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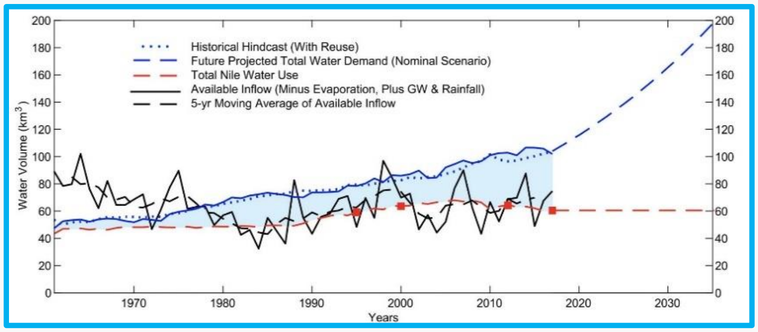
Introduction

In rural Egypt, farmers switched to chemical fertilizers to boost crop yields solving hunger at first. But when rains washed the excess into the Nile, algae blooms choked the water, killing fish and leaving villages with polluted drinking water. A short-term fix became a long-term crisis.

In Egypt, water pollution is a serious challenge, particularly in regions like the Nile Delta, where industrial waste and agricultural runoff have greatly impacted water quality. Because contaminated water sources damage aquatic ecosystems and cause diseases transmitted by water, these challenges are scarcity in freshwater amount, helping residents to live. By increasing the percentage of the population, water available to use as a potable drinking source decreases.



Graph (1)

Graph (1) shows Egypt's growing water crisis. While water demand (blue line) is projected to nearly double by 2040, it is because the population is increasing, water availability (black line) remains flat and highly variable. Nile water use (red line) stays constant around 60 km³/year. The widening gap between demand and supply highlights the risk of severe water scarcity unless major changes are made in water management, reuse, or sourcing.

Various solutions have been tried to solve the problem of water pollution. However, the problem still exists, which is why this project focuses on exploring more innovative ways to deal with water pollution and reduce its harmful effects in Egypt. Deep analysis of prior solutions, applying their advantages, and addressing their drawbacks will enable this to happen. The "Carlsbad desalination plant" and the "SFBW" were the two of them. Reverse osmosis is being used at the Carlsbad plant to transform untreated water into clean water for domestic use, but it will cost a lot to build—roughly 1 billion$—to do so. On the other hand, the second one, "SFBW," removes micropollutants from water during backwashing operations, but one of its disadvantages is that this plant requires a very large area. We created an outline for our idea using these and other prior solutions.

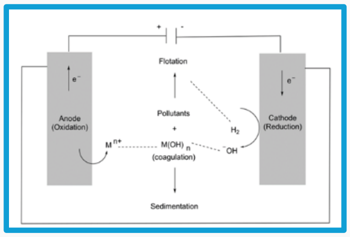


Fig (1)

Having some design specifications that can be used as a guide is essential to continue producing a project with successful results. One of these needs to get clean water that will be used in agriculture, The wastewater should have a salinity more than threshold value ~ 500 ppm (at least 1000 ppm), 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. These requirements must be achieved after getting the output water from ending up with the chosen solution, which starts by entering the input water into a beaker containing activated carbon and limestone stirring for about 10 minutes to react completely And continue into a second beaker with cellulose, then electrocoagulation filter , Graphite and aluminum electrodes to make an electrocoagulation cell as shown in figure (1). to have the output water. After measuring the results, we got them as wanted. Making this prototype requires many materials that will be discussed in the next section.

I. Present and Justify a Problem and Solution Requirements

Egypt's Grand Challenges

A. Address and reduce pollution fouling our air, water, and soil:

One of the greatest problems and challenges of our time is Pollution. Pollution is the introduction by humans into the environment of substances or energy that may cause risks to human health, harm to living resources and ecosystems, damage to structures or facilities, or interfere with legitimate uses of the environment. pollution poses a major threat to health and climate, where Ambient pollution is causing fine particulate matter which result in strokes, heart diseases, lung cancer and other acute diseases . Additionally, air pollution is associated with 7 million deaths annually.

(Fig (2) show air pollution caused by industry)

Pollution is caused by several factors:

• **Rapid Industrialization**: The concentration of industries in urban areas releases pollutants into the air, water, and soil, causing environmental pollution.

• **Rapid Urbanization:** The increased pace of urbanization in recent times has led to worsening environmental pollution.

• **Forest Fires:** Human activities, like land clearing and encroachment, have led to a rise in the frequency of air pollution.

• **Incorrect farming techniques:** Using chemical fertilizers and heavy irrigation in agriculture contributes to soil and water pollution and environmental pollution.

• **Deforestation:** This disrupts the local ecosystem balance and decreases nature's ability to filter pollutants, resulting in environmental contamination.

• **Other causes:** Other causes of environmental pollution include continued reliance on fossil fuels, vehicular emissions, and improper waste management.

These were the most important factors of Pollution and its impact on our environment and health in general, However, pollution can be categorized into various types like:

• **Air Pollution:** It is linked to respiratory and cardiovascular illnesses and plays a role in environmental problems such as acid rain and global warming.

• **Water Pollution**: Water sources like rivers, lakes, and oceans can become polluted by pollutants such as industrial waste, sewage, and agricultural. These toxins lower the quality of water, causing harm to marine life, disturbing ecosystems, and presenting serious health dangers to humans

B.Increase the industrial and agricultural bases of Egypt:

One of the most pressing challenges for Egypt is to strengthen its industrial and agricultural sectors to ensure sustainable economic growth, food security, and job creation. Egypt's economy, with a gross domestic product (GDP) of approximately 686.6 billion Egyptian pounds, relies heavily on its industrial and agricultural bases. The agricultural sector alone contributes 15% to the national economy, adding around 103 billion Egyptian pounds to the national income. Meanwhile, the industrial sector, particularly energy, plays a pivotal role in driving economic growth and foreign exchange earnings.

(Fig (3) show greenhouse to increase agricultural bases)

Causes:

1. **Rapid Population Growth**: Egypt's population is growing rapidly, increasing the demand for food, jobs, and infrastructure. This puts immense pressure on the agricultural sector to produce more food and on industries to create employment opportunities.
2. **Inefficient Agricultural Practices:** Traditional farming methods, inefficient water use, and reliance on chemical fertilizers have limited agricultural productivity. Modernizing agriculture through technology and sustainable practices is essential to increase yields and ensure food security.
3. **Outdated Industrial Infrastructure:** Many industries in Egypt rely on outdated technologies and insufficient infrastructure, making them less competitive globally. Upgrading industrial processes and adopting advanced technologies are necessary to boost productivity and economic growth.
4. **Global Economic Competition:** To remain competitive in the global market, Egypt must modernize its industrial and agricultural sectors. This includes adopting innovative technologies, improving supply chains, and increasing export capabilities.
5. **Environmental Challenges:** Climate change, water scarcity, and soil degradation threaten Egypt's agricultural and industrial output. Sustainable practices, such as efficient water management and renewable energy, are crucial to mitigate these challenges.

Effects:

1. **Rapid Population Growth:** Egypt's population is growing rapidly, increasing the demand for food, jobs, and infrastructure. This puts immense pressure on the agricultural sector to produce more food and on industries to create employment opportunities.

2. **Inefficient Agricultural Practices:** Traditional farming methods, inefficient water use, and reliance on chemical fertilizers have limited agricultural productivity. Modernizing

agriculture through technology and sustainable practices is essential to increase yields and ensure food security.

