2024-25

Optimizing a Floating Wetland: A System to Sequester Agrochemicals in Freshwater Ecosystems?

Logbook (2024-25)

Gayatri Sakharkar

Table of Contents

Daily Notes and Reflections 3

Background Research 15

References 29

Problem 31

Experimental Setup/Product Design/Research Methods 32

Data Collection 43

Analysis and Discussion 57

Conclusion 68

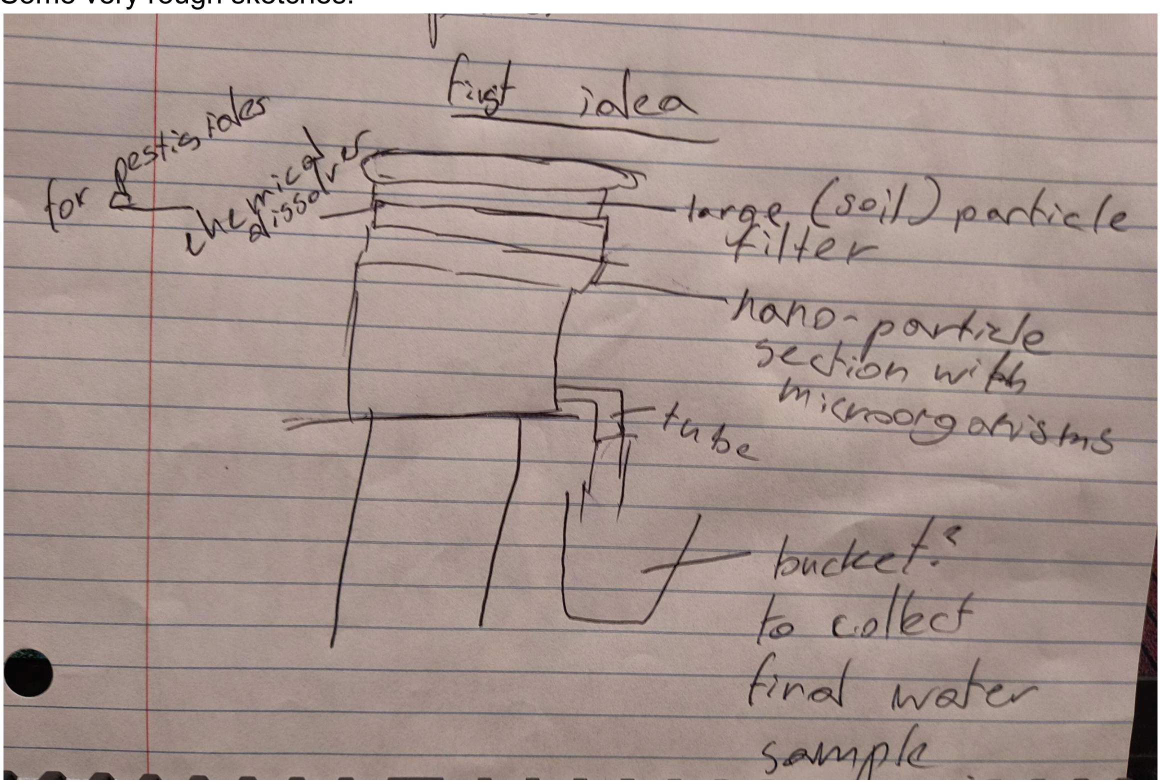
Daily Notes and Reflections

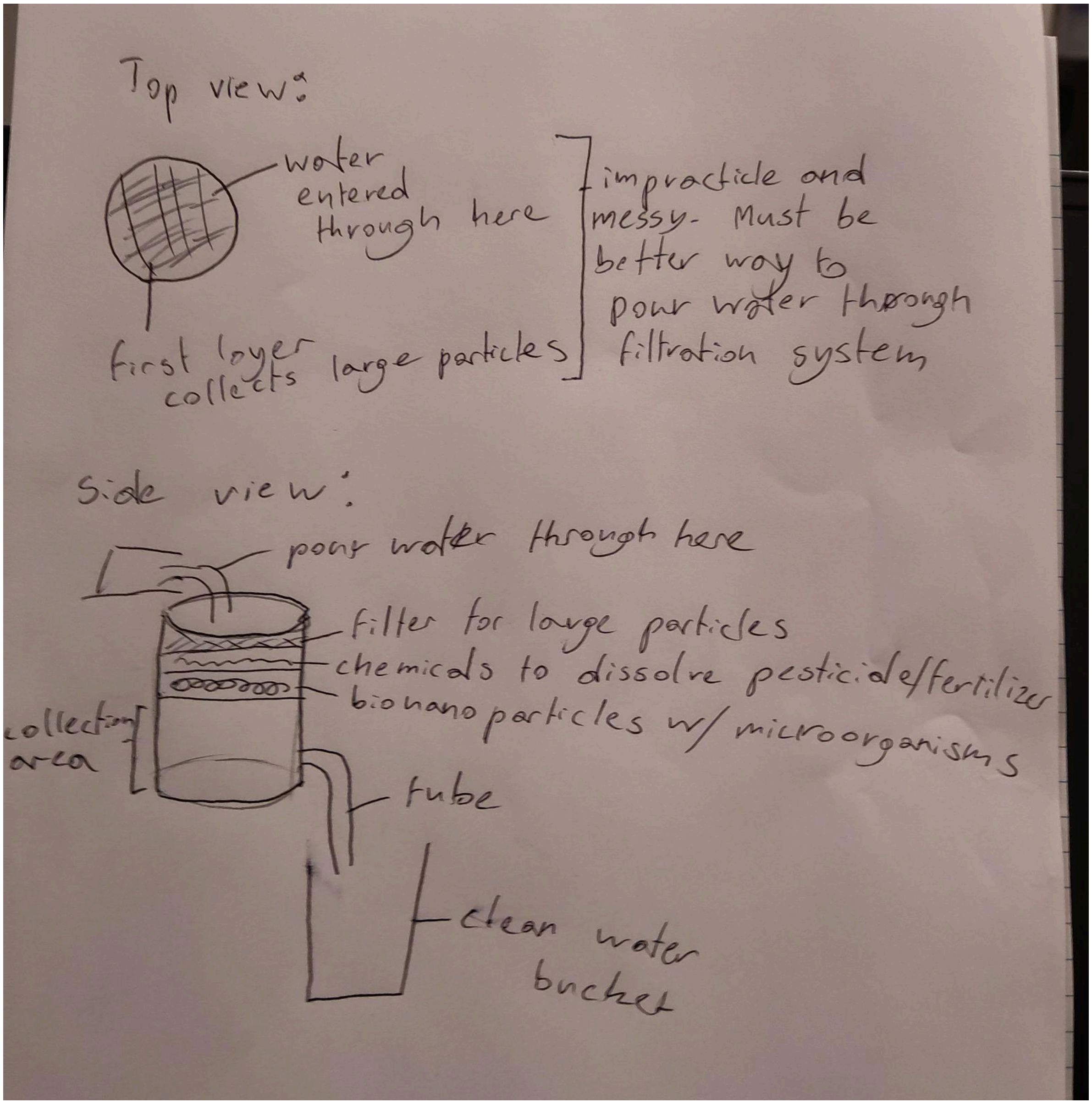
09/12/2023

Picking A Project/Initial Planning and Design

- After months of research and exposure to different fields, doing a project about water is highly beneficial to the world.
- Water pollution is a huge problem. This project may focus on agricultural pollution.
- Possible project idea is a water filtration system
- Objective of project: create a water filtration system that tackles agricultural pollutants such as pesticides, soil and fertilizer through the use of nanoparticles, chemical catalysts and various microorganisms.
    - Though there are many factors to consider with this innovation
        - What materials are needed?
        - How will the different parts of the filtration be separated? By layers? If so, how will I build the layers themselves?
        - How will I test for the purity of the water?
- water purity may be tested using the following:
    - PH strips
    - Phosphate detection kits
    - Pesticide testing kit
    - Dissolved oxygen testing kit

Some very rough sketches:



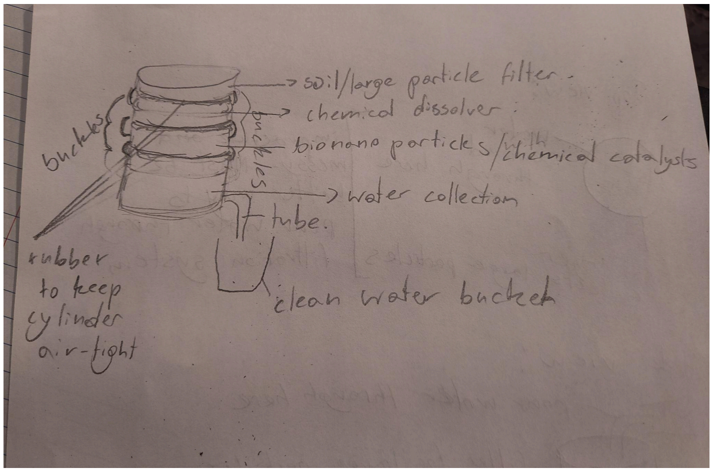


In these sketches, The filtration system is a cylindrical shape, with different layers for each "purifier"

Because this project deals with water, it can not be made out of wood due to mold. Must be made out of plastic or other substance. Someparts may be 3-D printed. Glass may also work for the project.

The way water enters and exits the cylinder, is very impractical and should be changed. This will likely be applicable to rivers. Consider the fact that river water is not stationary.

The cylinder has to be airtight, to keep the water from seeping out. Buckles and rubber may be used between each layer.



Above, is the edited design with buckles and rubber for keeping it air tight.

The tube may also work when scaled up. Large pipes can be applied to the filtration system, then being feeded into fresh bodies of water.

Sensors can be used to efficiently identify the purity of the water.

09/13/2024

Considering different ideas for the first prototype. What is needed to research for this innovation?

using actual river water found near agricultural sites is a possibility instead of manually mixing pesticides or fertilizer in water.

Boiling the water can be used for any bacteria that has absorbed the pesticide.

Sensor technology or AI may also be applied to the system to explore whether the filtration is working well or not.

What is needed to research?

- [ ] water pollutants
    - [x] ~~fertilizer~~
    - [x] ~~soils~~
    - [x] ~~pesticides~~
    - [ ] Nitrate/Phosphate pollution
    - [ ] Turbidity and PH levels
- [ ] Sensor technology
    - [ ] What technology should be used?
    - [ ] How can AI be applied here?
    - [ ] What can detect nitrates, phosphates and PH, turbidity and temperature?
    - [ ] How do sensors work?
- [ ] What is Raspberry Pi? How to include AI into this project?
- [ ] How can Machine Learning be applied?

        - [ ] What is machine learning?
        - [ ] Simple AI models to trigger notifications based on sensors
            - [ ] decision trees
            - [ ] thresh-hold based alerts
        - [ ] How to set up SMS/email based alerts
    - [ ] What is filtration?
    - [ ] What is Biological filtration?
        - [ ] What organisms may be used?
        - [ ] How do organisms break down pesticides?
    - [ ] What are nanoparticles?
        - [ ] What do they do?
        - [ ] How can they speed up chemical reactions?
    - [ ] What are chemical catalysts?
    - [ ] What is solar power?
        - [ ] How can it be used in this prototype?

Engineering Process

Phase 1- Conceptual Design
- Gather all information and create proof of concept (is this feasible or not)
- Write down all information
- Create the first rough design
- Return to this step until this is possible

Phase 2 - feasibility study
- What is feasible? What is not feasible?
- consider cost, time, concept
- Risk analysis
- Revision, revision, revision

Phase 3 - Detailed Design/Engineering
- Once the feasibility study is over, begin detailed design of the project

Phase 5 - Construction

Phase 6 - Start up and commissioning

After very limited research, Arduino may be the most suitable for this project if sensors were to be used. Data from water quality sensors may be displayed on a small 16 x 2 screen. SMS may also be used. As a goal, this small prototype should be able to use at least 1 litre of water. To power the Arduino, solar/wind power can be used, if budget permits. If not, batteries must be used.

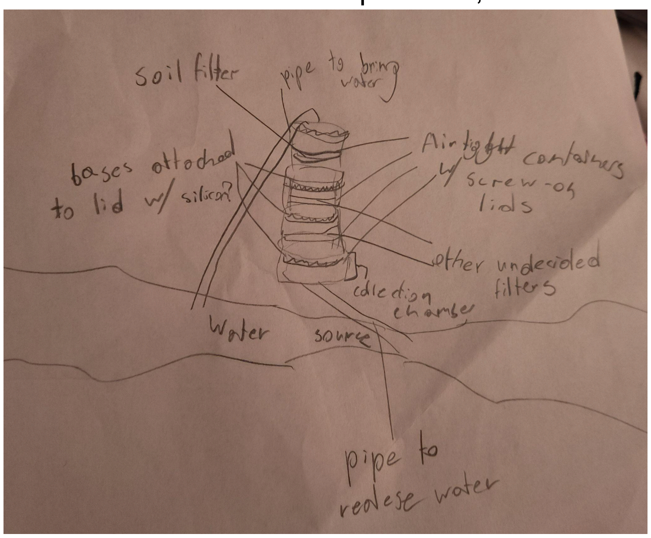
09/14/2024

How will this prototype be included in rivers?
- This project can only be used in small amounts but how will it deal with the whole river without the disruption of the flow of water?
- This can possibly be included in sewage systems near agricultural sites
- Possible ideas:
    - create a floating system
        - How can I make something so dense float?

        - place in a spot where it does not disturb the flow
        - use it for simply drinking water
        - create a system that directs an amount of water away from the main source and release it back into the main source after filtration
- What if it impacts organic matter such as grass, sticks and rocks?
        - add a plastic or metal mesh or chicken wire the size of about 5mm or lower? (this will not be a problem if I direct the water to another place.)

How will the application of nanoparticles or microorganisms work? What nanoparticles will I use? What microorganisms will I use? How will the application of these impact the filtration system?

- these are essential questions, without answering the final design can not be made

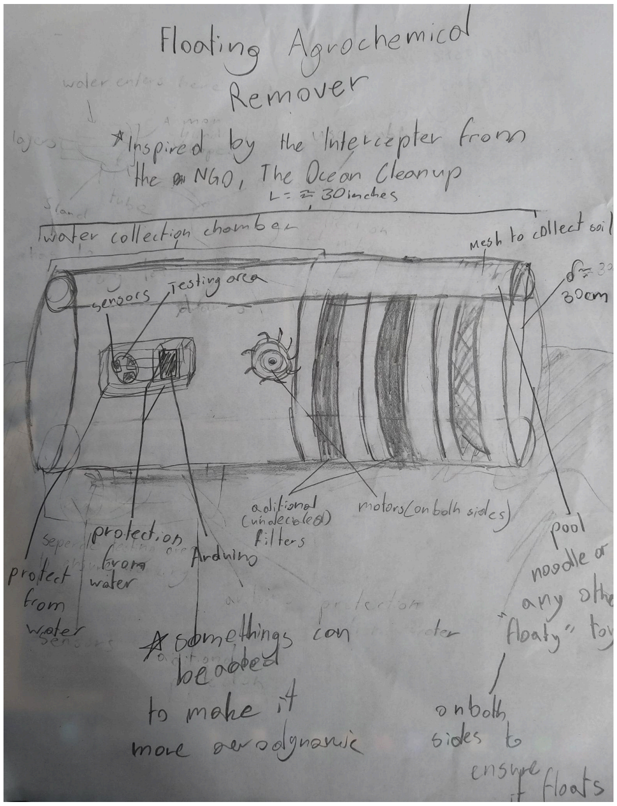


above is another sketch, this is my idea to stack screwable air tight containers and attach the lids to the base using silicon. This is also a sketch to show my idea of moving water away from the original source and releasing it after filtration. Silicon may also be replaced with epoxy resin. The plastic containers may also be replaced with glass, but it will be harder to make holes between each layer.

Sensors:

        - PH
        - Turbidity detection
        - TDS meter

Could not find any nitrate, phosphate or dissolved oxygen sensors, so instead a simple spectrophotometer may be built to identify the colour of the water after a chemical reaction. Nitrate is often prioritised, so I will focus on this.



Above, is the design if I were to make it floating, this is inspired by the Incercepter by The Ocean Cleanup NGO. I was inspired by Mark Rober's video about cleaning trash in the ocean. I used the idea to keep it floating so that it would not disturb aquatic life below. This is one of the most essential aspects to consider. I also included the idea for a separate testing area for the first time in any of my designs. I also included around how big I want the system to be. Though I have not decided on the material, if I wanted the design to stay afloat in water, the aerodynamics of it must be considered, hence why I think keeping the cylindrical shape with additional parts would be the best option.
Motors may also be included. One problem with this is that the filtered water will return to the same place resulting in the water getting polluted again.

Though the main objective of the prototype is to clean water polluted by agrochemicals and soil using an engineered filtration system, there are many other ideas that I would like to consider. Below is a list of all of the current ideas to apply to or change in the initial sketches:

- Using Arduino and a 16 x 2 screen to show purity after filtration
- Using Carbon Nanoparticles for filtration
- Using Algae for the absorption of nutrients such as potassium, phosphorus, and nitrogen
- Replacing the "pouring system" with something more efficient and easy to use
- Use of Solar Panels or Wind Turbines to power the Arduino
- Sensors attached to the Arduino for the detection of the following substances:
    - Phosphate
    - PH
    - Turbidity
    - Nitrate
    - **more research must be done in order for finding a way to determine the presence of pesticides**
- A large plastic 2-4 litre soda bottle may be used as the filtration base

09/17/2024

Instead of three filters I could incorporate up to five instead. The five being:

1. the initial filter for large particles such as leaves and rocks
2. Gravel and Sand for any large particles
3. Nanoparticles?
    a. Nanoparticles are very expensive
    b. They have a risk in forming bioaccumulation
    c. Can hurt the natural bacteria
4. Biochar or algae
5. Activated carbon
6. Final cloth or mesh for any additional particles

09/19/20244

Today I discussed, with my parents, the idea of incorporating Bioremediation which is a process where nature itself is used to purify pollutants. The only downside to bioremediation is its low efficiency rate and the risk of introducing harmful bacteria into the ecosystem. Other than that, bioremediation has the possibility to become the solution to all pollution-related problems. Considering wetlands and how they have the capacity to clean waters, I can include certain features of a wetland to my project. This will greatly improve the sustainability of my project.

New topic: The Smart Hybrid Water Filter: A Synergistic System of Filtration and Bioremediation for Agrochemical and Soil Pollution

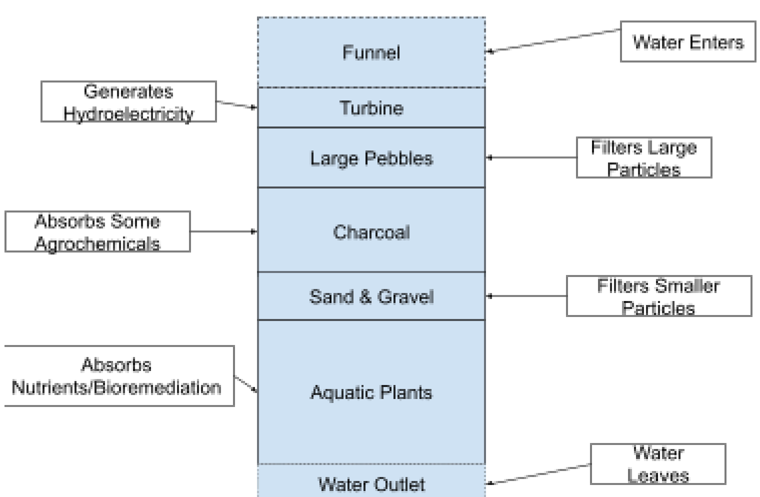
I will have to figure out how I can efficiently and effectively develop a filtration system using bioremediation.

