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Surface Functionalization of GO and r-GO in Water Purification

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ABSTRACT

Water is vital for human survival, health, and dignity and a fundamental resource for human development. Around 70 percent of our body is made up of water. So, for our daily life, we need to make sure about having clean water. Contaminated water can cause high-risk diseases for human beings sometimes it could be a reason for a person to die. Illnesses like Hepatitis, Cholera, Diarrhea, etc. are caused by contaminated water which could affect other people easily. Today there are several methods to get access to clean water, the methods used for water purification include physical processes such as filtration, sedimentation, and distillation; biological processes such as slow sand filters or biologically active carbon; chemical processes such as flocculation and chlorination; and the use of electromagnetic radiation such as ultraviolet light. Trusted technology for water purification is Nanofiltration(r-GO) technology and Reverse Osmosis (RO). GO technology has attracted many researchers because of its unique hydrophilicity properties and its cost-effectiveness in mass-scale production. The r-GO membrane is one of the nanofiltration technologies that has the advantages of partial removal of monovalent ions, low process osmotic pressure, low operating pressure Energy saving, and other advantages.

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I. Introduction

A. GO and r-GO Background

Schafhäeutl was the first to present a graphite intercalation execution in 1840. Brodie reported the first oxidation of graphite 15 years later, in Annales de Chimie, in 1855. It was first Staudenmaier who adopted a method for GO creation in 1898 that is a little complicated and harmful. Graphene was thought to be a component ingredient of graphite between 1940(Pan, 1991). Boehm et al. published a method in 1962 for chemically reducing oxidized graphite with the separation of carbon flakes by heating. However, Geim used a specific tape to periodically peel high directed pyrolytic graphite, resulting in monolayer graphene that remained thermodynamically stable in the atmosphere until 2004(Liu, 2017). Meanwhile Graphene was discovered to be a carbon material with a single atomic layer and a two-dimensional honeycomb lattice structure that is structured oxygenated planar molecule as a result of this research. This ground-breaking finding has attracted researchers from various sectors, including physical, chemical, and biological sciences.

Finally, in 1958, Hummers and Offerman devised a method for GO synthetization that was widely adopted and is still used today. Evidence demonstrates that the deflagration point of GO Hammers is lower than the GO Staudenmaier and GO Brodie, thanks to Matuyama's discovery of the first thermogravimetric analysis (TGA) in 1954. Impurities cause a lower deflagration point, according to the general rule. Charpy presented a methodology comparable to the Charpy-Hummers model 50 years before, however, the Charpy-Hummers model was more accurate. Boehm and Scholz compared the three methodologies of O/C ratio, finding that the Hummers approach (carbon content 47%) had the highest. Today the most extensively used method for producing GO as the thinnest and strongest material with a one-atom-thick sheet of sp2-bonded carbon atoms is to process graphite in a solution of sodium nitrate, potassium permanganate, and sulfuric acid(Perrozzi et al., 2015).

B. Different Methods and Technologies of Water Purification

Water has always been a fundamental necessity and basic right for all humans, but as the world's population grows, significant strains are placed on water supplies, and the quality of supplying freshwater remains a major concern for all societies. Because of the importance of water treatment for any beneficial purposes, researchers have been working on water treatment technologies for many years in order to develop appropriate ways (Fig. 1.) (Bhojwani et al., 2019).

In order to address the problem of obtaining purified water, which is the process of removing undesired chemicals, biological contaminants, suspended particles, and gases from water, a variety of water treatment technologies have been created over the years.

