The effect of air distributor shapes at fish ponds on the dissolved oxygen in water

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Abstract: Fish is one of the most important protein sources. Aquaculture can solve protein shortage problem in developing countries such as Egypt. Aeration is important to increase stock density, growth, cultivation fish yield and is widely used in fish culture systems. Many types of aerators have been used aquaculture facilities for aeration. The aim of this research was to find out the best air distributor shapes to supply fish ponds with the enough dissolved oxygen (concentration and saturation). To achieve this aim seven forms of air distribution density have been studied in addition to two different inter-holes diameters (1-2 mm) and two different inter-holes distances (15-30 cm). This study was carried out during 2014 to 2016 in a private farm located at Kafr El-Sheikh Governorate, Egypt. The results revealed that, the best shape of air distributors was big spiral shape (S1) because it achieved the highest bubbles free moving, distribution and diffusion on the pond and also attained significant distance from sides or walls as well as between air bubbles each other.

Keywords: Aquaculture, air distributor, fish ponds, dissolved oxygen

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1 Introduction

Fish is one of the most important protein sources. This is characterized by many health benefits that make it the first major food for people eat. Fish is also characterized by short life cycle to reach commercial size and weight. Fish production in Egypt was caught from lakes and sources of fresh water, estimated at about 387 thousand tons. This quantity does not meet domestic consumption, which leads to import about 220 thousand ton/year, so tend to encourage state aquaculture, producing about 668 thousand ton/year (Central Agency for Public Mobilization and Statistics, 2013). Aquaculture is the hope for solving a part of protein shortage problem in developing countries especially Egypt. Egyptian fish production has increased to over than 1362174 tons/year (GAFRD, 2011). Aeration is not new to aquaculture, but over the past few years interest in this process has increased tremendously. Aeration is widely used in fish culture and many types of aerators that have been tested for effectiveness (Sipaúba et al., 1999).

The dissolved oxygen (DO) is one of the limiting environmental factors effect fish feeding, growth and metabolism. DO fluctuation is affected by photosynthesis, respiration and daily fluctuation. These factors must be fully considered where DO is concerned. Ambient DOs range produce the best fish performance, while low DO levels limit respiration, growth and other metabolic activities of fish (Tsadik and Kutty,1987). Aeration is the process of bringing water and air into close contact by exposing drops or thin sheets of water to the air or by introducing small bubbles of air and letting them rise through the water. Aeration can remove certain dissolved gasses and minerals through oxidation (Igib et al., 2013).

Linde (2007) said that, successful fish production depends on good oxygen management. Oxygen is

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essential to the survival (respiration) of fish, to sustain health of fish and bacteria which decompose the waste produced by the fish, and to meet the biological oxygen demand (BOD) within culture system. Dissolved oxygen levels can affect fish respiration, as well as ammonia and nitrite toxicity. When the oxygen level is maintained near saturation or even at slightly super saturation at all times it will increase growth rates, reduce the food conversion ratio and increase overall fish production.

Ibrahim (2010) stated that, increased the surface interval disorder (water-air) efficiently improved contacts of air and water space. The more surface area between the water and the air bubbles the more the oxygen transmission rate increased. Tucker (2005) stated that, these systems were used with blowers or air compressors for air processing to diffusers. The diffusers had many small holes that release bubbles in the bottom of the culture tank. Jensen et al. (1989) mentioned that, aerators work by increasing of the area of contact between air and water. Aerators also circulate water so fish can find areas with higher oxygen concentrations. Circulation reduces water layering from stratification and increases oxygen transfer efficiency by moving oxygenated water away from the aerator. Bhuyar et al. (2009) mentioned that, all aerator are designed to create a greater amount of contact between the air and water to enhance gas transfer.

