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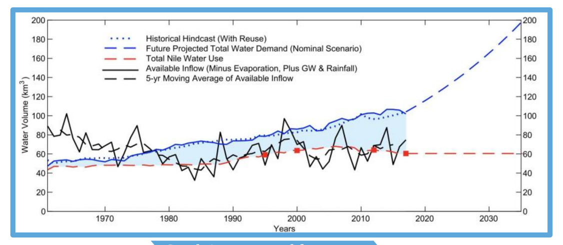
ABSTRACT

In 2016, Harbin's **"Black Tide"** crisis struck when the Songhua River in China became poisoned by industrial waste, turning tap water toxic and undrinkable. Hospitals overflowed with victims suffering burns and sickness, while riots broke out over bottled water. The disaster exposed extreme pollution—mercury and benzene levels 300 times above safe limits—forcing emergency clean-up efforts and stricter regulations, leaving a lasting scar on the city. So, the problem that the project attempts to solve is using polluted water from Agricultural drainage and converting it into clean water for agriculture. The prototype's target is to get clean water to use it in agriculture from the input polluted water by "high salinity and acidic PH and with high turbidity" this prototype was made with three stages, the first one is to activated carbon and limestone and cotton that capture large particles and adjust PH, then passes through cellulose to capture small particles, final stages, electrocoagulation by using graphite and aluminum electrodes to ensure that all impurities are gone completely. This prototype has the potential to successfully meet the design requirements. When the prototype was tested, it had a purification percentage equal 89%

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.

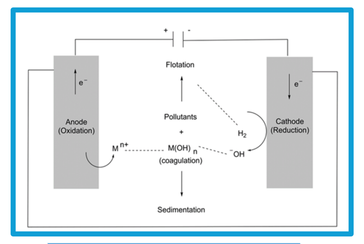
In Egypt, water pollution is a serious challenge, particularly in regions like the Nile Delta, where industrial waste and agricultural runoff have greatly impacted water quality. Because contaminated water sources damage aquatic ecosystems and cause diseases transmitted by water, these challenges are 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) 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.



Graph 1: water need for one per year(3)

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. 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 an electrocoagulation filter , aluminum electrodes, electrodes to make an electrocoagulation as shown in figure (1). then the last beaker with cellulose, 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.



Fig(1): how electrocoagulation work (2)

MATERIALS & METHODS

Item	Usage	Amount	Source	Picture
Wood	To make a prototype on which the elements will be attached	---------------------------------	Wasted	
Plastic containers	To store water inside and place the filter elements	4 containers	Wasted	
Hose	To transfer water from one place to another	2 Meters	Wasted	
Water Pumps	To transfer water from one place to another	2	Electronics shop	
Acid battery	To supply electricity to the prototype	1	Electronics shop	
Ph sensor	To measure the pH of water	1	Electronics shop	
TDS sensor	To measure the percentage of dissolved salts	1	Electronics shop	
Turbidity Sensor	To measure the turbidity of water	1	Electronics shop	
Water level Sensor	To measure the water level in the tank	1	Electronics shop	
Temperature Sensor	To measure water temperature	1	Electronics shop	
Jumpers	To complete the wiring of electronic components	30	Electronics shop	
Arduino Mega	To connect the sensors together and control them automatically	1	Electronics shop	
Solar panel	To charge the batteries	1	Electronics shop	
Cellulose	To purify water from impurities and reduce pH	---------------------------------	Environment	
Gravel	To purify water from salts and remove impurities	---------------------------------	Environment	
Sand	To purify water from salts and remove impurities	---------------------------------	Environment	
Limestone	To purify water from salts and remove impurities	---------------------------------	Environment	
Zeolite	To purify water from salts and remove impurities	---------------------------------	Environment	
Activated Carbon	To purify water from salts and remove impurities	---------------------------------	Old water filters	
Aluminum rods	To make a filter by electrocoagulation of water	2	Old wires	

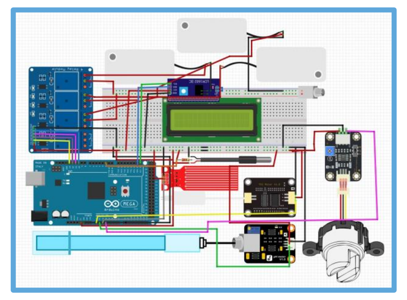
Table(1)

"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 (2).**
- 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.
- 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.

