Hybrid Botanical-Electro Purification

Gharbiya STEM school-semester Two G11-(2024-2025) -Group NO. (19210)

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ABSTRACT

Managing and increasing the sources of clean water became a serious challenge, specifically in rural areas that suffer from the shortage of clean water sources that affect their quality of life even the basic life requirements such as drinking clean water. So, a closed water purification system solution was chosen to encounter this challenge by helping these areas with purified water that can be used in cooling their industrial towers and increase industrial and agricultural base of Egypt. The agricultural wastewater coming from their land was chosen to be treated with three treatment stages, a primary chemical stage presented in coagulation using tamarind seed to decrease the turbidity level, then a secondary chemical stage presented in electrocoagulation to decrease the salinity level, and finally, a biological stage using reed bed system with papyrus plant to regulate pH level. The two design requirements chosen to test the quality of this solution were: the ability of this solution to regulate the three water parameters (turbidity (< 50NTU), salinity (< 500ppm) and pH (<9)), and the high output capacity of purified water. Tests were done, and the results have presented the efficiency of this solution as it met the two design requirements by decreasing the wastewater sample's turbidity to 49NTU, salinity to 493 ppm and pH to 8.5. Furthermore, the output capacity was 2.2 liters per 3 liters. To conclude, a successful closed water purification system solution was chosen to solve the problem of water pollution that has proved its effectiveness in tests conducted.

Introduction

Egypt's growing population will need more modifications and changes to suit all citizens. Water is an important field to focus on. Water pollution is a very serious problem associated with water, leading to a decrease in available sources of potable water. Human activities are the main reason for water pollution, as industrial wastes from factories, toxic chemicals and oil spills leaked from ships in oceans, and sewage. Additionally, agricultural waste is a main factor of water pollution because of excess fertilizers, especially nitrates and phosphates, leading to algal blooms. Serious effects were produced as a result of these factors. For example, diseases like cholera and typhoid, eutrophication leading to dead zones, and the destruction of the ecosystem (Denchak, 2023).

The prior solutions searched for are biological wastewater treatment, and Coagulation and flocculation.

Firstly, Biological wastewater treatment is the usage of microorganisms instead of chemicals to avoid the adverse effects of chemical treatment. This way of treatment is favorable and widespread because of its advantages, like saving the environment, as no chemical compounds are involved. Additionally, low operational costs and reusable water are strengths; this method of treatment depends on using microorganisms that require less cost compared to using expensive chemicals. Much time consumed, large space required, and inefficiency in removing inorganic chemicals (e.g., salts or chemicals) are disadvantages of this treatment method (ScienceDirect, 2024).

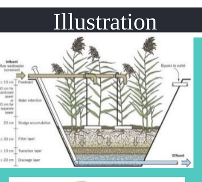
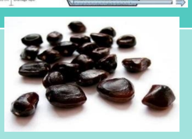
Secondly, Coagulation and flocculation method is the addition of compounds that promote the clumping of fine floc into larger flocs so that they can be more easily separated from the water. The advantages are efficiency in removing suspended particles, decreasing the turbidity of polluted water, and the ability to remove organic precursors, which may combine with chlorine to form disinfection by-products. The disadvantages are the chemicals used, which may be environmentally harmful, and less efficient in dissolved organic matter removal because it's mainly effective for suspended solids and colloids.

The solution chosen mainly consists of 3 stages. The first stage is coagulation and flocculation by tamarind seeds to reduce the turbidity. The second stage is electrocoagulation to decrease the salinity of water. The third stage is a biological filter by the reed bed system using the papyrus plant to decrease the pH. The first design requirement is parameters that must reach specific values (turbidity <50 NTU, Salinity <500 ppm, and PH <9). Secondly, its capacity must be 2.2 liters.

