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Design and fabrication of an aerator cum oxygen accumulator for live fish transport

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ABSTRACT

Bangladesh secured the third position in freshwater fish and fisheries product producing country where around 4.134 million metric ton of fish is extracted annually. Fish transporting in traditional method reduces fish freshness and thus causes serious economic loss. Further, for live fish transportation, maintaining water quality is a challenge, with the course of time, oxygen, pH and temperature of water deteriorate. Considering this issue, a study was undertaken to construct simple, low energy consumed aerator-cum-oxygen accumulator for live fish transport. A 12-volt 3-ampere DC motor operated 1100 GPH bilge pump was modified with the venturi principle to construct the aerator. The experiment was conducted to evaluate its performance for live fish transport and compared with the results in a condition of with and without an aerator. 45 (forty-five) numbers of Rohu fish (*Labeo Rohita*) with an average weight of 378 g were put in a tank of 650 liters for this experiment. After six hours of the test, different parameters were measured in both conditions. With the device, dissolved oxygen and pH level were found as 9.3 mg/l and 7.8 and without the device, dissolved oxygen and pH level were found 6.2 mg/l and 7.1, respectively in six hours of operation. On the other hand, without the device, the dissolved oxygen level decreased from 6.5 mg/l to 2.2 mg/l and pH level increased from 8.30 to 9.70 in six hrs of the test. Besides, by using, the device mortality rate of fishes was zero but without the device, the mortality rate was 11.11%. Water temperature changing was insignificant during the experiment. Results indicate that for reducing losses of fish and increase the income of fisherman, this device might be suitable for live fish transport.

Introduction

Bangladesh is one of the leading fishes producing countries in the world with a total production of 4.134 million metric ton per year (DoF, 2017), where aquaculture contributes 56.44 percent to the entire production. The average growth performance of this sector in the last 10 years is almost 5.43 percent. According to Fisheries Statistical Yearbook 2016-17, government is trying to sustain this growth performance, which eventually ensures to achieve the projected production target of 4.55 million metric ton by 2020-21. In terms of inland fish production, Bangladesh has ranked third in the world in 2018, according to a report by the Food and Agriculture Organization (FAO, 2018). FRSS (2016) describes that the fisheries sector also plays a very important role in the national economy as it contributes 3.69% to the GDP of the country and 22.60% to the agricultural GDP. This sector having more or less consistent growth rate ranging from 7.32% to 4.40% from 2009 to 2014 (Shamsuzzaman *et al.*, 2017).

Every year the small-scale fisheries in developing countries suffer from huge post-harvest losses. The huge loss in fisheries creates enormous pressure on food security of the country. Although the approach exists to double the fish production, the current post-harvest loss is emulated to be devastating, about 20-30% in different fish and fishery products (Nowsad, 2007). According to Nowsad (2010), a 50% reduction of such loss can save 950-1200 billion USD per annum. A dearth data of qualitative and quantitative post-harvest fish losses in Bangladesh is seen as a constraint to planning for the post-harvest sector at the country level and at the sector level. Freshness quality of fish reduces about 60-70% of 28% fish before it reached consumers in a local retail wet fish shop. The fisheries sector suffers from serious post-harvest loss every year due to ignorance and negligence in handling and processing at different stages of the supply chain from the harvest to retail distribution. Poor handling and processing reduce the quality of the products (BCAS, 2003; Nowsad, 2004).

The post-harvest quality loss in wet fish occurred, based on different species and seasons, from 7- 19%, with an average loss encountered, was 12.5%. When the fish was

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landed and sold to the nearer consumers within a few hrs of harvest, the post-harvest loss was negligible. When the travelling distance is long the amount of loss will also be high. From previous assessment study of losses, fish did not lose quality during handling by the fishermen, and fish farmers or at landing centers and primary fish markets, except fresh *T. Elisha* destined for the consumer market. Most of the quality losses were initiated at the transporters and commission agents from 4%-11% (Nowsad, 2010).

Live fish transport is important in the purpose of Bangladesh as traditional transport system creates serious economic loss and degrades the quality of fish. As a result, the price of fish gets down. If fishes are transported live then there will be no headache for quality and freshness and the price of fish will be beneficial for the fisherman, thus national income will rise. Live fish is transported in two ways- the closed system and the open system. The closed system is mainly a sealed container in which all the requirements for survival are self-contained i.e. a plastic bag sealed partly filled with water and oxygen. On the other hand, the open system consists of water-filled containers in which the required survival is supplied continuously from outside sources. The simple form of an open system is a small tank with an aerator stone.