Kepenyes and Varadi (1984) reported that, when the bubbles emerge and passed up to the water surface a part of their oxygen content was dissolved in the water, and also a secondary upwards water movement was generated, created a mixing effect. In order to increase the contact time between the gas and the water some technical modifications are needed. One is bubbling oxygenation where the oxygen gas comes in contact with the water by breaking into bubbles. Baker et al. (2014) mentioned that, dissolved oxygen levels may also be reported as percent saturation (i.e., a relative measure of the amount of oxygen dissolved in water). Barbieri (2010) found that, the feed conversion depended on oxygen concentration in trout culture. The DO range is offered as 5-8 mg L^{-1} in culture conditions for normal activities of fish. Boyd (2010) reported that, low dissolved-oxygen concentration was recognized as a stress, poor appetite, slow growth, disease susceptibility and mortality in aquatic animals. It is generally accepted that the minimum daily dissolved-oxygen concentration in pond culture systems should be above 3 mg L^{-1} for better feed consumption and growth. Tilapia can tolerate lower dissolved- oxygen levels than catfish and shrimp, but concentrations should not fall below 1 mg L^{-1} in culture ponds.

The main objective of this study was to determine the best air distributor shape to supply enough dissolved oxygen (saturation and concentration) for fish ponds.

2 Materials and Methods

This study was carried out during 2014 to 2016 in a private farm located at Kafr El-Sheikh Governorate, Egypt. The experiment of this research done to determine the best of air distributor shapes which that recorded the optimum dissolved oxygen (saturation and concentration) in pond water without fish. The seven air distributor shapes were big and small of spiral shape, serpentine shape, rectangular shape besides standard shape (straight line in the center of the pond).

2.1 Factors of study

1. Seven shapes of air distributors with the same length for small and big coverage areas of oxygen air distribution.

2. Two different inter-holes diameters (1-2 mm) for all distributors.

3. Two different inter-holes distance (15-30 cm) for all distributors.

2.2 Experimental design

An experimental design with 7 (shapes of air distributors) × 2 (different inter-holes diameters) × 2 (different inter-holes diameters) (28) treatments per treatment was performed in triplicate. The experimental group include of the following studied variables: Air was injected at the base of the riser tube. Perforated pipes were used to produce bubbles from approximately 1 to 3mm in diameter. This was the bubble size associated with commercial fine bubble aerators. Air pressure from the compressor was 6 bar. The oxygen saturation and concentrations were measured at 9 points in the plan level and at 3 vertical levels (27 points). All experiments were repeated three replicates.

2.2.1. Experimental tanks:

The experiment was performed in three plastic tanks (1000 liters) surrounded by iron box with wooden base, the water depth of all ponds was 100 cm each of these ponds have an inlet and outlet water valves to control water level of tanks. The water draining system of the experimental tanks is maintained by gravity.