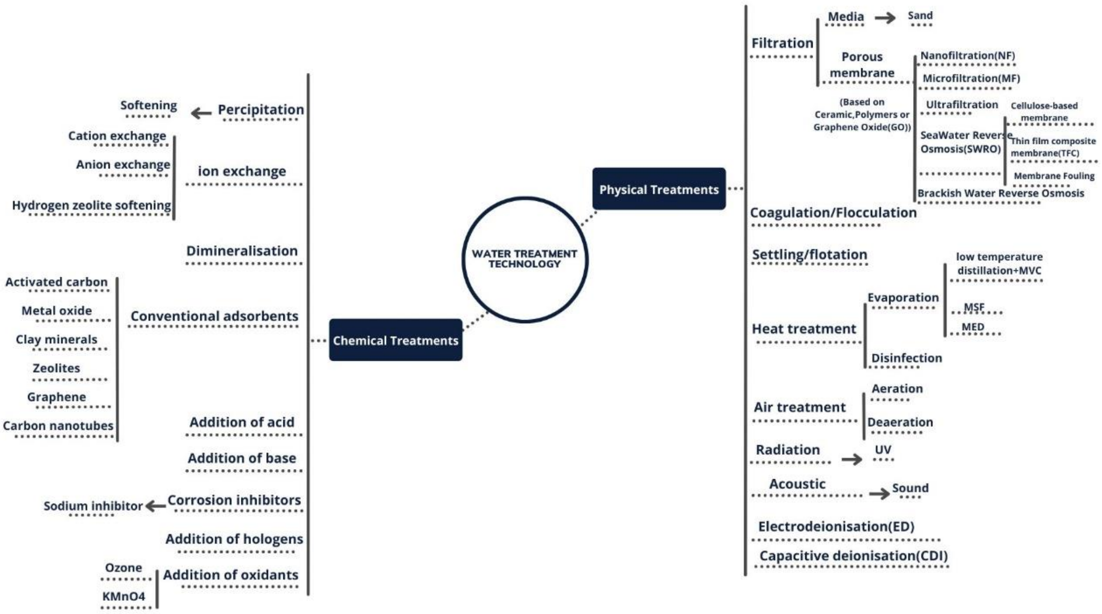


Fig. 1. Water treatment and technologies. Adapted from " Patent Landscape Report on Membrane Filtration and UV Water Treatment" by CambridgeIP - Helena van der Vegt, Ilian Iliev, Copyright 2012 by theWorld Intellectual Property Organization (WIPO).

1. Advanced Membranes and Technologies: With the invention of high-performance synthetic membranes in the 1960s, membranes became a practical method of water filtration. Membrane technology has progressed with the use of more advanced and innovative materials in a variety of designs. The hypothesis of utilizing ocean water became a reality as a result of a severe push over water resources. Membranes were first used to deliver clean water in 1970, with successful results coming from membrane technology to filter saltwater. Membranes have now become a leading evaporation-based method in the water treatment market(Sagle & Freeman, n.d.).

Membrane technology can be defined as a way of separating and passing specified species via a membrane while restricting others due to membrane material features. Membranes are categorized as dense or porous according to the key driver and the mechanism of ionizable movement. The rate of movement of the gas or liquid molecules called diffusion rate which is different in each membrane and depends on various factors like, the solubility, diffusivity, and porosity of the membrane (Lyu et al., 2018). Examples of porous membranes include those used in reverse osmosis, microfiltration, ultrafiltration, and nanofiltration. Of these, ceramic and polymer membranes are the most popular. Even with the current increase in water demand, membrane is still one of the most effective ways to acquire clean water(Sagle & Freeman, n.d.).

2. Desalination research history:

- *History of RO Membranes:* The copper ferrocyanide film was first introduced as one of the RO family membranes by Moritz Traube in 1867, during a time when the topic of RO membranes was very well-liked. Loeb and Sourirajan originally exhibited asymmetric cellulose acetate membranes (CA) in 1963, marking the introduction of RO technology to the market(Sagle & Freeman, n.d.). After the CA membrane gained popularity in 1972 due to its efficiency, salt rejection, great mechanical qualities, high flux, high salt rejection, and high resistance to chlorine, the thin-film composite (TFC) technology was introduced to the market. This TFC technology has many advantages over the CA technology, including the high rate of flux, stability across a wide temperature and pH range, and the ability to reject some low-level organic pollutants. However, they both have a significant drawback that is chlorine resistance, where the CA technology performs better. Fouling is a problem for both of these technologies, and while it can be resolved by pre-treatment procedures, it is still a significant problem for RO membranes.

- *Other Desalination Methods:* There are other different technologies that might be employed for desalination and producing drinkable seawater. Reverse osmosis (RO), multi-stage flash (MSF), and multiple-effect evaporation (MED) were among the first technologies employed in the 19th century (Sagle & Freeman, n.d.). MED and MSF both work on the heat transmission between steam and seawater then the final stage is collecting the clean condensate as clean water. However, the MSF between the two requires more power to make the water. Due to the RO's low energy requirements and use of brackish water, it was more competitive than other technologies in 1960.

There are a few more electrochemistry-based technologies, but they aren't commonly used in the market. Examples include mechanical vapor compression (MVC), capacitive deionization (CDI), and electrodialysis (ED). The ED method uses stacked anionic and cationic membranes to transfer seawater through a series of steps. High-salt solutions cannot be treated with this approach. The CDI method electro-sorbs ions onto charged porous electrodes to remove them. In comparison to other techniques, CDI has a variety of benefits, including strong mechanical properties, simplicity in cleaning, affordability, and reduced water electrolysis. One major drawback of CDI is the paucity of data for large-scale applications. MVC, on the other hand, is quite comparable to MSF and MED in that it uses steam to evaporate the feed water. However, the RO method is still one of the most widely used and cost-effective methods among these technologies due to its lower energy usage. However, there is a drawback to RO systems, which is that they heavily rely on salinity levels, which can raise osmotic pressure and result in increased energy demand. However, this issue has been resolved by the water's pre-treatment procedure throughout the years. If we were to choose a system that can process 27,000 m3 per day and cost $40 million, it would be MSF and MED. A $50 million RO system that could process 100,000 m3 per day would be expensive. Building a RO plant would therefore initially be more expensive, but the final result would be a significantly higher output rate. There are no clear winners when it comes to lessening the chemical impact on the environment because all three techniques can employ biocides that are discharged. Although RO, MED, and MSF brine outputs all have significant salinities and chemical additions, when it comes to discharge temperature, RO is the least harmful to the environment, making it a more environmentally friendly option. Overall, the RO process is more inexpensive and environmentally friendly than the other methods described.

