AQUA-TECH PURIFIER

Water purification

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Introduction

Like many other countries, Egypt faces many challenges that obstruct its progression. The capstone project, in general, aims to solve a specific problem in one or more of these challenges, which are: Improving sources of clean water, reducing urban congestion, increasing opportunities for Egyptians to stay and work in Egypt, reducing pollution, recycling and retain garbage for recycling, work to eradicate public health issues/diseases, improving the use of arid areas, increase the industrial base for Egypt, improve the use of alternative energies, and finally dealing with the exponential population growth. The capstone project is concerned mainly with five of those challenges. These challenges are improving the clean water sources for domestic uses, poor industrial and agricultural bases of Egypt, addressing and reducing pollution fouling on air, water, er, and soil, working to eradicate public health issues/disease, and the last challenge improving the uses of arid areas. Finally, the improvement process for the new world should not negatively affect the planet even if their consequences are aiding in the progression of human lives. Instead, the advancement of life should be paired with the safety of the earth and the continuity of green energy on the blue planet.

Egypt Grand Challenges:

1-Address and reduce pollution fouling on air, water, and soil:

The World Health Organization (WHO) estimated that 829,000 die each year from diarrhea as a result of polluted water such as unsafe drinking water and sanitation. Pollution is that negative impact that has recently resulted mostly from the industrial pollutants affecting the surrounding environment, and the living organisms exposed to these pollutants. Pollution is a severe problem in the new world called the global killer. According to the statistics, pollution kills 8.3 million people globally per year as shown in figure (1). The most severe conditions are not contagious diseases, but pollution nowadays can be listed among the top worldwide reasons for living organisms' deaths. Pollution has several types such as air pollution, water pollution, land pollution, noise pollution, and light pollution. About 4.2 million people die annually due to exposure to air pollution.

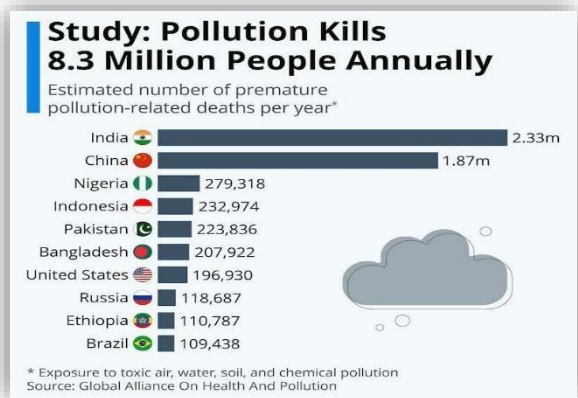


Fig.1

Causes:

❖ ***Throwing garbage***

About 16% of worldwide pollution is because of the spread of garbage in the streets, which leads to the spread of air pollution and water pollution if this garbage is thrown into the sea. This widespread pollution is because of the poor lifestyle and the lack of sufficient awareness about the efficiency of a clean environment. In terms of plastic, it was calculated that 8.3 million tons of it are discarded in the sea yearly. In 2016, the world generated 2.01 billion tons of solid waste.

With today's rapid population growth, annual waste generation is expected to increase by 70% from 2016 to 3.40 billion tons in 2050.

❖ Oil Leaks and Spills in oceans

Environmental Protection Agency (EPA) estimates that current leak rates across the natural gas supply chain are 2-3%. This leakage into the oceans leads to the pollution of the water of the area in which the leak occurred and the death of living creatures that live there and birds that feed on them. Also, this leakage might cause air pollution due to the smell of the dead living creatures that would spread into the atmosphere in that area.

❖ *The emission of greenhouse gases*

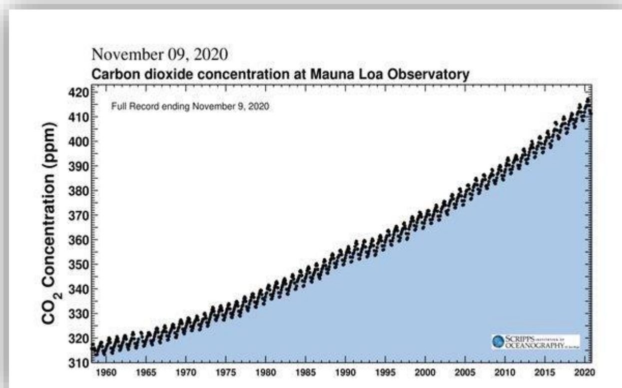


Fig.2

In 2016, about 219.377 million tons of greenhouse gases were emitted into the atmosphere of Egypt. The percentage of greenhouse gases generally increases one day after another in the atmosphere, as shown in figure (2). This increase in the emission of greenhouse gases into the atmosphere causes air pollution in the surrounding areas. It also leads to global warming that causes water temperatures to rise, which can kill water-dwelling animals and thus pollute the water. Those emissions are mainly because of human activities such as burning forests and fossils fuel and the smoke from the factories.

❖ *Natural disasters*

Each year, an average of ten tropical storms occurs. About six of them turn into hurricanes, which lead to air pollution by spreading the dust into the air and thus reducing the air quality. When volcanoes erupt, they throw volcanic ash and sky gases into the air, which leads to air pollution and the spread of grey smoke that is harmful to living organisms. Floods also might lead to pollution because they bring pollutants such as farm waste from the water to the land.

Impacts:

❖ *Poor public health*

Fig.3

Exposure to elevated levels of air pollution can lead to various negative health outcomes. It increases the risk of respiratory disease, heart disease, and lung cancer. According to the UN, about seven million people die annually because of air pollution. Also, polluted water is related to the Chapter I: Present and Justify a Problem and Solution Requirements. 16 transmission of diseases such as cholera, diarrhea, hepatitis A, typhoid, and giardia as shown in figure (3). In addition, many people suffer from diseases like digestive diseases because of contaminated fruits planted on polluted land exposed to soil pollution.

❖ *Contamination of the food chain*

Pollution also causes a disruption in the food chain by affecting one type of species in such a bad way that may lead to the extinction of that species. This affects the other organisms badly because it increases the number of preys of this type because the predatory type is no longer there to feed on them. In addition, fishing in polluted waters and using wastewater for livestock and agriculture can introduce toxins into foods that are harmful to human health when eaten.

❖ *High crime and poverty rates*

According to the World Bank, about 9.2% of the world's population (689 million people) live in extreme poverty states, as shown in figure (4). A study conducted in 2021 showed that pollution leads to an increase in poverty and crime rates. For example, a country exposed to soil pollution leads to spoiling its products, which leads to a depression in trade rates and poor economic conditions and thus the spread of poverty, which leads to an increase in the percentage of crimes committed in the country.