3. **Outdated Industrial Infrastructure:** Many industries in Egypt rely on outdated technologies and insufficient infrastructure, making them less competitive globally. Upgrading industrial processes and adopting advanced technologies are necessary to boost productivity and economic growth.

4. **Global Economic Competition:** To remain competitive in the global market, Egypt must modernize its industrial and agricultural sectors. This includes adopting innovative technologies, improving supply chains, and increasing export capabilities.

Effects of Expanding Industrial and Agricultural Bases:

1. **Economic Growth:** Strengthening these sectors boosts Egypt's GDP, increases foreign exchange earnings, and attracts investments. For example, the energy sector, including oil, natural gas, and renewables, is a major contributor to the economy.
2. **Job Creation:** Expanding industries and modernizing agriculture create employment opportunities, reducing unemployment and improving living standards. This is particularly important in rural areas, where agriculture is the primary source of income.
3. **Food Security:** Modernizing agriculture ensures a stable food supply for Egypt's growing population. Innovations in irrigation, crop management, and digital technology help farmers increase productivity and reduce reliance on food imports.

expanding Egypt's industrial and agricultural bases is essential for achieving sustainable economic growth, ensuring food security, and creating employment opportunities. The causes driving this expansion—such as population growth, inefficient practices, and global competition—highlight the urgent need for modernization. The effects, including economic growth, job creation, and environmental sustainability, demonstrate the far-reaching benefits of this expansion. Through initiatives like the Sustainable Agricultural Development Strategy 2030 (SADS 2030) and the adoption of advanced technologies, Egypt is well-positioned to strengthen its economy and secure a prosperous future for its people. This expansion not only benefits Egypt but also reinforces its role as a regional leader in agriculture and industry.

C. **Recycle garbage and waste for economic and environmental purposes:**

Waste management has grown as a significant social concern due to the increasing scarcity of resources and rising waste generation. Efficient waste management and recycling systems, particularly for materials like glass, aluminum, and plastic, have had positive impacts in developed countries by reducing environmental harm and offering low-cost recycled materials.

Fig (3)

However, several challenges limit recycling efforts:

- Mixed waste collection complicates sorting.
- Recycling processes are energy-intensive and expensive.
- Monitoring the quality of materials for multiple recycling loops is crucial, especially for metals and glass.

Government policies largely focus on reducing "**open consumption**" and promoting efficient recycling to lower environmental and financial costs.

Benefits of Recycling and Waste Reduction:

Reducing waste at its source and improving waste management systems are key strategies. Waste reduction is preferred over the creation of additional disposal facilities, and a hierarchy of alternatives should be implemented, including:

- Waste reduction
- Collection systems
- Recycling
- Composting
- Waste-to-energy processes
- Landfilling

Fig (4)

Types of Recyclable Materials

Recycling helps repurpose materials into new products, but proper sorting is critical. Main recyclable materials include:

- **Paper and Cardboard:** Recycling paper and cardboard can be easily incorporated into everyday life, like using reusable shopping bags and recycling fruit and vegetable containers. It's essential to ensure that paper and cardboard are separated from other waste to maintain quality for recycling.
- **Plastics:** Recycling plastic, especially PET and HDPE, have large markets, and their recycling involves mechanical and chemical processes to recover the materials for reuse.

Fig (5)

- **Glass and Metals:** Glass is an easy and highly recyclable material, while metals, such as steel and aluminum, can also be efficiently recycled, although their processes differ from those of plastics and glass.

Methods of Recycling

Recycling involves collection, separation, cleaning, and processing. Methods include:

- **Mechanical Recycling:** Commonly used for packaging, paper, and other wastes, though some materials, like food waste, are unsuitable.

- **Chemical Recycling:** Involves breaking down materials like plastics into their original components for reuse.

- B**iodegradable Material Recycling:** Composting allows organic materials to degrade naturally.

Innovative Technologies for Recycling

New technologies are being developed to address growing waste management challenges, particularly in Europe. These innovations include:

Fig (6)

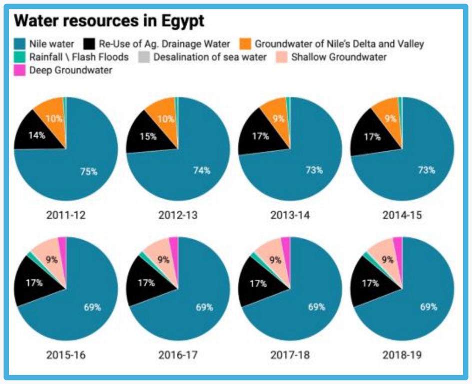
- **Biogas Production:** Utilizing municipal bio-waste for energy through anaerobic digestion, a more efficient and cost-effective method of generating energy from waste.

- **Green Technologies:** These methods improve waste management, offering better cost-to-benefit ratios and greater efficiency in recycling processes.

Promising developments in Europe, especially concerning municipal bio-waste, offer insights into better recycling practices that can be adopted globally, reducing the environmental footprint and operational costs.

D. Manage and increase the sources of clean water:

Human life depends on many factors, these factors could either be psychological or physiological; in Maslow's hierarchy of needs, water is located at the base of the pyramid in terms of physiological needs. In addition to its physiological properties, water also greatly benefits crops and agriculture in general. Despite the importance of water, according to the World Resources Institute about 50% of water is wasted every year. This information makes it much easier to conclude why the management and organization of water is one of the most important grand challenges that face Egypt.



Graph (2)

Causes of Managing and Increasing Water Resources:

1-Water Scarcity: Egypt is one of the most water-scarce countries in the world, with an annual water share of less than 560 cubic meters per capita, Egypt relies heavily on the Nile River, which provides about 72% of its consumption as shown in graph(X).

2-Population Growth: Egypt's population is growing rapidly, increasing the demand for water for drinking, agriculture, and industrial use.

3-Agricultural Demand: Agriculture accounts for 85% of Egypt's water consumption.

4-Climate Change: Rising temperatures, reduced rainfall, and increased evaporation rates due to climate change are reducing the availability of freshwater.

Effects:

1-Improved Water Security: ensure a stable water supply for drinking, agriculture, and industry, reducing the risk of shortages**.**

2-Economic Growth: stable water resources support agricultural productivity, and industrial development, contributing to economic growth and job creation.

3-Climate Resilience: Diversifying water sources and improving water efficiency can help Egypt adapt to the impacts of climate change, such as droughts and reduced Nile flow.

In conclusion, while the water management challenge in Egypt is significant, it is not insurmountable. With concerted efforts, the adoption of modern technologies, and increased public awareness, it can be ensured that every citizen has access to clean and safe water.

E. Improve the uses of arid areas:

Improving the use of arid areas in Egypt because Egypt's desert is 95% of Egypt (As shown in fig(X)) is a critical strategy for addressing the country's challenges related to water scarcity, food security, and population growth.

The causes:

1-Population Growth: the increasing of Egypt's population, creating pressure on limited arable land and water resources.

2-Climate Change: Rising temperatures and changing rainfall patterns are reducing the productivity of traditional agricultural areas.

3-Urban Expansion: Rapid urbanization in the Nile Valley and Delta is leading to the loss of fertile land.

4-Food Security: Egypt relies heavily on food imports.