Fig(2):3D model

- 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 and turbidity 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 Arduino mega microcontroller using the breadboard as shown in **figure (3)**
- Obtain a small solar panel and install it above the filter to capture sunlight then convert it to electric energy to charge the battery.
- To complete the prototype and make it ready for testing, collect all these parts and install them in the stand



Fig(3):Arduino circuit

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. and sensor is calibrated by using lab device

D. PH: PH is measured directly by using PH sensor and sensor is calibrated by using lab device

E. Turbidity: turbidity is measured directly by using turbidity sensor**.**

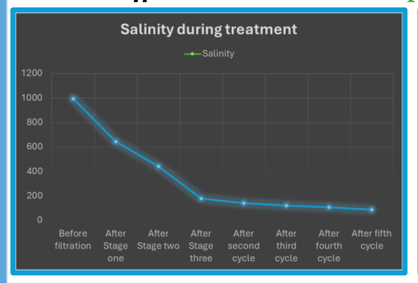
F. Temperature: temperature is measured directly by using temperature sensor**.**

RESULTS

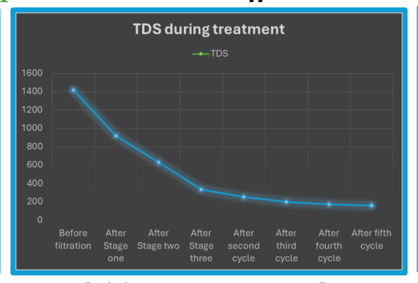
The Negative results:

- **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

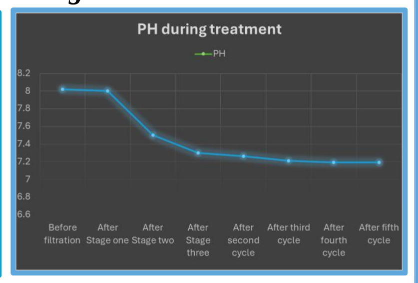
These difficulties led to various positive results and other valuable insight.



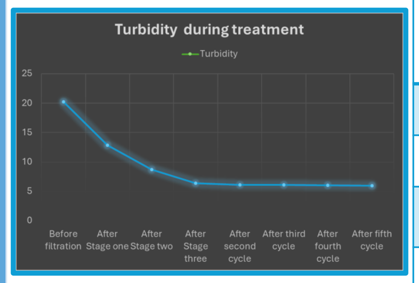
Graph(2):salinity readings by TDS sensor



Graph(3):TDS sensor readings



Graph(4):PH sensor readings



Graph(5):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(2) Calibration of sensors

	TDS	PH	Turbidity	Salinity
Before filtration	1420±2.33%	8.02±1.1%	20.24ntu	994ppm±2.33%
After stage one	920ppm±2.33%	8.00±1.1%	12.88ntu	644ppm±2.33%
After stage two	633ppm±2.33%	7.5±1.1%	8.71ntu	443ppm±2.33%
After third stage (After first cycle)	335ppm±2.33%	7.3±1.1%	6.42ntu	234ppm±2.33%
After second cycle	256ppm±2.33%	7.26±1.1%	6.13ntu	179ppm±2.33%
After third cycle	202ppm±2.33%	7.21±1.1%	6.09ntu	141ppm±2.33%
After fourth cycle	175ppm±2.33%	7.19±1.1%	6.02ntu	122ppm±2.33%
After fifth cycle	160ppm±2.33%	7.19±1.1%	6ntu	112ppm±2.33%
Efficiency	89%	81%	70%	89%

Table(3) sensors readings

ANALYSIS

The primary goal of the project is to transform aagri 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 evaluated 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(1):

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(5):

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 $\mathrm{Al}\,(s) \rightarrow \mathrm{Al}^{3+} + 3e^-$

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)

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

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.

