Hybrid Botanical-Electro Purification

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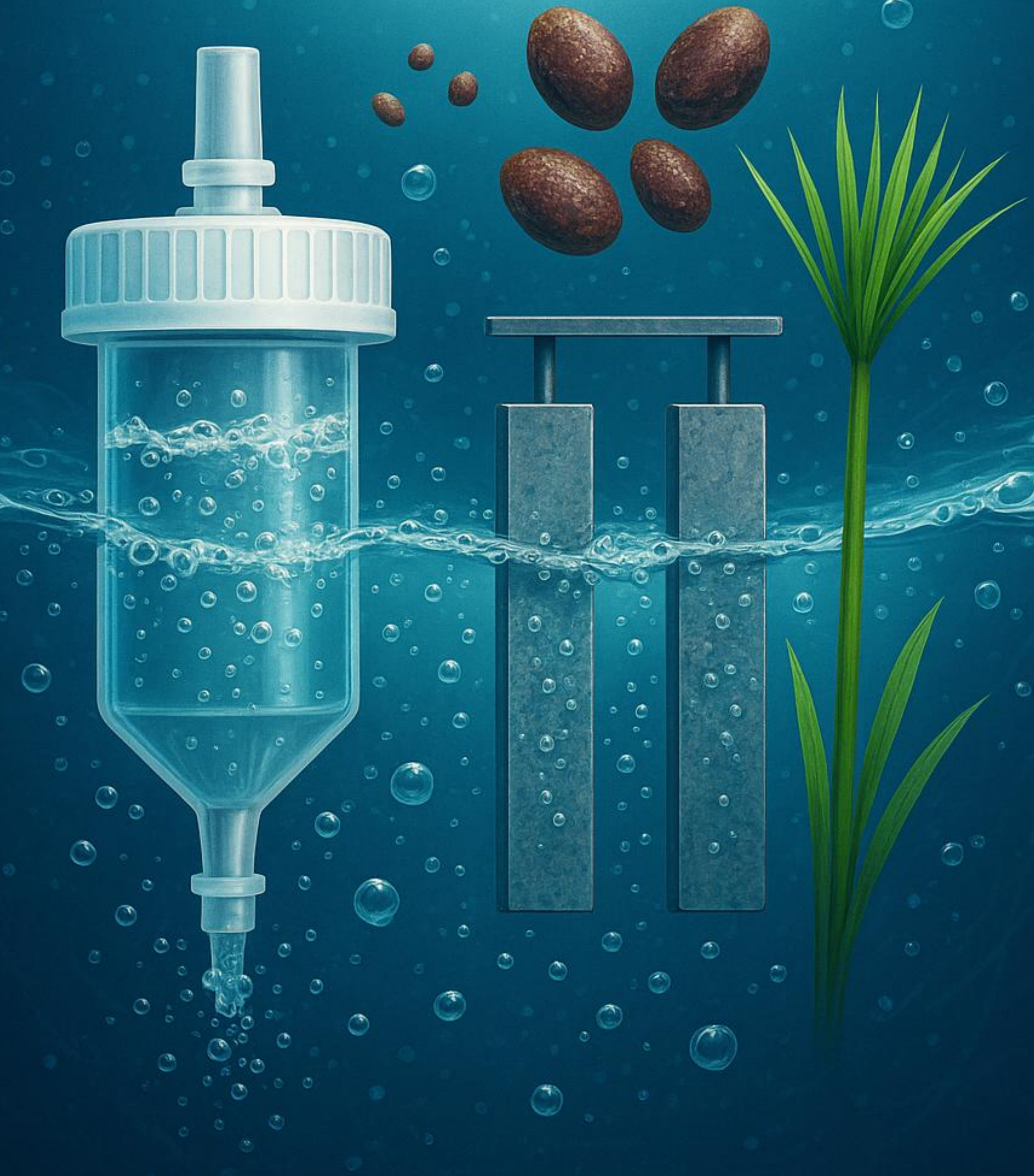

Hybrid Botanical-Electro Purification

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Ahmed. S. Maghawry- Mohamed. M. Abozina-Mohamed. S. Elrefaiy
Fares. M. Drwish

STEM Gharbiya High School

Mrs. Shaimaa Ramadan /G11 Capstone Leader

Mrs. Hala Hassan /General capstone leader

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Present and justify a problem and solution requirement

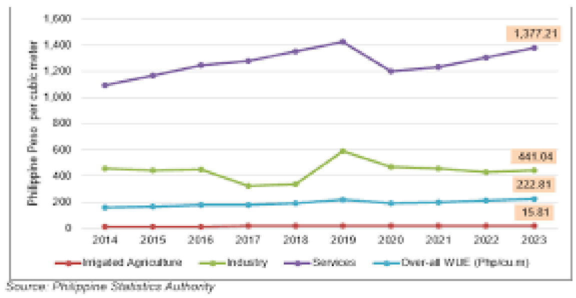
Egypt Grand Challenge

Water Scarcity:

A serious issue is water scarcity which threatens the development and stability of Egypt. Egypt, the most populous country in the Middle East, is feeling increasing pressure on its water resources, which are growing scarce due to rising demand, resource degradation, and uncertainties regarding the transboundary flows from its upstream neighbors. Water scarcity is the shortage of fresh water for various uses. Physical water scarcity occurs when there is not enough water to fulfill all the required purposes including the one that is required to support the natural environment. Deserts have a physical water scarcity. Economic water scarcity is brought about by a lack of funding to develop facilities and technologies that would help in obtaining water from rivers, aquifers, or any other water source. (Ha & Schleiger, 2025)

Figure 1

Water use efficiency by major sectors, 2014 to 2013



Source: Philippine Statistics Authority

Causes of Water Scarcity:

<u>Droughts and Climate Change:</u> Climate change has worsened drought as a natural occurrence defined by dryness and absence of rain, in areas such as Bangladesh and Somalia. These regions are already water-stressed owing to monsoons and droughts. Over-exploitation of water, combined with deforestation form what are known as 'heat islands', while soiling of the soil and other forms of pollution only exacerbate the situation in sub-Saharan Africa. The rise in sea levels means that water sources are being salinized, which in turn leads to water scarcity and the overall water crisis globally.