The effects:

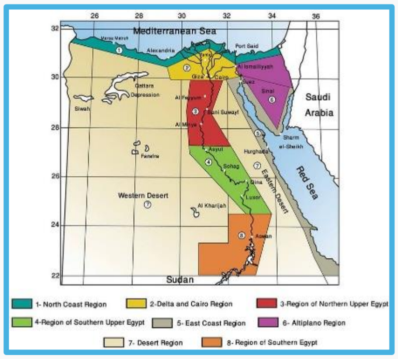


Fig (7)

1-Increased Agricultural Production: Reclaiming arid lands for agriculture can boost food production, enhance food security, and reduce reliance on imports.

2-Economic Growth: Development of arid areas can create jobs, attract investments, and diversify the economy through agriculture.

3-Improved Water Management: Advanced irrigation techniques and water recycling can optimize water use and reduce waste.

4-Urban Decongestion: Developing new cities and infrastructure in arid areas can reduce overcrowding in the Nile Valley and Delta.

Improving the use of arid areas in Egypt is a complex but necessary endeavor to address the country's challenges of population growth, water scarcity, and food security. While it offers significant benefits, such as increased agricultural production, economic growth, and technological innovation, it also poses risks, including environmental degradation, high costs, and social displacement.

Problem to be solved

After all problems are displayed, the conclusion is the main problem is water scarcity, that is why if this problem solves the others problems could be solved so to solve the those problems the water scarcity problem should be understood and how can deal with its effects and what are the positives if it is solved and its negatives if it is not solved

What if the problem is solved?

1. Improved Public Health

   Access to clean and sufficient water would reduce waterborne diseases, improving overall public health and reducing healthcare costs.

   Better sanitation and hygiene practices would become more widespread, further enhancing health outcomes.

2. Enhanced Food Security

   Reliable water supplies would support agricultural productivity, ensuring stable food production and reducing the risk of famine.

   Irrigation systems could be expanded and optimized, allowing for more diverse and resilient crop production.

3. Economic Growth

Industries that depend on water, such as agriculture, manufacturing, and energy production, would experience increased stability and growth.

Job creation in water-related sectors and improved productivity could boost local and national economies.

4. Improved Quality of Life

Access to clean water would enhance the overall quality of life, allowing people to focus on education, work, and personal development rather than struggling to meet basic needs.

Communities would have more time and resources to invest in cultural, social, and economic activities

What if the problem is not solved?

1. Public Health Crises

Increased Disease: Lack of access to clean water would lead to a rise in waterborne diseases such as cholera, dysentery, and typhoid.

Poor Sanitation: Inadequate water supply would exacerbate sanitation issues, leading to the spread of infections and diseases.

2. Food Insecurity

Agricultural Decline: Water scarcity would severely impact agriculture, leading to reduced crop yields and livestock production.

Famine and Malnutrition: Food shortages could result in famine, malnutrition, and increased mortality, particularly in vulnerable populations.

3. Economic Instability

Industrial Impact: Industries relying on water, such as manufacturing, energy production, and mining, would face operational challenges, leading to economic losses and job cuts.

Increased Costs: The cost of water would rise, putting financial strain on households, businesses, and governments.

4. Environmental Degradation

Ecosystem Collapse: Aquatic and terrestrial ecosystems would suffer, leading to loss of biodiversity and disruption of ecosystem services.

Deforestation and Desertification: Over-extraction of water resources could lead to deforestation and desertification, further exacerbating environmental degradation.

Research

Topics for researching the problem:

1. What are the causes of water scarcity in rural areas?
2. How does wastewater impact local water resources and ecosystems?
3. What are the health risks associated with untreated wastewater in rural communities?
4. What are the challenges in monitoring water quality in remote areas?
5. How does salinity affect agricultural productivity and freshwater resources?
6. What is the environmental impact of wastewater mismanagement?
7. How do microplastics and other pollutants affect human and ecosystem health?
8. What are the limitations of existing water treatment systems in rural regions?
9. What are the social and economic impacts of water pollution on rural communities?
10. How do cultural and traditional practices influence water management in rural settings?

Topics for researching the solution:

1. What natural materials are effective in reducing water salinity?
2. How can adsorption techniques (chemical and physical) be applied to water treatment?
3. What are the biological methods for treating wastewater?
4. How can natural and recycled materials like activated carbon and sand filters improve water quality?
5. What techniques are used for microplastic removal from water?
6. How does reverse osmosis work in desalination and water purification?
7. What are innovative approaches for recycling wastewater in small-scale systems?
8. How can solar energy or other renewable energy sources be utilized in water treatment?
9. What sensors are suitable for monitoring parameters like pH, turbidity, and salinity?
10. How can feedback loops be designed for water treatment systems?
11. How can treated wastewater be reused sustainably in agriculture or other local applications?
12. What are cost-effective and sustainable solutions for water treatment in rural areas?
13. How can the efficiency of water treatment processes be analyzed over multiple cycles?

14. How can bio-sourced materials, like cork or plant-based filters, enhance water purification?
15. What are best practices for calibrating water quality sensors in a portable system?

Other Solutions Already Tried

A. Sediment Filter:

A **sediment filter** is a type of water filter that removes solid particles (sediment) from water. These particles can include dirt, rust, sand, silt, and other physical debris that may be suspended in water. Sediment filters are usually the first stage in a multi-stage filtration system, helping to protect other filters and appliances from damage caused by these particles

Fig (8)

Mechanism: Mechanism: Sediment filters typically use a porous material, such as a mesh, pleated fabric, or a spooled filter, to trap larger particles. Some filters use a physical barrier like a screen or fabric, while others may have a more complex structure that captures smaller particles as well.

Its advantages:

1-Improves Water Clarity: Sediment filters remove visible particles, improving the appearance of water by making it clear and free of debris.

2-**Low Maintenance and Cost-Effective**: Sediment filters are typically affordable, easy to replace, and require minimal maintenance, making them a cost-effective option for many households.

3-**Wide Range of Applications**: Sediment filters can be used in various water systems, including municipal water supplies, well water, and even for whole-house filtration.

4-**Prevents Clogging of Other Filters**: By removing larger particles before they reach other filtration systems (like carbon or reverse osmosis filters), sediment filters help extend the lifespan and efficiency of these downstream filters.

Its disadvantages:

1- Does Not Remove Chemicals or Microorganisms: Sediment filters are not designed to remove chemical contaminants like chlorine, lead, or fluoride, nor do they eliminate bacteria or viruses. They only address physical impurities. If you're concerned about chemical contamination, you'll need additional filtration stages, like activated carbon or reverse osmosis.

2- Reduced Flow Rate: Over time, sediment filters can become clogged with particles, which reduces their efficiency and can affect the water flow rate. Some filters, like pleated or string-wound, require regular cleaning or replacement to maintain optimal performance.

3- May Not Catch Very Fine Particles: While sediment filters can capture large to medium-sized particles, very fine particles like colloidal matter or dissolved solids may pass through depending on the filter type.

4- Does Not Address Hardness or pH: If your water has high mineral content (hard water) or imbalanced pH, sediment filters will not address these issues. You would need additional treatments like water softeners or pH-adjusting filters for those problems.

B.Whole House Water Filters:

A **whole house water filter** also known as a point of entry filter is a filtration system installed at the main water supply entry point to a home, filtering all the water that enters. This means every tap, shower, and appliance in the house gets filtered water, which can be particularly useful for improving water quality throughout the entire home. These systems typically consist of multiple stages of filtration, which might include activated carbon, sediment, UV, or even reverse osmosis, depending on the model.