1. Seven perforated pipe shapes as shown in Figure 1.

2. Two distance 150 and 300 mm between holes in perforated pipe.

3. Two holes diameter for perforated pipes 1 and 2 mm.

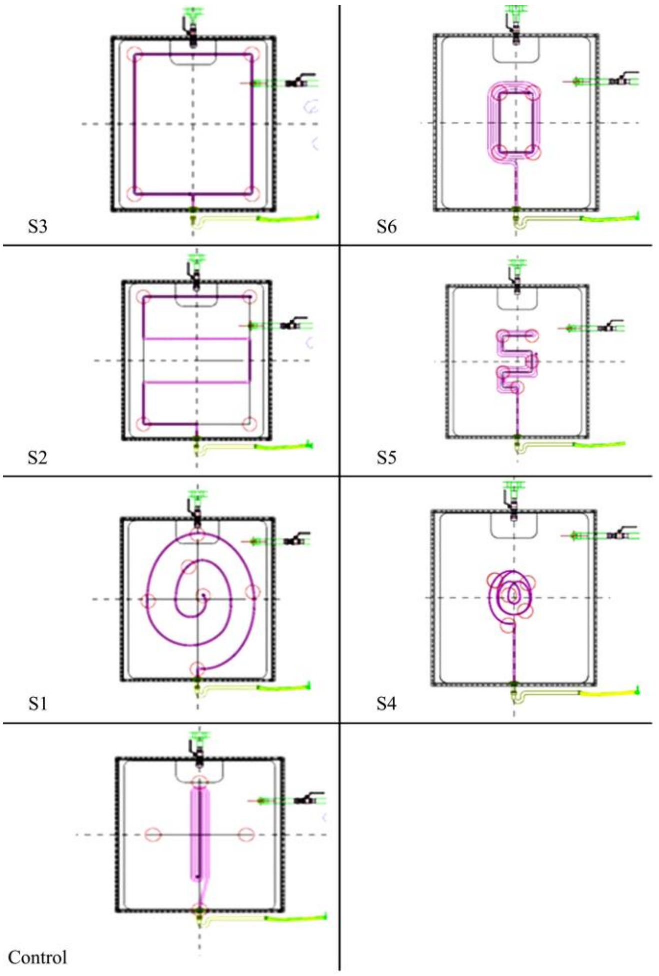


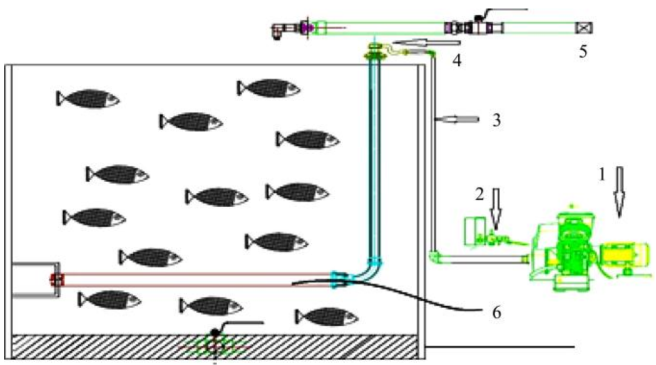
Figure 1 The tanks used in the experiment

2.2.2 Air supply system

The air supply system was consists of six main parts. Namely, they were air compressor, air hose, control valve, manometer, perforated pipe and timer in Figure 2.

2.3.3 Dissolved oxygen meter

All the data on dissolved oxygen concentration and tested water temperature was read by an electronic DO meter (Dissolved oxygen saturation and concentration).



1. Air compressor 2. Electronic timer 3. Air hose elbow 4. Air control valve 5. Manometer 6. Perforated pipe

Figure 2 Air supply system components

The dissolved oxygen concentration measurement was at 9 points in the plan level at 3 vertical levels to obtain 27 readings for the conditioning. An oxygen depletion event can be predicted and, therefore, prevented by monitoring dissolved oxygen levels in a pond. The most efficient tool for measuring DO is an electronic oxygen meter. Dissolved oxygen was recorded with the ELMETRON CO – (411) China oxygen meter. It consists of oxygen conductivity probe (a device that senses the amount of oxygen) and metal holder (catch the sensor).

3 Results and Discussion

The seven perforated pipe shape S1-S7, S1 is big spiral, S2 is big serpentine, S3 is big rectangle, S4 is small spiral, S5 is small serpentine, S6 is small rectangle and S7 is standard shapes.

Figure 3 showd the effect of different shapes air distributor on dissolved oxygen concentration at fish water pond in 1 mm diameter and 15 cm distance and it observed that DO concentration at up water surface were higher than middle of the pond. The highest concentration always was at depth of the pond because increasing of touch between air bubbles and water molecules at surface was more than at depth where bubbles moved up and from results, it was clear that using the big spiral shape (S1) to distribute oxygen on pond gave highest value of DO concentration in comparison of other different air distributers whether the highest value of DO concentration in all parameters was at up surface water in (S1) parameter was 8.81 mg L^{-1} then found at middle of the pond 8.5 mg L^{-1} was by using big spiral shape (S1), and then at down of the pond was 8.2 mg L^{-1} by using big spiral shape (S1). Where the lowest value at down of the pond was 4.52 mg L^{-1} by using straight shape (S7) and then at down of the pond 5.71 mg L^{-1} by using big rectangle shape (S3), then at middle of the pond was 5.5 mg L^{-1} by using straight shape (S7). This was consistent with EPA (1999) reported that, the performance of diffused aeration systems under normal operating conditions is directly related to the following parameters: Fouling, wastewater characteristics, process type and flow regime, loading conditions, basin geometry, diffuser type, size, shape, density, and airflow rate, mixed liquor dissolved oxygen control and air supply flexibility, mechanical integrity of the system and the quality of the preventive operation.