<u>Wastewater:</u> Poor wastewater treatment systems exist in many regions of the globe. Wastewater is the water that is affected by humans in their usage: household consumption such as dishwashing or showering, agriculture uses, and possibly industries where nutrients and waste heat make the water dirty. This water is really dangerous for humans if used without treatment. Wastewater is responsible for many diseases including cholera, dysentery, typhoid, and polio.

Pollution of water: contaminated and unwholesome water is another cause of water scarcity. Water pollution has a much greater effect than people realize because every year it kills people more than wars and other calamities combined. Human activities constitute a threat to water resources. Major causes of water pollution are sewage and wastewater. More than 80% of the world's wastewater flows back into the environment without treatment. In consequence, nefarious water resources got contaminated, leading to less freshwater and drinking water being available.

Effects of Water Shortages:

Food insecurity: Agriculture uses about 70 percent of total freshwater withdrawals around the world. As the world population approaches 9.6 billion by 2050, reduced availability of water will be a significant constraint on the ability to produce enough food to meet that demand. Intense and prolonged droughts have swept away crops feeding far greater lifetimes compared to their average and promise to become a leading cause of inflated food pricing in coming times.

Human Conflict Increases: water shortage increases conflicts and competition between water users, putting millions of lives at risk. For example, the Grand Ethiopian Renaissance Dam threatens Egypt's water supply. Although Ethiopia gains greatly economically and socially from the dam, which also provides energy to two-thirds of the population, Egypt may lose up to 36% of its total water supply as a result of the dam's reduction in water flowing downstream. To protect its water resources, Egypt may have to use force.

Industry and Energy: water is important for industrial processes and energy production. But, because of water scarcity many countries that depend on hydropower to produce energy will be affected. Additionally, water-intensive industries are forced to curtail their activities to save water as much as possible, leading to job losses and a decline in economic output. Furthermore, Agriculture, manufacturing, and other key sectors also rely heavily on water for their operations. Without water, these industries will lose their productivity. (Lai, 2022)

Increase the industrial and agricultural base of Egypt.

Egypt has many problems with industry and agriculture like lake of energy unreliable transportation in the industrial field, Skilled Labor Shortage, and food shortage and we see the effects of it on the lifestyle of Egyptians, their health, and their standard of living.

First: in industry:

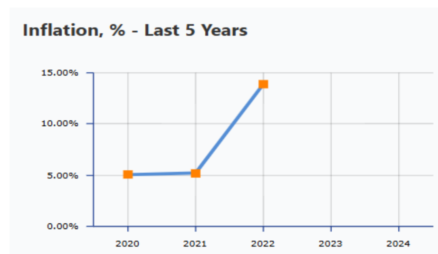
Figure 2

Improving industrial base

Egypt suffers from more than one problem in industry, with inflation reaching **13.90%**, unemployment at **6.96%**, and the external debt total is **143.25** billion dollars in 2021. And in 2022 imports of goods and services amounted to **104.39** billion dollars Net foreign direct investment inflows amounted to **11.40** billion dollars (globalEDGE, 2024). The **National Dialogue session on industry** highlighted key challenges facing Egypt's industrial sector: **Dependence on Imported Components**, as numbers say that Imports are more than exports, and that is an old problem as we see Egypt always depends on foreign products and raw materials, which made Economic Vulnerability, Trade Deficits, Impact on Domestic Industries, and Loss of Jobs. **Lack of Investment & Bureaucratic Hurdles**, Egypt needs foreign investment badly to improve the Egyptian industry and economy. In **Industrial Infrastructure Issues,** the companies suffer from power failure, transportation, polluted water that affects in and the shortage of other facilities that affect productivity and increase operational costs (Ahram Online, 2023).

Figure 3

Inflation, % Last 5 years



This problem should be solved to improve Egypt's progress and make a good life for the Egyptian people, and it can be solved by some points: **first Economic Diversification and Increasing Complexity**, The focus should be on transitioning from simple goods to high-value, complex products, This requires the development of a broad set of capabilities, skills, and coordination between different sectors to create a unique and sophisticated production system. **Attracting International Investments** is an important point, hence we need to Enhance political, economic, and financial stability to attract foreign investors. **Developing Institutional and Coordination capabilities**, learning from successful international experiences, and adapting them to Egypt's context.

Due to that, we will make great economic growth and increase exports and decrease imports in addition to Improving Quality of Life of course, Sustainable economic growth leads to better living standards and improved public services (Abuzaid, 2024).

Second in agriculture:

In Egypt agricultural is relatively bad specially in some areas like Rural areas because some reasons like: pollutant of the water, use traditional ways in agriculture, and climate change.

Take care of agriculture in Egypt is a Basic thing because it will affect in health, industry, and the quality of life in Egypt. The problem that faces Egypt in the agriculture field is:

The growth and sustainability of Egypt's agricultural sector is not without its substantial hurdles. Water scarcity is one of the nation’s most severe concerns, especially as it pivots toward proper irrigation through the Nile River. Unfortunately, the availability of water is disappearing due to climate change, increased demand, and poor management. Moreover, the gradual soil erosion, urbanization, unnatural irrigation systems, and over-fertilization all put a strain on land fertility. There is also a severe problem of financing available for farmers as loans are too hard to get due to stringent interest rates. This makes it immensely difficult for farmers to purchase state-of-the-art farming tools or techniques. Lastly, the lack of infrastructure such as those used for transporting goods, helping stores, or roads heavily contributes towards post-harvest wastage. Beyond that, the agricultural sector is filled with deficient farming methods, further making productivity unattainable. A lack of advanced farming machinery, new breeds of crops, and a shift towards more accurate farming gives way to an unquestionable throttle on farmers' productivity. Additionally, a number of other obstacles such as minimal value addition and barriers to trade do not allow farmers to maximize their profits (INTERNATIONAL JOURNAL OF MODERN AGRICULTUREAND, 2022).

Problem to be solved

Water pollution:

Water pollution is a serious environmental problem worldwide. Unsafe water kills more people each year than war and all other forms of violence combined. One of the main reasons people become sick from drinking water contamination is waterborne pathogens, which are bacteria and viruses that cause disease and are found in human and animal waste. Diseases spread by unsafe water include cholera, giardia, and typhoid. Dangerous chemicals and industrial pollutants in water cause health issues, from cancer to hormone disruption to altered brain function. Some examples of these chemicals are lead, heavy metals such as arsenic and mercury, pesticides, and nitrate fertilizers.

