PureDrop: Clean Drops Of Water

6 CLEAN WATER AND SANITATION

13 CLIMATE ACTION

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ABSTRACT

Clean water is considered a necessary human right for staying healthy. Unfortunately, clean water isn't easily provided to people who live in lower-middle-income areas, particularly in rural communities across Egypt. Since the rise in Egypt's population is being indicated, the demand for clean water is expected to increase, leading to a crisis because of the limited available clean water sources. The River Nile, Egypt's main water source, is strained by wastewater, which has created a need to develop technologies for wastewater treatment. A contribution to the Sustainable Development Goals (SDGs) and to solving some of Egypt's Grand Challenges (EGC) is aimed to be made through this project, focusing on the problem of improving the quality of water. Our work was conducted by designing a feedback loop system. **Nanofiltration (NF) Membrane** was prepared in the Faculty of Science at Fayoum University and was used as the first stage of filtration, removing **Salinity** with Removal (%) of **75.7% ± 7.57%**. A solution of **Sodium Hydroxide (NaOH)** was used as a chemical neutralizer to balance **PH** in the acidic wastewater with Removal (%) of **80% ± 3.4%**. **Clay** and **Seashells** were collected and used as natural adsorbents to remove **Turbidity** from wastewater with Removal (%) of **68.65% ± 6.86%**. The salinity of wastewater entering our system must be reduced **to below 500 ppm** for at least five complete treatment cycles by our project to be used in **irrigation**. Calibrated sensors were used to measure water quality before and after entering our system. Our project's percentage in reducing the chosen parameters was determined to be **74.8% ± 5.9%**, ensuring that our project represents a successful and realistic model meeting the requirements.

INTRODUCTION

Water pollution stands as a significant environmental problem because its effects merge with crucial sustainability problems that Egypt experienced in the past few decades, including the need to: **Recycle waste, supporting both economic and environmental purposes by reusing materials - Reduce the pollution fouling the air, water, and soil that threatens the public health. - Improve uses of arid areas, which will result in reducing the pressure on populated areas. - Increase the industrial and agricultural base of Egypt, which is vital for economic growth. - Manage and increase the sources of clean water for drinking, farming, and other critical uses.** These challenges are aimed to be solved by our project. In response, the Egyptian government seeks to solve these problems by establishing various projects and initiatives.

Abu Rawash Wastewater Treatment Plant (ARWWTP) is the most significant project for water treatment in Giza, Egypt. Its treated water is reused in agriculture, as in our project, where we used the filtered water for Irrigation purposes. Also, it provides good, healthy lives for humans and all living organisms as Economic and Social Benefits, similar to our project. After filtration, it produces sludge as a byproduct, so to avoid this, we designed our system to work without producing any byproducts. Furthermore, it is bulky and not easily transportable, so our system is characterized by this point by making a portable, lightweight, and low-cost prototype that is **less than 5 kilograms** (as a requirement).

To address these limitations, the proposed solution met specific design requirements, as **it used waste and natural materials (e.g. custom-made NF Membrane - Seashells collected from the sea - Clay collected from nearby riverbanks - NaOH solution from our chemistry lab in our school), while weighing less than 5 kilograms to be easy to mobilize. It also achieved treating wastewater from at least three different parameters: salinity (reducing it from 1000 ppm to below 500 ppm), turbidity, and neutralizing pH to reach a range of 6.5 to 8.** Our project helps reduce pollution, thus supporting the SDGs.

MATERIALS

Item	Quantity	Usage	Cost	Picture
Water Pump	3 pcs	directing water in all the system	185 EGP/pc	
Relay Module 12V	1 pc	Control the motors through Arduino	140 EGP	
Seashell	≈ 300gm	turbidity filtration layer	Free	
Arduino Nano	1 pc	The main Brain of the system	245 EGP	
Solenoid Valve	1pc	Open and close the water flow	220 EGP	
TDS Sensor	1 pc	Measure Water Salinity	750 EGP	
PH sensor	1 pc	Measure the PH of water	1700 EGP	
4V lithium battery	3 pcs	Connected give output of 12V	80 EGP/pc	
Turbidity sensor	1 pc	measure the turbidity of water	900 EGP	
DC Motor	1 pc	run the NaOH mechanism	30 EGP	
Jumpers	≈ 40 pc	Connect all the components	30 EGP	
Wooden Frame	1 pc	The frame for the project	Recycled from The Fab Lab	
Syringe + Box	1 pc	Add NaOH in the system	35 EGP	
Multimeter	1 pc	Measure the conductivity of water	550 EGP	
NF Membrane	1 pc	reduce the salinity of the water	Custom-made (350 EGP)	
Breadboard	1 pc	The central connections unit	70 EGP	
Tubes	≈ 2M	circulate water in all the system	50 EGP	
Clay	≈ 300 gm	adsorption filtration layer	Free	
Cotton - Gauze	≈ 250	layer of separation between different layers	30 EGP	
			Total : 5895	