The most efficient desalination technique is reverse osmosis (RO), which has a high salt rejection under a given pressure. Furthermore, because RO is a high-energy process, GO membranes have attracted the attention of many academics. Recently, a variety of adaptive materials for enhancing seawater desalination have been studied, including graphene-based membranes. GO has been viewed as a potential membrane material for water purification and separation applications due to its exceptional hydrophilicity, significant flaws, holes structure, and nanosized flakes. This paper focuses on the development of GO and r-GO membranes, their history in water purification, and applications outside of water purification. The paper concludes with a brief discussion of the social, health, and economic implications of water filtration systems and their significance.

II. A comprehensive review of GO and r-GO

In all forms of life, carbon is used, and this demonstrates the significance of this element's function in crucial processes including DNA creation and photosynthesis. There are numerous different forms of carbon, including graphite, amorphous carbon, and diamond. Graphene is now the basic building block of all carbon nanomaterials, and the most significant members of this family are graphene flakes, graphene oxides, and other graphene compounds. Graphene is produced at a far lower cost than other carbon-based nanomaterials. Over time, many industries have been drawn to use it because of its significant characteristics, such as its limitless design potential, high thermal conductivity, low anisotropic thermal expansion coefficient, high optical transparency and low reflectiveness, excellent mechanical properties, large surface area, and ability to be adjusted (Liu, 2017). Transistors, sensors, electrodes, batteries, capacitors, composites, solar cells, hydrogen storage, displays, spintronics, drug delivery, desalination, and water treatment are just a few of the numerous things it can be used for. The most well-known graphene derivative is graphene oxide. A considerable number of polar oxygen-containing functional groups, such as in-plane distributed hydroxyl groups, epoxy groups, and carboxyl groups at the edges, are found in the chemical oxidation-stripping of graphene oxide, which has a unique structure. Due to the structure's concentration of oxygen-containing functional groups, graphene oxide has a high level of hydrophilicity.

A. Preparation/Synthesis of GO and r-GO

Both synthesis and deposition Sir 2nd Baronet Benjamin Collins Brodie created GO for the first time in 1859 by oxidizing bulk graphite with potassium chlorate and nitric acid, but it took Lerf and Klinowsky more than a century to thoroughly examine the solid-state C13 nuclear magnetic resonance (NMR) spectra and determine the chemical and structural characteristics of GO (Perrozzi et al., 2015). In their ground-breaking investigation, Lerf and Klinowsky postulated that GO is composed of non-oxidized aromatic patches of various sizes, separated from one another by aliphatic 6-membered rings containing hydroxyl groups, epoxide groups, and double bonds. Fig.3. The polar nature and hydrophilic behaviour of GO are caused by the O functional groups, which are present in this model both above and below the basal plane. Graphite oxide can be changed into graphene oxide in a number different method. The most popular techniques are sonication, stirring, or a mix of the two. Sonication can be a very effective and time-efficient way to exfoliate graphite oxide and graphene, but it can also seriously damage graphene particles. The most widely used technique for producing GO, however, is the modified Hummers procedure, which uses sulfuric acid, sodium permanganate, and graphite to create a high yield of GO.

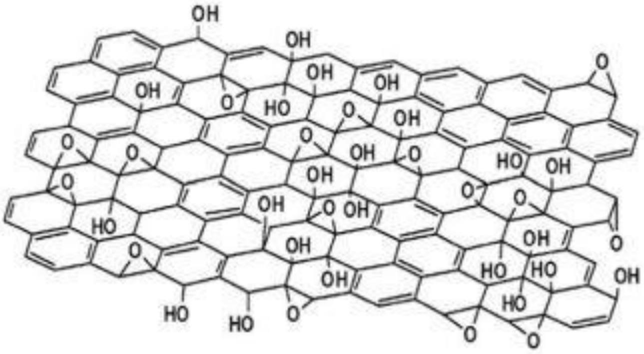


Fig. 3 .The Lerf–Klinowski model was used to create the chemical structure of GO. Reprinted from" Graphene oxide: From fundamentals to applications" by F Perrozzi, S Prezioso and L Ottaviano. Copyright 1998, Elsevier

