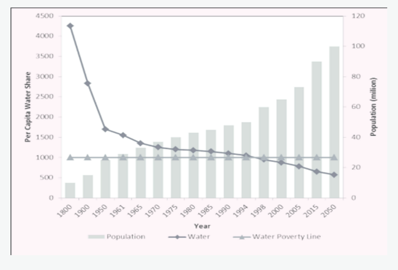
Abstract

Egypt's plans to achieve independence and prosperity are in danger due to the major challenges it must overcome. One of these grand challenges is the "lack of water sources", which means that with increasing the percentage of the population the amount of water used for domestic use decreases. So, the problem the project attempts to solve is using water coming from industrial wastes and converting it into clean water. The prototype's target is to get clean water for irrigation uses from the input water which is the wastewater of "pre-treatment for electrostatic powder coating". To make this prototype was made with three phases the first one is to make an electrocoagulation cell, then pass through filter paper. Also getting into some activated carbon by stirring it. After that, it goes through the sand filter to ensure that all impurities are gone completely. This project would be as successful as the maximum with meeting the design requirements, which are having the ph from 6 up to 8, with the TDS in the range from 200 to 500 ppm. Additionally, when doing the prototype for the first time, the results were hardly successful, but with some edits and modifications, the results the second time were enough to meet the design requirements at which the ph was equal to 7.67 and the TDS measurement was 404 ppm. Finally, this project would have an efficiency of not less than 80%.

Introduction

Egypt faces many severe challenges, with different reasons, causing different negative impacts. From these challenges is 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. The United Nations expected that Egypt will run out of water by 2025. Since the population increased to nearly 100 million. From studying graph (1), we observe that population increases by passing time by decreasing the amount of water used. This scarcity of water shown by this graph gave us a promising idea as we can treat water from unwanted materials in it which is the purpose of the study. Managing and increasing sources of clean water for domestic uses was chosen as the problem we should focus on.



Graph (1) shows the relation between population and water used

Searching for some previous solutions to grasp the advantages and disadvantages to learn more about the idea 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 used for irrigation (could be grade B: Cooked and prepared crops and vegetables and Medicinal plants, grade C: non-nutritive seeds, grade D: wooden trees), is for the pH to be between 6 and 8. TDS levels between 200 and 500 ppm. Additionally, for efficiency to be at least 80%. These requirements must be achieved after getting the output water from ending up with the chosen solution, .

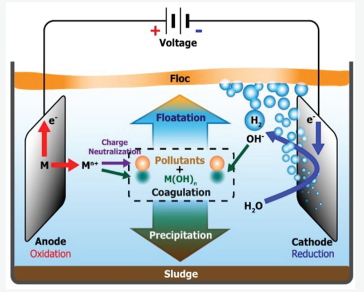


Figure (1) showing the electrocoagulation process

which starts by entering the input water into a beaker containing iron electrodes to make an electrocoagulation cell as shown in figure (1). And continue into a bottle with activated carbon, stirring for about 10 minutes to react completely, then filter it with the sand filter to have the output water. After measuring the results, we got them as wanted. Making this prototype required many materials that will be discussed in the next section

Materials & Methods

Wooden board	Iron sheets	Copper wire	Filter paper	Activated Carbon	Cotton
					
1 board	3 sheets	50 cm	1 paper	15 ml	¼ package
1 board with dimensions (122*244) cm	With dimension each (10*5)	50 cm of copper wire with the radius of 0.5 mm	1 filter paper of type of qualitative 3	15 ml of powdered activated carbon for half liter of water	Used in sand filter

Sand	Gravel	Plastic bottle	Battery	Water valve
				
¼ kg	½ kg	2 bottles	3 batteries	1 valve
Modified sand used in sand filter	Clean gravel with different sizes used in sand filter	Used as a container with a capacity of 1 liter	3.7-volt batteries connected in a series	The water filter valve used to handle the water flow

Methods:

The prototype consists of more than one part, and it is installed and equipped according to some steps for testing these steps are represented in:

-First, bringing a board of wood and cutting it into pieces and installing them together to make a holder in form of steps in dimensions that are shown in figure (2).

-Second, a plastic container and installing a water filter valve on it with sealing gun wax "as shown in figure (3)".

-Third, fixing the plastic container with the valve in the wooden holder in the first step "as shown in figure (3)"

Figure 2 dimensions of prototype

ELECTRO-SAND TREATMENT

STEM 6th October for boys - Grade 11, 2022/2023

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Key Words:

Electrocoagulation - Electrodes - Activated charcoal - Filter paper - Sand filter

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-Then, bringing iron sheet and cutting it into three pieces with dimensions 5*10 "as shown in figure (4)".