The most essential single factor in transporting fish is providing an adequate level of dissolved oxygen. However, an abundance of oxygen within a tank does not necessarily indicate that the fish are in good condition. Fish transport systems mostly contain water with oxygen levels that provide insufficient oxygen required to satisfy the fish bodies. To counterbalance this predicament, the fish will shift its metabolism to use the stored oxygen of the body. This modification of metabolism and lack of sufficient oxygen leads to quality deterioration and loss. The ability to transport fish to use oxygen depends on their tolerance to stress, water temperature, pH, and concentrations of carbon dioxide and metabolic products such as ammonia. The most favorable amount of dissolved oxygen in the case of transport fish is 5mg per liter (Berka, 1986). If this amount of oxygen is supplied to the transporting fish, the loss due to lack of oxygen can be reduced to a large extent. By adding oxygen and circulating water, required oxygen can be induced. Thus fish can be transported live with least wastage with minimum loss and degradation.

Conditioning of live fishes (preparing for transport) and their transport with least stress from source to markets as the case may increase fish survival rate, better the transport economics and provide healthy fish for stocking or live fishes for other intended purposes. During the transport of live fishes, fishes remain in a limited quantity of water that causes crowding and increases oxygen consumption due to increased metabolism in them leading to a higher concentration of CO_2 and ammonia, reduction of pH and increased bacterial contamination in transport water (Berka, 1986). When the oxygen supply is insufficient to meet the minimal energy demands of essential functions, suffocation occurs. Fishes are typically transported to processing plants or retailer shop at high densities (0.7 to 1.0 kg/L) in order to minimize transport costs. For short transport times (1-4 hr), transport water aeration is usually provided by a diesel-powered regenerative blower that forces large volumes of ambient air through the transport tanks and generates considerable turbulence. Use of blower aeration during the summer increases transport water temperature by injecting large volumes of warm ambient air. The combination of increased water temperature, which decreases oxygen solubility (Wetzel, 1983), and high fish densities reduces dissolved oxygen levels in catfish transport tanks. Water temperatures can exceed 32 °C and DO levels are generally less than 4 ppm during the summer months in transport tanks aerated by blowers (field observation). High water temperatures, turbulence, and reduced oxygen levels during transport may add to the general stress associated with fish harvest and transport. In addition, water temperature and oxygen levels may affect other water quality parameters (ammonia, nitrite, pH, and CO_2) that could influence the level of stress experienced by fish during transport (Amend *et al*., 1982; Erikson *et al*., 1997; Paterson *et al*., 2003). The major water quality effects experienced by fish during transport are low dissolved oxygen levels due to oxygen consumption by respiration; an increase of carbon dioxide from respiration; depression of pH caused by carbon dioxide accumulation; and increased ammonia levels resulting from ammonia excretion (Rimmer and Franklin, 1997).

Nowsad (2010) reported that after harvesting rough handling (15%), compactness (3%), delay icing (10%), no icing (45%), marketing process (15%) and transportation (7%) lead to loss of a major proportion of total quality. So around 5-7% of total harvested fish are lost for the poor transportation system, long distance, bamboo basket, dirty plastic box, compactness of fishes and mass handling (Hossain *et al*., 2002). Every year 10% total world's fish is lost due to improper handling, processing and preservation lacking (Nowsad, 2010). Improve fish handling can be very effective to utilize the whole world's fish catch.

Based on the above discussion for live fish transportation, the objectives of the study were to design and fabricate an aerator-cum oxygen-accumulator device to improve live fish transportation system with least physical stress to minimize economic losses, to test the performance of the device and compare different parameters using the device and traditional method of live fish transport. These achievable objectives would lead to improve the technical capacity of the primary stakeholders, reduce huge post-harvest losses, increase protein-food supply and enhance income for the poor fishers, traders, processors and enhance the economic growth through sustainable handling and processing systems.

Materials and Methods

The device was fabricated and tested at the Engineering Workshop, Department of Farm Power and Machinery, Bangladesh Agricultural University. It was a test model of Aerator-Cum-Oxygen Accumulator device that was made by the materials which were available in the market.