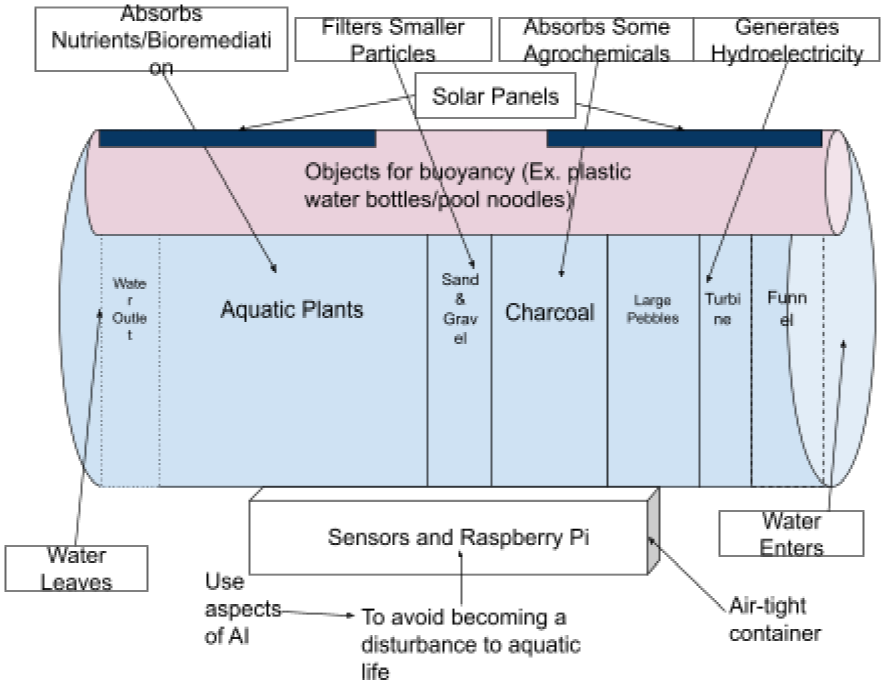
09/24/2024

After conducting background research, it was found that Cattails are one of the most suitable organisms to use for this project, so I am thinking of shaping the ecosystem around the Cattails. They also thrive in water-logged soil which is necessary.

09/29/2024

This filter may generate hydroelectricity, using a turbine in the design:

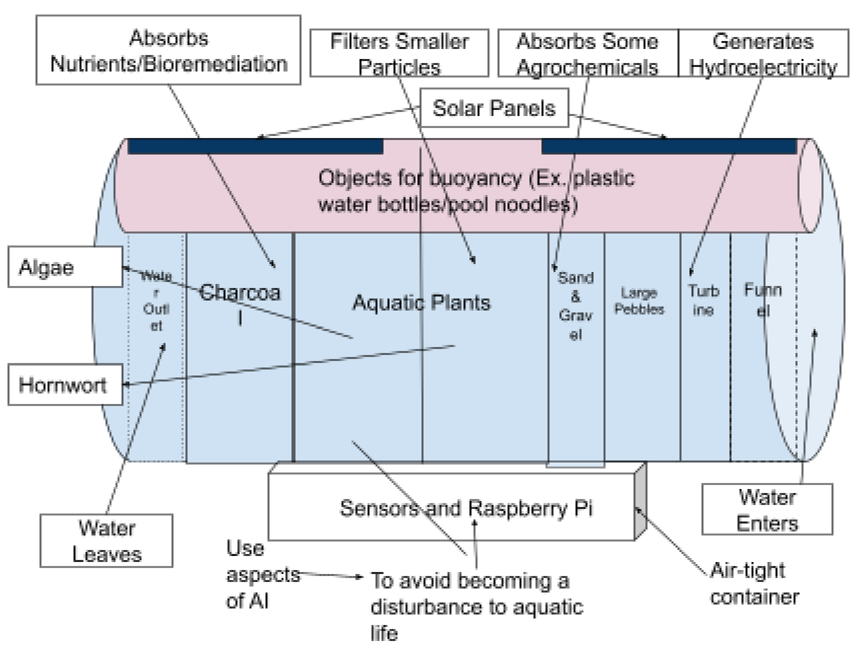




This design uses AI, solar panels, a turbine for hydroelectric power generation and aquatic plants for bioremediation and nutrient absorption. The most space is given to the plants because bioremediation is one of the main focuses for the project. There are a few options for the plants that will be used. Some examples that are being considered include: Cattails, Algae, and Bulrush. A mixture of multiple plants will likely be used for biodiversity and to further replicate a natural environment. Though a Raspberry Pi would have to be used, AI can be applied to the project to avoid the filter disturbing the natural environment. This will be done by pattern identification and avoiding areas where many aquatic animals pass through. Solar panels and turbines can be used to generate electricity not only for the system but the energy may also be stored and used for other purposes such as powering appliances in homes.

This should be used in canals that feed into larger rivers or are used by people. This will ensure strong enough water speed for the turbine to produce electricity in a necessary quantity, but also ensures that the water flow is not too strong.

10/02/2024



This new design was created with the charcoal after the plants sections to absorb any potential bed byproducts.

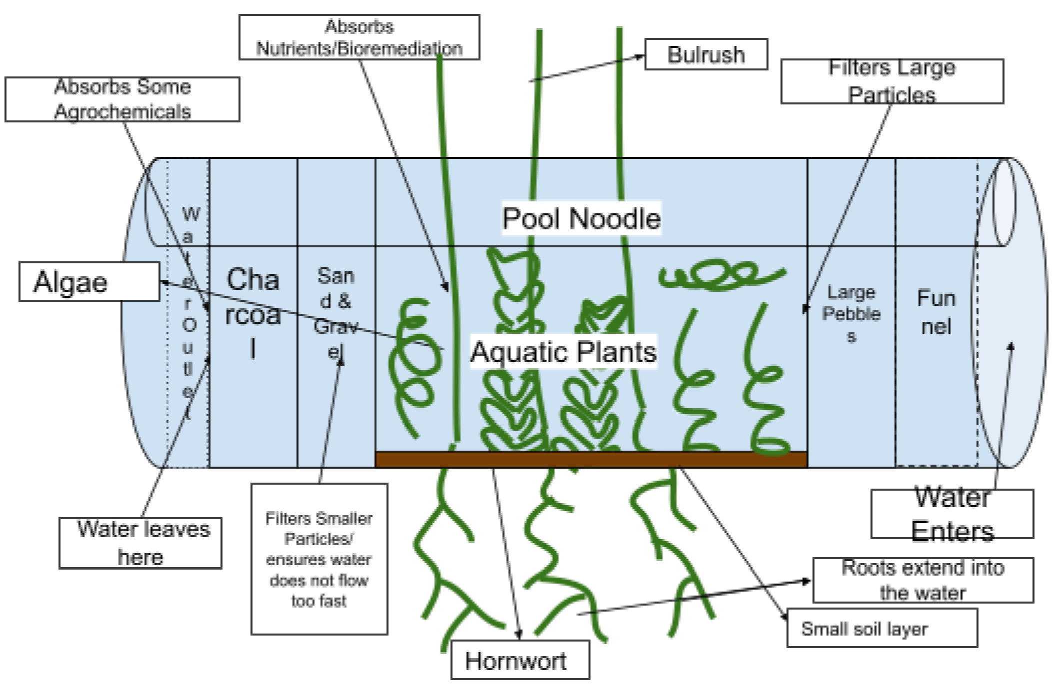
10/11/2024

Discussions with professional/further editing of the design.

Discussion One:

- Suggests simplifying the design, especially removing AI, sensors, and distance mapping.
- Recommends focusing on the water chemistry aspects and nutrient removal, which are the project's strengths.
- Notes that AI and sensors are expensive and would ruin one of the main objectives of the project
- Advises deploying the system in areas with nutrient accumulation (wetlands or lakes) rather than rivers, which are nutrient-poor.
- Encourages consideration of whether the system should be self-sustaining or temporary. " Will you deploy them and leave them forever, or should they be deployed for a certain period of time until native vegetation and natural wetland processes are established?"
- Likes the choice of bulrush and hornwort as good plant options.
- Warns about the risks of using certain types of algae, like toxic cyanobacteria.

To do:
- figure which algae to use
- figure out if it is self sustainable or temporary until native vegetation is established
- redo design without AI system
- consider other ways of producing electricity. Solar Panels? Will this be too expensive?



- Using an aquarium

Above is a diagram of the new filter. AI, turbines, and motors were removed. To make it more simple and cost effective, sand and gravel was moved to slow the flow of water.

10/17/2024

DIscussion Two:

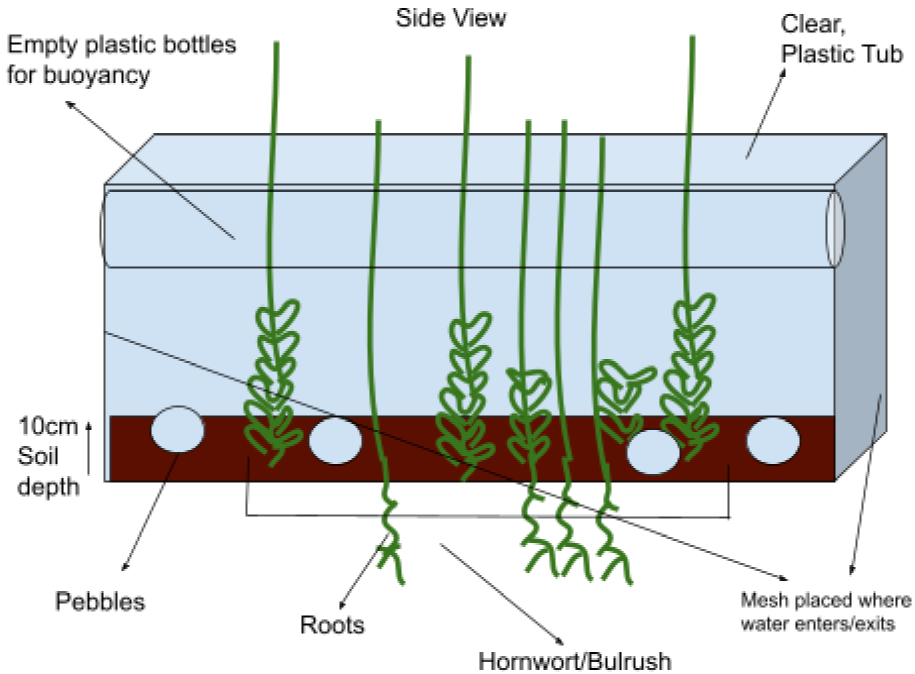
1. Focus on just agrochemicals because heavy metals and microplastics are more specialised
2. How long will the system be deployed?
3. Use archimedes principle to determine the type/amount of foam required to make float
    a. calculate weight of system and buoyant force should be equal to the weight of the system
    b. Calculate volume of foam
        i. Volume Displaced= Weight of System/Density of water×g
    c. Where:
        - **Density of Fluid**: water is approximately 1000 kg/m³
        - **Volume Displaced**: Volume of foam
        - **g**: approximately 9.81 m/s²
    d. select foam with known density
    e. Amount of foam
        i. Mass of Foam=Density of Foam×Volume of water Displaced
4. What type of algae will be used?

Notes

- How will the system deal with the pesticides? Is this even a big problem?
    - Due to the regulations on pesticides, especially in Canada, there is no need to deal with pesticides. By the time pesticides reach bodies of water, there will be such a limited amount of pesticides
        - They also will have a limited impact on the plants as the chosen plants are strong
- How will I deal with clogging?
- How do I determine the amount of time it will take to establish an ecosystem?
    -
- I discovered that algae grows very quickly so it's necessary to have a method to make sure the algae does not enter the water. How will I do this?
    - Algae grows very fast but the algae I have chosen does not necessarily create harmful blooms
    - I will have to make sure though that the algae does not out-compete the plants
        - remove algae completely from the system. Naturally occurring algae will grow: **Periphyton**

11/14/2024

A New Design

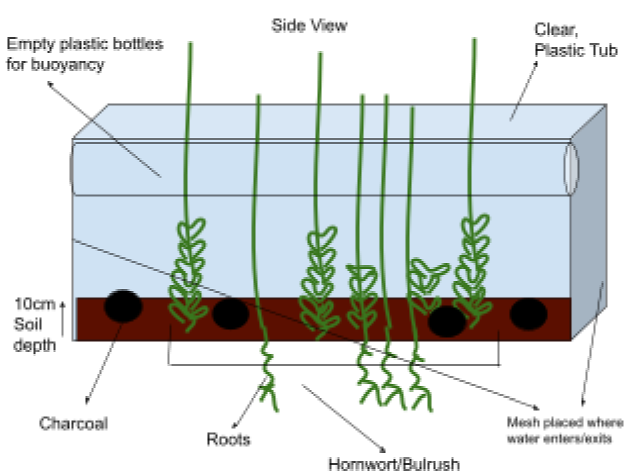


In this design, the clear plastic tub will displace lots of water. This is beneficial to the buoyancy of the design. The solid will likely have a layer of humus (compost) and other dead organisms. The soil will have mixtures of sand, silt, etc.

Notes:

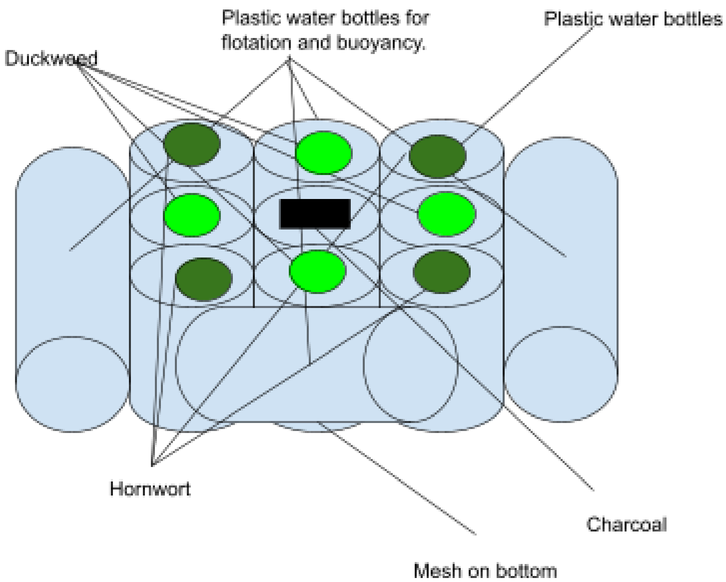
1. I was originally going to create separate layers but in this design, everything is kept in one place to more closely resemble a wetland.
2. Because of the change listed above, I am confused as to whether or not I should still use charcoal to absorb the nutrients.
3. Will this system in general disrupt the natural habitat or the aquatic animals?
4. The tub will likely have a capacity of around 85L. This means that the dimensions are the following: 80.01cm x 43.89 cm x 33.02 cm.

Further edits made:



In this design, pebbles were removed from the tub and replaced with charcoal. Pebbles are not necessary. Their weight can cause the box to sink.

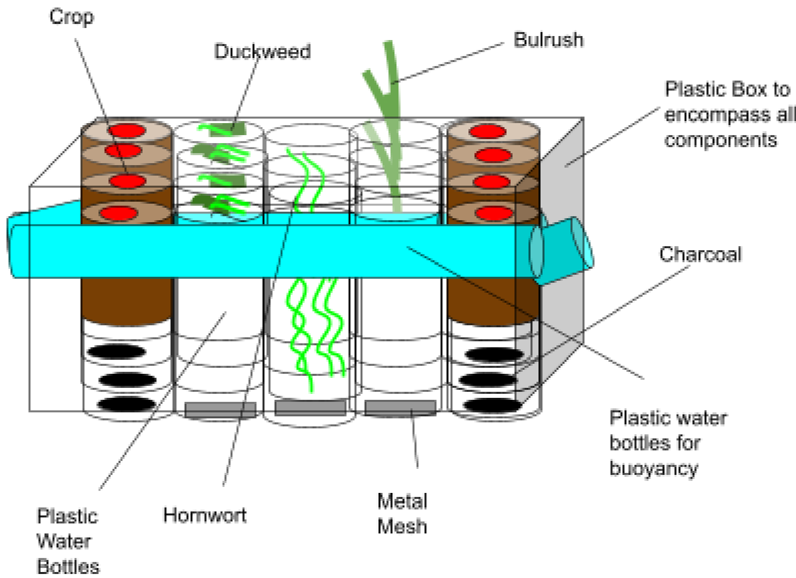
12/18/2024



A new design was made in order to house aquatic plants as well as floating plants. This was also the cheapest option, having an estimated value of $5.85.

12/19/2024

The future prototype will integrate additional features, such as a compartment for crop cultivation, allowing the system to utilize excess nutrients in the water while producing food. The design will also incorporate emergent plants like bulrush to mimic natural wetland ecosystems more closely. Although this design increases costs, the added benefit of creating space for crop growth makes this approach highly cost-effective in the long term. This allows for the system to be deployed in a variety of different settings. This is the design:



01/19/2024

Science fair done for now!

Background Research

09/12/2024

What are agrochemicals?

An agrochemical is any chemical used in agriculture. Examples include herbicides, pesticides and fertilizers.

09/17/2024

What is Nitrate?

Naturally occurring in low concentration inside of soil, air, water and some foods, nitrate is a substance that is made out of nitrogen and oxygen. It is required for animals and plants to thrive. It is vital and has no detectable colour, taste or smell in drinking water.

Drinking water with high levels of nitrate, specifically 50 mg/l can cause diseases such as baby blue syndrome in young infants. Nitrate may be absorbed into the blood which can interfere with oxygen transfer.

Nitrate reaches drinking water in a variety of ways. Nitrate is highly soluble meaning that it easily dissolves in water. Because of this, it is easy for it to transport through soil to groundwater. It then can reach various bodies of water through runoff from agricultural, domestic and industrial sites. Sources of contaminants include:

- decomposing plants
- too much fertilizer

- animal waste
- waste water
- septic tanks

What is Bioremediation?

Bioremediation is the use and application of living organisms to purify various types of pollutants. For example, contaminants and toxins in water, soil and other natural environments. Bioremediation may be applied for aspects such as contaminated ground water and oil spills.

Bioremediation works by stimulating the growth and productivity of certain microorganisms that utilise contaminants for energy. These microorganisms create harmless products such as carbon dioxide and water.

Bioremediation requires a mix of the correct temperature, nutrients, and food. When the organisms are not placed in the correct environment, the efficiency of pollutant degradation reduces. Because of this, certain "amendments" may be made to accelerate the degradation process.

There are two types of bioremediation:

Type	Definition
In situ	- located at the site of the contamination - lower costs than the Ex situ type
Ex situ	- directs contamination to a different location, away from the original site - may be used if the climate of the specific area does not have the correct environment to sustain the growth of the microbes

The bioremediation process may take up to several months to years depending on various factors such as size of contaminated area, temperature, concentration of contaminants, and the type of bioremediation process (In Situ or Ex Situ).

The Advantages of Bioremediation

Because it utilises natural methods, it reduces the damage done to ecosystems. In general, bioremediation has a much lower impact on the environment and animals than other cleaning methods. Furthermore, it is also normally cheaper than normal methods because of the reduced labour and substantial equipment required. The process of bioremediation also usually produces safe byproducts.

In Alaska, in 1989, the Exxon Valdez oil spill occurred. It ended up spilling around 11 million gallons of oil. During the time, bioremediation was gaining lots of attention. Because of this, over 100 000 pounds of fertilizer was applied and by 1992, the fertilizer had degraded all of the oil. Another example of bioremediation is compost because it reduces the amount of trash going into landfills.

The Types of Bioremediation

Type	Description
Biostimulation	- microbes stimulated to degrade pollutants with chemicals or nutrients
Bioaugmentation	- mainly used to clean soil - The process adds bacteria to the surface of affected area
Intrinsic Bioremediation	- converts toxic pollutants into useless materials - Uses native microbiome in the area
Mycoremediation	- A process that utilises fungi

What is agricultural pollution?

In unsustainable agriculture, pollutants are causing a huge threat to the water supply of humans. Agriculture is one of the leading causes of water pollution. Modern agriculture causes the discharge of various factors such as organic matter, agrochemicals, and sediments making their way into bodies of water.

During the time that followed the 2nd world war, there was a large boom in the agricultural industry. Global sale of pesticides went from around $1 billion to $35 billion in one year. 99% of deaths caused by pesticide use however, occurs in developing countries.

Irrigation is the world's largest producer of agricultural-related water waste. 115 million tons of mineral nitrogen fertilizers are given to crops each year. Around 20% of these fertilizers end up in soils or biomass and around 35% end up in oceans.

Furthermore, livestock production increased as well. Livestock numbers have tripled since 1970. This leads to increased organic matter in the drinking water of humans.

Aquaculture is now also responsible for releasing fish excreta, uneaten feed, fungicides, and antifouling agents in waters.

laws, reducing food waste, and minimizing pesticide use are ways that agriculture pollution could be reduced.

What is Runoff?

When there is excess water present in soil, runoff occurs. The runoff flows across the surface and reaches various bodies of water such as ponds, creeks and streams. This runoff may occur naturally but also due to human activities.

One example of runoff snowmelt. When mountains cannot absorb water from heavy snowfall, it leaves as natural runoff and forms lakes, rivers and other bodies of water. glaciers, snow and rain all cause natural runoff.

