Coco-vera filter

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Abstract

Egypt's water pollution is a crucial challenge that must be solved. Water pollution puts our health in danger. Unsafe water kills more people each year than wars and all other types of violence combined. By 2050, worldwide demand for freshwater is predicted to be one-third more than it is now. To solve these problems, a three-stage filter was built: coconut husks with eggshells, aloe vera, and biosand. They decrease turbidity, TDS, and PH. Using valves and Arduino to make a closed system that works automatically with sensors. This prototype must achieve some design requirements. The salinity level should be 500 PPM, PH in the range of 6.5 To 7.5, and the turbidity should be less than 10 NTU. The rate must be 250 ml in 10 minutes. The efficiency must not be decreased by more than 5% after 5 cycles of filtration. The power consumed must be less than 35 W. After some modifications, the success of the solution was proven by the reduction of salinity from 2043 to 392 PPM, the PH decreased to 7.2, the turbidity decreased to 7.3 NTU, and the rate was successfully determined by 250 ml in 5 minutes. The efficiency was decreased by 1.48 % after 5 filtration processes. The power consumption was determined by 30.5 W, ensuring a suitable medium for fish to live in. After testing the prototype, some conclusions were drawn, including that by increasing the surface area of the eggshells, the efficiency of adsorbing heavy metals increases.

Keywords: *Adsorption, Biosand, Coagulation, Fish farms, Textile wastewater, Valves*

Introduction

Water pollution puts our health in danger. Unsafe water kills more people each year than wars and all other types of violence combined. At the same time, less than 1% of the Earth's freshwater is accessible. Furthermore, the lack of clean sources results in many countries and people around the world drinking dirty water. In arid areas, the sun's rays go directly to the land, causing it to be extremely hot, which is dangerous for a lot of people and death so easily**.** ***(Robinson, 2022)***

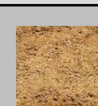
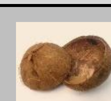
There were many prior solutions applied by different countries that tried to tackle these problems. The first prior solution is **ceramic filters**, which purify water from pathogens and turbidity from wastewater sources. The filter purifies water by first making it pass through the ceramic's pores (0.6-1.3 microns), which physically block. After that, the water passes through colloidal silver, where the bacterial cell membranes ensure residual protection against recontamination. The filtered water is collected below in food-grade plastic buckets. These filters are good for pathogen removal and sustainability, but there is no heavy metal removal. It is not efficient in purifying arsenic, lead, or fluoride, which are important in adjusting the salinity, which is a crucial parameter. ***(Yang et al., 2020)*** **Ferric chloride ($FeCl3$)** filter is a way that uses coagulation to filter water as when it is added to water it breaks down into positive iron ions, As these ions interact with negatively charged particles such as dirt or organic materials it can make them clump together to unite with them completing with this the coagulation process, while these particles clump together they form flocs. Since they are larger, they are easier to remove using filtration. But it needs a high dose to work as efficiently as wanted and to get high results when used in treating water, as it needs at least 15mg/L, which is very high compared to other coagulants. ***(Ebrahimi et al., 2017)***

The selected solution involves using three natural layers, each working on a specific wastewater parameter. The first layer is a composition of coconut husks and eggshell powder. The second layer is coagulation by aloe vera gel. The last layer is the biofilm layer, a biological treatment that depends on the bacteria formed in wet sand. It works on the PH level and adjusts the turbidity of wastewater. The prototype should achieve the following requirements. The salinity level should be under 500

PPM, PH in the range of 6.5 TO 7.5, and the turbidity should be less than 10 NTU, which are the parameters of water that fish can live in. The rate must be 250 ml in 10 minutes using the pump. The efficiency must not be decreased by more than 5% after 5 cycles of filtration to ensure the sustainability of the prototype. The energy consumed must be 30 J per second.

