2024~2025

Capstone portfolio

Group: 29219

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Introduction

Egypt has 11 grand challenges which leads to disable progress of development of the nation. It is essential to talk about these problems. In this semester, we are going to discuss some of these big problems as: recycling garbage and wastes, reducing pollution fouling the ecosystem, improving uses of arid areas, managing sources of clean water and increasing industrial and agricultural base of Egypt and some of other Egypt's grand challenge. Discussing these issues which are indispensable for Egypt to catch up with progress is indisputably important, as these challenges and issues create opportunities for conflicts and problems at the state and regional levels. Egypt faces significant challenges related to water pollution, which threaten both public health and national development. The Nile River, the country's primary water source, is heavily polluted due to untreated industrial waste, agricultural runoff containing fertilizers and pesticides, and domestic sewage. This contamination affects drinking water quality, harms aquatic life, and reduce agricultural productivity.

As a simulation for the solution that will provide these purposes, the prototype that we will construct will be a water treatment system. All the steps that we will follow in constructing it, how we will build it, the materials that we will use and all the procedures that we will follow while constructing it, we will record it in our portfolio. Our portfolio is a mirror of our project investigation. It gathers all the information we need, topics researched related to problems, problems we faced and solutions we performed. We followed the EDP steps to get scientific research to succeed so, through our faith in the soul of our teamwork and working together as one hand, we are happy to introduce our portfolio to you.

Group 29219.

1. Present and justify the problem and Solution Requirements:

1.1 Egypt Grand Challenges:

Address and reduce pollution

Work to eradicate public health issues

Deal with overgrowth population

Improve the use of alternative energies

Improve uses of arid areas

Increase the industrial bases for Egypt

Increase opportunities for egyptians to stay and work in Egypt

Reduce and adapt to the effect of climate change

Recyling garbage for economical and environmental purposes

Manage and increase the sources of clean water

Deal with urban congestion

Our Project this semester is to solve five grand challenges which are: -

1) Recycling Garbage for environmental and economical purposes: -

Our official statistics show that the maximum amount of house garbage is 15 million tons, the agricultural garbage is 30 million tons. Most people get rid of this garbage by burning it or throwing it into clean water. This comes back by a lot of impacts on public health. A new direction is to recycle this garbage and then use it in the manufacture of new products.

- To get rid of waste and toxins. This is usually done in the manner of 2 methods:

Fig (1)

1- **Burial of organic wastes** in the soil as shown in **fig (1)**, leaving the task for disposal of nature, believing that this is the perfect solution, but unfortunately analyzes of the waste in the soil show grave dangers, these wastes also affect sources of ground water. This water may not reach directly humans, but it affects plants and animals covered by humans and thus exposing them to many dangerous diseases like cancer and others.

2- **Burning the waste** as shown in **fig (2)**. This method is much worse than its predecessor, the smoke and sulfur dioxide resulting from the burning leads to formation acid rain which directly

fig (2)

affect the plants and animals and even the man himself, also increases the global warming rate and therefore strongly affect the climate. So, there must be another efficient method to get rid of waste products. We suggest that recycling is the way that makes the human get rid of the previous methods.

• The benefits of recycling:

The primary benefit of recycling is the conservation of natural resources and finding other sources to produce many materials used in everyday life are as follows: the use of paper more than once reduces the over-cutting of trees and thus preserves the natural balance of the planet. Recycling and reusing iron and steel and to reduce the effects of mining operations and iron depletion in nature. Plastic materials recycling maintains crude oil and reduces exhaust operations. These are just some very simple examples of materials that can be recycled and the availability of mostly non-renewable sources of natural resources, so it must be taken recycling operations in mind because of its natural benefits, health and economics. We can also save a lot and a lot of costs that can be directed at the development of infrastructure, rather than to be lost due to poor management.

• Types of recycling:

1. Glass recycling for the manufacture of new glass bottles or things.
2. Books and other papers recycling for the manufacture of newsprints and least expensive books.
3. Cloth and other tissues recycling for the manufacture of banners ads.
4. Rubber output of tires recycling for the manufacture of other rubber materials.
5. Recycling materials made of aluminum for the manufacture of aluminum

paper which is used for packaging.
6. Plastic materials used in the packaging industry for recycling for garbage bags or other.

Fig (3)

Recycling garbage and waste in Egypt plays a crucial role in both economic and environmental sustainability. By promoting recycling initiatives, the country can reduce the burden on landfills, conserve natural resources, and create job opportunities, particularly in the informal sector where many people collect, and sort recyclable materials as shown in fig (4). Economically, recycling can help reduce the costs associated with waste management and resource extraction, while also fostering green industries. Environmentally, recycling significantly reduces the pollution associated with waste disposal, such as greenhouse gas emissions from landfills. This, in turn, can have a positive impact on air quality, which is a major concern in urban areas of Egypt.

Fig (4)

2) Improving Sources of clean water: -

For decades the Nile supplied Egypt with more water than needed. As the population grew and the economy expanded, demand on water increased.

Nowadays, Egypt is highly vulnerable to water. According to the United Nations, the country could run out of water by 2025 (Gad, 2017). Furthermore, Egypt ranks 107 out of 181 countries in the 2019 ND-GAIN index that measures countries' vulnerability to water shortage caused by the climate change, the lower the index the more vulnerable the country is.

Challenges in water connections:

Fig (5)

In Egypt, water infrastructure coverage has grown substantially over the last decades. In 2014, around 91 percent of the Egyptian population received water directly into their residence. However, while access to water is almost fateful and reliable in urban areas, a significant number of houses are still not connected with the water system in rural areas and in urban slums. 7.3 million people are deprived of access to safe water, among which 5.8 million live in rural areas and 1.5 million in urban areas. In rural areas, around 12 percent of the population live in dwellings not connected to the water system while, in urban areas, it's 4 percent which do not have water connection. They are usually located in urban slums and poor houses.

In urban areas, only around 77% of households have piped water coming into their homes and in many cases the water connection is not legal.

3) Address and reduce pollution fouling our air, water, and soil:

Egypt has serious problems with pollution of the air, water, and soil:

- **Air pollution:** Burning agricultural waste, industrial activity, and car emissions are the main causes of high air pollution as shown in fig (6), particularly in cities like Cairo. This causes health issues, such as respiratory disorders.

Fig (6)

- **Water Pollution:** Runoff from agriculture, untreated sewage, and industrial waste all contribute significantly to the pollution of the Nile River. The quality of drinking water is impacted, as is agriculture because contaminated water is utilized for irrigation.

- **Soil Pollution:** Chemical fertilizers, pesticides, and industrial waste are the main causes of soil contamination. Food security and agriculture are impacted by the deterioration of soil quality.

These pollution types combined represent significant threats to Egypt's environment and public health.

4) Improve the use of arid areas:

Arid areas represent 95% of Egypt's whole area so if the government focused on this problem and provided these areas by social services, make it suitable for life then re- distribute the population through Egypt's whole area, farm and provision of food and materials and provide these arid areas with all life requirements to make these arid areas more attractable and encourage people to inhabit there, this will solve urban congestion, reduce pollution, increase the regions for the industrial base and increase the opportunities for Egyptians to stay and work in Egypt.