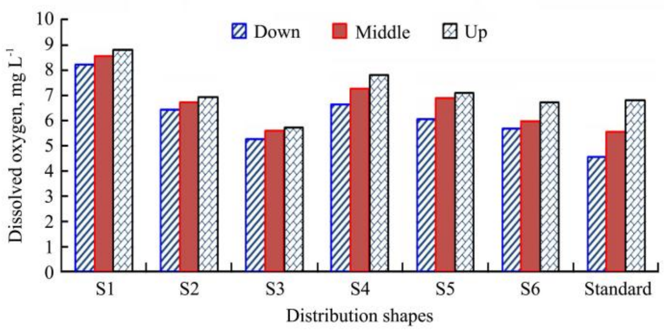


Figure 3 Distribution of DO concentration through all shapes in 1 mm diameter and 15 cm distance

This was because, of the distribution of air bubbles out from big spiral shape (S1) was the best diffusion on the pond and gave to bubbles free moving, distribution that not affected at each other. Where the worst distribution of air bubbles out was from straight shape (S7) due to bubbles diffusion concentration was only along the pond which has negative effect on movement bubbles. The clash with each other followed by distribution of air bubbles by using big rectangle shape (S3) this referred to diffuse of bubbles was only at side pond water edges so its friction with pond sides affected significantly on flowing up. This was consistent with Mallya and Thorarensen (2007) stated that, oxygen as a gas had a low solubility in water. Less oxygen can be held in fully air-saturated warm sea water than fully air-saturated cold freshwater.

Figure 4 showed the effect of different air shapes distributor on dissolved oxygen saturation at fish water pond in 1 mm diameter and 15 cm distance while the highest value of DO saturation in all parameters at up surface water was 84% (S1) parameter at middle of the pond was 83.34% by using big spiral shape (S1), and then found at up water surface was 77.1% by using big serpentine shape (S2). This was consistent with Igib et al. (2013) mentioned that, one of the problems of fish growing in ponds is the dissolved oxygen concentration in the water. In the fish farming business, the ability to maintain water quality is the key of improving fishery production capacity.

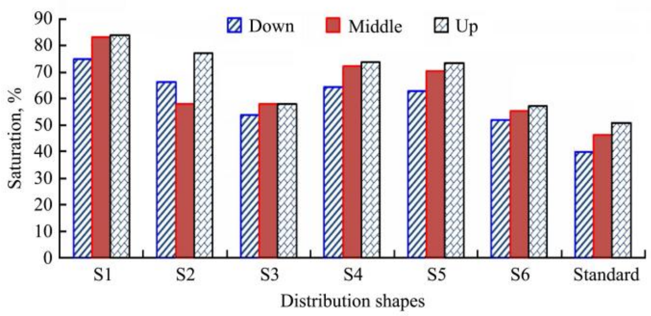


Figure 4 Distribution of DO saturation percent through all shapes in 1 mm diameter and 15 cm distance

The lowest value at down of the pond was 39.7% by using straight shape (S7), at middle of the pond was 46.3% by using straight shape (S7), and at up water surface was 50.8% by using straight shape (S7).