Table 1:

Materials

Items	Quantity	Usage	Price	Source	Picture
Eggshell	2 grams	Adsorption stage	Free	Restaurant	
Aloe vera gel	150 grams	Coagulation stage	Free	Cactus	
Sand	120 grams	Biological stage	30 L.E	Natural resources	
Gravel	120 grams	Biological stage	Free	Natural resources	
Coconut husks	100 grams	Adsorption stage	Free	Coconut	
TDS sensor	1 piece	Measure salinity	500 L. E	Electronics store	
Arduino nano	1 piece	Control the system	450 L.E	Electronics store	
Turbidity sensor	1 piece	Measure turbidity	500 L.E	Electronics store	
PH sensor	1 piece	Measure PH	1400 L.E	Electronics store	
Mini water pump	1 piece	Pump water into the system	Free	Previously owned	

solenoid valve	2 pieces	Regulate the flow of water	450 L.E	Electronics store	
Stand	1 piece	To stand the system	Free	Recycled	
plastic containers	3 pieces	Occupy water	120	Household supplies	
Relay	2 pieces	Increase voltage	200	Electronics store	
Total cost			3650 L.E		

Methods

Start constructing the prototype with the materials indicated in Table 1 while following safety precautions such as donning lab coats and safety gloves. The two primary components of the prototype's construction are the water treatment procedures and the application of the treated water for fish farming.

Our filtration system consists of 3 phases of filtration that target 3 parameters: TDS, Turbidity, and pH.

Figure 1:
Cactus gel

The first step of the construction of the prototype is getting the container of filtration materials. The process starts by getting 2 large water bottles, cutting their base, and putting a fabric layer to cover the neck of the bottle to prevent the components from falling. The two bottles will be put in a vertical position. The top water bottle will include the adsorption and coagulation phase, and the second bottle will contain the biological layer.

The construction of the coagulation phase starts with collecting Aloe vera leaves. Then, the gel should be scooped out from the Aloe vera leaves and collected in a container, as shown in **Figure (1)**. After finishing, the aloe vera gel should be put in the top water bottle container, and a layer of fabric over the aloe vera gel.

Figure 2:
Coconut husks

Figure 3:
Eggshells

After the Coagulation process, the system consists of two adsorption layers: coconut husk and eggshell powder. The absorption phase construction starts with collecting the raw materials, coconut and eggshells. After collecting the coconut husks in addition to eggshells, the process of preparing starts. For coconut husks, the husks should be removed from the coconuts, as shown in **Figure (2)**. Then, leave the husks in water for a day after separating them from each other to cover a large surface area. After a day, the husks will be cleaned well of any remaining waste. Then, the eggshell should be crushed into powder, as shown in **Figure (3)**. After preparing both components, the eggshell powder should be put over the aloe vera gel upper fabric, followed by another fabric layer. Then, the coconut husk over them.

The biological phase consists of bio-sand, which is a gravel-sand combination with standing water for bacterial growth, as shown in **Figure (4)**. The process of preparing it starts with gathering the gravel and sand. Then, make the water bottle in the shape of a standard bio-sand filter (BSF) by making a hole in the top of the bottle and connecting it with a water pipe. Then, the gravel should be put in the water bottle, followed by the sand, and covered with water. In addition, the pipe should be stuck to the body of the bottle to prevent water from falling. Waiting for up to 2 weeks in these conditions for the bacteria to grow. After that, the biological phase is ready for the filtration process.

Figure 4: Biosand

The TDS, turbidity, and pH sensors should be gotten and collaborated. The process of collaboration depended on putting the sensors in distilled water with about zero TDS, 0.1 NTU, and 7 pH while testing them using the following code (GitHub link). Then, they should be put below the filter in the system body. Since the filter will be vertical, a water pump will be brought and connected to a pipe connected to the gate that decides whether the water goes out of the system or continues to another cycle. The gates will be valves connected to the Arduino board, connected to the sensors. With enough distance between them, the system offers enough time for the gates to open for filtered water. The pump will be top of the filter to deliver the unfiltered water.

Test plan

- Energy consumption is calculated depending on the power of the pumps and valves, which is 30 W for the pump. The power of the valves is 0.5 W. That will be measured to ensure that the average power of the system is less than 35W.
- Determining the capacity of the filter every 10 minutes during a period of 1 hour using a graduated container, each 250ml to ensure the rate of filtration is more than 250ml every 10 min.
- The three parameters will be measured using sensors present in the graduated container at the 1.5 L container after passing the two filtration containers.
- At the end, the process of filtration should be repeated 5 times with testing the parameters to ensure that the filtration efficiency has not reduced by 5% or more.