Fig (9)

Mechanism: Installation Location: A whole house filter is typically installed where the water supply line enters the home, either before or after the water meter.

Filtration Process: Water passes through various filter stages (which could include sediment filters, activated carbon filters, and sometimes UV or reverse osmosis systems), depending on the contaminants present. The system treats the water before it flows through the rest of the house, ensuring that every faucet, shower, and appliance gets filtered water.

Its advantages:

1- Comprehensive Protection for the Entire Home: Whole house filters provide filtered water to all taps, showers, toilets, and appliances, ensuring cleaner water for drinking, bathing, cooking, and cleaning.

2- Convenience: You don't need to worry about replacing filters for individual faucets or pitchers. A whole house system treats all water entering the home, so there's no need for additional filtering at each water source.

3- Eliminates Chlorine and Harmful Chemicals: Many whole house filters effectively reduce chlorine, pesticides, VOCs, and other harmful chemicals, which are commonly found in municipal water supplies.

4- Health Benefits: By reducing chlorine and other harmful chemicals, a whole house filter can improve the quality of water for consumption, cooking, and bathing, which can benefit overall health, especially for individuals with sensitive skin, respiratory issues, or chemical sensitivities.

Its disadvantages:

1- Water Pressure Decreases: Some whole house filters, especially if they have multiple filtration stages, can reduce water flow and pressure, particularly if the filters become clogged. It's important to ensure the system is properly sized for the home to prevent this.

2- Space Requirements: Whole house filters require space for installation, which may be challenging for some homes, particularly if the water entry point is in a tight or difficult-to-access area like a crawl space or basement.

3- High Initial Cost: Whole house filtration systems tend to have a higher upfront cost due to the installation and equipment needed for comprehensive filtration. The installation can be complex and may require professional help, adding to the cost.

4- Ongoing Maintenance and Filter Replacement: Depending on the type of filter used, regular maintenance and filter replacements are required to keep the system working effectively. This could be monthly, quarterly, or annually, depending on the system.

For example, activated carbon filters may need to be replaced annually, while sediment filters may need more frequent changes.

C.The Lhasa Najin Water Treatment Plant (WTP):

It was built in 2017. Cost of 1.38 billion CNY (approximately 213 million USD). The output of the treatment water from WTP averages 480 m>3/day. Located in the Tibetan Plateau in the Tibet Region of China. This plant is the biggest water treatment plant in the world treating surface water. It is also the highest water treatment plant in the world using UV disinfection with a height of 3,658m. The plant can daily water demand of 1 million people in the central area of the Plateau near the Himalayas. The upgraded plant adopts a combined UV-chlorine disinfection technology to inactivate disease-causing microorganisms and reduce the amount of various cleaning byproducts in the water quickly and efficiently. The cost of the UV system is less than 0.02 CNY/ton from water, making this approach extremely efficient and the cost. It treats water from the Yarlung Tsangpo River.

Fig(10)he Lhasa Najin Water Treatment Plant

Its advantages:

1- Improved Water Quality: The plant ensures the removal of contaminants, sediments, and harmful microorganisms, providing safe drinking water to the population.

2-Public Health Benefits: Access to clean water reduces waterborne diseases such as cholera, typhoid, and dysentery, improving overall public health.

3-Technological Advancements: The plant likely incorporates modern water treatment technologies, such as membrane filtration, UV disinfection, or reverse osmosis, ensuring efficient and effective treatment.

Its disadvantages:

1-**Energy Consumption**: Water treatment plants are energy-intensive, which can contribute to carbon emissions and environmental impact unless renewable energy sources are used.

2-located in a high environment: In regions like Tibet, logistical challenges, like, transportation of materials, harsh climate) can increase costs and complicate maintenance.

3-It pollutes the environment: Discharge of treated wastewater, if not properly managed, can still affect downstream water quality.

D.DC Water Blur Plains Advanced Wastewater Treatment Plant:

The average daily of treated water is about 300 million gallons from wastewater and has the ability to treat over 1 billion gallons a day at top flow. The plant opened as a primary treatment in 1937. With time, add new processes and technologies. The Blue Plains facility now uses both primary and secondary treatment to work on removing nitrogen and chlorination or dichlorination during the treatment process. During the treatment process, useful products like biosolids and energy from wastewater are reused (recycled). recycling nitrogen and phosphorous back into local soils.

Fig(11)the DC Water Blur Plains

Its advantages:

1-Advanced Treatment Technology: The plant uses state-of-the-art wastewater treatment processes, including biological nutrient removal (BNR), membrane filtration, and disinfection, to produce high-quality effluence.

2-Environmental Protection: By treating wastewater to a high standard, the plant significantly reduces pollution in the Potomac River and Chesapeake Bay, helping to restore aquatic ecosystems and improve water quality.

3-Scalability and Capacity: With a treatment capacity of 370 million gallons per day, the plant can handle the wastewater needs of a large and growing urban population.

Its disadvantages:

1-High Operational Costs: The advanced treatment processes and technologies used at the plant require significant financial resources for operation, maintenance, and upgrades.

2-Energy Consumption: Despite energy recovery efforts, the plant remains energy-intensive, contributing to greenhouse gas emissions unless renewable energy sources are fully utilized.

3-Odor and Noise Concerns: Large wastewater treatment plants produce odors and noise, which may affect nearby communities and require mitigation measures.

II. Generating and Defending a Solution

Solution and design requirements

To solve the problem, we should select the most ideal solution. A successful solution should be implemented without any mistakes, and it should be implemented in a creative and innovative way. The general requirements that should be in any efficient, effective, and successful solution are:

• Wastewater Sample Quantity:

The collected wastewater sample must be sufficient for both recycling and data collection. This ensures that the prototype can operate continuously for multiple cycles without requiring additional samples. The volume of the sample should be large enough to allow for repeated testing and treatment cycles, enabling the team to evaluate the system's performance over time. This requirement emphasizes the importance of scalability and practicality in real-world applications.

•Salinity Threshold:

The wastewater must have a salinity level greater than a threshold value of approximately 500 ppm, with a minimum of 1000 ppm recommended. Salinity is a critical parameter because it directly impacts the usability of water for various applications, such as irrigation or industrial processes. High salinity levels pose challenges for treatment, making it an ideal parameter to test the prototype's effectiveness. The threshold value may be adjusted based on local applications, ensuring the system's adaptability to different contexts.

•Activating Suitable Pump:

The prototype must include a pump to circulate wastewater in a closed-cycle system. This requirement ensures that the system can operate autonomously and continuously, mimicking real-world wastewater treatment plants. The pump must be appropriately sized to handle the volume of wastewater and maintain consistent flow rates, which are critical for the effectiveness of the treatment processes.

•Treatment Using Recycled Materials:

The wastewater must be treated using natural or processed recycled materials for at least three water quality parameters, with salinity being one of them. The other two parameters should be chosen by the team based on scientific references and the intended application. For example, parameters like turbidity, pH, or heavy metal concentration could be selected. This requirement encourages the use of sustainable and cost-effective materials, aligning with the principles of circular economy and environmental stewardship.

•Diverse Treatment Techniques:

At least three different treatment techniques must be employed, and they should belong to distinct categories. For example:

- **Adsorption**: Using materials like activated carbon and cellulose to remove contaminants.
- **Coagulation**: Employing electric or magnetic fields to aggregate particles for easier removal.
- **Biological Treatment**: Utilizing microorganisms to break down organic pollutants.

