

Filtration using Graphene Membrane

Graphene Filtration

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Theme: Enhanced filtration using Graphene Oxide Membrane

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Introduction

Water forms the most pivotal part of our life. It constitutes a chunk of 60 % in our body, which puts forth our demand for clean water. Clean water is vital to our health, communities, and economy. We need clean water upstream to have healthy communities downstream. Yet, having clean water seems a daunting challenge for us in India, as 1,95,813 habitations in the country are reportedly vulnerable to contaminated water.

When we say contaminated water, we consider all parameters of TDS (Total Dissolved Salts), PH, DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand) and majorly ions and Heavy Metals etc.

The most commonly used way of water filtration at the root level is the use of ROs at homes. RO uses Reverse Osmosis as a method by which it filters out water through thin porous Polysulfone membrane. Even Though RO provided us with one of the best results, it still needs to be improved in terms of the Removal of Heavy Metals. Heavy metal pollution in India, is a silent killer to a part of the population., with nearly 152 districts of India affected.

Removing the already in place RO Filtration mechanism from daily life is a challenging task however improvising to fulfill our motive is a feasible step in ensuring hygienic water intake. Our process is designed to be installed in homes, catering to the public. The Graphene based membrane, checks all parameters to clean, healthy water, while also reducing the quantity of mineral-rich water, released through RO filter

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Project Motive

As stated in the Introduction, A large population of India is prone to consuming contaminated water. This is not only in terms of sediments but also other parameters which include TDS (Total Dissolved Salts), PH, DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), and most importantly ions and heavy metals, present in the water. One of the best ways to filter water is by using RO Filtration (Reverse Osmosis), which uses a membrane of Polysulfone through which water permeates, further filtering out a major chunk of contamination.

However, even though RO, serves as one of the major and best contributors to Water Filtration, it is still incapable of removing Heavy Metals which have now become the reason for fatalities in our country. Heavy metals lead to various diseases, for example, High Arsenic Amounts in the Human body can lead to Arsenicosis. Continued Contact with these heavy metals and extended intake can lead to hindering of the physical, neurological, and muscular functioning

Statistics tell us how heavy metal pollution is a prevalent factor in various states. To state through a news report by India Today, In some parts of 209 districts of 25 states, the amount of arsenic in groundwater counted to be more than 0.01 mg per liter. In around 491 districts of 29 states, the amount of iron in groundwater is more than 1 mg per liter. Lastly, in some parts of 29 districts of 11 states, the amount of cadmium in groundwater is more than 0.003 mg per liter. *

On thinking along the same line, we came up with an idea that helps sustainably remove heavy metals from water and provides the best quality of water. Our project focuses on removing this composition of Heavy metals in water by forming a membrane of graphene supporting the existing Polysulfone polymer layer, found in the RO membrane. The purpose of this membrane formation is to reduce the concentration of heavy metals in water

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Method

Step 1: The Synthesis of Graphene Oxide:

Graphene can be synthesized through various techniques**. One among them is the Hummers method. The procedure is as stated below:

- The procedure starts with 100 g graphite and 50 g of sodium nitrate in 2.3 liters of sulfuric acid at 66 °C which is then cooled to 0 °C. 300 g of potassium permanganate is then added to the solution and stirred. Water is then added in increments until the solution is approximately 32 liters.
- The final solution contains about 0.5% of solids to be then cleaned of impurities and dehydrated with phosphorus pentoxide.

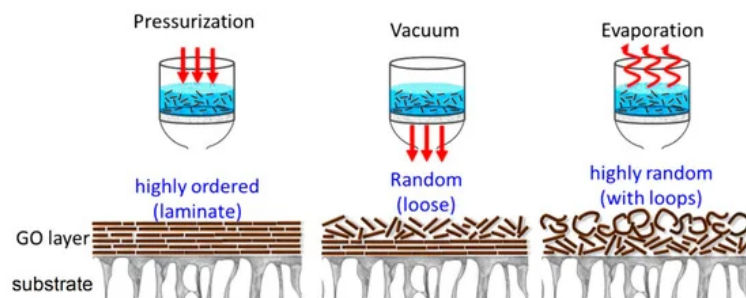
Other than making Graphene Oxide on your own it is available online with prices varying by quality and quantity.