Results

Table 2:
Trials comparing

Trial number	Trial outcome and explanation
1st	Negative The capacity of the filtration during the period of 10 min was less than required. That is because the size of the container was too small, which prevented the filter from working well, and it was mostly filled with bio-sand, which prevented the flow of water. So, it didn't pass the process of testing parameters.
2nd	Negative The level of turbidity and salinity was greater than the normal range of 500 ppm and 10NTU. That was because of putting the aloe vera in the first stage, which decreased the coagulation, leading to the high concentration of heavy metals and other particles, along with not adding the coconut along with eggshells, which resulted in a decreased adsorption ability. So, it didn't pass to following testing stages
3rd	Positive The trail has followed all stages of the test plan and could achieve all the design requirements

Table 3:
Capacity comparison (ml)

Time (min)	Trial 1	Trial 2	Trial 3
5	93.5	278.6	268.2
10	174.2	542.9	539.2
15	247.3	791.3	803.6
20	325.1	1012.5	1017.8
25	410.7	1222.9	1236.1
30	503.5	1365.4	1367.8
35	596.1	1448.7	1451.3
40	688	1500	1500
45	782.4	1500	1500
50	879.2	1500	1500
55	987.1	1500	1500
60	1147	1500	1500
Average rate	95.77273 ml	195.0167 ml	197.1833 ml

Table 4:
Parameters comparison

Parameters	TDS (ppm)	Turbidity (NTU)	Acidity (pH)	Cycles
Trail 2	2043	147	11.2	0
	1518	89	9.6	1
	1187	62	8.7	2
	937	41	8.1	3
	763	26	7.4	4
	681	17	7.2	5
Trail 3	2043	147	11.2	0
	1438	76	9.5	1
	1038	47	8.7	2
	784	23	8	3
	489	9	7.2	4
	392	7.3	7.1	5

Table 5:
Efficiency changes in the third tr ial

Efficiency changes per cycle	1	2	3	4	5
Trail 3	0%	0.57%	1.40%	1.26%	1.37%

Table 6:
Power consumption

tools	Voltage	Ampere	power (in watt)	Time used per hour (in sec)
Water pump	220	0.136363636	30	3600
2 valves	12	0.5	6	300
Energy/ hour	109800			
Average power	30.5			

Analysis

The project focuses on targeting the problem of textile wastewater. It targets some parameters that affect water quality, which are the salinity, turbidity, and pH as an indicator of water acidity. These parameters are affected by organic matter, such as dyes and chemicals used in the textile factories, as studied in ***(ES.2.04).***

The utilized filter depends on three techniques of filtration: adsorption, coagulation, and biological treatment**.** Each technique targets one or more of the wastewater parameters. The absorption is the attachment of waste matter to the surface of the adsorbent. In the adsorption process, the coconut husks and eggshells are used to target the salinity, mainly while reducing the turbidity. ***(Sari et al., 2021; Ezz et al., 2023)***. The second technique is coagulation, which is the process of attaching parts to form larger particles. Furthermore, the coagulation process depends on the aloe vera gel that targets the turbidity parameter and reduces the pH of the water ***(CH.2.01)***. The final stage is the biological stage, which will depend on bio sand that targets the pH mainly and reduces the other two parameters. The filtration process depends on the presence of "*Schmutzdecke"* bacteria. The process of bacteria formation depends on the combination of sand and gravel left in standing water for about **2 weeks**. ***(Mohammed & Solumon, 2021)***.

To keep a stable water level in the bio sand container, the system depends on the concept of a U-shaped tube and the pressure. The law of pressure is

$$\boldsymbol{P = \rho g h}$$

Where **P** is the pressure, **ρ** is the density of water, **g** is the gravity, and **h** is the height of the column.

Since the two sides contain water that is the same. Then, the height of the standing water in the biosand container could be specified depending on the height of the tube connected to the container. ***(PH.1.08)***

The system targets filtering **1.5** liters of water. Then, the water is stored in a container after each cycle until **1.5** liters pass through the cycle. The sensors will be placed within a range of **1.5** liters. Then, when the sensors read the water parameters, the way of water flow would be considered according to the sensors' readings, by using two solenoid valves to either return it to the system or let it leave the system.

