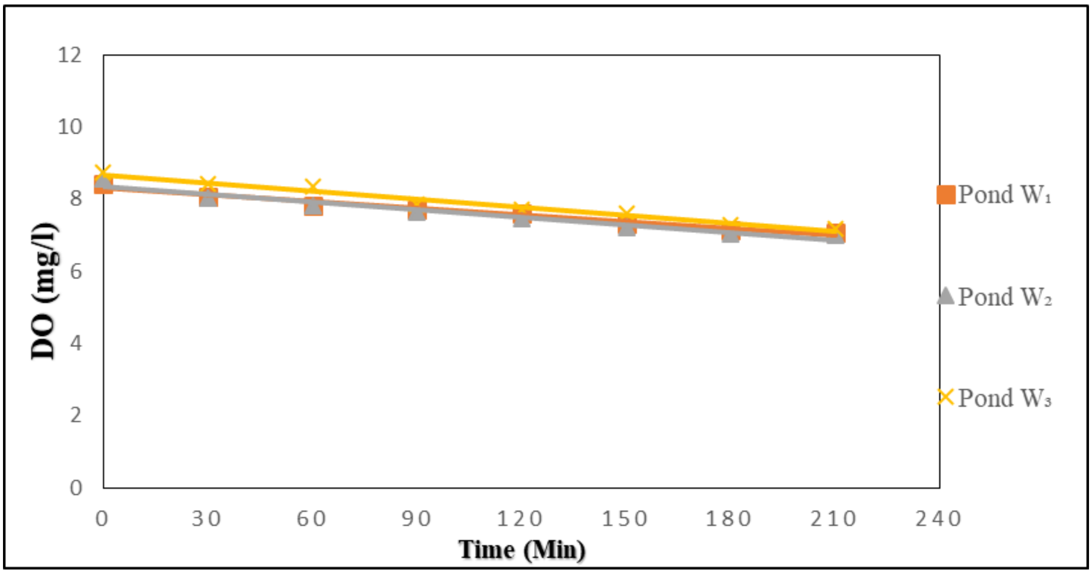

Fig 2: Decrease of dissolved oxygen content during nighttime (Without using aerators)

Dissolution of oxygen using rotating wheel aerators during daytime

The DO content initially measured were 6.71 mg/l, 6.66 mg/l, and 6.43 mg/l in ponds R1, R2, and R3 respectively. Rotating wheel aerators were used to increase the DO content of the pond water, initially DO concentration of pond water increased faster rate, slowly increased after some period, and finally it reached the values of 8.02 mg/l, 7.79 mg/l, and 7.87 mg/l in the above ponds respectively. An increase in dissolved oxygen content of the pond water is shown in Fig.3.