Causes:

Agriculture is one of the biggest causes of water pollution because of excess fertilizers, especially nitrates and phosphorus. This motivates the growth of algae in water, decreasing the amount of oxygen needed by fish. This causes dead zones because most fish will migrate to another area to get oxygen. This also affects humans as nitrate reduces the amount of oxygen carried by red blood cells. Too much nitrate can cause “blue-baby syndrome.” This can lead to suffocation. Secondly, sewage is also a water contaminant because it causes diseases like cholera and typhoid. It may also affects water groundwater. Thirdly, water used to cool turbines that are used to generate electricity is a threatening problem because it returns to rivers, lakes, seas, and oceans. It is typically 5 to 10°C warmer than the water that it enters. Hot water carries less oxygen which leads to the disappearance of some organisms (Denchak, 2023).

What if the problem was solved?

Improved human health: Water will be treated more and will be healthy for drinking and other uses. Furthermore, people won’t suffer to get clean water from distant areas because clean water will reach all homes in different ways like underground water pipes.

Economic growth: The water treatment process is very expensive. So, solving this problem could lead to increased economic activity, job creation, and improved standards of living.

Saving aquatic life: Fish won't die anymore because of water pollution. Furthermore, fish won't migrate from one habitat to another. This will increase food production and the economy.

Climate Regulation: cleaner oceans would enhance their ability to regulate the climate because oceans play an important role in the water cycle as most evaporated water comes from oceans. Furthermore, as water is purified, algal blooms will decrease leading to fewer dead zones. This will reduce climate change.

What if the problem wasn't solved?

Diseases: As humans and animals drink polluted water without being treated, they make themselves vulnerable to various life-threatening illnesses like hepatitis, cholera, typhoid, and many other water-borne diseases.

Disruption of Water Cycles and Ecosystems: Polluted water from sewage and agriculture can seep into groundwater which is considered a main source of water for some areas. Polluted water also releases some toxic gases like methane increasing global warming.

Destruction of Aquatic Ecosystems: Pesticides, industrial chemicals, and plastics are a major threat to aquatic creatures. Additionally, eutrophication is caused by excess fertilizers from agricultural processes causing dead zones of dead fish because of lack of oxygen. Furthermore, oil spills in oceans harm aquatic life badly.

Increased Costs for Water Treatment: Removing pollutants from water is an expensive process and as water becomes more polluted, the treatment process will be more expensive (Lorenz, 2024).

Research

Water Treatment

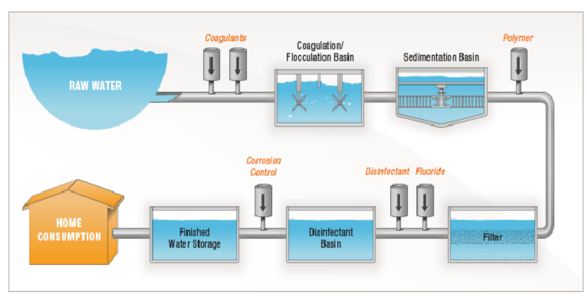
Water treatment is any process that improves the quality of water to make it appropriate for a specific end-use, like drinking, industrial water supply, irrigation, river flow maintenance, water recreation, etc... Water treatment removes contaminants and undesirable components or reduces their concentration so that the water becomes fit for its desired end-use. These components may be physical, chemical, or biological components that prevent water from doing its function properly in the field it is used for.

However, there are many types of water treatment, some of which are:

- Drinking Water Treatment: which involves the removal of contaminants and/or inactivation of any potentially harmful microbes from raw water.
- Wastewater Treatment: This involves removing contaminants from wastewater to make it suitable for human usage. Usually, the wastewater source is sewage, and this process must be done in Sewage Treatment Plant.
- Industrial Water Treatment: Which involves optimizing most water-based industrial processes, such as heating, cooling, processing, cleaning, and rinsing so that operating costs and risks are reduced.

Figure 4

Stages of wastewater treatment



The processes done within these treatments may be physical, chemical, biological, or mechanical. The ways are determined based on the nature of the water and the field in will be used in.

Water Quality Sensors

They are specific types of sensors that are used to determine the amount of pollutants and contaminants in water. Approximately, each type of water pollutants has its own type of sensor, which means that there is no sensor that can measure all water pollutants at once. These are some examples for water sensors:

- PH Sensors: They measure the pH of water. One example of these sensors is Module ph0-14 which costs around 4,400 L.E
- Turbidity Sensors: they measure the amount of light that is scattered by suspended solids in water. One example is the Water Turbidity Sensor Module (Generic), which costs about 1,000 L.E
- Dissolved Oxygen Sensors: they measure the amount of oxygen dissolved in water. One example is the Smart Bluetooth Dissolved Oxygen Meter (Generic), which costs about 6,500 L.E
- ORP Sensors: they measure the ability of a solution to act as an oxidizing or reducing agent. These types of sensors usually cost about 10,000 L.E
- TDS sensors: the dissolved combined content of all inorganic and organic substances present in a liquid in molecular, ionized, or micro-granular (colloidal sol) suspended form. They usually cost from 150 to 500 L.E based on the accuracy of the device.

There are many other types of water quality sensors, but these are considered the main types. It can be inferred from the mentioned prices that these sensors are very expensive and are owned only by water treatment companies.

Figure 5

Dissolved oxygen

Figure 6

pH sensor

Figure 7

TDS ammeter

Figure 8

Turbidity sensor

Figure 9

ORP sensor

Prior solution

1)Biological Treatment:

Figure 10

Example of the wastewater treatment plant

Biological wastewater treatment is a modern technique in which wastewater is treated with microorganisms instead of chemicals. In this way, the try is to prevent the adverse effects caused by chemical treatment of wastewater such as chemical accumulation in water bodies or algal blooming (ScienceDirect, 2024).

Strengths:

- Environmentally friendly that don't use harmful chemicals.
- Low operational costs.