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(5)

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 minimum point and it increase dramatically beginning of the second cycle that is because the number of ppm filtrate from water that are increase while the time passed. So, the efficiency will be75% in first cycle and It will be decrease over cycles. The total efficiency of all cycles is 89%

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

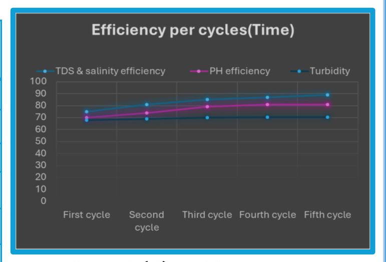
Law(1)

Calculation of power:

consume 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=25.65 W

Component	Quantity	Voltage (V)	Current (A)	Power (W/unit)	Total Power (W)
Water Pump	2	12	0.5	6.0	12.0
pH Sensor	1	5	0.01	0.05	0.05
TDS Sensor	1	5	0.02	0.1	0.1
Turbidity Sensor	1	5	0.03	0.15	0.15
Water Level Sensor	1	5	0.01	0.05	0.05
Temperature Sensor	1	5	0.01	0.05	0.05
Arduino Mega	1	5	0.25	1.25	1.25
Electrocoagulation	------------	12	1	12	12

Table(4)energy consumction of each element



Graph(6): effecieny per cycles

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

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.

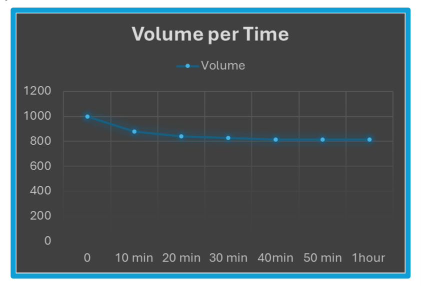
So, current density=7077.14 A/m².

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

Law(3)

Volume of water:

in the test plan that measure the volume(ml) 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 volume lose of one cycle is equal 88% and the efficiency of the five cycles is equal 81%



***Graph(7)*: water volume per time**

Negative result

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)water volume per Stage

LEARNING OUTCOMES:

- **In (Physics)(Concept: 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.
- **In (Chemistry) (Concept: 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.
- **In (Math)(Concept: 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.
- **In (Earth Science) (Concept: 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.

CONCLUSION

The primary objective of this project is to enhance the treatment of agriculture wastewater, addressing a critical environmental challenge. This issue was identified as the central problem to be investigated, analyzed, and simulated through the development of a functional prototype. The experimental results obtained were highly promising, demonstrating the project's capability to effectively utilize and treat wastewater, transforming it into a clean and sustainable alternative water source suitable for agricultural applications. This approach not only promotes water reuse but also provides an eco-friendly and highly efficient solution for managing industrial waste. The project has the potential to bring about a significant and positive change in the field of industrial wastewater treatment. Through thorough analysis, it was confirmed that the design requirements were successfully met. Specifically, the treatment system reduced the total dissolved salts from 994 ppm to 234 ppm in the first cycle and further down to 112 ppm after five cycles. Turbidity decreased from 20.24 NTU to 6.42 NTU in the first cycle and to 6 NTU after five cycles. Additionally, pH levels dropped from 8.02 to 7.3 in the first cycle, reaching 7.19 after five treatment cycles, and it has efficiency=88% for five cycles and 76% for first cycle

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.

LITERATURE CITED

"This work builds on the insights and findings of the studies listed below."

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