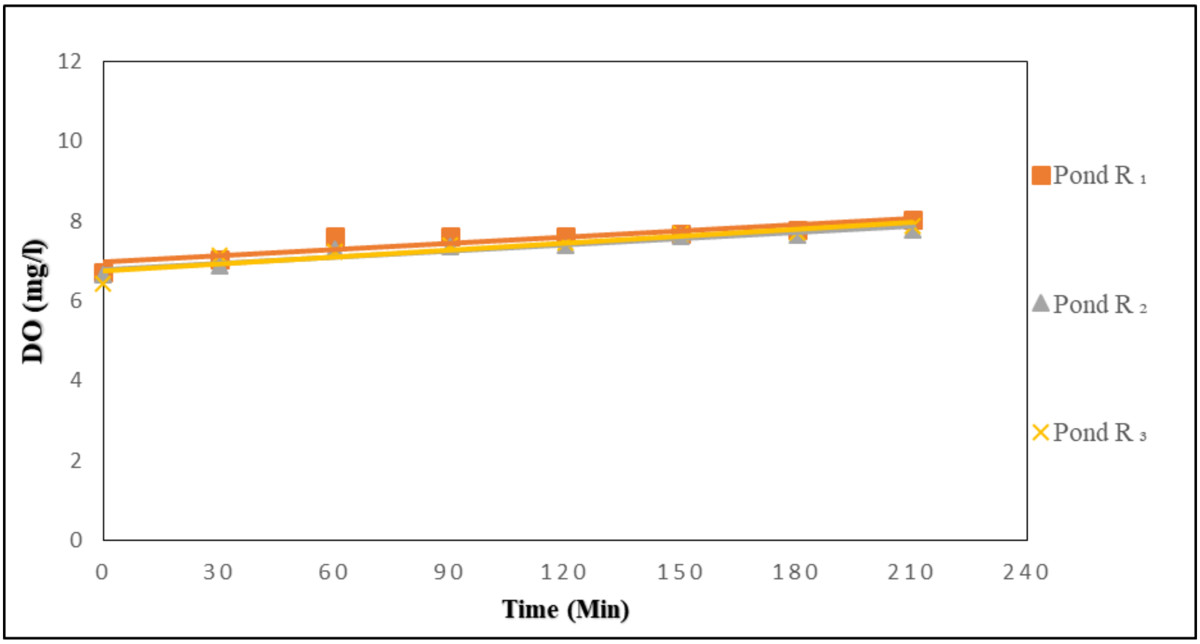

Fig 3: Increase of dissolved oxygen content during daytime (Rotating wheel aerators)

Dissolution of oxygen using rotating wheel aerators during nighttime

The dissolved oxygen content observed in the ponds water was 9.68 mg/l, 10.16 mg/l, and 10.32 mg/l in ponds R_1, R_2, and R_3 respectively at the beginning of the experiment. The dissolved oxygen content decreased gently during the study period and finally, it reached the values of 7.36 mg/l, 7.37 mg/l, and 7.42 mg/l in the above ponds correspondingly. The reduction in dissolved oxygen content of the pond water is depicted graphically in Fig.4.

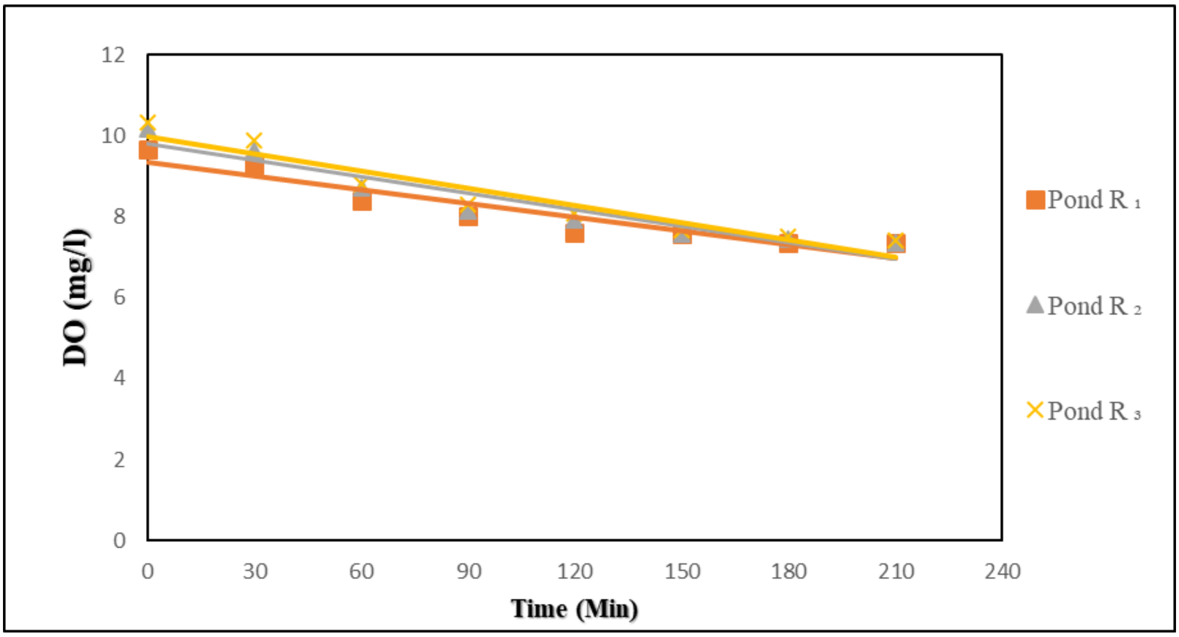

Fig 4: Decrease of dissolved oxygen content during nighttime (Rotating wheel aerators)

