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AquaPure

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Abstract

Egypt is facing plenty of challenges that should be solved which are called (Egypt's Grand Challenges). Addressing the grand challenges facing Egypt is essential for its development. This project covers many grand challenges, including the shortage of clean water sources, recycling waste for environmental purposes, a weak agricultural base, and pollution. The overarching focus is on managing and increasing clean water sources through the innovative approach of recycling and purifying wastewater for agricultural use. The chosen solution involves purifying cement factory wastewater, employing a three-step process encompassing Chemical and two physical treatments. The chemical phase removes the turbidity from the water by adding Alum and adding sodium hydroxide to . In the physical phase, Biochar is employed to diminish the total dissolved salts in the water and heavy metals in the wastewater. The second physical phase involves the use of sand and gravel to remove large particles from the water. The project's design requirements stipulated a Salinity Removal, Turbidity removal, and heavy metals.

Test results have shown success in meeting these requirements, by diminishing the salinity from 1986.92(±198.69) ppm to 457.47(±45.75) ppm, and the turbidity from 735(±73.5) NTU to 208.54(±20.85) NTU and the TDS from 1845(±184.5) ppm to 424.79(±42.48) ppm. The prototype was achieved in 70 minutes by 7 cycles. This has demonstrated the project's efficiency in increasing clean water sources for agricultural use in Egypt

Introduction

A world where water disappears exists only in imagination. The nation of Egypt faces many key difficulties that impact its water purification systems and drinking water protection. An escalating demand for clean, hydrated water, together with severe water pollution problems, has made it crucial to develop innovative solutions. The current scenario needs proper utilization of arid regions along with engineering-based support for health and industrialization projects. Electrodialysis stands out as a historical method that effectively lowers water salinity to produce drinkable water of high quality. The filtration systems function effectively for residential and commercial purposes yet require a basic understanding of their benefits and drawbacks, besides scheduled maintenance. The application of activated carbon filters emerges as an established water purification method because they extract both suspended solids and volatile organic compounds (VOCs), together with heavy metals and chloramines, from drinking water. The carbon treatment process creates minuscule pores throughout activated carbon to achieve an enormous adhesion surface area. This technological solution finds its usage in both industrial processing and water treatment facilities. The resolution of Egypt's vital modern challenges needs substantial implementation of modern innovative solutions to build sustainability among future generations. A high-tech storage solution emerges as a solution to handle wastewater generation while helping Egypt overcome major difficulties and fulfill the Sustainable Development Goals. The proposed design solutions received a comprehensive compliance evaluation that is presented in Fig 1. The water purification device, based on its fundamental design, purifies cement plant water so plants can receive irrigation water through alum combined with biochar, coupled with sand and gravel. The turbidity and TDS sensors provide exact readings to measure these parameters.



Fig (1): Grand challenges

In addition, the materials used in the process of prototype construction come from natural resources and waste products to provide environmentally friendly water purification.

Materials

Picture	Name	Price	Picture	Name	Price	Picture	Name	Price
	Plastic box	100 LE		Biochar	20 LE		Turbidity sensor	500 LE
	Wood	200 LE		Sand	10 LE		TDS sensor	550 LE
	Hose	20 LE		Gravel	15 LE		Relay module	200 LE
	Solenoid valve	210 LE		Alum	25 LE		Adaptor	60 LE
	Water pump	185 LE		Bread board	40 LE		Jumpers	25 LE
	LCD Display 16*2	140 LE		Arduino uno	400 LE		Coton	20 LE
							Total cost	2720 LE

Table (1): Table of materials

Methods

While constructing the prototype, shown in Fig. (2), safety protocols were strictly followed. Gloves, masks, and coats were worn to prevent harm during the process.

The work was conducted in a safe and suitable environment using appropriate tools under the supervision of lab teachers

The process starts by collecting the materials necessary for the construction.

