WorldFish

Guide to improving live fish transportation with special attention to the COVID-19 pandemic in Bangladesh and other tropical developing countries

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1. Introduction and objectives

The demand for live fish is high in Bangladesh, and because of this the price exceeds that for iced dead fish by BDT 20–30/kg. From observations taken in February–March 2020, the amount of live food fish transported to markets in Bangladesh is estimated at about 200 mt per day.

However, some farmers and traders use inappropriate transportation practices, which have led to health hazards during the COVID-19 pandemic. In addition, poor transportation techniques have resulted in high mortalities during shipping. Among those that do survive and make it to the market, many arrive in poor quality because of injuries sustained on the trip. On top of all this, these hazardous techniques also have dangerous impacts on road safety.

The main objective of this guide is to improve human safety during the COVID-19 pandemic in relation to harvesting and transporting live fish. Other objectives include (i) providing safer methods for handling and transportation, (ii) improving animal welfare, (iii) reducing road safety hazards, and (iv) detailing methods to reduce the cost of live fish transportation.

2. Review of live fish transportation techniques

2.1. Fish harvesting

Freshwater fishponds in Bangladesh are dug-out ponds, where draining the water using gravity is not possible. The water sources for the ponds are rain, groundwater (where the deeply excavated pond bottom is below the underground water table), and groundwater pumped from a borehole.

Prior to harvest, fish are often not fed for 1–2 days, as recommended by most fish traders. A specialized team usually harvests the fish. They often work closely together when netting, filling the bags to carry the fish, carrying the fishing basins by hand and standing in the water while capturing the fish. The team also travels closely together when driving to pond sites, often sitting on fishing nets kept on top of a rikshaw van.

The harvesting team carries the nets from one farm to another and use drying as their method of disinfecting the nets, but even then only if time and weather conditions permit. These practices are problematic, because they run the risk of transmitting fish diseases and parasites, particularly on rainy days. In addition, because the COVID-19 virus can survive in water, there is also the risk of human contamination from a freshly used wet net (Anon. 2020).

Typically, ponds are netted when they are full of water. The water is usually taken out gradually by a pump, while netting is done over a few days. In many cases, the water is pumped into another pond to save the cost of pumping water from a borehole. But filling another pond with “old” water, if untreated, is a potential biosecurity issue, as the water can transfer diseases and parasites.

When the members of the harvest team enter the water, they remove the fish by hand after pulling the nets through the pond. The fish are kept in rice bags or large plastic basins and then carried by hand to the rikshaw van, where they are placed into 200 L capacity drums that are kept on the vehicle. The fish are taken to the truck on the road outside the farm. Usually, aeration is not done at this stage, so the fish are often stressed because of a lack of dissolved oxygen (DO) in the water before to being loaded onto the truck for transportation to a fish conditioning center. The water is aerated on the truck during transportation, and up to 1 t of fish are carried to the conditioning tank(s) of the fish trader.

2.2. Fish conditioning

The purpose of fish conditioning is to minimize mortalities by allowing the fish to recover from the stress of harvest before being transported to markets.

Standard conditioning tanks (Plate 1) at a fish conditioning station are often about 5 m diameter. They are round in shape and can be filled to approximately 90 cm, providing 17.7 m^3 of water. Usually, up to 2 t of fish are kept in each tank for at least 6 hours for conditioning.

Releasing fish into a conditioning tank from a rice bag containing too many fish in one bag.

Unloading live fish from a transportation tank.

Plate 1. Conditioning and handling live fish.

2.2.1. Water quality management at fish conditioning stations

Water used at fish conditioning stations often comes directly from a borehole, without aeration. Water in the conditioning tank is recirculated by spraying it from pipe that is fitted on the circular side wall. This creates some aeration and circulation. When the water quality deteriorates, a portion of the water is discharged and new water is added from a borehole. The sediment from fish excreta is concentrated in the center, where it can be easily removed by opening the outlet pipe.

However, fish have often been observed gasping in conditioning tanks because of low DO levels and high levels of carbon dioxide in the water. The carbon dioxide levels in water from boreholes are often about 100 mg/L, and filling the conditioning tank or pumping the water into a transportation tank does not remove it.

As of early 2020, most traders and fish transporters have not been made aware of how important water quality is, particularly regarding the harmful effects of excess carbon dioxide in water taken from a borehole. Even though adequate aeration removes excess carbon dioxide, conditioning stations are not doing this. Observed water quality in trader conditioning stations and during transportation is shown in Table 1.