This requirement ensures a multi-faceted approach to wastewater treatment, increasing the likelihood of achieving desired water quality standards. It also encourages innovation and exploration of various methods.

•Automatic Two-Way Gate or Valves:

The prototype must include an automatic two-way gate or valves to either recycle the wastewater for further treatment or allow it to exit the system based on the monitored water quality parameters. This feature ensures that the system can make real-time decisions, enhancing its efficiency and practicality. The use of sensors and control systems to automate this process is essential for achieving a fully functional prototype.

•Efficiency Monitoring Over Multiple Cycles:

The team must monitor the treatment efficiency over at least five complete cycles, even if the threshold limits are reached earlier. This requirement ensures that the system's performance is evaluated under repeated use, providing insights into its durability and consistency. Graphical fitting methods should be used to analyze the data and predict the system's life expectancy, adding a layer of scientific rigor to the project.

•Capacity Study:

The team must study the prototype's capacity by measuring the volume of clean water produced over time, with readings taken every 10 minutes for at least one hour. Additionally, a third measurable factor, such as energy consumption or contaminant removal rate, should be chosen by the team. This requirement emphasizes the importance of quantifying the system's performance and identifying potential bottlenecks or areas for improvement.

•Energy Consumption Calculation:

The system's energy consumption per liter of clean water must be calculated. This involves using a calibrated multimeter to measure the electric current and voltage during operation. Energy efficiency is a critical factor in evaluating the sustainability and cost-effectiveness of the prototype, making this requirement essential for a comprehensive assessment.

•Sensor Calibration:

If sensors are used, they must be calibrated using standard methods or instruments. Calibration ensures the accuracy and reliability of the data collected, which is crucial for making informed decisions about the system's performance. This requirement highlights the importance of precision and attention to detail in scientific experimentation.

•Functional and Portable Prototype:

The prototype must be functional, workable, and portable on the exhibition day. Additionally, the team should bring a soft copy of their portfolio. This requirement ensures that the project is not only theoretically sound but also practically viable. Portability is particularly important for demonstrating the system's potential for real-world applications, such as in remote or resource-limited settings.

These requirements must be fulfilled for our solution to be effective. Now, let's discuss why each of those is required to produce the perfect one:

To meet these requirements, the team should follow a structured approach:

1. **Planning and Design**: Develop a detailed plan outlining the treatment methods, materials, and system components.
2. **Material Selection**: Choose recycled materials that are effective for the selected water quality parameters.
3. **Prototype Construction**: Build the prototype, ensuring all components (pump, valves, sensors, etc.) are integrated seamlessly.
4. **Testing and Calibration**: Conduct preliminary tests to calibrate sensors and optimize treatment processes.
5. **Data Collection and Analysis**: Monitor the system's performance over multiple cycles, collecting data on water quality, energy consumption, and production capacity.
6. **Documentation and Reporting**: Compile the results, create graphical representations, and prepare the video and portfolio

Selection of solution

Water filtration aims at keeping drinking water clean and safe for human consumption by removing damaging contaminants. The aim of our project is to present the operation of a 4-stage filtration system that can purify the water via reverse osmosis, electrochemical treatment, biological filtration, and mechanical filtration.

Benefits of our water filtration systems:

- Excellent purification: Removal of impurities, bacteria, heavy metals, and other salts so that water is safe for consumption.
- Environmentally safe and sustainable: Algae and bacteria occur naturally and are used in the biological filtration phase, thus limiting the use of chemicals.
- Cheap: Initial installation may demand funding, but maintenance and operating costs are very low, thus a wise choice long-term.
- Diverse and infinitely scalable: Suitable for both home use and large-scale industrial applications.

Stages of Filtration:

- **Physical Filtration Gravel, Sand, Limestone:**
  The first stage removes large particles such as dust, dirt, and sediment using layers of gravel, sand, and limestone, and adjust pH.
- **Electrochemical Treatment:**
  A low-voltage electric current is passed through the water to remove heavy metals like lead and mercury while neutralizing bacteria.
- **Cellulose Treatment:**
  the cellulose filter consists of two layers. In which each layer has a function in the process. The first layer is cellulose. The purpose of this layer is to prevent the filter's components from entering the water.

Cons are profuse:

Biological Filtration Ensure a natural balance of algae and bacteria to maximize passive purification efficiency. Design the system to self-regulate through strategic flow rates, substrate selection, and environmental conditions.

Electrochemical treatment-A stable power supply is required, and in remote areas, alternative means of power generation may be required.

Water Recovery Rate: A failure in RO efficiency gives a little unaccounted exit of water in waste. With proper design, this waste can be minimized.

Our Project Idea:

The four-stage filtration system guarantees clean and safe drinking water in an environmentally friendly way. The system handles water contaminants, especially where clean water is not available, and pollution is so widespread. Finally, construction provides a viable and sustainable option to water treatment, with an emphasis on achieving efficiency at an affordable cost while ensuring reduced adverse environmental impact.

Selection of prototype

Water can be purified through many methods, but a filter was designed with four integrated stages to ensure the removal of impurities, bacteria, and harmful minerals, while improving water quality and making it suitable for daily use.

The filter model consists of a metal structure in the form of an existing angle of iron, as it is a base and column to carry the filter units. The column contains a holder that is fixed to the filters in the form of successive tubes, which allows water to pass through each stage in a chain and organized stage and the filter consists of four stages.

- Mechanical nomination stage (Gravel, Sand, Limestone)

At this stage, water passes through different layers of gravel, sand, and limestone, which remove large particles such as sediments, dust, and outstanding impurities.

- Electrolysis

At this stage, we pass the water via the electrical analysis system, which helps remove heavy metals such as lead and mercury, and it also kills any bacteria or remaining viruses using low electrical current.

- cellulose:

he cellulose filter consists of two layers. In which each layer has a function in the process. The first layer is cellulose. The purpose of this layer is to prevent the filter's components from entering the water.

The measurement and control system:

We connected the filter to the Erdino plate containing sensors to measure water quality at each stage, such as a TDS sensor to measure the percentage of salts, and the PH sensor to measure pH. We also added a LCD screen displaying water purity, with LED lighting indicates the quality of the resulting water:

Green light if the purity level is high (TDS less than 50 PPM).

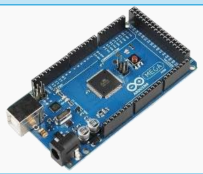
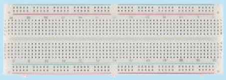
Yellow light if the purity level is average (TDS between 50-150 ppm).

Red light If the water is not pure and needs to be re -filled (TDS above 150 PPM).