The prototype incorporated rice husk ashes, alum (XAl(SO₄)₂ · 12H₂O), sodium hydroxide (NaOH) and sand with gravel. Four rectangular wooden columns that are 90 cm tall and width of 3 cm are used as a foundation of the prototype, four square wooden bases that have a length of 30 cm are used to hold the stages of the prototype, and five plastic jars that contain the materials of the stages, are connected by pipes across the four wooden bases.

Sensors monitored the water before and after the filtration process from substances that we will filter out, which include salinity, turbidity, and heavy metals (TDS), while solenoid valves ensured precise opening and closing of the stages. The water pump is used as a lifter for the water that carries water up after the filtration process ends, to repeat the cycle. Also, the first jar will contain the sensor so it can also monitor the water after each cycle ends. All the sensors connected to Arduino uno which control the whole system.

Two holes were made in the first jar that is in the first base, and it also contains the sensors, the two holes were connected to solenoid valves, the first hole is the entrance for the water to the stages and the second hole is the output for the filtrated water to the final jar that contain the filtrated water only.

Then, the treatment of the waste material (rice husks) to produce biochar.

The biochar was prepared: 500 grams of rice husks were subjected to a high temperature of 600-700°C, then dried to a weight of about 200 grams of dried rice husks then the dried rice husks put in the water to decrease its turbidity as shown in fig (3). Sand and gravel were mixed in a ratio of 2:1 (400g of sand to 200g of gravel), washed with water to get rid of any large particles, it and stirred magnetically for 13 minutes.

Calibration of sensors was done using samples that have been tested first by the chemistry lab instruments. After getting the results from the instruments, voltage reading of sensors is recorded for each sample then coded to read correctly.

The first jar was designed as a tank for polluted water, equipped with a TDS and turbidity sensor to calculate the initial pollution concentration, connecting with two solenoids valve that are considered as gates, the first of which opens for polluted water to enter the stages. The second gate is open for the filtered water to the empty jar for storage.

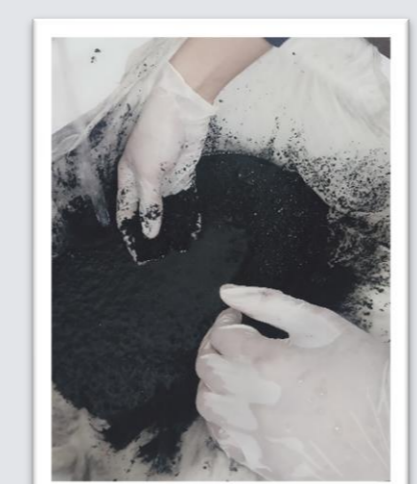
The second jar contains the biochar and another solenoid valve that lets the water move to the other stage.

The third jar contains alum mixed with sodium hydroxide (NaOH) to neutralize and decrease its salinity the water and another solenoid valve to make the water move, through to the next stage.

The fourth stage contains sand with gravel and a layer of cotton, and a pipe that makes the water flow through. The last jar contains the water pump that lifts the water to the first stage and starts the cycle again and again. After that we make sure our prototype achieved the design requirement: The wastewater should have a salinity > threshold value ~ 500 ppm (at least 1000 ppm). The collected wastewater sample must be in enough quantity to be recycled and for the step of data collection. 1. The prototype must include an automatic two-way gate 2. The wastewater should be treated using natural or processed recycled materials.



Fig (2): The prototype



Fig(3): Washing of the biochar

Results

After testing the prototype, we started to record the results in tables (2), (3), and (4), as they show the turbidity, salinity, and heavy particles before and after the filtration in the seven cycles. Each cycle takes 10 minutes to filter about 1500 ml, and after the seven cycles the water was about 1350 ml as each stage consumes amount of water, and the total time that the seven cycles take 70 minutes. After the Calculation of the energy that our project used to filter 1500 ml in the seven cycles, we found that 9240 joules were used. We start to weigh the prototype to find if it is portable or not, and its weight is about 15 kg. We started to test the project's closed system by moving water through it more than once, and we also tested the automatic system, and we found that it works without an interfilter.