Water quality parameters	Water from a borehole at the farm and from a truck at the start	Conditioning tank with fish	Truck at Sirajganj during transportation and prior to another water exchange*
Temperature (°C)	27	26	22
pH	7.0	7.0	8.25
DO mg/L	0.2	2.0	8.65
Carbon dioxide (CO_2) mg/L	99.8	115.2	110.8
TAN (Nitrogen: NH_3 + NH_4) mg/L	0.2	0.2	6.0

*DO increased by aeration. CO_2 and TAN has increased due to metabolic activity of fish and aeration failed to remove it.Although TAN is basic and it has increased, the reason for changing the pH to basic could not be understood. The litle amount of TAN is not makes such a pH change.

Table 1. Water quality parameters at a trader's installation and a water exchange station after four hours of transportation and prior to another water exchange.

2.3. Methods of live fish transportation

Generally, trucks with a 10 t capacity are used to carry live fish to Dhaka and other larger fish markets. Usually, three people accompany the fish: one or two drivers and one or two fish handlers. The relatively small cabin is not safe for three people, as it does not allow for proper distancing to avoid COVID-19 transmission. During transportation, only two people should travel in the front cabin of the truck to reduce the risk of transmition of the virus.

2.3.1. Open truck system

In the "open truck system," the cargo bed of a 10 t truck is covered with a tarpaulin so that it can hold water. The water volume depends on the area and depth of the bed and the carrying capacity of the truck. Commonly, the cargo beds are 4.87 m x 2.43 m in area and 1.20 m in height. Water is typically kept at a depth of 0.9 m, resulting in a capacity of about 10 m^3 (10 t) of water. Usually, a net is put over the top of the cargo bed to prevent the fish from escaping. However, water loss during transportation can reach as high as 50% as a result of water movement. Water falling out of the truck also increases the risk of accidents for other road users (Plate 2). In addition, water movement within the cargo bed can interfere with the stabilty of the truck, making it dangerous to drive. Although the water depth might start at 90 cm, on arrival it can be as low as 40–50 cm.

Being rolled around from the movement of the water in the truck stresses fish, as do High CO_2 and TAN levels. Low DO level occurs when the aeration pump fails, due to air entered in the suction pipe during excess water movement.

On arrival at markets, fish handlers enter the water in the truck to catch the fish and transfer them to the wholesalers. This can cause COVID-19 transmission when fish are handed over between workers.

Overall, the cost of live fish transportation over 100 km in an open truck system to markets is estimated at BDT 8.31/kg.

While the government has prohibited the use of open trucks for transporting fish, they are still being used because enforcement is ineffective. This system is not recommended since it causes signficant road safety issues and stress to fish.

2.3.2. Tank system

Live fish are also transported using low-cost water tanks that supply oxygen. Usually, secondhand plastic tanks with a capacity of 1 m^3 are used, which are reinforced by an iron frame with a few modifications. The tanks have a 1½ valve and use gravity to discharge water for water exchanges and tank cleaning. Up to eight tanks can be kept on a 10 t capacity truck (Plate 4). The price of this type of tank is approximately BDT 7000 before transformation. The cost of transformation consists of partially cutting the top of the tank and reinforcing the cover, which amounts to BDT 500. This method can be used to transport food fish, breeders and fingerlings. The advantage of this system is that it results in higher survival rates and less stress to the fish. The lid and the construction of the tank prevent water from being lost during transportation, and fully filled tanks will not interfere with driving or the stability of the truck. In addition, fish handlers do not have to enter the tanks to catch the fish on arrival at the wholesaler market (Plate 1).

A tank with a 1 m^3 capacity used with oxygen distributor pipes. Water cannot escape from the tank.

An open truck system that uses a diesel pump for aeration. Significant water loss occurs during transportation.

Plate 2. Two types of live fish transportation systems.

2.4. Aeration during transportation

Aeration is necessary to continuously supply DO in the water while removing carbon dioxide. There are two types of oxygen supply and/or aeration methods that are practiced.

2.4.1. Aeration by diesel pump

Most of the trucks used in the open truck system are equipped with a 4–6 hp diesel pump with a 3-inch diameter delivery pipe. About half a cusec (50 m3/h) of water falls from about 5 feet into the part of the truck that carries the fish. The turnover time for the water in the truck is 12 minutes at the start of the trip, but increases to about 24 minutes after arrival, when almost half of the water is lost. The heavy falling and turbulence of the water can stress and injure the fish. In addition, the water falls with little dispersion, so the effect on gas exchange is limited. Oxygen dissolves more easily, but removal of CO2 is difficcult. Customers also complain that diesel-driven pumps can lose fuel, which can fall into the water and contaminate the fish.