Soil erosion is also another process of natural runoff. Ih natural erosion, toxic chemicals may still enter waterways. For example, the toxic gasses from volcanoes may return to water or soil through precipitation.

Runoff caused by human activities come in two forms, point sources and Nonpoint sources. In point sources, is when pollution is directly released in a water way. Nonpoint source pollution is when runoff does not go directly in a waterway. One huge example of this is agriculture. In agriculture, however, pesticides and fertilizers are usually also carried into waterways.

Impervious surfaces such as roads, sidewalks and parking lots make it difficult for water to absorb, making runoff more prominent. Soaps, litter and spilled gas may all become runoff.

Runoff can ruin an entire ecosystem. Small microorganisms, like algae and plankton, absorb pollutants in the runoff, then larger fish feed on these organisms, birds later feed on these fish. This creates an increasing level of pollution in their bodies. In this process, known as biomagnification, increases the amount of pollutants in an animals' body. This can become a threat to human civilization as well.

To solve the problem, people must limit pollution and farmers can use less fertilizer. Amounts of impervious surfaces should also be reduced in urban areas. Furthermore, it is beneficial for communities to plant native vegetation as plants prevent erosion and runoff entering waterways.

09/13/2024

What is fertilizer?

Soil fertility is the quality of a soil that describes its ability to provide various compounds in adequate amounts to plants. fertilizer is a natural or artificial substance. They contain chemical elements that improve the quality of soil and in turn improve the growth of plants. Fertilizer either enhances or replaces chemical elements in soil.

Fertilizer is usually added to soil when the quality of the soil is reduced or diminished. Synthetic fertilizers or natural fertilizers such as compost may be added to improve the fertility of the soil.

Synthetic fertilizers

Most modern fertilizers use the three nutrients; nitrogen, phosphorus and potassium. These are considered the most important nutrients for plant growth

Most nitrogenous fertilizers are obtained from synthetic ammonia. This is used as either a gas, in a water solution, or is converted into a salt. Urea is also a type of nitrogenous fertilizer as well one of the most concentrated and cheapest. Phosphorus fertilizers normally come from calcium phosphate which is obtained from bones or phosphate rock. Potassium fertilizers like potassium chloride or potassium sulfate are mined from potash deposits.

Mixed fertilizers are also commonly used. They consist of more than one type of essential nutrients. For mixed fertilizers, a grade is used to express the quantity of each nutrient. Ex. 10-20-10

What is Soil, and How Does Soil Erosion Impact Freshwater?

Soil is a biologically active part of the crust of the Earth. It makes the uppermost surface. Soil is essential as it acts as a reservoir for water, nutrients and filtration. I also support the carbon cycle and other elements.

Though exacerbated by human activities, soil erosion is a natural process. It normally occurs because of factors such as water, wind, ice, or gravity. In water, raindrops break the bond that holds soil together. This soil later leaves as surface runoff. Sheet erosion and rill erosion are the most common types of erosion.

When soil erodes in excessive amounts, it may come with many adverse effects. Firstly through this process, it is likely that nutrient-rich topsoil will be lost, leading to less crop yields. Furthermore, sediments often end up in various water bodies. This causes increased water turbidity, damaged aquatic habitats and disturbed flow of water, affecting both the quality of the water and aquatic life.

Nutrient pollution from nitrogen, phosphorus and potassium which are usually naturally present in soil, may end up in water bodies. This increases algae growth and depletes water oxygen levels. This can lead to the death of aquatic life and contamination of drinking water.

Topsoil also contains pesticides, insecticides, herbicides and fertilizers. This further increases the threat to human water supply as well as aquatic life and ecosystems.

09/14/2024

What are Pesticides?

Pesticides are a large and diverse group of chemicals that are used to kill pests or reduce the damage done by the pest. Insects, mice, unwanted plants (weeds), fungi, bacteria, viruses, and other unwanted animals are examples of organisms for which pesticides are used. Pesticides may also be used for a variety of other tasks such as acting as a drying agent (desiccant), modifying plant growth (regulator), and causing a plant to drop its leaves completely (defoliant)

Though pesticides include a large variety of chemicals, the below table lists some of the most common types of pesticides.

Type	Purpose	Examples
Insecticides	Repels or kills ticks, insects, and mites.	- bug spray - insect repellent - ant/roach baits - garden dust - garden spray - moth balls - commercial farm and orchard sprays - flea shampoos - flea and tick collars

Herbicles	Kills weeds and unwanted plants	- weed killers - lawn care products - tree stump treatments
Fungicides	Kills various types of fungi including mould and mildew	- flower spray - commercial farm or orchard sprays - treated seeds - plant additives
Rondenticles	Kills mice, rats and other rodents	- mouse bait or traps
Disinfectants	Kills mould, bacteria, and mildew	- bleach - kitchen/bathroom cleaners
Wood preservatives	Protects wood from insects and fungi	- pressure treated wood

Pesticides are classified into families they either share a chemical property with or act in a similar way in terms of impacting the pest.

Below is a table of some common types of families

Name of Family	Characteristics	Examples
Organophosphates	• made up of several types of pesticides, only depending on chemical • usually made from phosphoric acid • most are insecticides • act on nervous system • most are highly toxic • used because they break down faster • many are being banned or only being used for critical use	• chlorpyrifos • dimethoate • fenthion • malathion • naled • temephos • trichlorfon
Organochlorines (Chlorinated Hydrocarbons)	• disrupts nerve impulse transmission • does not break down easily so may are currently not in use • accumulates in fatty	• aldrin • chlordane • dieldrin • endrin

	tissues • present is soil as well as human and animal bodies • traditionally used for insect and mite control	
Carbamates and Thiocarbamates	• impact to human and animal health is mild with herbicides/fungicides yet greater with insecticides • made from carbamic acid • Acts on the nervous system • generally less persistent in the environment than the organochlorine • Includes insecticides, herbicides, and fungicides	• Insecticides ○ carbaryl (Banned in European countries, only certain uses will be cancelled in Canada because of health risks) ○ propoxur (some uses will be banned in Canada) ○ methomyl (some uses will be canceled in Canada) ○ carbofuran (some uses banned in Canada) • Herbicides ○ barban ○ s-Ethyl dipropylthiocarbamate (EPTC) ○ propham ○ triallate • Fungicides ○ nabam
synthetic/pyrethroids	• disrupts nerve impulse transmission and leads to paralysis	• cyhalothrin • cypermethrin

	• stable in sunlight • does not degrade quickly	• deltamethrin

From the above chart, two families of pesticides are the least likely to degrade, synthetic and organochlorine.

Pesticides are created in liquid, gaseous or solid forms. This is necessary to know because some forms are more toxic than others. For example, liquid may be absorbed quicker than power into the skin. Adjuvants can be added to a spray solution, changing how much it sticks and gets absorbed into the skin. Pesticides may also contain inert ingredients apart from the 1-2 active ingredients. Inert ingredients may also be harmful. Because of the possible harmful effects, it is important to store and use pesticides with caution and proper research.

Currently, there are various laws and regulations in Canada to support the proper use of pesticides. The federal government ensures that all pesticides are registered through the Pest Control Products Act (PCPA). This system is re-evaluated every fifteen years based on new data and scientific discoveries. The provincial and territorial governments ensure safe use, transportation and storage of pesticides. They are also responsible for looking at training, certification, licensing or vendors, growers, and applicators. The provincial/territorial government is also responsible for looking after incidents such as spills. Municipal government state bylaws for the use of pesticides. For example, many have banned the use of pesticides for “aesthetic” purposes.

What is Phosphate and Nitrate pollution?

Plants need nutrients such as nitrogen and phosphorus but most of these elements found in waterways are due to human activities including the use of fertilizers. When crops are given excessive amounts of fertilizer, it seeps into groundwater and reaches various water bodies. This is known as runoff and has a bad impact on the environment.

Nutrients are chemical elements that act like food for plants, animals and humans. Phosphorus and nitrogen are among the most abundant nutrients. When there are excessive nutrients, algae, which feed on these nutrients, grow and dirty the surface of water. When too much algae starts to decay it may also lead to bad water taste and smell. The decomposition of the algae done by bacteria also consumes water which sometimes leads to the death of fish and other aquatic animals.

The most common type of pesticide are herbicides in the agricultural industry. Twelve out of the top 25 active ingredients in pesticides are herbicides. Other common active ingredients include fungicides, fungicides, and insecticides, accounting for four, five, and two, respectively, of the top 25 active ingredients. Glyphosate is the most common active ingredient while Chlorothalonil is the most common fungicide active ingredient.

What is the Phosphorus Cycle?

Phosphorus is one of the most important elements for all living organisms. It is an important part of ATP which is important for metabolic processes. It is also part of DNA and RNA.

Phosphorus is in soil as both organic and inorganic substances. Soil contains low amounts of phosphorus and only a limited amount of it is available to plants. Phosphorus usually moves by diffusion. In acidic conditions, P reacts with calcium, iron, magnesium, and aluminum to become less soluble in water.

The Phosphorus cycle describes the process by which phosphorus moves through the biosphere, lithosphere, and hydrosphere. The phosphorus cycle goes as the following:

Weathering

The main source of phosphorus is found in rocks, hence why the start of the phosphorus cycle is in weathering. various sources of erosion such as rain result in phosphorus ending up in soil.

Absorption by Plants

Organisms such as fungi and plants absorb the phosphorus from the soil. Animals may also absorb phosphorus from drinking water or eating plants. Some of this phosphorus may also end up in bodies of water.

Return to The Environment

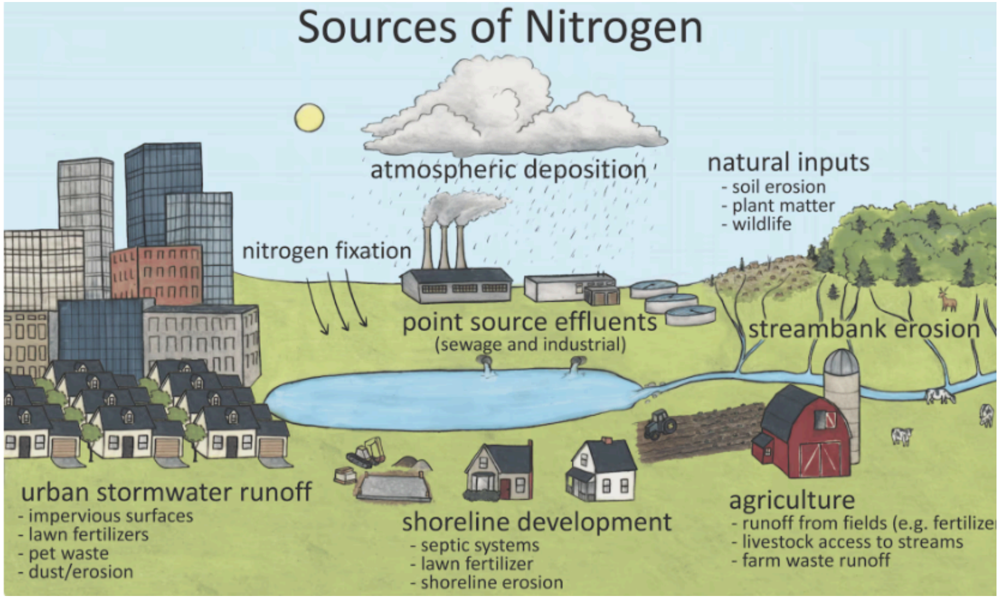
When plants and animals pass away, they return to the soil via decomposition, plants and fungi then reuse this phosphorus, repeating step two of the process.

Humans significantly impact the phosphorus cycle. Fertilizers, for example, add to the phosphorus levels in soil. This is especially detrimental to aquatic life. When phosphorus is naturally added to water, it is known as eutrophication. This amount of nutrients is good for the water but when too much phosphorus reaches water due to human activities, artificial or anthropogenic eutrophication. When too many nutrients are present in the water, it can cause excessive algae growth. This algae either dies or forms algal blooms. This harms aquatic life.

What are the differences between the different forms of nitrogen in water?

Some key forms of nitrogen in water include nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3), and ammonium (NH_4^+). These are classified as inorganic nitrogen and are bioavailable, meaning they are easily utilized by organisms in the water. Nitrate and nitrite are oxidized forms of nitrogen, while ammonia and ammonium are considered reduced forms, meaning they contain nitrogen in a lower oxidation state and can more easily donate electrons in chemical reactions. The balance between ammonia and ammonium depends on the pH of the water, with ammonia (NH_3) being more common in higher pH levels, and ammonium (NH_4^+) more prevalent in lower pH. Organic nitrogen, which comes from decaying plant and animal matter, is also present in water bodies. The total nitrogen content in freshwater includes both organic nitrogen and inorganic forms like ammonia, ammonium, nitrate, and nitrite. From fertilizers, ammonium and nitrate are the most common types. Urea is also common but eventually breaks down into ammonium and nitrate.

Below is an image showing various sources of nitrogen:



What types of organisms change or remove these different forms of nitrogen from the water?

1. Micro algae
    a. they can remove nitrogen compounds such as ammonium and nitrate and turn them into biomass
2. Denitrifying bacteria
    a. convert nitrate into nitrogen gas, this process is called denitrification
    b. common genera:
        i. *Thiobacillus denitrificans,*
        ii. *Micrococcus denitrificans*
    c. *some species of*
        i. *Serratia, Pseudomonas, and Achromobacter*
3. Wetland Plants
    a. They take in inorganic nutrients through the roots and/or foliage. Around 10-20 percent of pollutants absorbed is released back into the wetland through bioaccumulation but this is relatively than other removal processes
    b. Bacteria also plays a huge role in this process
    c. In the end, harmless nitrogen gas is released back into the atmosphere. The main transformation processes:
        i. ammonification
        ii. nitrification
        iii. denitrification
            1. it is one of the most important processes in cleaning fertilizer pollution as nitrate is a common part of agricultural run off
    d. Examples of Wetland Plants:
        i. Hornwort *(Ceratophyllum demersum) - global distribution*
            1. because of its rapid growth rate, it takes up many nutrients
            2. may exhibit weed-like growth
            3. produces biochemicals to inhibit phytoplankton and algal growth
        ii. Cattails (*typha* spp.) - Mostly in The Northern Hemisphere

1. exists along the edge of many large fresh-water bodies of water in the Northern Hemisphere
2. Tolerable of partial submersion
3. generally efficient because of fast growth rate

iii. Soft rush *(Juncus effusus)*

1. Thrives in Edges of Ponds
2. Has been shown to aid in the purification of agricultural runoff
3. Roots and the surrounding biofilm efficiently take up nitrogen and phosphorus compounds
4. Has the tendency to become invasive because of its fast metabolism

What are the differences between the different forms of phosphorus in water?

1. Inorganic Phosphorus
   a. Orthophosphate
      i. often found in fertilizers and normally enters water bodies from agricultural runoff
      ii. Readily available for biological uptake (bioavailable)
      iii. Simplest form of phosphate
   b. Condensed Phosphate
      i. complex
      ii. eventually break down to Orthophosphate
      iii. often used in detergents and water treatment processes
2. Organic Phosphorus
   a. enters water bodies because of decomposition of any organic matter
   b. significant part of phosphorus cycle

What types of organisms change or remove these different forms of phosphorus from the water?

Because Orthophosphate is very bioavailable, many different types of plants can absorb this type of phosphorus easily. Some examples include Cattails, Algae, and Water Hyacinth (Eichhornia crassipes). All of these species not only purify water from phosphorus but also nitrogen in the form of ammonium or nitrate.

What are Wetlands?

A wetland is an area of land that is either saturated with water or is covered with water, for at least part of the year. Wetlands are known as transition zones. They are neither completely wet nor dry. Wetlands may be created by groundwater, sea water, as well as a river or lake.

The vegetation that grows in wetlands is adjusted to the hydric soil and different vegetation is determined by how saturated the water is. Plants living in wetlands are known as hydrophytes. Occasionally dry wetlands or wetlands with slow-moving water support the growth of trees whilst ones that are consistently flooded.

Wetlands can be found everywhere in the world except for Antarctica. They can be as large as salt marshes or as small as prairie-potholes. Some major examples of wetlands include: swamps, peatlands, sloughs, marshes, and bogs.

Wetlands have many benefits. During heavy rains. They absorb excess water. They can protect coastal communities from storm surges. They can also filter Nitrates and other chemicals that make it into wetlands from farms. Pollutants not absorbed eventually settle into the soil and form sediment.

Many wetlands have been destroyed because removing them was an accepted practice until recently. Wetlands used to be looked at as a useless area of land, being hard to build on and containing many pests such as insects and crocodiles. Nearly half of the Wetlands in America have been destroyed.

10/01/2024

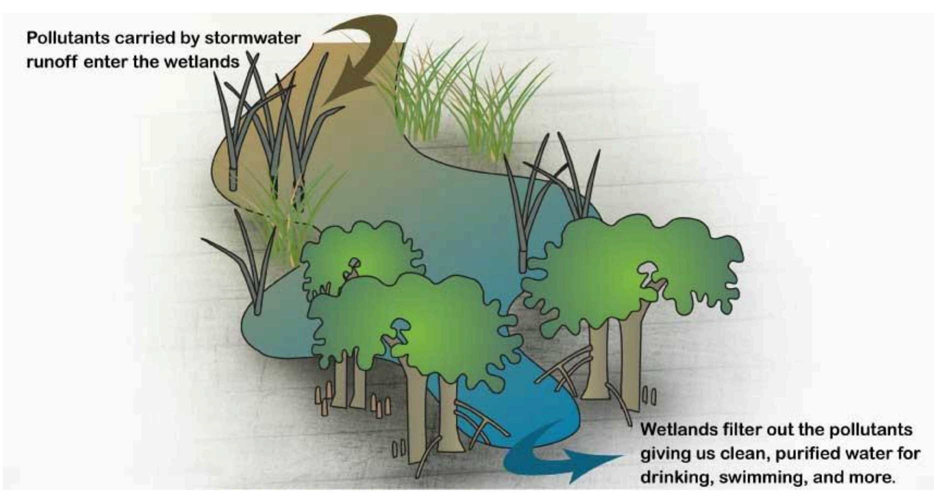
What are Algal Blooms?

An algal bloom, also known as algae blooms occur when there is a rapid accumulation of algae. This can be recognised by a discoloration of the water due to the algae's pigments. They are caused by nutrients from various sources such as fertilizer runoff and nutrient pollution. Algal blooms can deplete the oxygen levels in the water and some blooms may also release toxic byproducts.

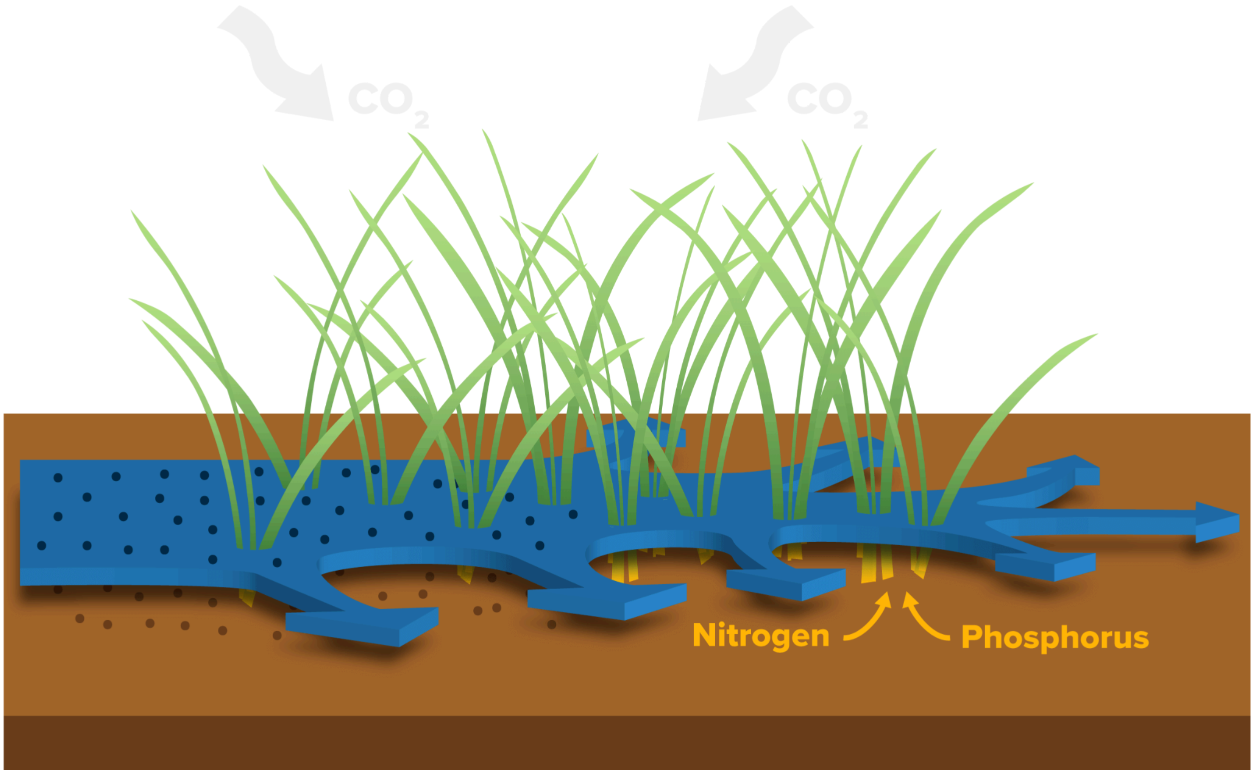
10/11/2024

How do wetlands purify water?