III. Constructing and Testing a Prototype

Materials

Item	Usage	Amount	Source	Price	Picture
Wood	To make a prototype on which the elements will be attached	------------ ------------ ----------	Wasted	**Wasted**	
Plastic containers	To store water inside and place the filter elements	**4**	Wasted	**Wasted**	
Hose	To transfer water from one place to another	**2 Meters**	Wasted	**Wasted**	
Water Pumps	To transfer water from one place to another	**2**	Electronics shop	**300**	
Acid battery	To supply electricity to the prototype	**1**	Electronics shop	**500**	
Ph sensor	To measure the pH of water	**1**	Electronics shop	**1700**	
TDS sensor	To measure the percentage of dissolved salts	**1**	Electronics shop	**750**	

Turbidity Sensor	To measure the turbidity of water	**1**	Electronics shop	**700**	
Water level Sensor	To measure the water level in the tank	**1**	Electronics shop	**20**	
Sensor	To measure water temperature	**1**	Electronics shop	**65**	
Jumpers	To complete the wiring of electronic components	**30**	Electronics shop	**30**	
Arduino Mega	To connect the sensors together and control them automatically	**1**	Electronics shop	**1200**	
Bread board	To connect wires and electronic components	**1**	Electronics shop	**35**	
Cellulose	To purify water from impurities and reduce pH	----------------------------------	From environment	**Natural**	
Gravel	To purify water from salts and remove impurities	----------------------------------	From environment	**Natural**	
Sand	To purify water from salts and remove impurities	----------------------------------	From environment	**Natural**	
Limestone	To purify water from salts and remove impurities	----------------------------------	From environment	**Natural**	
Zeolite	To purify water from salts and remove impurities	----------------------------------	From environment	**Natural**	

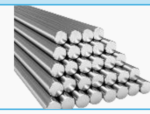
Activated Carbon	To purify water from salts and remove impurities	**----------------------------------**	Wasted	**Wasted**	
Aluminum rods	To make a filter by electrocoagulation of water	**2**	Wasted	**Wasted**	

Table (1)

Method

"Here's how the prototype was brought to life step by step."

- Initially, sketch up a 3D model for the prototype to prevent any errors or occurring something wrong as shown in **figure (X)**
- Get a wood stand to put boxes on it and to be the skeleton of the filter
- A suitable Plastic box to be the main body of the filter it was a reused one with the correct dimensions and was able to support the inner components.
- The project involves three vertical stages of water purification: activated carbon, cellulose treatment, and electrocoagulation.

Fig (12)

- In the activated carbon stage, the orange peel was burned in the vacuum container and it reformed to activated carbon. Then it was put in this stage with other layer the first layer is sand then the activated carbon, then the gravel and all of those were held with a piece of fabric from the downside.
- In the cellulose stage, cotton was chemically treated to extract pure cellulose by heating it in distilled water at 70 °C for 10 minutes, soaking in 10% NaOH at 60 °C for 3 hours, and treating it with 5% NaClO at 70 °C for 30 minutes. It was then washed, neutralized with ethanol, and dried at 60 °C for 8 hours.
- For electrocoagulation, a container was divided into three compartments saltwater in the center, distilled water on the sides separated by cation and anion exchange membranes (CEM and AEM). Graphite electrodes were placed behind each membrane, with the cathode behind the CEM and the anode behind the AEM.
- PH and TDS sensors were obtained from a hardware supply store to identify the PH and TDS of water. Then, get an Arduino mega microcontroller, connect the sensors to it, and use the mobile device to display the sensor readings.
-
- The sensors were connected to the ESP microcontroller using the breadboard as shown in **figure (X)**
- Obtain a small solar panel and install it above the filter to capture sunlight then convert it to electric energy to charge the battery.

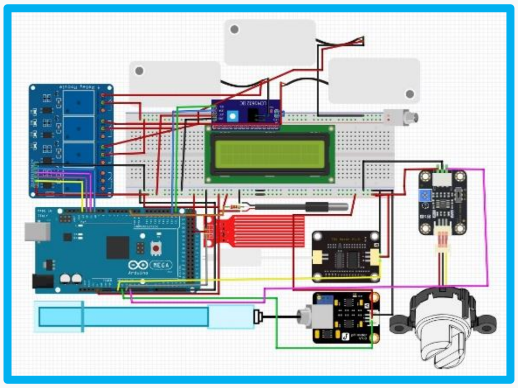


Fig (13)

- In order to complete the prototype and make it ready for testing, collect all these parts and install them in the main cylinder.

Test plan

"Testing begins: will the prototype deliver its promise? "

A. **Volume:** the water sample must measure its volume every 10 minutes the volume will be calculated directly using the beaker
B. **Power:** The power must calculate every cycle; the power will be calculated indirectly using power rule V*I=Power (Watt) by getting the volt and ampere of each component
C. **Salinity:** the water sample must have a salinity of more than one thousand ppm the salinity will be calculated indirectly by using TDS sensor, the TDS readings multiplied 0,7.
D. **PH:** PH is measured directly by using PH sensor**.**
E. **Turbidity:** turbidity is measured directly by using turbidity sensor

The safety precautions

Item	Usage	Picture
Lab coat	To protect the bodyof the person working.	
Latex gloves	To protect against the dirt and microbes that the person working onthe project might get exposed to.	
Goggles	To protect the eyesof the person.	

Table (2)

Data collection

Tools used in measuring:

Tool	Purpose in Measurement
PH Sensors	Measures the PH to evaluate filtration efficiency.
Arduino mega	Displays sensor readings on a connected smartphone for real-time monitoring and analysis.
Stopwatch	Tracks the time required for the filtration process to ensure it meets the 10-minute limit.
Digital Scale	Measures the mass of methane to ensure the air sample is within the required volume range.
TDS Sensors	Measures the TDS to evaluate filtration efficiency.

Table (3)

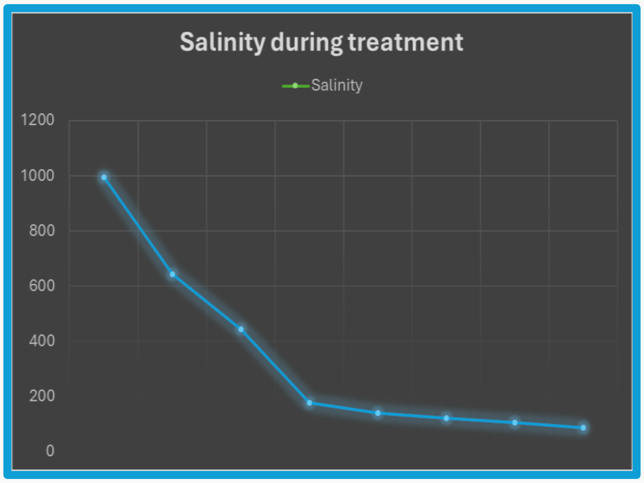
Results

The Negative results:

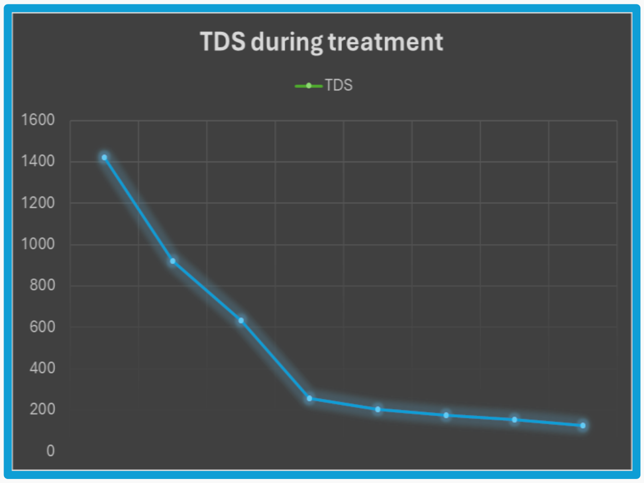
❑ **Filter Clogging**: Frequent clogging occurs in the first and third, reducing system efficiency.