MATERIALS & METHODS

Table 1

Materials

Materials	Quantity	Cost	Usage	Source	Illustration
Reed bed system using papyrus	One seedling	150L.E	**Papyrus plants help filter water by absorbing nutrients, oxygenating the root zone, supporting beneficial bacteria, and contributing to natural pH balance.**	From nature around water banks	
Tamarind Seeds	0.6kg	30L.E	Tamarind seeds act as a natural coagulant, helping to remove turbidity, heavy metals, and organic pollutants from water.	From the fruit shop	
Alumonium sheets	2 pieces	Recycled	Destabilizes the dissolved, suspended, and emulsified contaminants from an aqueous medium by neutralizing the charge and aggregate to form floc.	From scrap metal shops	
Ardunio Uno	One Board	300L.E	Controlling the system and sensors	Electronics shop	
pH Sensor	One piece	1700L.E	To measure pH of water	Electronics shop	
Salinity sensor	One piece	750L.E	To measure the Salinity in the water	Electronics shop	
Turbidity sensor	One piece	600L.E	To measure the turbidity in the water	Electronics shop	
Total cost			3530L.E		

Methods:

The construction of the prototype was divided mainly into two parts which are: 1- Preparing the filtration system. 2- Establishing the prototype.

The filtration system contains three stages which were prepared as follows:

The first stage: Tamarind seeds were heated in oven at 50˚C for about 8 hours, they were grinded and mixed with 0.5M NaCl solution. After this, the powder added into perforated sheets.

Figure 1

Tamarind seeds

The second stage: Aluminum sheets were prepared by getting wasted aluminum and compressing it. Then it was put in a solution of water, lemon, vinegar and carbonate to remove the outer oxidized layer. After that, four sheets were placed in the container, each one was connected to 12V electric source.

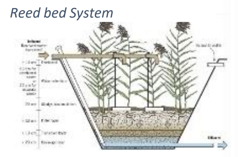
Figure 2

Aluminum Sheets

The third stage: Papyrus plant reed bed system was prepared by placing gravel, then sand then soil in a container and placing the papyrus plant in this soil.

Figure 3

Reed bed System



Building the prototype started by establishing its body, were the containers were connected by plastic pipes, based on the design in Figure (4). Then the openings made the containers were isolated well to avoid any dripping from the prototype.

After that, each filter was placed in its proper place, where tamarind seeds' filter and Aluminum sheets were placed in the upper container, while the papyrus reed bed system was placed in the container on the right. The lower container contains the

Figure 4

Prototype design

The whole system was controlled by the Arduino, where the sensors were calibrated water parameters, and based on the reading they get, the Arduino makes decisions about the next path the water will move in.

Test Plan:

The prototype was expected to:

- Be able to treat the water sample by regulating its turbidity, salinity and pH.
- Be durable to overcome high speed water charging and large water quantities.
- Have low power consumption.
- Be able to carry a quantity of **3** liters of water.

So, to make sure that the prototype will achieve the mentioned criteria, the test plan included the following steps:

1. **Water purification test:**

A quantity of 3 liters of water entered the purification system. The pH of the water was 11.2, the turbidity was 965 NTU, and the salinity was 800ppm. The prototype was expected to decrease these parameters in a limited period.

Durability test:

3 liters of water were pumped into the prototype, then it was let for 2 hours to make sure it'll hold high amounts of water for long time periods.

Power consumption test:

The power consumption of the prototype was measured with a multimeter for 1 hr.

Capacity test:

The amount of purified water that comes out of the system was determined to make sure that it is effective enough.

RESULTS

The first trial involved 3 water cycles, the second one involved 4, and the third one involved 6 cycles. The results of each trial are shown in the following table:

Table 2

Results

Trials	Before	After
1st trial (Negative)	Salinity: ± 800 ppm Turbidity: ±965 NTU pH: ± 11.2	Salinity: ± 721 ppm Turbidity: ± 654 NTU pH: ± 10 Capacity: ±2.7 Liters Power consumption: 41 watts
2nd trial (Negative)	Salinity: ±800 ppm Turbidity: ± 965 NTU pH: ± 11.2	Salinity: ± 654 ppm Turbidity: ± 259 NTU pH: ± 9 Capacity: ±2.5 Liters Power consumption: 41 watts
3rd trial (Positive)	Salinity: ± 800 ppm Turbidity: ± 965 NTU pH: ± 11.2	Salinity: ± 493 ppm Turbidity: ± 49 NTU pH: ± 8.5 Capacity: ±2.2 Liters Power consumption: 41 watts

Table 3

Power Consumption

Device	Volt (V)	Current (A)	Time (h)	Energy (W.h)
Valve (x2)	24	0.5	0.0107	0.1284
Pump	15		0.05	0.75
EC	12	0.5	0.1	0.6
Sensors (x3)	15	0.5	0.23	1.725
Arduino	5	0.1	0.23	0.115
Relay (x3)	15	0.5	0.23	1.725
Total				5.0434

Then the total power consumption of the system equals 48.5 watts.