The process of returning the water to the system depends on a water pump connected to one of the solenoid valves. The power of the pump and the solenoid valves will be calculated using the law of:

$$P = IV$$

The power of the pump is **30 watts**, and that of the valves is about **12 watts**. The voltage and the current of the pump are **220V** and about **0.13636A** with an AC source. The valves need **12V** and **0.5A** with a DC source. ***(Halliday et al., 2022)***

The valve depends on producing a magnetic field by passing electricity through its solenoid part. The produced magnetic field attracts a movable part into the center of the solenoid coil. That actuates a small valve mechanism. ***(Kuphaldt, 2022) (PH.2.08)***

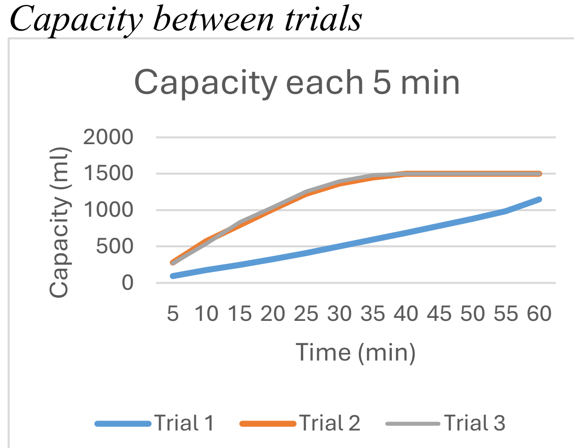
The process of drawing the graphs depends on the concept of limits and derivatives to ensure their clarity and accuracy. That is because the limit specifies a specific value of a function when x approaches the threshold of parameters ***(MA.2.06).***

The filtered water will be used in fish farming as an application of use. The type of fish that the water will be used is Tilapia fish. The Tilapia fish is selected because of its economic significance.

To determine the efficiency of the solution, three trials of constructing the prototype were tested, depending on some design requirements: two gave negative results, and one gave positive results. The negative results have been analyzed to identify the prototype's drawbacks, thus improving it to reach a positive result successfully.

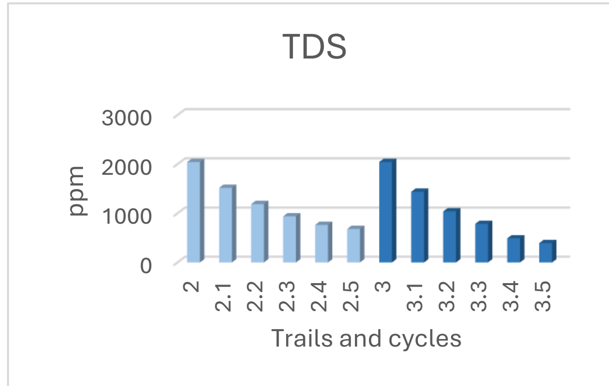
After the first trial, negative results were obtained. Since the rate of filtration was less than the target of **250 mL** average rate in each **10 minutes** within one hour. However, it filtered at about **191.54mL** on average only, as shown in **Figure (5)**. That was caused because of the use of small containers for the stages, especially the sand container. Since the small volume container has increased height, it requires water to pass through more sand before reaching the bottom of the container. To solve this problem, a

Figure 5:
Capacity between trials



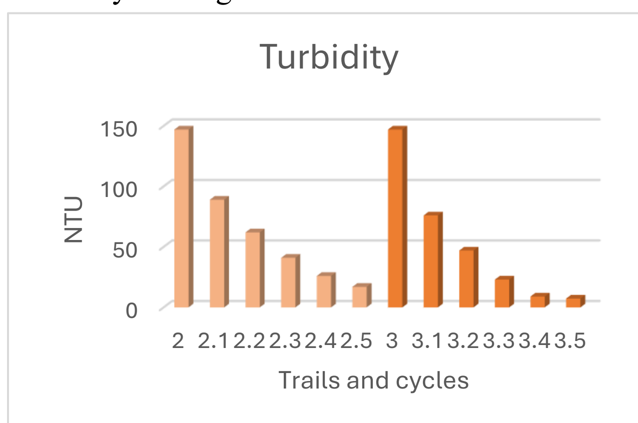
bigger container was used while saving the same amount of sand, which provided a larger surface area of filtration while reducing the time needed for the water to pass through the bio sand stage.