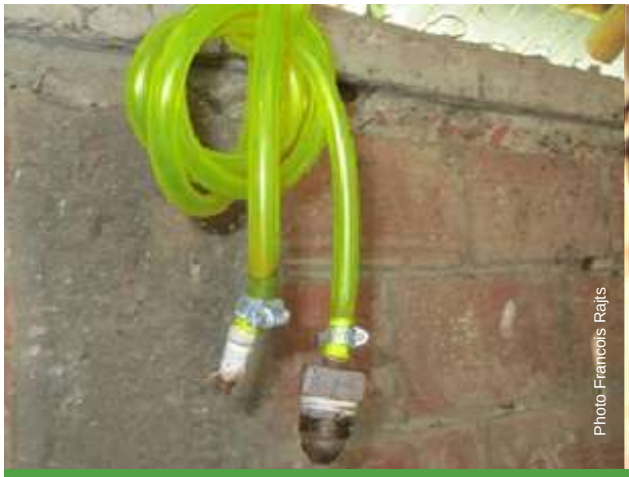
2.4.2. Oxygen cylinder and oxygen diffusion pipes

In the tank system, oxygen is diffused, in the form of small bubbles, from the bottom of the tank into the water. The smaller the bubbles, the larger their relative surface area, and the more oxygen is dissolved. Smaller bubbles also move more slowly to the surface, which transfers oxygen into the water more effectively.

In the Rajshahi region, the length of submerged oxygen diffusor pipes and their quality are inadequate. As a result, they release large bubbles, which escape from the water quickly, wasting oxygen and inefficiently aerating the tanks. In the Jashore area, the distribution pipes are generally of better quality, but pressure regulators are rarely used. Generally, each transportation tank is connected to one oxygen cylinder, and the amount of oxygen flow is regulated by opening the valve of the cylinder, without a manometer (pressure regulator). Instead of a manometer, locally made direct connectors are used. These are called *budka* (Plate 3). The pipe is not reinforced, so it can potentially rupture when the valve on the oxygen cylinder is opened, resulting in serious eye injuries.

2.4.3. Agitators and compressors

In few cases battery-operated compressors or water agitators are used for transportation of few hundred kilogram of live fish.



A locally made adapter to a cylinder, without a manometer, called a *budka*. This is a bad practice, because it supplies only one tank/diffusor.

Inappropriate diffusor pipe. Oxygen escapes from one side only, and large bubbles are less effective.

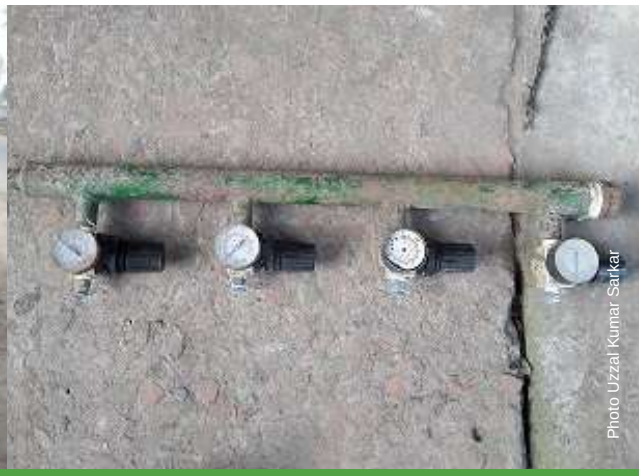
Plate 3. A locally made direct connector to link a single oxygen diffusor pipe.

When a *budka* is used, the flow of oxygen is uncertain because of the following:

- As the flow of oxygen is modified from shaking during transportation, this can result in faster flow. In this case, oversaturation of oxygen can affect the fish and cause them to die a few days later from gas embolism.
- The cylinder can empty too fast because the driver cannot see it when driving. This can result in fish mortalities.
- The flow of oxygen is reducing, following reduced pressure in the cylinder. This may result fish mortality
- Sometimes, rust inside the cylinder can block the flow of oxygen.
- A significant amount of oxygen is wasted because of the lack of a gauge.

The cost of transportation per fish in the tank system is estimated at BDT 5.66/kg per 100 km. Tank systems with proper gauges and pressure regulators that can control oxygen levels are recommended for live fish transport. Plate 4 shows improved oxygen distribution equipment.

A locally made perforated oxygen diffusor pipe, made of crystal PVC pipe.



An oxygen distributor device, which can supply oxygen to four tanks. Pressure is precisely regulated, and the driver can observe the flow of oxygen while driving.

Plate 4. Improved oxygen distribution equipment in Jahsore.

2.5. Handling fish

Fish are carried by hand in rice bags to and from the truck and into the conditioning tank. In both the open truck system and in conditioning tanks, fish handlers enter the water to catch the fish and place them in rice bags. This requires a second person, who holds the rice bag. The distance between workers is less than 1 m, and physical contact is almost inevitable.

In the case of the tank transportation system, workers do not have to enter the tank to discharge the fish. Instead, they use a plastic basket to remove them (Plate 1). However, close contact occurs when passing the basket to another worker, so it is important for them to use a dip net with a long handle to reduce the risk of COVID-19 transmission. Workers must also take care to handle the fish properly in concrete conditioning tanks, because the fish can injure their skin while trying to escape.

The amount of fish a truck transports is usually 800–1000 kg, depending on the temperature, species and size. The high stocking density and constant water movement in the trucks stress the fish, and about 1% die from repeated handling. The duration of transportation and the number of people handling the fish from the pond to the customer in the market is shown in Table 2.

Transportation	Estimated time to complete	Number of times fish are handled from pond to customer	Observation
Fish are loaded onto a rikshaw van while workers stand on the pond dike.	5 mins	1	Fish are carried by hand in rice bags from the pond to the rikshaw van.
Fish are transferred from the rikshaw van to the trader's truck.	10 mins	1	Without aeration, the process results in about a 1% mortality rate.
Fish are transported from the fish farm to the trader's conditioning farm.	45 mins	1	Fish are weighed in a rice bag and then kept in a conditioning tank.
Fish remain in the conditioning tank.	7 hours	0	Insufficient aeration causes the fish to gasp at the surface
Fish are then transferred from the conditioning tank to a water exchange station.	4 hours	1	There is an increase in ammonia and carbon dioxide levels, and about 50% of the water is lost in the open truck system.
Fish are then transported from the water exchange station to a wholesale market.	4 hours	1	There is an increase in ammonia and carbon dioxide levels. The fish become tired, which results in a further 1% mortality rate.
Fish are transported from the wholesale market to a retail market.	1 hour	1	Because of the different sizes of vehicles and containers, small containers are not aerated. This results in increased injuries to the fish.
Finally, fish are bought from the market by customers.	2 hours	1	Fish still being alive in the market results in top prices, however at the least extremely fresh fish are provided.
Total	**19 hours**	**7**	

Table 2. Fish handling steps, from pond to customer in retail markets.

2.6. Water quality changes during live fish transportation

Water quality changes were observed in transporting 1 t of live rohu in an open truck system from the trader's station in Rajshahi to the water exchange station in Sirajganj. The distance is 127 km, but the trip took 4 hours because of poor road conditions. The average size of the rohu was 1.5 kg. Privately owned water exchange "stations" are available at the side of the roads, where boreholes and pumps are installed. There is space and infrastructure at the stations for up to five trucks to change their water at the same time. The water is sold for BDT 300 by truck

(Plate 5).

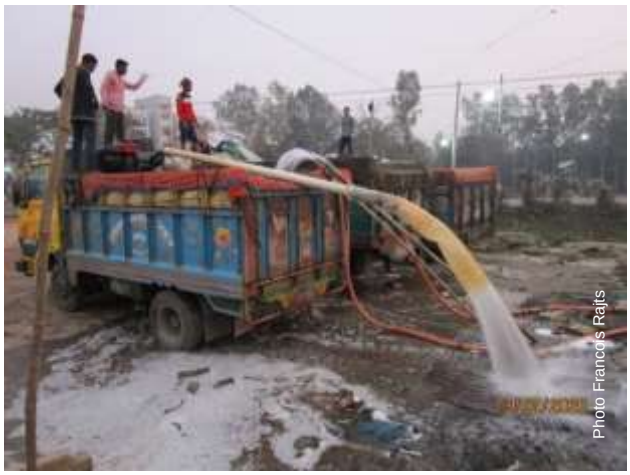


Plate 5. Water exchange during transportation at Sirajganj.

When the water was changed at Sirajganj, the fish were alive and shiny, but they were stressed and moving slowly. About one third of the water was lost during the trip. In some places, the road was wet, particularly at intersections and on turns because of all the water splashed around from trucks carrying fish. On any given day with a pick on Thursday night, there are estimated to be hundreds of trucks carrying live fish to various wholesale markets.

A 4 hp, 3-inch diameter diesel pump was continuously recirculating the carrying water by creating heavy turbulence and aeration in the tank. Water samples were taken on arrival in Sirajganj prior to water exchange, and the parameters were measured by a HACH FF-2 analysis kit. The water was turbid from the excreta of the fish, which indicated that the 5-hour conditioning period was too short. The fish were producing carbon dioxide, so the level in the water increased slightly from 99.8 to 110 mg/L during transportation even though the water had been continuously aerated. The DO level of the water was 0.2 ppm from the borehole at Rajshahi, and this increased close to 100% saturation (8.65 ppm at 22°C) on arrival in Sirajganj. total ammonia nitrogen (TAN) had increased from 0.2 to 6 ppm. This corresponds to 0.5 ppm highly toxic un-ionised ammonia (NH_3). The increase in TAN originated from fish metabolism and from bacterial decomposition of excreta. During the 4-hour trip, the temperature decreased from 27°C to 22°C, and the air temperature was 20°C on arrival. The measured water quality parameters are shown in Table 1.

3. Guidelines for live fish transportation

Implementing these guidelines will help aquaculture operators carry out farm activities. Special attention must be paid to controlling the risk of spreading the COVID-19 virus among all involved in fish farming operators and related staff. Not only should this reduce the risk of spreading the virus among humans, but it will also reduce the transmission of other pathogens to both human and aquatic animals. Working with fish frequently requires close contact between members of the working group. The COVID-19 virus is spread by droplets from coughing, sneezing or speaking. The droplets are either inhaled or make their way into the body through contact with the eyes, mouth or nose. In addition, the settled droplets can remain active on surfaces for some time, which could contaminate other people. That is why there is an urgent need to modify the traditional operating practices in the live fish transportation sector. There are many factors to take into consideration for successfully transporting live fish. Improving these could result in lower transmission of COVID-19 between workers and less stress and mortality for fish.

3.1. Health of fish and previous conditioning for transportation

It is important that fish are healthy for live fish transportation. Diseases, parasites, stress from bad water quality and inappropriate or poor handling can all impact fish health. Transporting unhealthy fish is not advised.

Conditioning for transportation is widely used in Bangladesh. Food fish should be starved for at least 48 hours prior to harvesting and then kept in conditioning tanks for about 12 hours before transportation. Conditioning tanks are provided with aeration by pumping water, but this is typically inadequate. Water at the conditioning stages should be aerated by using a water tower or another technology.

3.2. Temperature of water

In tropical conditions, the water temperature can vary significantly during the day, so transportation is preferable at night or early morning, when temperatures are lowest. During high temperatures, the metabolism of fish increases, resulting in higher oxygen consumption and greater production of harmful carbon dioxide and ammonia. The water temperature from boreholes is generally 27°C, except in the north, where it is 26°C throughout the year. From October to March, the temperature of borehole water can be lowered by keeping it overnight in open tanks. Lowering the water temperature in transportation tanks can be done with ice. Placing 2 kg of ice blocks on the surface of the water will reduce the temperature of 100 L of water by about 1.5°C. While the blocks float, they will gradually reduce the temperature as they melt, which will in turn cool the fish slowly. Thermal stratification in ponds results from higher water temperatures on the surface, so any water used for transportation from ponds should be taken from the deeper parts of the pond. Pondwater should be mixed with cooled transport water to gradually equalize the temperatures.

3.3. Dissolved oxygen

The fish species, age, mass, temperature and stress, as well as the actual level of dissolved oxygen and presence of other gases, all influence oxygen consumption during transportation. Without adequate oxygen supply, fish can die in the transportation tank. For Indian major carps, Chinese carps, common carps and other cyprinids, the minimum recommended DO level is 4 mg/L. This should be the target for conditioning stations and in tanks during transportation.

Oxygen consumption is higher in a tank if the fish are young, because they consume relatively more oxygen (for the same biomass as larger ones). It is also higher for species like catla, which need more oxygen than fish living in stagnant water, such as tilapia. Stressed fish and higher water temperatures will also result in increased oxygen consumption.

Oxygen consumption in the tank decreases if the water temperature is lower or if the fish are tranquilized during transportation. There are also some species, such as magur, shing and koi, that can use atmospheric oxygen, which can lower consumption within the tank.

3.4. Carbon dioxide and ammonia

Stress and related mortalities from elevated carbon dioxide and ammonia levels can only be avoided by aerating the water and through water changes during transporation.

The pH of water indicates the toxicity level of carbon dioxide and ammonia. In well buffered water, where alkalinity high, the pH will not change quickly. Water from boreholes is generally higher in alkalinity than surface water of the same area. Carbon dioxide is toxic when the pH is acidic (free carbon dioxide). Free carbon dioxide prevents the hemoglobin in the blood of fish from effectively carrying oxygen.

Ammonia toxicity increases with rising pH. Both carbon dioxide and ammonia are metabolic wastes of fish. In addition, bacteria grown on fish excreta both produce gases and consume oxygen. Accordingly, the amount of dissolved toxic gases is directly related to the elapsed time during transportation. Although carbon dioxide and ammonia can be released into the atmosphere through aeration, changing the water is generally required after the first 4 hours and then later after 5–6 hours. The toxic form of ammonia (NH_3) can kill fish even at low levels (2 ppm). The percentage of un-ionized ammonia in relation to temperature and pH of water is presented in Table 4.

Temp. (°C)	pH				
	6.0	7.0	8.0	9.0	10.0
0	0.008	0.08	0.82	7.64	45.3
2	0.01	0.10	0.97	8.90	49.3
4	0.01	0.12	1.14	10.3	53.5
6	0.01	0.14	1.34	11.9	57.6
8	0.02	0.16	1.57	13.7	61.4
10	0.02	0.19	1.83	15.7	65.1
12	0.02	0.22	2.13	17.9	68.5
14	0.03	0.25	2.48	20.2	71.7
16	0.03	0.29	2.87	22.8	74.7
18	0.03	0.34	3.31	25.5	77.4
20	0.04	0.40	3.82	28.4	79.9
22	0.05	0.46	4.39	31.5	82.1
24	0.05	0.53	5.03	34.6	84.1
26	0.06	0.61	5.75	37.9	85.9
28	0.07	0.70	6.56	41.2	87.5
30	0.08	0.80	7.46	44.6	89.0

Source: Emerson et al. 1975.

Table 4. Percent of un-ionized ammonia in relation to water temperature and pH.

4. Guidelines for conditioning fish

Conditioning fish before transporting them to markets is a relatively new practice in Bangladesh. Fish traders started it to improve the survival of live fish. Currently, there is a lack of knowledge among operators regarding how to best manage water quality at the conditioning stations.

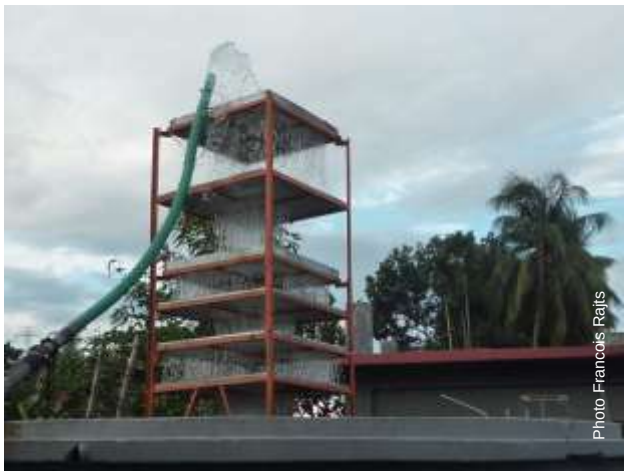


Plate 7. Water aeration structure (water tower) in Bangladesh.

The following are the best practices that should be used for managing water quality at conditioning stations:

- Pump water into conditioning tanks from boreholes.
- Aerate the water so that fish are conditioned in well-oxygenated water (above 4 mg/L) before being transported to market.
- Aerate the borewater using a “water tower,” which is an aeration structure used by hatcheries (Plate 7). A water tower can automatically lower carbon dioxide in borewater to safe levels and increase the DO content up to 100% saturation before the water goes into the conditioning tanks.
- Fill the conditioning tank for 30 minutes. The tank needs to be fully filled before the fish arrive at the station, or at least before fish are put into the tank. Otherwise, there is potential for them to get injured if the water in the tank is too shallow.
- The maximum holding capacity of a standard conditioning tank (17 m^3) is 2 t of fish, if continuous aeration of water is provided.
- For safety reasons, install at least two oxygen cylinders and oxygen diffuser pipes on the transportation truck.
- Fill the tanks on the trucks with aerated water (over 4 ppm of oxygen).
- Replace the water every 2 hours within the conditioning tanks to ensure better quality water and improved survival of fish during transportation.
- If water is circulated, the round shape of conditioning tanks allows concentrates waste into the center. To achieve this, direct the inlet water sprayers in such a way as to circulate the water.
- From time to time, when feces accumulate, open the central outlet to drain off accumulated waste from the conditioning tank.

- Handle fish using well-constructed dip nets with long handles to allow social distancing of 6 feet.
- When installing an aeration tower, it is recommended to have perforated successive platforms to remove carbon dioxide from the water pumped from a borehole. As the water falls into the conditioning tank or into a transportation truck, it dissolves oxygen into the water.
- Add 1 ppt of common salt to water used in transportation to improve TAN tolerance and help fish regenerate the mucus covering their bodies.

5. Guidelines for transporting live fish

The following are the recommended guidelines for transporting live fish in four 1000 L tanks on a 5 t capacity truck:

- Confirm all arrangements in advance, starting with harvesting from the supplying farm all the way to receiving the fish at the conditioning station.
- Check the truck's documents, engine, breaks, lights, spare wheel, etc. to make sure the vehicle is in good condition.
- Disinfect the cabin and the platform, including all tanks, nets and accessories prior to use. To disinfect hard surfaces, wipe them using sodium hypochlorite at 1000 ppm. (In 10 L of water dilute 200 ml of household bleach, such as Chlorox 5%, which is available in Bangladesh). For sensitive items, use alcohol-based wipes.
- In the cabin, alcohol-based hand sanitizer and hygienic wipes or sprays are recommended for sanitizing hands and surfaces. (70% alcohol concentration is required).
- Make sure aerators/agitators are in working condition, if available.
- Ensure that three 12 V batteries for the aerators/agitators are fully charged and that the cables are connected.
- Check to make sure the oxygen gauges/manometers are connected in a series and operational. (There are two high and four low pressure ones for four tanks, including one standby high-pressure gauge. The first reduces the pressure of the cylinder roughly, and the released pressure changes with the exhausting pressure in the cylinder. The second ensures precise and constant pressure to the diffusers.)
- Sometimes, rust and condensed water from inside the cylinder can block or damage the gauges/manometers. So it is important that oxygen cylinders (at least two) are full and fixed in a vertical position on the truck (valve up).
- Make sure oxygen pipes are in good condition and underwater diffusor pipes are not damaged.
- Ensure that wrenches/tools for oxygen cylinder exchange and pressure reducers are available.
- Put tools and chemicals in a box to keep them dry and to avoid rusting.
- For weighing the fish properly, make sure that the equipment is available and in working condition. There are three options for weighing fish: (1) a weighing scale, (2) a machine and buckets, or (3) some containers.
- Check to make sure that the fish are healthy and in good condition before transportation. Many fish can die in the tank if they are unhealthy, have recently recovered from a disease, or are not well-prepared during harvesting/conditioning.

- Train the fish in the ponds for shipping by organizing several net pulls during the week before transportation. This will minimize the stress on the fish when the actual event occurs.
- Do not feed fish for 2 days before transportation. This will minimize waste production, including feces and secreted metabolic wastes, such as ammonia.
- Condition the fish for a minimum of 12 hours, preferably in a conditioning tank with adequate water exchange or aeration to maintain a minimum DO level of 4 ppm. This length of time is required for the fish to recover from stress, regenerate their mucus membrane and for habituating crowded conditions.
- If possible, fill the transportation tanks the previous evening and keep them open to cool down the water. This will save the cost of ice.
- Identify the availability of ice for water exchange on the expected route to market.
- Sometimes, salt is used in transportation water (0.5–2 kg/m^3), so make sure to have it on hand.
- In case the water exchange station is unavailable, keep a pump filled with petrol, together with suction/delivery pipes, for exchanging water from pond or river.
- Ensure that rubber gaskets for hermetically fitting suction and delivery pipes are available, including spares.
- Make sure that the covers/lids of the transportation tanks are operational.
- Fit a sponge on the inner site of the tank covers to prevent fish injuries from screws or other sharp surfaces (Plate 2).
- Ensure a trained live fish handler is on hand at all times and accompanies the fish in the truck.
- For transportation, it is preferable to take water from a borehole, though pondwater can be used when the water temperature is lower than 27°C.
- If taking water from a pond, place the end of the suction pipe 1–1.5 m below the surface to avoid the hot water on top.
- Cover the end of the suction pipe with a protective screen, and use a float to keep the pipe at the desired depth.
- Keep the water in the transportation tanks well aerated.
- Measure the water quality 30 minutes before loading. The pH should be 7–8.5, the DO above 6 and the carbon dioxide under 15 ppm. A HACH-FF2 kit and digital DO meter (for oxygen only) are useful, but small kits for aquarium hobbyists are accurate enough and also affordable.
- Start the oxygen distribution before loading the fish. It is necessary to ensure that there is adequate, homogenous distribution of oxygen bubbles in the tank.
- To reduce water movement during the trip, fill the transportation tanks and maintain them at that depth.
- Make sure weighing bags have an inside plastic layer to avoid damage to the mucus covering of the fish.
- Carry food fish at a maximum density of 150 kg/1 m^3 for up to 10 hours or at 200 kg/1 m^3 for 15 hours at a water temperature below 25°C.
- During transportation, avoid stopping the truck for more than 10 minutes. If stopped, keep it under shelter for no more than 10 minutes to avoid overheating the water and the fish.
- During transportation, check the oxygen supply or agitators every hour. The best system is one in which the driver can see the gauges/manometers while driving.
- To avoid thermal shock while loading or unloading fish, make sure the temperature in the fishpond and transportation tank does not differ by more than

3°C. If it does, adjust the temperature by pumping receiving water into the transportation tank.

- After loading the fish, keep blocks of ice on hand to lower the temperature in the transportation tanks. (Do not use grinded ice or small pieces to avoid sudden changes in temperature.) Two kg of ice will reduce the temperature in 100 L of water by about 1.5°C.
- While placing blocks of ice in the tank, take care not to damage the agitator or the fish.
- Monitor the water quality every 2–3 hours during transportation. If the DO level is low, and fish are gasping at the surface, increase the amount of diffused oxygen. Replace the water if un-ionised ammonia rises above 0.2 ppm.
- Change the water if the tanks are becoming polluted with excreta and mucus. Ensure that the replacement water is of good quality.
- Upon delivery, pump the water from the receiving pond into the fish tank (partial exchange) to equalize the physicochemical quality of the water.
- Count the fish while loading in the carrying bags or dip nets—not when releasing them in the conditioning tank or pond. This will avoid double handling if more than one fish is kept in a bag or net.
- While loading or unloading fish, use dip nets with long handles to allow for social distancing.

6. Guidelines for fish harvesting

Before harvest, take a sample of about 20 fish in the pond using a net, and examine them for signs of disease and parasites. Treatment is required if the fish are sick or parasites are present. A specialist extension worker or veterinarian should identify the disease or parasite and provide advice on the treatment required.

Pond treatment of fish using chemicals/therapeutants

- For oral treatment, reduce the quantity of feed by half.
- To treat the water, reduce the depth to a safe minimum before applying the chemical or medication.
- Run pond aerators at night to ensure a safe level of oxygen in the pond.
- If possible, refill or change the water in the pond after treatment.
- Determine the authorized safe date of harvesting to avoid any residues in treated fish by the time the fish are consumed.

- Prepare a plan of action for harvesting. Informe or organize all stakeholders and include measures to prevent the transmission of COVID-19.
- Repair all equipment, such as nets and buckets, for use during the harvest.

Disinfecting all equipment prior to harvest

- Soak fishing nets for 15 minutes in sodium hypochlorite using a household bleach such as Chlorox 5%, which is available in Bangladesh. The dilution rate is 1000 ppm: 200 ml of Chlorox into 100 L of water.
- Soak fishing nets for 15 minutes in benzalkonium chloride (BKC) at a dilution rate of 250 ppm of the active ingredient. The disinfectant effect against COVID-19 is not confirmed. Timsen®, which contains 40% BKC, is available in Bangladesh.

- Starve the fish 2–3 days before harvesting.
- Remove the water from the pond gradually.
- Make sure that the fish harvesting contractors arrive early in the morning. Advise all members about social distancing. Usually, the group arrives on a rikshaw van, sitting together on fishing nets.
- Staff must clean their hands at the entrance of the farm using hand sanitizer or by washing their hands for 20 seconds with soap and water.
- If anyone appears sick or has a fever, avoid all personal contact, then send them home and advise a doctor.
- For fish transportation, make sure that fresh, aerated water is available, preferably from a borehole, which has a temperature of 26°C–27°C in Bangladesh.
- Prepare equipment at the pond site, including nets, buckets, carrying bags, 60 L plastic basins, weighing scales, dip nets and sorting tables.
- Before beginning the harvest, hold a briefing to organize the procedures. Take special care to maintain social distancing of 6 feet between participants.
- Minimize the handling of live fish.
- Use a knotless, soft net with an appropriate mesh size that will not damage the skin and mucus covering of the fish. Damaged mucus layers, skin or scales are

entry points for infection by pathogenic microorganisms.

- Do not pull the fish together strongly in the seine net while harvesting. This will prevent the fish from scraping each other and jumping excessively, which can result in injuries to fish and even the handlers.
- Take care to ensure that the fish are out of water for the shortest possible time.
- During netting and harvesting, pull the net slowly and handle the fish carefully to avoid stressing the fish.
- During the last seven days before harvesting, net and release the fish back into the pond three times to reduce stress during the harvesting/transportation process.
- For harvesting, use dip nets with long handles and an appropriate mesh size to avoid fishers getting too close to each other. The risk of transmitting COVID-19 increases when fish are transferred using dip nets with short handles or by hand from one fisher to another.
- After harvesting, carry the fish from the farm and onto a truck or van for transportation to a conditioning station. A rikshaw van equipped with two 200 L drums is often used.
- Make sure that the weight of the fish in each drum does not exceed 40 kg for short periods (10 minutes).
- Use oxygen to aerate the water, or splash the water in the drums by hand.

7. References and suggested literature

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