Step 2: Graphene Oxide membrane Synthesis:

After Graphene Oxide is prepared, membrane synthesis can be done through various techniques (as stated in Step 1). One of them is Vacuum Filtration. Vacuum filtration is a technique widely used to fabricate GO membranes. This method uses a vacuum pump to create a pressure differential between the two sides of a membrane, which allows the liquid to pass through while retaining the solid particles. To perform the vacuum filtration, a filter funnel is fitted with a membrane (in our case it was a polysulfone layer) and placed on top of a receiving flask. The GO dispersion to be filtered is poured into the funnel, and a vacuum pump is connected to the receiving flask. The vacuum generated by the pump draws the liquid through the membrane and into the receiving flask while the GO flakes stack on each other on the supporting membrane. At the end of the process, a GO membrane is formed on top of the supporting membrane.

PRECAUTION

Depending on the GO layer's final thickness and the supporting membrane's nature, this process can require a higher vacuum level and a longer time. For this reason, hydrophilic membranes with large pores are preferred.



Step 3: Installation of the Graphene-layered - Polysulfone membrane into the main RO system:

To install the Graphene-layered - Polysulfone membrane into the RO system, just roll the membrane in on itself on the percolating tube and fit it into the main RO cartridge. This membrane can absorb Cd(II) up to 44.64mg/g*** and has a high absorption capacity for Fe^{3+} , Zn^{2+} , and Pb^{2+} .

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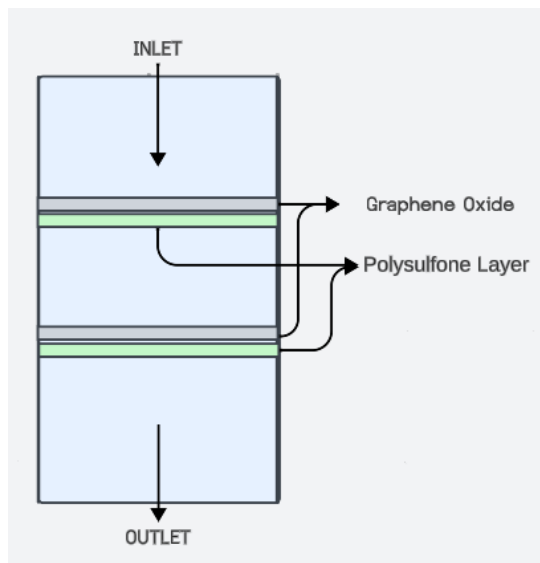
Model

Industrial Model

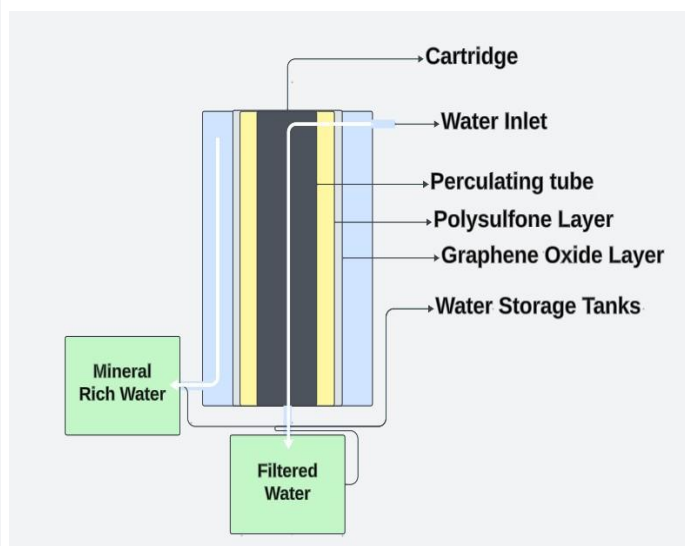
The industrial level model is aimed at maximizing yield and efficiency. The model consists of a primary sediment filter, an activated carbon filter, a Graphene/Polysulfone membrane, UV/UF filters, and 2 water storage tanks. First, the sediment filter would be a standard filter to filter out large sediment after which the water will pass through the activated carbon filter where certain chemicals and biological chemicals are removed****. Next, the water passes through the Graphene/Polysulfone membrane where excess minerals and heavy metals are removed, and which is further filtered by the UV/UF filter by removing any biological contaminant present in the water*****. Furthermore, whenever the main membrane is being cleaned the excess wastewater is stored in a separate tank which can also be connected to a main tap for further use.

Prototype

The prototype has been designed with proof of work being the main motive. Hence, the prototype consists of only a Graphene/Polysulfone Membrane layered on top of each other in a cylinder that has a water inlet as well as an outlet. The model works on the same principles as the industrial level model but it is just for testing purposes.