Fig.4

2- Manage and increase sources of clean water:

Providing and delivering clean water is a top priority for any country, including Egypt. This is due to the importance and many uses of water. Water usage is divided into three main sectors: domestic, agricultural, and industrial. Starting with domestic use (also called municipal use), it is essentially the usage of water by citizens to meet their needs. This includes indoor and outdoor uses in all households. Examples of these uses include – but are not limited to – drinking, food cooking, bathing & hygiene care, and washing clothes. This sector demands the highest quality of water as humans directly use it. **As shown in figure 5**, domestic use of water

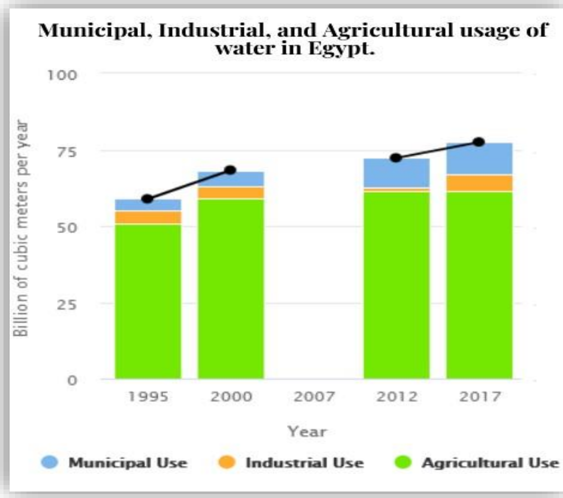


Fig.5

consumed only around 14% of total consumption in Egypt. The next sector is the agricultural use of water. This sector consumes the most significant amount of water in Egypt, as 79% of water is consumed for agricultural use. This sector uses water in growing crops by irrigating and cooling them, and sustaining livestock, by cleaning and giving water to animals. According to the World Bank org., the agriculture sector contributed 11.8% to Egypt's GDP in 2021 and employed 21% of total employment in 2019. Although agriculture's GDP share and employment percentage have been slowly declining in recent years, it is still an essential factor in Egypt's economy. This is why providing water of a quality that is suitable for agricultural applications is crucial to the Egyptian government.

The third and last sector is the industrial use of water. It is the lowest consuming sector, consuming only 7% of total water in Egypt. However, its uses in the sector vary widely. Some water uses in this sector are cooling, washing, smelting, or diluting. According to the World Bank org., industry shared 15% percent of Egypt's GDP in 2021. It is important to note that the industry's reliance on water is lower than agriculture, as industries mainly depend on raw materials like metals and fuel sources like oil and natural gas.

The three sectors require clean water to accommodate their uses. However, according to the United Nations, Egypt has a water shortage of around seven billion cubic meters of water every year and is likely to run out of water by 2025. This shortage of water affects the sectors thoroughly.

In the case of agriculture, it causes food shortages due to crops not being able to grow. And for industry, it affects the economy negatively, as factories that depend on the water will slow or even cease production in the case of water shortages. Most importantly, the domestic sector does not get enough water. According to the United Nations, in 2014, 7.3 million people were deprived of clean water. This is a critical issue, as water deprivation causes serious health issues and deaths. And with the steady increase of the population in Egypt, clean water is expected to become a precious resource rather than a necessity.

Therefore, Egypt should look for more clean water sources, and the government should declare laws that prohibit wasting water from citizens, farms, and factories while researching new ways to utilize and clean wastewater for recycling.

Causes *for clean water scarcity:*

❖ Population growth

The population in Egypt reached 106 million in 2022, and the number is increasing with an annual change of 1.9%. Consequently, the bigger population demands more clean water in the domestic sector for drinking and hygiene, the agricultural sector to provide more nutrition, and the industrial sector due to the ***Figure 6: Graphs Egypt's use of domestic water (bar)*** increase in product demand. The ***vs the population (line) from 2005 to 2015.***

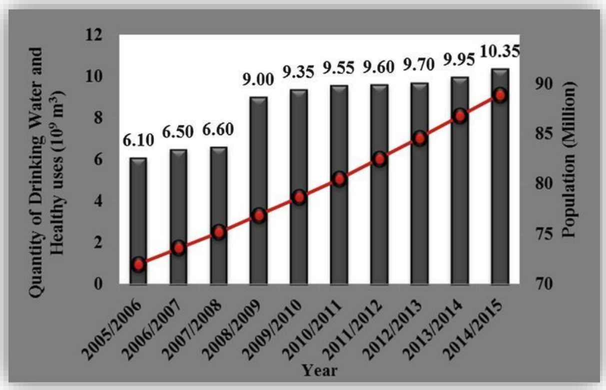


Fig.6

Egyptian CAPMAS provided data in 2016 that showed an increase in drinking and healthy water from 6.10 BCM usage in 2006 to 10.35 in 2015, **as shown in figure 6.** This corresponds to a net gain of 4.25 BCM. The steady increase in demand will still grow for years, and yet Egypt has access to few water resources. Therefore, the population growth is causing water scarcity in the country.

❖ *The pollution of water bodies*

Many industries in Egypt dump their wastewater in water bodies, polluting the water in the process. This wastewater can contain pollutants like mercury, lead, or sulfur, which are difficult to separate from water, causing irreversible damage. According to the EEAA, the amount of these industrial contaminants thrown into the Nile reaches 4.5 tons per year, in addition to the millions of tons of organic pollutants thrown. Furthermore, areas with no sewage systems discharge their wastes into the Nile and other nearby freshwater sources. The agricultural field is also responsible for the pollution of water sources, as chemical pesticides and fertilizers runoff contaminate the Nile.

3- Recycle garbage and waste for economic and environmental purposes

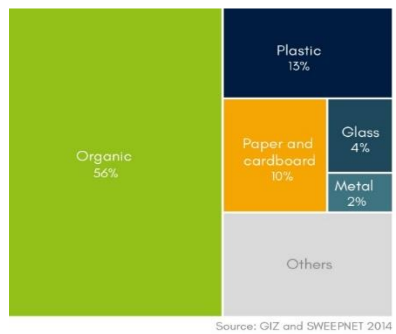


Fig.7

Fig.8

Recycling is important nowadays as we need to reuse materials as shown in figure (7) and have a cleaner and healthier environment. Recycling helps in reducing the volume of waste in landfills. It also can lead to economic benefits where some people can work in waste management and gain money to have a better living. It saves a lot of energy and also, protects natural habitats for the future. Recycling can prevent pollution by reducing the need to collect new raw materials. Not recycling will lead to the spread of infectious diseases and increase pollution in Egypt. Some of the materials that can be recycled are glass, paper, plastic, wood, chemicals, tires, organics, and used oil as shown in figure (8). It also can have bad economic impacts like lower land values and reduced tourism which can be high financial income for Egypt due to the difference of currencies from one country to another. Egypt has high rates of waste generation due to urbanization and high population growth which make it hard to manage the process of recycling perfectly. The rate of waste recycling in Egypt is remarkable given the lack of investment in this area by public authorities. Egypt produces a high amount of waste annually like it produces around 100 million tons of waste annually divided into The main streams of waste in Egypt are agricultural waste (34%), cleansing of canals and irrigation networks (28%), MSW (23%), construction waste (6%) and industrial waste (5%). That's a high amount yearly. Urban areas have a waste collection rate of up to 85%, while rural areas lag behind at 35%. Salvage, reuse, and recycling practices fuel a real economy that is plugged into global networks. The country is working to improve its recycling industry. The government is planning to produce 31 waste treatment and recycling plants all over Egypt to reduce air pollution and have a green environment. Plastic is the most recycled material in Egypt. Many people in Egypt don't understand how to recycle or don't even know its importance as we need to recycle most of our materials to reuse them again or to protect ourselves from air and water pollution as this makes us have a bad environment and bad health conditions. Egypt should make awareness campaigns everywhere to spread awareness about recycling as it is important in our lives.