Schematic diagram of Aerator-Cum-Oxygen Accumulator

The schematic diagram of Aerator-Cum-Oxygen Accumulator was designed using Fusion 360 3D design software. Figure 1 shows the design of Aerator-Cum-Oxygen Accumulator.

Fabrication of Aerator-Cum-Oxygen Accumulator

The major materials required to fabricate the machine were a submersible pump, PVC pipe, PVC female reducer, rubber tube. The specification of aerator-cum-oxygen accumulator is given in Table 1.

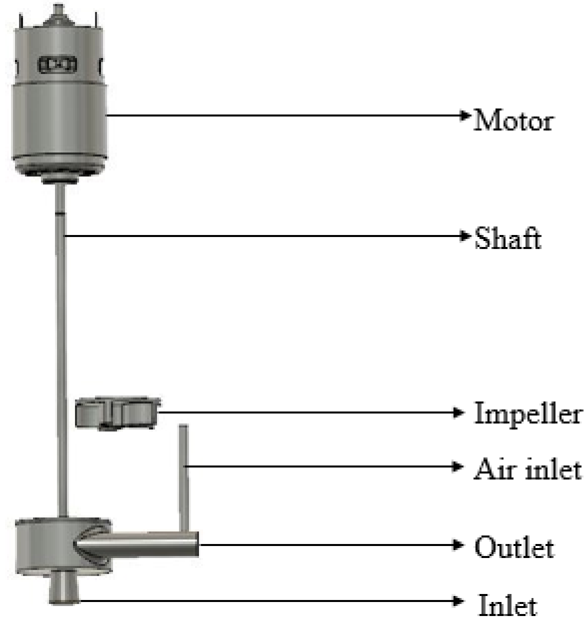

Fig. 1 Schematic diagram of the aerator-cum-oxygen accumulator

Table 1. Specification of Aerator-Cum-Oxygen Accumulator

Name	Specification	Material	Nos.
Submersible Pump	12V, 3-amp bilge pump, 1100GPH discharge Weight: 362.87gm Height: 10.7 cm, Diameter: 6 cm with 2.9 cm (1 1/8 ") bore hose.	Casing: Plastic body with integrated sieve Impeller: Plastic	2
Venturi	Inlet and outlet Diameter :1.91cm Length: 0.50cm Throat diameter: 1.25cm Throat length: 4cm	PVC pipe	2
Rubber tube	Diameter: 0.8 cm Length: 30 cm	Rubber	2
Outlet pipe	Length: 25cm Diameter: 1.91cm	PVC pipe	2

The submersible pump used was a bilge water pump. Two PVC reducers were attached face to face to make a venturi for pressure drop. The venturi was attached by one end to the pump outlet. The other end of the venturi unit was joined with a PVC pipe of 25 cm length. At the divergent end, a hole was drilled and a rubber tube was added to accumulate ambient air. Water pressure drops and air mixes with water at the venturi unit following the venturi principle (Baylar, 2006).

Laboratory test setup

The materials needed for a laboratory test are transportation tank, plastic covering, vehicle dynamo, battery, 12v relay, Aerator-Cum-Oxygen Accumulator device and most importantly live fish. Table 2 describes the materials used for the laboratory test in detail.

Table 2. Detailed information about laboratory test setup

Name	Specification	Nos.
Transportation tank	Dimension: Length:207.26cm Width: 106.68cm Height: 30.48cm Amount of water: 650 litter	1
Triple or plastic sheet	365.76 cm×304.8 cm	1
Truck dynamo	-	-
Battery	Model: Lucas Classic NX120-7 Voltage: 12 AH (ampere hour): 80	1
12v relay	5 Pin,12v DC Relay	1
Aerator-Cum-Oxygen Accumulator device	-	-
Fish	Fish: Ruho (*Labeorohita)* Total Weight of Fish: 17kg Average weight of fish: 378g	45

There are some factors governing for the performance evaluation of Aerator-Cum Oxygen-Accumulator device for live fish transport. Such as in the experiment pond water was used for the source of water for transportation as it contains much oxygen. Secondly fishes were in good condition and fish density was 35 kg/m^3 and fishes was handled with care. Thirdly, distance and type of road is an important factor, which was considered. Last but not the least similar variety and sized fishes was used.

Figure 2 describes the power supply unit to operate the Aerator-Cum-Oxygen Accumulator device. When the vehicle was in operation, the device got electric power from vehicle dynamo. But when the vehicle was static and the engine was stopped, the relay changed the circuit and power supply unit switched to the battery of the vehicle.