Weaknesses:

- Slow process requires large space.
- Ineffective at removing inorganic pollutants (e.g., salts or chemicals).
- Fluctuating influent characteristics, temperature variations, and the presence of toxic compounds affect the performance and stability of biological treatment systems.
- Need skilled personnel and stringent process control measures underscores the importance of proper design, operation, and monitoring of biological treatment facilities (Gulf Water Treatment, 2025).

2) Coagulation and flocculation:

In water treatment, coagulation and flocculation involve the addition of compounds that promote the clumping of fine floc into larger flocs so that they can be more easily separated from the water.

Strengths:

- Fast and effective at removing suspended particles.
- Enable highly charged ions to give a high charge density to neutralize suspended particles, which allows hydrated inorganic hydroxides to form and produce short polymer chains that enhance microfloc formation and heavy floc
- Capable of removing a portion of the organic precursors which may combine with chlorine to form disinfection by-products
- Low unit cost and widespread availability

Figure 11

Coagulation and flocculation

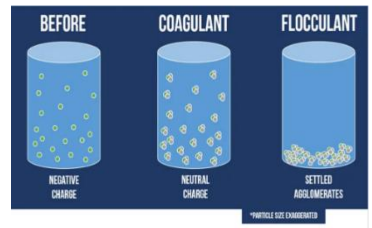
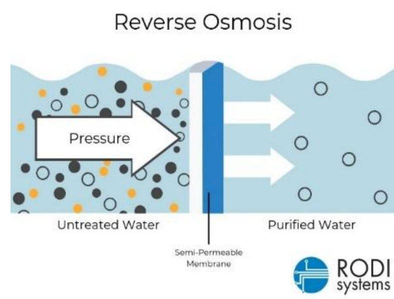


Figure 12

Reverse Osmosis in wastewater treatment



Weaknesses:

- Rely on chemicals that can be costly or environmentally harmful.
- Does not address dissolved pollutants.
- They create large volumes of floc, rich in metal, which must be disposed of in an environmentally appropriate manner, which can add significant cost to disposal.
- They can significantly alter the pH of the water, where pH is critical for effective coagulation, necessitating pH control. They also require corrosion-resistant storage and feed equipment (Greaves, 2022).

3) Reverse Osmosis (RO):

Reverse osmosis (RO) is a water purification process that uses a semi-permeable membrane to separate water molecules from other substances. It applies pressure to overcome osmotic pressure that favors even distributions.

RO can remove dissolved or suspended chemical species as well as biological substances (principally bacteria) and is used in industrial processes and the production of potable water.

Strengths:

- Highly efficient at removing salt and micropollutants.
- High quality filtration for non-potable tap water with e.g. bacteria or heavy metals.
- Can make tap water with extremely high mineral content (TDS of 1500 or higher) drinkable.

Weaknesses:

- High energy consumption and operational costs.
- Membranes are prone to clogging and require frequent maintenance.
- Requires professional maintenance to ensure effectiveness and safety.

4) Electrocoagulation water treatment:

Electrocoagulation (EC) is a process used by supplying electric current with sacrificial electrodes for the removal of pollutants from wastewater.

Strengths:

- Simple and low-cost.
- Effective for removing large impurities.
- It is a moderately fast treatment process.
  Can be treated large volumes and higher organic loadings.
  Particles electro flotation by H_2 bubbles.
- Very good removal efficiency of ionic and colloidal matter.

- Electrode cost is relatively low.
- Operation is probable to run in continual mode.

Weaknesses:

- Limited ability to remove dissolved pollutants (e.g., salts).
- Requires regular replacement of filter materials.
- The sludge is produced during operation.
- The electrode is dissolved, and replacement is needed.

(Ebba et al., 2022)

5) Solar Distillation:

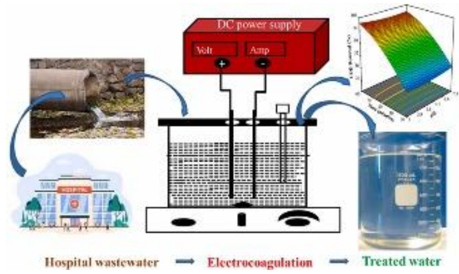
Solar distillation is a process of using solar energy to purify water through evaporation and condensation (ScienceDirect, 2024).

Strengths:

- No external energy required (eco-friendly).
- It is a relatively cheap and low-maintenance system.
- It can be used at the household level and scaled up through programmatic approaches.
- There are climate change adaptation and mitigation benefits.
- There are no moving parts.

Figure 13

Electrocoagulation usage in wastewater treatment



Weaknesses:

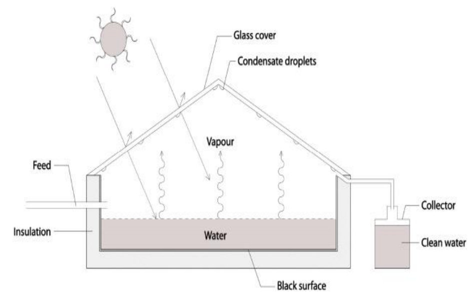
- The rate of distillation is usually very slow (6 liters of water per sunny day).

- It is not suitable for larger consumption needs.
- The materials required for the distiller may be difficult to obtain in some areas.
- If not correctly disposed of, the distillation process waste stream can be a potential source of environmental pollution (high concentrations of salts and pollutants).
- Solar energy is only available during the day.

(Solar Water Distillation, 2024)

Figure 14

Example solar distillation system



Generating and defending a solution

Solution and Design Requirements

For any successful project/solution there are some goals that must be achieved to consider that it is a successful one, so, we have chosen some design requirements to achieve our goal.

1) The prototype should treat wastewater using natural and/or processed recycled materials to maintain the sustainability of green areas and reduce pollution.

2) The prototype must be a closed-cycle water feedback system that addresses wastewater management issues including monitoring and treatment.

3) The prototype must incorporate a feedback loop that monitors at least three independent water-related parameters such as (pH, turbidity, salinity, microplastics, oil, … etc.) using calibrated sensors or experimental techniques and implement corrective actions when the studied parameters exceed specified thresholds.

4) The prototype can treat wastewater that has a salinity > threshold value ~ 500 ppm (at least 1000 pm).