5) Increase the industrial and agricultural base of Egypt:

In recent years Egypt has faced serious challenges due to natural resource mismanagement and this is because the deterioration of agriculture and industry and lack of interest.

Industrialization is the process of building up a country's capacity to process raw materials and to manufacture goods for consumption or further production.

Fig (7)

Agriculture is the science or practice of farming, including cultivation of the soil for the growing of crops and the rearing of animals to provide food, wool, and other products.

Fig (8)

The reasons for the problem:

- The lack of application of scientific methods in solving problems in agricultural and industrial work, mechanization, the factory system and the division of labor.
- Shortage of energy that run agriculture and industrial machinery.
- The products are of a low quality.
- Lack of dollar and foreign currencies.
- Shortage of industry and agriculture equipment.

The results of the problem:

- Imports from other countries will increase by high rate.
- Spread and increase unemployment.
- Not be able to save the demands of the Egyptians.
- Decreasing the national income and deterioration of the Egyptian

economy. If this problem is solved, this will increase the national income, increase the exports and save jobs for young people.

If this problem isn't solved, this will increase imports and the industrial and agriculture deterioration.

1.2 Problem to be solved: -

"The increasing amount of wastewater being dumped into our surface waters is deeply troubling. Access to quality water is essential for human health and human development. Both are at risk if we fail to stop the pollution." *(Jacqueline McGlade, Chief Scientist of UN environment, 2016)*

The capstone challenge is solving the problem of water pollution by reusing wasted materials from sources of locally grown waste materials. The problem of water pollution is being addressed, as it is dangerous for people and nature. Harmful substances like chemicals, heavy metals, and bacteria. Also, plants are negatively affected, farming becomes more difficult, and the environment is damaged.

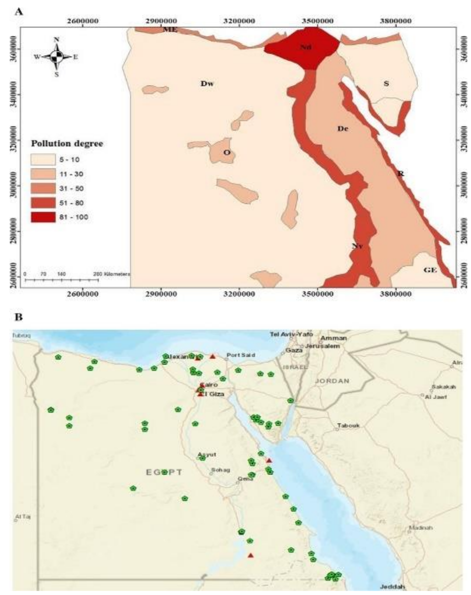

Fig (9)

Impacts of the Problem:

- **Health Impacts:** Diseases like cholera, typhoid, and lead toxicity are spread by polluted water.
- **Environmental Impacts:** Ecosystems are disrupted by pollution, marine life is harmed, and biodiversity is reduced.
- **Economic Impacts:** Billions of dollars are spent every year by governments on healthcare and water purification to reduce the effects of pollution.

Positive Impacts if the Problem is Solved Improved:

- **Public Health:** Disease rates would be low and public health would improve with clean water supply.

- **Environmental Protection**: Clean water sources maintain ecosystems and protect biodiversity.

- **Economic Benefits:** Medical care costs will be minimized and agricultural productivity maximized.

Negative Impacts if the Problem is Not Solved:

- **Increased Disease:** More people will be affected by waterborne illnesses.

- **Environmental Degradation:** Freshwater sources will continue to decline, making farming and industry more difficult.

- **Higher Economic Problems:** More money will need to be spent by governments on healthcare and water treatment.

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1.3 Research: -

Topics about the Problem:

- Overview about recycling garbage, improving sources of clean water, water, air and soil pollutions, improve the use of arid areas, increase industrial and agricultural base in Egypt.
- Water pollution problem in Egypt and its causes.
- Egypt efforts in recycling old materials.
- Sources of wastewater.
- Types of wastewater pollutants.

Topics about the Solution:

- Types of filtration mechanisms.
- Arduino sensors that are used in water pollution measurements.
- Membranes used in reverse osmosis.
- Electrocoagulation process.
- Types of sand used in water filtration.
- Role of silica gel in water filtration.
- Activated carbon usage and importance in water filtration.
- Identifying the optimal TDS and NTU levels for lemon trees for irrigation.

1.4 Prior Solutions: -

- **Water filtration systems and environment solutions have been developed widely across different countries, each tailored to address specific water quality challenges.**

- **Water filtration systems vary widely across different countries, often tailored to address specific water quality challenges.**

First: Methods used for water filtration: -

1-Activated sludge process:

The Activated Sludge Process is a widely used method for treating wastewater such as sewage from homes or industrial waste. This process uses microorganisms and aeration to break down organic pollutants which will result in cleaner water suitable for discharge or reuse by humans. In 1913, engineers Edward Ardern and W.T. Lockett, who were working at the Davyhulme Sewage works in Manchester, England, discovered that introducing air into sewage containing microorganisms significantly reduced its organic content. This observation led to the development of the activated sludge process which is a term derived from the activated nature of the biological sludge formed during treatment.

Fig (10)

These are the steps of treatment:

1. Aeration Tank:

Wastewater is introduced into an aeration tank containing a suspension of microorganisms known as activated sludge.
Aeration: Air or oxygen is continuously supplied to the tank through diffused aeration systems or mechanical surface aerators. This aeration provides the necessary oxygen for microorganisms to live and ensures mixing of the wastewater and the biological sludge.

2. Biological Degradation:

Microbial Activity: The microorganisms metabolize organic pollutants by converting them into carbon dioxide, water and new cellular material.
This process effectively reduces the biochemical oxygen demand (**BOD**) and the concentration of organic pollutants in wastewater.

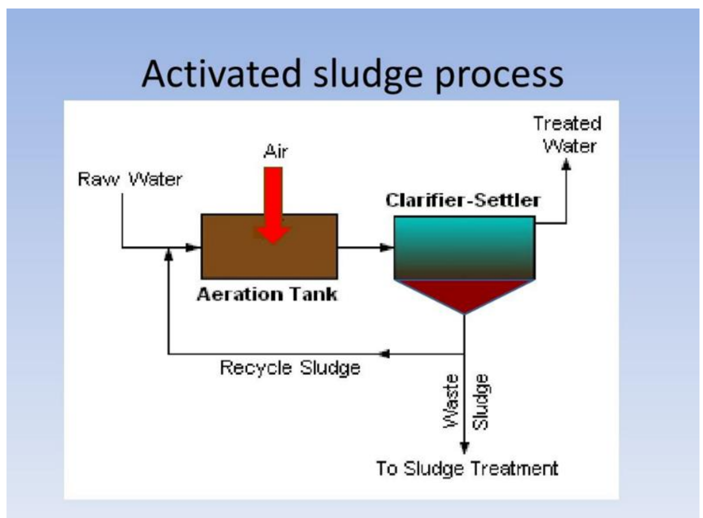


Fig (11)

3. Sludge Recycling and Waste:

Return Activated Sludge (RAS): A part of the settled sludge which are rich in active microorganisms are recycled back into the aeration tank to maintain an effective concentration of biomass.