Figure 5

Water parameters graph

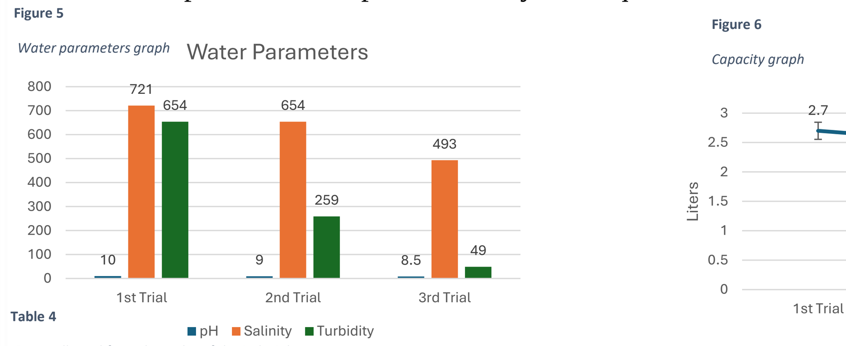


Figure 6

Capacity graph

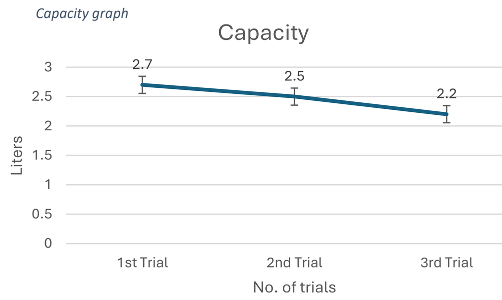


Table 4

Data collected from the cycles of the 3rd trial

No. of cycles	Salinity	Turbidity	pH
0	800	965	11.2
1	721	654	10
2	654	259	9
3	579	168	8.8
4	506	87	8.6
5	493	49	8.5

Time (min)	Total Filtred water capacity (L)
10	1.63
20	1.86
30	1.94
40	2.02
50	2.11
60	2.2

To conclude, the prototype appeared to have a high efficiency of tolerating the water parameters, outputting high clean water capacity and utilizing low power consumption.

ANALYSIS

Nowadays, Egypt faces many challenges that impedes its progression and threaten its existence like the scarcity of clean water. Rural reefs are known for agriculture, so making a project that treats agricultural wastewater can be a satisfactory solution for the problem. For this project to be effective, it should be low in cost and be made from available materials. These two criteria are achieved in this project; where it uses cheap available materials like tamarind seeds and *Cyperus papyrus* plant to treat agricultural wastewater. This treatment will make water suitable for usage in industrial fields, especially in cooling towers.

The water treatment process involves four main stages which are: screening, coagulation, filtering and disinfection **(ES.2.04)**.

The 1st stage in this project involves a perforated board covered with tamarind seeds powder, which helps in decreasing turbidity of water through the proteins it contains, where they will make coagulation with the pollutants **(SS et al., 2024)**. After the coagulation is done, the coagulants' mass increases, so they will move to the bottom of the container by the effect of gravity depending on the following law:

$$F_g = G\frac{Mm}{r^2} \quad \textbf{(Serway \& Vuille, 2012)} \qquad \textbf{(PH.2.01)}$$

The 2nd stage is electrocoagulation using Aluminum sheets that act as electrodes. The Following equations show what happens exactly:

Anode reaction: $Al \rightarrow Al^{3+} + 3e^{-}$

Cathode reaction: $2H_2O + 2e^{-} \rightarrow H_2 + 2OH^{-}$

Overall reaction: $2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2$

(Nurfahasdi et al., 2024) (CH.2.09)

The 3rd stage is responsible for decreasing the pH of water by using *Cyperus papyrus* plant that's placed in a reed system. Some types of bacteria live in the roots of this plant, so when water passes on them, they feed on heavy materials found in water, decreasing the pH of it. The final box contains three types of sensors: pH sensor, Turbidity sensor and TDS sensor. Water will remain in this box until the sensors read the three parameters. Based on these readings, the Arduino will select a way out of two for water to pass through: Either water will get out of the system if it was completely purified, or it will be pushed by a water pump for another treatment cycle if it wasn't completely purified **(RAL.3.03)**.