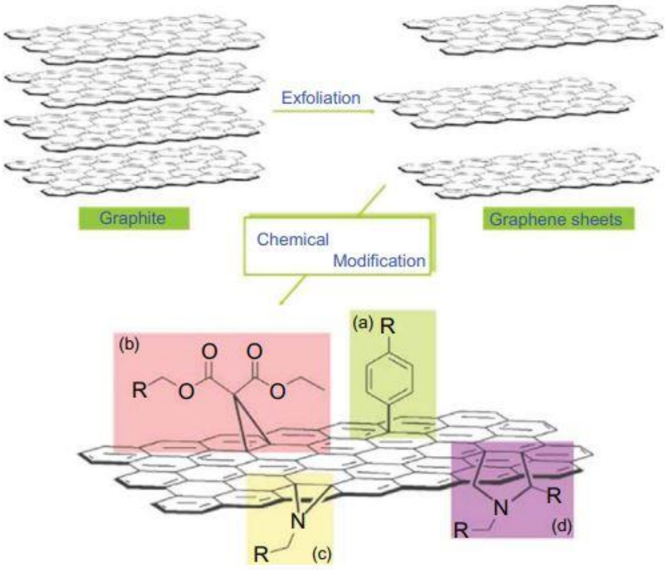


Fig. 4 . General chemical modification routes for exfoliated graphene sheets. (a) [3 1 2] 1,3-dipolar cycloaddition of in situ-generated azomethine ylides, (b) [1 1 2] Bingel cycloaddition, (c) aryl diazonium addition, and (d) azide addition. Reprinted from " Graphene oxide: from fundamentals to applications" by F Perrozzi, S Prezioso and L Ottaviano. Copyright 1998, Elsevier

GO is a single-atomic layer substance consisting of carbon, hydrogen, and oxygen molecules, as depicted in Figure 4 (Stergiou et al., 2014). This makes it simple to process and water-soluble.

removing the oxygen-carrying components from graphene oxide (GO), which is a form of chemically generated graphen, reduced graphen can be created. This reduced graphen is also known as converted graphen, chemically modified graphene, and functionalized graphen, among others (Eda & Chhowalla, 2010).The process of lowering GO to form r-GO affects the quality of the r-GO, which determines how close it will be to pure graphene in structure (Chuang et al., 2014). R-GO is the best alternative for scientific engineers who need vast amounts of graphene for industrial applications like energy storage because it is easy to produce (Ray, 2015).

Earlier, scientists used these methods to produce r-GO from GO (Ray, 2015):

- Using hydrazine hydrate to treat GO and keeping the solution at 100 for 24 hours
- For a few seconds, exposing GO to hydrogen plasma
- Exposing GO to another sort of intense pulse light, such as that produced by xenon flashtubes
- GO was heated in distilled water at various temperatures for various lengths of time.
- Combining GO with an expansion reduction agent such as urea and then heating the solution to cause the urea to release reducing gases, followed by cooling.
- Linear sweep voltammetry
- Directly heating GO to very high levels in a furnace

The most common reduction procedures employed today are thermal, chemical, and solvothermal reduction (Lyu et al., 2018). Some of these techniques can produce extremely high-quality r-GO that looks and feels like pristine graphene, but they can be difficult or time-consuming to implement. Here are several popular r-GO production methods:

1. Thermal Reduction: This process is classified into three types: thermal annealing, microwave, and light irradiation. By rapidly heating graphite oxide (>2000 C) in a non-oxygen furnace, the thermal annealing method lowers it (Lyu et al., 2018). Two stacked GO flakes could be easily peeled off using this method at a pressure of 2.5 MPa. Meanwhile, because to the high pressure and temperature, a significant amount of CO and CO2 will be emitted when oxygen is taken from functional groups containing oxygen and carbon is removed from the graphene-like region of the GO. As a result, wrinkled r-GO flakes can be formed by heating the r-GO flakes in the furnace.Thermal annealing is a highly effective GO reduction method; however, due to the release of CO and CO2, the graphene planes in r-GO nanoflakes prepared by rapid annealing reduction may suffer structural damage, resulting in lower conductivity in the r-GO product than pure graphene and resistance to heating GO membranes deposited on a low melting point substrate material; however, this problem has not been addressed. It is also an energy-intensive technique because a high reaction temperature is required. Researchers have also attempted to synthesize r-GO using microwave or photo-assistance, which can speed up the reduction process by using novel heating methods.