Figure 5 showed the effect of different air shapes distributor on dissolved oxygen concentration in 1 mm diameter and 30 cm distance in fish water pond while the highest value of DO concentration in all parameters was at up surface water was 8.13 mg L^{-1} (S1), then found at middle of the pond was 7.83 mg L^{-1} by using big spiral shape (S1), then at depth of the pond was 7.3 mg L^{-1} by using big spiral shape (S1). The lowest value at depth of the pond was 3.4 mg L^{-1} by using straight shape (S7), then at middle of the pond was 4.1 mg L^{-1} by using straight shape (S3), then at down of the pond was 4.3 mg L^{-1} by using rectangle shape (S3). This was consistent with Jensen et al. (1989) mentioned that, aerators worked by increasing the area of contact between air and water. Aerators also circulated water so fish can find areas with higher oxygen concentrations. Circulation reduced water layering from stratification and increased oxygen transfer efficiency by moving oxygenated water away from the aerator.

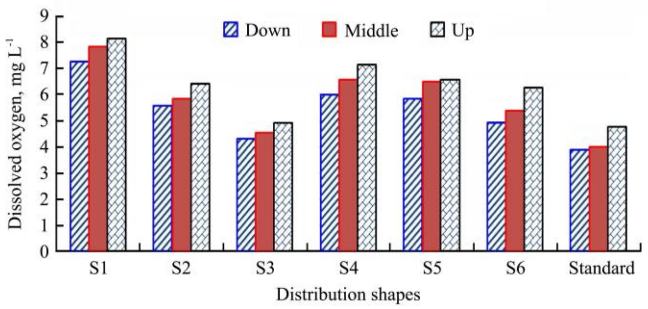


Figure 5 Distribution of DO concentration through all shapes in 1 mm diameter and 30 cm distance

Figure 6 showed the effect of different air shapes distributor on dissolved oxygen saturation at fish water pond in 1 mm diameter and 30 cm distance while the highest value of DO saturation in all parameters at up surface water was 75.3% (S1), then found at up water surface was 71.7% by using small spiral shape (S4), then at middle of the pond was 70.4% by using big spiral shape (S1). This corresponded to Baker et al. (2014) mentioned that, the maximum amount of oxygen that can be dissolved in water depended on the temperature of the water. Warm water hold less dissolved oxygen than cold water; it was "saturated" with less oxygen. This was illustrated by the bubbles that formed on the bottom of a pot of water that was brought to a boil; the water holds less dissolved oxygen at warmer temperatures, and so the oxygen began to come out of the water, in the form of bubbles. The lowest value at depth of the pond was 26.8% by using straight shape (S7), then at middle of the pond was 33.4% by using straight shape (S7), then found at up water surface was 37.4% by using straight shape (S7). This corresponded to Tucker (2005) stated that, these systems were used blowers or air compressors for air processing to diffusers. The diffusers had many small holes that release bubbles in the bottom of the culture tank. In the Increase of oxygen transmission of the smaller size of the bubble and the bubble, when the starting point deeper into the water, the greater the oxygen content in the bubble.

Figure 7 showed the effect of different air shapes distributor on dissolved oxygen concentration at fish water pond at 2 mm diameter and 15 cm distance, while the highest value of DO concentration in all parameters at up surface water was 8.6 mg L^{-1} (S1), then found at middle of the pond was 8.2 mg L^{-1} by using big spiral shape (S1), then at down of the pond was 7.9 mg L^{-1} by using big spiral shape (S1).

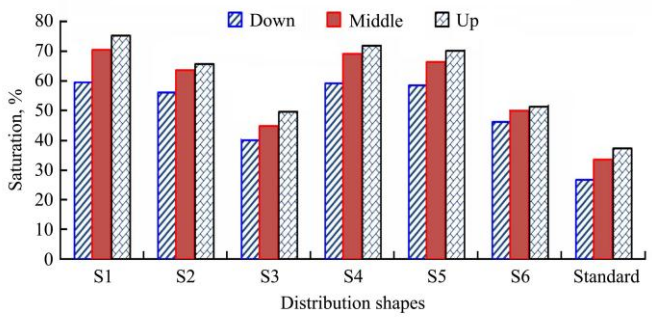


Figure 6 Distribution of DO saturation percent through all shapes in 1 mm diameter and 30 cm distance