The power consumption of the two valves, the water pump and the Electrocoagulation process was calculated using this law:

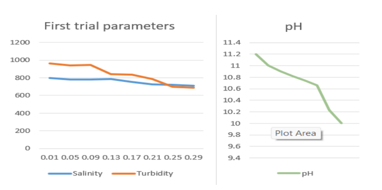
$$P = \frac{W}{t} \qquad \textbf{(Halliday et al., 2011)}$$

where (P) is the power, (W) is the work done, and (t) is the time **(ME.2.05)**.

The prototype was tested to make sure it meets the chosen design requirements. The 1st trial gave negative results for two reasons. The first one was the treatment of tamarind seeds powder with 0.8M of NaCl solution, which resulted in high turbidity (97NTU). The second reason was using iron electrodes which have low efficiency in electrocoagulation; because of its low oxidation potential (0.44v), which resulted in high salinity (603ppm). The parameters are shown in **Figure 6**.

Figure 6

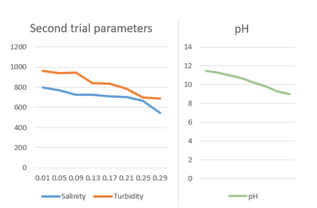
First trial parameters



In the 2nd trial, the tamarind seeds powder was treated with a 0.5M NaCl solution instead of 0.8M; as the maximum efficiency of the coagulant proteins is reached when using 0.5M. Also, the iron electrodes were replaced by aluminum sheets whose oxidation potential is 1.66v, which increases the released ions from the oxidation process. The results obtained were better, where the turbidity decreased to 67 NTU, and the salinity decreased to 654 ppm. But unfortunately, the pH of the water remained high (7.6); because of using Foxtail Millet in the reed system, which doesn't contain enough bacteria in its roots. The parameters are shown in **Figure 7**.

Figure 7

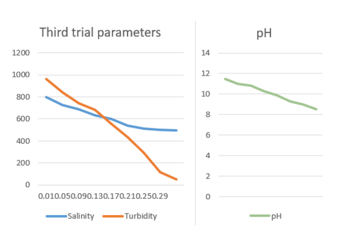
Second trial parameters



In the 3rd trial, the *Foxtail millet* plant was replaced by *Cyperus papyrus*, whose roots are known to be a good habitat for bacteria, which is able to feed on organic matter dissolved in water. This led to a significant improvement in the water quality; where the turbidity decreased to 49 NTU, the salinity decreased to 493 ppm, and the pH decreased to 7.01. The parameters are shown in **Figure 8**.

Figure 8

Second trial parameters



CONCLUSION

The conclusions derived from the analysis indicate that the project was able to treat the agricultural wastewater to be usable in industrial fields. The trials' results show that the the Papyrus reed system, Electrocoagulation using Aluminum, and tamarind seeds were significantly effective in decreasing the pH, the salinity, and the turbidity of the water respectively. The turbidity decreased from 965 NTU to 49 NTU, the pH from 11.2 to 8.5, and the Salinity from 800 ppm to 493 ppm. This remarkable improvement in the quality of water makes it usable in industrial fields in the rural reefs, especially in cooling towers; where using water with high pH, Salinity, or turbidity damages the towers, which costs much money to fix them. When compared to the prior solution (which is the Reverse Osmosis), it can be noticed that this project is superior to it, where reverse osmosis consume much energy, and consequently much money, while this project consume low energy. Furthermore, reverse osmosis requires professional maintenance to ensure its effectiveness, while this project is easy to maintain and develop.

RECOMMENDATION

When adopting this solution for large-scale treatment plant construction, especially if proper governmental aid is given, here are some points that are recommended to improve this project as follows:

- Grinding tamarind seeds finely and sieving them to improve surface area and reactivity. Furthermore, using another coagulant such as Moringa seed powder to increase the purification efficiency in high turbid water.
- To increase the efficiency of the electrocoagulation stage: Proper Mixing to keep water moving around the electrodes to prevent localized ion buildup. This can be done by using a powerful recirculation pump. Using perforated plates or mesh electrodes to increase surface area.
- To increase the efficiency of the Reed bed system using the papyrus plant: Using primary settling tanks, roughing filters, or natural coagulants to reduce solids and turbidity before entering the Reed bed.
- Using polycarbonate materials that have more durability and are not affected by increasing pressure or any factors that could damage the container.

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