2. Chemical Reagent Reduction: Chemical reduction is preferable to thermal reduction, and it occurs in the chemical environment with chemical solvent. Following the review of the papers, many experiments are conducted to find alternative chemicals to achieve the r-GO and reduce the GO. (Stankovich et al., 2007) were the first to demonstrate that hydrazine may reduce GO the most effectively. Another method reported by (Periasamy & Thirumalaikumar, 2000) reveals that metal hydrides($NaBH_4$) can reduce GO and produce r-GO. Another method indicated in the studies by (Pei et al., 2010) is the use of hydroiodic acid (HI) to create r-GO with a stable structure.

3. Hydrothermal Reduction: This procedure is more reliable and productive and can result in high-quality r-GO. For this strategy, a complicated system is not required. The final r-GO produced by this process includes graphene hydrogels, stable r-GO solutions, and other phases. This procedure begins with a container that is sealed and that begins to boil at a temperature greater than the solvent (Lyu et al., 2018). When the temperature is elevated, the concentration of H+ in the solution rises, which causes the amount of GO sheets to decrease. (Zhou et al., 2009) have demonstrated that GO can be hydrothermally converted to a stable r-GO aqueous environment at a temperature of 50 degrees Celsius. In this case, (Zhou et al., 2009) found that an alkaline GO suspension (pH = 11) may carry out r-GO solution while an acidic GO suspension (pH = 3) has a tendency to agglomerate r-GO flakes. Figure 5 shows the process of r-GO in general.

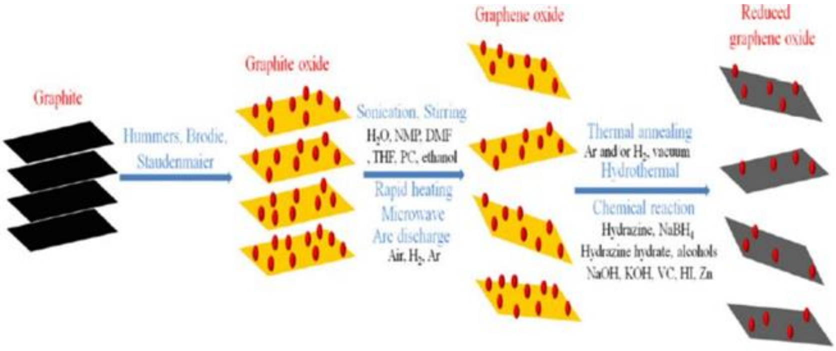


Fig. 5 . The Process of r-GO Production in the Three Mentioned Reduction Methods. Reprinted from " Separation and purification using GO and r-GO membranes" by Lyu et al., 2018.

III. GO AND R-GO CHARACTERIZATION/PROPERTIES

A. Morphological properties

1. Size: Two approaches, normal optical or fluorescence microscopy, can be used to see their size ranges (Zhang et al., 2009) (Pan & Aksay, 2011). The study by (Perrozzi et al., 2015) claims that they employed sonication to measure the lateral size of GO, which may be used to repeatedly fragmentate GO to lower its size. According to this study, increasing the sonication period may result in smaller GO flakes.

2. Thickness: Another morphological attribute that can be determined by AFM is thickness, a morphological characteristic with a measurement range of 1.0 nm to 1.4 nm for GO, with significant technical uncertainty. Very accurate structural and morphological data on GO can be obtained by downscaling microscopy methods to the atomic resolution limit (Jung et al., 2008; Perrozzi et al., 2015; Stankovich et al., 2007). According to a different study, DFM testing showed that the GO sheet layers are 2- to 3-nm thick, which is somewhat thicker than single-layer graphene (Song et al., 2014). The part of the sheet that stiffens up is mostly caused by the addition of functional groups containing oxygen. Furthermore, the thickness of GO sheets was higher at the margins and lower in the center because the oxygen-energy groups were largely linked with the edges of GO sheets.

B. Fundamental Characterization

Thermal and optical are the two main properties are described here.

1. Thermal Properties: The GO was extensively tested to assess its quality based on the study by Song et al. (2014). This study demonstrates in three stages that when the temperature is around 100°C, 2% of the GO quality is lost as a result of the loss of H_2O molecules. Thermal breakdown of instable oxygen-containing functional groups caused a 32% quality loss when the temperature was raised to 225°C. When the temperature is raised to 620°C during the experiment's last phase, about 45% of the quality is lost as a result of the carbon skeleton's burning. Under general, the GO looks are stable and function well in high temperatures. Other research demonstrates that the high thermal conductivity of GO, which is roughly

5000W$m^{-1}K^{-1}$, has attracted considerable interest for its potential in the development of novel materials by fusing it with polymers, and that GO inherited this property from graphite (Balandin, 2011; Balandin et al., 2008; Graphene Oxide, 2016).