Fig.9

4- Improve uses of arid areas:

A land is considered arid when it lacks water to the point of hindering the development of plants and animals. Environments subject to arid climates are called xeric or deserts and tend to lack vegetation. Egypt has one million km^2 of land, but only 4% of that land is inhabited by its 104-million-person population, usually around the Nile's valley and the Delta. The rest of the land is avoided for being arid. Arid environments vary greatly in terms of their soils, landforms, flora, fauna, water balances, and human activities. And **as shown in figure 10,** a map with the aridity index of Egypt informs that 95% of its land is an enormous desert that depends on the Nile River**.**

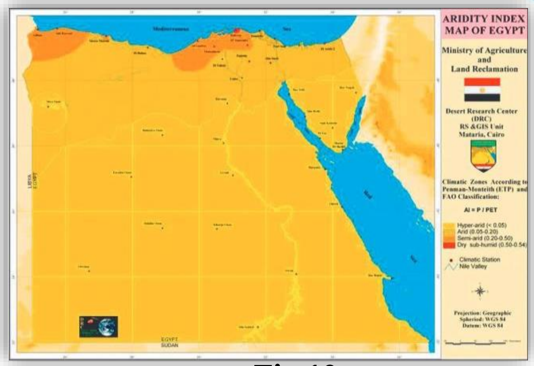


Fig.10

Arid areas in Egypt are divided into three parts:

Sinai Peninsula:

Sinai Peninsula is located in the northeastern portion of Egypt and occupies a very small portion of the extremely SW part of the Asian continent. The total area of Sinai is 61,000 km^2

Eastern Desert:

The Eastern Desert covers an area of about 223,000 km ^{2}. It is bordered by the Nile Valley on the West, the Suez Canal, the Gulf of Suez, and the Red Sea on the East.

Western Desert:

The Western Desert occupies a vast area that has an area of about 681,000 km^2. extends over a vast area occupying about 681,000 km2. It consists of a large, rocky surface with the highest part in the southwestern corner where Gebel (mountain) Uweinat is found. North of Uweinat, the Great Gulf plateau was formed of Nubian Sandstone occurred.

Causes:

❖*Global warming*

Under a scenario of climate warming, arid regions are predicted to see major changes, but there is great range and uncertainty in these estimates between different scenarios. For climate change modeling in arid areas, the complexity of precipitation changes, vegetation-climate feedbacks, and direct physiological effects of CO_2 on vegetation present significant challenges. The predicted reactions of dry environments to increased CO_2 and global warming are highly unknown. The frequency, severity, and subregional patterns of previous changes in the world's deserts that are not usually reflected by climatic models are shown by paleo data. However, it is crucial to keep in mind that global mechanisms underlying Quaternary climate variability were distinct from current patterns, making any comparisons between the past and today extremely cautious. Even though paleo data offer useful information, it seems unlikely that the history of the world's deserts will provide information into how the vegetation-climate system will change in the future.

❖*Lack of investors*

The lack of incentive for investors to invest in the development of arid areas caused a big problem in Egypt. The problem of arid areas in Egypt can be solved if new developments and projects are done in those areas. However, no investors are interested in developing arid areas as they see a lack of economic profit from them. Therefore, more investments should be done to solve the problem of arid areas.

❖*The high-sun period*

Through the high-sun period, strong and dampening heat spreads. Noon readings of 40 and 45° C are common during this season. During the low sun, the days are still warm, with the daily maximum usually averaging 15 to 20° C and occasionally reaching 25°C. Nights are distinctly chilly with an average minimum of about 10°C.

5- Increase the industrial and agricultural base of Egypt

Poor hygiene, crowding and bad nutritional habits were primary causes for the common illnesses seen throughout Egypt in 2010. The most common everyday health problems involved influenza in its many forms. Lamia Mohsen, secretary general for the National Council of Childhood and Motherhood and professor of pediatrics and neonatology at Cairo University, points out that these cases were “not necessarily the H1N1.” Essay Gouda is professor of chest diseases and allergies at Alexandria University's faculty of medicine, and a fellow of the American College of Chest Physicians. He says 2010 started out with an H1N1 epidemic: many patients were infected by the virus and the percentage of deaths from influenza was slightly above the norm. However, towards the end of the year numbers decreased and the epidemic ceased. According to the website Flucount.org, the flu infected 204.6 per millions of Egypt's population and 1.7 percent of those cases were fatal.

Problem to be solved

Water Pollution in Egypt:

A report by the Egyptian Organization for Human Rights titled “Water Pollution: A ticking time bomb threatening the life of the Egyptians” says that approximately 38 million people drink polluted water. It also reports that the amount of untreated or partially treated industrial pollutants that enter the water supply is estimated at about 4.5 million tons per year. It pointed out that the high rates of poisoning cases are caused by pollution from the different cities of Egypt; 35% by Cairo, 12% by Giza, and 50% by Qalyubiyah. According to several reports and studies, on water, 100,000 people are diagnosed with cancer every year, and 15,000 people get kidney failure along with other diseases due to the water pollution in Egypt.(Fady Michael, April 1st 2014.)

Causes of water pollution:

1- Agricultural:

Not only is the agricultural sector the biggest consumer of global freshwater resources, with farming and livestock production using about **70 percent** of the earth’s surface water supplies, but it’s also a serious water polluter. Around the world, agriculture is the leading cause of water degradation. In the United States, agricultural pollution is **the top** source of contamination in rivers and streams, the second-biggest source in wetlands, and the third main source in lakes. It’s also a major contributor of contamination to estuaries and groundwater. Every time it rains, fertilizers, pesticides, and animal waste from farms and livestock operations wash nutrients and pathogens—such bacteria and viruses—into our waterways. Nutrient pollution, caused by excess nitrogen and phosphorus in water or air, is the number-one threat to water quality worldwide and can cause algal blooms, a toxic soup of blue-green algae that can be harmful to people and wildlife.

2- Sewage and wastewater

Used water is wastewater. It comes from our sinks, showers, and toilets (think sewage) and from commercial, industrial, and agricultural activities (think metals, solvents, and toxic sludge). The term also includes stormwater runoff, which occurs when rainfall carries road salts, oil, grease, chemicals, and debris from impermeable surfaces into our waterways

3- Oil pollution:

Big spills may dominate headlines, but consumers account for the vast majority of oil pollution in our seas, including oil and gasoline that drips from millions of cars and trucks every day. Moreover, nearly half of the estimated 1 million tons of oil that makes its way into marine environments each year comes not from tanker spills but from land-based sources such as factories, farms, and cities. At sea, tanker spills account for about 10 percent of the oil in waters around the world, while regular operations of the shipping industry—through both legal and illegal discharges—contribute about one-third. Oil is also naturally released from under the ocean floor through fractures known as seeps.