Dissolution of oxygen using three-tier perforated tray aerators during daytime

The dissolved oxygen content in the pond water was observed initially as 7.05 mg/l, 6.90 mg/l, and 6.79 mg/l in ponds T_1, T_2, and T_3 separately. The dissolved oxygen content increased gradually during the experimental period and finally, it reached the values of 8.43 mg/l, 8.48 mg/l, and 8.45 mg/l in the above-mentioned ponds respectively. The increase in dissolved oxygen content of the pond water is portrayed graphically in Fig.5.

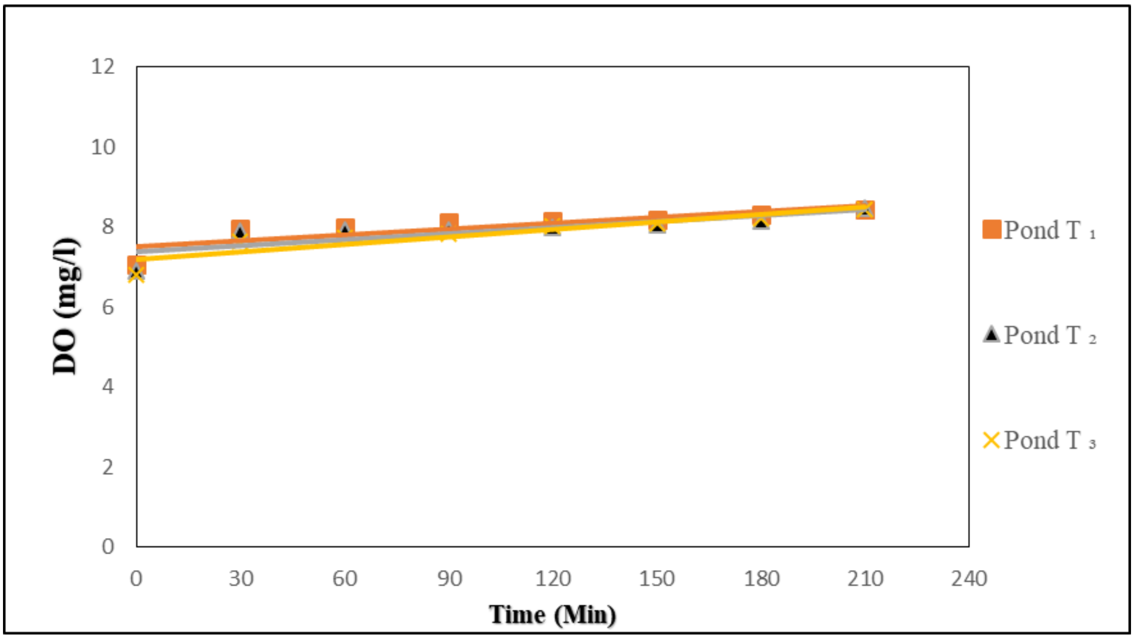

Fig 5. Increase of dissolved oxygen content during daytime (Three tier perforated tray aerators)

Dissolution of oxygen using three tier perforated tray aerators during nighttime

The DO content initially recorded as 8.52 mg/l, 8.51 mg/l and 9.68 mg/l in ponds T_1, T_2 and T_3 individually. During the experimental period it was observed that the dissolved oxygen content decreased gently until it reached the final values of 6.47 mg/l, 6.28 mg/l and 6.73 mg/l in the above ponds. Decrease in dissolved oxygen content of the pond water shown in the Fig.6.