Waste Activated Sludge (WAS): The remaining sludge is removed from the system for further treatment like digestion, dewatering and get rid of it at the end or beneficial use.

Advantages:

High-Quality sewage water: The process effectively reduces organic pollutants and produce sewage water suitable for discharge into natural water like oceans or seas or reusing it in applications like irrigation.

Space Efficiency: Activated sludge systems can be designed to occupy less space compared to some other treatment methods which make them suitable for urban and industrial environment where space is limited.

Operational Flexibility: Operators can adjust aeration rates and sludge recycling to treat different wastewater characteristics which will increase the system's adaptability to different conditions.

Disadvantages:

High Energy Consumption: Continuous aeration requires significant energy which will lead to higher operational costs.

Sludge Management: The process generates excess sludge that requires proper handling, treatment and disposal which will make this operation more complex and costly.

Sensitivity to Variations: Changing in wastewater composition, flow rates or temperature can disrupt microbial activity which will lead to affect the treatment efficiency.

2-Chlorination:

Chlorination has been a crucial method for water purification which significantly reduces waterborne diseases and improves public health overall.

Overview of the chlorination process:

Chlorine was first identified in 1744 in Sweden. It is used initially in 1835; chlorine was used to remove odors from water where it was linked in the past between smell and microbe transmission. By 1890, chlorine's efficiency as a disinfectant was admitted which led to using it in water treatment and filtration. Routine chlorination began in Jersey City, New Jersey, in 1908, marking a significant increase in public health.

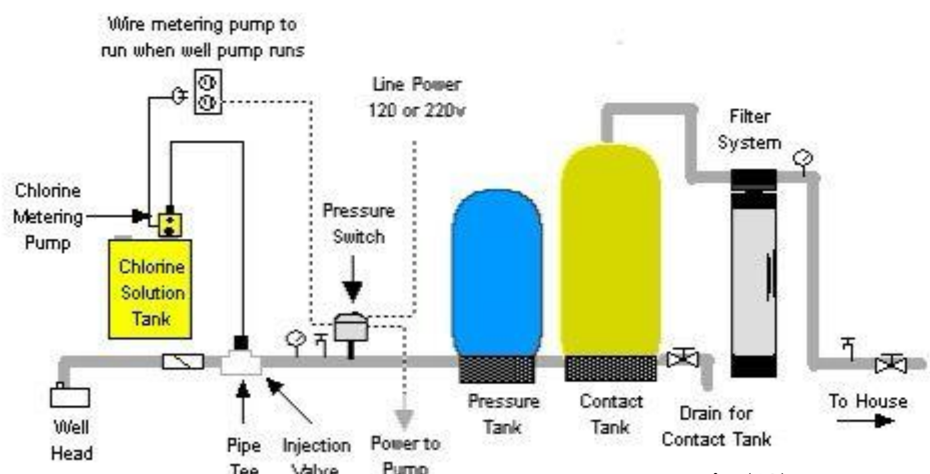


Fig (12)

Chlorination process is divided into three steps:

- **Chlorine addition:** chlorine is introduced into the water in one of the following forms:

1) **Chlorine gas (Cl_2):** a powerful disinfectant but it requires careful use due to its toxicity
2) **Sodium Hypochlorite (NaClO):** a liquid bleach commonly used in municipal treatment.
3) **Calcium Hypochlorite ($Ca(ClO)_2$):** A solid tablet or powder form,

often used in smaller systems or emergency disinfection.

- **Mixing and Contact Time:**

After chlorine is added, the water is stirred or allowed to mix naturally to ensure distribution all over solution. The chlorine needs time to react with the wastewater to kill bacteria, viruses, and other pathogens. The required contact time depends on factors like:

1) Chlorine concentration
2) Water temperature
3) pH level
4) Level of contaminants
5) Typically, the contact time ranges from 30 minutes to several hours to achieve full disinfection.

- **Disinfection and Residual Chlorine:**

Chlorine destroys pathogens by breaking down their cell walls and disrupting cellular processes. A small amount of chlorine remains in the water after disinfection called residual chlorine to protect against pollution. The ideal remaining of chlorine level in water is 0.2–2.0 mg/L (as per WHO and EPA guidelines).

Advantages:

Effective Disinfection: Chlorine effectively eliminates harmful microorganisms, including bacteria and viruses which prevent the spread of waterborne diseases and microbes.

Remaining Protection: Chlorine provides a continuous disinfection as it maintains some remaining of it in the water supply which ensures protection against pollutants and microbes during distribution.

Cost-Effectiveness: The process is relatively inexpensive which makes it easy to get for use in every community.

Easy to Implementation: Chlorination systems are straightforward to install and to operate which is advantage for areas lacking in advanced infrastructure like Africa.

Disadvantages:

Formation of Disinfection Byproducts (DBPs): Chlorine can react with organic matter in water to form DBPs such as trihalomethanes (THMs) which have been linked to health risks like increasing risks of certain cancers.

Taste and Odor Issues: Chlorinated water can have an unpleasant taste and smell which may make consumers hate it and do not buy it.

Environmental Concerns: The release of chlorine treated water into ecosystems can harm aquatic life and disrupt natural balances.

Second: Projects established for water filtration: -

1-The Carlsbad Desalination Plant:

The Carlsbad Desalination Plant in California is known as the largest seawater desalination plant in the U.S. Reverse osmosis technology is used to turn seawater into potable water. Around 50 million gallons of water are produced each day. During the process, seawater is pumped into the plant, where it is first pre-treated to remove sediments. Then, it is passed through RO membranes so that salinity and heavy metals like lead and mercury are removed.

Fig (13)

Strength points:

1. **Reliable Water Supply:** Provides up to 50 million gallons of fresh water per day (enough for 400,000 people).

2. **High Quality Water Output:** Effectively removes salinity, sediments, and heavy metals through multi-stage filtration and reverse osmosis.

Weaknesses:

1. **High Energy Consumption:** consumes about 3.6 kilowatt-hours per cubic meter of water produced.
2. **High Cost of Water:** Costs are passed on to ratepayers, making it less economically favorable.