4- Radioactive substances

Radioactive waste is any pollution that emits radiation beyond what is naturally released by the environment. It’s generated by uranium mining, nuclear power plants, and the production and testing of military weapons, as well as by universities and hospitals that use radioactive materials for research and medicine. Radioactive waste can persist in the environment for thousands of years, making disposal a major challenge. Consider the decommissioned Hanford nuclear weapons production site in Washington, where the cleanup of 56 million gallons of radioactive waste is expected to cost more than $100 billion and last through 2060. Accidentally released or improperly disposed of contaminants threaten groundwater, surface water, and marine resources.

How to reduce the water pollution:

- Reduce your plastic consumption and reuse or recycle plastic when you can.
- Properly dispose of chemical cleaners, oils and non-biodegradable items.
- Use phosphate-free detergents – phosphates lead to algae blooms and kill fish and other aquatic animals by reducing the oxygen in the water.
- Dispose of medical waste properly.
- Eat more organic food, which is produced without the use of pesticides.
- Cut down on your meat consumption – raising animals for meat takes lots of water for the grains and other feed they need. Furthermore, the antibiotics and solid waste are both likely to end up in groundwater and rivers

Positive impacts if water pollution is solved:

- **Improved public health** – Reduced waterborne diseases and better drinking water quality.
- **Restoration of biodiversity** – Healthier aquatic ecosystems and increased wildlife.
- **Better agriculture** – Safer irrigation and improved crop yields.
- **Economic growth** – More jobs and opportunities in clean industries like fisheries and tourism.
- **Reduced water scarcity** – More clean freshwater resources available.
- **Stronger global cooperation** – Increased collaboration between nations for environmental protection.
- **Enhanced climate resilience** – Healthier ecosystems better equipped to handle climate impacts.
- **Public awareness and sustainability** – Promotes environmental consciousness and sustainable practices.

Negative impacts if water pollution isn't solved:

• **Health crises** – Increased spread of waterborne diseases, causing illness and death.

• **Loss of biodiversity** – Harm to aquatic life, leading to species extinction and ecosystem collapse.

• **Food insecurity** – Contaminated water affecting agriculture and fishery industries.

• **Economic losses** – Decreased productivity in sectors like tourism, agriculture, and fisheries due to poor water quality.

• **Water scarcity** – Further contamination of freshwater sources, worsening global water shortages.

• **Social inequality** – Disproportionate impact on vulnerable communities with limited access to clean water.

• **Climate vulnerability** – Ecosystems that can't adapt to climate change, leading to worsened environmental disasters.

Research

- How we can increase source of clean water?
- What is the water pollution?
- What is the causes of water pollution?
- What are the types of filters?
- What is the water treatment?
- What are the pollutants of water needed to be filtered?
- What are the harms of drinking polluted water?
- High turbidity of industrial wastewater.
- Industrial water toxicity.
- Increased industrial usage of water.
- Efficient wastewater collection from factories.
- What are the components of the water filter?
- What physical processes can be used to filter water?
- What chemical processes can be used to filter water?
- What plants can be used to filter water?
- How we can use ionization or electrolytic cell to filter water?
- How we can measure PH of the water?
- Prior solution in Egypt and other countries.

Other solutions already tried

1- Water treatment and environmental remediation applications of two-dimensional metal carbides (MXenes)

MXenes integrate the advantages of adsorptive, reductive, antibacterial and metallic properties combined with high hydrophilicity, electronic conductivity, and processability. This has lead to a growing interest in utilizing MXene derivatives in water/wastewater treatment applications. Specifically, $Ti_3C_2T_x$ and its composites have demonstrated efficient removal and sequestration of heavy metals, dyes, and radionuclides; while simultaneously acting as antibacterial agents for water disinfection [47,49,87]. Until now, application of MXenes in water/wastewater treatment can be categorized into three main directions, namely: adsorbents, membranes, and electrode materials for electrochemical separation and deionization.

Advantages of MXenes:

1. **High Electrical Conductivity:**
   - MXenes exhibit excellent electrical conductivity, making them ideal for use in applications such as energy storage devices (e.g., supercapacitors and batteries) and electronic components.
2. **Large Surface Area:**
   - Due to their 2D nature, MXenes have a very large surface area, which is beneficial for applications like energy storage, catalysis, and sensors, where surface interactions are critical.
3. **Tunability:**
   - The properties of MXenes can be tuned by adjusting their chemical composition, surface chemistry, and structure. This makes them versatile for various applications.

Disadvantages of MXenes:

1. **Air Sensitivity:**
   - MXenes are highly sensitive to air and moisture, which can cause oxidation of the surface and degradation of their properties. This sensitivity limits their practical use in some environments.
2. **Complex Synthesis:**
   - The synthesis of MXenes can be complex and requires specialized techniques such as selective etching, which can be expensive and time-consuming.
3. **Limited Scalability:**
   - While MXenes show great promise in lab-scale studies, scaling up the production process for industrial applications remains challenging and may not be cost-effective in some cases.
4. **Surface Functionalization Issues:**
   - The properties of MXenes depend heavily on their surface chemistry. While surface functionalization can improve performance, it can also introduce instability or uneven properties, making it difficult to control in large-scale applications.
5. **Environmental Concerns:**
   - Some of the etching processes used to prepare MXenes involve harmful chemicals, which raises concerns about their environmental impact and the sustainability of their production methods.

2- Design and simulation of a renewable-based sustainable electrification system for a water purification plant

The proposed hybrid renewable-based electrification system for water purification application described in this chapter has high technical performance with viable economic benefits as observed over the existing base case of conventional-based electrification. This case study clearly describes the techno-economic analysis of a renewable energy-based water purification system at the Hyderabad-based educational institute campus. The outcomes of this study attained sustainable energy that was able to reduce the utility energy bill and environmental pollutants. The system performance was also verified with various user constraints and accepted benchmarking values as guided by global sustainability agencies.

Advantages of a Renewable-Based Sustainable Electrification System:

1. **Environmental Benefits:**
    - **Reduced Carbon Footprint:** Using renewable energy sources like solar and wind helps to reduce the reliance on fossil fuels, thereby decreasing the carbon emissions associated with conventional power generation.
    - **Sustainability:** The system helps to promote sustainable energy usage, which is crucial in mitigating climate change and reducing the environmental impact of the water purification process.
2. **Cost Savings in the Long Term:**
    - **Lower Operational Costs:** Once the renewable infrastructure (solar panels, wind turbines, etc.) is installed, operational and maintenance costs are generally lower compared to conventional energy sources. This results in long-term cost savings for the plant.
    - **Reduced Energy Bills:** The plant would become less reliant on grid electricity, reducing energy costs over time, especially in areas with high electricity prices.
3. **Energy Independence:**
    - **Autonomy:** By generating electricity from renewable sources, the plant becomes less dependent on the grid, which is particularly beneficial in remote or off-grid locations.

- **Energy Security:** A renewable-based system provides a more resilient and reliable power source for critical infrastructure like water purification plants, which must operate continuously.