Table (1): Materials table.

METHODS

First of all, sensors were calibrated in the Chemistry Lab using the calibrated devices in there as shown in **Figure (1)** & **Figure (2)**, reaching these equations as **Figure (3)** & **Figure (4)**

Reaching the next point, which is the prototype:

The wooden frame found in the Fab-Lab was considered as a suitable frame for all the components to be attached on it. After it was cleaned to make it suitable for construction, these steps were taken during the construction:

1- A box was added, as it was the brain of the project where all the sensors were attached.

2- A hole was made through it, so the valve was inserted.

3- The first seashell layer was attached below the valve.

4- Then, the second layer of clay was also attached and the NaOH system was made using a syringe and a nail.

5- Then, it was connected to the cell membrane, which we made in Faculty of Science at El-Fayoum University to reduce salinity, as shown in **Figure (5)** & **Figure (6)**.

6- The purified water was returned to the box using electric pump to check if additional cycles were needed or not.

Note: All of this was achieved by depending on gravity and the pressure made by the pumps (the pressure was increased by adding two pumps to push the water in the system).

7- The electric circuit was made as illustrated in **Figure (7)**, Relay and energy source were used to control all these motors and the valve, and the final prototype is illustrated in **Figure (8)** & **Figure (9)**.

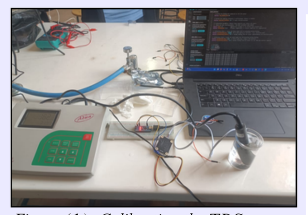


Figure (1): Calibrating the TDS sensor.

Figure (2): Calibrating PH sensor.

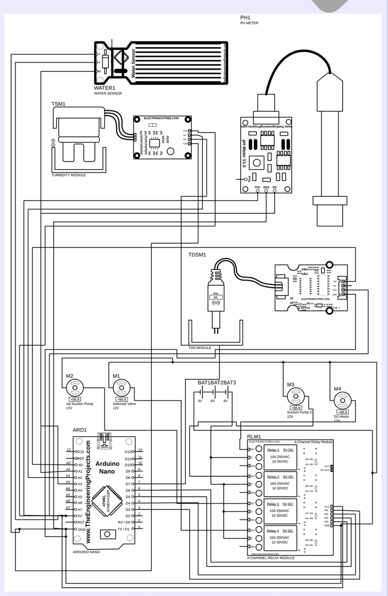


Figure (7): The Project circuit diagram.

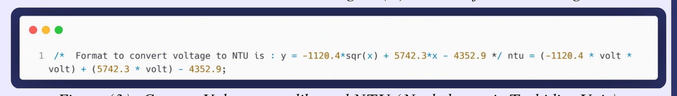


Figure (3): Convert Voltage to calibrated NTU (Nephelometric Turbidity Unit).

```
#define SLOPE 447.886        /* The calculated slope from calibration*/
#define OFFSET -14.666972    /* The calculated offset from calibration*/

int rawValue = analogRead(TdsSensorPin);
float voltage = rawValue * VREF / 1024.0;
float tdsValue = ((SLOPE * voltage) + OFFSET) * 100; // Apply calibration
```

Figure (4): TDS Calibration Code to convert Voltage to PPM (parts per million).

Figure (5): testing membrane in university.

Figure (6): During preparing the membrane.

Figure (8): Final Prototype with all layers added.