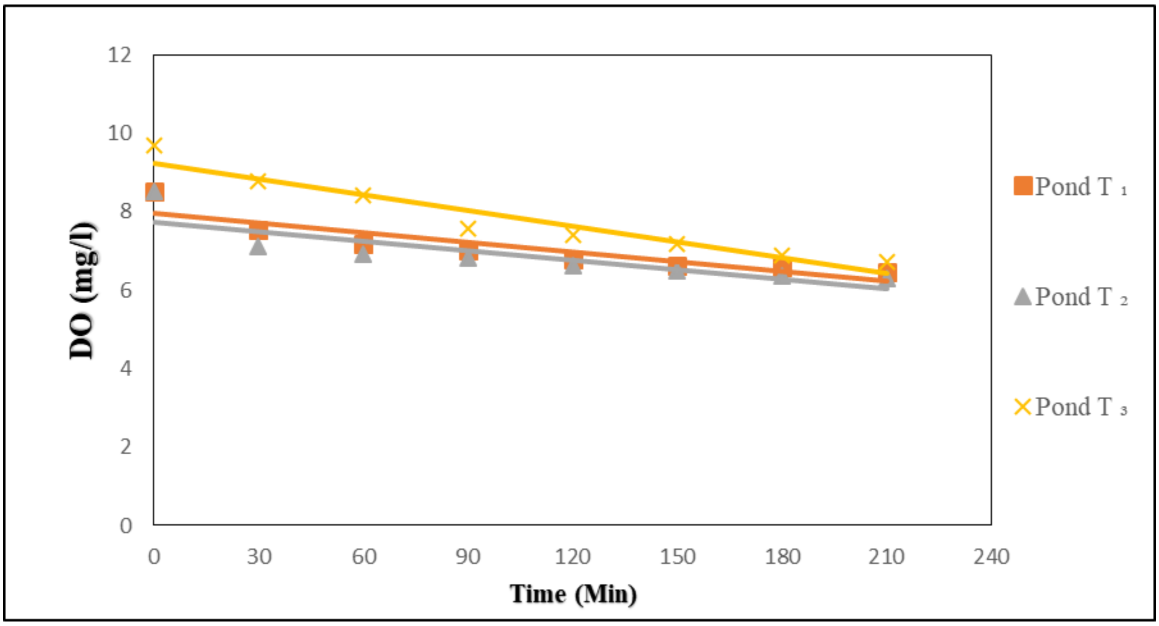

Fig 6: Decrease of dissolved oxygen content during nighttime (Three tier perforated tray aerators)

Dissolution of oxygen using vertical perforated cylindrical aerators during daytime

Initially dissolved oxygen content of water was 6.60 mg/l, 6.43 mg/l, and 6.57 mg/l in ponds V_1, V_2, and V_3 respectively. By using the vertical perforated sheet aerator DO concentration of pond water increased slowly during the experimental period and finally it reached the values of 8.00 mg/l, 8.04 mg/l, and 8.03 mg/l in the above-mentioned ponds respectively. The rise in dissolved oxygen content of the pond water is represented graphically in Fig.7.