Cycles	TDS in (ppm) before the filtration process	TDS in (ppm) after the filtration process	Cycles	Turbidity in (NTU) before the filtration process	Turbidity in (NTU) after the filtration process
1 st	1845 (±184.5) ppm	1217.7 (±121.7) ppm	1 st	735 (±73.5) NTU	492.45 (±49.24) NTU
2 nd	1217.7 (±121.7) ppm	876.74 (±87.67) ppm	2 nd	492.45 (±49.2) NTU	359.49 (±35.95) NTU
3 rd	876.74 (±87.67) ppm	666.32 (±66.63) ppm	3 rd	359.49 (±35.95) NTU	294.74 (±29.47) NTU
4 th	666.32 (±66.63) ppm	546.38 (±54.64) ppm	4 th	294.74 (±29.47) NTU	259.37 (±25.93) NTU
5 th	546.38 (±54.64) ppm	480.819 (±48.08) ppm	5 th	259.37 (±25.93) NTU	236.02 (±23.60) NTU
6 th	480.81 (±48.08) ppm	447.15 (±44.72) ppm	6 th	236.02 (±23.60) NTU	219.50 (±21.95) NTU
7 th	447.15 (±44.72) ppm	424.79 (±42.48) ppm	7 th	219.50 (±21.95) NTU	208.54 (±20.85) NTU

Table (2): The concentration of the TDS before and after purification.

Cycles	Salinity in (ppm) before the filtration process	Salinity in (ppm) after the filtration process
1 st	1986.92 (±198.69) ppm	1311.37 (±131.14) ppm
2 nd	1311.37 (±131.14) ppm	944.18 (±94.42) ppm
3 rd	944.18 (±94.42) ppm	717.58 (±71.76) ppm
4 th	717.58 (±71.76) ppm	588.41 (±58.84) ppm
5 th	588.41 (±58.84) ppm	517.80 (±51.78) ppm
6 th	517.80 (±51.78) ppm	481.55 (±48.16) ppm
7 th	481.55 (±48.16) ppm	457.47 (±45.75) ppm

Table (3): The concentration of the turbidity before and after filtration.

Cycles	Salinity in (ppm) before the filtration process	Salinity in (ppm) after the filtration process
1 st	1986.92 (±198.69) ppm	1311.37 (±131.14) ppm
2 nd	1311.37 (±131.14) ppm	944.18 (±94.42) ppm
3 rd	944.18 (±94.42) ppm	717.58 (±71.76) ppm
4 th	717.58 (±71.76) ppm	588.41 (±58.84) ppm
5 th	588.41 (±58.84) ppm	517.80 (±51.78) ppm
6 th	517.80 (±51.78) ppm	481.55 (±48.16) ppm
7 th	481.55 (±48.16) ppm	457.47 (±45.75) ppm

Table (4): The concentration of the salinity before and after purification.

Analysis

The wastewater produced in cement industries poses a serious environmental challenge owing to elevated concentrations of turbidity, salinity, and heavy metals. Egypt suffers from a large freshwater deficit, alongside rampant pollution, meaning that the country requires efficient solutions for wastewater treatment, reclamation, and repurposing for agricultural purposes. To this end, the proposed project is an automated multi-stage water purification system designed to be constructed with basic tools.

Scientific Base

The cement wastewater treatment plant's sections treating supernatant and sediment water employ a water purification system that integrates physical adsorption, chemical reactions, filters, and selective adsorption techniques.

1. Treatment of Chemicals – Coagulation of Alum

Alum Horn's (Aluminum Sulfate) is applied as a coagulant: Coagulation of suspended negatively charged particles, which include cement dust and fine solids. Removes particles (flocculation) and settles out, aka turbidity, in a large amount. This reaction is represented chemically as $Al_2(SO_4)_3 + 6H_2O \rightarrow 2Al(OH)_3 \downarrow + 3H_2SO_4$

2. Physical Treatment – Filtration Layers

Biochar Filtration:

Biochar is a porous, carbon-laden substance procured from biological materials. Efficiency of contaminant removal leads to a better caliber of water and declines TDS (total dissolved solids), salinity, and tough salts, defined substances with a high atomic weight, such as lead and arsenic.