2-The Ras Al-Khair Desalination Plant:

The Ras Al-Khair Desalination Plant is considered one of the largest desalination plants in the world, located in Saudi Arabia. Multi-effect distillation (MED) and reverse osmosis (RO) technologies are used to convert seawater into potable water. Over 1 million cubic meters of water are produced daily by the plant. Ras Al-Khair Power and Desalination Plant, located 75km NW of Jubail, is the world's largest hybrid water desalination plant, using both thermal multistage flash (8 MSF units) and reverse osmosis (17 RO units) technologies. With astonishing production of 1,036,000 m^3/day, the colossal Ras Al-Khair can serve approximately 3.5 million people in Riyadh. Offshore works included among others 3Km long GRP discharge pipes, an intake

Fig (14)

dredged channel with two 1.4 km-long rock breakwaters and a seawater intake pumphouse. Civil and building works with a total area of over 55,000 m^2 as well as the installation of underground services covering the entire plant area were also executed.

Strength points:

1) **Massive Production Capacity:** producing over 1 million cubic meters of water per day, enough to supply millions of people.

2) **Integrated Power and Water Production:** Generates around 2,400 MW of electricity, supporting both plant operations and supplying power to nearby areas

3) **Improves Water Security:** Reduces Saudi Arabia’s dependence on groundwater and increases access to reliable clean water in the eastern and central regions.

4) **Supports Industrial and Economic Growth:** Supplies water to Jubail Industrial City, one of the largest industrial zones, supporting economic expansion and industrial activities.

Weaknesses:

1) **High energy consumption:** The plant uses both Multi-Stage Flash and reverse Osmosis, both of which are energy-intensive processes.

2) **Environmental impacts:** Discharge of highly concentrated brine into the Arabian Gulf may harm marine ecosystems.

3) **High Capital Cost:** The plant had a very high construction cost (over $7 billion USD), making replication difficult in other regions without significant investment.

2. Generating and Defining a Solution:

2.1 Solution and Design Requirements:

Design Requirements: -

1. The collected wastewater sample must be in enough quantity to be treated.
2. The wastewater must be filtered to reach TDS values less than 700 ppm.
3. Pumps will be inserted into the system to circulate the wastewater in a closed-cycle system.
4. The wastewater will be treated using gravel and pebbles from nature, silica gel, activated carbon, aluminum sheets for coagulation, and TFC polyamide in reverse osmosis. They filtered water from three parameters which are salinity, heavy metals, and sediments.
5. The wastewater will be treated by using three different stages, geologic stages, electrocoagulation and reverse osmosis (RO membrane) that decrease the salinity to be less than 700 ppm.
6. The prototype will include gates by using solenoid valves with relays to give it orders to open or close according to readings of sensors.
7. The system will filter the water in 5 cycles and then collect the results in graphs to determine the equivalent life expectancy of the treatment system.
8. The water will be measured its quantity after each cycle and every 10 min in an hour.
9. Energy consumption per liter of clean water will be calculated by using a calibrated multimeter.

10. The sensors will be calibrated before (Turbidity and TDS sensors).

Solution Requirements: -

A successful solution must have some characteristics such as: -

- The cost of the project is low compared with others.
- The used materials are available in Egypt’s environment.
- The prototype is applicable.
- The solution is eco-friendly.
- It meets the design requirements in a creative way.
- It is safe for the environment.
- It is hard enough to carry the heavy load and the stored water.
- It must reach a high rate of effectiveness.

Constrains: -

- Leaking of the system from openings of the hoses was avoided.
- The minimum storage time of the maximum capacity of polluted water, during testing our prototype should be at least 5 min per cycle.
- The minimum number of stages in the prototype at least 3 stages with 3 different parameters.

2.2 Selection of Solution:

Since we started our capstone, we searched for an answer to this question: “How to overcome these challenges?”

After a long time of brainstorming, thinking, searching and discussions we chose our solution depending on scientific methods. The filtration system has three stages, and here we talk about each stage in some detail.

Our prototype target is to filter the polluted water that its source is the waste of aluminum factory to irrigate the lemon trees in our school, so our target is to make the salinity reach less than 700 ppm to be safe for lemon trees. At the end of the cycles in our system, we reached more than expected.

The filtration system has three stages, and here we are going to talk about each stage in order in some detail.

- ***Geologic stage:***

Its idea depends on filtration by using three different layers. The first is gravels and pebbles that remove any large waste in the polluted water, the second one is silica gel, it depends on absorption of some dissolved substances such as: organic components, metal ions and others. and the third stage is activated carbon, also it depends on absorption for heavy metals, chemicals, herbicides, pesticides and including odors and smells.

Advantage: it removes large fragments and coagulations of waste.

Disadvantage: it takes more time than the other stages.

- ***Electrocoagulation:***

Electrocoagulation (EC) is a water and wastewater treatment process that uses electrical current to remove contaminants. In this process, an electric current is passed through metal electrodes (commonly aluminum or iron, but aluminum was used) submerged in the water. This causes the metal to dissolve and form coagulant agents in situ, which destabilize and aggregate pollutants, allowing them to be removed by flotation, sedimentation, or filtration.

Contaminants Treated by Electrocoagulation:

• Heavy metals, like: lead, arsenic, chromium….etc.
• Suspended solids
• Oil and grease
• Dyes and pigments
• Phosphates
• Nitrates
• Bacteria and viruses
• Organic compounds

Advantage: Minimal chemical usage: Unlike traditional coagulation, EC often requires little or no added chemicals, reducing secondary pollution and sludge volume.

Disadvantage: Energy consumption: The process can be energy-intensive, especially for large-scale applications or waters with high conductivity or contamination loads.

- ***Reverse osmosis (RO membrane):***

The reverse osmosis stage depends on the pressure of the water through the pores in the middle tube in the center of the membrane, the pump pushes the water directly through the openings of the TFC polyamide membrane and then water goes down to the pores in the tube and passes by the effect of the pressure.

Advantages: It removes very tiny particles like salts that are dissolved in water.

Disadvantages: It leaves a few amounts of water at the bottom of the bottle but this will be solved because the water moves as cycles in the system so the water will be replaced by the end of each cycle.

2.3 Selection of Prototype:

Our prototype focuses on purification of polluted water using three stages, the first one is geologic stage that depends on pebbles and gravels with silica gel and activated carbon so this stage is responsible for filtrate the water from large fragments and coagulations of the wastes, the second one is electrocoagulation which has a mechanism that depends on the reaction between metal and hydroxide to form metal hydroxide that can react with heavy metals and oils and precipitate them, the third one is reverse osmosis that depends on the pressure of the water that passes through the TFC polyamide membrane and then moves through the pores of the tube.

We decided to use specially these three filters to ensure that the water is purified from all wastes that can harm lemon trees by decreasing the pollutants to be less than 700 ppm salts in water.

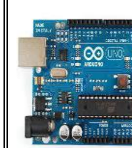
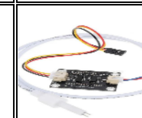
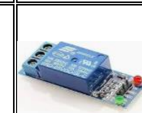
The design of the prototype was designed to be in the form of ladder to decrease energy consumption by depending on gravity in the first stage to pull the water down passing through solenoid valve and then move to the second stage by using pump and keep water about 2 minutes in this stage to react then to the third stage by another pump and the last pump to return the water up again.