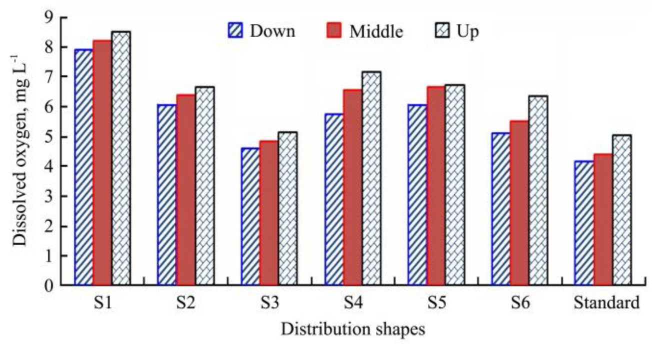


Figure 7 Distribution of DO concentration through all shapes in 2 mm diameter and 15 cm distance

The lowest value at down of the pond was 4.2 mg L^{-1} by using straight shape (S7), then at middle of the pond was 4.41 mg L^{-1} by using straight shape (S3), then at down of the pond was 4.7 mg L^{-1} by using rectangle shape (S3). This was consistent with Ibrahim (2010) stated that, oxygen moved to spread through the fluid and given layer because the bubbles raised in the water column, there was a relative movement between the water and the bubbles leaded to the water circulation and the renewal of the surface area of contact of the bubbles, which leading to increased transmission of oxygen.

Figure 8 showed the effect of different air shapes distributor on dissolved oxygen saturation at fish water pond in 2 mm diameter and 15 cm distance while the highest value of DO saturation in all parameters at up surface water was 75.9% (S1), then found at middle of the pond was 74.6% by using big spiral shape (S1), then at up water surface was 73.6% by using small spiral shape (S1).

The lowest value at down of the pond was 30.9% by using straight shape (S7), then at middle of the pond was

35.4% by using straight shape (S7), then found at up water surface was 39.5% by using straight shape (S7). This corresponded to Sarkar et al. (2012) reported that, it was found that both the growth rate and detachment diameter increased with increasing wire diameter. Conversely, current density had little effect on the released bubble size. It was also found that the detached bubbles rapidly increased in volume as they rose through the liquid as a result decreasing hydrostatic pressure and high levels of dissolved hydrogen gas in the surrounding liquid.

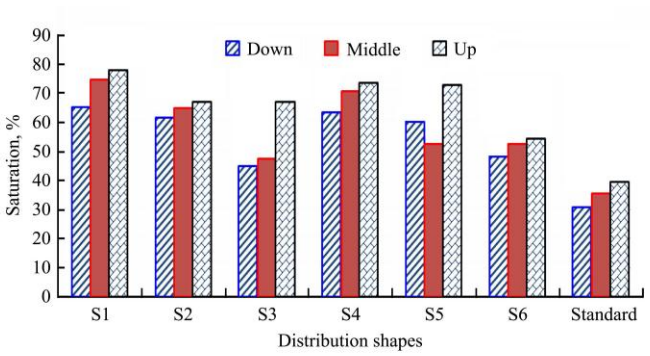


Figure 8 Distribution of DO saturation percent through all shapes in 2 mm diameter and 15 cm distance

Figure 9 showed the effect of different air shapes distributor on dissolved oxygen concentration at fish water pond in 2 mm diameter and 30 cm distance while the highest value of DO concentration in all parameters at middle of the pond was 7.1 mg L^{-1} (S1), then found at up water surface was 6.74 mg L^{-1} by using small spiral shape (S4), then at down of the pond was 6.7 mg L^{-1} by using big spiral shape (S1).