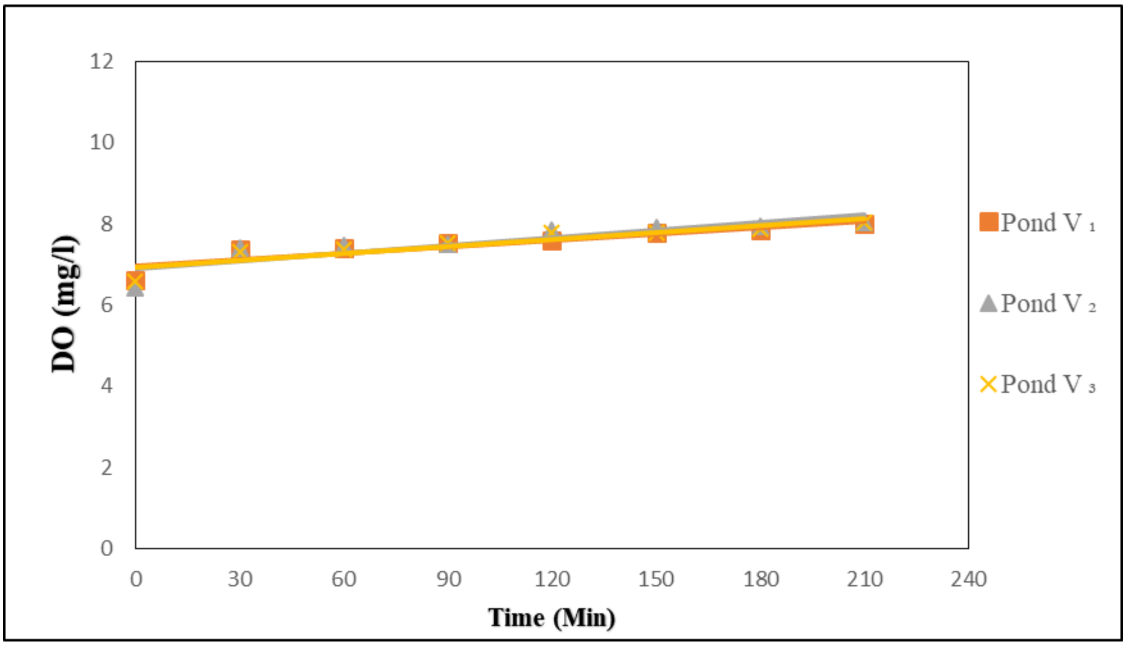

Fig 7. Increase of dissolved oxygen content during daytime (Vertical perforated cylindricalaerators)

Dissolution of oxygen using vertical perforated cylindrical aerators during nighttime

In the beginning, the dissolved oxygen content of water was 10.27 mg/l, 10.48 mg/l, and 10.34 mg/l in ponds V_1, V_2 and V_3 individually. It was noticed that during the study period the dissolved oxygen content decreased gently until it reached the final values of 7.64 mg/l, 7.39 mg/l, and 7.51 mg/l in the above ponds respectively. A decrease in dissolved oxygen content of the pond is depicted graphically in Fig.8.

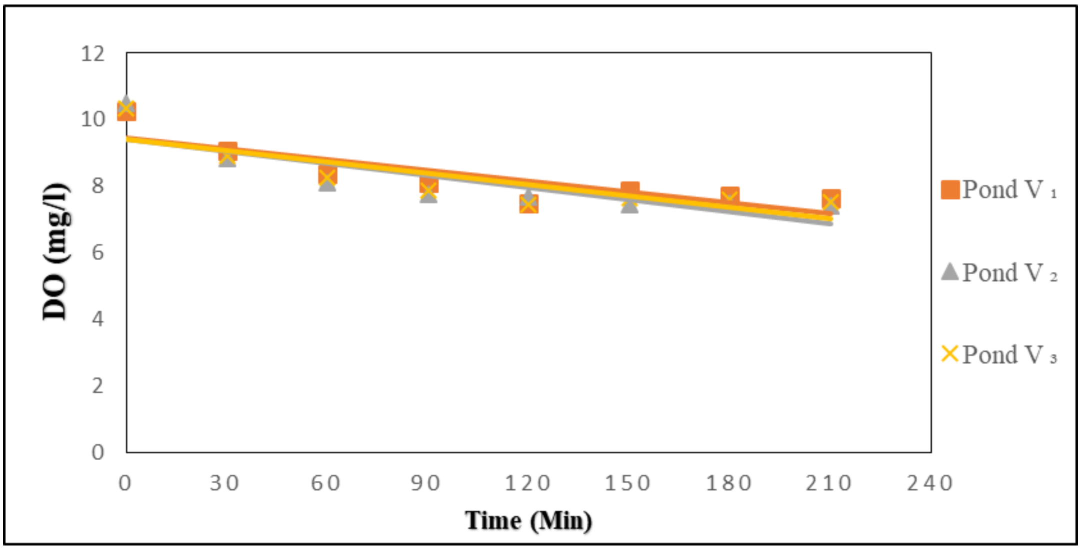

Fig 8: Decrease of dissolved oxygen content during nighttime (Vertical perforated cylindrical aerators)

Dissolution of oxygen using cascading wooden plank aerators during daytime

The dissolved oxygen content of water was observed as 6.32 mg/l, 6.47 mg/l, and 6.45 mg/l in ponds C_1, C_2, and C_3 separately in the beginning. The dissolved oxygen content increased gradually and finally, it reached the values of 7.99 mg/l, 7.79 mg/l, and 7.93 mg/l in the above-mentioned ponds respectively. An increase in dissolved oxygen content of the pond's water is represented graphically in Fig.9.