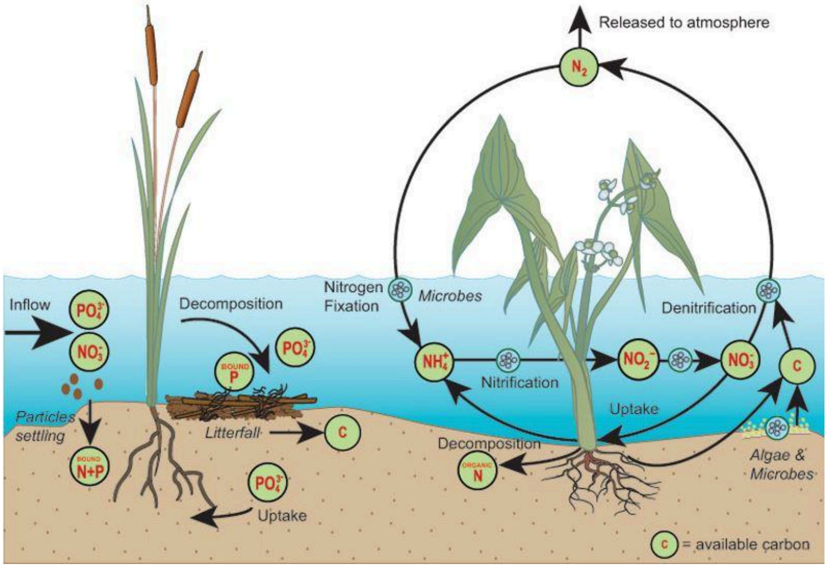
Wetlands, known as the kidneys of our watershed, are water purifiers that are able to filter sediments and other toxic chemicals. In developing areas, oftentimes, excess nutrients from fertilizers end up in bodies of water. This can cause eutrophication. The cost to filter water can range between 298.1 billion to 344.8 billion. This cost can be heavily reduced. For example, updating wastewater facilities can cost $8.56/lb of nitrogen while conserving wetlands costs 3.10/lb of nitrogen, reducing the cost by over half.



Wetlands do this by slowing the flow of water. This not only prevents erosion but also allows any sediment to settle at the bottom, acting as a natural filter. Wetlands are also able to prevent downstream flooding. Furthermore, the roots of the plants absorb any nutrients in the water. Plants also absorb CO2, which is a greenhouse gas.



There are many physical processes that happen in wetlands. For example, physical processes of nutrient removal in which the particle settles (sedimentation), volatilization (releasing the nutrient as gas into the atmosphere), and sorption (when two substances attach). There are also chemical processes that involve changing nutrients from one form to another. This includes chemical precipitation. Biological processes are assimilation (uptake, when organisms, such as bacteria, plants, and algae use the nutrients). All these processes occur in various areas of the wetland and contribute to the purification of water.



Will chlorella be a good fit for this project?

Chlorella

- According to studies done in 2016 and 2012, using chlorella to remove phosphate and nitrate is highly effective
    - A 2016 study looked at how two types of microalgae, *Spirulina platensis* and *Chlorella vulgaris*, can remove nitrate and phosphate from water. The researchers added different amounts of nitrate and phosphate (0.25, 0.35, and 0.45 g/L) to water samples and measured how much the algae was removed over 8 days. *Chlorella vulgaris* removed the most nitrate, 89.80%, at the lowest concentration (0.25 g/L), while *Spirulina platensis* removed 81.49% at the same concentration. For phosphate, *Spirulina platensis* removed 81.49% at the highest concentration (0.45 g/L), and *Chlorella vulgaris* removed 88% at the same level. The study showed that both types of algae significantly reduced nitrate and phosphate, with *Chlorella vulgaris* performing better overall.
        - in 2016 study, Chlorella vulgaris removed 89.80% of the 0.25g/L and 88% 0.45g/L (KNO_3, K_2HPO_4) in eight days potassium nitrate and dipotassium phosphate
    - The 2012 study looked at using a type of algae, *Scenedesmus sp.*, trapped in gel sheets to clean dirty water by removing harmful nutrients like nitrogen and phosphorus. The scientists found that the amount of algae in the gel was really important. With the right amount, they were able to remove 99.1% of nitrogen after 105 minutes and all of it after 135 minutes. They also removed all of the phosphorus in just 15 minutes. The system worked well over nine cycles in 21 days, showing it could be a good way to clean water.
    - 89.80% nitrate, 98.81% ammonia-nitrogen 100% phosphorus-orthophosphate (Chlorella Vulgaris)

What are the Living Conditions of Hornwort, Bulrush and Chlorella Vulgaris?

Hornwort	- Slow-moving - Freshwater - lives in 10-30°C - survive in low light as well. - Absorbs many nutrients due to the fast growing rate
Bulrush	- Around 10 cm to more than 1.5 m of soil is required - **Plant Guide for hardstem bulrush (Schoenoplectus acutus)** -  - Western Native Seed - https://www.westernnativeseed.com › schacupg -
Chlorella	- CO_2 - H_2O - Sunlight - small amount of nutrients

What are indicators for early algal blooms?

1. Fish Assemblage - the variety and amount of fish in a water body
    a. The variety/amount of fish can signify the quality of water because they are easily affected by temperature, dissolved oxygen, pH, and more
2. Nitrogen/phosphorus
    a. From fertilizer, atmospheric deposition, runoff. Stimulates algae growth and may cause algal blooms
3. Dissolved oxygen
    a. DO is one of the main measurements for water quality
        i. DO levels less than 5 mg/L - stressful for fish
        ii. DO levels less than 3 mg/L - too low for fish to live.
        iii. DO levels below 1 mg/L are considered hypoxic and usually can not support any life at all
4. Plant community
    a. They can easily signify nutrient enrichment, turbidity, etc.
5. Water clarity
    a. Waters naturally may be turbid but fertilizer runoff, sediments, and more can cause even more turbidity.

References

1. Atwood, D., Paisley-Jones, C., Biological and Economic Analysis Division, Office of Pesticide Programs, Office of Chemical Safety and Pollution Prevention, & U.S. Environmental Protection Agency. (2017). Pesticides Industry Sales and Usage 2008-2012 Market Estimates. In U.S. Environmental Protection Agency. https://www.epa.gov/sites/default/files/2017-01/documents/pesticides-industry-sales-usage-2016_0.pdf
2. Biology Dictionary. (2017, June 5). Phosphorus Cycle. https://biologydictionary.net/phosphorus-cycle/
3. Clean Water. (n.d.). Wetlands Work. https://www.wetlandswork.org/wetland-benefits/clean-water#:~:text=Since%20the%20flow%20of%20water,of%20creeks%20and%20rivers%20downstream
4. Encyclopædia Britannica, inc. (n.d.). Denitrifying bacteria. Encyclopædia Britannica. https://www.britannica.com/science/denitrifying-bacteria
5. Environmental Protection Agency. (2012, March 6). 5.6 phosphorus. EPA. https://archive.epa.gov/water/archive/web/html/vms56.html
6. Floating wetlands for low-cost wastewater treatment. (2024). Springer Nature Communities. https://communities.springernature.com/posts/floating-wetlands-for-low-cost-wastewater-treatment
7. Gonzalez, P. (2021, April 14). Understanding phosphorus. Chem Inc. https://www.cheminc.com/post/understanding-phosphorus
8. Government of Canada, Canadian Centre for Occupational Health and Safety. (2024, May 10). Pesticides - General. https://www.ccohs.ca/oshanswers/chemicals/pesticides/general.html
9. Government of Canada, Canadian Centre for Occupational Health and Safety. (2024b, May 10). Pesticides - Health Effects. https://www.ccohs.ca/oshanswers/chemicals/pesticides/health_effects.html
10. How much do artificial wetlands cost. (2024). Bing. https://www.bing.com/search?q=how%20much%20do%20artificial%20wetlands%20cost&qs=n&form=QBRE&sp=-1&lq=0&pq=how%20much%20do%20artificial%20wetlands%20cost&sc=12-36&sk=&cvid=28777706FBB145C084D97A35A2250F17&ghsh=0&ghacc=0&ghpl=
11. Indicators: Phosphorus | US EPA. (2024, May 30). US EPA. https://www.epa.gov/national-aquatic-resource-surveys/indicators-phosphorus
12. Mays, C., McLoughlin, S., Frank, T. D., Fielding, C. R., Slater, S. M., & Vajda, V. (2021). Lethal microbial blooms delayed freshwater ecosystem recovery following the end-Permian extinction. Nature Communications, 12(1). https://doi.org/10.1038/s41467-021-25711-3
13. Mitchell, C. (2024, May 18). What Is Bioremediation and How Does It Work? Investopedia. https://www.investopedia.com/terms/b/bioremediation.asp
14. Nitrogen - Water Quality Guide - DataStream. (n.d.). DataStream. https://datastream.org/en-ca/guidebook/nitrogen
15. Nitrate in drinking water. (2024, July 9). Health Information and Services. https://info.health.nz/keeping-healthy/environmental-health/nitrate-in-drinking-water#:~:text=Nitrate%20is%20a%20 naturally%20 occurring,or%20smell%20in%20drinking%20water
16. Nutrient Removal — The Wetlands Initiative. (n.d.). The Wetlands Initiative. https://www.wetlands-initiative.org/nutrient-removal#:~:text=These%20naturally%20occurring%20processes%20adsorb,the%20atmosphere
17. Nutrients and Eutrophication | U.S. Geological Survey. (2019, March 2). https://www.usgs.gov/mission-areas/water-resources/science/nutrients-and-eutrophication
18. OpenAI. (2024). ChatGPT (September 11 version) [Large language model]. https://chat.openai.com/

19. Parker, J., Pell, J., Tim, & (Chris), P. I. (2024, June 1). 12 best plants that Clean & Filter Pond Water. Pond Informer. https://pondinformer.com/plants-that-clean-water/
20. Phosphorus Cycle | Southwest Research and Outreach Center. (n.d.). https://swroc.cfans.umn.edu/research/soil-water/phosphorus-cycle
21. Pollutants from agriculture a serious threat to world's water. (n.d.). Newsroom. https://www.fao.org/newsroom/detail/Pollutants-from-agriculture-a-serious-threat-to-world's-water/en#:~:text=Agricultural%20water%20pollution%3A%20Numbers%20of%20note%201%20Irrigation,sprayed%20into%20the%20environment%20every%20year.%20More%20items
22. Runoff. (n.d.). https://education.nationalgeographic.org/resource/runoff/
23. Sayadi, M. H., et al. "Removal of nitrate and phosphate from aqueous solutions by microalgae: An experimental study." (2016): 357-364.
24. Sposito, G. (2024, August 16). Soil | Definition, Importance, Types, Erosion, Composition, & Facts. Encyclopedia Britannica. https://www.britannica.com/science/soil/Soil-erosion
25. Stewart, R. E. (2024, August 31). Fertilizer | Definition, Types, Plant Nutrients, Application, & Facts. Encyclopedia Britannica. https://www.britannica.com/topic/fertilizer
26. Taziki, M., Ahmadzadeh, H., Murry, M. A., & Lyon, S. R. (1970, January 1). Nitrate and nitrite removal from wastewater using algae. Latest TOC RSS. https://www.ingentaconnect.com/content/ben/cbiot/2015/00000004/00000004/art00005#:~:text=Microalgae%20have%20a%20high%20capability%20to%20remove%20combined,opportunity%20for%20efficient%20recycling%20of%20nutrients%20in%20wastewater.
27. The Editors of Encyclopaedia Britannica. (2009, February 20). Agrochemical | Pesticides, Fertilizers & Herbicides. Encyclopedia Britannica. https://www.britannica.com/technology/agrochemical
28. Wetland. (n.d.). https://education.nationalgeographic.org/resource/wetland/
29. Wetlands Purify - DNREC. (2024, August 26). DNREC. https://dnrec.delaware.gov/watershed-stewardship/wetlands/purify/#:~:text=Wetlands%20purify%20our%20water%20by,the%20kidneys%20of%20our%20watersheds.%E2%80%9D
30. What Are Algae Blooms? (2019, November 22). Sciencing. https://sciencing.com/algae-blooms-8266246.html
31. Why are there so many toxic algae blooms this year (cnbc.com). (2016, July 26). https://www.cnbc.com/2016/07/26/why-are-there-so-many-toxic-algae-blooms-this-year.html
32. Zumdahl, S. S. (2024, August 2). Ammonia | Definition & Uses. Encyclopedia Britannica. https://www.britannica.com/science/ammonia

Problem

Objective

The objective of this innovation project is to create a floating wetland system for the conditions of Alberta. The main purpose of the system is to filter agrochemicals, focusing on nitrate and phosphate removal in bodies of water through the use of plants and bioremediation. The goal is to create a system that can not only be cheap and sustainable, but also usable locally in the province of Alberta.

Significance

This project is significant to humans because it purifies one of Earth's most important substances, water. Agrochemicals are some of the most prominent pollutants in water, especially in developing countries. Many people are being affected by this, for example, infants aged up to six months can develop Baby Blue Syndrome because of nitrate, a common type of nitrogen in fertilisers, poisoning. Symptoms of this disease include shortness of breath, seizures and rapid heartbeat. Moreover, aquatic life is also greatly impacted by high levels of nutrients in water. When too much nitrate or phosphorus is present, algae can grow extremely quickly, causing a drop in oxygen levels. This can be fatal for many different forms of aquatic life. Because of this, creating a low cost, sustainable filter is very important. This project will also utilise various aspects of a wetland to filter nitrate, ammonium, and phosphorus. This process, known as bioremediation, is much more cost effective and sustainable in the long run than traditional methods due to the fact that it runs consistently and requires very minimal maintenance. This project will be portable. This continues to make the project cost effective because of the expensive cost to build a wetland. When a permanent wetland is established, the cost can go over 50 000 dollars. In addition, this project will not only be much cheaper to make up-front, it can also be transported to various rivers, further reducing the cost.

Method

10/09/2024 - 11/18/2024

Designing the System

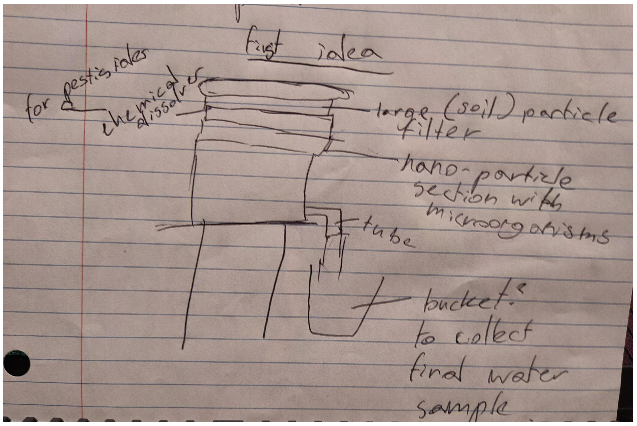
After months of research and exposure to different fields, doing a project about water is highly beneficial to the world.
Water pollution is a huge problem. This project may focus on agricultural pollution.
Possible project idea is a water filtration system
Objective of project: create a water filtration system that tackles agricultural pollutants such as pesticides, soil and fertilizer through the use of nanoparticles, chemical catalysts and various microorganisms.
There are many factors to consider with this innovation.

What materials are needed?
How will the different parts of the filtration be separated? By layers? If so, how will I build the layers themselves?
How will I test for the purity of the water?

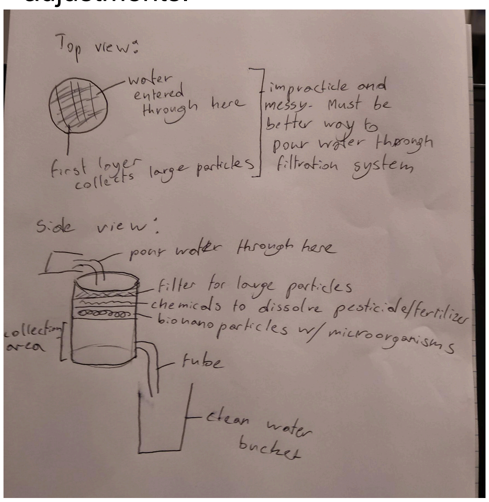
water purity may be tested using the following:

- PH strips
- Phosphate detection kits
- Pesticide testing kit
- Dissolved oxygen testing kit

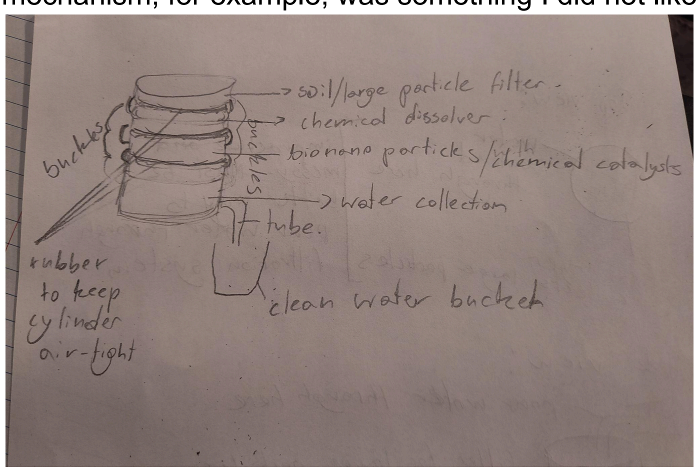
Whilst coming up with project ideas, I created a few very rough sketches of what the final product may look like:



Above, is the first sketch I had made of my prototype, though it does need a large amount of adjustments.



The same day I had also made a slightly more detailed sketch of my initial idea. It was clear from the beginning that some aspects of the prototype needed a lot of edits, the tube mechanism, for example, was something I did not like at that moment.



Later on, I considered the idea to include buckles and rubber to keep the different layers air-tight. Overall, the concept of this design was to create a filtration system people could use at their home specifically for agrochemicals.

However, this did not make sense for a variety of reasons. For example:

- One could simply use a multi-purpose filter which would work for agrochemicals
- It would be a cost effective way to target the source itself.

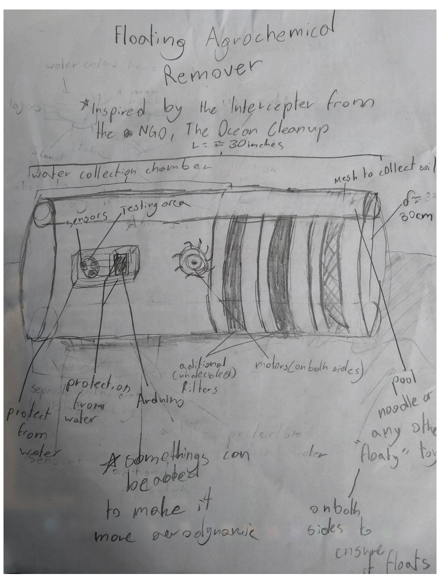
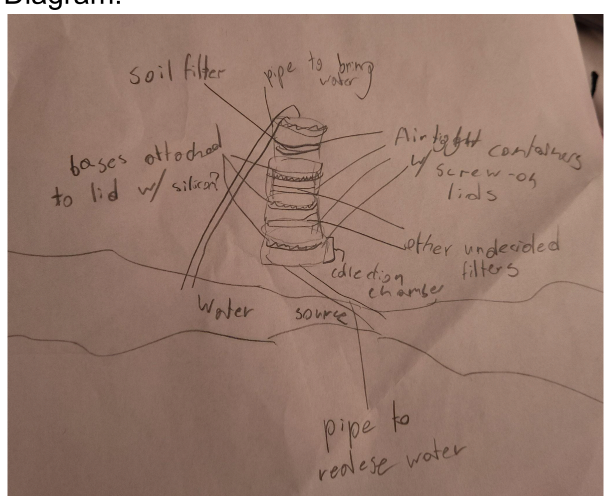
From the above ideas, two main designs were created:

1. Creating a floating filter system.
2. Creating a filter system that diverts water to another area to be filtered.

In the floating system, the idea is to keep it floating so that it would not disturb aquatic life below. This is one of the most essential aspects to consider. To ensure that the design stays afloat in water, the aerodynamics of it must be considered. Motors may also be included in this design.