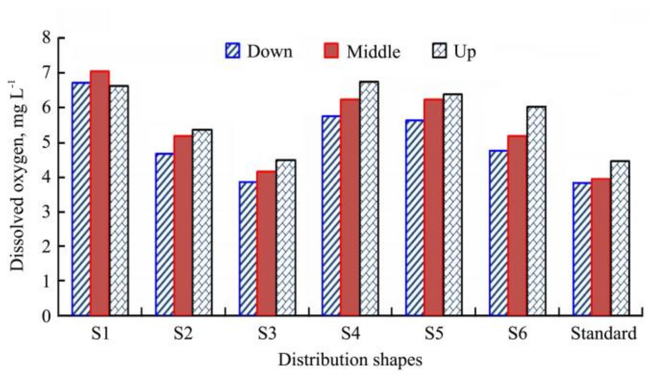


Figure 9 Distribution of DO concentration through all shapes in 2 mm diameter and 30 cm distance

The lowest value at down of the pond was 3.8 mg L^{-1} by using straight shape (S7), and then at down of the pond was 3.84 mg L^{-1} by using rectangle shape (S3) then at middle of the pond was 3.9 mg L^{-1} by using straight shape (S7). This was consistent with Jensen et al. (1989) mentioned that, diffuser aerators operated by low pressure air blowers or compressors forcing air through weighted aeration lines or diffuser stones released air bubbles at the pond bottom or several feet below the water surface. Efficiency of oxygen transfer was related to the size of air bubbles released and water depth. The smaller the bubble and the deeper it was released, the more efficient this type aerator became.

Figure 10 showed the effect of different air shapes distributor on dissolved oxygen saturation at fish water pond in 2 mm diameter and 30 cm distance while the highest value of DO saturation in all parameters at up surface water was 68.1% by using small spiral (S4), then found at up water surface was 67% by using small serpentine shape (S5), then at middle of the pond was 64.9% by using small spiral shape (S4).

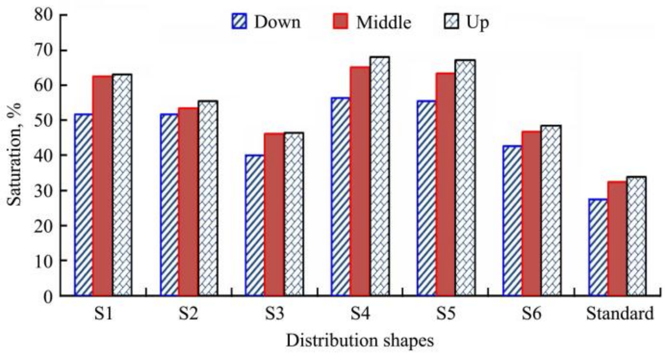


Figure 10 Distribution of DO saturation percent through all shapes in 2 mm diameter and 30 cm distance

The lowest value at down of the pond was 27.6% by using straight shape (S7), then at middle of the pond was 32.4% by using straight shape (S7), then found at up water surface was 33.9% by using straight shape (S7). This corresponded to Kepenyes and Varadi (1984) reported that, when the bubbles emerged and passed up to the water surface a part of their oxygen content was dissolved in the water, and also a secondary upwards water movement was generated, creating a mixing effect. In order to increase the contact time between the gas and the water some technical modifications were needed. One was bubbling oxygenation where the oxygen gas came in contact with the water by breaking into bubbles.

4 Conclusion

From the above mentioned study, it observed that DO concentration at up water surface level was higher than middle of the pond. The highest concentration always was at depth of the pond because increasing of touch between air bubbles and water molecules at surface level was more than at depth where bubbles move up and from results, it was clear that using the big spiral shape (S1) to distribute oxygen on pond gave the highest value of DO concentration in comparison of other different air distributers.

This is because, distribution of air bubbles out from big spiral shape (S1) was the best diffusion on the pond and gave to bubbles free moving, distribution and diffusion also not affected at each other. The worst distribution of air bubbles was out from control shape (S7) as bubbles diffusion concentration was only along the pond which had negative effect on movement bubbles. And clash with each other followed by distribution of air bubbles by using big rectangle shape (S3) this referred to diffuse of bubbles was only at side pond water edges so its friction with pond sides affected significantly on flowing up.

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