4. **Scalability and Flexibility:**
   - **Scalable Systems:** Renewable-based electrification systems can be adapted and scaled depending on the plant's size and the renewable energy resources available, making them suitable for both small and large-scale water purification plants.
   - **Hybrid Systems:** A combination of solar, wind, and storage technologies (like batteries) can ensure a consistent power supply, even during periods of low renewable energy production.

Disadvantages of a Renewable-Based Sustainable Electrification System:

1. **High Initial Capital Costs:**
   - **Expensive Infrastructure:** The upfront costs for renewable energy systems (solar panels, wind turbines, energy storage, etc.) can be high. While the long-term savings may offset these costs, the initial investment can be a barrier to implementation, especially in regions with limited financial resources.
2. **Intermittency and Reliability:**
   - **Variable Energy Supply:** Renewable energy sources like solar and wind are intermittent; energy generation depends on weather conditions. This variability can lead to periods of low or no power production, affecting the reliability of the system.
   - **Need for Energy Storage:** To ensure consistent power for the water purification plant, energy storage solutions (such as batteries) must be integrated into the system, which adds complexity and cost.

3. **Land and Space Requirements:**
   - **Space for Installation:** Renewable energy systems, especially solar farms and wind turbines, require large areas of land. In densely populated or space-constrained areas, finding appropriate locations for these installations can be challenging.
   - **Aesthetic and Environmental Concerns:** Large-scale installations may raise aesthetic concerns, and depending on the location, renewable infrastructure may impact local ecosystems.
4. **Maintenance and Technological Challenges:**
   - **Maintenance Complexity:** Although renewable energy systems have relatively low operating costs, they still require regular maintenance to ensure they function efficiently. In remote areas, this maintenance can be more difficult and costly.
   - **Technology Integration Issues:** Integrating renewable energy with existing infrastructure may require complex design and simulation processes to ensure compatibility, and system failures or technical glitches could cause disruptions.

3-Elemental sulfur as electron donor and/or acceptor Mechanisms, applications and perspectives for biological water and wastewater treatment:

Elemental sulfur, a non-toxic, cheap, insoluble, and easily available chemical, has been used as electron donor and/or acceptor in S^0-based biotechnologies for water and wastewater treatment. This study systematically reviews the principles, microorganisms, mechanisms and applications of S^0-based biotechnologies. S^0 can undergo oxidative and reductive conversion by a wide array of organisms. This has been recently explored in water and wastewater treatment targeting various contaminants.

Advantages of Elemental Sulfur in Biological Water and Wastewater Treatment:

1. **Cost-Effective and Abundant:**
   - **Availability:** Elemental sulfur is relatively inexpensive and abundant, making it an accessible resource for large-scale wastewater treatment applications.
   - **Low-Cost Treatment Method:** Compared to other chemical agents or complex systems, using elemental sulfur can lower operational costs for wastewater treatment plants.
2. **Effective in Sulfate-Reducing Environments:**
   - **Electron Donor for Sulfate-Reducing Bacteria (SRB):** Elemental sulfur can serve as an electron donor in anaerobic environments, particularly for **sulfate-reducing bacteria**. These bacteria play a significant role in reducing sulfate to hydrogen sulfide, which can be a useful process in removing excess sulfate from wastewater.
3. **Hydrogen Sulfide Production:**
   - **Wastewater Treatment:** When used as an electron donor, elemental sulfur can stimulate the production of **hydrogen sulfide (H_2S)**, which is useful in specific industrial processes, such as in the treatment of metals or the removal of nitrogen compounds (like nitrate and nitrite) in wastewater.
4. **Bioremediation Potential:**
   - **Heavy Metal Removal:** Elemental sulfur can be used in bioremediation processes to help remove **heavy metals** like arsenic, lead, and cadmium, through processes that involve microbial sulfur oxidation and reduction. This can be especially important in mining or industrial wastewater treatment.
   - **Sulfide Precipitation:** The reduced sulfur species, such as hydrogen sulfide, can precipitate heavy metals as sulfide salts, which are less toxic and easier to remove from water.

Disadvantages of Elemental Sulfur in Biological Water and Wastewater Treatment:

1. **Formation of Toxic Byproducts:**
    - **Hydrogen Sulfide Toxicity:** While hydrogen sulfide can be useful in some treatment processes, it is also toxic and poses a safety hazard. The production of H_2S in high concentrations can lead to **air quality problems**, unpleasant odors, and potential health risks for workers and surrounding communities.
    - **Corrosion Issues:** Hydrogen sulfide and other sulfur compounds can cause corrosion of pipes, tanks, and equipment, leading to high maintenance costs and potential operational failures.
2. **Slow Biodegradation Process:**
    - **Slow Kinetics:** Some microorganisms require slow and carefully controlled conditions to degrade elemental sulfur effectively. The biological processes involved in sulfur oxidation or reduction might not be as fast as chemical methods, leading to longer treatment times and less efficient performance in certain applications.
    - **Microbial Growth Conditions:** Not all environments or wastewater types support the growth of sulfur-oxidizing or sulfate-reducing bacteria efficiently. In some cases, specific conditions (e.g., pH, temperature) need to be maintained, making the treatment process more complex and challenging.
3. **Formation of Unwanted Sulfur Compounds:**
    - **Sulfur Colloids:** Elemental sulfur may not be fully utilized by microorganisms, leading to the accumulation of **sulfur colloids** or other solid sulfur forms that are difficult to manage or remove from the treated water.
    - **Potential for Uncontrolled Sulfur Reactions:** If the treatment system isn't carefully controlled, elemental sulfur might undergo unwanted reactions, leading to the formation

of various sulfur species that complicate the treatment process.

4- Polymer-based nano-enhanced microfiltration/ultrafiltration membranes

Around the world, around 780 million people drink water from unimproved sources, and an additional 1.2 billion people drink contaminated water. Providing reliable and treated drinking water to every family is a global goal, also supported by improvements in the water supply. Functionalized membranes containing nanoparticles provide a new alternative for the degradation of organic pollutants and for the selective removal of contaminants, without the drawback of the potential loss of nanoparticles in the surrounding environment. These environmentally friendly and sustainable technological approaches allow for various water treatment applications.

Advantages of 4-Polymer-based Nano-enhanced MF/UF Membranes:

1. **Enhanced Filtration Performance:**
   - **Improved Selectivity and Permeability:** The incorporation of nanoparticles into the polymer matrix enhances the membrane's ability to selectively filter particles at the nanoscale, improving both the filtration rate and the rejection of contaminants such as bacteria, viruses, and organic compounds.
   - **Smaller Pore Sizes:** Nano-enhanced membranes can achieve finer filtration compared to conventional polymer membranes, providing better separation of smaller particles, colloids, and organic matter.
2. **Antifouling Properties:**
   - **Reduced Membrane Fouling:** Nano-enhanced membranes often exhibit improved resistance to fouling (clogging)

because nanoparticles, such as silver, titanium dioxide (TiO_2), or carbon nanotubes, can impart antimicrobial or hydrophilic properties to the membrane surface. This reduces biofouling, scaling, and the accumulation of organic or inorganic matter, which can lower maintenance requirements and increase membrane lifespan.