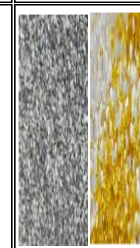
Also, the prototype is safe for humans and environment where it is constructed from waste materials such as plastic fridge boxes, hoses and …etc.

3. Constructing and testing a prototype:

3.1 Materials and Methods:

Our chosen materials: (Table 1)

#	Item	Quan-tity	Descrip-tion	Usage	Source	Cost	Ima-ge
1	Arduino UNO	1	Microco-ntroller board	It is used to control the sensors and display the readings coming out of it.	Electrical tool store	450 L.E	
2	TDS Sensor	1	Analog sensor	Used to measure the total dissolved solid in water	Electrical tool store	750 L.E	
3	Turbidity Sensor	1	Analog sensor	Used to measure the turbidity of the water	Electrical tool store	750 L.E	
4	Water pump	3	pump	Used to pump the water.	Electrical tool store	195 L.E/one	
5	Solenoid valve	1	Solenoid gate	Used to control the flow of the water by closing or opening	Electrical tool store	220 L.E	
6	Relays	3	Analog regulator	Used to turn pumps and valve on or off	Electrical tool store	50 L.E/one	
7	TFC-Polyamide	0.5 Meter^2	membrane layer	Used to make reverse osmosis membrane	Pharmacy	50 L.E	

8	**Gravel, pebbles**	**100 gm**	**Natural components**	**Remove suspended particles and impurities by trapping dirt, debris, and sediments**	**From nature**	**-**	
9	**Activated carbon**	**10 gm**	**Natural components**	**Absorb harmful organic chemicals**	**We made it from coconut shells**	**-**	
10	**Aluminum sheets**	**2 per 5 cycles**	**Artificial components**	**For the Electrocoagulation process**	**From our school's kitchen**	**-**	

So, the total cost of the project is 2955 L.E

Our Safety Precautions:

1. Using gloves while working.
2. Wearing coats to protect clothes during our work inside the FabLab.
3. Stay at a distance while testing.
4. Work under the supervision of a teacher.

Manufacturing process:

After the materials for the prototype were obtained. The waste and recycled materials were used in the construction to preserve the environment, and of course, with the fulfillment and observation of the rubric that met design requirements:

1. A 3D model of the prototype was designed using Blender to visualize the final shape before construction.

2. The frame for the prototype was then constructed to support the system.

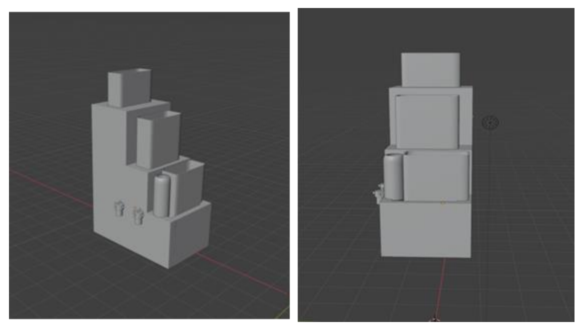


Fig (15)

3. Containers of 3 liters were used to ensure that the components of each stage would be supported, while a 2-liter container was used in the first stage to match the volume of polluted water.

4. Activated carbon was made in Misr University for Science and Technology from coconut shells by cleaning the shells, carbonizing them at high temperatures in an oxygen limited environment, and then activating the resulting char using calcium chloride to increase porosity.

5. The first stage was constructed by using small gravels, pebbles, silica gel, and activated carbon, which were separated by layers of gauze.

6. The second stage was constructed using the **electrocoagulation** method, with aluminum sheets used as the anode and cathode, and electricity was Supplied by 2 DC batteries. According to

7. In the third stage, the method used in modern filters which is reverse osmosis (**RO membranes**) was applied using:
Long layer of TFC polyamide and a layer of plastic mesh rolled together. A tube with pores and gauze around it was placed in the middle to allow only water molecules to pass through the membrane.

8. Three water pumps were installed: the first to absorb water from the valve in the container, the second to pump it directly into the **RO membrane** which required high pressure, and the third to complete the circulation of water from the lower stage to the higher one.

9. For the readings, a TDS sensor was used to measure salinity and heavy metals, and a turbidity sensor was used to measure turbidity.

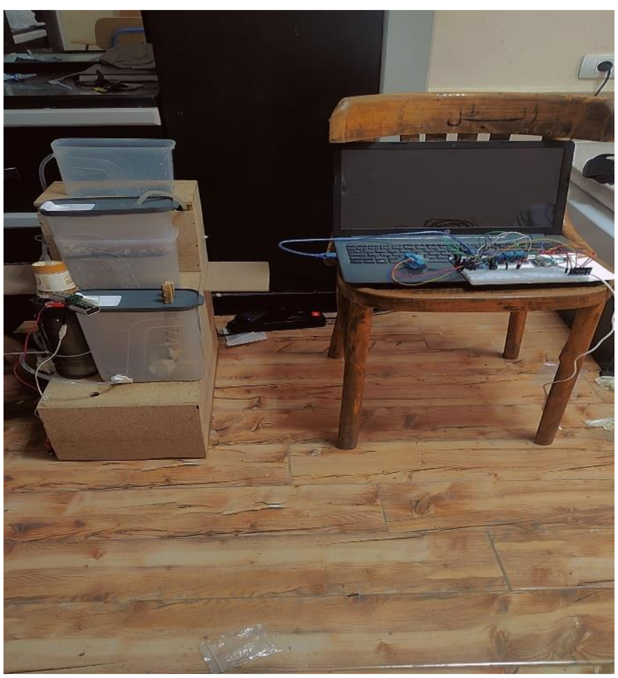


Fig (16)

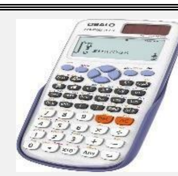
Fig (17)

3.2 Test Plan:

1. Each cycle is required to be tested separately to measure efficiency of each one.
2. Water is moved through the system to ensure no leakage occurs at any point.
3. Sensors are calibrated to ensure that the readings are close to the actual values.
4. The **Arduino** circuit is tested to ensure that it operates automatically.