2. Optical Properties: The investigation on the UV-VIS diffuse reflectance spectra of GO sheets reveals that GO exhibits substantial absorption in the visible range (380–800 nm),the visibility of the GO in ultraviolet is based on its electronic transitions where there are two places where this visibility happen first at ~ 230nm the π→π* transitions in the aromatic C=C bonds happens and second its absorption at 300 nm indicates the presence of carbonyl groups in GO where the n→π* transitions in the C=O bonds happens which is less energetic (Chen et al., 2013; *Graphene Oxide*, 2016; Trikkaliotis et al., 2021), as determined by X-ray photoelectron spectroscopy (XPS). Nevertheless, UV absorption decreased (Song et al., 2014).

IV. THE APPLICATIONS OF GO AND R-GO

The functionalized process and GO characterization may differ depending on where we use GO in the applications. Examples include the following. Covalent and noncovalent approaches are employed in the functionalization process. The functionalization technique has divided GO and r-GO applications into six categories:

A. GO/r-GO in Electronics Devices

A variety of electrical devices have at least one component made using GO as a starting material. One such device is a graphene-based field-effect transistor (FET)(Ray, 2015; Su et al., 2010; Wang et al., 2010).

B. GO/r-GO as Energy Storage Device

GO and r-GO are being considered for use as electrode materials in batteries, double-layered capacitors, fuel cells, and solar cells because of their large surface area (Ray, 2015; Zhu, Murali, Cai, et al., 2010; Zhu, Murali, Stoller, et al., 2010).

C. GO/r-GO as Biosensors and materials for healthcare applications

A fluorescent molecule called GO/r-GO may be used for biosensing, early disease detection, and possibly to help with the search for cancer treatments and the identification of biologically important substances. Improved diagnostics are promised by the successful use of GO in fluorescent-based biosensors for DNA and protein detection (Ray, 2015). According to the findings, a bioactive multifunctional CePO4/CS/GO scaffold with capabilities like photothermal treatment for tumor killing is produced by coupling graphene oxide (GO) nanoparticles, hydrated CePO4 nanorods, and bioactive chitosan (CS) (Ge et al., 2021).

D. GO/r-GO as Biomedical Applications

In medication delivery systems, GO is frequently used in the biomedical industry. GO is probably preferable to many other anticancer drugs because it only targets tumors and has little harm (Ray, 2015; Yang et al., 2011).

E. GO/r-GO in Water purification

As mentioned, GO is one of the new technologies that is best for water membranes, even if it weighs more than Ro membranes. Here are low-energy and simple methods for depositing synthesized GO for water membranes (Liu, 2017).

1. Vacuum Filtration Method:

This method filters GO suspension and deposits freestanding GO membranes with strong vacuum pressure (Lyu et al., 2018). This approach can to make GO membranes for larger scales because the produced GO needs to have a support material for using as a membrane in beg scale (Liu, 2017).The vacuum pump's continuous suction force swiftly transports water, causing high electrostatic repulsion among GO flakes, which overcomes graphene oxide aggregation and produces ordered laminated GO membranes. Tickness in this method could be controlled and the recent research Huang et al. employed a filtering approach to manufacture graphene oxide membranes by adjusting pressure, salt concentration, and pH, which may be used to control the graphene oxide channel size (Liu, 2017).

2. Spray Coating Method:

Spray coating equipment evenly sprays the solution over the substrate, then evaporating the solvent yields the membrane. The cannon atomizes liquids into tiny droplets and warms the substrate to speed up volatile solvents. The spray method is affordable, has a high production efficiency, can be sprayed on any substrate, and prepares a large area (Liu, 2017).

3. Spin Coating Method:

Put the graphene solution on the substrate, rotate it, and control its speed. First, drop the GO solution on a base. After spinning the plate, the centrifugal force-structured thin layer is the final phase. Changing graphene solution concentration and speed while filming can change membrane thickness (Liu, 2017).

4. Dip Coating Method:

Dip coating includes immersing the substrate in a graphene oxide solution, extracting it using a machine, and recovering the solution. Mechanical batch processing adjusts solution temperature, concentration, and pulling speed to control film thickness (Liu, 2017).

5. Layer by Layer self-assembly Method (LBL)

This method deposits stable GO nanosheets via covalent bonding and electrostatic interaction. Hydroxyl and carboxyl acid groups give GO flakes a negative charge. Thus, substantial electrostatic contact between the positively charged substrate and the negatively charged GO nanosheets facilitates GO sheet deposition. These functional groups react with several substances, enabling LBL assembly. Since GO is amphiphilic, hydrophilic substrates help assemble GO membranes by producing one-layer water molecules between the bottom-graphene layer's oxide sheet and substrate. The solution pH can affect the microstructure of LBL-assembled stacked GO sheets. The LBL method produce more efficient and stable GO membranes than vacuum filtering method (Lyu et al., 2018).