Prototype Model



Industrial Chamber Mod

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Cost Analysis

The Cost analysis has been done based on figures and data to the best knowledge available. The 2 given tables below represent the Cost analysis of our prototype and the Cost analysis of our final product:

Prototype

Cost of Graphene Oxide per gram	₹300
Amount of Graphene Oxide	~1 grams
<i>Total Cost of Graphene Oxide</i>	₹300
<i>Total Cost of Polysulfone</i>	₹800
Water Filter Cartridge	~₹400
Total Cost of the Project	₹1500

Final Product

Cost of Graphene Oxide per gram	₹300
Amount of Graphene Oxide	~7 grams
<i>Total Cost of Graphene Oxide</i>	₹2100
<i>Total Cost of Polysulfone</i>	₹800
Water Filter Cartridge	~₹400
Total Cost of the Project	₹3300

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Follow Up Plan

The follow-up plan for this project involves making it more profitable and more beneficial for the environment.

Environmental Benefit

One of the reasons we are using Graphene for filtration is to reduce excess water loss from normal RO (Reverse Osmosis) filters. Graphene oxide's strong chemical affinity to contaminants makes the polysulfone fibers more effective at filtering out unwanted material. The membrane also filters out heavy metals, PFAs, and many more contaminants, to ensure a steady flow of safe water.

Carbon Credits

As we know graphite is a naturally occurring material. GO (Graphene Oxide) can be synthesized by the oxidation of graphite into graphite oxide followed by the exfoliation of this graphite oxide into GO (as we mentioned before). The production process may involve energy-intensive steps and the use of chemicals, which can contribute to the overall carbon footprint. As GO gets more in use, we may find a more sustainable way of producing GO.

Profitability

As GO gets more in use, we will see cheaper production of GO. The more circulation GO would also result in GO getting cheaper over time. This cut in Production and the price of GO would result in our filter becoming more profitable

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Mentor's Note

Mrs. Vernika Sharma, our chemistry teacher at St. Mary's School has guided us throughout our project discussions since the beginning. Mrs. Vernika has helped us critically analyze our projects multiple times and has helped us at various stages of our project

She has been an integral part of the project, and has helped make our idea turn into reality. More than giving us factual knowledge, she has been with us in every step of the project, helping us to build our project with the right strategy. Mrs. Vernika, put her confidence in us, making the process simple and smooth. She helped us with our research work and arranged for the resources we required. Her guidance played an important role in our project, leading us till we established the result required.

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References

* Synthesis of graphene oxide:

<https://www.sciencedirect.com/science/article/pii/S2589965119300042#sec2>

** Absorption of Cd(II) by Graphene oxide:

<https://www.mdpi.com/2297-8739/9/12/401>

***High absorptive capacity of Graphene for Heavy Metal:

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5456948/>

****Activated Carbon Filters:

[https://www.health.state.mn.us/communities/environment/hazardous/topics/gac.html#:~:text=A%20filter%20with%20granular%20activated,rotten%20eggs%20odor\)%20or%20chlorine.](https://www.health.state.mn.us/communities/environment/hazardous/topics/gac.html#:~:text=A%20filter%20with%20granular%20activated,rotten%20eggs%20odor)%20or%20chlorine.)

*****UV filters:

[https://www.health.state.mn.us/communities/environment/hazardous/topics/gac.html#:~:text=A%20filter%20with%20granular%20activated,rotten%20eggs%20odor\)%20or%20chlorine.](https://www.health.state.mn.us/communities/environment/hazardous/topics/gac.html#:~:text=A%20filter%20with%20granular%20activated,rotten%20eggs%20odor)%20or%20chlorine.)

*****Graphene Flagships :

<https://graphene-flagship.eu/materials/news/graphene-applications-graphil/#:~:text=Graphene%20oxide's%20strong%20chemical%20affinity%20to%20contaminants%20makes%20the%20poly sulfone,steady%20flow%20of%20safe%20water.>

*****Statistics on Heavy Metal Pollution:

<https://www.indiatoday.in/india/story/poison-not-water-govt-data-shows-toxic-metals-groundwater-1982841-2022-08-02>

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Graphene Filtration

PROGRESS TILL NOW

St. Mary's School,
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Theme: Enhanced filtration using Graphene Oxide Membrane

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PROGRESS TILL NOW

1. Improvisation of Vacuum Pump
2. Fabrication of Membrane
3. Sampling
4. Further Plan of Action
 - a. Prototype Creation

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1. IMPROVISATION OF VACUUM PUMP

Firstly, we changed the setup of the Vacuum Pump, as to counter the problems arising due to use of tape and a smaller Buchner Funnel. This eased the vacuum filtration Process, which was then used for the second round of fabrication as well as the sampling

2. FABRICATION OF MEMBRANES

After improvising the vacuum pump, it was now easy for us to create a larger sample of the membrane. First, we checked it's working by placing a substrate on the büchner funnel and then passing water through it, in order to check if this conducts filtration.