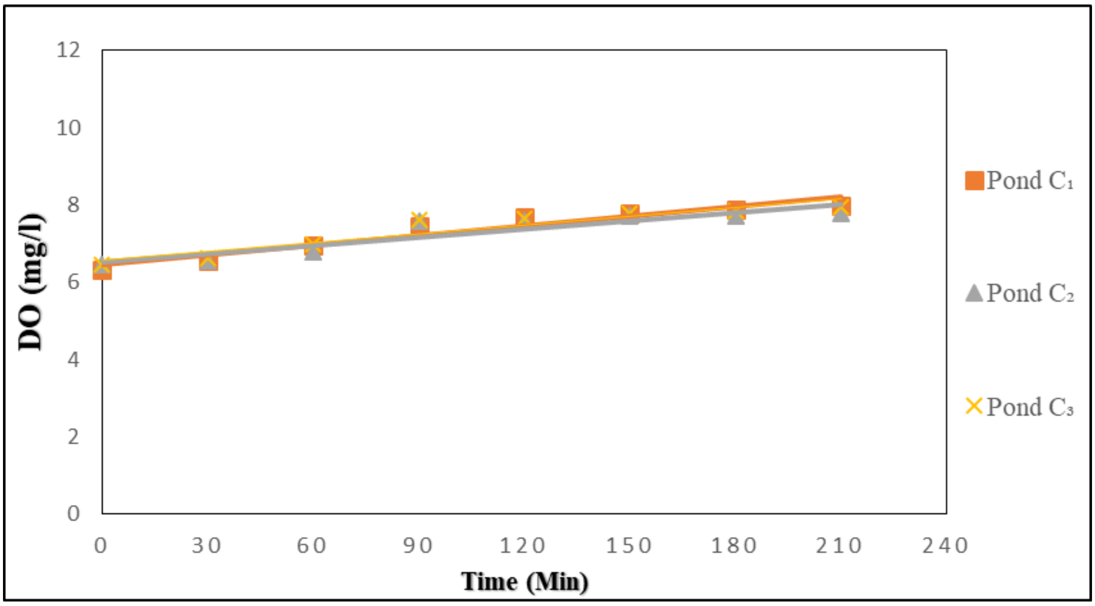

Fig 9: Increase of dissolved oxygen content during daytime (Cascading wooden plank aerators)

Dissolution of oxygen using cascading wooden plank aerators during nighttime

Experiments have also been carried out to find out the dissolution of oxygen in pond water using cascading wooden plank aerators. Initially, the pond water temperature recorded was 30 °C in all three ponds. The DO content initially measured was 9.37 mg/l, 10.22 mg/l, and 9.68 mg/l in ponds C_1, C_2, and C_3 respectively. The dissolved oxygen content decreased gently before reaching the final values of 7.18 mg/l, 7.84 mg/l, and 7.57 mg/l in the above ponds respectively. Decrease in dissolved oxygen content of the pond water graphically the Fig.10.