-After that, fixing a battery on the first step of the holder and connecting it with the iron pieces and putting it in the plastic container "as shown in figure (4)".

-Additionally, making a hole in the second step in the holder and bringing a plastic bottle and cutting the bottom of it and fixing it into the hole to put the activated carbon in it and put a funnel with filter paper "as shown in figure (3)".

-Finally, grabbing another plastic bottle and cutting the bottom of it and putting the layers of the sand filter inside it and fixing it on another plastic container for final produced water "as shown in figure (5)".

Figure 3 step two in the prototype

Figure 4 the electrodes and the battery

Figure 5 sand filter and the container of the product

Test plane:

To get the result and ensure that the prototype is going well, there must be a test plan and follow the design requirements as discussed before, which are having a Ph range from 6 up to 8, and TDS from 200 to 500 ppm. Also, to an efficiency of not less than 80%. This project's prototype also lasted for 3.5 hours to see the results. TDS, PH, and efficiency measurements affect the outcomes. The electrocoagulation procedure took the input water 1.5 hours. Use the filter paper for an additional 45 minutes, followed by the activated carbon for 15 minutes, and finally the sand filter for an additional 30 minutes. The database shown in the next section was built using the data that was gathered.

Results

The first trial of the prototype was a negative result since the chosen treatment to be chemical treatment was to use a polymer material "chitosan" to make a process called "polymerization" and "flocculation" for impurities and minerals in water but, this polymer was not soluble in our water so, we could not do this treatment.

After performing the process, samples of polluted water and the water obtained after the process modification are tested by measuring its pH, TDS, TSS, COD, BOD, Turbidity and hardness to ensure the success of the project and meeting the results with the design requirements and the ability of water to be reused again in agriculture and irrigation usages. The results were as follows tables:

Input water	Output water	Efficiency
500 ml	400 ml	80%
1000 ml	840 ml	84%
800 ml	625 ml	78%
Avg.		81%

	Initial	Final	Efficiency
PH	7.8	7.6	
TDS	3352 ppm	404 ppm	87.79%

And to ensure that the product water will be usable for irrigation the results of TSS, COD, BOD, Turbidity and hardness are in the following table:

TSS	COD	BOD	Turbidity	EC	Hardness
9.3 ppm	14 ppm	8.78 ppm	5.4 ntu	0.63 dc/m	174 ppm

Analysis

The primary goal of the project is to transform industrial wastewater into clean water that can be used for irrigation in order 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.

During the electrocoagulation process, using iron electrodes coupled to a DC power source, coagulants are created electrically.

The mechanism of electrocoagulation:

the electrochemical cell that houses the electrodes and is coupled to an external current source makes up the electrocoagulation unit. By dissolving the anode material, coagulants, or metal ions, are produced in vitro analysis. By dissolving the anode material as in the equation: $M_{(s)}$ M^{n+}_{aq} + ne On the other side, as shown in figure (6) the hydrolysis process takes place at the cathode, where water is converted to hydroxide and hydrogen gas is discharged into the air as bubbles. (As in the below equation) 3H2O + 3e 3/2 H2 (g) + 3OH (aq)

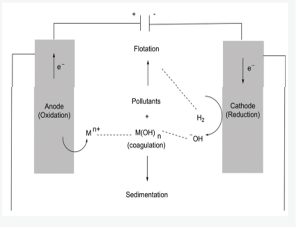

figure 6 mechanism of electrocoagulation

Water is reduced on the cathode in a reaction that produces hydroxyl ions and hydrogen gas as a by-product. 4H2O+ 4e + 2H2(g) + 4HO-(aq)

Water oxidation is the reaction that occurs on the anode, with the equation

H2O 4H+(aq) + O2(g) + 4e-

iron is also preferred over other metals, including iron since its buffer action causes the solution's pH to be stabilised 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 (TSS and TDS), turbidity, and colour, iron is also much more effective than other metals.