- **Lower Cleaning Frequency:** The enhanced resistance to fouling allows for longer intervals between membrane cleaning and maintenance, which translates to lower operational costs and better overall system performance.

3. **Increased Mechanical and Thermal Stability:**
   - **Improved Structural Integrity:** The incorporation of nanoparticles can enhance the mechanical strength of polymer membranes, making them more resistant to physical stresses (e.g., pressure or shear forces) and extending their operational life.
   - **Higher Thermal Resistance:** Nano-enhanced membranes can exhibit improved thermal stability, allowing them to perform better in high-temperature applications, such as industrial wastewater treatment.
4. **Hydrophilicity and Anti-Scaling:**
   - **Enhanced Hydrophilicity:** The surface modification by nanoparticles can increase the hydrophilicity of the membrane, which improves water flux by reducing the tendency for water to form a thin boundary layer on the membrane surface. This facilitates better flow and higher filtration rates.
   - **Reduced Scaling:** Some nanoparticles (e.g., TiO_2) can prevent the precipitation of salts and minerals (scaling), which is especially useful in treating hard water or in desalination processes.

Disadvantages of 4-Polymer-based Nano-enhanced MF/UF Membranes:

1. **High Manufacturing Costs:**
   - **Expensive Production:** The process of synthesizing and integrating nanoparticles into polymer membranes can be complex and costly. The cost of high-performance nanoparticles (e.g., silver, carbon nanotubes) can significantly increase the overall cost of the membrane compared to conventional polymer membranes.
   - **Scaling Challenges:** The cost of mass production and scaling up nano-enhanced membrane technologies may still be prohibitively high, limiting their adoption in certain markets or applications, especially in developing regions.
2. **Potential Release of Nanoparticles:**
   - **Environmental and Health Risks:** There are concerns about the potential leaching or release of nanoparticles into the treated water or the environment. If nanoparticles are not well bound or stabilized within the membrane, they could pose environmental and health risks, especially in applications involving drinking water or aquatic ecosystems.
   - **Regulatory Issues:** The use of nanoparticles in water treatment may be subject to regulatory scrutiny, as the safety and environmental impact of nanomaterials are still being studied. This may slow down the widespread adoption of nano-enhanced membranes.
3. **Limited Long-Term Stability:**
   - **Aging and Degradation:** While nano-enhanced membranes may provide improved performance in the short term, the long-term stability of the nanoparticles within the polymer matrix could be a concern. Over time, the nanoparticles may degrade, detach, or migrate out of the membrane, reducing its effectiveness and potentially causing environmental concerns.
   - .

Solution and Design Requirements

- **Design Requirements:**

1.The wastewater should have a salinity > threshold value ~ 500 ppm (at least 1000 pm).
2. The wastewater should be treated using **natural and/or processed recycled materials** for at **least three** water quality parameters: one of them is **salinity**, and the others are chosen by the capstone team determining their threshold values based on scientific reference and according to the chosen application.
3. The wastewater should be treated using at least three different techniques e.g., adsorption (chemical or physical), coagulation using electric add/or magnetic field, biological, … etc.
4. The prototype must include an automatic two-way gate or suitable valves to either recycle the wastewater for treatment again or exit from the output gate based on the threshold values reading of all monitored water quality parameters.
5. Students should follow up the efficiency of the treatment processes every cycle for at **least five complete treatment** cycles for the same wastewater sample even if the threshold limit is reached in the case of only collecting results.
6. The team should study the capacity of the prototypes (i.e., study the volume of produced clean water with time) every **10 min for at least 1** hour. Besides, a third effective measurable factor is chosen by the team.
7. Students should calculate the system **energy consumption per liter** of clean water. Note that, the team should use a **calibrated multimeter** to measure the electric current and voltage that must be available on the exhibition day.
8. If the team used **sensors, they must be calibrated** using standard methods or instruments.

- **Solution Requirements:**

-**Efficiency:** We intend for building a filter that is extremely effective, but both inexpensive and labor-intensive. The filter should have high efficiency in targeting and filtering air pollutant particles.

- **Low cost:** The materials should be affordable and waste materials.

- **Easiness to be applied:** The project should be simple and easy to apply so that anyone can apply it by reading the documentation of the project.

- **Future plans:** the project must have a future plan for modification to increase its efficiency and to give it more features.

Selection of solution

- **The chosen wastewater:** water that comes out of the house's sink drain poses a serious threat to the environment. It contains various types of hazardous dyes that significantly reduce the aesthetic value of water bodies, raise BOD and COD levels, inhibit photosynthesis, stop plant growth, enter the food chain, cause recalcitrance and bioaccumulation, and may promote toxicity, mutagenicity, and carcinogenicity. As a result, the dye wastewater should be treated for it to be used again for domestic purposes.
- **The solution**: is focusing on using four main stages in the treatment of wastewater effluents from the dye industry.

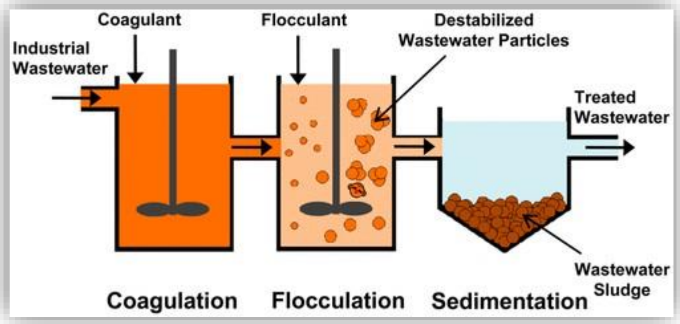


Fig.11

- **First Stage:** using filter paper as a pre filter
    - to filter the solid particles from the water.
- **Second Stage:** the physio-chemical process, chemical coagulation using a bio-coagulant (moringa seeds**).** Moringa seeds, derived from the Moringa oleifera tree, are increasingly recognized for their ability to purify water. The proteins in Moringa seeds act as natural coagulants. When crushed seeds are added to contaminated water, the proteins bind with dirt particles, bacteria, and other pollutants, forming flocs that settle at the bottom. **As shown in figure (11)**
- **Third Stage:** a physical process that is an activated carbon filter (from coconut shells) that relies on physical adsorption.
    - Activated carbon is produced by heating coconut shells to very high temperatures in the absence of oxygen, a process known as "activation." This process opens up millions of tiny pores on the surface of the carbon, increasing its surface area significantly and giving it its adsorptive properties.
    - When water passes through an activated carbon filter, contaminants stick to the surface of the carbon particles due to van der Waals forces (a weak attraction between molecules) and other interactions
- **Fourth Stage:** electro oxidation,
    - is to get rid of the organic substances in the water.
    - The process typically takes place in an electrochemical cell, where two electrodes (an anode and a cathode) are immersed in the water. A voltage is applied across the electrodes, which causes the water molecules to undergo electrochemical reactions.

Selection of Prototype

The prototype consists of:

1- **The Container**

To store the polluted/clean water.

2- The pipes

For the water movement.