V. THE AVAILABILITY OF GO AND R-GO

Although GO and r-GO are produced in several nations, only US-based enterprises are listed in Table I. Graphene is produced in the United States by mail-order companies for niche customers. Graphene may be used for a variety of things, including fabrics and batteries.

Based on engagement metrics, the top graphene suppliers on Thomasnet.com are included in this table in no particular order.

TABLE I
Top Graphene Suppliers Based on USA

Company Name	City, State
1st Graphene	Santa Ana, CA
Global Graphene Group	Dayton, OH
Graphene 3d Lab, Inc	Ronkonkoma, NY
Graphene One LLC	Los Angeles, CA
Graphenea Inc.	Cambridge, MA
Graphite Central	Rockleigh, NJ
Grolltex	San Diego, CA
TCI America	Portland, OR
XG Sciences, Inc	Lansing, MI

Since graphene production is still in its infancy, there are numerous active manufacturers outside of the United States who have listed with Thomasnet.com. Australia, Canada, China, Italy, and the United Kingdom are home to the most well-known of these businesses. Subsidiaries with a graphene concentration can be found in several of the biggest businesses. Table II shows the list of global manufacturers.

TABLE II
Global Graphene Manufacturers

Company Name	Location
Directa Plus PLC	Italy
Talga Resources Ltd.	Australia
Versarien PLC	United Kingdom
Saint Jean Carbon Inc	Canada
Haydale Graphene Industries	United Kingdom
Group Nanoxplore Inc.	Canada
Graphene NanoChem LLC	United Kingdom
First Graphene	Australia
Elcora Advanced Materials	Canada
China Carbon Graphite Group	China

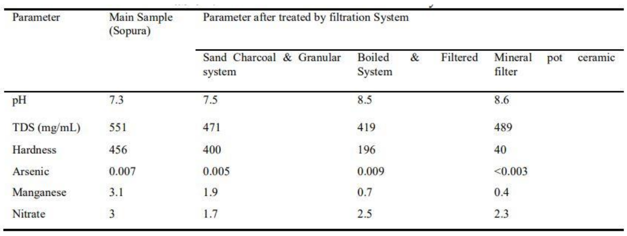
VI. SOCIAL, HEALTH, AND ECONOMICAL IMPACTS OF WATER PURIFICATION

Access to safe drinking water was the first Millennium Development Goal attained in 2012. The first goal, stated in 2000, was to reduce by half by 2015 the number of people without access to safe drinking water and basic sanitation (*Patent Landscape Report on Membrane Filtration and UV Water Treatment*, n.d.). To attain this goal, they employ basic, low-cost technologies and water treatments. Simultaneously, water difficulties will continue to intensify, needing further investment and technological innovation to meet global demands. Clean water is essential to the public health, economic development, and national security of a country, especially for women and girls. Numerous causes, such as population expansion, rising affluence in emerging nations, continued urbanization and industrialisation, and climate change, are exerting pressure on the world's water supplies, necessitating substantial investments in water treatment technologies. Improving the water quality of existing freshwater sources, as well as the measures outlined in this essay, has been a substantial solution to this problem during the past several decades. The effects of these water purifiers on health, women's empowerment, and the environment are described below.

A. The Importance of Water Purification

Since access to clean water is essential for human health, illnesses brought on by a lack of it, like nervous system disorders and gastrointestinal illnesses, can put people's lives in danger. 783 million people globally lack access to safe drinking water, with 84 percent of them living in rural areas, according to a UNICEF and WHO study published in 2012 (Hasan et al., 2021). Due to significant developments like population growth and industrial expansion, both surface and groundwater are being used more and more. Water quantity and quality are therefore important and should be taken into consideration. Since they discovered arsenic in the water and discovered that many people were impacted by this poisonous pollution, they began testing the water quality in various countries, such as Bangladesh, which is the subject of the case study of (Hasan et al., 2021)'s paper investigation. The Rajshahi metropolitan area, where people were having problems due to the high concentration of non-toxic contaminants including iron and manganese in bathing and drinking water, was the focus of the case study. This study aims to explain how water purifiers have influenced the region's water quality. Table III displays the effects of using three water purification techniques on a water sample from the Sopura area of the Rajshahi metropolitan area. We can see in this table the significant reduction in pollution on the water sample after using these water purification techniques on water quality.

TABLE III
The Result of Sopura's Water Quality After Using Three Water Treatment Methods (Hasan et al., 2021).
Reprinted from "Quality Measurement of Drinking Water in Rajshahi City Corporation and Effectiveness of Different Water Purifiers".