❑ **Coding error:** The sensor readings show a negative filtration percentage under the same conditions

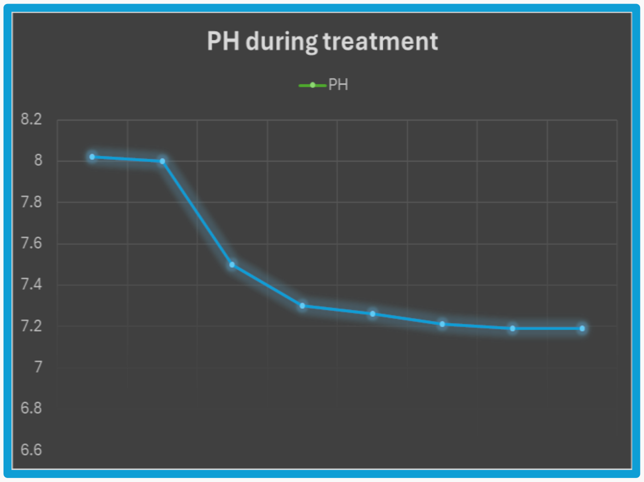
These difficulties led to various positive results and offered valuable insight.



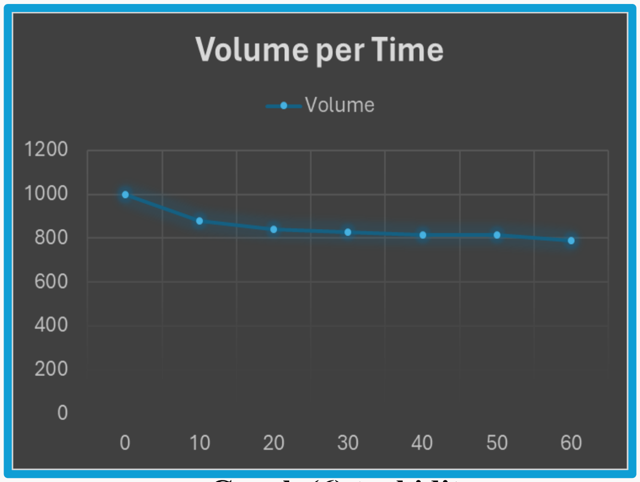
Graph (3) salinity readings by TDS sensor



Graph (4) TDS sensor readings



Graph (5) PH sensor readings



Graph (6) turbidity sensor readings

	Lab TDS readings	TDS sensor reading	Lab PH readings	PH sensor reading	Salinity (Lab readings)	Salinity(Sensor readings)
Trial one	1410 ppm	1390 ppm	8.0	8.08	987 ppm	973ppm
Trial two	1450 ppm	1430ppm	8.2	8.14	1015ppm	1001ppm
Trial three	1470 ppm	1440ppm	8.13	7.86	1050ppm	1008ppm
Avg:	1443ppm	1420ppm	8.05	8.02	1010ppm	994ppm
Error ratio	Error ratio= ±2.33%		Error ratio=±1.1%		Error ratio=±2.33%	

Table (4) Calibration of sensors

	TDS	PH	Turbidity	Salinity
Before filtration	1420±2.33%	8.02±1.93%	20.24ntu	994ppm±2.33%
After stage one	920ppm±2.33%	8.00±1.93%	12.88ntu	644ppm±2.33%
After stage two	633ppm±2.33%	7.5±1.93%	8.71ntu	443ppm±2.33%
After third stage (After first cycle)	256ppm±2.33%	7.3±1.93%	6.42ntu	179ppm±2.33%
After second cycle	202ppm±2.33%	7.26±1.93%	6.13ntu	141ppm±2.33%
After third cycle	175ppm±2.33%	7.21±1.93%	6.09ntu	122ppm±2.33%
After fourth cycle	153ppm±2.33%	7.19±1.93%	6.02ntu	107ppm±2.33%
After fifth cycle	124ppm±2.33%	7.19±1.93%	6ntu	86.8ppm±2.33%

Table (5) sensors readings

IV. Evaluation, Reflection, Recommendations

Analysis and discussion

The primary goal of the project is to transform industrial wastewater into clean water that can be used for irrigation to alleviate the wastewater problem and locate a new supply of irrigation water. According to a strong scientific foundation that is extensively documented in this section, the project ultimately produced standard findings and satisfied the design requirements.

In the test of evaluating the system's durability and strength, the primary issue that led to system failure was the water pump. During each trial, the water pump was consistently the first component to malfunction, causing the entire system to stop operating. As a result, the water pump was identified as the main reason for system failure. After conducting multiple tests and calculating the average performance, the estimated lifespan of the entire system was determined to be approximately one week. This is due to the critical role of the water pump once it fails, water flow is interrupted, and the system requires maintenance to resume functioning.

The mechanism of First Stage :

The first layer is the sand layer. Sand hold particles within its pores, allowing only the water to pass through this layer. The sand serves as the natural filter's first layer, removing turbidity, pathogens, and suspended particles from water. It also has a 40% porosity, which is the same as its permeability.

The second one is small-sized gravel and large-sized gravel. make up the topmost strata. Gravel plays a crucial role in preventing the loss of filter sand during filtering.

The third layer is activated carbon, Removing natural organic compounds, taste and odor compounds, and synthetic organic chemicals requires having activated carbon, which is a form of carbon also called 'activated charcoal'. Because of its larger surface area, capacity for micro porousness, the chemical complexity of its exterior area, and huge porosity, activated carbon has a good potential for adsorbing heavy metals. Also, a powerful adsorbent. Contaminants can bind to its surface. Used to filter water with the adsorption process.

The mechanism of Second Stage:

This stage is consisting of one treatment method, electrocoagulation, The mechanism of electrocoagulation: the electrochemical cell that houses the electrodes and is coupled to an external current source makes up the electrocoagulation unit. material, coagulants, or metal ions, are produced in vitro analysis. By dissolving the anode material

as: $\mathbf{Al\ (s) \rightarrow Al^{3+} + 3e^{-}}$ On the other side, the hydrolysis process takes place at the cathode, where water is converted to hydroxide and hydrogen gas is discharged into the air as bubbles.

($2H_2O+2e^- \rightarrow H_2(g)+2OH^-$)the over all reaction as shown in fig (4) Aluminum is also preferred over other metals, including iron since its buffer action causes the solution's pH to be stabilized at a pH between 7 and 8, which is higher than that of most other metals. However, it was chosen other metals erode from it much more slowly. In terms of removing contaminants (TDS), turbidity, and color, Aluminum is also much more effective than other metals.

$$\mathrm{Al}\,(\mathrm{s}) + 3H_2O \rightarrow \mathrm{Al(OH)}_3 + \frac{3}{2}H_2(g)$$

***FIg*(14)**

The mechanism of Third Stage(1):

the cellulose filter consists of two layers. In which each layer has a function in the process. The first layer is cellulose. The purpose of this layer is to prevent the filter's components from entering the water.