In laboratory test setup a tank was used to carry water and fish. Polythene cover was used to confine the water in the tank and seal the leakage of the tank. Aerator-Cum-Oxygen Accumulator device was used to enhance the level of DO (dissolve oxygen) and circulate the water for a uniform mixture of oxygen in the water for fish welfare. Live fishes were collected from a local pond.

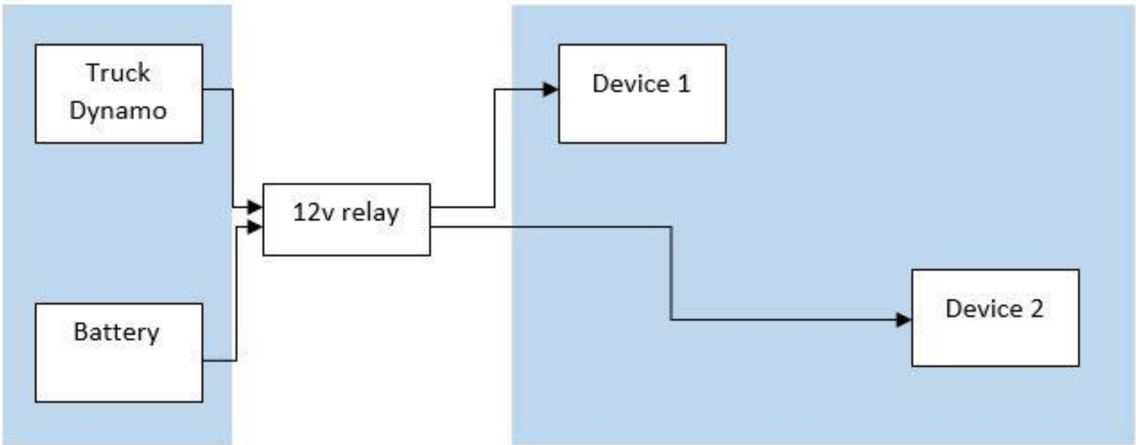

Fig. 2 Flow diagram of power supply system to the device

Parameter testing

To assess a study or work some parameters needs to be tested. The parameters that were tested in this study are the mortality rate of fish, DO (dissolve oxygen) level, temperature and pH level.

Mortality rate

The most imperative parameter for evaluating this study is mortality rate with respect to time. The mortality rate of fish was inspected visually and calculated against the total number of fishes that were used in the experiment. The mortality rate was calculated by-

$$\text{Mortality rate (\%)} = \frac{\text{No. of dead fish}}{\text{No. of total fish used}} \times 100 \quad .... \quad (1)$$

DO (dissolve oxygen) level

Oxygen is a salient property of water to transport live fish. Dissolved oxygen (DO) is a measure of the amount of oxygen freely available in the water. A higher dissolved oxygen level indicates better water quality. The fluctuation of DO was measured by a portable dissolved oxygen meter named Lutron Do-5509 Dissolved Oxygen Meter with an accuracy of ± 0.4 mg/L and resolution of 0.1 mg/L. Figure 3 shows the dissolve oxygen sensor that was used during the experiment.

Fig. 3 Lutron Do-5509 Dissolved Oxygen Meter

Temperature measurement

Water temperature affects the mortality rate and oxygen requirement of fishes. The temperature was measured by a temperature sensor which was collaborated with a microcontroller (Arduino-UNO). A waterproof DS18B20 Digital Thermal Probe or Sensor was used as temperature sensor and a 10K resistor was used to control electrical current. The pictorial presentation of temperature sensor is given in Figure 4.

Fig. 4 Temperature and Flow Sensor with Microcontroller

pH sensor

At the time of live fish transport, respiration level and feces get increased as a result of stress. Hence the pH level of water gets changed. The oxygen concentration of water also depends on the pH level of water. The pH level of water was measured using a pH meter. Hanna Pocket Sized pH Meter Hi96107 was used to measure pH of water and recorded in a computer. The pH meter used in this experiment is presented in Figure 5.

Fig. 5 Hanna Pocket Sized pH Meter

Experimental setup for performance test

The first experiment was done with no load condition i.e. the only aerator was used with no fish. In the second case, only the fishes (17 kg) were loaded in the transportation tank without any aerator. At last, fishes were loaded in the transportation tank with the aerator device as the third case. Figure 6 describes experimental set up and fish welfare at the time of experiment.