In the Water Diversion system, water will be directed to the filtration system and redirected to a cleaner area. It will likely use gravity to collect the water and divert it. It will also make use of many pipes.

Both systems will make use of the “external testing area” which will be a part of the filtration system where the water is tested for nitrate, PH, turbidity and TDS. This is important to ensure that the system is functioning properly.

<table>
<tr><td colspan="2">Type of Filtration system</td></tr>
<tr><td>Floating</td><td>Water Diversion</td></tr>
<tr><td>Diagram: 
</td><td>Diagram:

</td></tr>
<tr><td><table><tr><td>Pros</td><td>Cons</td></tr><tr><td>- Less disturbance to aquatic</td><td>- may be less efficient
- noise</td></tr></table></td><td><table><tr><td>Pros</td><td>Cons</td></tr><tr><td>- efficient
- re-pollution avoided</td><td>- more complicated in some</td></tr></table></td></tr>
</table>

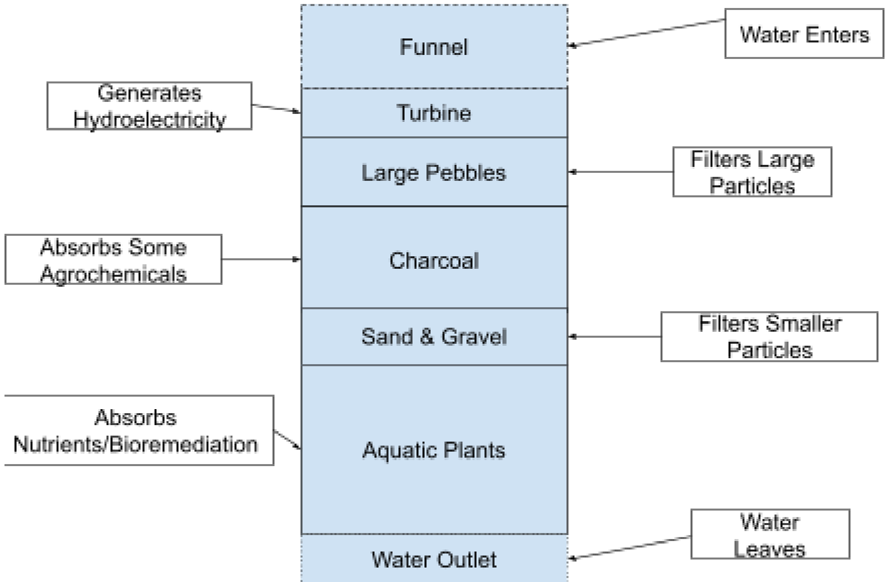
life - Less complicated in some aspects - Is much more flexible - Much cheaper than using a system that diverts water to another area	pollution from motors may disturb aquatic life - must consider the safety of the Arduino in the water - aerodynamics must be considered	- the Arduino can not get wet - more freedom over shape and material	aspects - Can affect wildlife with pipes or habitat loss when scaled up

In the end, the floating filtration system was chosen because it will most likely work better for what this is being designed for. This is because the water filtration system is not meant to be a permanent solution, instead it is a way to purify currently-polluted water. Having flexibility in terms of moving the filter makes it easier to stop the use of it when the time comes. Furthermore, this design has limited interference with under-water wildlife. These are the reasons as to why this design was chosen in the end. However there are some problems with the floating system:

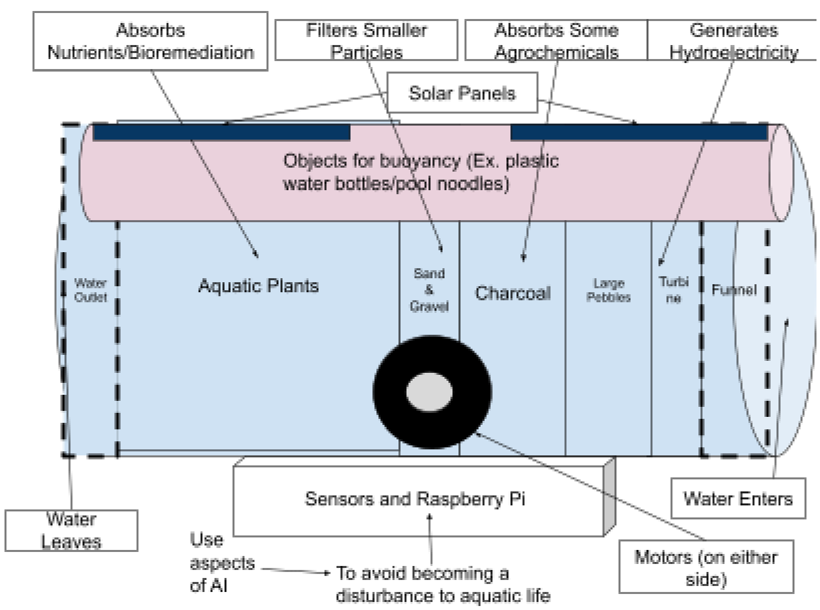
- Water re-pollution
- Aerodynamics
- Noise Pollution

Originally the plan was to use sensors and an arduino to examine the purity of the water before release but after a discussion with a professional, it was realised that using aquarium test kits are cheaper and more accessible. However, I still want to include AI in the design and I am currently considering using AI to somehow reduce the disturbance to animals. Possibly for aquatic animal behavioural monitoring?

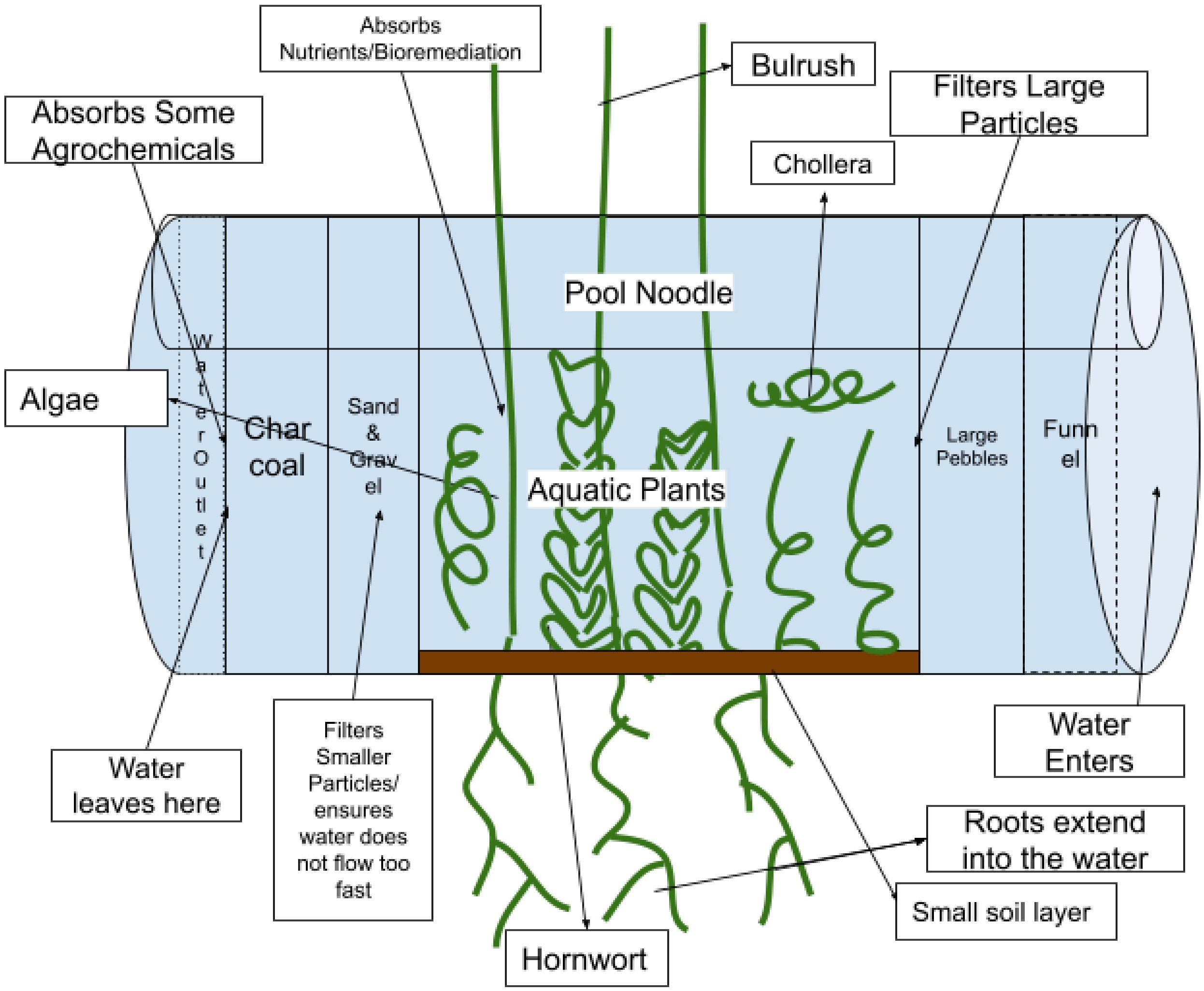
Another idea which may be included into the final design is a turbine to generate hydroelectric power alongside solar panels.



This system produces electricity as well which may be beneficial to people.



This design uses AI, solar panels, a turbine for hydroelectric power generation and aquatic plants for bioremediation and nutrient absorption. The most space is given to the plants because bioremediation is one of the main focuses for the project. There are a few options for the plants that will be used. Some examples that are being considered include: Cattails, Algae, and Bulrush. A mixture of multiple plants will likely be used for biodiversity and to further replicate a natural environment. Though a Raspberry Pi would have to be used, AI can be applied to the project to avoid the filter disturbing the natural environment. This will be done by pattern identification and avoiding areas where many aquatic animals pass through. Solar panels and turbines can be used to generate electricity not only for the system but the energy may also be stored and used for other purposes such as powering appliances in homes.



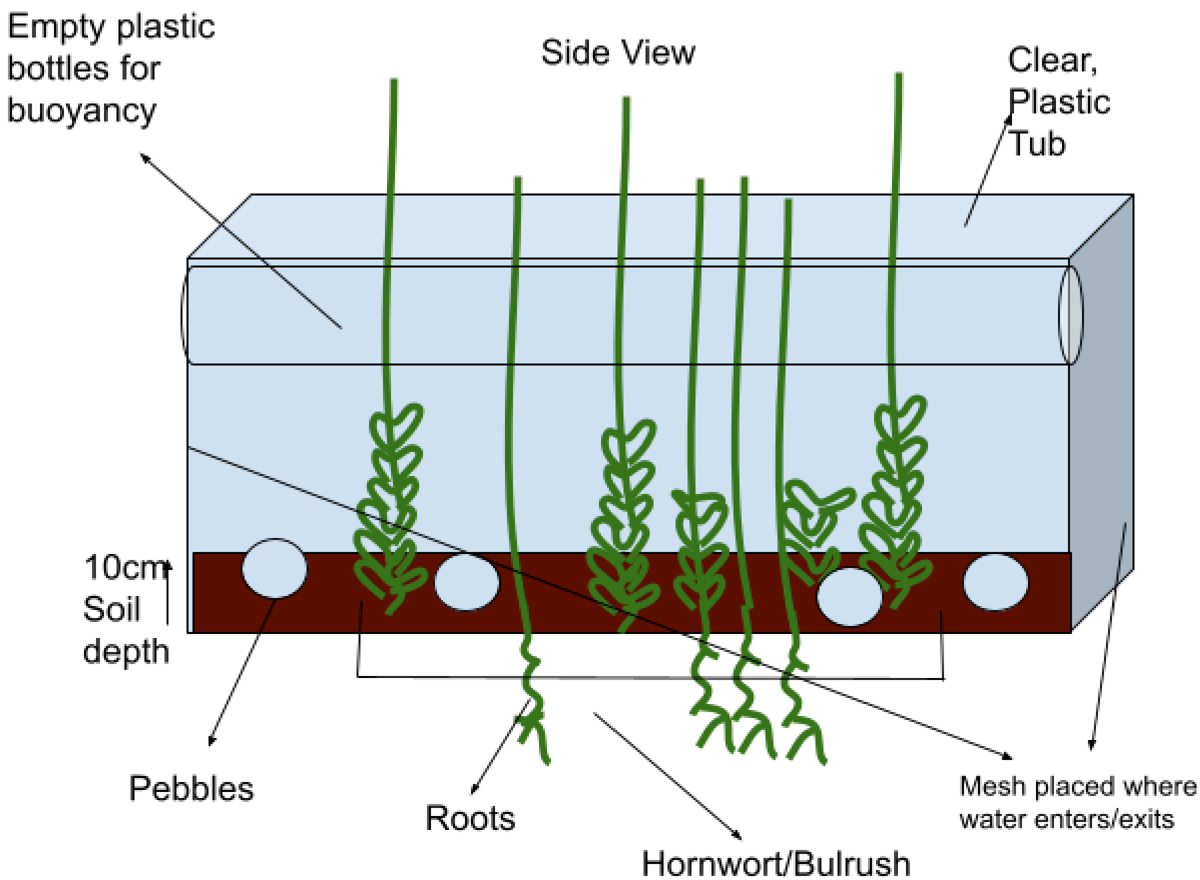
However, after some further consideration, it was realised that turbines will not work in this specific system because the most nutrients and agrochemical pollution actually end up in waters that are primarily static. For example, lakes and wetlands. Because of this, it would be immensely difficult to make much significant contributions to electricity generation.

Later, I decided to remove the AI and motor along with the methods of renewable energy such as the solar panels and turbine. This is because in Alberta, water has strong circulation. So, if the system is deployed in one area, it can purify the entire lake. Also, AI can make the system much more expensive. Removing AI will make the system more accessible to people who could not afford expensive technology.

The design above is the filter that utilises only plants and other abiotic factors such as pebbles, gravel, sand, and charcoal. The sand was moved to the end of the plant section to slow the speed of the water flow and charcoal was kept at the end to absorb any potential toxic chemicals from the plants.

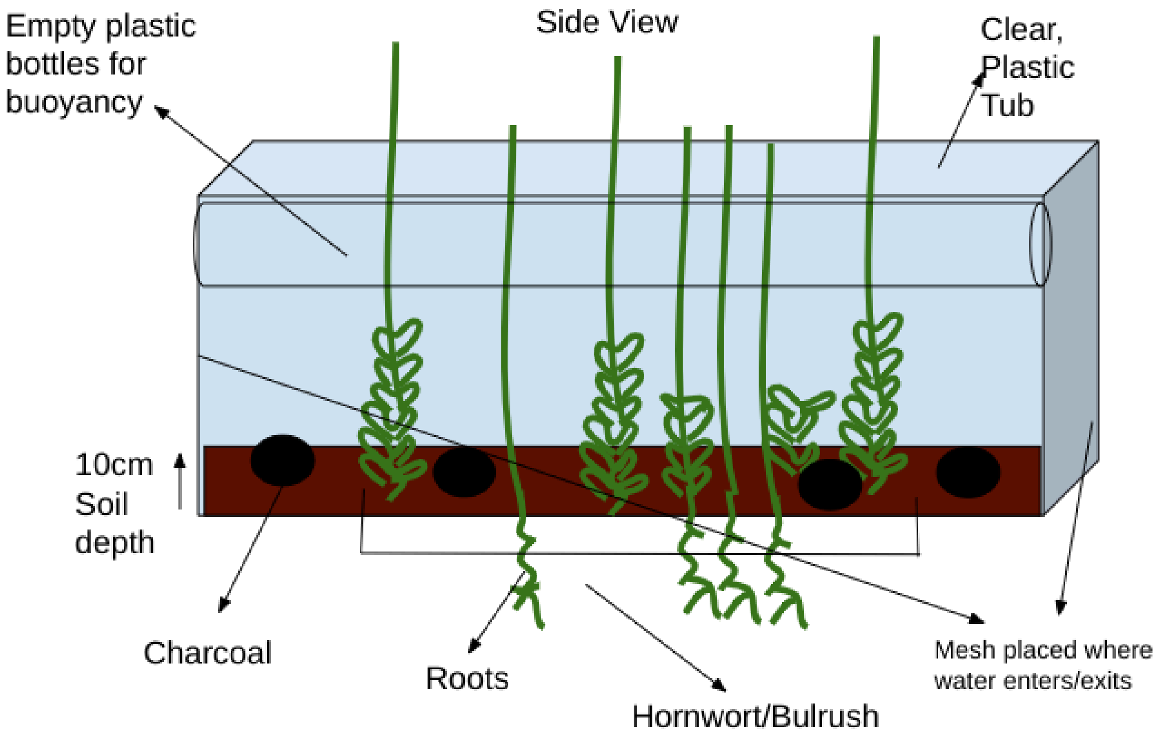
Why was hornwort, cholera, and bulrush chosen?

For this system, resilient, hardy, and fast growing plants were required. Hornwort is an aquatic plant that grows extremely quickly. It is often used to reduce nitrogen, phosphorus, and its forms in aquariums, furthermore it is very common in Alberta. Bulrush is an emergent plant. It is one of the most common wetland plants in Alberta and is very effective in reducing nutrients in water. Cholera is a type of algae. Though I may face some problems with out-competing bulrush and hornwort, Cholera is the fastest at reducing nutrients in this list. A study was done showing these results: Cholera was able to reduce close to 90% of nitrate at a concentration of 0.25 g/L over the course of eight days

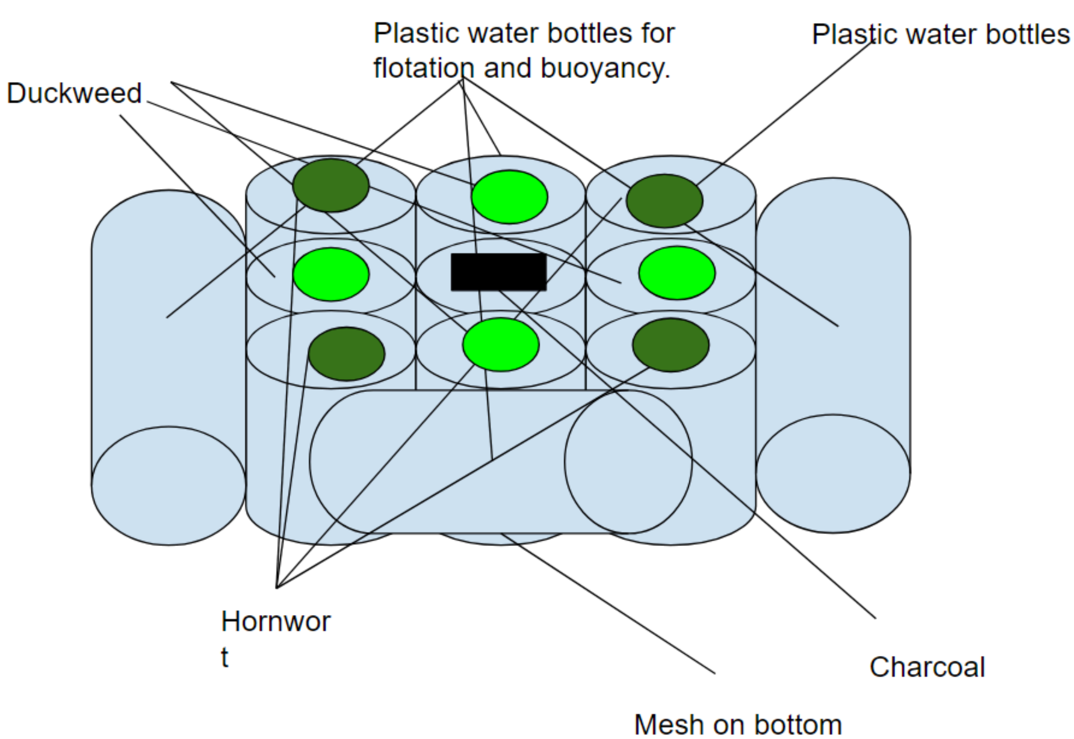


To make the system even more simple and affordable, many aspects were removed. This is the most cost effective design so far. This involves the use of plants such as hornwort and bulrush as well as abiotic factors like rocks and bottles for buoyancy. In this design I also decided to remove the algae because the chances of the algae blooming are high and also have a chance of out-competing the main plants which will affect the system's ability to reproduce its plants in the lake/wetland.

It was also determined that, in a real application, the system would have to be deployed from mid-late spring until fall. This is because spring is when farmers use the most fertilizer. A lot of this ends up in waters, requiring additional support of this system.



Later on, this design was created. It made use of charcoal instead of pebbles. The pebbles were removed to reduce weight. Charcoal is great at reducing many forms of pollutants. Other than this change, most aspects were kept the same.



Unfortunately, it was impossible to bulrush during December. Because of this I resorted to using a floating plant, duckweed as a replacement. Duckweed is very fast growing and can double the size within two days. This also means that duckweed absorbs nutrients very quickly. However, problems related to the duckweed escaping may be faced with the design preceding this. Also, in the same design, the use of floating plants can drastically reduce the light the hornwort can receive. Because of this, I had the idea of creating various sections made of plastic water bottles to house different plants. Through doing so, the hornwort can still easily receive light.

The charcoal is placed in the center of nine bottles which have been cut. The hornwort/bulrush is placed around the charcoal. Plastic bottles are used throughout the system which is actually cheaper than the previous design.

Estimating the cost:

- 24 plastic water bottles cost roughly $3.27. 13 were used for the system. Cost: $1.77
- Charcoal. Cost: $4.17
- 4.17 + 1.77 = 5.94 Total cost for one system: roughly $5.94

Five dollars is extremely cheap. Roughly 100x less money to build a real wetland.

Final Method:

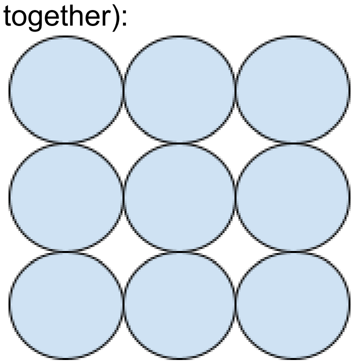
Required Materials

Abiotic components:

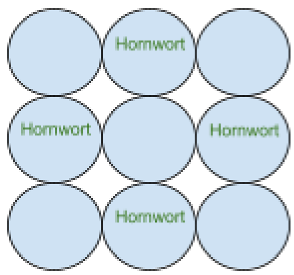
- Components of the FWS
  - Abiotic Components
    - Charcoal (8-10 pieces)
    - 4400 cm^2 of stainless steel woven wire
    - 13 plastic water bottles
    - Several zip-ties
  - Biotic components:
    - Bulrush
    - Hornwort
    - Nitrifying bacteria
- Testing Setup
  - 2 Plastic tubs with a capacity of at least 29L
  - Any liquid fertilizer that contains a 10-15-10 ratio
  - Water
  - One pack of phosphate aquarium testing kits
  - One pack of nitrate aquarium testing kits
  - Timer
  - One pack of ammonium test kits
  - One pack of ammonia nitrogen test kits
  - One pack of pH test kits
  - One pack of Free Chlorine test kits
  - Access to a computer for data collection
  - Secchi Disk
    - Any disk (a play dough cap was used in this experiment)
    - A permanent marker
    - String

        - Weighted object
- Tools
    - Measuring spoons for measurement
    - Spoons for dissolving
    - Ruler
    - Pencil
    - Camera or device with a camera
    - Compass
    - Scissors
    - Weighing scale to measure mass
- Safety Equipment
    - Several pairs of gloves

Building the FWS

1. Gather the following equipment:
    a. Charcoal
    b. 2200 cm^2 of stainless steel woven wire
    c. 2 plastic tubs with a capacity of at least 29L
    d. 13 plastic bottles
    e. Scissors
    f. zip-ties
    g. Phone for a camera
    h. Compass
    i. Plants
        i. Preferably, choosing plants native to one's area is beneficial
        ii. For this project hornwort and duckweed was used
    j. Nitrifying Bacteria
2. Assemble the base
    a. Cut 13 plastic water bottles in half so that each will be around 10 cm tall.
    b. Using the bottom part of the plastic water bottles, remove the bottom of each bottle to create a "tube"
    c. Use the "tube" parts of the plastic water bottles and attach 9 of them into a 9x9 grid as such (using a drill to make holes on the sides and zip-ties to attach the bottles together):
        i. 
    d. On all of the bottom of each bottles, place metal mesh, cut to measurements of 3 cm x 3 cm
        i. This is to act as something for the plants to "grab" onto, without using soil.
    e. Repeat step "2d" two more times
    f. Gather four additional plastic bottles
        i. Attach four of the bottles to the outside of the 9x9 plastic water bottle gird using gorilla glue

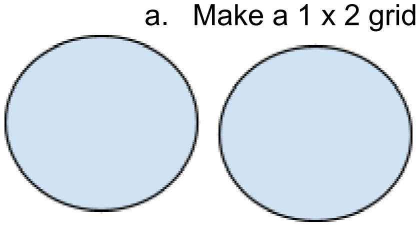
g. Repeat step “2f” on all of the grids of plastic water bottles.

3. Adding Biotic and Abiotic elements
    a. Firstly, insert the Abiotic elements.
        i. Inside the middle hole with metal mesh on the bottom, add the bag of charcoal
        ii. Insert Biotic Elements
        iii. Measuring starting height of the plants
        iv. In one system:
            1. Transplant the hornwort into 4 holes of the system as such:
            2. 

            3. In the 4 other holes, transplant the duckweed.

Setting up testing

1. Fill 2 buckets with about 25.85 litres of water
2. Add exactly 12.5 mL of liquid fertilizer to each bucket
    a. Using a spoon, dissolve the Miracle Gro powder by stirring until the water appears clear
3. Place the buckets in areas with good sunlight
    a. Make a 1 x 2 grid with the buckets, as such:



    b. In front of each bucket, add a sign to signify the types of testing (with system, without system, only hornwort, only bulrush)
4. Measure phosphate and nitrate levels using aquarium testing kits

Testing

1. In one bucket, the finished floating wetland system. Leave one bucket empty.
2. Add Nitrifying bacteria to each bucket
3. Make daily observations
    i. Record the height of the plant every day
    ii. Make qualitative observations based on the health of the plants
4. After one week:

   b. Measure and record the turbidity of the water using the secchi disk made earlier
   c. Measure and record the phosphorus and nitrate levels in the water using aquarium testing kits
5. Repeat steps “2a - 2b” every week for two weeks

Data Collection

Quantitative Observations

System deployed bucket:

Variable	Day 0 (12/30/2024)	Day 7 (01/06/2024)	Day 14 (01/13/2024)
Ammonium (ppm)	0	100	0
Nitrite (ppm)	0	0	25
Nitrate (ppm)	0	5	0
Free chlorine (ppm)	0	0.5	0
Hardness (ppm)	0	0	0
Total Alkalinity (ppm)	0	240	240
pH	7.6	7.8	7.6
Sodium Chloride (ppm)	0	0	0
Ammonia Nitrogen (ppm)	0	0	0
Phosphate (ppb)	400	70	0
Turbidity (NTU)	10.3	10	10

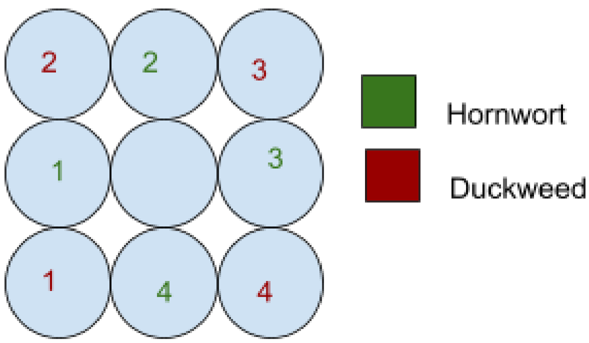
Control bucket:

Variable	Day 0 (12/30/2024)	Day 7 (01/06/2024)	Day 14 (01/13/2024)
Ammonium (ppm)	0	50	0
Nitrite (ppm)	0	3.5	50
Nitrate (ppm)	0	15	0
Free chlorine (ppm)	0	2	0
Hardness (ppm)	0	0	0

Total Alkalinity (ppm)	0	240	240
pH	7.6	7.8	7.6
Sodium Chloride (ppm)	0	0	0
Ammonia Nitrogen (ppm)	0	0	0
Phosphate (ppb)	400	125	150
Turbidity (NTU)	10.3	10	10

Growth of Plants

*For hornwort and duckweed, the numbers refer to the bottle they were kept in:

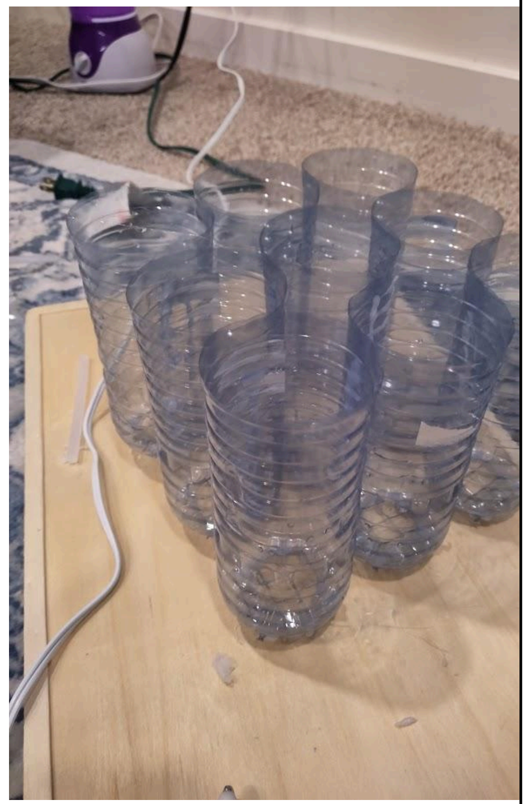
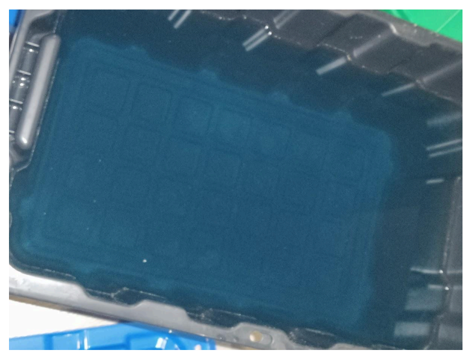


Date	12/30	12/31	01/01	01/02	01/03	01/04	01/05	01/06	01/07	01/08	01/09	01/10	01/11	01/12	01/13
Hornwort (cm)	1. 15 2. 15 3. 15 4. 15	1. 15 2. 15 3. 15 4. 15	1. 15 2. 15 3. 12 4. 15	1. 15 2. 12 3. 13 4. 11.5	1. 10.5 2. 13.5 3. 11.5 4. 11	1. 9.5 2. 0 3. 15 4. 0	1. 0 2. 0 3. 0 4. 0	1. 0 2. 0 3. 0 4. 0	1. 0 2. 0 3. 0 4. 0	1. 0 2. 0 3. 0 4. 0	1. 0 2. 0 3. 0 4. 0	1. 0 2. 0 3. 0 4. 0	1. 0 2. 0 3. 0 4. 0	1. 0 2. 0 3. 0 4. 0	1. 0 2. 0 3. 0 4. 0
Duckweed	1.5%	AVG:	AVG:	AVG:	1.6%	1.9%	2.1%	1.3%	AVG:	AVG:	AVG:	AVG:	AVG:	4.1%	4.1%

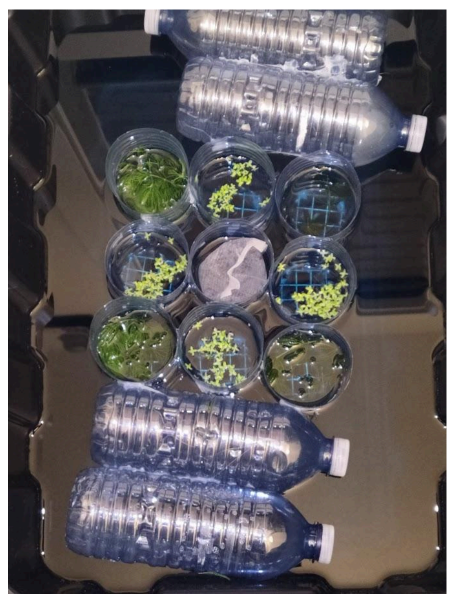
Qualitative Observations

Official testing began on Dec. 30, 2024 and ended on Jan. 13, 2024.

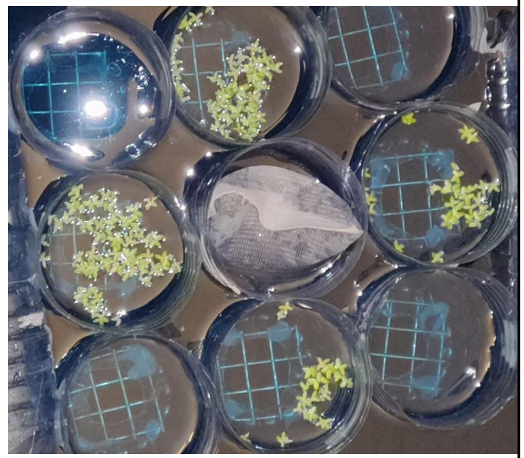
Date	Observations
12/17/2024	- Finished creating all three projects - The plastic water bottles were moved to the right and left sides to fit in the buckets. - In one of the buckets, Miracle Gro was dissolved but the water was tinted slightly blue, because of this, the systems were not deployed. - Why is it turning blue? Shouldn't the powder dissolve completely? -  - 

	-  -  -
12/18/2024	- Reason for insolubility: some particles in the fertilizer might be insoluble - Roughly 1 ¾ of bacteria starter was added - In some buckets a “foam” appeared which went away after 20 minutes

- 
- After a few hours, the bottles came apart.
    - New adhesive will be required
    - Will change the adhesive later, for now it will be required to consistently re-apply hot glue
- Charcoal
    - “sizzles “ when taken out of water
    - Must be washed once a month
- The quality of the hornwort was not amazing so I tried to balance it by having 2 “unhealthy” stems in two holes and 2 “healthy” stems into other holes.



- Hornwort:
    - Cut to 15 cm
    - Roughly 1 tsp was added
- In one system only hornwort was

	added, and in the other only duckweed was added. 
	- 
12/19/2024	- Some of the systems were completely destroyed. A new adhesive was needed urgently.
12/20/2024	- No observations recorded
12/21/2024	- No observations recorded

12/22/2024	- All of the systems are officially destroyed. - Checking water quality - Originally, only phosphate was checked. Furthermore, only one bucket was checked. Test will be re-done.
12/23/1014	- No observations recorded
12/24/2024	- No observations recorded

12/25/2024	- Finished the rebuilding of systems, this time using zip-ties
	- Used nitrogen test kits on all buckets but all were measured to be at 0 (nitrate, ammonia, nitrite)
	    - There can be many reasons. I think it is because the fertilizer did not completely dissolve and the sediments could not appear on the test kits or there is not much nitrogen in the fertilizer.
	    - To check this I will dissolve a smaller amount of fertilizer in a smaller volume of water.
	- I added miracle gro to a bottle and shook it but only started to foam and did not dissolve completely even minutes of shaking.
	- Testing of bottled water:
	    - Nitrate - 0 ppm
	    - Nitrite - 0 ppm
	    - Ammonia Nitrogen <0.5 ppm
	- A new fertilizer is required:
	    - Liquid fertilizer
	    - High nitrogen and phosphorus ratios
	- Todays observations:
	    - The tubs are still filled w/ water
	    - The control is the clearest

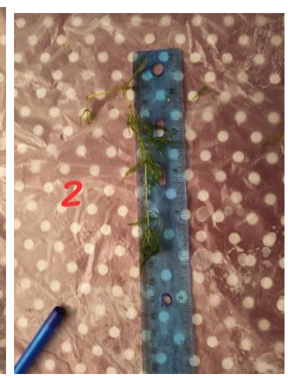
	- Each bucket has ammonia, nitrate, and nitrite concentration of 0
	- Phosphate
	    - Impossible to take readings due to the colour of the water
	    - However, phosphate results are highly necessary.

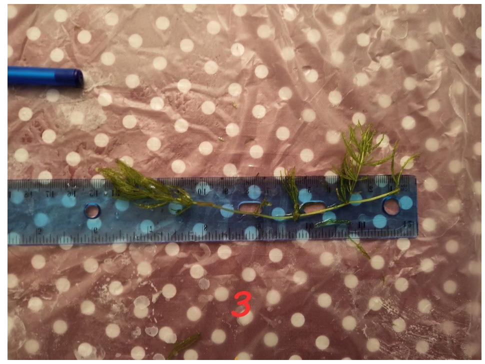
12/26/2024	- No observations recorded

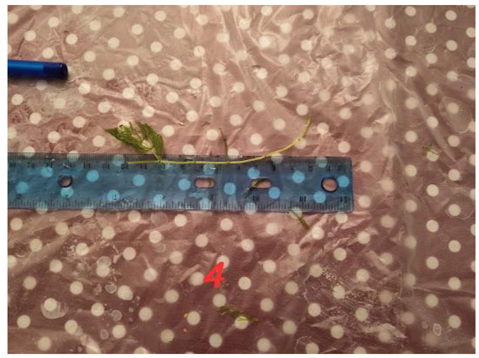
12/27/2024	- Emptied and refilled all four buckets.
	- Calculating the volume of water:
	- V = m/d
	    - Mass
	        - Research on these specific bucket - they weigh roughly 4lbs
	        - Weight of the bucket with water is 61 lbs.
	        - 61 lbs - 4 lbs = 57 lbs = 25.85 kg
	    - Density
	        - 1 kg/L
	    - 25.85/1 = 25.85 L
	- Using this the amount of bacteria and liquid fertilizer can be determined
	    - Bacteria
	        - Ratio: 5 mL/19 mL
	        - 25.85(5/19) = 6.8 mL
	        - 6.8 mL of nitrifying bacteria in each bucket.

12/28/2024	- Bought liquid fertilizer. - Figure out the amount. - In the real world, the maximum amount of nitrate in water to be considered polluted is much higher than the maximum amount of phosphate, these calculations will be completely based on nitrogen.

	- Concentration needed: 100 mg/L x 25.85 L = 2585 = 2.585 g of nitrogen. - 2.585/0.1 = 25.85 mL of liquid fertilizer. This is roughly 5 teaspoons. - Bacteria and fertilizer were added to all four buckets but when stirred, the solution became cloudy, most likely due to the fertilizer. I will wait a few hours before deploying the system to see if the cloudiness reduces. -  - After a few hours, the water cleared but a “mist” settled to the bottom. - 
12/29/2024	- No observations recorded

12/30/2024	- Day of testing! - Starting height of all hornwort plant stems: 15 cm - One thing that I noticed is that even though I added the same amount (tsp) of duckweed, it is much less than before. This is fine, it will make it easier to compare before and after of how the system operated.
01/01/2025	- The hornwort seems healthy so far. However, it is losing so many leaves.
01/02/2025	- Duckweed seems very healthy but has not grown much yet. - Hornwort is shrinking and losing many needles. - This is likely due to light since these buckets are basically pitch-black
01/03/2025	- Hornwort 1: lost almost all needles - Hornwort 2: losing needles - Hornwort 3: losing needles - Hornwort 4: almost all needles gone - Also, on this day I started to notice the first signs of algae. - The water started to turn slightly yellow. - I also quickly tested for nitrogen. Some nitrate/nitrite was present but more in the control bucket.  


3


4

01/04/2025	- Hornwort 2 and 4 have no more data because it cm=ame completely apart. - Duckweed seems like it is growing and continues to notice a yellow/brown color in water.   
01/05/2025	- All hornwort officially broken.

01/06/2025	- First week is over!
	- A few observations:
	    - Duckweed growing
	    - Hornwort will be replaced a few times in this week
	- There is already a significant decrease/increase in some nutrients (especially phosphate). Nitrogen forms are increasing due to the nitrogen cycle.
	- Today, I figured that the stuff that appeared on the floor of the buckets might be periphyton.
	    - More algae was found on the control bucket
	- Lets see how the system performs during an algal bloom.

	
01/07/2025	- No observations recorded. 
01/08/2025	- Replaced more hornwort.