The limestone layer is made to Adds Beneficial Minerals by Releasing calcium ions (Ca^{2+}) into the water as shown in fig (5), This helps re-mineralize soft or aggressive water, improving health of plants.

$$CaCO_3 + 2H^+ \rightarrow Ca^{2+} + CO_2 + H_2O$$

***Fig*(15)**

Efficiency measurement:

the calculation of efficiency of the system is required to know how is the performance of the system while the filtration process and to calculate the efficiency use law(1), and the efficiency while each cycle is shown in graph(6) as shown the efficiency in the first cycle was in its maximum point and it decreases dramatically beginning of the second cycle that is because the number of ppm is very small to filtrate from water that are the reasons that make the efficiency decreases while the time passed. So, the efficiency will be81% in first cycle and It will be decrease over cycles. The total efficiency of all cycles is 89%

***Law*(1)**

$$\frac{\Delta concentration}{concentration before\ filtration} \times 100$$

Calculation of power:

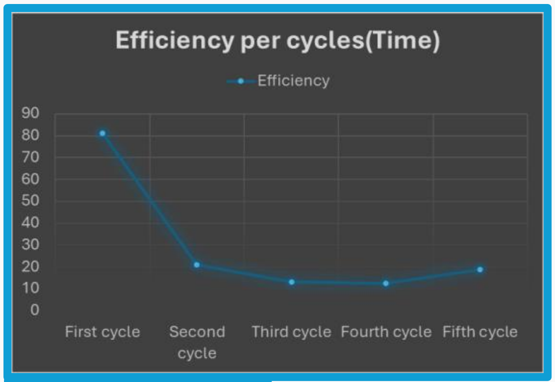
Consuming energy the law of the power is shown in law(2) and the table (4) is shown how much each device consume energy and as shown the most device consume energy is the water pump and the total energy of the system at all is equal=13.65 W

$$voltage(V) \times \mathrm{current(A)}$$

***Law*(2)**

Current density:

the quantity of electrical current passing the electrode's unit area, or current density, is one of the electrocoagulation process's most crucial operating factors. The applied current density will be directly proportional to the number of ions produced by anode dissolution, it calculated by using law(3) which the battery is 5 amperes, and the area of electrode is 7.065cm² it equal to 0.0007065 m². So, current density=7077.14 A/m².



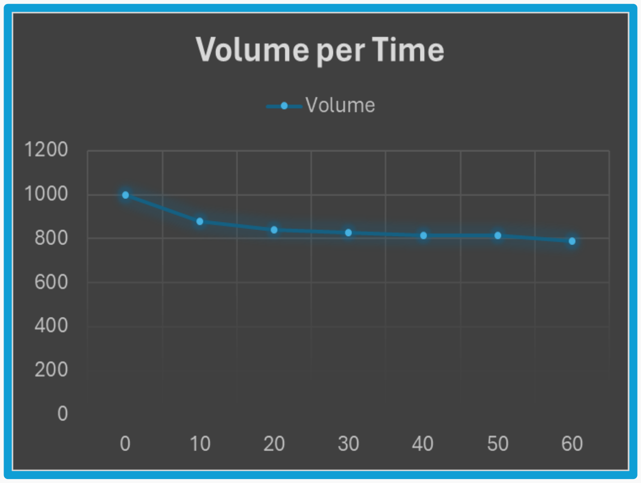
***Graph*(7)**

$$J = \frac{I}{A}$$

***Law*(3)**

Volume of water:

in the test plan that measure the volume of the water before after and after the filtration process the results that are gotten are displayed in graph(7) and table (5), after analyzing these data to know what is the reason of this loss of the water , the result is this lost causes by to reasons the first one the wastes that found in the water before the filtration and the second and the bigger lost is the cellulose absorb some water while the flow. The efficiency of one cycle is equal 88% and the efficiency of the five cycles is equal 81%.



***Graph*(8)**

Water volume per stages(Time)	
Before filtration	**1000 ml**
After first stage	**945 ml**
After second stage	**925 ml**
After third stage	**880 ml**
After second cycle	**840 ml**
After third cycle	**825 ml**
After fourth cycle	**815 ml**
After fifth cycle	**800 ml**

***Table*(5)**

Recommendation

"Nothing is perfect...!"

As known in science, complete work does not exist; therefore, the idea behind the development of prior solutions is that heirs will further improve it. Numerous suggestions for improving the project were developed, but for a variety of reasons, including time, equipment and cost, they were unable to be implemented in the prototype. Therefore, it is recommended that

Materials:

Using Garnet sand: Instead of fine sand, Almandite garnet deposits are the source of garnet sand, a hard rock garnet. It is perfect for use in multi-media systems as the water filtration-grained layer. With useful diameters ranging from 2.0 mm to 20 mm, garnet is renowned for its high hardness and endurance. Garnets are a perfect alternative to fine sand because it can remove suspended particulates as small as 1 m and is thick enough (between 120 and 140 pounds per cubic foot) to allow for quicker backwashing in the rapids and filter. The problem with using garnets is that it is expensive compared to fine sand.

Real life application:

Using DI system: DI system is used to remove all the minerals from the contaminated water such as cations like sodium, calcium, iron, and copper, and anions like chloride and sulfate. This process will happen by using ion exchange media using cation and anion resin to exchange hydrogen (H+) and hydroxyl (OH-) ions for dissolved minerals and then recombine to make water. Due to the unavailability of the cation and anion resin in Egypt, this modification couldn't be applied.

Using Microbial Fuel Cells: Using microbial fuel cells to treat wastewater while simultaneously generating electricity from the microbial breakdown of organic matter in the water. This is a complex technology that integrates both water treatment and energy generation but is still in early stages of development for large-scale applications.

Learning outcomes

Subject	Concept	Skill gained
Math	Continuity, Limits, and Rates of Change	Understanding the concept of limits, continuity, and derivatives supports the mathematical modeling of water quality parameters such as pH, turbidity, or salinity across time or treatment cycles.
Math	Definite Integrals and Accumulation	By using integration, students can model the total volume of water treated over time, which helps analyze system capacity and long-term performance.
Physics	Transformers and Energy Transmission Efficiency	Using transformer principles and mutual induction. By selecting step-up and step-down transformers, the system can better regulate voltage to power pumps and sensors efficiently meeting the Capstone requirement to monitor energy consumption per liter of clean water.
Biology	Human Impact and Biodiversity Sustainability	Understanding the impact of human activities on biodiversity helps students design wastewater recycling systems that reduce environmental and health risks. By considering microbial biodiversity, they can apply biological principles to choose or improve biological treatment methods like biofilters or bioreactors. This aligns with the Capstone goal of treating polluted water effectively and sustainably while preserving natural ecosystems.
mechanics	Power and Energy Transfer in Systems	calculate the rate of energy consumption in their prototype's mechanical parts—such as the pump used to circulate water, By applying equations such as $P = W/t$ and $P = Fv \cos(\theta)$
Chemistry	Electrolysis and Environmental Impact	Exploring electrolysis as a method for removing ions or pollutants from wastewater allows to integrate an electrochemical treatment stage using simple electrolytic cell or recovered materials.
Physics – Mechanics	Momentum and Impulse in Fluid Systems	Understanding impulse and momentum helps in optimizing the mechanical design of water-moving components, such as pumps or valves. By reducing energy loss due to water surges or flow collisions, the prototype becomes more energy-efficient, directly supporting Capstone objectives around sustainable operation.
Earth Science	Properties of Water and Its Impact on Systems	The ability of water to dissolve, transport materials, and expand can inspire how your filter captures and processes pollutants in a gaseous state.

Physics	**Gravitational Force**	Understanding gravitational forces aids in designing air filtration systems that consider particle settling, enabling the removal of larger particles through gravity-based filters
Math	**Polynomial Functions and Modeling**	Polynomial functions could model the flow rate of Wateer and pollutant concentration changes across different filtration layers.

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Message of thanks and appreciation

"Every success owes its gratitude to others' support...!"

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