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Microplastic Eradicator

Portfolio Report

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STEM
EGYPT

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I. Chapter 1: Definition and Justifying the Problem and Solution Requirements

This chapter goes through the definition of the problem and a review on the current circumstances concerning the proposed solution, with a brief illustration of its structure and properties.

A. Grand Challenges

Introduction

There is no such a country without challenges that it faces. Egypt is no exception for that, which is evident in the lots of challenges and goals that can be summarized in the following list:

- Reduce pollution
- Recycle and retain garbage for recycling
- Improve sources of clean water
- Work to eradicate public health issues/diseases
- Reduce urban congestion
- Improve use of arid areas
- Deal with the exponential population growth
- Increase opportunities for Egyptians to stay and work in Egypt
- Increase the industrial base for Egypt
- Improve the use of alternative energies

In the following, the subject that the proposed solution is concerned with is going to be discussed thoroughly.

1. Overpopulation

Figure I.1 An overcrowded street

One of the most harming problems that Egypt is still suffering from is overpopulation (illustrated in Figure I.1). A couple of decades ago, Egypt had a good family planning, but now the situation is completely different. Starting from the 1980s, the fertility rate was about 3.2 child per woman, increasing to about 3.8 in rural areas and 2.9 in urban areas 2014. (Zanty, 2014, pp. 39-40) This is an obstacle that threats our progress and development to future. In addition, it leads to other challenges including increased pollution and, consequently, the need to recycle materials.

a) Causes

(1) The technological revolutions

Figure I.2 Overpopulation due to the industrial revolution

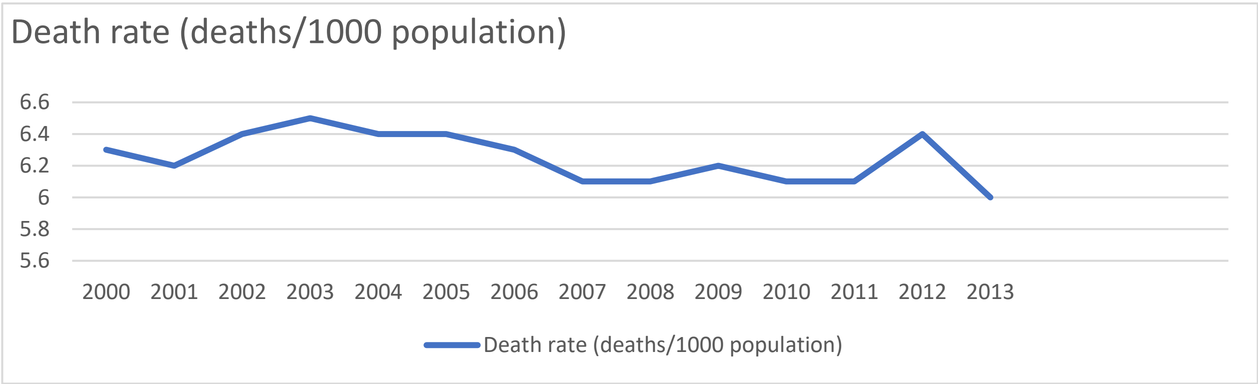
Looking throughout history, technological revolutions have resulted in a population expansion. (Ehrlich & Ehrlich, 1990) The three major evolutions (the tool-making revolution, the agricultural revolution and the industrial revolution) have allowed more access to food, resulting in a more life expectancy of a person, especially for children. Industrial revolution is a revolution that took place in Europe in the middle of 18th century. Industrial revolution changes our behaviors from dependence on primitive resources of energy to new resources, such as coal. Industrial revolution has many bad effects on rising population on the earth. Figure I.2 shows overpopulation due to the industrial revolution. At the dawn of industrial revolution, the number of people grew by 57% to reach about 700 million and was estimated

Graph I.1 shows the raising in population number in the six continents to be 1 billion in 1800. But everything changed when this revolution started. The birth of the industrial revolution altered medicine and living standard resulting in the great population explosion after that. During the 20th century, the population number increased by exponential proportions to 6 billion. About 400% increase of population in one single century. The industrial revolution shows us how far the development or the use of new resources effects on our life badly when used wrongly.

There is another reason that encouraged the huge raise in population number, it is the tool-making revolution. The use of tools, such as the bow and arrow allowed the primitive hunters a greater access to a high-energy food, as it was the only way to hunt and to get enough food. Likewise, the transition from hunting to farming later greatly increased the overall food supply, which was used to support more people, and abruptly, for the first time they found excess food which encouraged people to bring children expecting that future is safe and secure. On the other hand, a father farmer needed sons to help him in his farming chores, instead of renting other men. This also was a main reason for the overpopulation in the farming age. The food industry further increased as the machinery, fertilizers and pesticides were used to increase the land under cultivation.

(2) Decline in death rates

At the root of overpopulation is the difference between the overall birth rate and death rate in population. If the number of children born every year equal to deaths the ratio will be stabilize, like what happened in developed countries in 2010, for example, Germany experienced a ratio of population growth being -0.19%.



Graph I.2 The decline in death rates in Egypt

As shown in Graph I.2, there is a decline in the death rate happening in Egypt. (Zanty, 2014, p. 24)

b) Consequences

(3) Depletion of natural resources

It is logical to say that if the population number raises, the demands on daily resources increase, so there is a strong relation between wealth and over population of country and energy consumption. The more the population the more energy used and the faster depletion of natural resources happens.

Figure I.3 Petroleum; a natural resource

Many troubles such as water shortage and lack of petroleum (depicted in Figure I.3) didn't appear until the growth of population started to raise dramatically. Population grew from 1.49 billion in 1890 through 2.5 billion in 1950 to 5.32 billion in 1990, energy consumption grew even faster, from 1 terawatt in 1890 through 3.3 terawatts in 1950 to 13.7 terawatts in 1990. Energy consumption grows not only as population grows but also as poor people become richer. People in the developing world each use 0.28 kilowatts a year, while those in the developed world use 3.2 kilowatts and people in the United States 9 kilowatts.

The overuse of non-renewable resources and overpopulation will result in depletion of natural resources. This will lead us eventually to wars between countries because of the need of these resources. It can be passed by depending on recycling or renewable clean resources. For example, instead of throwing rubbish in the streets, and with the right instruments, it is possible to be turned into energy to derive replacement fuel instead of oil, so the crisis of oil nowadays can be overcome by recycling. This will produce new forms of energy such as what is needed to substitute oil.

(4) Conflicts and wars

As a result of the reduction of natural resources, people start to fight so that to gain as much resources as possible. For example, conflicts over water may lead to tension between countries, which could result in wars. Starvation is also a huge matter facing the world and the mortality of rate of the children is affected by it.

(5) Rise in unemployment

When the population raises uncontrollably in a country, the amount of available jobs for youth does not rise proportionally with it, as depicted in Figure I.4. As a result, only a group of people are with jobs available to them and other groups aren't.

Figure I.4 Unemployment

(6) High cost of living

As difference between demand and supply continues to expand, the prices of various supplies (including food, shelter and healthcare) are raised. This means that people must pay more in order to survive and feed their families.

(7) More pollution and increased need for recycling and energy

The rise in the population has caused more people to throw rubbish and pollutants to the environment increasing the need for recycling those wasteful materials into useful resources, most importantly energy.

2. Pollution

Pollution, which is also called "environmental pollution", is the addition of any substance (solid, liquid, gas) or any form of energy, such as (heat, sound, radioactivity) to the environment at a rate faster than it can be dispersed, diluted, decomposed, recycled, or stored in some harmless form.

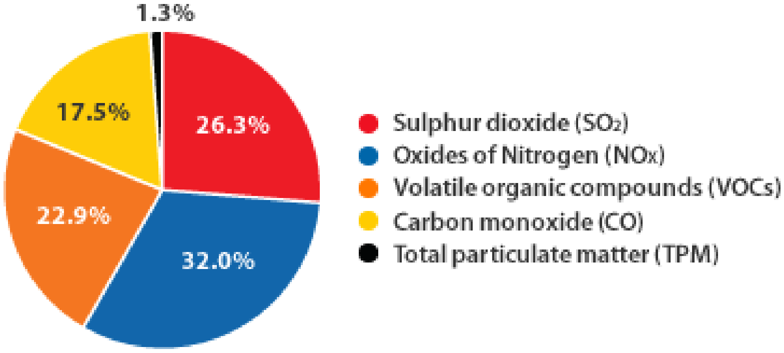
Figure I.5 Air pollution

There are many kinds of pollution usually classified by environment according to their severity, they are classified into:

1. Air pollution (illustrated in Figure I.5)
2. Water pollution
3. Land pollution

Air pollution

The air is approximately the most important thing that our life depends on, air consists of many gases which are all important to us, our life depend mainly on oxygen gas and CO_2 gas, as



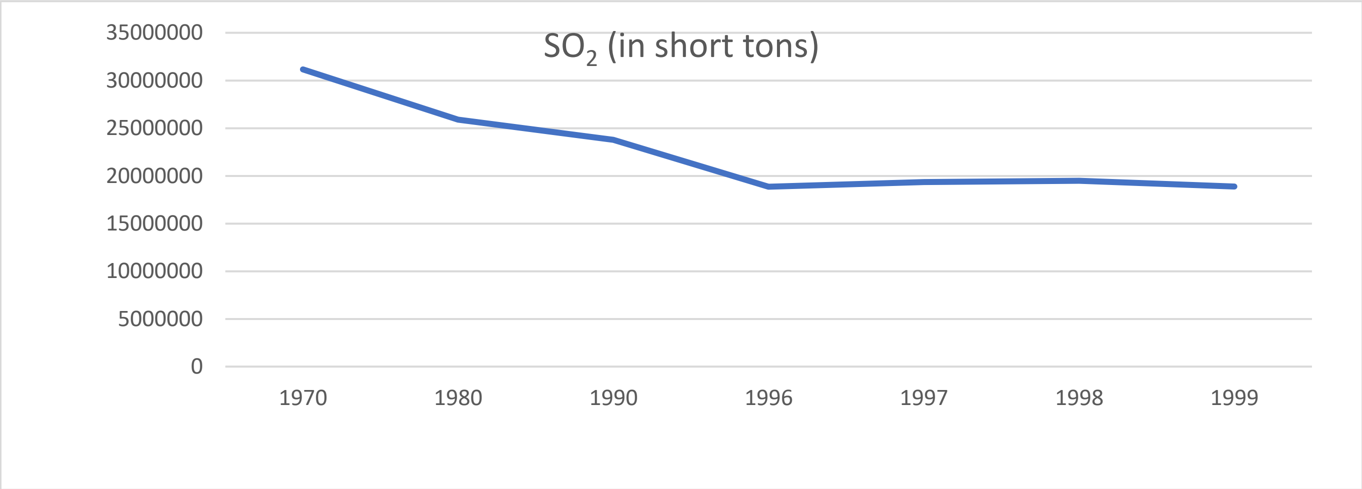
Graph I.3 Percentages of air pollutants there is an exchange between O_2 and CO_2 during photosynthesis process.

The benefit of air isn't limited for O_2 and CO_2 only, but there are many useful gases in air. However, some harmful polluntants, whose percentages are shown in Graph I.3, slip into the atmosphere and cause adverse effects.

a) Causes

1) Burning of fossil fuel

The burning of fossil fuel plays an important role in polluting the environment, especially air pollution. The combustion of fossil fuels like coal, petroleum, and other factory combustibles emits sulfur dioxide, which is a noticeable component in the atmosphere. sulfur dioxide has major significant impacts upon human health. The emission rate is shown in Graph I.4. Inhaling sulfur dioxide is associated with increased symptoms and diseases related to the respiratory system such as difficulty in breath, Children, the elderly,



Graph I.4 Emissions of sulfur dioxide from 1970 to 1999 and those who suffer from asthma are especially sensitive to effects of SO_2. To plants and trees, sulfur oxides can damage their foliage and decrease their growth rate. It also causes acidic rain which, when falls, causes building corrosion; damage to soil biology and chemistry; fog and clouds in forests; killing of fish and other aquatic animals living near or in surface water; and other associated effects. . (Bakhshipour, Asadi, Huat, Sridharan, & Kawasaki, 2016) Carbon dioxide and methane are also released during the burning process. These gases are greenhouse gases, that is they cause global warming which is a very delicate problem.

2) Agricultural activities

Ammonia is a very common by product from agriculture related gases (emissions illustrated in Figure I.6), and is one of the most dangerous gases in the atmosphere, that causes severe air pollution.

Figure I.6 Agricultural pollution

3) Exhaust from factories and industries

Manufacturing industries release large amount of carbon monoxide, hydrocarbons, organic compounds, and chemicals into the air.

b) Effects

The effects of Air pollution can be summarized in Figure I.7.

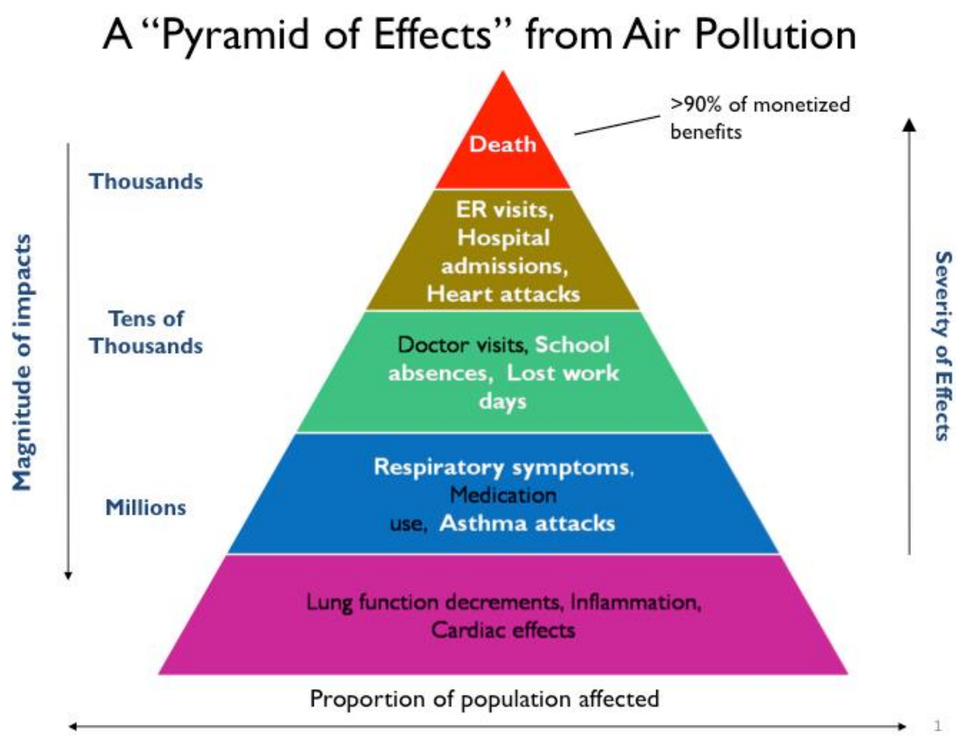


Figure I.7 A figure summarizing the effects of air pollution

1) Respiratory and heart problems

Air pollution is known to create several respiratory and heart conditions, along with cancer, among other threats to the body.