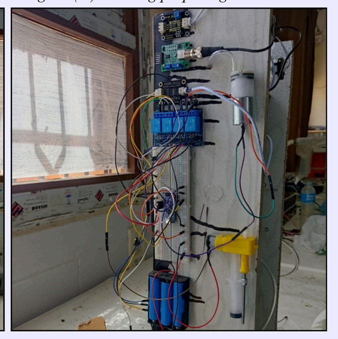


Figure (9): Final Circuit view with sensors.

Our test plan followed various criteria to meet the requirements, these are (in **Table (2)**):

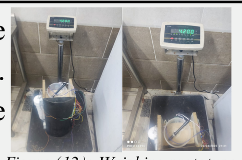
Design Requirement	Test Plan Procedures
Salinity must drop from 1000 to 500 ppm or less.	**Test Plan 1:** After calibrating TDS sensor, we measured salinity before and after full system run. We ensured initial readings are > 1000 ppm. After 5 treatment cycles, we confirmed that final TDS readings are ≤ 500 ppm. We repeated this process over 3 separate water samples (as shown in **Figure (10)**) for reliability.  Figure (10): Wastewater sample.
The system must neutralize PH to 6.5 ~ 8 and reduce turbidity to < 40 NTU	**Test Plan 2:** After calibrating PH and Turbidity sensors (the sensors were checked again by being tested on untreated wastewater), we measured the initial PH of acidic wastewater (target ~1–5) and Turbidity values. We recorded PH and turbidity readings after each cycle. We repeated the test over 3 trials and obtained our values. Check QR code (in **Figure (11)**) for more information about our project and calibrating sensors. SCAN ME Figure (11): QR code.
System must use waste materials, weigh <5 kg, and be easy to mobilize	**Test Plan 3:** We weighed the full prototype using a digital scale (as shown in **Figure (12)**). Confirmed use of recycled materials. Test portability by moving the system across a 5-meter distance to simulate the ease of real-world transportation and mobility.  Figure (12): Weighing prototype.

Table (2): Test plan table.

RESULTS

After testing the prototype, the results where gathered from the sensors, the prototype was weighted firstly and it was **4.2 Kg** (meeting the requirements) as in in **Figure (13)**. All the results were gathered from the sensors and shown in **Table (3)**.

Figure (13): Prototype weight.

Cycles	Trial One	Effeciency	Energy consumed (J)
Initial	NTU: 107.2 - PH: 4.70 - PPM: 1664	-	-
First	NTU: 71.6 - PH: 6.03 - PPM: 1020	NTU: 33.2% - PH: 57.8% - PPM: 38.7%	5155.2 Joule
Second	NTU: 51.3 - PH: 6.71 - PPM: 645.3	NTU: 28.3% - PH: 87.4% - PPM: 36.7%	5155.2 Joule
Third	NTU: 39.8 - PH: 7.05 - PPM: 546.2	NTU: 22.4% - PH: 97.8% - PPM: 15.4%	5155.2 Joule
Fourth	NTU: 35.16 - PH: 7.39 - PPM: 462	NTU: 11.7% - PH: 83% - PPM: 14.3%	5155.2 Joule
Fifth	NTU: 33.6 - PH: 7.46 - PPM: 402	NTU: 4.43% - PH: 80% - PPM: 12.9%	5239.2 Joule
Overall	-	NTU: 68.65% - PH: 80% - PPM: 75.7%	25,860 Joule

Table (3): Results.

ANALYSIS

Egypt faces multiple grand challenges that hinder its development as a country, with water pollution being the most crucial one. Our project aims to address the pollution of the water, focusing on three parameters:

Salinity through Nanofiltration (NF) Membrane:

A membrane is an interfacial structure that restricts the movement of some species while allowing other species to permeate through if there is a driving force, pressure, concentration, or chemical potential. **Figure (14)** illustrates the Classification of membranes for water purification in terms of pore size and retained species. Based on this figure, polymeric membranes were chosen because they are currently used the most in seawater desalination and wastewater treatment industries due to their well-developed, outstanding performance, and their availability in Egypt. According to a research article published in a journal, three types of membranes - NF, RO, and Hybrid (NF/RO) - were tested, and their percentage of salinity reduction came out to be **50.21%**, **72.82%** and **78.65%**, respectively, as in **Figure (15)**.