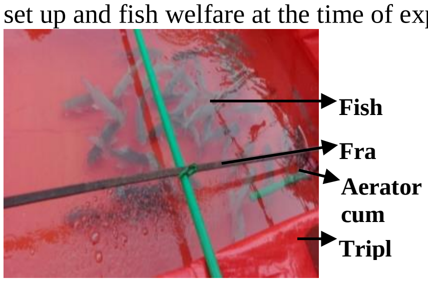

Fig. 6 Live fish transportation reservoir with aerator cum oxygen accumulator

Results and Discussion

Fabrication of aerator-cum oxygen-accumulator

Aerator-Cum Oxygen-Accumulator was battery or dynamo operated device which consists of a submersible pump, a venturi (two reducers jointed together) and an air tube. Venturi effect is the reduction in fluid pressure that results when a fluid flows through a constricted section (or choke) of a pipe. Figure 7 shows the laboratory test model of Aerator-Cum Oxygen-Accumulator device. Parameters related to live fish transport was calculated and compared with normal live fish transport.

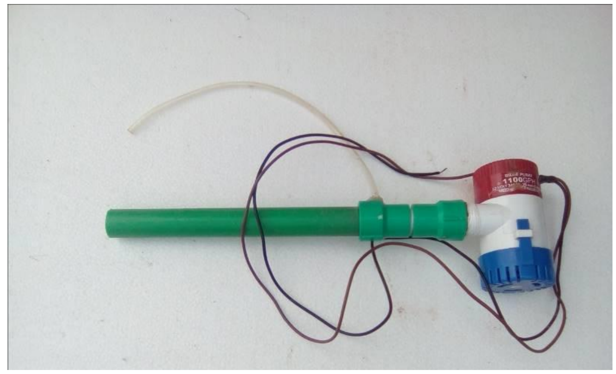

Fig. 7 A model of Aerator-Cum Oxygen-Accumulator device

DO (dissolve oxygen) level

From Table 3, the dissolved oxygen level increases with time for the first case. The oxygen level at load condition with no aerator, decreases with time as there is no supply of oxygen to be dissolved in water. But, in the third case, the oxygen level was maintained at an average rate of 8.48 ml per liter of water with a standard deviation of 0.76. From the comparison, it is clear that Aerator-Cum Oxygen-Accumulator device performed satisfactorily for live fish transport as the oxygen level of water remains in the fish welfare zone (>5 mg/L) (Berka, 1986).

Table 3. Level of DO (dissolve oxygen) in three cases of laboratory test

Time	Dissolve oxygen level (mg/L)		
	No load with aerator	Load without aerator	Load with aerator
First hr, t_0	6.2	6.5	9.5
Second hr, t_1	6.5	6.2	7.9
Third hr, t_2	7.4	5.7	8.3
Forth hr, t_3	8.5	4.5	7.5
Fifth hr, t_4	8.9	3.5	9.2
Sixth hr, t_5	9.3	2.2	8.5
Avg.	-	-	8.48
SD.	-	-	0.76

Temperature

Figure 8 reveals the graphical representation of temperature all over the experiment day and the study was undertaken from 9 am to 2 pm. Figure 9 defines the graphical representation of water temperature level with time. Graph reveals that, at all three conditions, the temperature increased with time as atmospheric temperature was increasing. Besides, as ambient air was mixing with water, the temperature also increased. But from the graph, it can be said that the temperature at load condition with aerator increases slower than other condition.