5) The prototype must include an activating suitable pump to circulate the wastewater in a closed-cycle system.

6) The prototype must address at least three water quality parameters: one of them is salinity.

7) The prototype must treat wastewater using at least three different techniques which are chemical, physical and biological.

8) The prototype must include an automatic two-way gate or suitable valves to either recycle the wastewater for treatment again or exit from the output gate based on the threshold values reading of all monitored water quality parameters.

9) The prototype can tolerate at least five complete treatment cycles for the same wastewater sample.

10) The prototype must use the least energy consumption as possible.

11) The prototype must be testable, workable, and portable at any time.

Selection of solution

- Water pollution is one of the main problems in Egypt. After identifying the problem, we proposed a solution to the pollution problem through the reuse of recycled and natural materials. The current industrial system relies heavily on-air purification technologies that use materials that may run out over time, or expensive and difficult-to-maintain technologies. Therefore, we turned to using recycled materials and low-cost technologies to solve the pollution problem. Our solution is mainly composed of 3 stages.
- The source of wastewater is agricultural wastewater. Agricultural wastewater has high turbidity, salinity, and PH. So, specific treatment is chosen to eliminate the pollution parameters, as follows:

Treatment Process:

1) The first stage is coagulation and flocculation. Its purpose is to decrease the turbidity of water. Coagulation is adding a positive charge coagulant to the negative charge pollutants in water. Then, these pollutants will be attracted to the coagulant and become denser and then be sedimented. We decided to use Tamarind seeds to do this process instead of alum because it makes the water unsuitable for drinking. Tamarind seeds work as natural coagulants that decrease the turbidity of polluted water. Tamarind seed can remove heavy metals, Zinc, and Chromium. The specific protein in Tamarind seeds responsible for coagulation is xyloglucan. To extract this protein, tamarind seeds are dried for about 8 hours at 50 °C. Then, tamarind seeds will be smashed into powder. After that, 0.5 M solution of NaCl is added to the powder. Finally, the powder is ready to work as a coagulant.

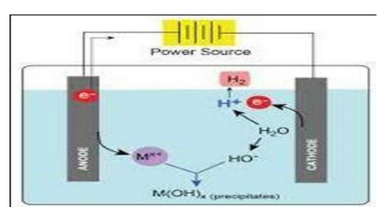
Figure 15

Tamarind seeds and their powder

2) The second stage is electrocoagulation. Its purpose is to decrease the salinity of water. This treatment is based on applying electrical current to treat and flocculate contaminants. There will be 2 rods of aluminum. As the current passes, metal ions are released from the electrodes. These metal ions act as coagulants. These ions are hydrolyzed in the presence of water, forming metal hydroxides, which are strong coagulants. The anodic reaction is (**$Al \rightarrow Al^{3+} + 3e^-$**). The cathodic reaction is (**$2H_2O + 2e^- \rightarrow 2OH^- + H_2$**).

Figure 16

Electrocoagulation process using electrodes

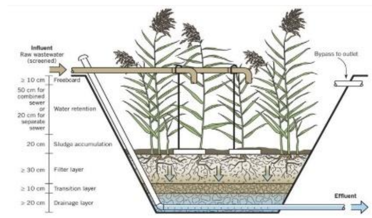


The metal hydroxides neutralize the charges on suspended particles, leading to aggregation into flocs. Then, these flocs are settled by gravity, and H_2 gas forms at the cathode. The total reaction is (**$2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2$**).

3) The third stage is the biological filter. The main purpose of this stage is to decrease PH. In this stage, the reed bed system using the papyrus plant will be used. A reed bed is a natural filtration system that can be used to treat and improve water quality before discharging into the environment. It utilizes the ability of a reed to transport oxygen to the soil, hence encouraging microorganisms to digest the contaminants in the effluent. Reed beds come in various forms and are sized based on the volume of flow per day. Two of the most popular forms of reed beds are “vertical flow” and “horizontal flow”. A vertical flow reed bed allows wastewater to flow from one end to the other. Water flows through gravel at the base of the reed bed. The roots of the reeds reach down into the gravel to find water. Oxygen is transferred to the water via the roots, encouraging bacteria growth in this oxygen-rich environment, much like in a sewage treatment plant. Water must have a long retention time (around 8 days) to enable effective cleaning. We will use this type of reed bed.

Figure 17

Reed bed system plant example



- The local application of water after application is cooling towers in factories. It was chosen because of the importance of this field. Furthermore, the water needed for this application has low turbidity and salinity. Additionally, its PH approaches neutral.

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Selection of prototype

Design Requirements:

1- The TDS of the treated water must be less than 750 ppm.
2- The pH of the water must be neutral (7).
3- The Turbidity of the treated water must be less than 50 NTU.

Prototype Design:

The water will enter the purifying system from an open in the box of the sensors, then it moves upwards by the water pump towards the first box. This box is made of plastic, where it contains two slides which are covered with powder of tamarind seeds. In addition to that, there are four electrodes made from Aluminum. Each electrode is connected to an electric source from a 12V battery. There is a fan that is used to make sure that the water is mixed well with the powder, as shown in **Figure (18)**.

The water will remain in this container for a period of about 30 min, then the Arduino will open the valve so that water moves by the effect of gravity towards the second container, which is also made of plastic. This box contains papyrus plants placed in a reed system, as shown in **Figure (19)**.

Water is dropped slowly after being filtered, then it also moves by the effect of gravity towards the last box which contains the sensors. On the other side, the box has two openings. The first one is to get water out of the system if it was filtered, and the other will push the water upward to get another filtration cycle if it wasn't filtered, as shown in **Figure (20)**.

The final shape of the prototype is shown in **Figure (21)**.