3.3 Data collection:

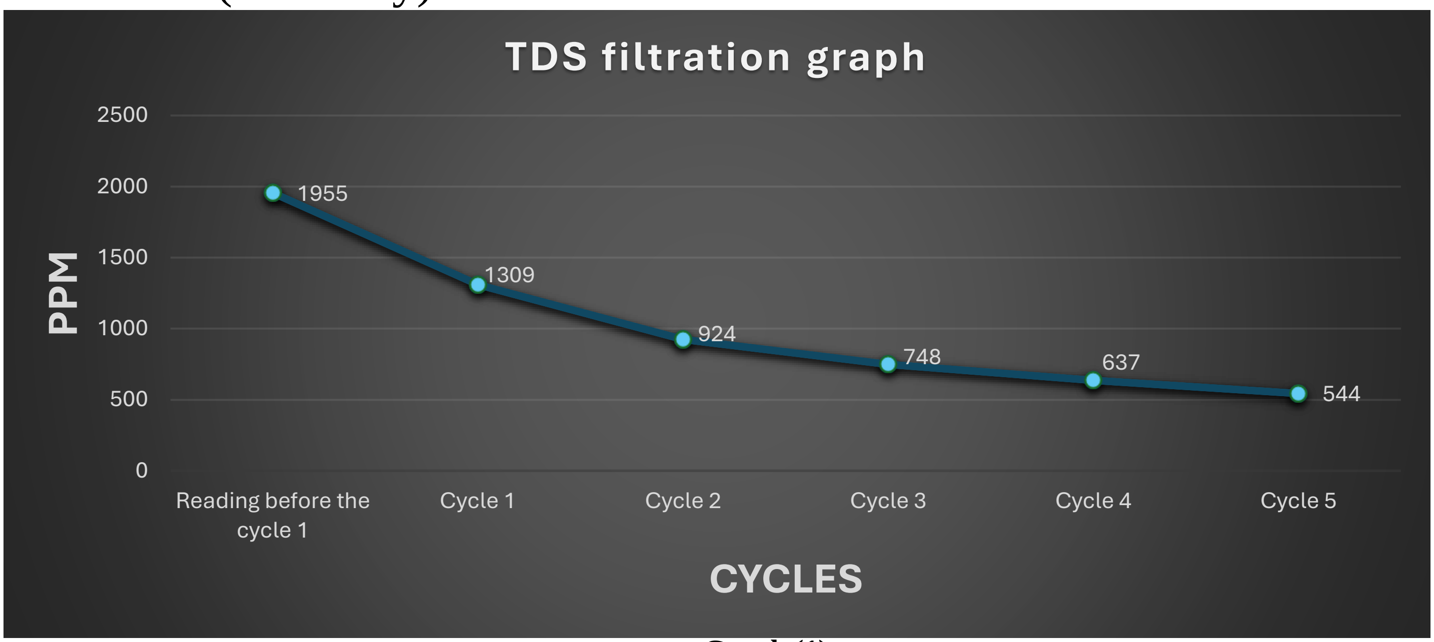
Our Tools: (Table 2)

Tool	Function	Our usage	Images
Multim -eter	Calculating the electric current intensity and potential difference and resistance	We used it to measure the electric current intensity and the electric potential difference to get the consumed energy per each cycle.	
Meter tape	Measuring tall lengths in centimeters	We measured the dimensions of the wooden frame.	
Stop watch	Measuring time in milliseconds	We measured the time of each cycle.	
Digital balance scale	Measuring big masses	We measured the different masses of the components that we used in making the stages.	
Calculator	Calculating mathematic equations	We used it in the mathematical calculations.	

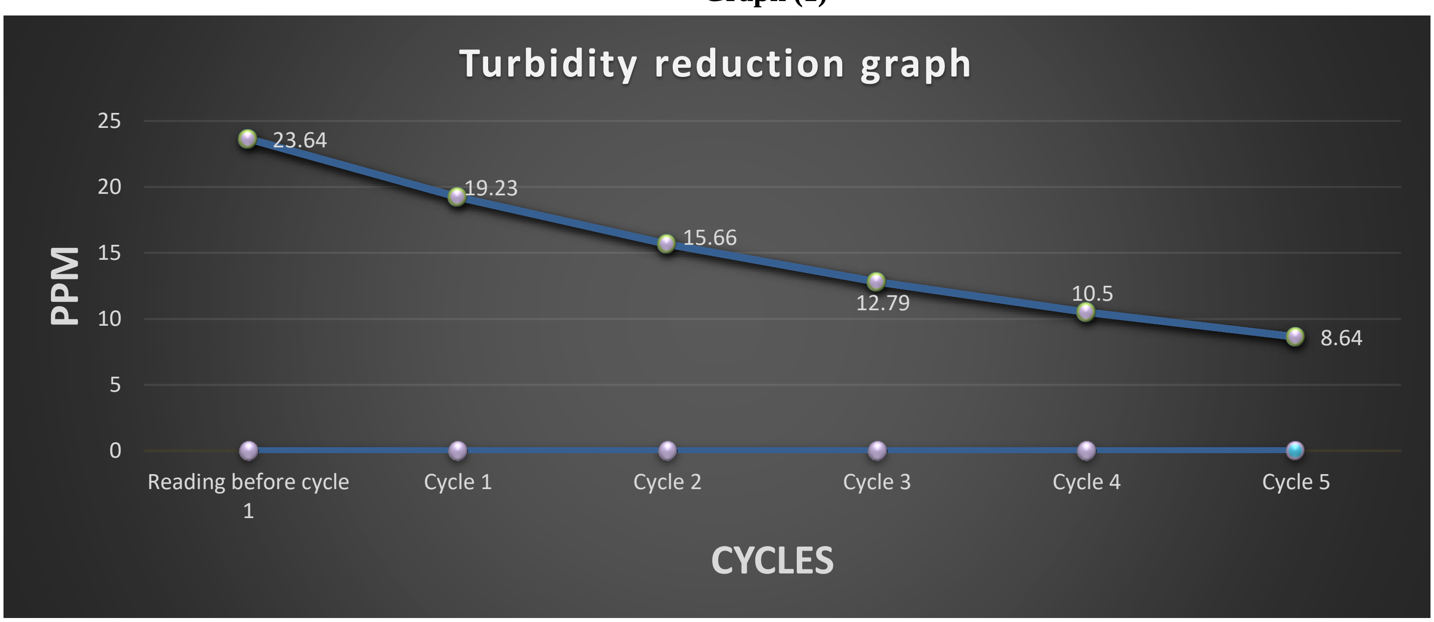
❖ **And other tools which are found inside our school's FabLab, such as: Laser cutter and carpentry tools.**

Our prototype achieved the design requirements successfully and this is explained in the following data:

The readings of the sensors for the wastewater sample was noticed to be 1956 ppm (TDS) and 23.65 NTU (Turbidity). With each cycle, the sensor readings decrease until they reach readings 544 ppm (TDS) and 8.63 NTU (Turbidity).



Graph (1)



Graph (2)

4. Evaluation, Reflection and discussion.

4.1 Analysis and Discussion:

Egypt grapples with significant water pollution challenges, primarily due to industrial wastewater discharges. According to a study published on **(Academia.edu)**, approximately **80%** of the country's industrial effluent is discharged untreated into the Nile River, canals, wells, municipal sewage systems, and ultimately the Mediterranean Sea. This volume of untreated industrial waste contributes to the degradation of water quality and poses serious environmental and public health risks. The industrial sector in Egypt comprises around **329** major industries, many of them are concentrated in urban areas such as Cairo. These industries discharge an estimated **2.5** million cubic meters per day of untreated effluent into water bodies. Notably, **50%** to **64%** of industrial activity is in Cairo, exacerbating the pollution levels in the Nile and surrounding waterways. In response to these challenges, Egypt established a national monitoring network in 2021 under the Egyptian Environmental Affairs Agency **(EEAA)**. The previous statistics underscore the urgent need for comprehensive water management strategies, stricter pollution controls, and enhanced public awareness to address Egypt's water pollution and scarcity issues.