Parameter	Main Sample (Sopura)	Parameter after treated by filtration System		
		Sand Charcoal & Granular system	Boiled & Filtered System	Mineral pot ceramic filter
pH	7.3	7.5	8.5	8.6
TDS (mg/mL)	551	471	419	489
Hardness	456	400	196	40
Arsenic	0.007	0.005	0.009	<0.003
Manganese	3.1	1.9	0.7	0.4
Nitrate	3	1.7	2.5	2.3

It can demonstrate that the various strategies have a substantial impact on achieving a standard range. Manganese, hardness, and nitrate were all dramatically reduced in the water samples. The mineral pot ceramic filter and the Sand Charcoal & Granular system were both successful in removing arsenic from the samples, while the Boiled & Filtered System was not. In general, utilizing more complex water purifiers improved the majority of the criteria and resulted in drinkable water.

B. Water Purifiers and Women Empowerment

It is still expected of women and girls in some traditional cultures to collect water and obtain access to clean water because it is their duty to do so. This makes it difficult for them to participate in significant global issues in worldwide global associations and to stand up for their rights, education, and participation. But from a different perspective, women can also fight for themselves by getting involved in water projects. The Wanaraniya Water Project, which is located in Wanaraniya, a GN Division in the Rattota district of Matale, is a prime example of how each woman involved in this project is able to develop her own strength.

1. The Economy Status of Wanaraniya: The total population of this community, which includes 485 women and girls and 479 men and boys, is estimated to be around 964 according to the paper by Aladuwaka and Momsen (2010). Out of the 283 families in the village, 173 are recipients of Samurdhi, the National Poverty Alleviation Program. This is a good indicator for demonstrating the extent of the poverty in this area and where people are more likely to receive assistance (Aladuwaka & Momsen, 2010).

2. Current Water Condition: Since wells and streams are the only readily available water sources in the village, the water quality isn't very good, and homes must use them to obtain water. Due to the fact that these sources dry up during the dry season, the residents are only able to access water from the Bambara Kiri Ella River, which is 6.5 kilometers away from the community and a difficult task for women and girls to do.

3. The Start Point of "Power Within" for Wanaraniya's Women: The ladies in this village resolved to alter their lives and the lives of the other villagers by building a dam in the village's annual stream, which is located 6.5 kilometres away, and they also chose to design a pipeline for each family to have easy access to water for basic daily needs (Aladuwaka & Momsen, 2010). They first provided assistance and required funding to cover costs, and the Rattota Pradeshiya Sabha (PS) (local government unit) estimated that the initiative would cost about four million rupees. The Rattota Pradeshiya Sabha didn't provide financial support for the project, so the women didn't have much time to waste asking for outside assistance. Instead, they came up with the idea of asking each household to pay their own share, which was roughly 100 rupees, in order to gain access to the water pipeline. In July 2001, the project was launched with financial support from the households and technical assistance from one of Sri Lanka's biggest non-governmental organizations, Sarvodaya Rural Technical Services (SRTS). They encountered many forms of financial difficulty during the process; therefore they initially chose to borrow money from the Christian group Ecumenical Loan Fund, Sri Lanka (ECLOP) at a rate of 12%. However, after some time, a second issue surfaced: they were unable to pay back the debts. Because of their innovative thinking, they chose to hold a lottery that they sold tickets for over a month in order to pay back the debts. Fortunately, they were only able to effectively complete the project in seven months. The project was completed in February 2002 with the installation of the pipeline for the approximately 147 houses that have paid their portion. However, as the other inhabitants witnessed the project's successful conclusion, they chose to contribute to get the pipeline for their homes as well, but they would have to do so now at a greater cost. These households asserted that their initial hesitation to pay the money was due to a lack of faith in the project leading by women.

While working on this project, women faced a variety of challenges, including male resistance and financial difficulties, but in the end, they were able to make a substantial difference in the villagers' access to education, health care, and most importantly, power.

VII. CONCLUSION

There are many water treatment technologies, but they all have drawbacks, including the need for higher energy costs and expensive costs for businesses. However, GO has developed a new technique that may use less energy and cost even on a large scale. The two most recent technologies, GO and r-Go, are succeeding well in the market and are used for water membranes in the process of purifying water because of their excellent features, particularly high hydrophilicity. Hummers method is one of the greatest ways to manufacture GO. Applications for GO and r-GO range from electronic devices to use in cancer treatment, and finally for water treatment, where one of the finest ways to create water membrane from GO is Layer by Layer self-assembly Method.

Due to its popularity in industrial applications, several nations today, particularly the USA, attempt to produce GO. At the end the goal of this essay was to demonstrate the significance of water purification in terms of women's empowerment, health, and water quality in the community of Sopura, where access to clean water is problematic.

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