Figure 6:
TDS readings between trials



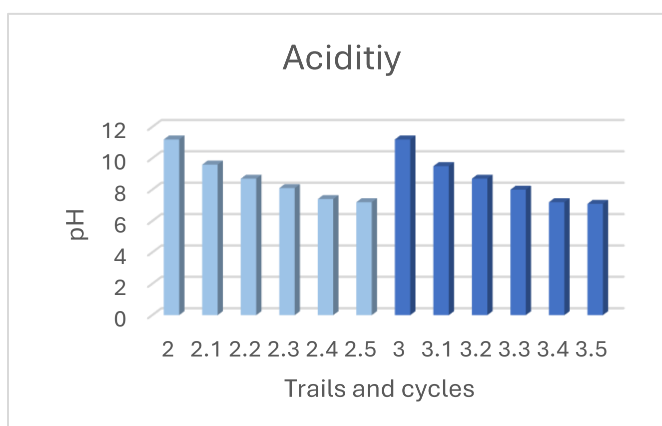
However, after testing the second trial, it was also negative but improved result. It achieved a filtration rate targeted at **250mL** and achieved about **390mL** on average during the **1 hour** as shown in **Figure (5)**. However, the filter couldn't achieve the targeted parameter values. In this trial, the pH has been reduced until it has reached the accepted limit of **6.5** to **7.5** by reaching **7.2** at the end of the **5 cycles**, as shown in **Figure (8)**. However, it couldn't reach the targeted limit. Since the TDS reached only **681 ppm** and the turbidity to **17 NTU** after the **5 cycles** of filtration, as shown in **Figure (6,7)**. The second trial contained only eggshells as an adsorbent. So, to solve this problem, coconut husks were added over the eggshells because of their ability to target the TDS and turbidity.

Figure 7:
Turbidity readings between trials



Finally, the third trial could achieve the design requirements. Since it could achieve an average of **403.36** every 10 minutes in **1 hour**, as shown in **Figure (5)**. In addition, the trial could reduce the three parameters under the threshold. Since the TDS could be reduced to **392 ppm**, the Turbidity to **7.3 NTU**, and the pH to **7.1**, as shown in **Figure (6,7,8)**. Furthermore, the optimum cycle that all parameters reach the threshold is the fourth, where TDS became **489 ppm**, turbidity became **9 NTU**, and pH became **7.2**. After that, the process of filtration has been repeated 4 times after the first process. Moreover, the trial efficiency was

Figure 8:
Acidity readings between trials



reduced by only **1.37%** from the first process and achieved the design requirement of less than **5%** in change.

Conclusion

After finishing the prototype, some conclusions were drawn, First, as aloe vera has a high coagulation property, it works best with a low to moderate concentration of heavy metals and organic materials, but declines a little bit with high concentrations on the other hand ferric chloride needs more steps to clean it from the water. Secondly, the eggshells' adsorbing ability could be increased by crushing the eggshells before using them, since as the grains get smaller, it increases their surface area, which ensures better adsorption by removing different kinds of heavy metals and particles that the ceramic filters aren't able to purify with a higher rate of purification. Thirdly, by combining different adsorbents like eggshells and coconut husks, it increases the adsorption ability of both materials significantly, which ensures better quality of the produced water. Lastly, bio-sand depends heavenly on the size of the grains since as they get smaller, it makes the water flow harder as the pores become smaller, which increases the contact time, which ensures higher purification efficiency without using any chemicals in the purification process, which ensures water cleanliness.

Recommendation

For future studies, some recommendations should be taken into consideration:

- Combine the aloe vera with natural gums (long-chain carbons derived from organic materials) to increase the thickness and the viscosity of the aloe vera, which will help in increasing the coagulation ability of the aloe vera.
- Heat the coconut husks using steam (200 °C - 400 °C) to further increase the microscopic pores and increase the surface area, which will further increase the adsorption ability of the coconut husks
- To increase the function of the bio-sand add some helpful bacteria (from compost tea) to help the bacteria in the degradation process while also adding some zeolites and active carbon in the middle layer to catch any chemicals present after the degradation process while ending it with gravel in the bottom layer to ensure water flow.
- Modifying the water pump to make it connectable to the Arduino. Then, make it work according to the reading of the sensors. That will reduce the energy consumed by the system a lot. However, this wasn't applied because of the need for higher technical devices and higher costs.
- On the large scale, the filter system is suggested to be installed in any of the Egyptian Spinning and Weaving Company in El-Mahalla El-Kubra. That could help in reducing the harmful effects of the textile wastewater there.

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