2) Global warming

Another direct effect is the immediate alternations of weather that the world is witnessing due to global warming.

3) Acidic rain

Figure I.8 Effects of acidic rain

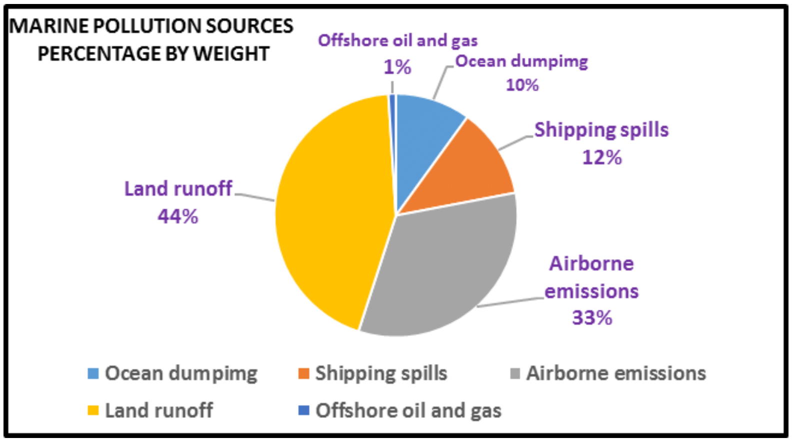
Harmful gases like nitrogen oxides and sulfur oxides are released into the atmosphere during burning of fossil fuels which cause acidic rains.

c) How cities in the world are tackling air pollution

- **Paris:** cars are banned in many historic central districts at weekends, which imposes streets to be fresh-aired.
- **Delhi:** the reports which the pollution levels in Delhi matched those in Beijing spurred the city to ban all new large diesel cars and SUVs with engines of more than 2,000CC, and to face this, the city has experimented with alternately banning cars with odd and even number plates.
- **Netherlands:** politicians want to ban the sale of all petrol and diesel cars from 2025, allowing only electric or hydrogen vehicles.

Water pollution

Water pollution can be defined in many ways. Usually, it means one or more substances have built up in water to such an extent that they cause problems for animals or people. Oceans, lakes, rivers, and other inland waters can naturally clean up a certain amount of pollution by dispersing it harmlessly. If you poured a cup of black ink into a river, the ink would quickly disappear into the river's much larger volume of clean water. The ink would still be there in the river, but in such a low concentration that you would not be able to see it. Nonetheless, some pollutants still greatly affect the earth's ecosystem, the important of them is shown in Graph I.5.



Graph I.5 Percentages of water pollutants

a) Causes

1) Sewage Disposal

Sewage from domestic households, factories and commercial buildings can prove to be problematic. Sewage that is treated in water treatment plants is often disposed into the sea. It can be more problematic when people flush chemicals and pharmaceutical substances down the toilet.

2) Dumbing solid wastes

Dumbing wastes and littering (shown in Figure I.9) by humans in rivers, lakes and oceans can be a cause of the spreading of many diseases like Hepatitis A, and others. Littering items include cardboard, Styrofoam, aluminum, plastic and glass.

Figure I.9 A picture demonstrating solid wastes

3) Industrial waste from factories

These wastes, which use freshwater to carry waste from the plant into rivers, contaminate waters with pollutants such as asbestos, lead, mercury and petrochemicals.

4) Plastic Pollution

Plastic pollution is the amassing of plastic objects and particles on Earth's surface or in waterbodies that adversely affects the ecosystem, wildlife habitat, and humans. Plastics polluting earth are categorized into micro-,

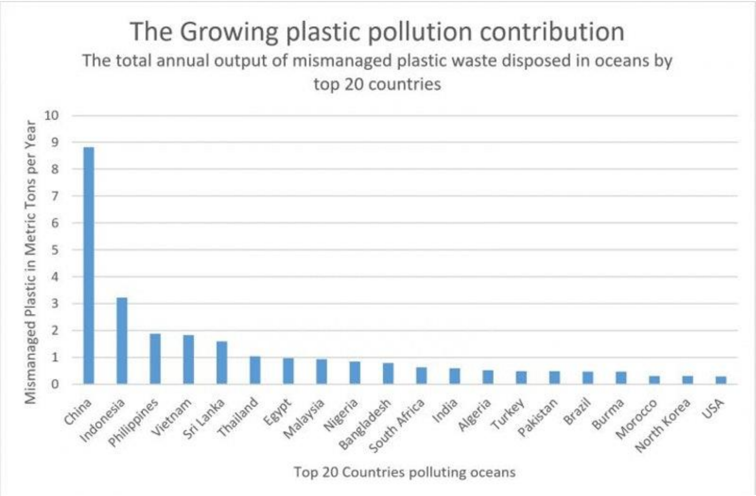


Figure I.10 the countries contributing in plastic pollution meso-, or macro debris, based on their size. Plastics production has grown rapidly during the last decade. In 2017, the global plastic production reached 348 million metric tons, 64 million metric tons of them were produced in Europe alone. Chemical structure of most plastics makes them resistant to many natural processes of degradation or decomposition. Plastic pollution can affect land, waterways and oceans. It is estimated that 1.1 to 8.8 million metric tons (MT) of plastic waste enters the ocean from coastal areas each year. Figure I.10 shows the most costal countries contributing in plastic pollution. Plastics in landfills degrade slowly penetrating the soil and finally reaching the underground water as microplastics. Plastics in oceans and waterbodies take decades to become microplastics then settle down in ocean floor. Microplastics in ocean floor are seen by many marine creatures as micro living organisms “their natural nutrition source”. Feeding on these microplastic puts many species in danger of extinction, threatening the ecological balance of the aquatic ecosystem.

b) Effects

1) Groundwater contamination

Groundwater contamination, and other source contamination as shown in Figure I.11, due to pesticides causes reproductive damage within wildlife in ecosystems.

Figure I.11 Polluting of the natural water

2) The depletion of oxygen

Sewage, fertilizer, and agricultural run-off contain organic materials that when discharged into waters, increase the growth of algae, which causes the depletion of oxygen.

3) Health problems

Swimming in and drinking contaminated water causes skin rashes and health problems like cancer, reproductive problems, typhoid fever and stomach sickness in humans.

4) Fish contamination

Industrial chemicals and agricultural pesticides that end up in aquatic environments can accumulate in fish that are later eaten by humans. Also, the death of fish is caused which can be viewed in Figure I.12.

Figure I.12 Dead fish because of contamination

3. Water Crisis

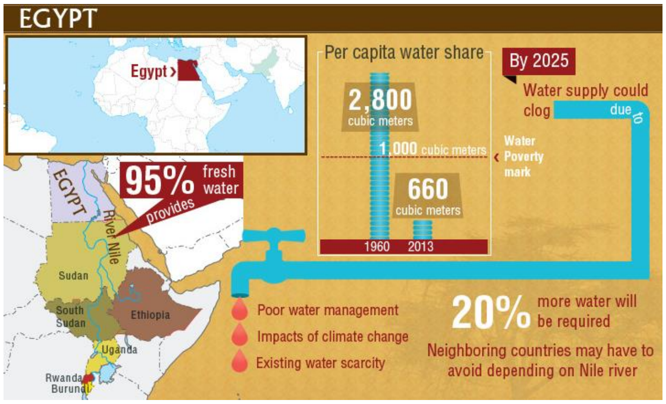


Figure I.13 an overview of the water crisis in Egypt

Egypt reached a state where the quantity of water available is affecting the pace of development. The pace of population growth in Egypt will continue as it will increase to be about 120 or 150 million by 2050. (Bedawy, 2014) As Egypt has low rain rate in addition to having large water screens causing water to evaporate, Egypt is classified as a hyper-arid country as illustrated in Figure I.13. According to the Ministry of Water Resources and Irrigation, Egypt will need 20% more water by 2020 as it's already using 127% of its water resources which means that Egypt imports 27% of the used water through imported products; by 2020, Egypt will be using an average of 147%.A statistic from the United Nations now says that Egypt would be water scarce by 2025.

Egypt is suffering from a severe water scarcity challenge in the recent years. Uneven water distribution, misusages of water resources and primitive irrigation systems are some of the major factors affecting the problem in Egypt. Egypt has only 20 cubic meters per person of internal renewable freshwater resources. As a result, Egypt relies desperately on the Nile River being the main source of water. The Nile is the backbone of the industrial and agricultural sectors in Egypt in addition to be the main source of drinking water for the population.

a) Causes

(1) Population Explosion

Egypt’s population is rapidly increasing at a hazarding rate as it has increased by 41% since the early 1990s. Recent reports by the government says that around 4,700 newborns are born every week, and future projections predicts that the population will increase from a total of 92 million to 110 million by 2025. (Gad, 2017)

This rapid growth in population overstresses on Egypt’s water supplies due to more water demands for the domestic consumption in addition to the increased irrigation to meet higher food demands.

(2) Inefficient Irrigation

Egypt’s rate of rainfall per year is less than 80 mm as shown in Figure I.14; 6% of the country’s land is arable and agricultural, with the rest of the country being desert. As Egypt uses primitive ways of irrigation such as flood irrigation, A lot of the water is being wasted and evaporated or in some cases it does damage the crops.

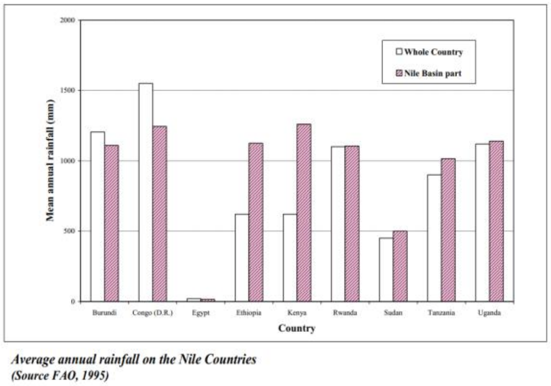


Figure I.14 The amount of rain water in Egypt in comparison with other African countries

Nowadays, Egypt’s irrigation network is coming from the Aswan High Dam which is watering all the farmlands alongside the river.

This system is inefficient as we lose 3 billion cubic meters of Nile's water per year through evaporation.

Any sort of shortage in the water supplies in Egypt would lead to a decreasing the arable land available for agriculture or living. As agriculture is the major employer of youth and work force in Egypt, water scarcity could lead to increasing the unemployment levels.

(3) Pollution

The pollution crisis of the Nile river is a major issue that is regularly underestimated and margined as it is considered as a supplementary problem. As many people are relying desperately on the Nile for drinking and other domestic uses, agricultural, and municipal use. The quality of that water that is used specifically for domestic uses should be ultra clean not to cause diseases or plagues. In fact, the water of the Nile is being polluted by municipal wastes and industrial wastes, with many recorded cases of leakage of wastewater or some extraordinary cases such as throwing animals or washing them in the Nile, and the release of chemical and hazardous industrial waste into the river such as those boats or wastewater.

b) Effects

(1) Damaged Ecosystems

When water becomes a real crisis, natural landscapes often get damaged, e.g., the Aral Sea that is located central Asia was the world's 4th largest freshwater lake, but in only three decades, the sea lost an area the same size as Lake Michigan; now, it's as salty as the any ocean or sea due to the contamination and the changes in water for irrigation and power generation. This ecological catastrophe has created food shortages in addition to a disorder in the marine food chain and ecosystem.

(2) Lack of Access to Clean Water

Currently, over 1 billion people all over the globe lack access to clean freshwater or it's excessively hard to reach. Without access to clean freshwater, these vulnerable millions of lives are exposed to deadly contaminated water-borne illnesses. Furthermore, water gathering can limit educational and economic opportunities as the global population grows and water resources shrink, greater numbers will face the crisis of uneven water accessibility.

(3) Economic Slowdown

The United Nations estimates that half of the world's population will live have a hardship to reach clean water easily by the year 2030. It is difficult to have a developing country that is developing its economy when fresh water is not easily accessible for industrial, farming, and individual use. Production of goods that demand high water like cars, food e.g. such as rice and cotton, and clothing could be decreased by lack of freshwater resources. Lack of freshwater affects the work force productivity by causing illnesses in addition to reduction of household disposable income due to higher water costs for individuals.

4. Recycling

Figure I.15 Assembling of waste materials

Recycling is the reclamation and remanufacturing of discarded used materials to be reused for new products. The well-known stages in recycling are the assemblage of waste materials as in Figure I.15, their processing or manufacture into new products, and the purchase of those products, which may then themselves be recycled over and over again. Usual materials that are recycled include steel fragments and iron, glass bottles, plastics, wood, paper and aluminum cans. The materials recycled are considered as replacements for raw materials obtained from such extremely rare natural resources as natural gas, mineral ores, petroleum, trees and coal. Recycling can help decrease the amounts of solid waste dumped in junkyard, which have become increasingly expensive. Recycling also reduces the air, water, and land pollution resulting from waste disposal, as the wastes piling up the area, they can help in spreading diseases and harming the environment.

Stages of Recycling

- Collection of Recyclable materials.
- Separating different materials from each other ex. plastics and paper
- Processing and reprocessing of materials according to their type
- Reshaping materials, making them into the new desired shapes.

Ways to increase recycling rates

Figure I.16 Recycling Trash Cans

- Increase the number of recycling factories.
- Advice people and enrich their knowledge about the importance of recycling.
- Provide the streets with Trash cans as in Figure I.16.

There are two wide-ranging categories of recycling operations: internal and external.

a) *Internal recycling*

Internal recycling is the reuse in a production process of materials that are a waste product of that process. Internal recycling is mostly-used in the metals industry, for example. Producing copper tubing results in a certain amount of waste in the form of tube ends and trimmings; this material is re-melted and reshaped. Another form of internal recycling is seen in the distilling industry, in which, after the distillation, spent grain mash is dried and processed into an edible foodstuff for cattle.

b) *External recycling*

External recycling is the retrieving of materials from a product that has been worn out or rendered outdated. An example of external recycling is the collection of timeworn magazines and newspapers for their creation into new paper products. Glass bottles and aluminum cans are other examples from everyday usage. These materials can be collected by any of three main methods: buy-back centers, which purchase waste materials that have been sorted and brought in by consumers; drop-off centers, where consumers can deposit waste materials but are not paid for them; and curbside collection, in which homes and businesses sort their waste materials and deposit them by the curb for collection by a central agency.

Simply, when someone wants to start a recycling business, they should take care of some points. The recycled materials should not be precious or valuable as some kinds of metals, as they might lose their value after recycling. The recycling process shall not cost too much, as the main purpose of recycling is saving costs on new raw materials, or the process will become worthless.

c) *Recycling process of different materials*

(8) Paper

Figure I.17 Paper recycling

Paper makes up over 35% of municipal solid waste collected, more than any other material. The United recycles almost 42.2% of the paper they use. (EPA, 2013) This recovered paper is used to make new paper products, saving trees and other natural resources. Paper recycling (shown in Figure I.17) is widely-accepted and well-known throughout the world. When you go shopping, look for products that are made from recycled paper.

(9) Batteries

Figure I.18 Battery Recycling

Dry-Cell Batteries are used in a wide range of electronics and include alkaline and carbon zinc (9-volt, D, C, AA, AAA), mercuric-oxide (button, some cylindrical and rectangular), silver-oxide and zinc-air (button), and lithium (9-volt, C, AA, coin, button, rechargeable) batteries. (Fisher, Wallén, Paul, Collins, & Collins, 2006)

To be able to recycle alkaline batteries, in a specialized "room temperature," mechanical separation process. The alkaline battery components are divided into three end products. These items are a zinc and manganese concentrate, steel, and paper, plastic and brass fractions. Then it is used in new products to cut down their cost. Collection of batteries can be seen in Figure I.18.

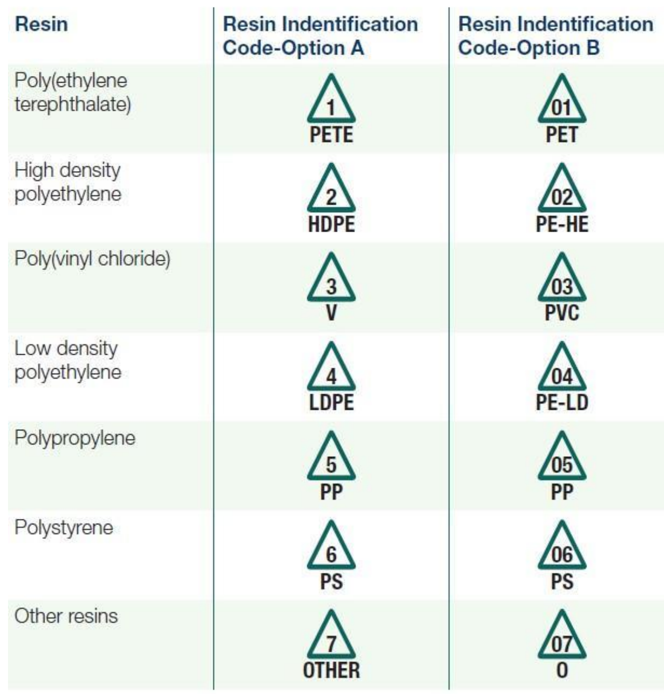
(10) Plastics

Figure I.19 Recycling Plastics

Almost 35 million tons of plastics were generated in the United States in 2015, about 13 percent of the waste stream. Only 9.1 percent of plastics were recycled in 2015. (Geyer, Jambeck, & Law, 2017) Some types of plastics are recycled much more than others as in Figure I.19. Most community recycling programs accept some, but not all, types of plastics.

(a) Meaning of symbols on plastic containers

As shown in Figure I.20, these symbols were created by plastic producers to help people identify the kind of plastic used to make the container. This can help you determine if the container can be accepted by your local recycling program. The resin number is contained in a triangle, which looks very similar to the recycling symbol, but this does not indicate if it is recyclable or not in your community. Although some kinds of plastic are not recyclable.



Resin	Resin Indentification Code-Option A	Resin Indentification Code-Option B
Poly(ethylene terephthalate)	1 PETE	01 PET
High density polyethylene	2 HDPE	02 PE-HE
Poly(vinyl chloride)	3 V	03 PVC
Low density polyethylene	4 LDPE	04 PE-LD
Polypropylene	5 PP	05 PP
Polystyrene	6 PS	06 PS
Other resins	7 OTHER	07 O

Figure I.20 (Photo courtesy of ASTM) Meaning of symbols on plastic containers

(11) Glass

Glass, especially glass food, cups and bottles, can be recycled over and over again. In the United States in 2015, 11.5 million tons of glass were generated, about 26 percent of which was

Figure I.21 Recycling Glass

recovered for recycling. Making new raw glass from recycled glass is way cheaper than using raw materials, although, raw glass is made by burning sand. Most recycling programs accept different glass colors and types mixed together as in Figure I.21, and then glass is sorted at the recovery facility.

d) Recycling wastes into Energy

Recycling saves energy and natural resources; making a product from recycled materials almost always requires less energy than it does to make the product from new materials, as exemplified in Figure I.22. Furthermore, many recycled materials can be used to generate energy. For example, there has been ways that converts unused plastics that are found in landfills to a biogas. One plastics-to-fuel company says that its system can convert 50 tons of plastic waste into 12,600 gallons of oil—per day. The method includes melting then vaporizing of the sorted plastic into gases that are then cooled and condensed into a wide variety of useful products, such as synthetic crude oil, synthetic diesel fuel, kerosene and more. By doing this, 70% of greenhouse gas emissions can be reduced, decreasing pollution and public health problems.

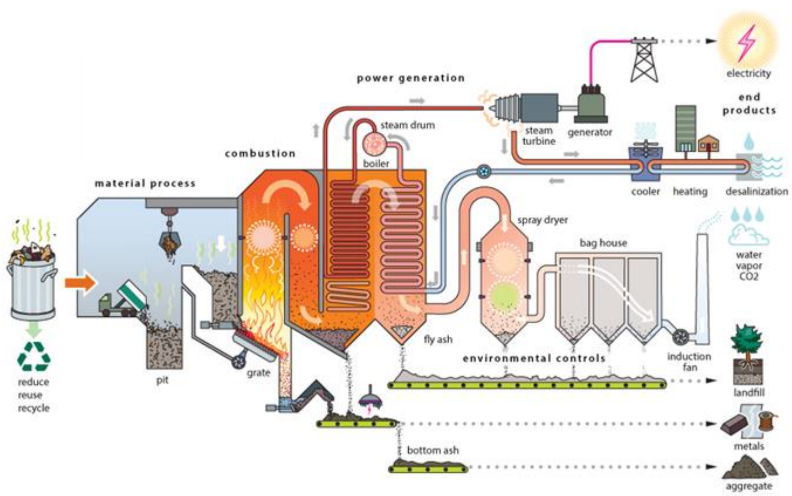


Figure I.22 An example of converting MSW into energy

5. Public Health

Figure I.23 A hospital in Egypt

Public health is "the science and art of preventing disease, prolonging life and promoting human health through organized efforts and informed choices of society, organizations, public and private, communities and individuals" (Winslow, 1920). "Public" can be as small as a score of people or as large as to include several continents. "Health" refers to physical, mental and social well-being, and not merely the absence of disease or infirmity.

The Healthcare system in Egypt, which can be exemplified in Figure I.23, is fragmented between the Ministry of Health of Population which delivers 30% of services, the Ministry of Higher Education and Scientific Research delivering 30% of services through University hospitals, the Health Insurance Organization providing 10% of services and independent ministries providing the remainder.

Central Government is responsible for:

- Primary and Emergency healthcare for Egyptian citizens.
- Healthcare Policy and strategy
- Healthcare Public Financing

There are governmental campaigns to reform healthcare and also to implement a universal health insurance for every Egyptian by 2030. Nevertheless, there are some problems that Egypt faces concerning public health.

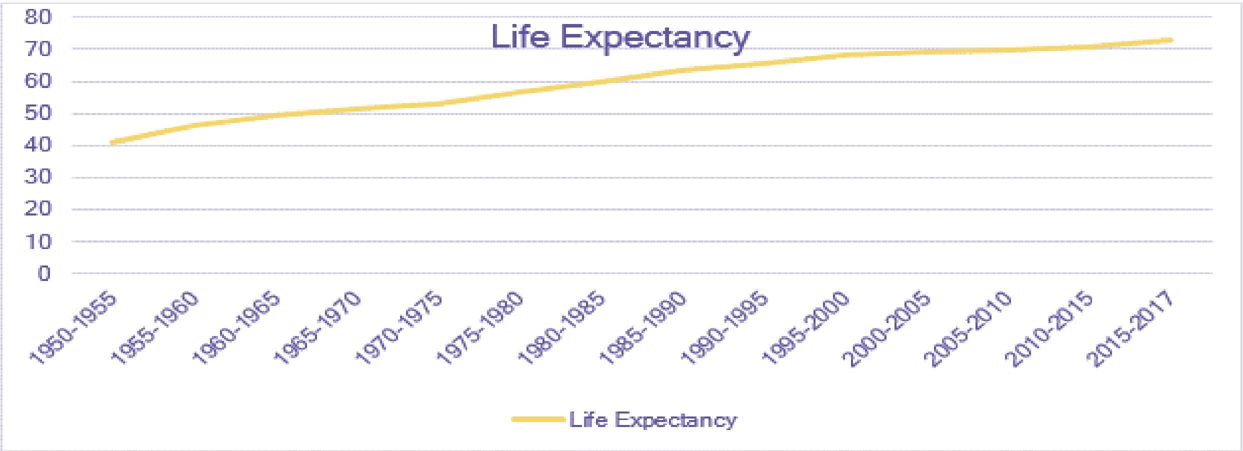
a) *Causes & Effects*

(1) Low life expectancy

The life expectancy in Egypt is generally low compared to other countries. According to the CIA Factbook and Egypt DHS 2014, Egypt is the 142th country with life expectancy of 72 years. (Zanty, 2014, p. 24) The below graph (Graph I.6) shows the life expectancy of Egyptians throughout the period

> *"OF THE $1 TRILLION IN FEDERAL SPENDING, ONLY 1 PERCENT IS ON PUBLIC HEALTH—AN INFRASTRUCTURE THAT SAVES LIVES." KAREN DESALVO, FORMER NEW ORLEANS HEALTH COMMISSIONER*

between 1950 until now.



Graph I.6 Egypt's life expectancy from 1950 till 2017

(2) Food safety

Food safety is a crucial problem that needs to be solved. Food safety is a discipline describing handling, preparation and storage of food in ways that prevent food-borne illness. Food has the ability to transfer pathogens (germs) that can result in the illness or even death of a person and other animals. As such, it's a very important task to regulate the handling and processing of food by issuing laws and protocols that control the process.

In theory, preventing food poisoning is possible (up to 100%). According to the WHO, there are five key principles of food hygiene, which can be summarized in:

- Prevent food contaminated with pathogens from spreading between people, pets and pests.
- Separate raw and cooked foods to prevent infecting the cooked foods.

- Cook foods for the appropriate duration at the appropriate temperature.
- Store food at the proper temperature.
- Use safe water and safe raw materials.

Locally, there have been and are efforts that are being done to reduce such effects. The most recent one is the signed agreement between the WFP (The World Food Programme) and Egypt's NFSA (National Food Safety Authority). This five-year agreement is to raise public awareness on food safety and hygiene (the five principles). In addition, it adds to the government's capacity to ensure access to healthy safe nutritious food.

(3) Healthcare-associated infections


Figure I.24 An image showing potential pathogen holders

Health-Care Associated Infections (HAI or HCAI) is an infection that's acquired during a hospital visit or any other health-care facilities. Sources can be viewed in Figure I.24. This type of infection is acquired through many means. Health care staff can spread infection, for example. Other means are contaminated equipment, bed linens and air droplets. The source of infection varies also; it can be due to another patient infected, one of the staff or in some cases it cannot be determined.

In Egypt, limited data are available because most hospital lack surveillance systems for health care-associated infections. Nonetheless, there was a study done in Cairo University Hospitals (CHU) in the period between 1 September 2014 till 31 March 2016. (Elkholy, Gaber, & Mostafa, 2016) Surveillance was active prospective and focused on ICU (Intensive Care Unit) patients; this was due to severity of their illness, their high exposure to invasive procedures and devices and their high use of broad-spectrum antibiotics. The results were as following: of the 94877 patients, 1272 HAIs has occurred (1.3%). Of these, 224 (18%) are ICU acquired, 111 (9%) ward acquired, 808 (63%) infections present on ICU admission and

129 (10%) SSI (Surgical Site Infection). These results are relatively high putting in mind that the surveillances are only covering one group of hospitals.

Last, implementing a standardized surveillance system in a resource-limited country like Egypt is possible. Having a continuous and sustainable surveillance system is considered a success that leads to many developments in the infrastructure of health care organizations. Also, surveillance is fundamental to have benchmark of infections and to plan for prevention strategies.

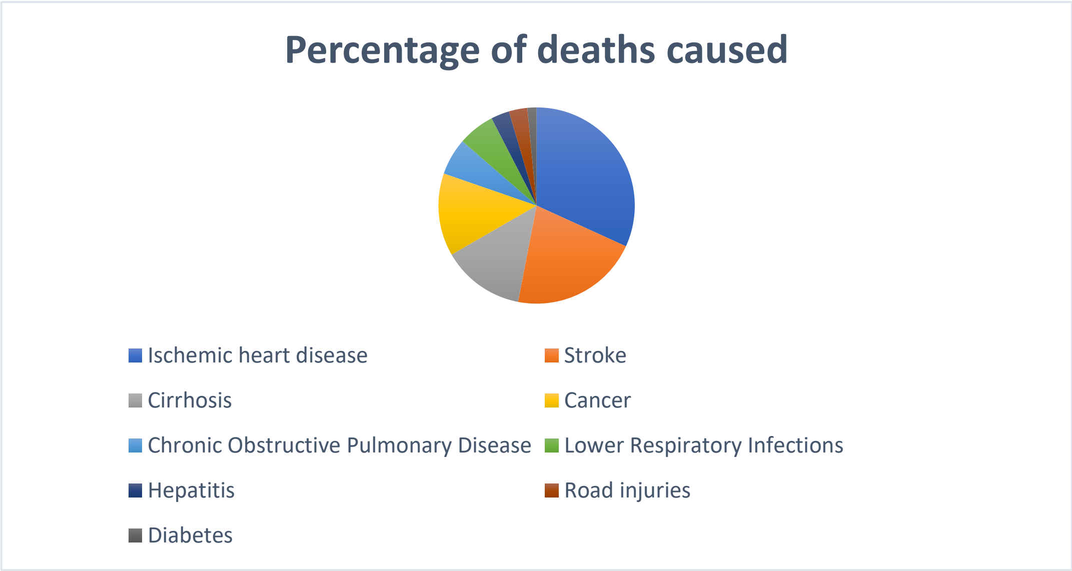
Other causes of death in Egypt include: *road traffic accidents, violence, birth trauma, other injuries, drug use,* and *malnutrition.*

(4) Diseases and stroke

Coronary heart disease is one of the most common diseases related to the heart. A common symptom of it is chest pain or discomfort which may propagate into the shoulder, arm, back, neck, or jaw. Sometimes, it may feel like heartburn. Usually, symptoms occur with exercise or emotional stress, last for a few minutes, and improve with rest. In many cases, the first sign is a heart attack. Other complications include heart failure or an abnormal heartbeat.

Coronary heart disease is the leading cause of death in Egypt with the ratio of 24.58%.

Other causes of death in Egypt include: road traffic accidents, violence, birth trauma, other injuries, drug use, and malnutrition.



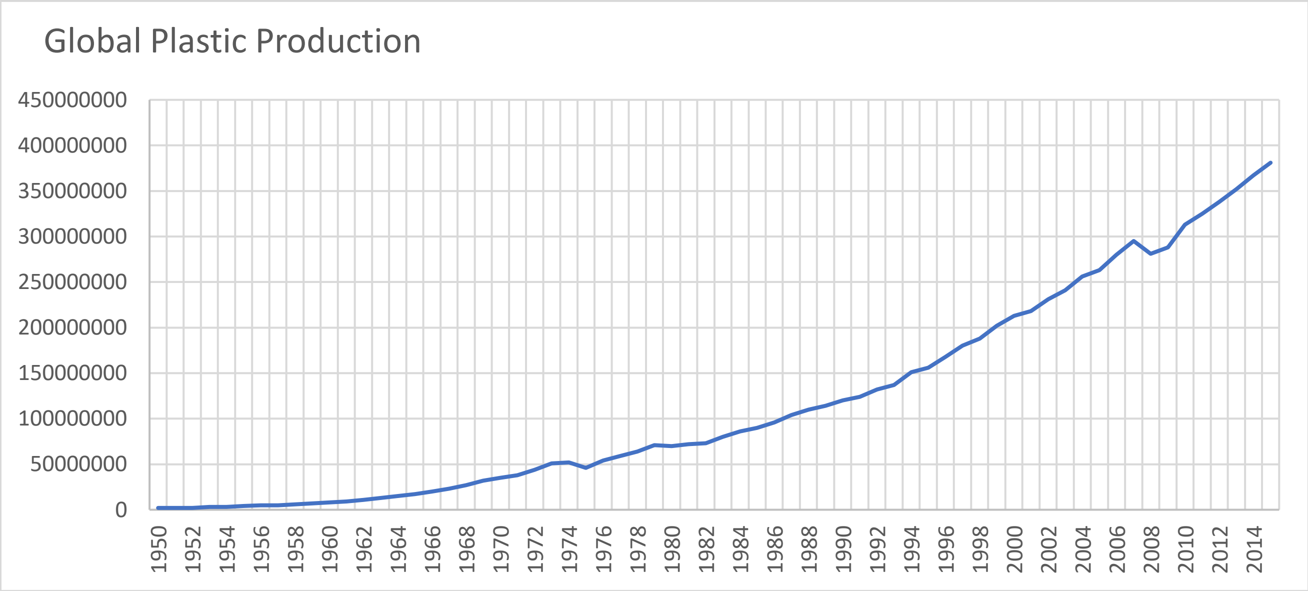
Graph I.7 Deaths and their percentage of deaths caused

Diseases and their percentage of deaths cause are represented in Graph I.7.

(5) Existence of pollutants in the environments

Figure I.25 Plastic bottles containing microplastics

Many pollutants in the environment make their way into the human systems and cause diseases. The most evident of those is plastics. The first artificial plastic was produced in 1907, but the rate of production has been increased by unusual rate as in 1950 the production of plastic was not huge and it increased by the years as it reached 8 million tons annually in 1960 and still increase till it reached over 381 million tons annually in 2015 (trend is shown in Graph I.8). According to the UNEP (United Nations Environment Programme), by 2050 there will be more plastic than fish in the sea.



Graph I.8 The production of microplastics over the years

Plastics are broken and become small particles which are microplastics, and they have many dangerous impacts as they damage the aquatic life and cause many diseases which damage the human life. 93% of drinking water bottles contains microplastics (shown in Figure I.25).

B. Problem to Be Solved: Eradicating Microplastics

Microplastics (shown in Figure I.26) are the small pieces of plastic that are existent in several environmental contexts and pollute the environment. The word “micro” contributes to the naming by referring to the size of the particles and not their actual composition. That size is defined to being less than 5mm in length according to the US National Oceanic and Atmospheric Administration (NOAA).

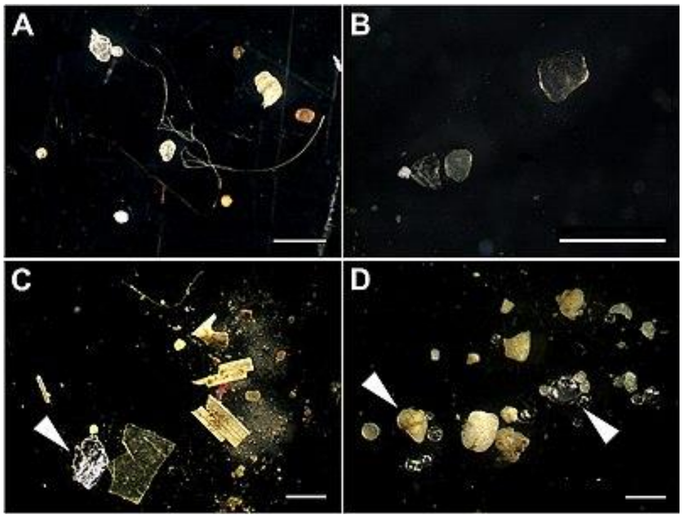


Figure I.26 Microplastics under a microscope

Microplastics are classified into two categories: the first being primary microplastics and the other being secondary microplastics. Primary microplastics are products that are intentionally synthesized to be small. These include microbeads, cosmetics, plastic pellets, and microfibers. Secondary microplastics are the result of wear and tear of plastic products. These include sources such as water and soda bottles. Both types are as dangerous and catastrophic as the other and should be handled and treated with great care and caution. Both are also found excessively in marine and aquatic environments. This results in major issues that accumulate and cause problems over time and in different places.

1. Classification

As stated above, microplastics are classified into two categories: primary and secondary microplastics. In the following, each category will be discussed briefly in order to clarify the problem.

a) Primary Microplastics

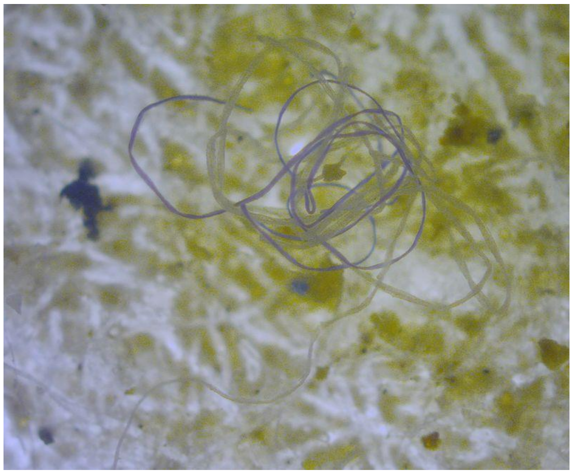


Figure I.27 Microfibers in a marine environment

Primary microplastics are pieces of plastics that are manufactured to serve a single purpose (for example microfibers which are shown in Figure I.27). They are found largely in cosmetics and other uses where minute particles are required. These uses may include medicine, air blasting technology, and scrubbers. These types of microplastics have over the years replaced natural ingredients such as ground almonds, oatmeal, and pumice. Despite their green roots as opposed to artificial plastics, those natural ingredients have been replaced by corporations to plastics due to their high availability and low cost. Companies are now starting to realize the danger of their doing and began decreasing their production of microbeads. And due to its long degradation life, they are still present in oceans and other microsystems.

b) Secondary Microplastics

Secondary microplastics (shown in Figure I.28) derive from the breakdown of large products of plastics such as bottles and soda cans. Exposure to external sources such as sunlight exposure can lead to the disintegration of the plastic products into pieces that cannot be seen by the naked eye. This process (the disintegration from large pieces into small pieces) is called fragmentation.

Figure I.28 Secondary Microplastics

2. Prevalence

a) Oceans

Although research is still in its infancy regarding the amount of microplastics in the oceans, a study done in 2015 estimated a number between 93 and 236 thousand metric tons. (Sebille et al., 2015) This number is on the rise though the study admits further research is needed in order to predict trends in ocean plastic concentration.

b) Freshwater ecosystems

Fewer studies have been done on freshwater ecosystems regarding the amount of microplastics; nonetheless, microplastics have been increasingly discovered in freshwater aquatic environments.

c) Soil

Figure 1.29 Microfibers in soil

Even fewer research has been done concerning the amount of microplastics that end up in the soil; still, a substantial portion of microplastics are expected to be in the world's soils (illustrated in Figure 1.29). Microfibers are among the most prevalent types of microplastics in the soil because water treatment systems fail to completely filter them. Some organisms such as earthworms could contribute to the amount of microplastic in the soil with via digestive processes that convert regular plastic debris into microplastics.

d) Air

Air was not leisured either; microplastics have made their way into them. Indoors and outdoors, microplastics are out there waiting to get inhaled into an organism's respiratory tract, possibly a human. A study conducted in 2017 concluded that indoor atmosphere carried microfibers constituting a concentration of 1.0-60.0 microfibers per cubic meter.

3. Effects on the Environment

As stated above, microplastics are now present in every part of the environment. While it has not been ecologically proved that there are widespread risks from plastic pollution yet, within the next years and if pollution continues at its current rate risks will start to become evident and widespread.

Microplastics not only make their occurrence in marine environments but also have reached freshwater ecosystems. While most evidence point to larger plastic parts being the larger concern in harming marine life–they lead to suffocation, entanglement, ingestion, and debilitation leading to death and/or strandings, microplastics' effect is not as conspicuous: they enter the food chain from the bottom, get embedded in the animal tissue, and consequently become invisible to unaided eye inspection. In Freshwater, samples collected across 29 Great Lakes from six states in the US were found to contain plastic particles, 98% of which were microplastics.

The effects of such particles are still not wholly researched, but can be summarized in the following points.

a) Integration into organisms

Microplastics even made to their way to live tissues. They get integrated and embedded to an organism's biological systems through respiration or ingestion. Various species were found to have microplastics integrated in their tissues (illustrated in Figure I.30). For example, lugworms were found to have the minute plastic particles in their digestive tracts, and many

Figure I.30 A shrimp with a plastic particle in its system species of crabs were found to have microplastics in their respiratory tracts.

Even some unicellular organisms have been observed to ingest microplastics. For example, zooplankton ingest microplastic beads (1.7-30.6 μm) (Cole et al., 2013) and excrete fecal matter containing microplastics. Organisms such as the zooplankton ingest microplastics because microplastics release similar chemicals to that released by their natural preys, making them unable to differentiate between them.

b) Humans

Fishes are among the most important resources of protein for humans, accounting for 6.1% for all the protein consumed globally in 2007. The microplastics first consumed by fish and other species of marine or non-marine organism can then be transferred to humans at the end of the food chain.

c) Buoyancy

Because of microplastics' density (and other factors), they generally sink to the bottom of the ocean or sea they are in and interfere with sediment-dwelling species and sedimental gas exchange. For some types of plastics, however, they float on the surface of the ocean and cause the formation of a buoyant biofilm layer, interfering with the amount of light passing through the water and hurting autotrophs that make their food from light.

d) *Persistent organic pollutants*

Chemicals and substances that harm the environment (called Persistent Organic Pollutants, or POP) can be carried and transferred to organisms and to the environment on the shoulder of microplastics. They act as the carriers to the additives added to them during manufacture, enabling them to leach out upon ingestion, potentially causing several harms to the organism. Moreover, plastics are virtually non-biodegradable, making them the perfect candidate for causing such prolonged harmful effect.

4. Consequences if Eradicated

There several implications that would arise if the problem of microplastics is solved, the good and the bad. In the following both will be discussed.

a) *Positive Consequences*

Of course, the majority of the consequences would be positive; it is a problem after all. For example, all of the above diverse effects would find a solution and be more idle and less causing. However, it is important to name a few.

(1) No more plastic in our food

Eradicating microplastic would eliminate the possibility of having plastics in our food, be it fish or shrimps. Microplastics would not make their way to the tissues of those organisms and humans will have more healthy food at their disposal.

(2) More functional ecosystem

Along the food chain, there would be no pollutants among the organisms. All organisms would be plastic-free and healthier.

(3) More light in the oceans

Because microplastics cause more light to reflect from oceans and obstruct it from reaching autotrophic organisms, eradicating microplastics would result in light reaching the oceans more and nurturing and benefiting those organisms that depend on light.

(4) Less pollutants in the organisms

Because microplastics carry chemicals that are harmful to the environment and make their way to organisms (the POP substances), eradicating microplastics would result in a greener environment that is devoid of any of these pollutants.

b) Negative Consequences

Although most of the consequences will be positive, there exists some negative consequences that might accompany the chosen solution in eradicating microplastics. The following list is not comprehensive.

(1) Dead organisms

Some chemical-based treatment plants do not account for living small organisms that cannot be seen by naked eyes, for example phytoplankton. Those animals are very beneficial to the environment (phytoplankton alone produces most of earth's oxygen) and killing those animals while treating microplastics can have serious harmful effects.

(2) More pollution

Again, chemical-based treatments play a role in this. Those chemical, if leaked to freshwater or water-inhabited regions, may cause adverse consequences. If leaked to freshwater, a human might ingest this water again and be harmed by the substance. If leaked to water-inhabited regions, organisms living there might be harmed by the surrounding harmful water.

And other consequences that will arise depending on the solution executed.

C. Researches Related to the Problem

1. Spontaneous Spread of Microplastics

a) Microplastic formation

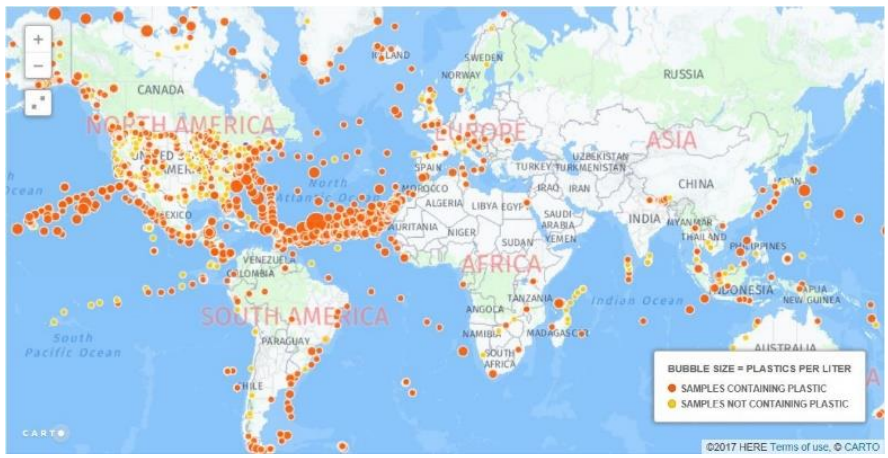


Figure I.31 The spread microplastics

Microplastic issue arises due to the increasing usage of plastics in daily life. Plastics-due to their complicated structure-cannot be easily degraded or dissolved as most of organic materials. However, plastics start to degrade after decades of exposure to weathering conditions. Degrading doesn't change the chemical structure of plastic; it only changes its size transforming it into microplastics "smaller than or equal to 5mm in diameter". The spread of microplastics is shown in Figure I.31.

b) Microplastic spread

Microplastics spread faster more easily, reaching more areas and polluting them as shown in figure. Microplastics have two main types categorized according to their source. Primary microplastics are manufactured as microbeads, capsules, fibers or pellets. Microbeads are used in cosmetics and personal care products, industrial scrubbers are used for abrasive blast cleaning, microfibers are used in textiles, and virgin resin pellets are used in plastic manufacturing processes. Secondary microplastics result from the breaking down of larger pieces of plastic into smaller pieces. This occurs when plastic debris is exposed to sunlight and weathering making it break down to tiny fragments.

2. Environmental Risks of Microplastics

a) Greenhouse effects

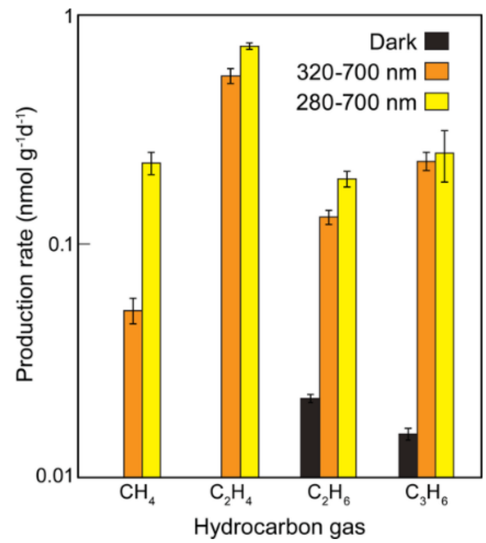


Figure I.32 The emissions of greenhouse gases

Many plastics give off different greenhouse gases as they break down, contributing to climate change. Low-density polyethylene (or LDPE) is the plastic type which has the highest rate of gases release. LDPE has a weaker and less dense chemical structure than most plastics that contributes in its fast breaking down. Heat and light emitted by the sun are the main catalysts for the plastics gaseous release. The most obviously released gases are methane and ethylene as shown in Figure I.32. Methane is 21 times more potent than carbon dioxide concerning the greenhouse effect. As these gases are released daily with increasing amounts, they contribute more in global warming which threatens life continuity on earth

b) Exposure of aquatic creatures to microplastics

Figure I.33 A phytoplankton consuming a microplastic particle

Primary microplastics existence in oceans has a disastrous effect on the marine life. Microplastics-due to their relatively high density-usually settle down and stay suspended near the ocean floor. Due to its tiny size, microplastics are thought to be micro living organisms by marine creatures as shown in Figure I.33. That makes numerous marine creatures feed on them instead of their natural nutrition source.

c) Dangers of microplastics exposure

Microplastics cannot be digested as other organic foods, causing several diseases or even death to many aquatic creatures. On the long term, it can lead to the extinction of several aquatic species that are necessary for the survival of many other species. These changes in the marine ecosystem can lead to disastrous consequences as the destruction of the food chain therefore the failure of ecosystem.

3. Health Risks of Microplastics

a) *Exposure by vectors*

Microplastics existence in waterbodies can be hazardous to human in several ways. Marine living organisms are one of the human's main nutrition sources. Direct exposure of marine creatures to microplastics increase their chances of being infected with several diseases. These creatures can be an effective vector to transform malignant diseases as cancer.

b) *Direct Exposure*

Direct exposure of human to microplastics is extremely perilous. This exposure is due to drinking water containing unseen microplastics. When these plastics enter the digestive system, they are not being digested. Their chemical structure reacts with acids inside the body causing life threatening diseases as cancer or poisoning.

E. Researches Related to the Solutions

1. Carbon blocks faucet filters

a) *Mechanism*

Carbon filters (shown in Figure I.34) are used to filter water. In this process, the activated carbon is used to remove impurities and containments. Carbon is the most absorbent material that absorb thousands of tiny pores and it is uniquely efficient. Such as: a pound of carbon offers 125 acres of filtering surface area.

Figure I.34 A carbon filter

b) *Used Materials*

Most carbon water filters are made from powdered block carbon material, or granular activated carbon, the carbon blocks are the most effective as they have larger ratio of activated carbon surface area to water, and also because powdered block is denser and water travels more slowly through it. If larger surface area is created by the block carbon, and the water contact with the carbon in more time, the more contaminants are removed

Activate carbon water filters are rated by how much containment they remove, and these filters range from 50 microns to 0.5 microns. The smaller measurement gives more efficiency, it has the ability to remove the small containment particles.

2. Density separation

a) Mechanism

The density separation is an effective solution and effective method for separating high-density natural particles and low-density plastic particles.

Density separation is a process in which the sample is mixed into a solution with a higher specific gravity than the estimated for the collected plastic particles, this makes the high-density inorganic substances precipitate and recovering the floating low-density plastic particles.

Figure I.35 Density separation in practice

b) Materials Used

Common solutions that are used for the density separation of microplastics are shown in Table I.1.

Salt	Density (g cm^{-3})
Sodium Chloride (NaCl)	1.2
Sodium Polytungstate (PST)	1.4

Sodium Iodide (NaI)	1.6
Zinc Chloride (ZnCl2)	1.7
	1.6

Table I.1 Density of some solutions

3. Granular activated carbon faucet filters

a) Mechanism

It is a filter (shown in Figure I.36 that has activated carbon it is a confirmed option to remove some chemicals, organic chemicals and some microplastics from the water, the activated carbon remove some chemicals and microplastics that are dissolved in water after passing through a filter that has GAC by absorbing the chemical in the GAC.

Figure I.36 GAC filters

b) Used Materials

Granular activated carbon is made from some raw organic materials, such as coal or coconut shells that are rich in carbon. The heat is used to activate the surface are of the carbon, the activated carbon is responsible for removing some chemicals and some microplastics from water after passing through the GAC filters by trapping them in the GAC.

F. Prior Solutions

1. Electrodialysis and Electrodialysis Reversal

Electrodialysis reversal (EDR) for fresh water (shown in Figure I.38) provides efficient water treatment, reducing water scarcity. (Strathmann, 2004) Electrodialysis or EDR is known to treat water or sewage with moderate concentrations of dissolved ions efficiently. Electrodialysis is an advanced membrane that uses the flow of ions to desalinate water.

Figure I.38 EDR unit

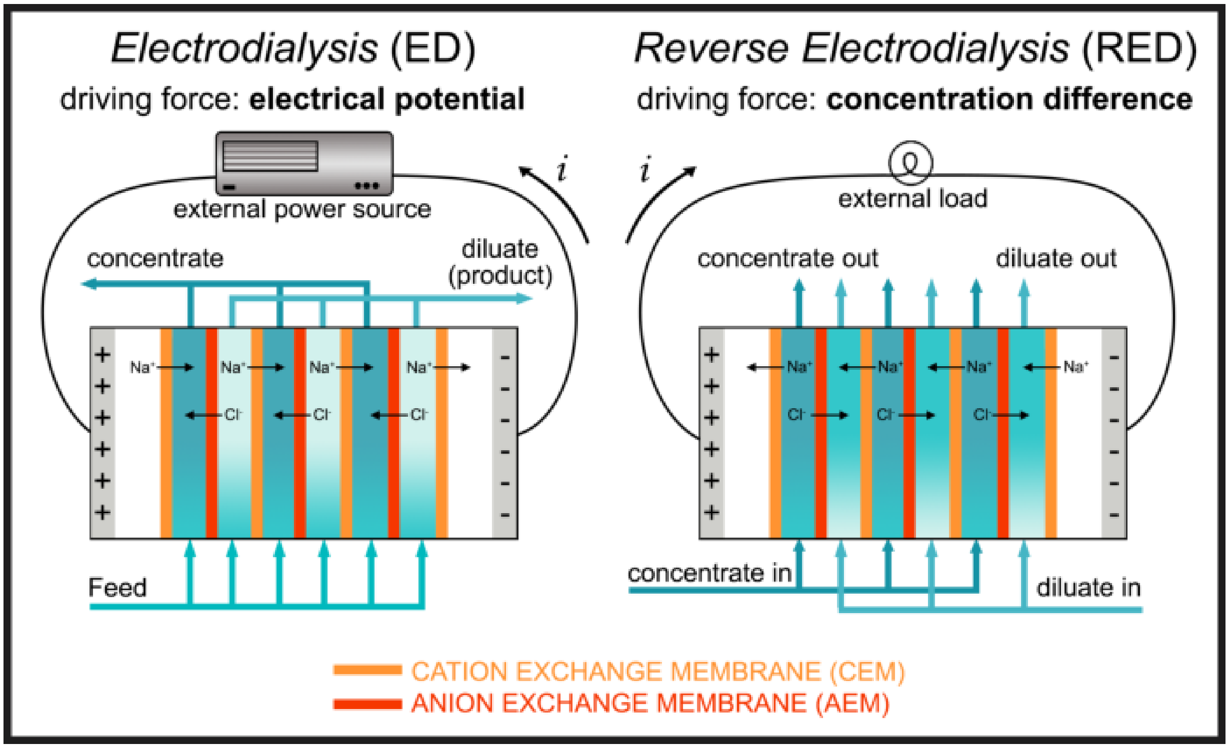


Figure I.37 The mechanism of ED and RED

Electricity is applied to electrodes to pull naturally occurring dissolved salts through an ion exchange membrane separating salts from water. The mechanism is illustrated in Figure I.37.

a) Advantages

1. In the reversal process, electrodes' polarities are switched to reduce the formation of deposit and precipitations of salts and solid wastes allowing the EDR to achieve higher water recoveries.

2. Consisting of only one filtration phase, the energy consumption of this method is relatively very low.

3. Water recovery percentage can be up to 90% in addition to salts' removal which varies from 50 to 95%.

4. The plant has very long membrane life and the water itself requires less pretreatment than usual plants.

b) Disadvantages

1. Some organic matter, colloids and SiO_2 aren't removed by ED system.

2. As this method is relatively new, this makes it expensive in terms of its components' prices

3. Neutral toxic components such as viruses or bacteria are not removed by electrodialysis.

4. The generation of chlorine gas at the anode can lead to corrosion problems in the surrounding of the plant.

2. RO-EDI Water Treatment System

RO EDI (Reverse Osmosis Electro deionization), which is shown in Figure I.39, is the one of the most preferred water purification methods used in Pharmaceutical and Food industries. Those are units that are commercially manufactured by many companies but the share the same stages' sequence. It is made of two-step treatment (illustrated in Figure I.40):

Figure I.39 RO-EDI unit

1. Reverse Osmosis: the pre-stage, RO system uses strong pressure gradient to drive water through the semi-permeable membrane while removing impurities, thus leaving water purified. Then the water goes through a sequence of stages as pre-purifying. It might be repeated twice as a maximum.

2. Electro deionization: the main, second and final stage, the process combines semi-impermeable membrane and ion exchange which enable efficient demineralization process. This removes ionic impurities leaving a purified water product as only ions pass

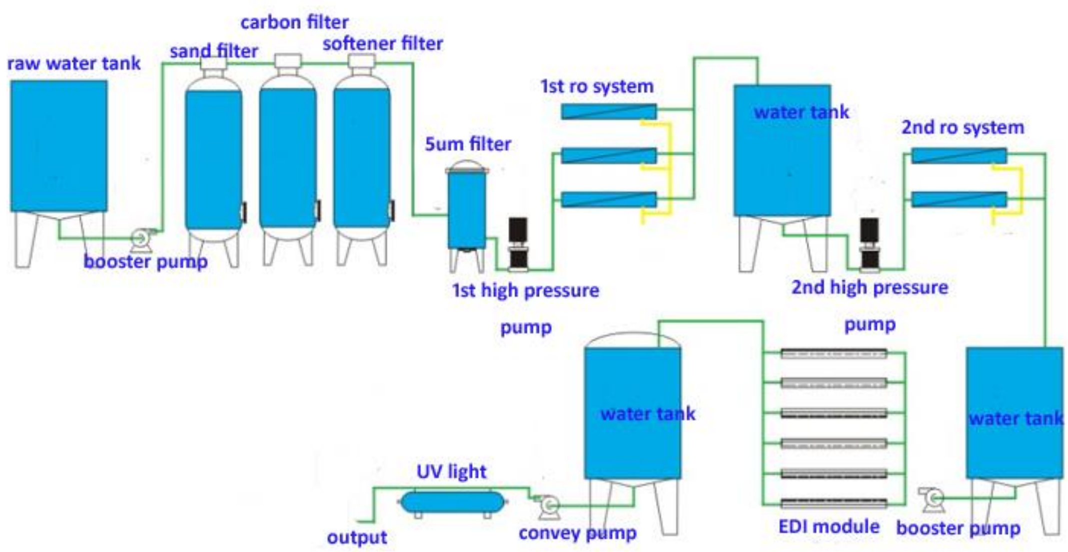


Figure I.40 The mechanism of RO-EDI

through the semi-impermeable membrane while the water is blocked.

a) Advantages

RO-EDI plants have several advantages.

1. RO is the natural, safest and most efficient way to remove bacteria from contaminated water without using any chemical additives.

2. As this way is natural-based, water preserves its taste and quality.

3. Its water is safe for patients even though their immune system is weak.

4. RO is much safer than other solutions as it works on removing all the containments, chemicals and harmful substances such as sodium, lead and arsenic.

b) Disadvantages

Nonetheless, RO-EDI still has some disadvantages that devalue its use.

1. This project is just units of different sizes being sold which makes it so expensive to apply in normal water supply treatment.

2. The way water is being processed makes it dead as it kills all the nutrients and minerals on it.

3. The sanitizing system need to be repaired every 6 or 12 months among some other parts as well, which makes this even more expensive and sophisticated to deal with.

3. Nanofiltration

Figure I.41 Nanofiltration unit

Nanofiltration is a developed high-end pressure-based membrane water treatment process. Natural organic matter and inorganic pollutants in surface water are the main focus of this water treatment method. Since the surface water has low osmotic pressure, a low-pressure operation of Nanofiltration is possible. Nanofiltration is a good replacement for reverse osmosis (RO) in many applications as it consumes less energy than RO and bears higher flux rates. Nanofiltration does not allow any organic matter and salts to pass through. Substances that cannot go through these NF's membrane have valence ions. The valence ions are ions that have a valency of two and have the same organic structure. That's why salts such as calcium and magnesium are not allowed to go through the pores of the membrane. It also does not permit any viruses to pass through.

a) Advantages

1. No chemicals are used in this method; therefore, it is an ecofriendly method that does not affect the quality of water.

2. Viruses, organic elements, and valence ions are removed from water.

3. The membrane has very tiny holes, so most of the molecules cannot go through.

b) Disadvantages

1. Pretreatment of the water going through Nanofiltration is important to protect the membrane from repetitive maintenance and to improve the performance of Nanofiltration.

2. Nanofiltration does not remove any dissolved substances, so that means that if there was a dissolved substance in the water, it couldn't be separated from water.

4. Chlorine Dioxide water treatment

Figure I.42 Chlorine Dioxide water treatment plant

Chlorine dioxide is a chemical compound with the formula of ClO_2. As one of several oxides of chlorine, it is an oxidizing agent used in water treatment and in bleaching. Chlorine dioxide's usage for pre-disinfection of fresh water has increased significantly over the past 20 years. Chlorine dioxide is an incredibly powerful natural pesticide, and sanitizer that is effective against many pathogens such as bacteria, viruses even at concentrations as low as 0.1 ppm to 0.5 ppm. Pathogens include Legionella bacteria, E. coli, Coliforms, Pseudomonas, Cryptosporidium, Giardia Cysts, Algae and Amoebae. It also eliminates both planktonic and sessile bacteria in water. Chlorine dioxide is certified to be safe at specific concentrations less than 0.5 ppm total oxidant (chlorine dioxide + chlorate + chlorite). Chlorine dioxide is ideal for use in the purification of drinking water as it causes no unwanted taste or odor issues, unlike chlorine.

a) Advantages

1. It is a more effective disinfectant than chlorine as it has a huge effect on bacteria and viruses, but it is not as strong as free chlorine.

2. It produces less harmful byproducts than chlorine.

b) Disadvantages

1. Often, chlorine dioxide is generated onsite from sodium chlorite and chlorine gas, and thus requires all of the precautions associated with the transportation and handling of chlorine gas.

2. During the process of making Chlorine Dioxide, the excess amounts of untreated chlorite or excessive amounts of chlorine in the treated water can be so harmful. Some studies on chlorine dioxide have also identified issues with taste and odor.

3. Chlorine dioxide is a very unstable substance; when it comes in contact with sunlight, it decomposes.

4. Chlorine dioxide is about 5 to 10 times more expensive than chlorine.

5. YUNA Filter


Figure I.43 YUNA filter illustration

YUNA (shown in Figure I.43) is an anchor buoy with a filter technology that gathers microplastics from water. It provides sustainable and supported solution on a local scale by the circular economy. It is made to eradicate microplastics that are found sideways the coast by collecting them with the help of tides.

a) Mechanism of YUNA

It requires a very small amount of energy to work; the design of the structure is based on the ocean sunfish. The design was made because of the dynamic method in which it adapts to the course of changing sea currents. As the buoy spins from the sea currents, it collects microplastics. The filter has numerous layers ordered by grammage from high to low, to filter the plastics depending on its size.

Activated carbon and similar elements filter very small particles that are measured in microns. When the microplastics are filtered, they are collected and recycled, so they don't return to the sea.

b) Strengths

1. It doesn't pollute the environment.
2. It creates a circular and very sustainable product.

c) *Weaknesses*

1. Its efficiency is low compared to other solutions, and costs more money.

6. Ferrofluid

Figure I.44 Ferrofluid Oil

In Google science fair, ferrofluid solution was developed a. Ferrofluid solution is a combination of magnetite powder and oil to create a ferrofluid in the water containing microplastics. They are colloidal liquids made of nanoscale ferrimagnetic, or ferromagnetic, particles suspended in a transporter fluid (usually an organic solvent or water). Each small particle is coated with a surfactant to hinder clumping. after 1000 tests, the efficiency of the method was 87% in removing microplastics. This may prevent the microplastics from reaching waterways and the ocean.

a) Mechanism

Vegetable oil is put into a dish, just enough to make a thin film across the bottom. iron filings are poured into the oil then mixed until they become a thick, sludge-like material, making the ferrofluid. A napkin is used to absorb any excess oil to let the ferrofluid become thicker. A good way to perform this is to attach a magnet to the outer side of the dish. This will solidify the fluid and provide more range for dropping away extra oil. Attaching a magnet to the dish that contains the ferrofluid; the fluid will solidify and take the shape of the magnetic field, Removing the magnetic field will let the ferrofluid to flow as a liquid again. Then, it filters any containments in the water.

The microplastics mixed with the ferrofluid (the combination of magnetite powder and oil) which was then removed. After the microplastics had bound to the ferrofluid, a magnet was used to eradicate the microplastics and leave only water.

b) Strengths

1. It gives an impressive efficiency.
2. It doesn't cost a lot of money.

c) Weaknesses

1. It isn't widely used.

II. Chapter 2: Generating and Defending a Solution

This chapter goes through the description of the prototypes, the solution and design requirements, and the test plan the proposed solution is evaluated by.

A. Solution and Design Requirements

1. Solution Requirements

a) Eco-friendliness

The prototype has to be eco-friendly so it does not harm the environment. Using eco-friendly materials is essential to save the environment, the aquatic life, and the human public health. If the prototype is eco-friendly, it will help the country and save the environment in many different aspects. Using materials which are not polluted to achieve the eco-friendly requirement is a must in our prototype. Most recycled materials represent a good candidate for this part as they do not pollute the environment and effectively save the environment from harmful but recyclable materials. For the above reasons, we pursue the inclusion of this design requirement in our prototype.

b) Cost Effectiveness

Having a low cost for the project is a must for the proposed solution. If the solution achieves its required task while being a low-cost project, there would be no trouble while installing the solution in several places, and countries would be accepting its implementation. Achieving that can be done by using few available materials that are low-cost and efficient. Recycled materials can also be used for achieving this design requirement. Cost is essential in making any project, and so is it here.

c) Sustainability

It is the formidability of the project as it is maintaining its good shape and function. Our project's unit must retain its good shape without requiring any maintenance for quite a long time. Maintenance will be required only if an extreme disaster occurs. This is important because it will save more money as maintenance required will cost more money especially if it is repetitive. Furthermore, it will have a huge impact on the efficiency of the project itself as it will be working almost all the time with no need to be maintained.

d) Durability

Durability refers to the ability of a physical product to remain functional, without requiring excessive maintenance or repair, when faced with the challenges of normal operation over its design lifetime. To get the longest durability time of a machine, the best and most durable materials must be used in the construction in order to guarantee a smooth efficient performance. In the case of microplastics filtration, durability of the prototype means that it can filter water from any type of microplastic without breaking down or needing maintenance. The longer the device can work efficiently without technical issues, the more durable it is. Durability is one of the main factors determining whether the prototype can be implemented in real life or not.

e) Practicality

Practicality is the state of being feasible or easily accessible. Being practical is an essential characteristic for any project as it contributes in its accessibility by users. To be practical, the device must be easy to utilize by users and the operating process must be fast. It must have the ability to be used on a range of implementation sites without or with minimum additions and modifications. This ensures that the prototype is implementable, while still being easily installable.

f) Availability

In this context, availability refers to the availability of the units and the materials used. The project's materials must be available so that it does not become complicated in addition to being substitutional if needed. The units themselves must be available to anyone who needs them. Our project's materials will be easy to find, so the units of projects will be available. Availability includes the availability of spare parts and easy maintenance. For the project to be available, it will increase the spread and usage of those units. Availability on its own is a huge indicator to the project's success and an evidence in terms of its efficiency.

g) Usability

Having the prototype being easily operable is a must for the proposed solution. This can be done in the prototype by providing a simple interface through which you can read measurements and make adjustments. This factor makes the solution easy, quick and effective.

2. Design Requirement

In order to achieve a successful prototype, some criteria and specifications that should be followed: removal efficiency and water quality. The prototype must be as efficient as possible in filtering microplastics from water. Moreover, water quality should not be neglected; it should be untampered with after the prototype, especially the pH.

In the chosen prototype, the efficiency is measured by first measuring the TSS (Total Suspended Solids) of distilled water with microplastic added before (C_0) and after (C) and then using the equation $E = \frac{C_0 - C}{C_0}$ to calculate efficiency. Then, water quality is tested by conducting one or more of the following tests: pH, TDS, DO, and turbidity and making sure that they are in an optimum range.

Succeeding in achieving those, means that the prototype can effectively filter the microplastic particles from water bodies in real life.

B. Selection of Solution

In order to diminish the problem to be solved, a solution is proposed:

1. Filtration of Microplastics

With their dangers on the environment, filtering microplastic from water is the best course of action. The method used to conduct this filtering is simple: first, microplastic particles are coagulated to form larger flocs. Then, a rapid sand filter can be used to remove those flocculated particles, resulting in microplastic-free water that is highly useful.

C. Selection of prototype

1. Description of Prototype: Electrocoagulation and Rapid Sand Filter

The provided prototype offers high removal rate of microplastic without altering any of water's properties significantly, essentially achieving the design requirement.

a) *Electrocoagulation Chamber*

The electrocoagulation prototype is made up of electrodes set up on a wooden holder attached to a glass container. When an AC current gets applied, reactions occur that coagulates any floating particles, producing larger particles.

b) *Settling Unit*

The settling unit is used as a mixing unit, clumping particles together more essentially increasing their size. This is achieved by having sheets of glass obstructing the flow of water, driving the water to another path, but with the molecules mixed.

c) *Rapid Sand Filter*

A rapid sand filters removes contaminants from water using the processes of mechanical straining and physical adsorption. Its layers are arranged based the specific gravity of the material, namely activated carbon, sand, and finally gravel.

2. Test Plan

To measure the efficiency of microplastic removal, two methods are employed: first, using TSS with sample added of microplastic to distilled water without any contaminants, and second, using a microscope to get the numbers of pixels of microplastic before and after filtration. Furthermore, to measure water quality the following is done: measuring any water quality indicative property before and after filtration and making sure they are in an optimum range.

III. Chapter 3: Constructing and Testing the Prototype

This chapter goes through how the prototypes were constructed, tested, and also the data collected from these tests.

A. Materials and Method

1. Materials

Shown below (Table III.1) are the materials used in constructing the prototype.

Name	*Description and/or Usage*	*Cost*	*Source*	*Quantity*	*Illustration*
Sand	Fine sand for the filtration of water in the rapid sand filter	Free	Collected and Washed	$(25 \times 25 \times 5.5)\ cm^3$	
Gravel	Gravel for the diffusion of the water in the rapid sand filter	Free	Collected and Washed	$(25 \times 25 \times 7)\ cm^3$	

Activated Carbon	Fine activated carbon grains for the microfiltration of the water in the rapid sand filter	30 L.E.	Plumber's	2 packs constituting (25 × 25 × 1) cm^3	
Cotton	Cotton was used to collect the suspended particles from clogging the faucet and the tap filter	7 L.E.	Pharmacy	2 Packs	

Glass containers	25 × 30 × 25 cm^3 container was used for electrocoagulation 20 × 50 × 20 cm^3 container was used for coagulants settling 20 × 25 × 25 cm^3 container was used for the rapid sand filter	170 L.E.	Glazier's	3 Containers	

Plastic Container	Plastic container was used to store water after it was electrocoagulated	25 L.E.	Plastics Shop	1 Container	
Faucet	It was used to get the water out of the container	15 L.E.	Plumber's	1 Piece	
Hoses	Hoses with 0.75-inch diameter was used to transfer water through containers	10 L.E.	Plumber's	2 meters	

Nile Red Dye	A dye used to indicate suspended solids in water	4.5 L.E.	Chemist's	10 g	
Crocodile Wires	It was used to connect electrodes with the power supply	Free	Provided by School	12 Wires	
Electrodes	Aluminum Electrodes of dimensions 11.5 cm × 20 cm × 1 mm was used for electrocoagulation	Free	Scrap at home	10 Pieces	

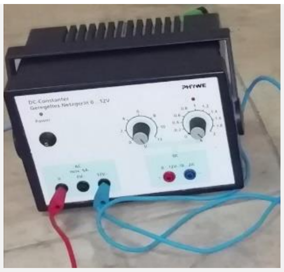
Water Tap Filter	It was used to make sure that there are no more macro particles that would ger in the water final product	3 L.E.	Plumber's	1 Piece	
Power Supply	It was used to stabilize an electric current and to control its properties	Free	Provided by School	1 Piece	

Table III.1 Prototype materials

2. Safety Precautions

Before heading towards building the prototype, safety precautions must be put into consideration:

- Safety gloves should be worn dealing with the wires, the wood, the glass, and the agitating silicone rubber adhesive.
- Apron and goggles should be worn while sawing wood.
- Insulting gloves should be worn while handling electricity.
- While holding glass and transferring the containers, care should be taken in order not to drop and break them.

3. Measurement Tools

Name	*Purpose of use*	*Illustration*
Digital balance	Used to measure the masses of the materials used in the prototype.	
Beaker	Used to measure the volume of the activated carbon, sand, gravel used in the prototype	

Measuring tape	Used to measure the length of the wood, glass, and hoses used in the prototype 

4. Methods

a) Electrocoagulation Chamber

- First, glass was cut and assembled using silicon to form a 25 × 30 × 25 cm3 container.
- Second, a wooden plate with length 25 cm was cut in a zigzag shape to hold the electrodes in the water and it was hanged in a longer plate of length 35 cm.
- Third, aluminum electrodes of dimensions 11.5 × 20 cm^2 were fixed to the zigzag shaped plate to be held during the coagulation, as shown in Figure III.2.

- Fourth, crocodile wires were connected to the electrodes and the power supply to start the coagulation as shown in Figure III.1.

Figure III.2 Electrodes configuration

Figure III.1 Final unit

b) Settling Chamber

- First, glass was cut and assembled using silicon to form a 50 × 20 × 20 cm^3 container.
- Second, four glass sheets were fixed inside the container as shown in Figure III.3, where two sheets were fixed up, and two down.

Figure III.3 Settling unit

c) Rapid sand filter Chamber

- First, glass was cut and assembled using silicon to form a 25 × 20 × 25 cm^3 container.

- Second, a faucet was fixed to the container wall to let water out when needed as shown in Figure III.5, and a water tap filter was fixed to prevent sand from going inside the faucet.
- Third, activated carbon, sand and gravel were washed several times to make sure they are dust free.
- Fourth, 7 cm of gravel were put at the bottom, then a mesh was put to prevent sand from going between the gravel grains.
- Fifth, 5.5 cm of sand were put above the mesh, then another mesh layer was put to prevent activated carbon grains from mixing with sand grains.
- Finally, 1 cm of activated carbon were put above the mesh and they were covered by a cotton layer to distribute water on the whole filtering area as shown in Figure III.4.

Figure III.5 The faucet

Figure III.4 Final rapid sand filter

The final prototype is shown in Figure III.6.

Figure III.6 Final prototype

5. Test Plan

a) To measure the efficiency of microplastic removal, two methods are employed:

(1) First

1. First, a sample of microplastic is added to distilled water without any contaminants.

2. Second, TSS in water is measured (C_0).
3. Third, the method of filtration is run.
4. Fourth, TSS in water is measured again (C)
5. Finally, efficiency is calculated using the equation $\frac{C_0 - C}{C_0} \times 100\%$

(2) Second

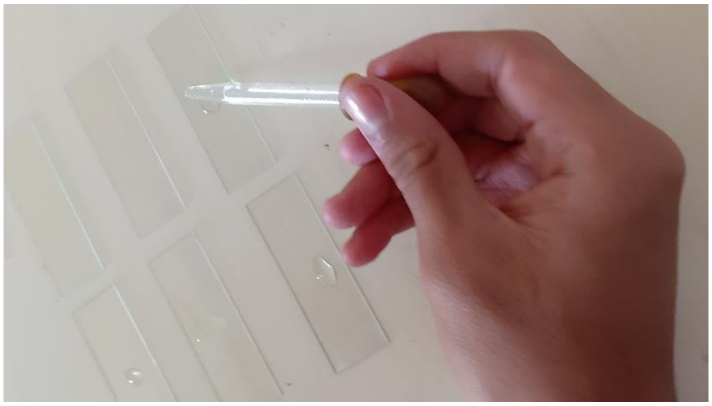


Figure III.7 Slide preparation

1. First, 6 microscope slides of water, 3 unfiltered and 3 filtered, is measured as shown in Figure III.7.
2. Second, a picture of each slide under the microscope is taken and stored.
3. Third, for the unfiltered slides, the number of pixels in which microplastic particulates occur to exist is calculated as C_0.
4. Fourth, for the filtered slides, the number of pixels in which microplastic particulates occur to exist is calculated as C.
5. Fifth, efficiency is calculated using the equation $\frac{C_0 - C}{C_0}$.
6. Finally, the average is taken.

b) To measure water quality the following is done:

1. First, any water quality indicative property (such as pH shown in Figure III.8) is measured before the filtration
2. Second, the filtration is run.
3. Third, that same indicative of water quality is remeasured.
4. Finally, changes are made sure to be in an optimum range.

Figure III.8 Measuring the pH of water

6. Data Collection

a) Negative Results

While constructing the project, negative results were faced, where some unintended errors took place, which led to the reconstruction of some parts of the prototype. For instance, while working on the rapid sand filter, the materials were arranged based only porosity. However, after adding water during the test, the materials were mixed because of the difference in specific gravity, heavy materials went down and the light up.

b) Results

Three tests were done to ensure efficiency in removal of microplastic and the quality of resultant water, which are the design requirements.

(1) TSS Test

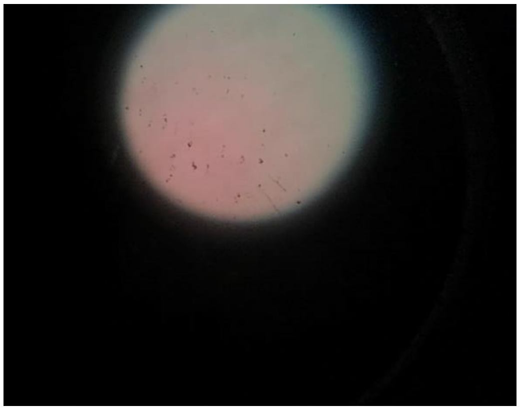
To measure the amount of microplastic removal, a TSS (Total Suspended Solids) apparatus by the name of ZS-680 SS Concentration Controller (shown in Figure III.9) was used. It measured any undissolved solids suspended in water, which includes microplastics. Employing the test plan, the initial reading of the TSS in the contaminated water was 92 mg/L. Moreover, the filtered water showed a TSS of only 12 mg/L, making the removal efficiency $\frac{92-12}{92}$ = 87.0%.

Figure III.9 TSS Apparatus

(2) Microscope Test

Another test that was employed to measure the amount of microplastic removed was the microscope test. Therein, the number of microplastic pixels were 16489 for every 190080 pixels (illustrated in Figure III.10(a)). With the filtered water, this number was reduced to only 1172 pixels for every 144622 pixels on average (illustrated in Figure III.10(b)), showing a removal efficiency $\frac{\frac{16489}{190080}-\frac{1172}{144622}}{\frac{16489}{190080}} = 90.7\%$.

(a) Contaminated Water



(b) Filtered Water

Figure III.10 Filtration of water

(3) pH Test

To measure water quality, a pH test was executed, whereby the acidity and alkalinity was made sure not to fall out of the optimum range. Providentially, the pH of water before and after the filtration has been measured to be in the range 7-8, as shown in Figure III.11.

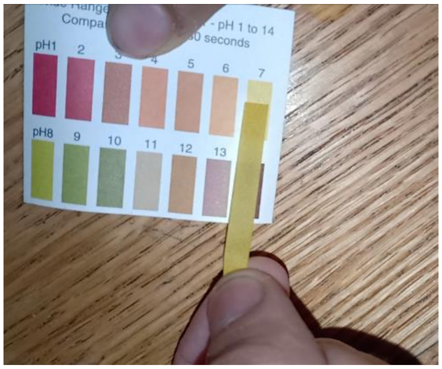


Figure III.11 pH of water

(4) Final

Results are collected in Table III.2.

Test	*Unfiltered*	*Filtered*
TSS	92 mg/L	12 mg/L
Microscope	0.088 mp pixel / white pixel	0.008 mp pixel / white pixel
pH	~7-8	~7-8

Table III.2 Collected Results

IV. Chapter 4: Evaluation, Reflection, Recommendations

This chapter goes through the evaluation, analysis, reflection and some recommendations related to the prototype

A. Analysis and Discussion

As affirmed in the results section, the project has achieved its design requirement, removing microplastics and resulting in water that is usable and highly unpolluted. Next will be explained why that is so.

1. Electrocoagulation Chamber

a) Overview

An electrocoagulation unit (illustrated in Figure IV.1) is an electrolytic cell made up of an anode and a cathode. When a potential is applied from an external power supply, the anode material (metal M) undergoes oxidation, (M. Yousuf A. Mollah, Schennach, Parga, & Cocke, 2001) as shown in Equation IV.1 and Equation IV.2:

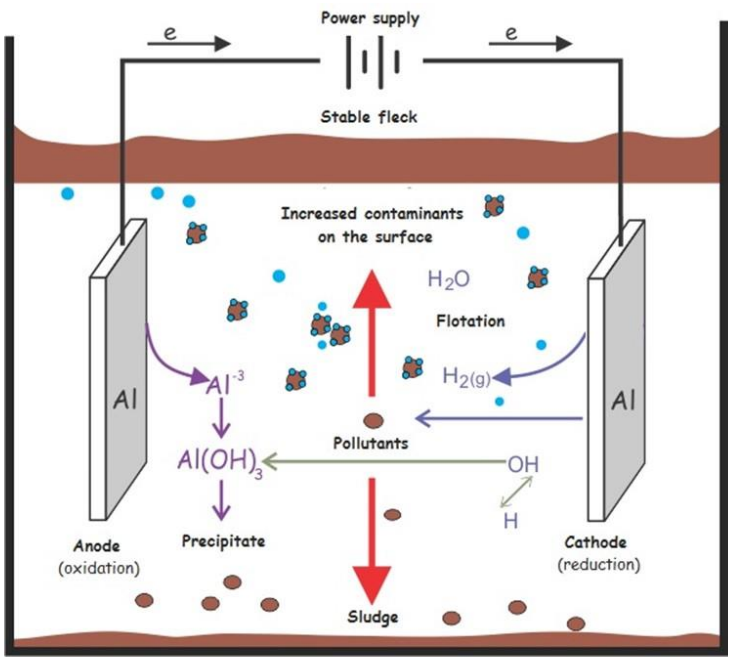


Figure IV.1 Overview of electrocoagulation

$$M_{(s)} \rightarrow {M_{(aq)}}^{Z+} + Ze^-$$

Equation IV.1 Oxidation half-reaction

Water may also be oxidized forming hydronium ion and elevated oxygen,

$$2H_2O_{(l)} \rightarrow 4H^+{}_{(aq)} + O_{2\,(g)} + 4e^-$$

Equation IV.2 Oxidation of water

while the cathode will be subjected to reduction, as shown in Equation IV.3 and Equation IV.4:

$$M_{(aq)}{}^{Z+} + Ze^- \rightarrow M_{(s)}$$

Equation IV.3 Reduction half-reaction

$$2H_2O_{(l)} + 2e^- \rightarrow 2H_{2\,(g)} + 2OH^-{}_{(aq)}$$

Equation IV.4 Electrolysis of water

(where Z is the number of electrons transferred in the anodic dissolution process per mole of metal).

With its simple design and easy operability, this technology removes metal, colloidal solids, suspended particles, and soluble inorganic pollutants from aqueous media by introducing highly charged polymeric metal hydroxide species. Those species neutralize the electrostatic charges on suspended solids to facilitate agglomeration or coagulation and the subsequent separation from the aqueous phase.

b) Microplastic Suspension

Microplastic's presence in water can be explained using the phenomenon of colloidal stability. (Moussa, El-Naas, Nasser, & Al-Marri, 2017) Due to the occurrence of repulsive electrical charges on the surface of the particles, they remain in the dispersed state. Given that their total surface area is large compared to their mass and size, the gravitational forces of colloids are often neglected compared to the surface phenomena of the fluid. The particles remain suspended and stable due to the fact that they carry a similar charge (acquired as per triboelectric effect between

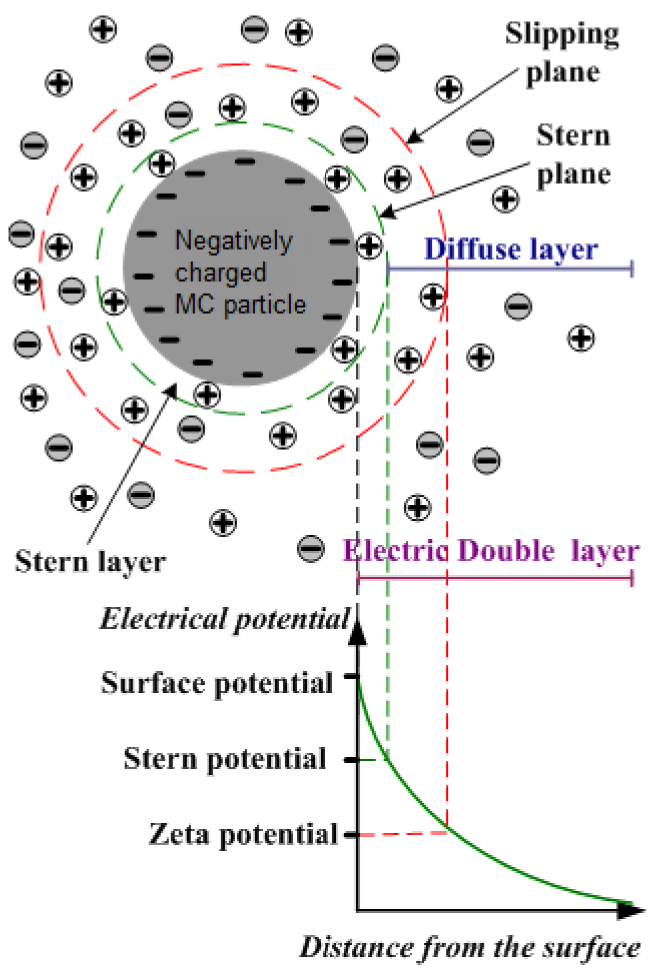


Figure IV.2 Electric double layer illustration

the particle and water, as explained in physics), usually negative, so repulsion arises. In order to destabilize this suspension, the repulsive forces are to be overcome and instead interaction forces should dominate. One way is to neutralize this charge and consequently break suspension by using oppositely charged particles that get attracted to the surface of the colloids forming an electric double layer as illustrated in Figure IV.2.

The electric double layer consists of an inner section (stern layer), where ions of opposite charge bond to the surface of colloidal particles, and an outer section (ion diffuse layer or slipping plane), where the ions enter and leave freely as per diffusion. This double layer creates a repulsive field around it, which is dictated by its extent (as the thickness of the double layer increases, the repulsive forces also increases, and vice versa).

c) *Microplastic Destabilization*

To overcome those repulsive forces, adding counter charged ions to the solution by the oxidation of the anode is done. (Perren, Wojtasik, & Cai, 2018) Those metal ions are provided by the oxidation reaction at the cathode, which results in Al^{3+} ions. By doing so, the metal ions will diffuse through the double layer and adhere to the particle, causing higher counter ion concertation around the particle. This in turn reduces the layer thickness and repulsive forces, making room for the van der Waals forces to appear and predominate, and resulting in particles coming easier together forming larger flocs. (Ammar, Ismail, Ali, & Abbas, 2019)

At appropriate pH values, Al^{3+} continues to react to form $Al(OH)_3$, which is finally polymerized to $Al_n(OH)_{3n}$, conforming to Equation IV.1 (with Z = 3), and to the equations Equation IV.5 and Equation IV.6:

$$Al^{3+}{}_{(aq)} + 3H_2O_{(l)} \rightarrow Al(OH)_{3\,(s)} + 3H^{+}{}_{(aq)}$$

Equation IV.5 Aluminum ions' transformation

$$nAl(OH)_3 \rightarrow Al_n(OH)_{3n}$$

Equation IV.6 Polymerization of aluminum hydroxide

When those polymerized molecules reach higher molecular weight and longer chain lengths, the obtain the ability to form "bridges" between the particles. Those bridges result in larger particles and hence better destabilization. Moreover, as some insoluble metal hydrates precipitate, they cause sweep coagulation, where they entrap colloidal particles, falling with them. (Fayad, 2018)

d) The Electrodes

The choice of electrode materials carries some consequences. Two choices are the most extensively used: iron and aluminum. Iron is the first plausible choice, being the most abundant and the least expensive of the two. However, several problems arise with iron: (1) iron exhibits the buffer effect in a weaker manner than aluminum, leaving effluent water with 9 or 10 pH value, even if the initial pH is acidic; (2) iron(II) ions are highly soluble and, therefore, less capable of destabilizing a colloid by $Fe(OH)_3$; (3) iron requires aeration of water to increase the dissolved oxygen concentration and, consequently, iron(II) oxidation; and (4) iron requires the pH to be 7.5 or higher to increase iron(II) oxidation rate. (Mohammad Y.A. Mollah et al., 2004) To avert those downsides, and with their advantages in mind, aluminum electrodes were chosen. According to most authors, aluminum results in more efficient destabilization and, thus, removal of particles. Also, because the Lewis acidity of aluminum ions at the cathode balances the formation of OH^- at the anode, the aforementioned buffer effect takes place, which results a final pH between 7 and 8.

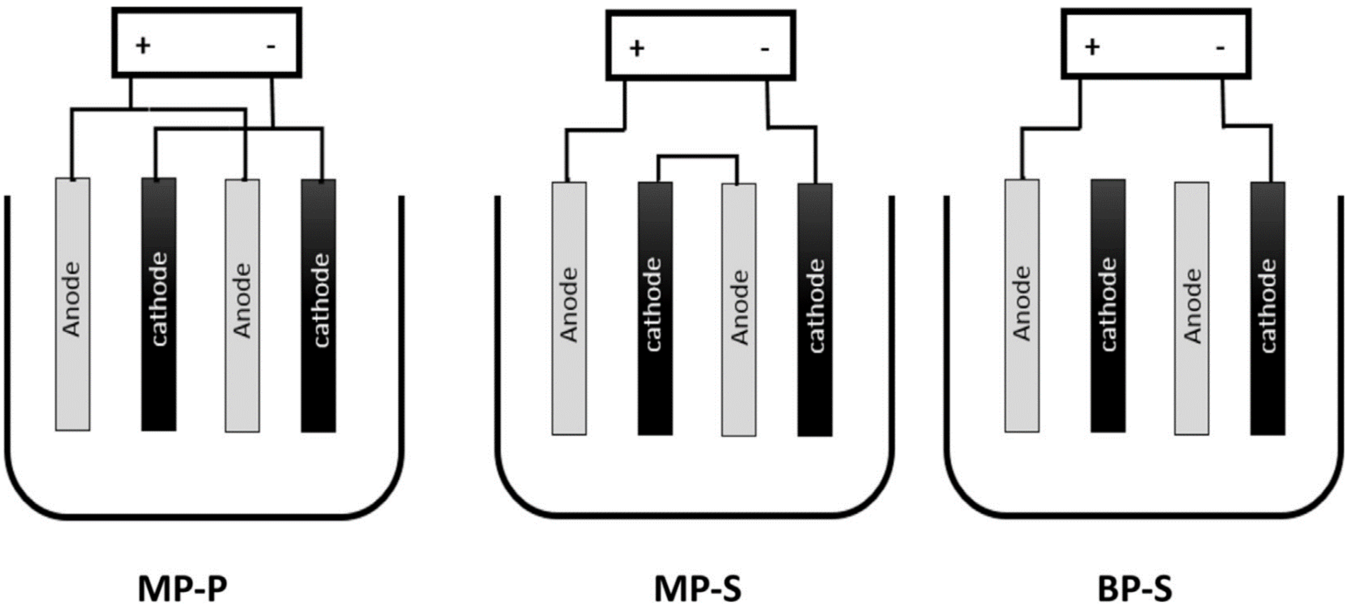


Figure IV.3 Different configurations of electrodes

Apart from the material, other were taken into consideration. First, MP-P (Figure IV.3) electrodes configurations has been deemed by many authors as the most efficient configuration: monopolar electrodes are less costly than bipolar electrodes, and attaching them in parallel results in a better distribution of charges, consequently better destabilization. Second, AC power supply was used in favor of DC current (which causes passivation of the cathode), resulting in a better current efficiency and a better electrode life. Third, current density, as it increases, results in more coagulations agents (aluminum ions), and consequently better particle flocculation. However, there exists a certain limit in above which a higher chance of wasting electrical energy in heating the water thereby reducing current efficiency. So, an 21.7 mA/cm^2 current density was used. Finally, the distance between each two electrodes was minimized to be 2 cm in order to maximize floating by hydrogenation.

e) Electrode Dissolution

As explained in chemistry, Faraday's law (stated in Equation IV.7) can be employed to measure the rate of dissolution of the anode.

$$m = \frac{ItM_w}{ZF}$$

Equation IV.7 Faraday's law

The terms of Faraday's law are I (the current in A), t (time of the operation in s), M_w (the molecular weight in g/mol), F (Faraday's constant being 96485 C/mol), Z (the number of valency), and m (the mass of anode dissolved in g). This law can be used to predict an estimated time by which the cathode will be used up.

2. Settling Chamber

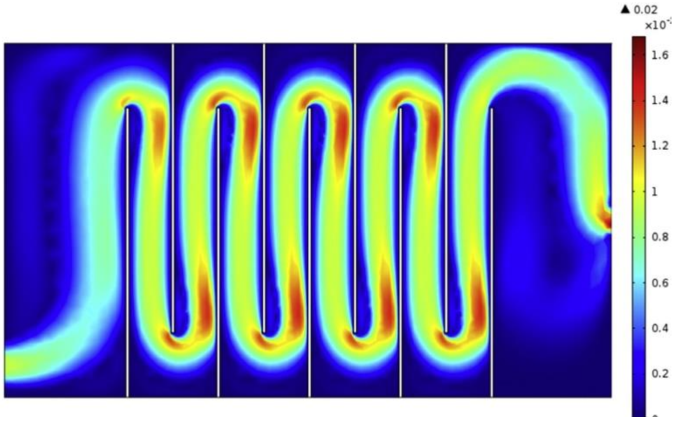


Figure IV.4 Flow path

The settling chamber gives the coagulated material the chance to mix and collide more. These collisions make the van der Waals forces predominate between them, resulting in larger flocs and coagulants, easing their filtration in the rapid sand filter. The path that the water takes is illustrated in Figure IV.4.

3. Rapid Sand Filter Chamber

Sand bed filters work by providing the particulate solids with chances to adhere to the surface of a grain. As water flows across the porous sand along a winding route, the particulates get closer to the grains and collide with them. The layers are arranged based on specific gravity to diminish the danger of mixing. In the following, each layer will be talked about thoroughly.

a) Activated Carbon

With the least specific gravity, activated carbon was put first, causing physical adsorption (illustrated in Figure IV.5), a property dependent on the van der Waal forces between its high surface area and the particulates, to the smaller particles, any odor- or test-making molecules and such.

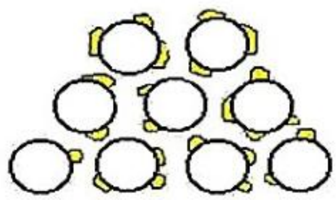


Figure IV.5 Illustration of physical adsorption

b) Sand Grains

Next come the Sand grains, providing the process of mechanical straining (illustrated in Figure IV.6), which is dependent on the porosity of sand, so that larger particulates resulted from coagulation or flocculation processes not penetrate the small pores between the grains, making the medium only permeable for water.

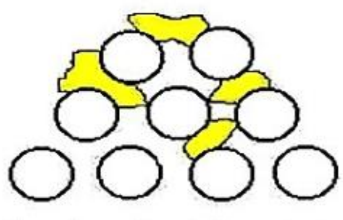


Figure IV.6 Illustration of mechanical straining

c) Gravel Particles

During filtration, the gravel ensures a smooth and diffused flow and avoids the sand layer being disturbed during backwash.

4. Final Statement

The prototype clearly shows how the design requirements was met, being highly efficient, and producing high quality water. Having a high efficiency, as stated in the design requirement, the project helps solve the problems to be solved, and thus contributes to the diminishing of the related grand challenges. They also evidently help the world filter one of the most hurtful kinds of pollution, and that is microplastics.

B. Recommendations

1. Better Test: Raman Spectrometer

Figure IV.7 A Spectrometer

In order to get more accurate results, an apparatus by the name of Spectrometer (shown in Figure IV.7) can be used to measure the concentration of microplastics in water. This apparatus sends a spectrum that has units of relative wave number shift (cm^{-1}). Quantized vibrational modes within the molecule have different energies, leading to peaks in different places on the spectrum, akin to a fingerprint for each material. This results in more accurate and effective results, measuring only microplastics and allowing for more types of water to be measured. With all those advantages, however, a Raman spectrometer is more expensive compared to the methods used.

2. The Efficient Sufficient: Cationic Polymer and Aeration

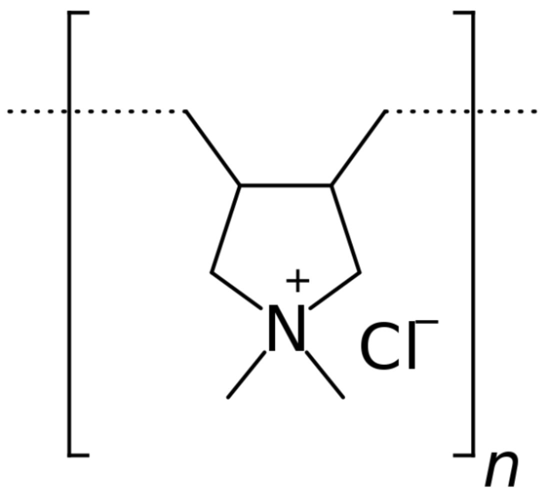


Figure IV.8 Dadmac monomer

Increasing the efficiency of the project is essential. As such, two methods are proposed that accomplish this feat. The two methods play part during the flocculation phase, enhancing it, but each with its different technique. Cationic polymer increases the bridging effect between the particles, causing larger, more stable flocs to form. PolyDADMAC (shown in Figure IV.8) is an example of such cationic polymer. Efficiency can also be increasing by aerating the water. This results in better steering of the flocs, more collisions, and thus bigger flocs that are easier to filter.

3. Water, Drinkable: Chlorination

A final stage is required to construct a device that filters wastewater to drinkable water, and it is chlorination. Chlorination (illustrated in Figure IV.9) is

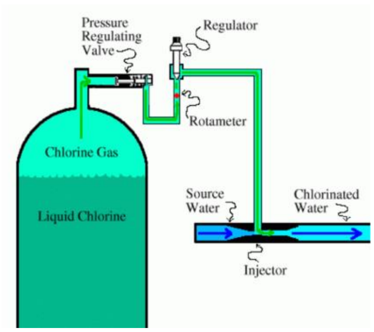


Figure IV.9 Chlorination

the disinfection process wherein chlorine or a chlorine compound such as solid calcium hypochlorite ($Ca(OCl)_2$) or sodium hypochlorite solution ($NaOCl$) are added to the water. This causes germs and other microorganisms to die, preventing the spread of waterborne diseases such as cholera, dysentery, and typhoid, which leaves water that is drinkable and not unhealthy.

4. Recycling or Incineration: the Hydrocyclone

Based on the ratio of their centripetal force to fluid resistance, the hydrocyclone (shown in Figure IV.10) classifies, separates, or sorts particles in a liquid suspension. This device can be implemented after the electrocoagulation in order to achieve two things: (1) mixing (and hence larger flocs) and (2) an effluent with the larger flocs in it, allowing the ability of the microplastic particles to be more easily retained. The retained materials can then be incinerated to generate electricity or firstly separated based on density and then each group melted together. The inability to create such an intricate device was the reason behind hindering the progress towards its implementation.

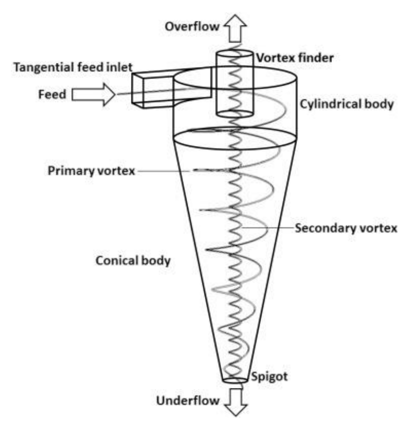


Figure IV.10 A hydrocyclone

C. Learning Outcomes

Not only did the study of the learning outcomes in our curriculum help us in the cracking of the problem that we were assigned to solve, but they also opened to us new viewpoints that from which we looked at the problem from a different angle, helping us understand and comprehend what was the problem’ s causes, effects, and, also, possible solutions. In Table IV.1, the LOs which helped us the most are mentioned.

L.O. Code	Subject	Description	Concepts	Project Connection
ME.2.04	Mechanic s	• Distinguishing and calculating different storage modalities of energy and applying the conservation of mechanical energy	• Conservation of mechanical Energy • Gravitational Potential Energy • Kinetic Energy • Potential Energy	We learned how to calculate the potential and kinetic energies of water, therefore it’s mechanical energy while descending from container to another to calculate the speed and flow rate.

			• