Design and Test an Air Lift Siphon

LESSON

Background:

Water movement in an aquaponics system is critical for aeration and the circulation of nutrients and oxygen. There are several possible methods to lift the water back to the surface in a gravity fed system. One inexpensive option is an air lift pump that uses compressed air to lift or elevate water. The airlift pump was first invented at the end of the 18th century by Carl Emanuel Loscher, a German. An air lift pump is composed of PVC, an airline, and a simple aquarium pump (that is not in the water); it contains no moving parts. It helps to keep the water aerated and circulating in the closed system. In the field of fluid mechanics this is an example of two-phase flow where one phase of water is present in liquid state and the other as a gas.

The principle that explains this process is Archimedes principle, "the buoyancy force is caused by the pressure exerted by the fluid in which it is submersed and that the buoyant force points upwards because the pressure increases with depth". The PVC tube controls the air flow to the surface of the water. As air moves to the surface, there is less pressure and the gas in the air bubbles expand slightly increasing its circumference, thus quickly moving more water up the tube.

The advantages of an airlift pump are numerous, but must be weighed against the disadvantages. In aquaponics, disadvantages include the low flow rate, poor suction (although this can also be an advantage), and limited lift height. Advantages for the system include a low initial cost (aquarium pump, airline, and PVC pipe sections), reduced use of energy (lower cost to operate), much of the air stays in the water resulting in increased aeration, and small space requirements.

Airlift pumps aren't just used in aquaculture and aquaponics, in fact they were initially used in the petroleum industry. They are excellent for moving toxic or corrosive materials. These systems are currently are used in ocean mining, the petroleum industry, and waste water treatment bioreactors.

Learning Objective:

Students will build upon prior knowledge of air and water density, importance of water circulation and use basic engineering and mechanics to develop a air lift siphon to move water between two aquaponics tanks.

Essential Questions:

1. Why does water need to move or circulate in the aquaponics system?
2. How does pressure affect air at depth?
3. How do you determine flow rate for air or water?
4. What are the limits to an air lift siphon system?

Core Idea:

Use lessons from physics to help us design a pump that can transport water with limited additional energy.

Standards Correlation:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Science/Engineering practice: Asking questions, anaylzing and interpreting data.

Crosscutting Concepts: The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values.

Vocabulary:

- **air siphon pump** – a liquid reservoir in an inverted U-tube, used to move liquid from one reservoir to another while moving over a higher level or barrier; the flow of water is caused by air and is maintained using an air pump
- **circulation** – movement or passage of liquid in a system
- **flow rate** – the volume of fluid that moves from the siphon each second or minute; (flow rate in a pipe is defined as Q=Av where Q is the flow rate, A is the circumference of the pipe through which the fluid is moving and v is the speed of the fluid)
- **fluid** – a state of matter including liquid or gas substance that yields easily to external pressure and has no fixed shape
- **gravity** - force with which the earth, moon, or other massively large object attracts another object towards itself
- **physics** – the branch of science concerned with the nature of matter and energy and the interaction between them
- **pressure** – continuous force exerted on or against the surface of an object or material per unit area
- **siphon** – to raise liquid from one location to another overcoming a barrier using air suction (by removal of air) through priming or immersion; once started a siphon is able to continue is all factors remain constant

Materials:

- plastic cup with two holes in the side: one close to the bottom on the side and one directly 3 cm above the first hole
- electrical tape to cover holes
- water
- towels
- air pumps and airlines for each group
- airstones
- two buckets
- pieces of pvc cut in different lengths
- pvc corners
- pvc connectors
- timer or cell phone
- graduated cylinder
- empty water bottle
- paper and pencils

Engage

(5 minutes)

One of the goals of aquaponics is to produce healthy food sustainably, using as little energy as possible. Today we will focus on the movement of water.

Ask students: In 1 minute write down as many reasons as you can think of about why water needs to circulate in the aquaponics system?

- move wastes away from fish
- move nitrogen to bacteria,
- move nitrates (fertilizer) to plants
- bring oxygen to fish, roots and microbes
- ensure mixing of water for equal distribution of nutrients and oxygen
- provide habitat for fish
- keep submersed pump working
- etc.

Now take a minute and create a master list for your table group or for the class adding all of your ideas together. Share out some of the results.

Explore

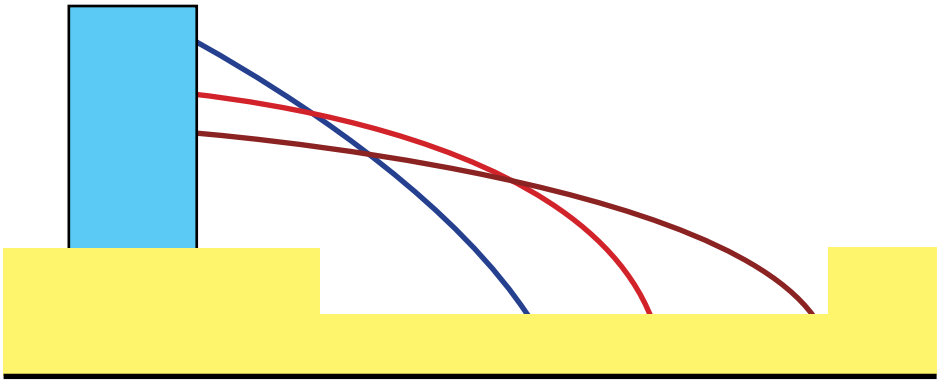
(25 – 55 minutes)

Air and water are both fluids. Both of these fluids flow in your system so as we take a minute to think about your system.

What causes the water to move or flow in your system without needing electrical energy? If needed, get up and look at the system and draw where is the water moving. *(gravity)*

There is another force acting upon the water as well. Lets look at this cup. I've poked two holes in the cup, one about 3 cm above the other. When I pour in water what do you expect to see?
(if students mention bottom hole will flow further ask them why, if not demonstrate first)

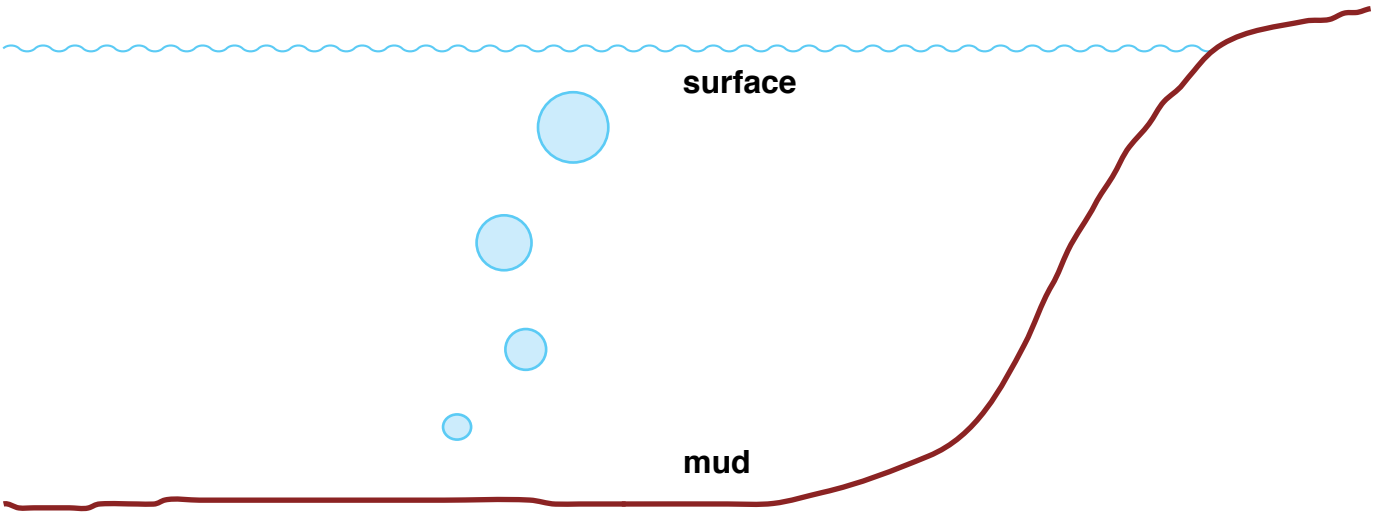
Let's give it a try. What causes the water to flow?



Hydrostatic pressure is what causes water to flow out of a hole in a cup – it forces fluid forwards or outwards. Ask what caused the lower stream to flow further out than the upper stream *(increased pressure with more water above the lower hole)*.

Next take a minute to think about how does air and water interact at depth? What if air is introduced and released from below water, what happens? *It floats through the air to the surface as it is less dense.*

What happens to air bubbles as you go deeper in the water? What force acts on those bubbles? (think of a scuba divers if that helps) *the air compresses with increased pressure so an air bubble gets smaller as it goes deeper and larger as it rises to the surface.* Draw a cartoon for students to see.



Today we are asking you to work in groups to move water by using the physics of this process, air expanding as it rises due to less pressure. The materials you have available to use include an air pump (please keep the pump itself out of the water), air tubing, PVC piping and connectors, an airstone, an empty plastic bottle, graduated cylinders, water, paper and pencil.

Your challenge is as a team to move water from one bucket to the other bucket using air. You'll need to plan out your idea, select materials, test your idea, record your observations and retest. It is essential you record each change and the result of that change so that your work can be replicated.

The ultimate goal is to move the greatest amount of water continuously using an airlift siphon that you will build. Take time to talk about what you plan, to draw your work and to record your observations so that you don't miss any steps. When you are finished you will have a drawing of your system, the steps you went through in your design and the flow rate for your system. Do you have any questions?

When you calculate the flow rate of your air pump and the flow rate of water you move with your air pump siphon test it more than one time to get an average.

Please remember with electricity, keep the electrical connections dry. These are not submersible pumps.

Before the end of the class we would like you to explain:

- what you did including revisions (make sure to keep a record of changes – as if writing directions, be specific);
- a final drawing of your completed air siphon pump;
- what makes your airlift siphon work best;
- what are its limitations;
- how you might change it if you had infinite materials and time to refine your design the flow rate of your system.

Have students share their results.

Explain

Have students look at the bell siphon in their aquaponics system. See if they can identify how it works – describe the process.

How a bell siphon works:

- As the water level rises in the grow-bed, water is forced through the teeth on the bottom of the bell and up between the walls of the standpipe and bell.
- As the water level exceeds the height of the stand pipe and the drain begins to fill, a siphon is created.
- Most of the water in the grow-bed is then drained by the siphon until the water level reaches the height of the teeth and tip of the snorkel.
- Air is then forced through the snorkel, and as a result the siphon is broken, resulting in the grow-bed beginning to fill again; the cycle then repeats itself. More information can be found here: http://www.ctahr.hawaii.edu/oc/freepubs/pdf/bio-10.pdf

As the water flushes from the top bed into the bottom bed, the splashing increases the amount of oxygen available in the water as dissolved oxygen. Think for a minute about movement of gases from the atmosphere into water. Oxygen is dissolved into water and is used by fish living in the water. The largest amount of oxygen present in most tank water has worked its way down from the surface, which is one of the reasons that a wide, shallow tank is a better choice for most fish than a tall, narrow one. The larger the surface area of the tank is, the greater the amount of oxygen that can be dissolved into the water. There is often not enough oxygen for fish, bacteria and roots so we add splash or use airstones to add oxygen.

Evaluate

Have students evaluate the their air lift siphon.

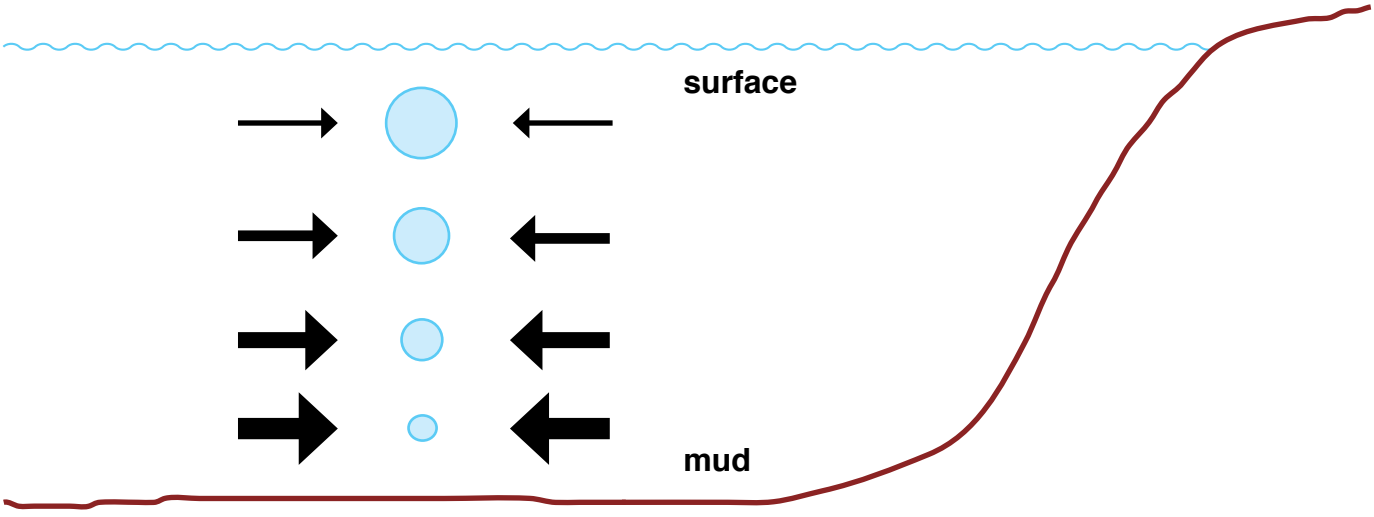
1. How does the air siphon pump address the water movement in an aquaponics system?

2. What are the limitations within the system including what scientific or engineering processes are relevant to these limitations?

3. How does one solution or system compare to other solutions or systems in the class?

4. How does it or does it not provide a solution on a large scale?

5. What impact would using an air siphon pump make on the environment?



Additional Resources:

1) History and use of airlift pumps - http://www.koinet.net/j/index.php/articles/148-airlift-pumps-part-1.html

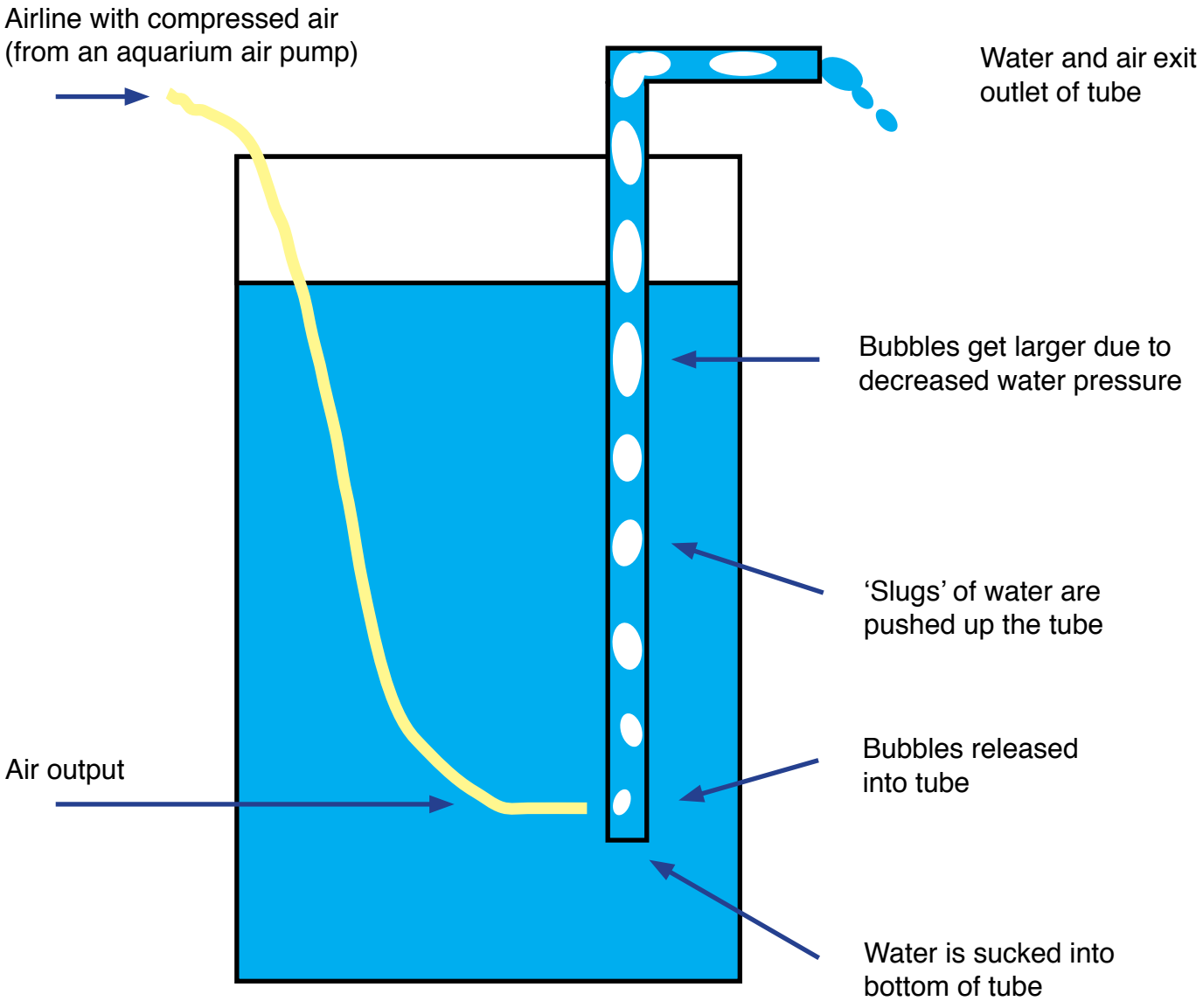
2) Video of how air-lift pump works - https://www.youtube.com/watch?v=03EmME_OB-s

3) An Investigation of the Air Lift Pump, Vol.6, Issues 1 -7 by George Jacob Davis and Carl Robert Veidner - https://books.google.com/books?id=-qVIAAAAMAAJ&pg=PA15&lpg=PA15&dq=invention+of+air+lift+pump&source=bl&ots=UmebFJnfqk&sig=yOKBHNkchbF2eQogQsW0zLzzSdw&hl=en&sa=X&ved=0ahUKEwiXsrbOu6vRAhXKiVQKHdTGC4sQ6AEIdTAT#v=onepage&q=invention%20of%20air%20lift%20pump&f=false

4) Performance and Design Characteristics of Airlift Pumps http://www.aces.edu/users/davisda/classes/facilities/resources/AirliftPumps.pdf

Attachment A:

How an air lift works

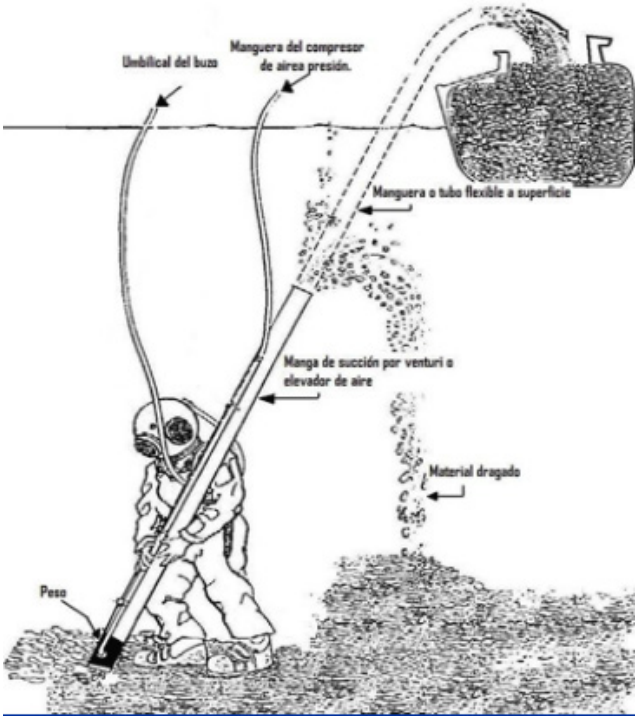


Attachment B:

How an air lift works

An airlift is a type of small suction dredge handheld underwater by DIVERS. It works by blowing air into the pipe, and that air, being lighter than water, rises inside the pipe, dragging water with it. The mixture rises and creates a differential pressure that lift water, or semisolid material, up the pipe. Deeper the air lift is working, more efficient it will be.

Air lifts are frequently used to clear mud and loose silt. They can remove semisolid or slurried materials continuously. But they will normally lift loose material only in the immediate vicinity of the lower end (about 10 - 15 meter away). Water jetting in the immediate vicinity of an air lift may break up heavy or hard-packed material and increase the efficiency of air lifts by discharging hard materials farther.



Source: http://www.abcdiving.com/pages/civilworks/dredg.jetting.html