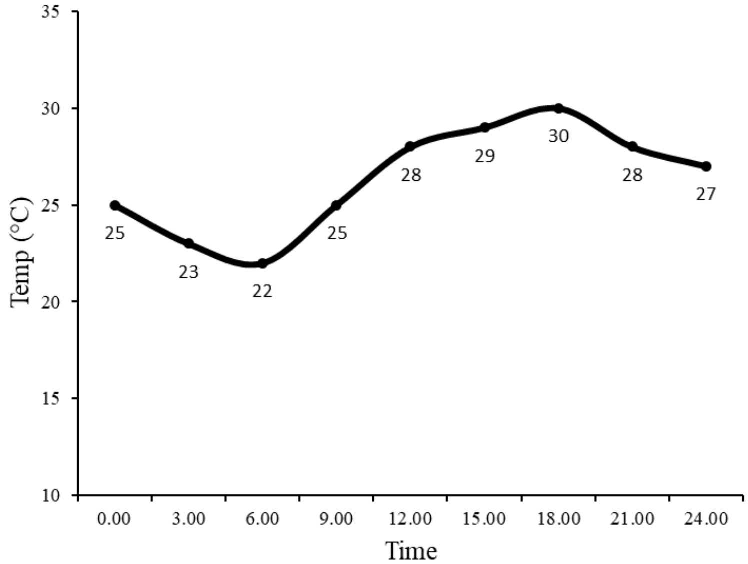

Fig. 8 Ambient temperature profile during the experiment

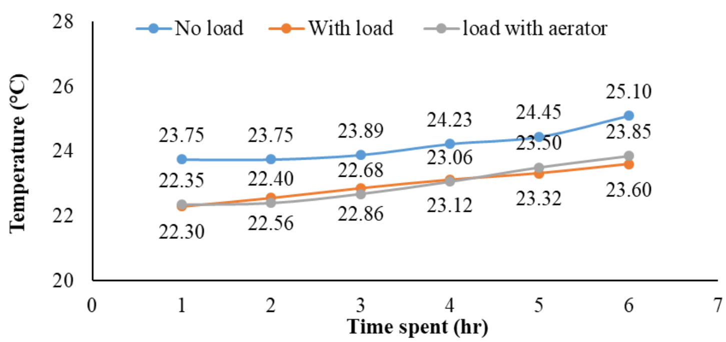

Fig. 9 Temperature of water changes with time of all three conditions

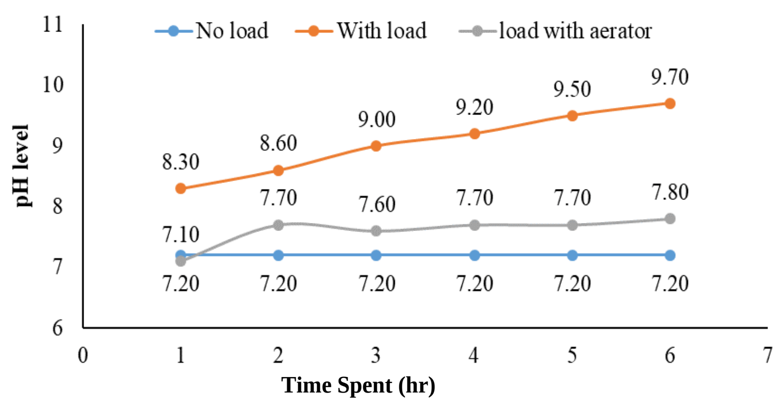

Fig. 10 pH level in three conditions

pH measurement

At no load condition, as there is no living organism like fish in the water so the pH level of water was almost the same (average 7.2). At only load condition without an aerator, for the fishes and its metabolism, the pH level of water was gradually changed against time. At the last hr, the pH level was hazardous for fishes. For the third condition, load with aerator, as water was circulating, the pH level of the tank water was fairly constant with minimum fluctuation. Figure 10 describes the level of pH in three cases. Water pH levels about 7–8 are considered as optimum for fish transportation of live fishes and their short period storage (Berka, 1986).

Mortality rate

At load without aerator, the total number of fishes was 45 (forty-five). After six hrs of test 5 (five) fishes were dead due to low dissolved oxygen (2.2 mg/l) in the tank. The mortality level of this condition was 11.11%. At load with aerator, the total number of fishes was 40 (forty). After six hrs of test no fish was found died. This only happened for having enough dissolved oxygen in the water for using the device. So, the mortality level of this condition was zero (for 8.5 mg/l DO and pH 7.80). Even after completing the test, around 8 hrs later the number of live fishes was also same.

Conclusion

For transporting live fish, it is necessary to provide oxygen and circulate the water. The concentration of dissolved oxygen is an important indicator of water quality because aquatic life lives on the dissolved oxygen in the water. Aeration can increase dissolved oxygen when levels become deficient. By using the device above two criteria are fulfilled. The device was found worthy for live fish transport and if fishes can be transported live then losses will be small, fishermen will be benefitted and national income will be increased. Besides, it is lightweight, easy construction, negligible maintenance and runs by the power of the vehicle engine. Future research is needed to conduct in the aquaculture farm, where live fishes are transported to study the ideal condition and cost analysis of the technology.

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