Upon confirmation of working of the vacuum pump we then fabricated two new membranes, one of graphene and one of Activated Charcoal. Upon drying the same membranes were now used for sampling of different water samples

3. SAMPLING

After the fabrication, we directly began with the sampling where in, we used vacuum filtration itself to conduct filtration of the water samples.

The water samples taken by us were of Tap Water, Distilled Water, water from Basket Ball Court Dispenser and Water from 1st Floor Dispenser. A comparative analysis table was then made, which noted down the TDS (Total Dissolved Salts) reading of all our samples from when passed through Control (Nothing), RO membrane, Graphene Membrane and the Charcoal membrane

Upon filtration, the Graphene Membrane gave the best results as it lowered the TDS values drastically. A little change in the TDS was also observed due to the Charcoal Membrane RO membrane, but the Graphene membrane gave a TDS Way lower than both, this can lead to the conclusion that the graphene membrane is better filtration mechanism as compared to RO membranes

4. AFTER PLAN OF ACTION

Now that we have reached the conclusion, that graphene membrane can efficiently filter water samples, drastically reducing their TDS, we will send the samples into testing to check whether heavy metal count is reduced. After which, we can move forward with the creation of a prototype model of the membrane along with its fitting in the conventional RO system

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PROGRESS TILL NOW

1. Durability
2. Sampling

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1. DURABILITY OF THE MEMBRANES

Firstly, we observed that the membranes we created demonstrated impressive durability, remaining intact and effective for months after production. Additionally, the filtration process is highly efficient, as nearly all of the input water emerges as filtrate, resulting in minimal waste.

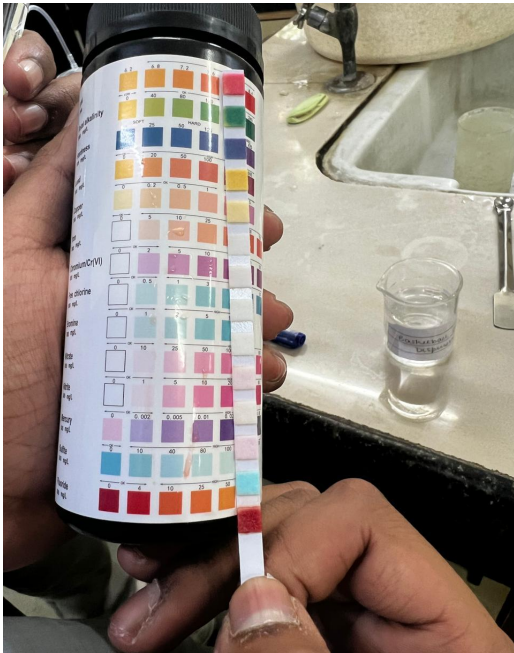
2. SAMPLING

After the sampling with TDS values, we are now progressing with the sampling of heavy metals testing, which was conducted using the heavy metal test strips

Recently, we tried the testing by using a solution of $\text{Pb}(\text{NO}_3)_2$ [Lead Nitrate] and filtered it through the vacuum pump, to check whether there is a change observed in the readings. Before filtering we used the heavy metal testing and checked the readings for the solution, and did the same after filtering out the solution. Upon filtration, the Graphene Membrane gave satisfactory results as it lowered the heavy metal values to a certain amount.

Sample	Metal Concentration	Heavy metal Count of Control	Heavy metal Count of filtrate
Lead Nitrate [$\text{Pb}(\text{NO}_3)_2$]	Nitrates (NO_3)	150	100
	Lead (Pb)	75	50

We are now progressing with the actual testing of heavy metals using water samples from the school and will complete the same by 11/11/24. The water samples taken by us would be Tap Water, water from Basketball Court Dispenser and Water from 1st Floor Dispenser. A comparative analysis table will then be made, which will note down the range of heavy metal concentration shown using the test kits and then compare the same.