For our project, after treatment using the NF membrane, salinity levels dropped significantly from **~1660 ± 166** ppm to **~403 ± 40.3** ppm - with minor variation across trials as **Figure (16)** illustrates - with a reduction efficiency (%) = [(1660 – 403) / (1660)] x 100 = **75.7% ± 7.57%** (meeting the requirements). Efficiency removal is calculated using equation: **Rejection (%) = [(ConcB – ConcF) / (ConcB)] x 100**, Where ConcB is Concentration before treatment and ConcF is average Concentration after treatment.

Turbidity through Seashells and clay:

Seashells and clay are natural biofilter adsorbents that help remove turbidity, odorous compounds, and various contaminants from wastewater through physical, chemical, and adsorption processes. According to a research article, they tested the performance of three filters made of clay and seashells, and their percentage of turbidity reduction came out to be **≈ 93.8%** for both clay and seashells together as shown in **Figure (17)**.

For our project, the turbidity levels dropped from **~107.2 ± 10.72 NTU** to **~33.6 ± 3.36 NTU** as **Figure (18)** shows, with a reduction efficiency (%) = [(107.2 – 33.6) / (107.2)] x 100 = **68.65% ± 6.86%** (meeting the requirements).

PH through NaOH solution:

Sodium hydroxide (NaOH) stands as a typical strong base solution that serves as a neutralizer for treating acidic wastewater. when introduced to the acidic wastewater, it will completely dissociate within water to produce hydroxide ions (OH^-), which will interact with the excess H^+ ions in the solution, producing (H_2O) molecules and neutralizing the PH level. In our project, NaOH neutralized the PH of acidic water from **~4.7 ± 0.2** to **~7.46 ± 0.3** as **Figure (19)** shows, with a reduction efficiency (%) = [1- (7.46 – 7) / (4.7 – 7)] x 100 = **80% ± 3.4%** (meeting the requirements).

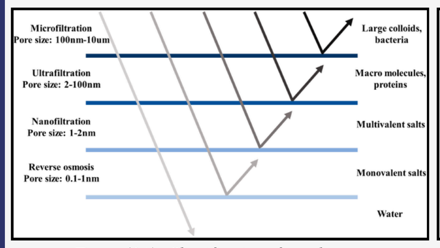


Figure (14): Classification of membranes.

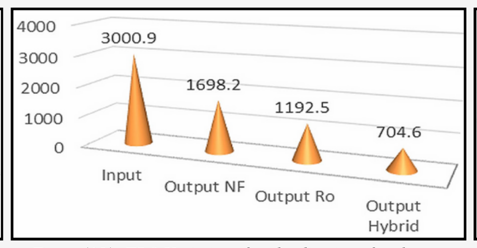


Figure (15): TDS Variation after desalination of each type.

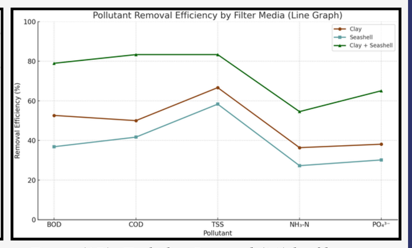


Figure (17): Turbidity Removal (%) by filter type.

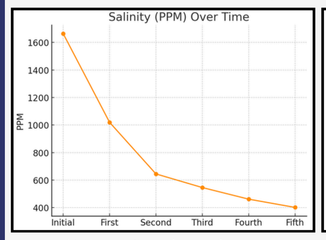


Figure (16): TDS readings after treatment.

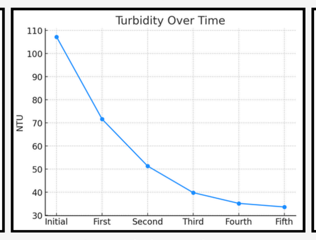


Figure (18): Turbidity readings over time.

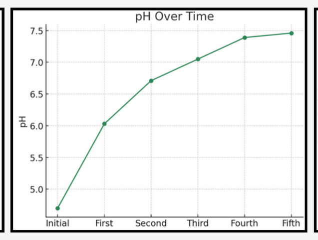


Figure (19): PH readings before and after.