Sand and Gravel Filtration:

Banishes big sediment particles and renders coarse physical clarification. As probiotic filters with multi-layer supports, they serve as 'old-school' and trustworthy DIY solutions yielding enhanced filtration, but not alone.

Sensor's calibration

TDS sensor:

we start calibrating on the TDS sensor with two samples. The first sample had 625 ppm with (1.5 voltage and 237 raw). The second sample had 1524 ppm with (2.6 voltage and 368 raw). After that, we calculated the slope of the TDS sensor graph by the equation:

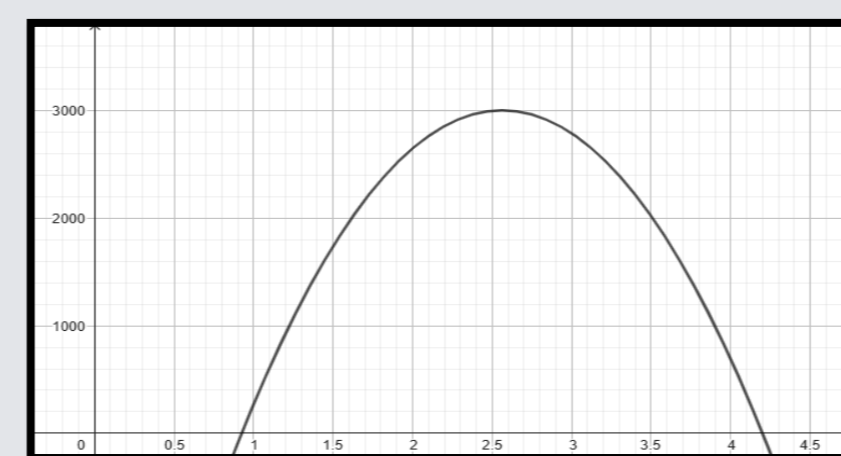
$$ppm(2) - ppm(1) \text{ So, the slope of the two samples was } 817.3. \text{ For the general formula } y = mx + b$$

We deduce that the change in the voltage will make a change in the TDS sensor readings. So, we

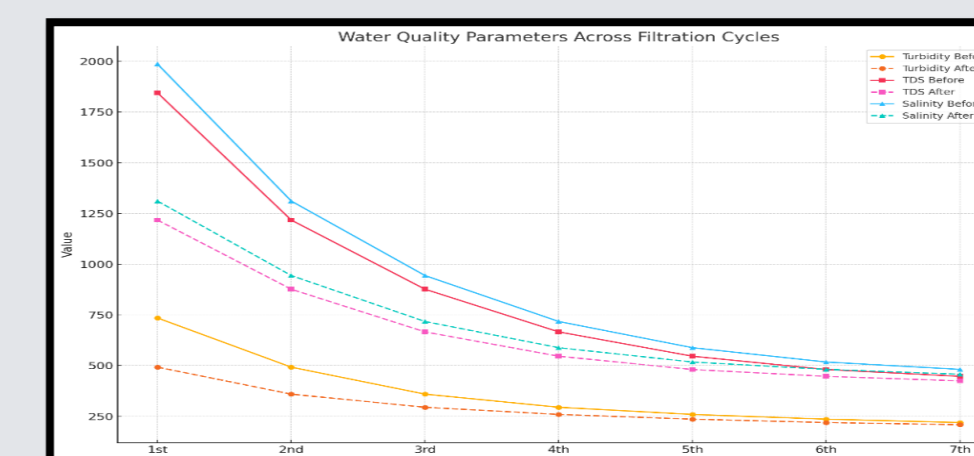
can convert from TDS to conductivity by the equation $Ec (\mu S/cm) = TDS (ppm) / K$, the K is equal to 0.65, which is the empirical conversion factor for mixed dissolved soiled. to convert from the conductivity to salinity, we use the equation $Salinity (ppm) = 0.7 * Ec (\mu S/cm)$

Turbidity SENSOR

we use an equation $y = -1120.4 * \sqrt{x} + 5742.3 * x - 4352.9$, where we compute the value of y, which is (NTU), by the value of the voltage, which is the output of the sensor. Which the the equation from a library that is called DTH_Turbidity, and to verify that the results that is exit from the equation are accurate, we tried the voltages for the voltages of known samples, and as shown in graph (1) it shows all of this and in graph (2) it shows the decreasing the concentration of the parameters from first cycle to the last cycle.