3- The pump

To pump the water through the pipes.

4- The stages of the filter

a- Filter paper
b- Moringa seeds
c- Activated Carbon
d- Electro Oxidation

5- Built-in calibrated sensors

For measuring the ppm of the pollutant.

6- Gates

To allow/prevent the movement of water according to the output of the sensors.

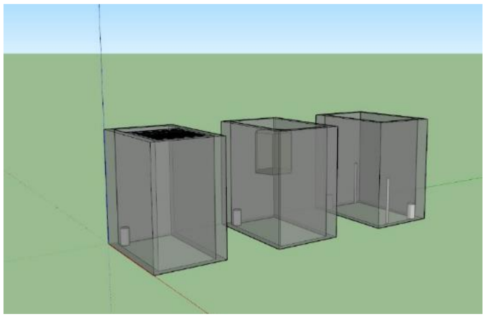


Fig.12

Materials and methods

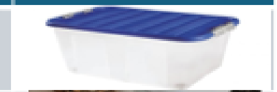
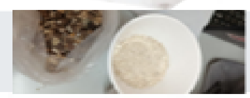
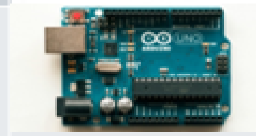
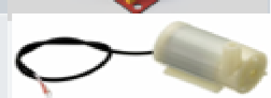
Item	Usage	Amount	Source	Image
Plastic Box	Container of the filters	3	Plastics store	
Moringa seeds	To reduce turbidity	100gm	Herbalist	
Silicon hose	Transfer water between filter phases	4 meters	Electronic store	
Arduino Uno	Embed software with hardware	2	Electronic store	
Gauze	A pre filter	2 rolls	Pharmacy	
Active Carbon & Organza bag	Activated carbon (coconut shells) was put in organza bag to neutralize water and reduce organic matters	200 gm 4 bags	Recycled Gift shop	
H-Bridge	Controlling pumps	2	Electronic shop	
Water pump	Pump water to transfer through hoses	4		
Carbonic rods	To be used in Electrolytic cell	2	From old battery	
Bread board& Jumpers& crocodile	Connecting different devices	1 board 15 jump. 2 Croco.	Electronic store	
Dc motors & 3d printed fans	Stirring and mixing water with moringa seeds	2 motors 2 Fans	Electronic store 3d printer	 

Table.1

There are 4 main phases that have been followed to construct the prototype :

The First Phase was the Moringa seeds:

-The **first** step was fixing the gauze on top of the first box to make the pre filter that filters large particles as shown in figure (13)

-The **second** step was grinding Moringa seeds and filter the non-grinded particles with the sieve as shown in figure (14)

Fig.14

Fig.13

-The **third** step was mixing grinded Moringa seeds with water to put it on the wastewater to start filtration as shown in figure (15)

Fig.15

The second main phase was the activated carbon:

-The **first** step was activating the carbon found in coconut shells physically by heating the shells in the muffle furnace at 500 C for 15 min then soaking the resultant powder in ZnCl2 for 12 hours then washing the solution from ZnCl2 by water then heating the resultant in muffle furnace at 350 C in 15 min to form the powder as shown in figure (16)

Fig.16

Fig.17

-The **second** step was putting the powder in the organza bag then fixing it in the hose as shown in figure (17)

The third phase was the electrolytic cell to reduce the salinity by doing a reaction:

$(2H_2O \rightarrow 2H_2 + O)$

-The first step was extracting the carbon rods found in old batteries to be used as cathode and anode in the electrolytic cell

-The second step was connecting it with crocodiles to the power supply and fixing it in the box

The fourth phase was the circuit for controlling the system:

- By using Arduino uno and 2 motor drivers

Test Plan

Testing the prototype should pass **through 3 steps** to get the best readings and highest efficiency:

- The **first** one is testing the salinity parameter and how the prototype will reduce it to meet the design requirements, salinity should be filtered by electrolytic cell, it will be tested by TDS sensor in the beginning of each cycle.
- The **second** on is testing the PH parameter which will be neutralized by the activated carbon, it will be tested by using PH sensor at the beginning of each cycle
- The **third** one is testing turbidity that will be filtered by Moringa seeds, it will be tested using Turbidity sensor

Data Collection

After doing all the methods and the test plan, there were Negative and Positive results:

Negative results:

There were some negative results before achieving the positive results due to mistakes made during the construction of the prototype and test plan:

– A high concentration of Moringa powder was added without doing research on the optimum concentration, leading to the turbidity of water after the first process, **we solved this problem** by searching about the best amount of it and we put a small spoon on half liter of water.

– When the system was turned on for the first time, there was a wrong in a code for Arduino and the water pump push the water to the three stages for one cycle only and didn't complete, **we solved this problem** by correcting the code on the Arduino.

– The activated carbon was put directly in the water, which make the water

pump clogged, **we solved this problem** by putting the activated carbon in an organza bag

as shown in figure (18).

Fig.18

Positive results:

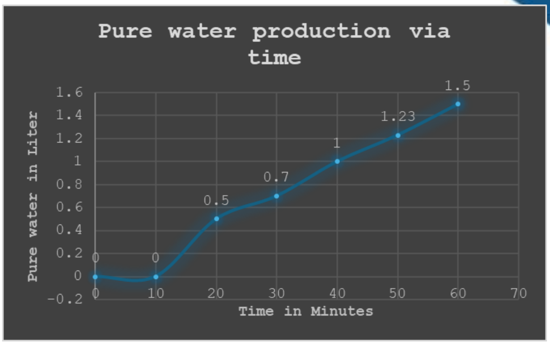
After solving the issues that were producing the negative results, positive results were achieved.

- For the first design requirement, water quality, the moringa seeds able to reduce the turbidity of the water, the activated carbon able to make the water neutralize, electrolysis able to reduce TDS. the results after 50 minutes are as shown in table (2)

Water parameter	Inlet	Outlet	Removal Efficiency
TDS	1228	250	79 % $\pm$ 0.64%
Turbidity	1024	312	69 % $\pm$0.53%
PH	5	7.1	-

Table.2

– The amount of pure water produced after 10 minutes equal zero as shown in graph (1). But, after 50 minutes the three stages (moringa seeds, activated carbon, electrolysis) of the filter were able to produce **1.5** liter of pure water to use it in the agriculture and irragation.



Graph.1

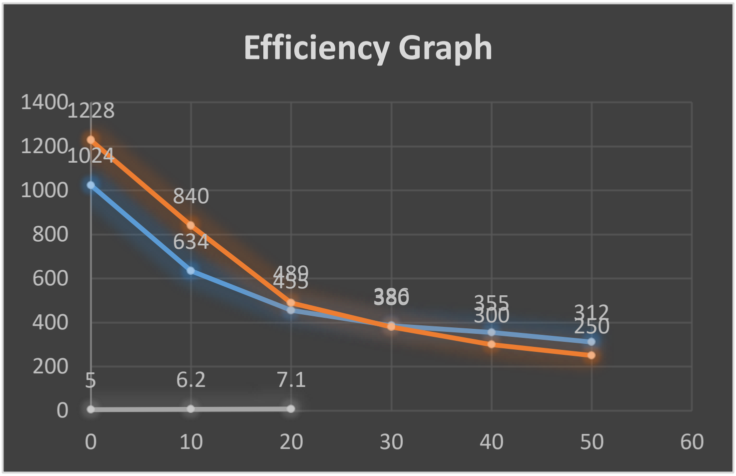
– Our project can be used for a long time because it is easy to refix it and change the filters inside it.