01/09/2025	- No observations recorded.
01/10/2025	- No observations recorded.
01/11/2025	- No observations recorded.

01/12/2025	- There is visible growth in the duckweed compared to past pictures.
	- How will I quantify the growth of the duckweed?
	    - A code?
	    - Estimation?
	    - Physical counting?
	

01/13/2025	FINAL TESTING DAY - I noticed that the algae in the system bucket may have decreased?

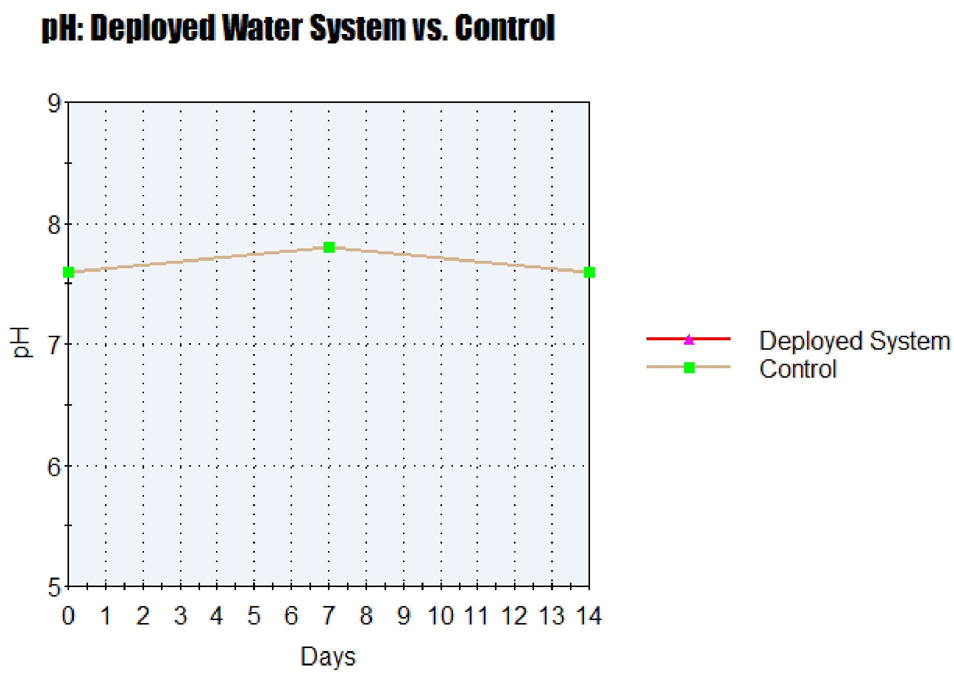
Analysis and Discussion

01/18/2024 - 01/19/2025

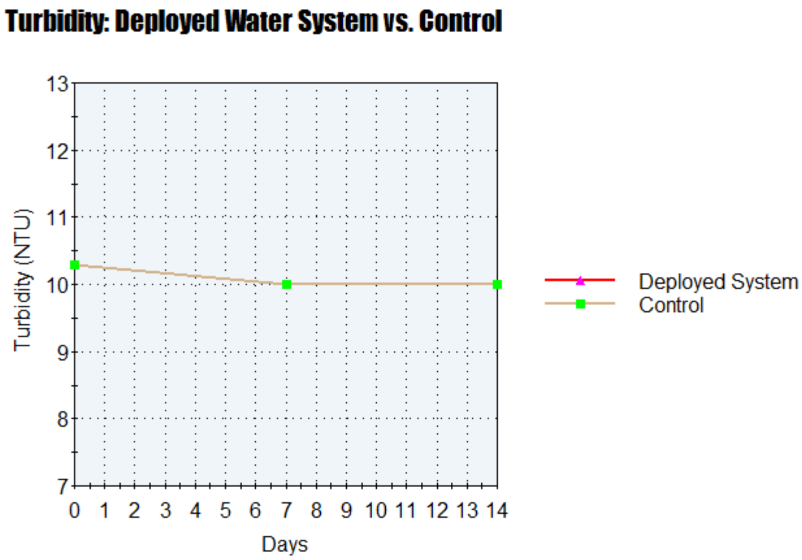
The project aims to address agrochemical runoff, particularly exploring nutrients. Excessive runoff can lead to eutrophication and ecosystem degradation. By optimizing both function and cost, this system has the ability to make significant contributions to environmental preservation and sustainable water management. The two main goals of the project were optimizing function and cost. These goals were proven to be achieved through a series of successful experiments and data analysis. This will be further discussed in this section.

Function Analysis

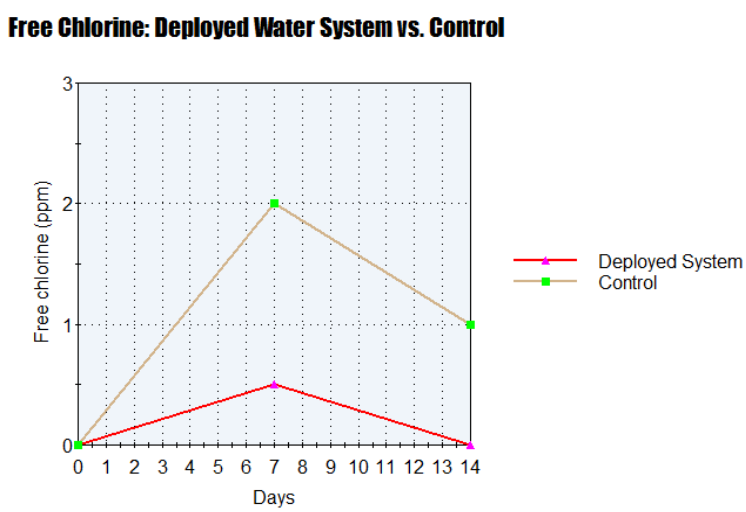
Firstly, the function will be examined. Through the observation and analysis of various nutrients, it was found that this system was efficiently reducing many different forms of nitrogen and phosphorus in an efficient manner. Secondly, the cost aspect will also be explored to provide further insights on the effectiveness of the system. Analysis on individual aspects:



pH was measured. Before testing, it was expected that pH could provide insights on the nutrients available in the water due to the fact that pH impacts many chemical reactions as well as living organisms in water systems. For example, in highly acidic conditions, certain nutrients may become too soluble, and in basic conditions, essential nutrients may precipitate and become unavailable. Furthermore, processes like nitrification may impact the pH of the water itself, providing important insights. However, very small changes in the water were noticed. In both the buckets, the pH measured 7.6, then increased to around 7.8 and decreased to 7.6 once more. This is a change of roughly only 3% throughout the test. This indicates that the water has a stable pH level. Therefore, the pH did not provide much insight on the effectiveness of the system.

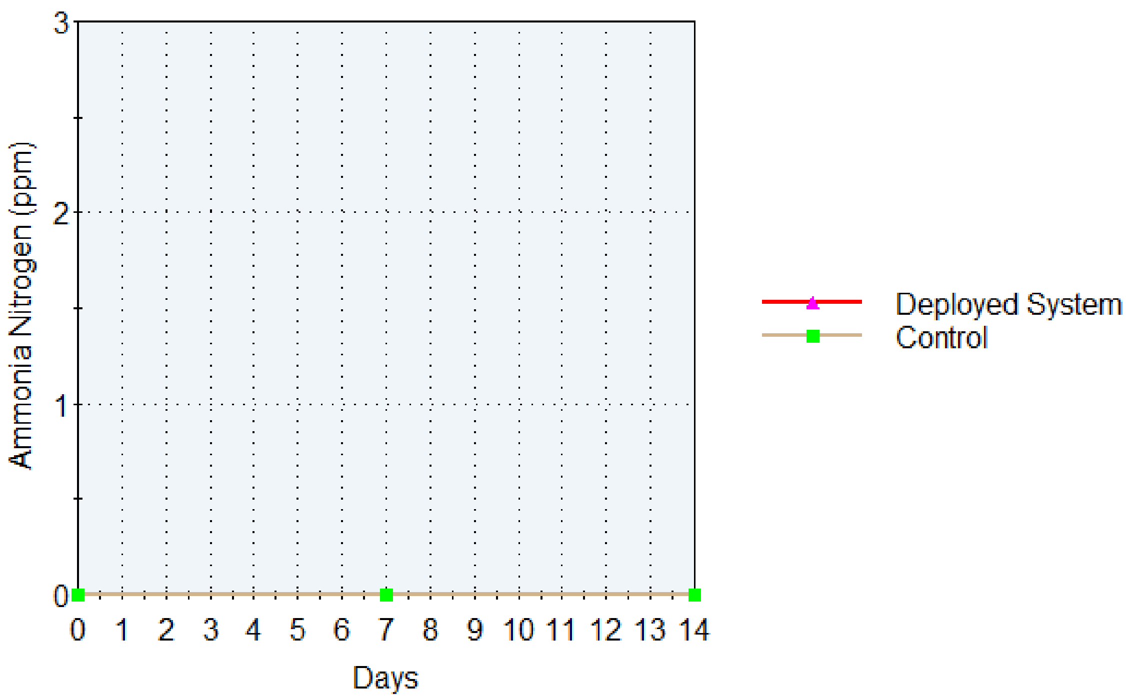


Secondly, the turbidity was also measured. There were small amounts of precipitation during the experiment, likely due to the basic conditions of the water. Turbidity was measured to see if the addition of plants would make any changes to the precipitation of the experiment. However, given that the turbidity was caused by precipitation, there were naturally minimal changes in the turbidity measurements. However, in a real river, measuring turbidity may be highly effective in determining water quality and the impact of plant additions.



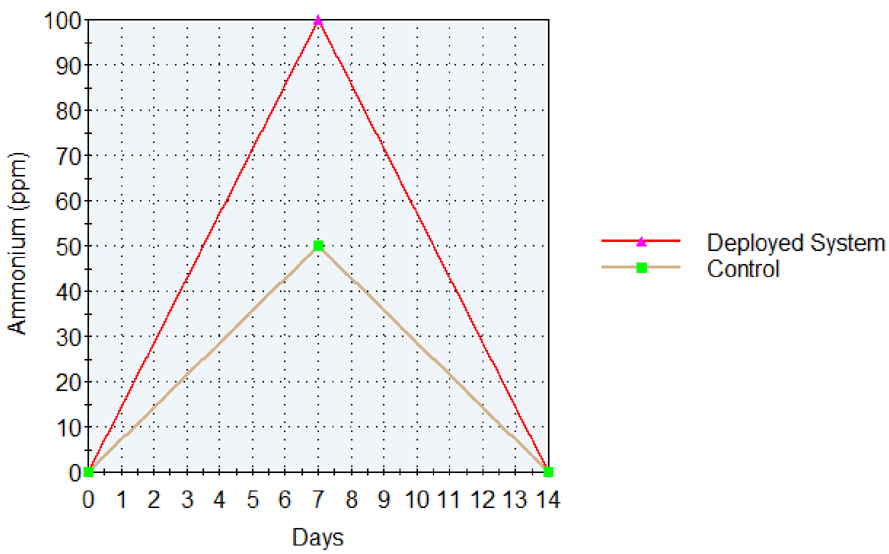
Free chlorine is the available chlorine in a water sample. Chlorine is present in some fertilizers as a micronutrient. It can be in many forms, such as potassium chloride or ammonium chloride. Although they do not serve the same purpose as disinfection chlorine in water, they may behave in similar ways. This can impact the microorganisms in the water, eventually hurting the plants and other aquatic life in the water. This was an essential aspect to measure due to these reasons. From the graph above, the function of my system could easily be understood. By the end of the two weeks, it can be seen that the control bucket had roughly 1 ppm of free chlorine, yet the deployed system had 0 ppm of free chlorine; the control bucket had 100% more free chlorine. In the graph, it is seen that the system was much quicker than the control bucket. Throughout the testing, the control bucket started at 0 ppm of free chlorine and rose to roughly 2 ppm the first week and dropped down to roughly 0.5 ppm by the end of the second week. In the deployed system bucket, the free chlorine started at 0 ppm, rose to 0.5 ppm after the first week, and dropped to 0 ppm after two weeks. The control bucket could only reduce 75% of all free chlorine, but the deployed system bucket reduced it by 100%.

Ammonia Nitrogen: Deployed Water System vs. Control



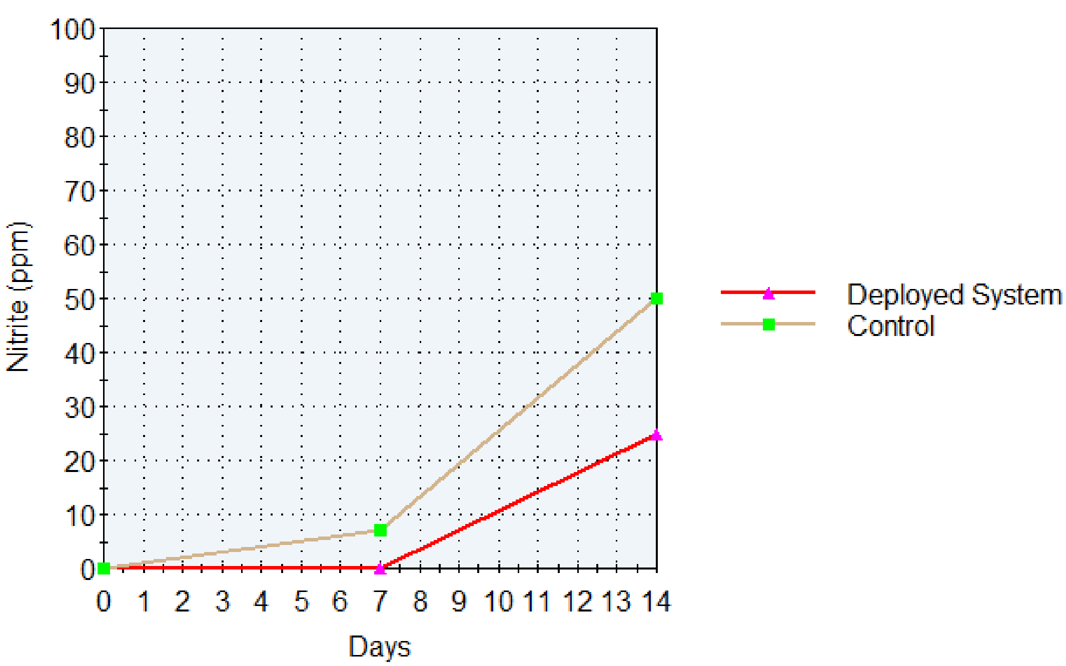
Ammonia nitrogen was not found at all during the whole experiment, likely because of the rapid conversion to nitrification. Possibly, if more water samples were examined, ammonia nitrogen may have been a visible change.

Ammonium: Deployed Water System vs. Control

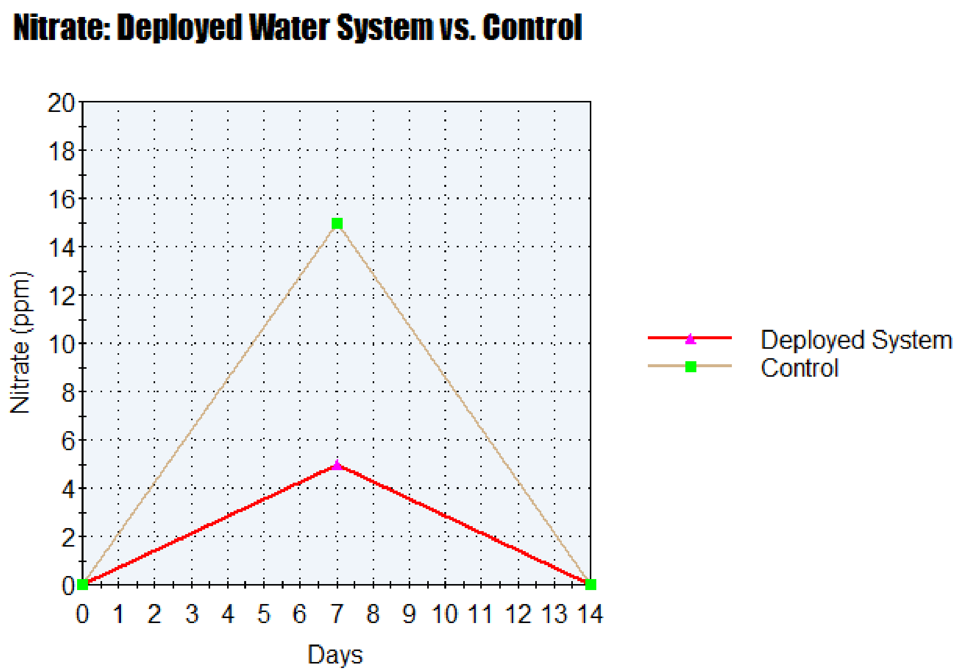


Ammonium was also measured. The graph above shows that the deployed system was slower for this nutrient. This is likely due to the fact that there was more algae in the control bucket than the system-deployed bucket. This will be further explored in upcoming sections. The control bucket worked better for this specific nutrient because it peaked at a lower ammonium concentration (50 ppm compared to 100 ppm of the system-deployed bucket) and still was able to remove all ammonium without any sharp increases of the nutrient. However, by the end of the two weeks, the system-deployed bucket was still able to reduce ammonium completely. This further proves the function of the system despite having no algae.

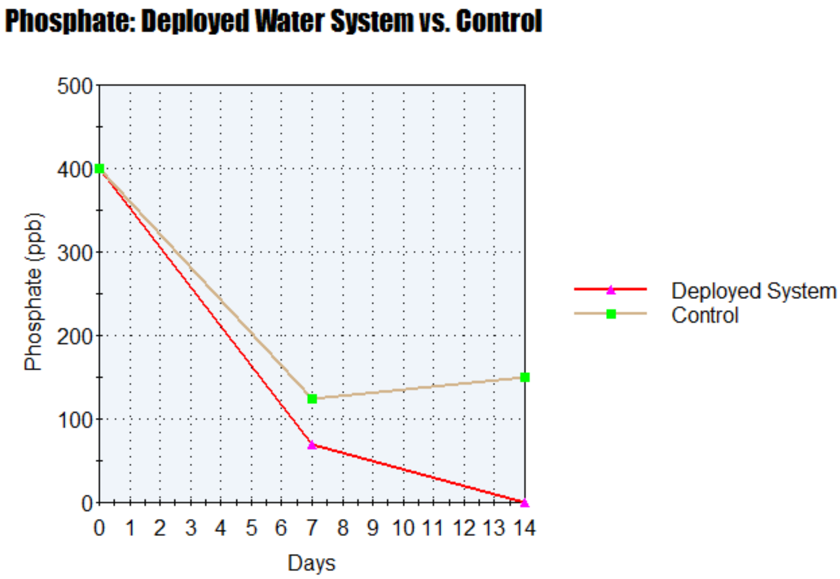
Nitrite: Deployed Water System vs. Control



For nitrite testing, other interesting incidents occurred. From the graph above, it is actually visible that the nitrite levels increased throughout the two weeks. This is likely because nitrite is one of the hardest forms of nitrogen for plants to sequester compared to nitrate, even for algae. Because of this, the nitrite levels can be seen increasing in both the control bucket and the deployed system bucket. However, the nitrite levels in the deployed system bucket increased much more gradually. This can be proven because when averaging the increase of nitrite in each bucket, it was found that the control bucket increased roughly 3.57 ppm per day. In the system deployed bucket, it increased by around 1.43 ppm per day.