Due to the creation of polyvalent ions and numerous hydrolysis products that depend on the pH of the solution as well as the potential for generating polynuclear complexes, iron is most frequently utilised to manufacture anodes. As a result, the effectiveness of electrocoagulation is greatly influenced by the pH of the solution. The equation can be used to represent the hydrolysis reaction. M3+ Me (OH)2+ Me (OH)+2 Me (OH)3 Me (OH)-4

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. Faraday's law can be used to describe the connection between current density and the quantity of produced ions. "W = j * t * m/n. F" w is where the amount of electrode material that dissolves (g cm-2), t is the duration of electrolysis (s), j is the applied current density (mA cm-2), m is the relative molar mass of the electrode from which the electrode was made (g mol-1), n is the number of exchanged electrons in the reaction and F is Faraday's constant (96 500 C mol-1)

Inter-electrode distance:

Another crucial element in the electrocoagulation process is the distance between the electrodes. The produced ions will move more slowly the farther apart the cathode and anode are. The produced ions have more time to form flocs and coagulate contaminants because of the slower flow. The effectiveness of the process decreases as the distance is increased over the ideal amount because it slows down the breakdown of the anode material and extends the distance over which the ions must travel to produce flocs.

The conductivity of the treated water will also affect how effective the electrocoagulation procedure is. The relationship between the electrical conductivity and the distance between the electrodes is straightforward. Equation illustrates how the resistance of the cell increases as the distance between the cathode and the anode increases. "R= d/kA" where d is the inter-electrode distance (cm), R is the resistance of the cell (Ω), κ is the specific conductivity (S cm-1) and A is the electrode surface area (cm2). With a reduction in resistance, the current will increase. As a result, the number of ions generated, and the effectiveness of the electrocoagulation process will both increase to avoid spilling water from the container or having the filtering process slowed down or impeded by the intense pressure exerted from the top due to the heavyweight, the flow rate of water through filter should be sufficient.

For the filter, porous and permeable materials were used (as learned in Learning outcome 2.03 in Geology). One of these materials is the filter paper.

Filter paper:

It is preferred to use a 3 qualitative cellulose filter paper with a poor size of 6µm in the prototype, to filter most of the participated dirt and pollutants collected after the process of electrocoagulation. After treating water with activated carbon, this pore size was preferred for chosen. This is the best size to use for the process because a 3 qualitative is twice as thick as a 1 qualitative, it has greater wet strength and can hold more precipitation without clogging. A 3 qualitative cellulose is a good choice for sample transfer following collection because of its high absorbency. This size depends on gravity only. A 1 qualitative cellulose may need a water pump to make the water flow because it is scalable to clogging.

To determine the proper flow rate of water through the filter and avoid crowding, the flow rate was also measured. The flow rate's equation is R=V/T where R is the flow rate, V is the volume that has flowed through the sand filter, and T is the time through which the volume has flowed.

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'. Wastes with a high carbon content are used to make activated carbon. For the production of activated carbons, lignocellulose and coal materials have been used as raw materials. Physical activation and chemical activation are the two methods for producing activated carbon that can be used in water filtration systems. 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. This is the way molecules, atoms, or ions attach to the activated carbon particles' surface.

At last, after the activated carbon stage, we put the water in a water filter called a "sand filter" made of sand, gravel, and cotton is constructed.

Sand filter:

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

The second layer is the sand layer. Sand uses mechanical straining as shown in figure(7) to hold particles within its pores, allowing only the waer to pass through this layer. The sand serves as the natural filter's second layer, removing turbidity, pathogens, and suspended particles from water. It also has a 40% porosity, which is the same as its permeability. The third one is small-sized gravel and large-sized gravel. make up the topmost strata, where the final stage of the filtration process took place. Gravel plays a crucial role in preventing the loss of filter sand during filtering.

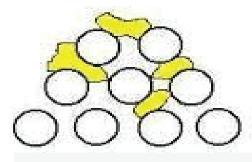

figure 7 mechanical straining

Measurements

The project aims to remove as many pollutants from the water as possible before using it. As a result, it must use the molarity equation to compute the concentration of the pollutants before and after the change (as in LO2.01 in Chemistry): M = n/v where M is the Molarity of the solution, n is the number of moles of the solute and V is the volume of the solution. The concentration formula can be used to calculate TDS and TSS.

Relation between TSS and turbidity:

A substitute for TSS, turbidity enables quick automated analysis of batches of samples. A log-linear model with the regression equation [ln (TSS)=0.979 ln (Turb.) +0.574] demonstrates a high positive association between TSS and turbidity (R2=0.9374). To calculate the TSS, this model can be simply applied to the findings of a turbidity analysis.