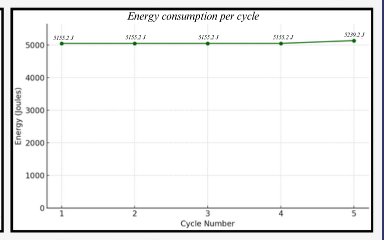


Figure (20): Energy derived from water.

$$\text{PH Efficiency (\%)} = \left(1 - \frac{|\text{PH final} - 7.0|}{|\text{PH initial} - 7.0|}\right) \times 100$$

Total reduction efficiency = (75.7% + 68.65% + 80% / 3) ± (7.57 + 6.86 + 3.4 / 3)= 74.8% ± 5.9%

Flow rate (ℓ/h) = (volume filtered [ℓ]) / (time [h]) = (2.5 [ℓ] x 0.5 [h]) = 5 ℓ/h.

Power (W) = (Voltage (V) x Current (A)) = (12 x 0.35) = 4.2 watts.

To calculate **Energy consumption** from our power source (12V battery), we first determined how much power each component consumes in its operating time per cycle, as in **Figure (20).** This was done for all cycles, considering component changes like the extra suction pump in the final cycle.

To calculate **Equivalent Lifetime** for the filter, we first calculated Average Total Efficiency per Cycle, applied Linear Regression (**y = mx + b**), then solved for Cycle Number to find when efficiency reaches zero, and came out to be: **0 = –3.605 x Cycle Number + 52.415 ⇒ ≈ 14.5 cycles.**

Energy Per Liter (J/L) = (Total E (J) / Volume (flow rate x time)) = (25,860 / 5 x 0.83) = 6,206.4 J/L.

Capacity (L/min) = (Liters Collected / Time (min) = (2.5 / 10) = 0.25 L/Cycle.

Learning Transfer:

Learning Outcomes	How we got benefit from it
PH.1.09	We studied how to calculate the flow rate so we could utilize it in our project to calculate the flow rate of the water in the system.
PH.2.03	We studied how to calculate Power (P = V * I) which helped in calculating the power of the system and the Energy (E = P * T) consumed.
MA.2.06	We learned about continuity, which helped us decide when to stop the system and how to control it when it approaches its capacity limit.
CH.2.08	We learned about ions and how (NaOH) dissociates in water, releasing (OH^-) ions, which can neutralize the acidic wastewater.
CH.2.09	We learned battery types, particularly Lithium-ion battery used, and how to connect them to achieve a 12-volt battery needed to run the system.

Table (4): Learning transfer table.

CONCLUSION

Finally, the goal was achieved at the end of the road. The successful testing of the prototype validated its ability to reduce salinity levels below 500 ppm and improve water quality using natural and recycled materials, meeting all of the design requirements. Our system has been confirmed that it works properly for wastewater treatment into reusable water for **Surface Irrigation** projects. Dissolved solids decreased from **1660 ± 166** ppm to **402 ± 40.3 ppm** during the testing phase showed how well the system extracted dissolved salts. The neutralization reaction between NaOH and the acidic wastewater adjusted PH values from **4.70 ± 0.2** to **7.46 ± 0.2**, aligning with the appropriate standard range for irrigation uses. Furthermore, the reduction in turbidity values from **107.2 ± 10.72 NTU** to **33.6± 3.36 NTU** showed how well the system cleared the wastewater.

Our outcome in reduction, which was determined to be **74.8% ± 5.9%**, met the expectations that was set by the scientific research we had throughout the development of the project, and in some cases exceeded. Additionally, it addressed several limitations we found in the prior studied solutions, like **Zeolite filters** and **Ion exchange resins**, offering better efficiency as a wastewater treatment solution.

RECOMMENDATION

After finishing our prototype, we have faced many hardships, and we recommend the following suggestions for future researchers who will continue working on this project:

- Increase the surface area and the layer thickness of the natural adsorbents (seashells and clay) to increase the contact time and pollutant removal.
- Utilize more stages in the system because when we increase the stages, filtration efficiency increases, like using a resin.
- Develop a modular version of the system that can be scaled up or down depending on the volume of water treated, making it suitable for both small communities and industrial facilities.
- Perform experimentation in a safe area with proper safety precautions, and be aware of while using any electric component because it might cause burns.

These suggestions aim to improve the effectiveness of our project and make it better. We advise anyone who is going to try constructing it in the future to follow these recommendations and make their own inventions.

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