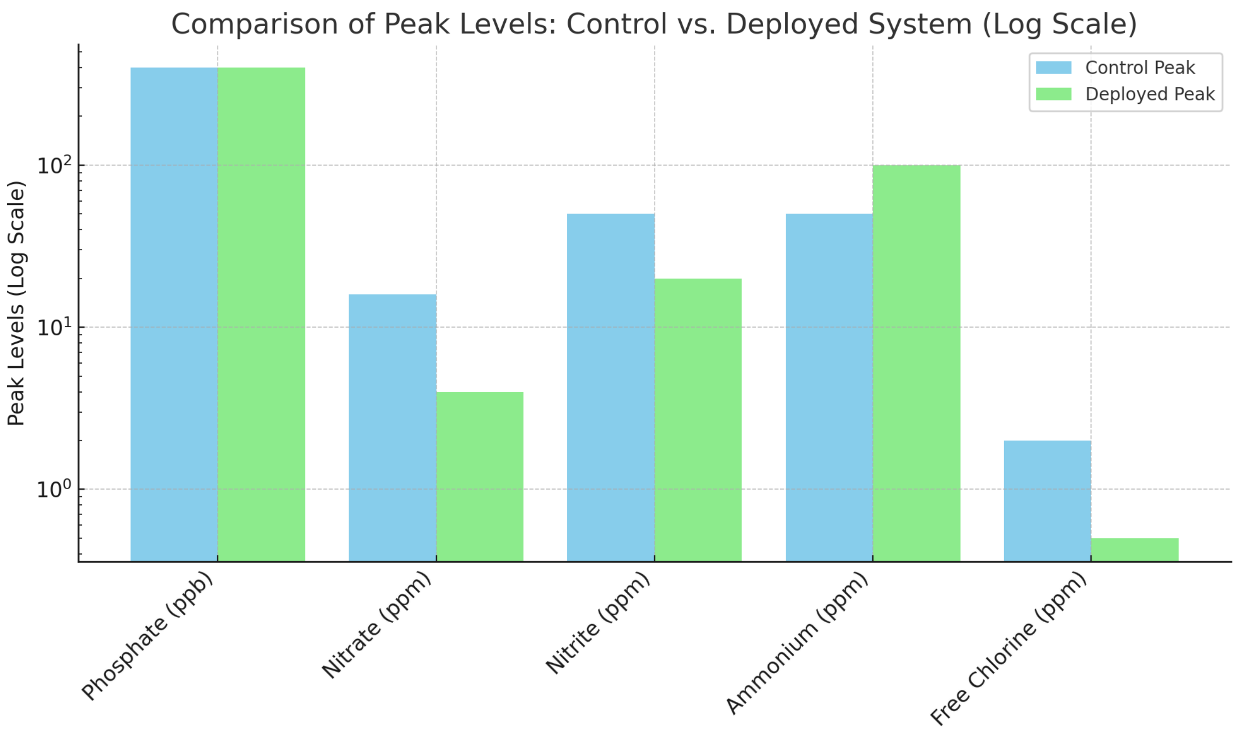
Nitrate testing went almost exactly as predicted. As seen in the graph above, the bucket with the deployed system most quickly reduced nitrate with the least extreme spikes in nitrate amounts. The deployed system was also much faster than the control despite the control having more algae. Nitrate levels are likely one of the most important nutrients to measure because they provide direct insight on the efficiency of the plants and microorganism health as nitrate is the easiest nutrient for plants to sequester. Because of this, high nitrate levels can also lead to a greater likelihood of algal blooms and eutrophication .



Phosphorus is the easiest identifier to whether an algal bloom will occur. The most common type of phosphorus in fertilizers is orthophosphate. It is extremely difficult to find test kits for primarily orthophosphate so a test kit to identify phosphate was used. In the graph above, it provides the best insight on the function of the system, showing the reduction of the phosphate in comparison to the algae and bacteria in the control bucket. This can be proven because in the control bucket it had an average reduction of 28.57 ppb per day while the control reduced only about 17.86 ppb per day. The system was approximately 60% higher.

Function Comparison Between Various Nutrients

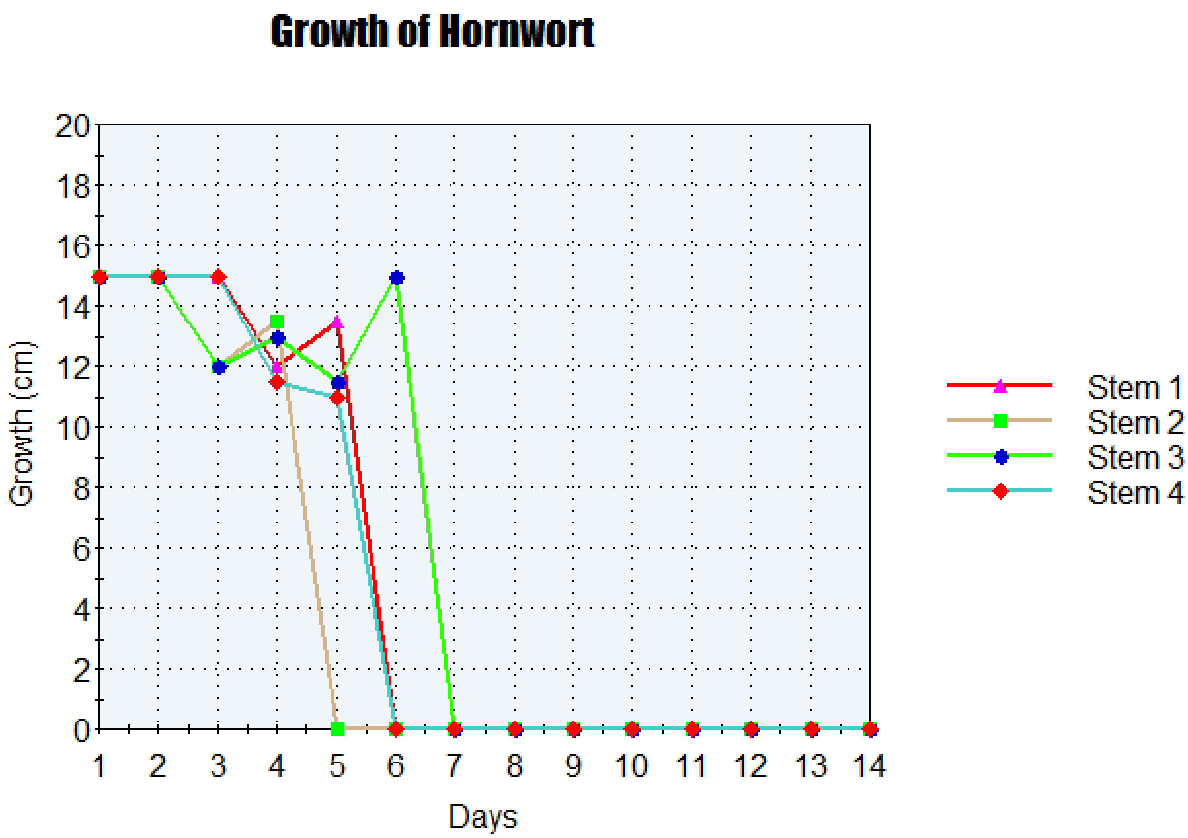
Variable	**Control Peak**	**Deployed Peak**
Phosphate (ppb)	400	400
Nitrate (ppm)	15	5
Nitrite (ppm)	50	25
Ammonium (ppm)	100	50
Free Chlorine (ppm)	2	0.5

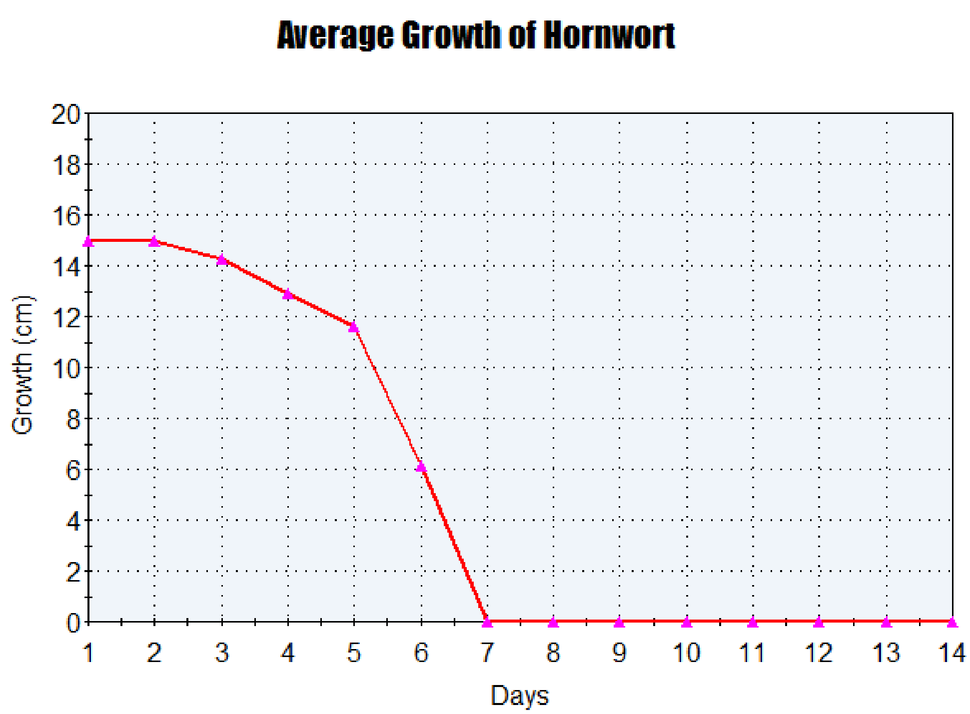


Although the above graph is not a great way to compare phosphate, the peak heights give insight for the efficiency of the system compared to the control bucket and algae. In the graph, the higher the bar, the worse the performance. This is because the bucket with the highest peak has the most amount of nutrients. This graph proves that the control bucket was only able to perform better in sequestering ammonium. This is because algae prefers this form of nitrogen over even nitrate. This is because nitrate has a higher energy requirement for assimilation. Nevertheless, the system was still able to completely reduce ammonium despite having much less algae.

Average Growth of Hornwort

Date	12/30	12/31	01/01	01/02	01/03	01/04	01/05	01/06	01/07	01/08	01/09	01/10	01/11	01/12	01/13
Horn wort (cm)	15	15	14.25	12.875	11.625	6.125	0	0	0	0	0	0	0	0	0


Growth of Hornwort
Growth (cm)
Days
Stem 1
Stem 2
Stem 3
Stem 4


Average Growth of Hornwort
Growth (cm)
Days

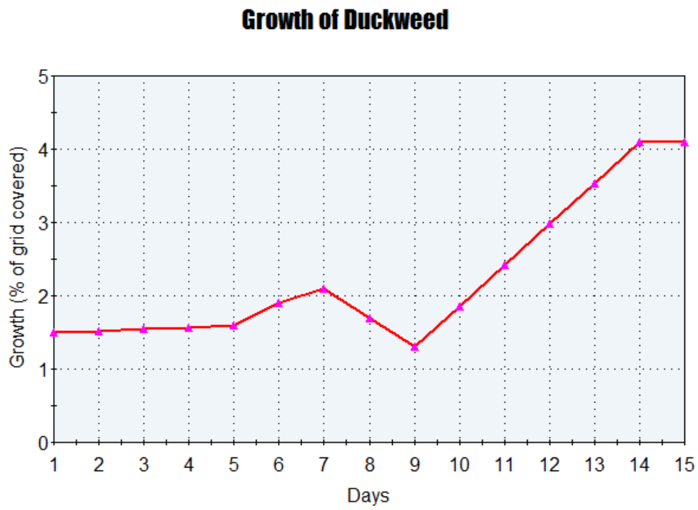
The growth of hornwort was the least successful aspect of this project. As seen in the graphs above, the height of the hornwort reduced and broke apart by the end. This was due to the lighting situation. The hornwort were kept in buckets like these:

As seen in the image above, the box is completely black which lets almost no light inside of the bucket. A solution to this would be using a clear bucket next time. However, it was very difficult for me to find the same size bucket for an affordable price. Throughout the second week, I had to add some more hornwort into the system.

Growth of Duckweed:

The growth of duckweed is very hard to measure because of the large amount of individual fronds making it very difficult and time consuming to measure each one individually. Because of this, an estimation kwon as grid-based estimation was used. In this method, a grid is placed on top of a photograph of the duckweed and it is estimated how much duckweed fills the individual squares of the grid. The number is then divided by the total number of squares, in this case 900. Below is the rough estimate of the amount of duckweed throughout the two weeks. For some days the images were lost. EST signifies that it is just a rough estimate based on past trends.

Date	12/30	12/31	01/01	01/02	01/03	01/04	01/05	01/06	01/07	01/08	01/09	01/10	01/11	01/12	01/13
Duckweed Growth	1.5%	EST: 1.52%	EST: 1.55%	EST: 1.57%	1.6%	1.9%	2.1%	EST: 1.7%	1.3%	EST: 1.86%	EST: 2.42%	EST: 2.98%	EST: 3.54%	4.1%	4.1%



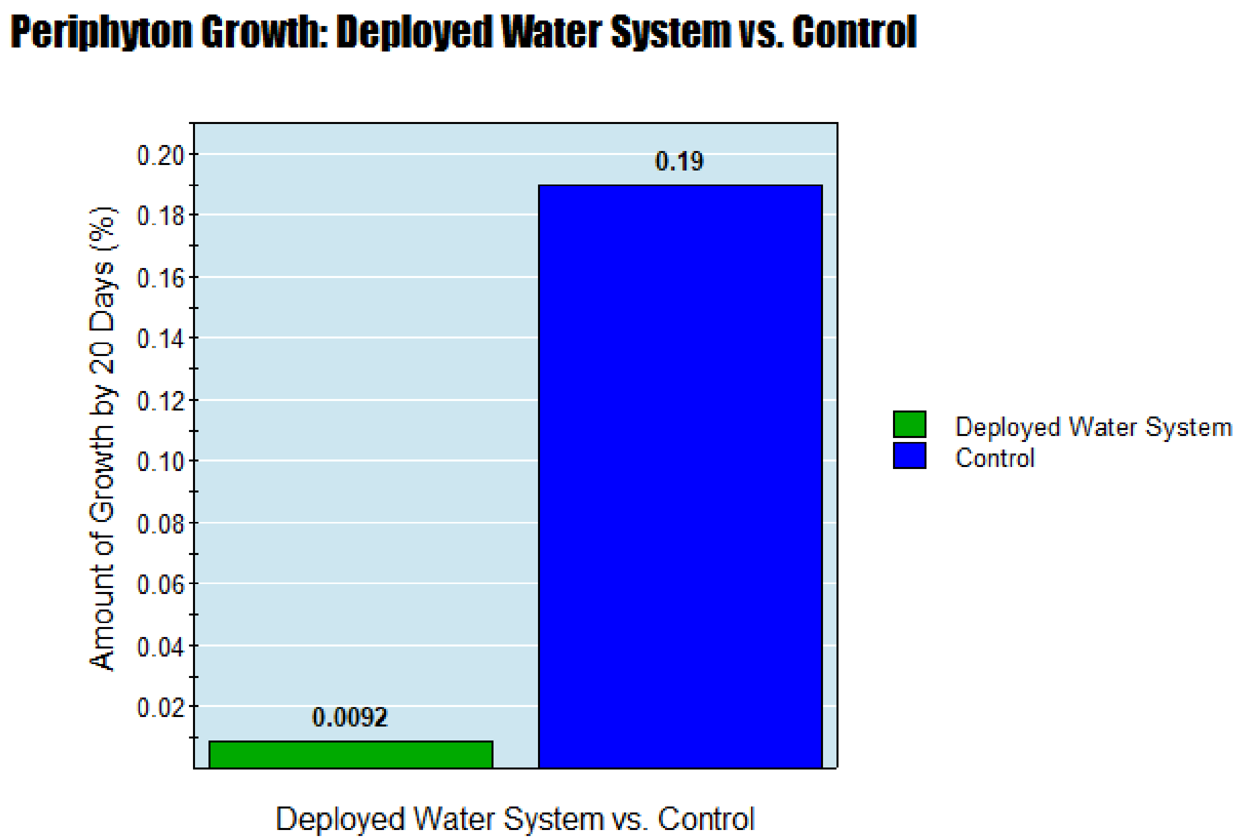
From the graph above, it is clear that the overall growth of the duckweed was substantial. The growth accelerated in the second week, likely due to the conversion of nutrients. However, there was one outlier. On 01/07/2025, it was found that the amount of duckweed was approximately 63% less than the previous day but returned to normal levels throughout the week.

There are many reasons this may have happened. One possible reason is environmental stress, as the temperature during this week suddenly changed from −11°C to +9°C within 72 hours. This is a roughly 182% difference and could have disrupted the duckweed. Other factors, such as extreme changes in pH levels, nutrient imbalances, or even human error during estimation, may have contributed. It is worth noting that this is an estimate, and perfect accuracy can not be expected.

01/29/2025

Periphyton is an organism that contains bacteria, fungus and mostly algae. It is beneficial as it can remove pollutants and serve as food for aquatic life. However, if it experiences overgrowth, eutrophication can occur. Cyanobacteria may also be part of periphyton and if this happens, toxins may further release into the environment. However, for the most part periphyton is actually very beneficial.

The same estimation method was used to determine the amount of periphyton growth in water. This is the graph showing this:



There was an approximated 19% of periphyton in the area measured for the control bucket and 0.0092% in the deployed water system bucket. The control bucket had over 200 000% more periphyton growth. It is also important to note that this is not necessarily a bad thing that the system was preventing periphyton growth, even if it is a beneficial organism. This is because it shows that the system was able to effectively compete with other organisms.

Cost Analysis

Traditional floating wetland systems are already highly cost-effective, typically costing around $35. However, this project introduced several improvements to traditional designs. For instance, soil was not used in this system, allowing it to house both aquatic and floating plants, which traditional floating wetland systems do not support. Additionally, it makes use of additional materials such as activated charcoal to more efficiently reduce nutrients in water. This adaptation helps to more closely mimic a natural wetland ecosystem. Despite these enhancements, the system has an estimated cost of $5.85, making it approximately seven times less expensive than traditional floating wetland systems. This significant reduction in cost makes the system highly affordable when scaling it for broader implications. Additionally, floating wetlands are far more affordable compared to constructing large, artificial wetlands, which costs an average of $18 000, reducing the cost by around 3000x. By leveraging these cost benefits, the system offers a practical and affordable solution.

Limitations and Future Improvements

Challenges were faced in many aspects of this project. One of the biggest challenges was figuring out lighting. Due to inadequate light, the hornwort could not grow and consistently had to be replaced during the second week of testing. Using a clear bucket would have allowed light to reach the hornwort, ensuring better testing.

Another major limitation was the inaccessibility to emergent plants. This test was done during winter, and during this time, no shops sold bulrush, a plant I was originally planning to use. When replicating this experiment, it will be a huge benefit to include bulrush or any other emergent plant native to Alberta.

Human error may also be a potential challenge because some errors in measurement may have occurred, such as adding too much fertilizer or bacteria or a mismeasurement in the amount of water in a bucket. A weighing scale would have helped with this problem, but currently, I do not have access to a weighing scale that can measure such small amounts.

The accuracy of the test kits may have also impacted the results. It is almost impossible to identify the exact quantity of a specific nutrient or pollutant in the water just by looking at colored test kits. Sensors would have made this much more accurate.

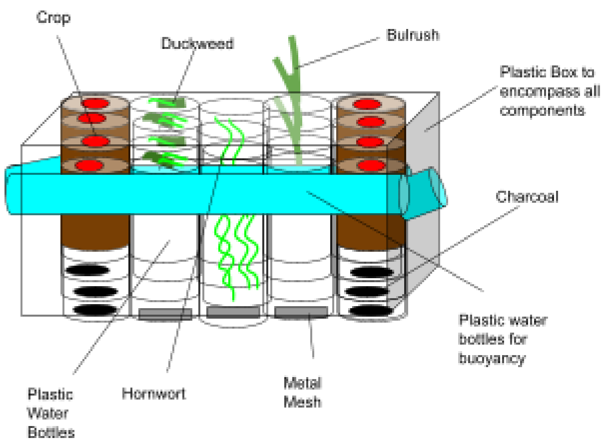
Another improvement would be using the system in real freshwater ecosystems to see how it performs under natural conditions. The system could also be optimized to filter pesticides, herbicides, and other agrochemicals.

Conclusion

01/19/2025

The objective of this project was to create an affordable and effective system capable of removing agricultural runoff from freshwater ecosystems. Since then, this project evolved into a practical floating wetland system designed for local use in Alberta. The system has proven to be highly effective, as seen in the data. For instance, phosphate reduction in the system-deployed bucket was approximately 60% faster than in the control bucket (28.57 ppb/day versus 17.86 ppb/day). Additionally, nitrate levels were reduced significantly faster, with the highest nitrate concentration in the control bucket being 30% higher than in the system-deployed bucket. These results further validate the functionality of the floating wetland system.

The future prototype will integrate additional features, such as a compartment for crop cultivation, allowing the system to utilize excess nutrients in the water while producing food. The design will also incorporate emergent plants like bulrush to mimic natural wetland ecosystems more closely. Although this design increases costs, the added benefit of creating space for crop growth makes this approach highly cost-effective in the long term. This allows for the system to be deployed in a variety of different settings. This is the design:


Crop
Duckweed
Bulrush
Plastic Box to encompass all components
Charcoal
Plastic water bottles for buoyancy
Plastic Water Bottles
Hornwort
Metal Mesh