Graph (1): presentation of the turbidity equation



Graph (2): decreasing the parameter from first cycle to the last cycle

Energy consumption

The prototype energy consumption system is low because it is designed to work with basic power needs, which makes it usable in power-scarce rural regions. Its energy consumption is very effective due to the specificity of the passive nature filtration components. Energy consumption for this system during the entire treatment cycle process is 9240 joules, and this is calculated by the equation energy = current * voltage * time, while the water yields 1500 ml. and an adaptor of 11 amperes. In comparison to industrial models, which use anywhere from 1000 to 5000 joules per liter, this model is significantly more effective. With this system, over the course of 7 treatment cycles, the energy consumption rate improves.

We also calculate the efficiency of the prototype every cycle and put it in the table as shown in the table (5)

Parameters	TDS	Turbidity	Salinity
Efficiency of the first cycle	34%	33%	34%
Efficiency of the second cycle	28%	27%	25%
Efficiency of the third cycle	24%	18%	22%
Efficiency of the fourth cycle	18%	12%	17%
Efficiency of the fifth cycle	12%	9%	11%
Efficiency of the sixth cycle	7%	6%	8%
Efficiency of the seventh cycle	5%	5%	4%

Table (5): The efficiency of the TDS, Turbidity and Salinity through seven cycles

Ph.2.08	Electromagnetic principles like Faraday's Law are applied to power pumps and sensors that monitor water quality. This ensures efficient energy use, as electromagnetic induction regulates pump operation based on real-time data.
Ch.2.08	electrochemical principles are applied in electrocoagulation and electrooxidation to achieve higher efficiency in the removal of contaminants.
Bio.2.08	Biological systems, like the human reproductive system, rely on feedback loops to maintain balance and function properly, like how our wastewater treatment system uses sensors and automated controls.
ES.2.09	Geochemical cycles, which involve natural processes that filter water through minerals and rocks, are like the physical treatment processes in our wastewater system.
Mech.2.05	Automated systems like sensors and gates also require power to function. Tracking their energy use is essential to ensure the system filters water with minimal energy waste.

Conclusion

From the result and test plan, we found that our water treatment prototype successfully met the design requirements. The system organizes heavy particles (TDS) levels, effectively reduces turbidity, and lowers salinity, making the water safer and more suitable for use. This was completed using low-cost, locally available materials, including alum, sodium hydroxide (NaOH), biochar, sand, and gravel.

Our project directly addresses one of Egypt's grand challenges, providing access to clean and safe water, espionage in areas suffering from water pollution and confined treatment infrastructure.

Our revelation came from traditional multi-layer filtration systems that use sand and gravel; however, we improved the designs by adding:

- Alum to help solve suspended particles.
- Biochar to help in modifying salinity.

Compared to conventional methods, our prototype is:

- More efficient at removing pollution.
- More environmentally friendly, using sustainable and locally sourced materials
- And more attainable for rural or low-income communities

Recommendation

After building, constraining the prototype, and searching for Egypt's grand challenge, we recommend that anyone who will do the prototype in real life do the following:

A new biological stage can be introduced by employing beneficial microorganisms to naturally eliminate toxic substances like nitrogen and ammonia. As a result, the system is more environmentally friendly, and agricultural water quality is improved.

Titanium dioxide (TiO₂) can be used as a photocatalyst by aggregating tiny particles in wastewater to improve the coagulation process. This will enhance the removal of suspended materials, resulting in cleaner water prior to subsequent stages of treatment.

By employing centrifugal force to remove solid particles from wastewater, a decanter centrifuge can enhance the water's quality and suitability for additional treatment.

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