After identifying the problem and defining its solution, let’s talk about characteristics of our prototype:

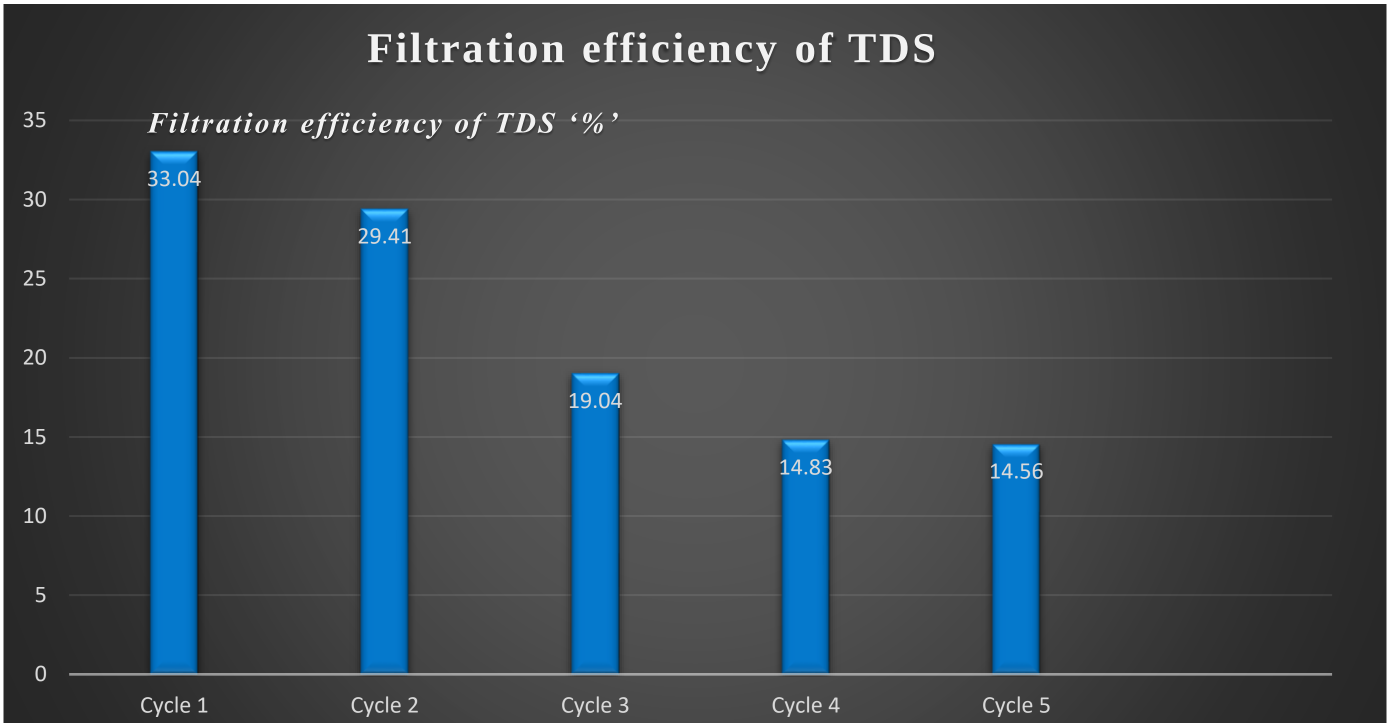
1) Eco-Friendly Design:

The prototype is designed using recycled materials, making it highly eco-friendly. Plastic containers and hoses, along with old wooden boards, are used to build the structure and hold the filtration units. This not only reduces waste but also lowers production costs and promotes sustainability. All these things contribute to making the prototype of low cost.

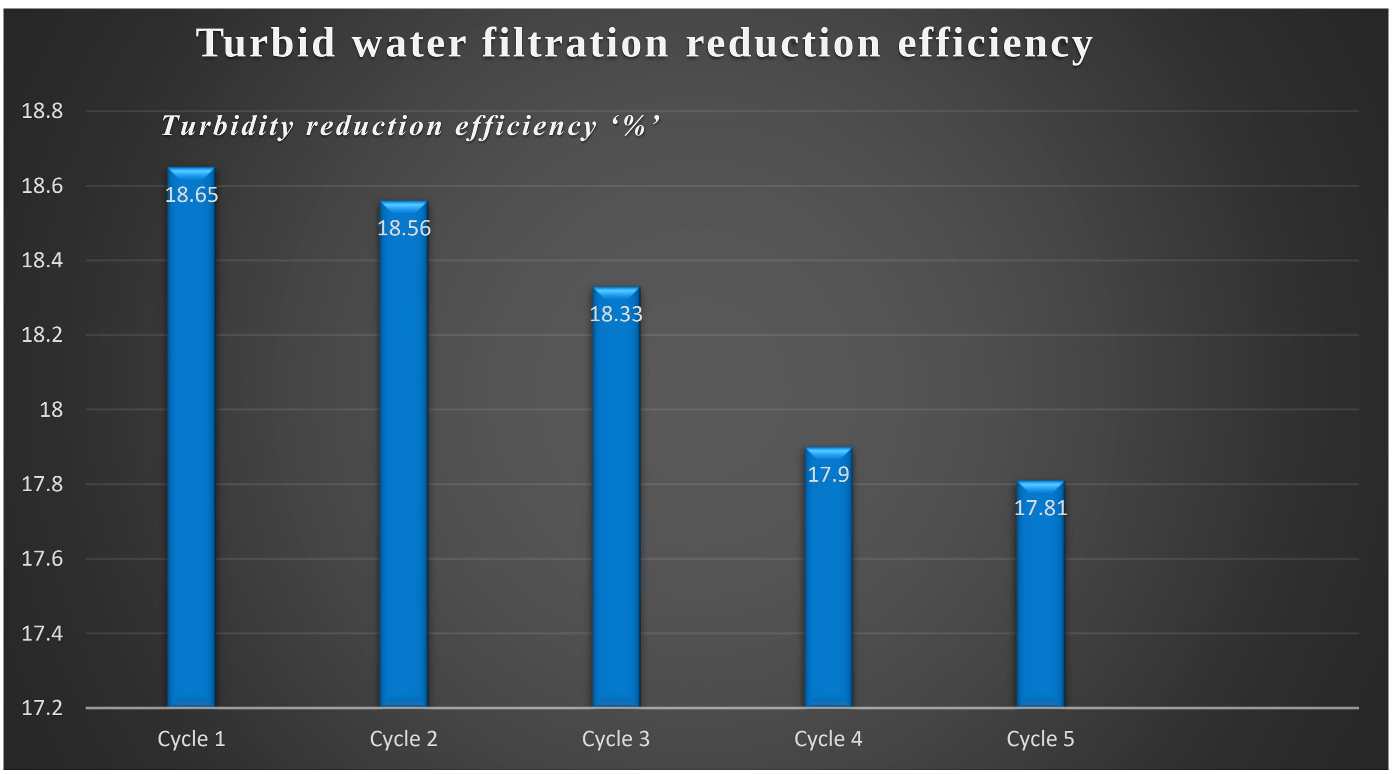
2) High filtration efficiency:

The system demonstrates strong efficiency in treating Aluminum factory industrial discharge. It significantly reduces contaminants such as salinity, heavy metals (like aluminum and lead), organic biomaterials, large, suspended particles, and general impurities. This performance is achieved through a three-stage filtration process.