- The removal efficiency was calculated using the formula: efficiency = 1 - $(\frac{outlet}{inlet}) * 100$
- **The energy consumed by the prototype =**

Potential * Current * Time = (12 * 2 * 30000) + (12 * 2 * 30000) = 144000 **joules** .

Comparing to the design requirements:

The prototype achieved TDS of **166** mg/L ± **2** mg/L and has efficiency = **79 %** $\pm \mathbf{0.64}$ **,** reduce the turbidity of the wastewater from **1024** to **312** with efficiency **69 %** $\pm \mathbf{0.53}\%$ **,** make the water nutralize and provide the PH from **5** to **7.1** as shown in grarh (2)



Graph.2

Analysis and discussion

Laws and Theories

The laws that were used during building and testing the prototype:

- Calculation of the energy consumed:

1-Power = electric potential *electric current

∑ Watt =∑ volt * ∑ ampere.

- Calculation of the efficiency:

2-Efficiency = $(1- (\frac{filter_{out}}{filter_{in}}))*100$

- Calculation of the flow rate:

3-Flow rate= $\frac{Volume\ of\ water}{time}$

Trial.1 (Failed)

- The first trial for the prototype didn't come with positive results:

The power supply which was only 9v wasn't sufficient to power the 4 pumps and the other circuit's components.

- This problem was solved by using a DC Adaptor that supplies 12v and 2A to be able to power the whole system.

Trial.2 (Partially failed)

- The problem of the power supply was solved but:

The pumps couldn't afford to pump the water after adding the sensors on the same power supply. As the power supply had a huge load on it.

- This problem was solved by using a separate power supply for the **(electrolysis stage and the sensors)** .

Trial.3 (Succeeded)

- This trial came up with promising results:

Stage one: The moringa seeds to reduce the turbidity

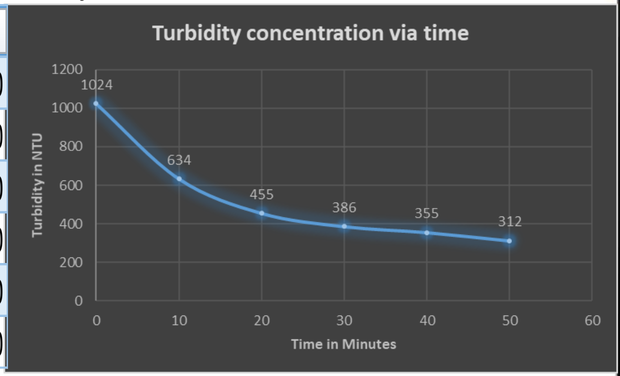
This graph shows the output data of the turbidity sensor:

It shows the turbidity's concentration via time

The efficiency = 69 ± 53%

Turbidity	Time
1024	0
634	10
455	20
386	30
355	40
312	50

Table.3



Graph.3

Stage two: The Activated Carbon and the reduction of the salinity (TDS)

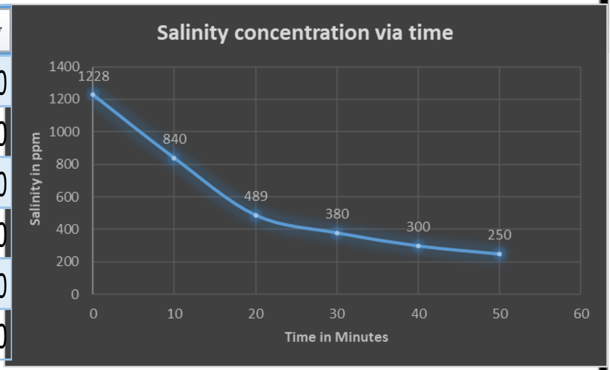
This graph shows the output data of the TDS sensor:

It shows the Salinity's concentration via time

The efficiency = 79 ± 64%

TDS (Sali	Time
1228	0
840	10
489	20
380	30
300	40
250	50

Table.4



Graph.4

Stage three: The electrolysis and the Ph.

This graph shows the output data of the Ph. sensor:

It shows the Ph. via time

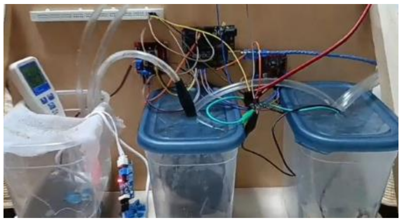
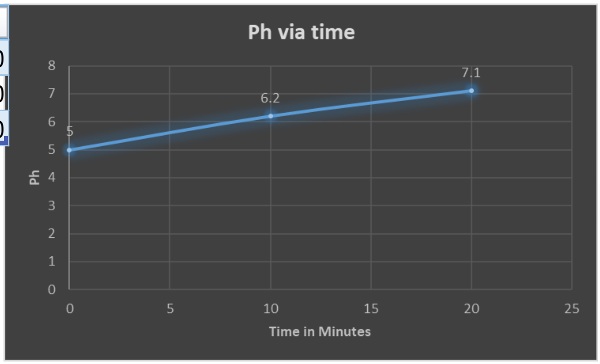


Fig.19

Ph	Time
5	0
6.2	10
7.1	20

Table.5



Graph.5

<u>Recommendation</u>

- Using the water after treatment in agriculture of non-food crops **(chosen application)**
- Increasing the voltage in the electrolysis stage will increase its efficiency
- Changing the activated carbon particles periodically after the end of the 5th cycle as it will be polluted
- Passing the water into a filter paper before entering the purification system to remove large pollutant
- Periodically cleaning and changing the tubes of the system after it is polluted
- Cleaning the air pumps from the large particles that clogs the pump.
- Using esp8266 rather than the Arduino uno for higher efficiency and respond
- **Scale-Up for Real-World Application**
  It is recommended to design larger-scale prototypes to evaluate the filter's effectiveness in real-world conditions, such as in households or rural areas lacking access to clean water.

Learning transfer

Subject	Connection
Chemistry Lo.8	It helped us in making the electrolysis stage
Mechanics Lo.5	It helped us in calculating the power used by the system
Computer Science Lo.5	Developing a mobile application to display the output data of the sensors
Biology Lo.9	The hormones feedback system is familiar to the sensor feedback system
Physics Lo.9	Studying the back e.m.f of the water pump motor
English	Writing academic English in the portfolio and poster
Math Lo.6	Helped us evaluate a limit equation for the concentration of pollutants
Physics Lo.10	Studying the Dc motors and how to increase its efficiency
Earth Science Lo.10	Studying the Earth's spheres evolution and how it goes according to several stages
Physics Lo.8	Using the Electromagnetic induction

Table.6

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