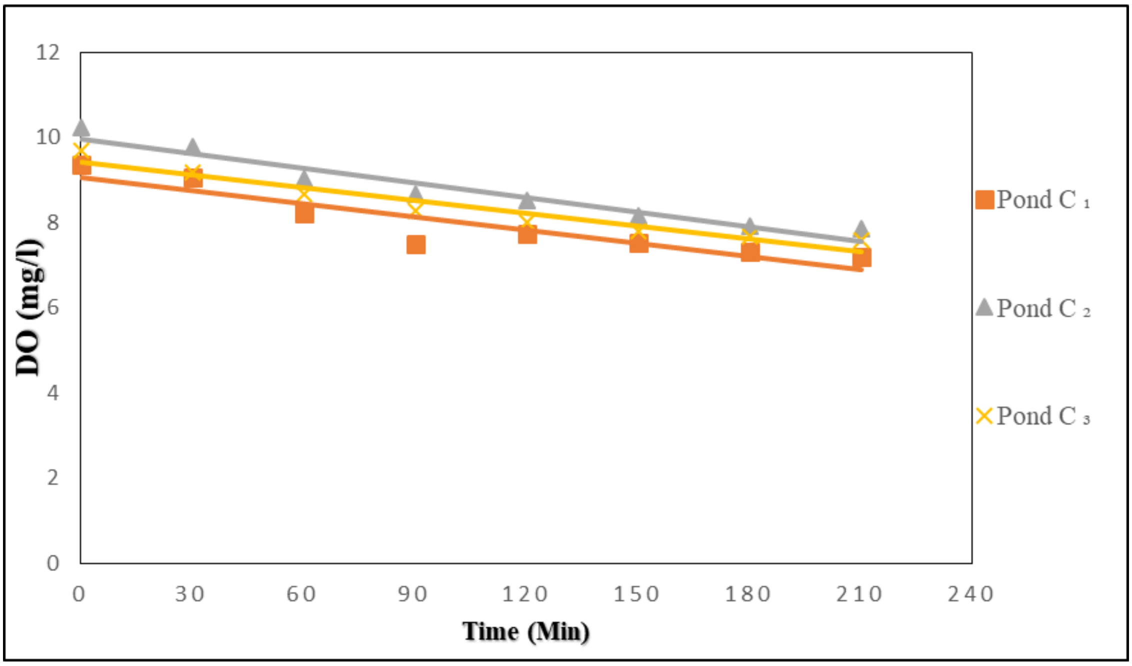

Fig 10: Decrease of dissolved oxygen content during nighttime (Cascading wooden plank aerators)

Discussion

In aquaculture ponds, plankton not only could be a key element of the food cycle, but also features a significant effect on the climate and also the composition of the atmosphere, particularly on the number of oxygen. Plankton consists of two different taxa: phytoplankton and zooplankton. As most plants do, phytoplankton can produce oxygen in photosynthesis when sufficient light is offered, e.g., within the photic layer of the water column during the daytime. The oxygen first involves the water and eventually into the air through the surface, thus contributing to the full oxygen budget within the pond. One can expect that a decrease within the rate of the oxygen production by phytoplankton may have catastrophic consequences for all times on earth, possibly leading to mass extinction of organisms. Besides having capabilities to provide oxygen, planktonic community also depends on the oxygen availability and its confounding factors. During nighttime respiration of fauna and flora, decomposition of organic matter, reduction because of other gases like methane, CO_2 which accumulate within the bottom rise and wash out the oxygen dissolved in water. The practical use of aerators in aquaculture is based on applying enough aeration to avoid dissolved oxygen concentration from declining below an acceptable level of about 3–4 mg/L for most species (Boyd, Torrans, Tucker, 2017) [3]. As lack of oxygen is commonly observed in the morning hours, it seems a reasonable ideal to aerate the water at night. In fact, some fish farmer associations and carp specific literature promote aeration late at night or in the small hours. The dynamics of photosynthesis in a turbid pond are multifaceted. It might appear counterproductive to move algae down into dimly lit layers, as this will decrease their photosynthetic oxygen production. It is important to keep in mind that an excess of light can inhibit photosynthesis by damaging the pigments involved or (especially the ultraviolet fraction of sunlight) the organism itself (Hader, 2006) [10]. Nevertheless, aeration typically is not required or required at a lesser rate in daytime than at night in ponds. Water could be conserved by aerating ponds only when the dissolved oxygen concentration is low enough to negatively impact fish, shrimp or other cultured species. The most reliable means of controlling aerator operation to periods of undesirable low dissolved oxygen concentration is to use an automated system that turns aerators on and off in response to concentration monitored by an oxygen sensor that communicates with the aerator (Jescovitch, Boyd, Whitis, 2017; McGraw, Teichert-Coddington, Rouse, Boyd, 2001) [12, 14].

Conclusion

Aeration with fabricated aerators increased the dissolution of oxygen levels during the daytime, while the decrease in DO levels at night was evident. The increased oxygen dissolution during daytime was probably due to congenial environmental temperatures that complimented the dissolution of oxygen into the water. While the drop in environmental temperatures during the night and accelerated growth of microbial populations would have affected the dissolution of oxygen. Overall, our results show that in shallow ponds, aeration during the day yields better results than during the night, as it increases oxygen concentration throughout the water column. However, we only measured during sunny days, when photosynthetic oxygen production is substantially higher compared to overcast days. We also want to stress that our findings are valid for shallow ponds.

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