Graphene Filtration

Team Name: Marmoris Vernika

Progress Till Now
{ 1.5.25-23.5.25 }

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1. REFABRICATION OF GO MEMBRANE

2. HOMOGENOUS GO MEMBRANE

Step 1: Fabrication of Graphene Oxide Membrane

- Firstly, 0.05 grams of Graphene Oxide was added to 60 ml of water, and the formed solution was then stirred using a Magnetic stirrer for 1 hour, while maintaining a temperature of 50-60° C
- During the stirring, regular checking was done to observe the change in colour of the solution
- After an hour, the desired brownish colour was achieved in the solution while the sediments were left to settle on the base of the flask

Step 2- Layering on Polysulfone Substrate

- Following the previous procedure for this step, We prepared the substrate for membrane fabrication by removing the Polyamide layer on top of the Polysulfone membrane
- The graphene oxide dispersion (after extraction of the sediments) was then filtered out, after placing the substrate (Polysulfone) on the Vacuum Pump.
- Vacuum was generated by the syringe, which caused the water in the graphene solution to penetrate through the membrane into the bottle, while the graphene flakes formed a layer on the polysulfone substrate
- At the end of the process, a homogenous GO membrane was formed on top of the supporting membrane.

3. CROSSLINKING MEMBRANE

Step 1: Formation of GO+CaCl₂ Solution

- Using the same procedure as that used for the fabrication of the homogeneous Graphene Oxide (GO) membrane, another dispersion of Graphene Oxide was prepared.
- Then, 0.2 grams of CaCl₂ was dissolved in 100 mL of distilled water, and the resulting solution was stirred using a magnetic stirrer to dissolve the added CaCl₂ fully.

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- After stirring for the specified duration, the Graphene Oxide dispersion prepared earlier was added drop by drop to the CaCl_2 solution.
- The resulting mixture was then stirred continuously for another 30 minutes to ensure uniform mixing.

Step 2- Layering on Polysulfone Substrate

- Following the previous procedure for this step, we prepared the substrate for membrane fabrication by removing the Polyamide layer on top of the Polysulfone membrane and treating it with dilute Ethanol ($\text{C}_2\text{H}_5\text{OH}$)
- After placing the substrate (Polysulfone) on the Vacuum Pump, the prepared CaCl_2 +GO dispersion (after extraction of the sediments) was filtered out.
- Vacuum was generated by the syringe, which caused the water in the solution to penetrate through the membrane into the bottle, while the solid flakes formed a layer on the Polysulfone substrate
- After the first filtration process, the prepared membrane was left to dry, and the same procedure was repeated several times, forming a steady membrane

4. SAMPLING/OBSERVATIONS

❖ TDS (TOTAL DISSOLVED SALTS) TESTING

Date-13.05.25 & 20.05.25

S.NO	NAME OF SAMPLE	FILTRATION TECHNIQUES USED		
		Control	RO membrane	Graphene membrane
1	Chromium Nitrate	522*	450	438

*Solution prepared by adding 3-4 drops of $\text{Cr}(\text{NO}_3)_3$ in 60 mL Dil. H_2O

Date-22.05.25

S.NO	NAME OF SAMPLE	FILTRATION TECHNIQUES USED		
		Control	Homogenous Graphene membrane	GO+ CaCl_2 membrane
1	TAP WATER	438	407	400

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Date-23.05.25

S.no	Name of Sample	Filtration Techniques used			
		Control	RO membrane	GO+CaCl ₂ membrane	New Homogeneous GO Membrane
1	TAP WATER	430	390	409	350
2	BASKETBALL COURT DISPENSER	425	390	394	336
3	2nd FLOOR DISPENSER	129	133	122	136

5. OBSERVATIONS

1. Probability of tear in membranes

The performance and lifespan of filtration membranes can be affected by several factors during their usage and preparation. Improper handling and storing may cause physical damage such as scratches or bending, leading to leakage paths. During formation of the membrane, if the applied pressure is non-uniform or uneven, it can result in weak spots and structural inconsistencies, making the membrane prone to early failure.

Additionally, stress generated during vacuum filtration and drying may cause micro-cracks that gradually expand under operational flow. Variations in thickness during fabrication can also create regions of higher stress concentration, which become the first points of wear under continuous use. Prolonged exposure to fluctuating water pressure further accelerates fatigue, eventually lowering the efficiency of contaminant removal.

6. CONCLUSIONS

With regards to the above observations, we have concluded the following factors and would increase our focus on these specific areas in the next month

1. Structural Analysis
2. Sampling

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3. Strength Analysis of Membrane