Salinity measurement (EC) and unit conversion

Electrical conductivity is a common way to test the salinity of soil and water (EC). Deci Siemens per meter (dS/m) and millimho per centimeter (mmho/cm) are the two most widely used EC units. 1 dS/m = 1 mmho/cm. Simple relationships are used to convert EC to TDS, or vice Versa:

TDS (mg/L or ppm) = EC (dS/m) x 640 (EC from 0.1 to 5 dS/m)

To determine COD, use the formula below:

COD = 8000 (b – s) n / sample volume

where s is the amount of FAS in the original sample, b is the number of FAS utilized in the blank sample, and n is the FAS normality. If volume measurements are regularly made in milliliters, the COD calculation's outcome is displayed in mg/L.

Efficiency measurement:

The general law to measure the efficiency is [(output/input) * 100] then to measure the efficiency of the prototype from point of water volume is calculated using [(volume of product water "output" / volume of initial water "input") * 100] and to measure the efficiency of the prototype from point of pollution removal [((initial TDS – final TDS) "output") / (initial TDS "input") * 100]

It should measure the power used in the entire procedure to identify the energy used at a time, as well as the price of the electricity. The power equation is P = VI. Where P is the power in watt. V is the voltage of the power supply, and I is the current intensity (as known in LO2.03 in Physics)

Conclusion

Finally, the project aims to increase the treatment of industrial wastewater which was the specific problem that should be investigated and simulated in the prototype. The results were promising, and the project proved its ability to utilize wastewater and convert it into a clean alternative water source used for laundry, making an eco-friendly and highly efficient solution. The project will make a significant change in the field of industrial wastewater treatment. So, the analysis shows that the project achieved the design requirement which is maintaining a pH reading between 6 and 8 and to minimize the amount of total dissolved substances in the treated water.

Recomendation

For sure, any project solving a specific problem able to modify to be more efficient. The prototype could use to help with the water produced per year. Therefore, there are some recommendations to let the project more effective when it is used in real life for both the design and the location.

In fact, this project is both affordable and simple and should encourage its widespread implementation in Egypt's industrial in industrial area on 6th October. Therefore, using this method for real-world companies results in greater cost savings than money lost due to extensive wastewater.

Garnet sand figure 8:

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 of their high specific gravity of 4.0 and exceptional abrasion and chemical resistance. Additionally, 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.

figure 8 granet sand

Solar pannel figure 9:

It recommended using solar panels instead of power supply because it is renewable and did not use electrical energy. If it uses, it will produce more eco-friendly energy and make the process quick. The problem with using this solar panel is that it is expensive compared to the power supply

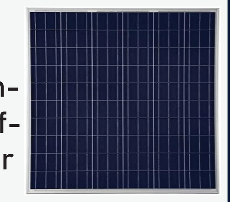

figure 9 solar pannel

DI system figure 10:

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.

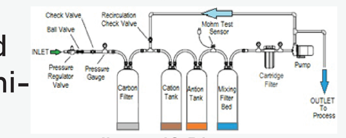

figure 10 DI system mechanisem

Literature Cited

Jovanović, T., Velinov, N., Petrović, M., Najdanović, S., Bojić, D., Radović, M., & Bojić, A. (2021). Mechanism of the electrocoagulation process and its application for treatment of wastewater: A review. Advanced Technologies, 10(1), 63–72. https://doi.org/10.5937/savteh2101063j

Li, W., Liang, X., Duan, J., Beecham, S., & Mulcahy, D. (2018). Influence of spent filter backwash water recycling on pesticide removal in a conventional drinking water treatment process. Environmental Science:

Water Research &Amp; Technology, 4(7), 1057–1067. https://doi.org/10.1039/c7ew00530j

Water Treatment using Chemically Activated Charcoal. (2020). Journal of Science and Technology, 5(3), 72–78. https://doi.org/10.46243/jst.2020.v5.i3.pp72-78

Zumdahl, S. S., & Zumdahl, S. A. (2013). Chemistry (9th ed.). Cengage Learning.

Arias-Paic, M., Cawley, K. M., Byg, S., & Rosario-Ortiz, F. L. (2016). Enhanced DOC removal using anion and cation ion exchange resins. Water Research, 88, 981–989. https://doi.org/10.1016/j.watres.2015.11.019

Acknowledgement

First of all, and before anyone, we must thank God for guiding and helping us throughout the project from scratch we would like to give the humble thanks for the incredible effort those people had made to aid us in our work and those people are: Mr. Hesham Abdel-Razek (capstone supervisor in STEM unit), Mr. Mohamed bekhet (Capstone leader of STEM 6th of October school),Mrs. samia (chemistry teacher), Mr. Salah Abdel-Sattar (physics teacher)