- **TDS filtration efficiency: It starts with 33.04% in the 1st cycle and ends with 14.56% in the 5th (last cycle), with an average filtration efficiency of 22.18%.**
- **Turbidity reduction efficiency: It starts with 18.65% in the 1st cycle and ends with 17.81% in the 5th (last cycle), with an average filtration efficiency of 18.25%.**



Graph (3)



Graph (4)

3) The Three stages:

- **Stage One:** A physical filtration layer made of pebbles, gravel, silica gel, and activated carbon removes large particles and sediments and volatile organic compounds (VOCs).

- **Stage Two:** The electrocoagulation stage uses electric current to destabilize and remove dissolved contaminants and heavy metals.

- **Stage Three:** A reverse osmosis membrane filters out fine particles, salts, and any remaining impurities at the molecular level.

4) Energy consumed, capacity and time of each cycle:

Table (3)

Cycle no.	1	2	3	4	5
Duration	8 min	7 min & 54 sec	7 min & 48 sec	7 min & 42 sec	7 min & 36 sec

Table (4)

Cycle no.	1	2	3	4	5
Energy Consumed	1840.7 J	1805.8 J	1770.4 J	1735.3 J	1700.1 J

- The wastewater that is filtered was 1100ml and it reaches after the 5^{th} cycle about 1 liter (1000ml). This reduction in volume is because of many things, from them:

- Filters retain an amount of water in them.
- Deposits and flocs caused by electrocoagulation cause a reduction in volume.
- A small amount of water is trapped in filter housings.

- Energy consumed per each cycle decreases gradually from the 1st to the 5th cycle due to decreasing the resistance of water flowing as the filtration process progresses during each cycle and as the time of system processing decreases due to a little decrease in the amount of water from one cycle to another.

- According to table (2), about 8852 joules of energy were consumed in time of 2340 seconds (39 minutes) {Total time of system operation}. This is a very low energy consumption.

- **The primary goal of this project is to convert factory wastewater into water suitable for irrigating lemon trees. The appropriate total dissolved solids (TDS) content in lemon tree irrigation water ranges from 500 to 1,000 ppm. After five cycles, the TDS level in the contaminated water decreased from 1,955 ppm to 544 ppm, demonstrating the project's effectiveness in achieving its goal.**

- ## <u>The following laws were used in constructing and testing:</u>

1) P=IV (Power (in Watts) = Voltage (in Volts) x Current (in Amps))
According to (Serway & Jewett, 2014)

2) P=W/T (Power (in Watts) = Energy consumed (in joules) / Time (in seconds).

3) Filtration efficiency (%)= $\frac{\text{Initial value}-\text{Final value}}{\text{Initial value}} * 100$

4.2 Recommendations:

The performance and efficiency of the water purification system can be enhanced through several improvements. Key stages can be upgraded, and new technologies can be introduced to achieve better results. These changes will help to increase the system's sustainability and make it more cost effective. Additionally, further research and testing can be conducted to optimize each stage of the process for a wider range of water conditions. There are some proposals to help develop it in real life, such as:

1) Add a cleaning system for the filters and RO membrane by pressure so it lasts longer without manual work.

2) Use ultraviolet light to kill bacteria, viruses and protozoa like E-coli and cholera.

3) AI-based Prediction: Later, add basic machine learning to predict filter life or detect unusual water contamination.

4) Use an original Arduino sensor for accurate readings and accurate results.

5) Use $Fe_{70}Cr_{17}Ni_{12}Mo_2$ where it can handle more electricity and filter more wastewater in shorter period of time than the aluminum sheets.

6) Increase the length of the RO membrane so the efficiency will increase, and more water is going to be filtered.

7.Improve the design of the system to be mainly dependent on gravity with few energy consumption.

8.Increase the time taken in the second stage (Electro coagulation) to increase the efficiency of reaction in this stage.

9.Use solenoid valve with three gates to make three ways for water, one for entering the water, one for returning to the system and the last one after being fully filtered.

4.3 Learning Transfer:

(Table 5)

CHEM 2.08, 2.09	Faraday's Law of Electrolysis supports the electrocoagulation process by quantifying the relation between electric current and metal removal is studied to help in constructing the second filter stage
PH 2.15	The focus is on how diodes function in AC/DC circuits, especially in one-way current flow and rectification are learnt. The prototype applies this concept when using relays and protection diodes to safely switch high-power devices such as pumps without damaging the Arduino. These diodes ensure that current flows only in the desired direction.
MECH 2.05	This learning outcome is centered on understanding how power relates to energy transfer, specifically through equations like **P = W/t** and **P = FV**. It emphasizes using these relationships to analyze systems and quantify energy flow. In the prototype, this understanding was applied by using power values and the operation time to calculate the total energy consumed by the pumps and valves, following the principal **E = P × t.**
ES 2.09	The properties of Earth materials such as minerals, rocks, soil, and water and how these properties influence their function in natural systems are learnt. In the prototype, this was applied during the first stage of filtration where materials like pebbles, silicate sand, activated carbon and cotton were selected for their ability to trap and remove contaminants. Their permeability and adsorption properties were directly linked to the concepts covered in this outcome.
PH 2.16	This learning outcome is about understanding how bipolar transistors are used as digital switches in electronic circuits. In the prototype, this concept was used by using an Arduino and relay modules where electrical signals were used to control pumps and valves. Like how transistors switch a circuit on or off, relays were used to do the same task automatically and the switching logic was programmed based on sensor inputs,
CS 2.05	Making mobile applications through using JavaScript is studied in this learning transfer which will be used in making mobile application that receives the readings of the sensors.

ME 2.06	We learned about the center of gravity of rigid bodies how to calculate and localize the center of gravity of composite lamina and this help us while designing the prototype to make its center of gravity near the earth to make the porotype more balanced.
MA 2.06	We learned about the properties of limits and how to use and graph it and this helped as we used it in the graphical fitting methods to estimate system lifetime.
PH 2.16	This learning outcome explains the logic gates where it works as switch where it opens or closes based on input. We used this concept through using a relay where it functions based on the readings of the sensors.
MA 2.09	We learned about the concept of antiderivative, which is also called integration and this helped us to choose our idea as we chose the technique that is against the contaminates to purify the contaminants in the water.
ME 2.05	We learned about energy and power and their properties and cases and how to calculate them and this learning helped us as we applied the law of energy and calculated our system energy consumption per cycle.

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