Figure 18

tamarind seeds and aluminum electrodes box

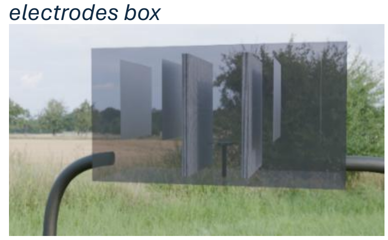


Figure 19

The reed bed system container

Figure 20

The sensors box

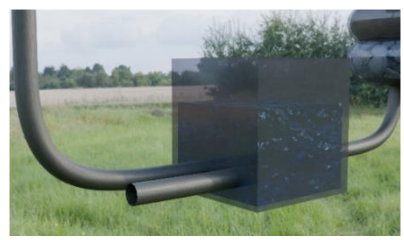


Figure 21

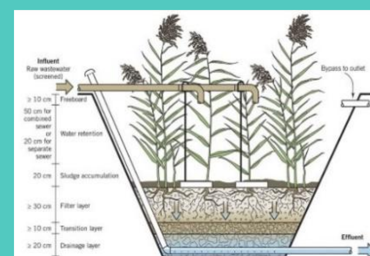
the overall shape of the prototype

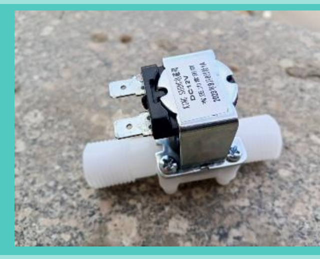
Constructing and testing prototype

Materials and methods

Table 1

materials used in the project

Items	Quantity	Cost	Usage	Source	Illustration
Reed bed system using papyrus	one seedling	150L.E (Free)	Papyrus plants help filter water by absorbing nutrients, oxygenating the root zone, supporting beneficial bacteria, and contributing to natural pH balance.	From nature around water banks	
tamarind seeds	0.6Kg	30L.E (Free)	Tamarind seeds act as a natural coagulant, helping to remove turbidity, heavy metals, and organic pollutants from water.	From The fruit shop	
Aluminum sheets	Four electrodes	10L.E each (Free)	destabilizes the dissolved, suspended, and emulsified contaminants from an aqueous medium by neutralizing the charge and aggregating to form floc	Recycled	

Arduino uno	One Arduino	350L.E	**Controlling the system and sensors**	Electronics shop	
Breadboard	One Breadboard	20L.E	Allowing components to be easily inserted and removed for prototyping.	Electronics shop	
Jumper wires	40 wires	1L.E each	Connecting electronic pieces	Electronics shop	
Servo valve	Two piece	250L.E	**To manage and control the movement of water**	Electronics shop	
Water pump	one pieces	250L.E	**To pump the water into the filter and manage its movement**	Electronics shop	
Batteries	One 12v battery	100L.E	Power supply for the prototype	Electronics shop	

pH sensor	One piece	1600L.E	To measure the pH in the water	Electronics shop	
Salinity sensor	One piece	750L.E	To measure the Salinity in the water	Electronics shop	
Turbidity sensor	One piece	600L.E	To measure the turbidity in the water	Electronics shop	
Containers	Three pieces	30L.E each	to contain the water and the filters x	Home appliance store	
pipes	1m	50L.E (Free)	To connect between the containers to transport the water	plumbing shop	
Schnur	One piece	10L.E	To ensure that there are no leaks in the pipes and in the prototype	plumbing shop	
Total coast			3990L.E		

Methods:

The construction of the prototype was divided mainly into two parts which are: 1- Preparing the filtration system. 2- Establishing the prototype.

Figure 22

The filtration system contains three stages which were prepared as follows:

<u>The first stage</u>: Tamarind seeds were heated in oven at 50˚C for about 8 hours, then they were grinded and mixed with 0.5M NaCl solution. After this, the powder was added into perforated sheets.

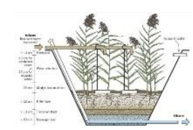
Figure 23

Aluminum Sheets

<u>The second stage</u>: Aluminum sheets were prepared by getting wasted aluminum and compressing it. Then it was put in a solution of water, lemon, vinegar and carbonate to remove the outer oxidized layer. After that, four sheets were placed in the container, and each one was connected to 12V electric source.

Figure 24

Reed bed System



<u>The third stage</u>: Papyrus plant reed bed system was prepared by placing gravel, then sand then soil in a container and placing the papyrus plant in this soil.

Figure 25

Prototype design

Building the prototype started by establishing its body, were the containers were connected by plastic pipes, based on the design in Figure (4). Then the openings made in the containers were isolated well to avoid any dripping from the prototype.

After that, each filter was placed in its proper place, where tamarind seeds' filter and Aluminum sheets were placed in the upper container, while the papyrus reed bed system was placed in the container on the right. The lower container contains the sensors.

The whole system was controlled by the Arduino, where the sensors were calibrated to read the water parameters, and based on the reading they get, the Arduino makes decisions about the next path the water will move in.

Test plan

The prototype was expected to:

- Be able to treat the water sample by regulating its turbidity, salinity and pH.
- Be durable to overcome high speed water charging and large water quantities.
- Have low power consumption.
- Be able to carry a quantity of **3** liters of water.

So, to make sure that the prototype will achieve the mentioned criteria, the test plan included the following steps:

1. **Water purification test:**

A quantity of 3 liters of water entered the purification system. The pH of the water was 11.2, the turbidity was 965 NTU, and the salinity was 800ppm. The prototype was expected to decrease these parameters in a limited period.

2. **Durability test:**

3 liters of water were pumped into the prototype, then it was let for 2 hours to make sure it'll hold high amounts of water for long time periods.

3. **Power consumption test:**

The power consumption of the prototype was measured with a multimeter for 1 hr.

4. **Capacity test:**

The amount of purified water that comes out of the system was determined to make sure that it is effective enough.

Data collection

Table 2

tools used

tool	Usage	Illustration
Glue gun	To ensure that there are no leaks in the pipes by isolate all the holes with it	
Cutter	Cut the pipes	
Soldering iron	To make holes to the pipes in the containers	
Graduated meter	To ensure accurate measurements	

Table 3

safety tools

Lab coat	It is essential for staying warm and protected from the toxic elements	
Gloves	It is important for keeping hands warm and protecting them from the elements. Investing in gloves that are windproof will provide extra protection and while dealing with electric staff.	
Goggles	Wearing goggles will help to protect the eyes from the elements. Investing in goggles that are scratch resistant will provide extra protection	

The first trial involved 3 water cycles, the second one involved 4, and the third one involved 6 cycles. The results of each trial are shown in the following table:

Table 4

Results

Trials	Before	After
1st trial (Negative)	Salinity: ± 800 ppm Turbidity: ±965 NTU pH: ± 11.2	Salinity: ± 721 ppm Turbidity: ± 654 NTU pH: ± 10 Capacity: ±2.7 Liters Power consumption: 41 watts
2nd trial (Negative)	Salinity: ±800 ppm Turbidity: ± 965 NTU pH: ± 11.2	Salinity: ± 654 ppm Turbidity: ± 259 NTU pH: ± 9 Capacity: ±2.5 Liters Power consumption: 41 watts
3rd trial (Positive)	Salinity: ± 800 ppm Turbidity: ± 965 NTU pH: ± 11.2	Salinity: ± 493 ppm Turbidity: ± 49 NTU pH: ± 8.5 Capacity: ±2.2 Liters Power consumption: 41 watts

Figure 26

Water parameters graph

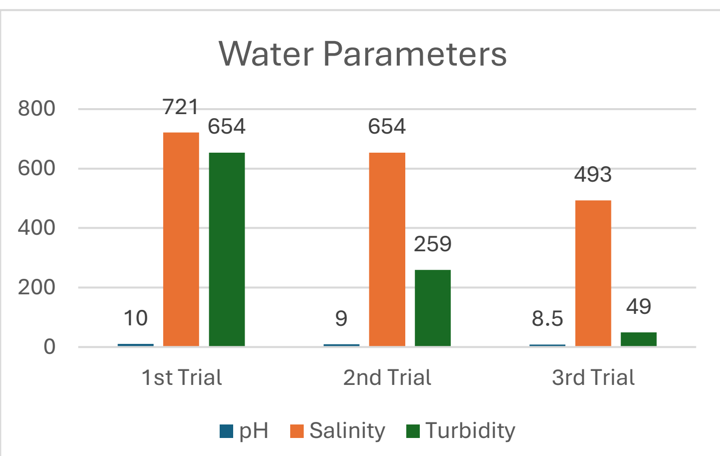


Figure 27

Capacity graph

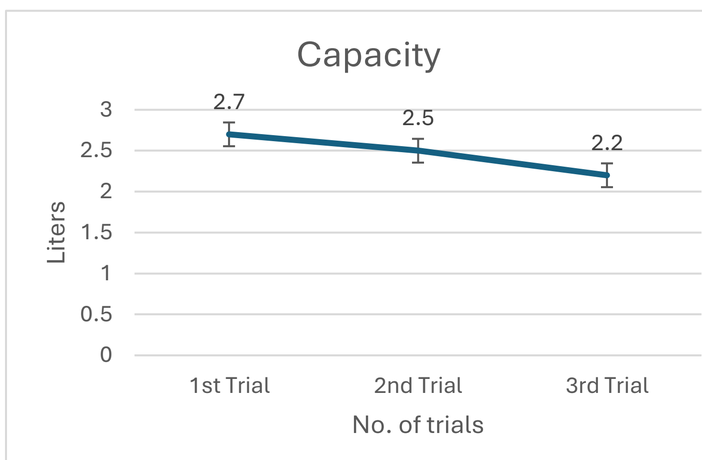


Table 5

Power Consumption

Device	Volt (V)	Current (A)	Time (h)	Energy (W.h)
Valve (x2)	24	0.5	0.0107	0.1284
Pump	15		0.05	0.75
EC	12	0.5	0.1	0.6
Sensors (x3)	15	0.5	0.23	1.725
Arduino	5	0.1	0.23	0.115
Relay (x3)	15	0.5	0.23	1.725
Total				5.0434

Then the total power consumption of the system equals 48.5 watts.

Table 6

Data collected from the cycles of the 3rd trial

No. of cycles	Salinity	Turbidity	pH
0	800	965	11.2
1	721	654	10
2	654	259	9
3	579	168	8.8
4	506	87	8.6
5	493	49	8.5

Table 7

Water output capacity

Time (min)	Total Filtred water capacity (L)
10	1.63
20	1.86
30	1.94
40	2.02
50	2.11
60	2.2

To conclude, the prototype appeared to have a high efficiency of tolerating the water parameters, outputting high clean water capacity and utilizing low power consumption.

Evaluating, Reflection, Recommendation

Analysis and Discussions

Nowadays, Egypt faces many challenges that impedes its progression and threaten its existence like the scarcity of clean water. Rural reefs are known for agriculture, so making a project that treats agricultural wastewater can be a satisfactory solution for the problem. For this project to be effective, it should be low in cost and be made from available materials. These two criteria are achieved in this project; where it uses cheap available materials like tamarind seeds and *Cyperus papyrus* plant to treat agricultural wastewater. This treatment will make water suitable for usage in industrial fields, especially in cooling towers.

The water treatment process involves four main stages which are: screening, coagulation, filtering and disinfection **(ES.2.04)**.

The 1st stage in this project involves a perforated board covered with tamarind seeds powder, which helps in decreasing turbidity of water through the proteins it contains, where they will make coagulation with the pollutants (SS et al., 2024). After the coagulation is done, the coagulants' mass increases, so they will move to the bottom of the container by the effect of gravity depending on the following law:

$$\boldsymbol{F_g = G\frac{Mm}{r^2}}$$ (Serway & Vuille, College Physics, 2012)

(PH.2.01)

The 2nd stage is electrocoagulation using Aluminum sheets that act as electrodes. The Following equations show what happens exactly:

Anode reaction: $Al \rightarrow Al^{3+} + 3e^-$

Cathode reaction: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

Overall reaction: $2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2$

(Nurfahasdi et al., 2024) **(CH.2.09)**

The 3rd stage is responsible for decreasing the pH of water by using *Cyperus papyrus* plant that's placed in a reed system. Some types of bacteria live in the roots of this plant, so when water passes on them, they feed on heavy materials found in water, decreasing the pH of it. The final box contains three types of sensors: pH sensor, Turbidity sensor and TDS sensor. Water will remain in this box until the sensors read the three parameters. Based on these readings, the Arduino will select a way out of two for water to pass through: Either water will get out of the system if it was completely purified, or it will be pushed by a water pump for another treatment cycle if it wasn't completely purified **(RAL.3.03)**.

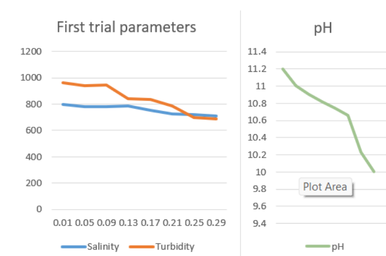
The power consumption of the two valves, the water pump and the Electrocoagulation process was calculated using this law:

$$\boldsymbol{P} = \frac{\boldsymbol{W}}{\boldsymbol{t}} \qquad \text{(Halliday et al., FUNDAMENTALS OF PHYSICS, 2011)}$$

where (P) is the power, (W) is the work done, and (t) is the time **(ME.2.05)**.

Figure 28

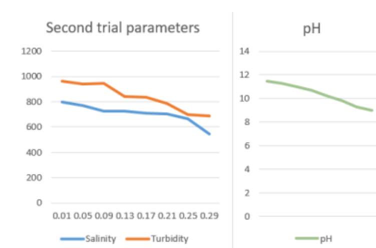
First trial parameters



The prototype was tested to make sure it meets the chosen design requirements. The 1st trial gave negative results for two reasons. The first one was the treatment of tamarind seeds powder with 0.8M of NaCl solution, which resulted in high turbidity (97NTU). The second reason was using iron electrodes which have low efficiency in electrocoagulation; because of its low oxidation potential (0.44v), which resulted in high salinity (603ppm). The parameters are shown in **Figure 24**.

Figure 29

Second trial parameters

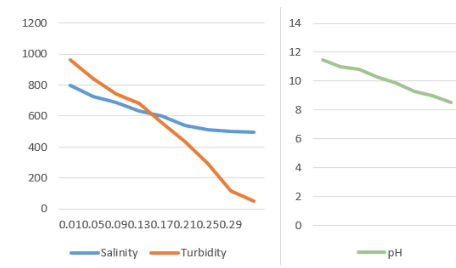


In the 2nd trial, the tamarind seeds powder was treated with a 0.5M NaCl solution instead of 0.8M; as the maximum efficiency of the coagulant proteins is reached when using 0.5M. Also, the iron electrodes were replaced by aluminum sheets whose oxidation potential is 1.66v, which increases the released ions from the oxidation process. The results obtained were better, where the turbidity decreased to 67 NTU, and the salinity decreased to 654 ppm. But unfortunately, the pH of the water remained high (7.6); because of using Foxtail Millet in the reed system, which doesn't contain enough bacteria in its roots. The parameters are shown in **Figure 25**.

In the 3rd trial, the *Foxtail millet* plant was replaced by *Cyperus papyrus*, whose roots are known to be a good habitat for bacteria, which is able to feed on organic matter dissolved in water. This led to a significant improvement in the water quality; where the turbidity decreased to 49 NTU, the salinity decreased to 493 ppm, and the pH decreased to 7.01. The parameters are shown in **Figure 26**.

Figure 30

Second trial parameters



Recommendation

When adopting this solution for large-scale treatment plant construction, especially if proper governmental aid is given, here are some points that are recommended to improve this project as follows:

- Grinding tamarind seeds finely and sieving them to improve surface area and reactivity. Furthermore, using another coagulant such as Moringa seed powder to increase the purification efficiency in high turbid water.

- To increase the efficiency of the electrocoagulation stage: Proper Mixing to keep water moving around the electrodes to prevent localized ion buildup. This can be done by using a powerful recirculation pump. Using perforated plates or mesh electrodes to increase surface area.

- To increase the efficiency of the Reed bed system using the papyrus plant: Using primary settling tanks, roughing filters, or natural coagulants to reduce solids and turbidity before entering the Reed bed.

- Using polycarbonate materials that have more durability and are not affected by increasing pressure or any factors that could damage the container.

Learning outcomes

Table 8

Learning outcomes connected with the capstone project

Number of LOS	Learning Outcome	Connection
1	CH.2.09	We benefit from the concept of the electrolytic cell in the electrocoagulation process, as Aluminum is the anode and graphite is the cathode (Zumdahl et al., 2018).
2	PH.2.01	We benefit from the concept of Newton's Law of Universal Gravitation because when the coagulation process occurs, the pollutants are collected, forming large masses, which are settled by the effect of gravity. Gravity is directly proportional to mass. $f_g = G\frac{m_1 m_2}{r^2}$ (Halliday et al., GRAVITATION, 2011)
3	ME.2.05	We benefit from the concept of power to calculate the total power consumption of the system (Serway & Vuille, Power, 2012).
4	ES.2.04	We benefit from the concept of water treatment and the stages of this process. (screening, flocculation, filtering, and disinfecting) (Benbow et al., POLLUTION IN SURFACE WATER AND GROUNDWATER, 2012).
5	RAL.3.03	We benefit from this Learning outcome that talks about types of Arduinos and how we connect the Arduino with other devices, so we take advantage of this learning outcome to choose the suitable type of Arduino to connect with sensors and measure the amounts of pollutants in water.

6	MA.2.06	We benefit from the concept of limits as we make results graphs, then conclude the function of the graph, and apply the limit concept. For example, in the case of PH, the limit function approaches 7 (Stewart et al., 2016).
7	BI.2.08	The concept of positive and negative feedback in the reproductive system is like the project. For instance, as turbidity increases, positive feedback will happen, and the number of cycles of water treatment increases (Urry et al., 2021).
8	PH.1.01	The concept of measurement errors was applied in cutting plastic sheets to make the container. Additionally, it was applied to detect the small changes in turbidity, TDS, and PH (Zumdahl et al., 2018).
9	PH.2.02	Studying the electric field (E), which is a region in which an electric charge experiences a force. Regarding its usage in our project, the application of an electric field during the Electric coagulation process (Chemical Treatment) created forces that caused charged particles (contaminants) to move, collide and then settle down at the bottom of the container (Halliday et al., coulomb's law, 2011).
10	ES.2.03	Utilize it in finding solutions for the challenge of increasing the amount of clean water. Using methods like drip irrigation and Xeriscaping can be considered good methods to reduce the amount of consumptive water, as there is no extra water to evaporate (Benbow et al., FRESHWATER USE, 2012).

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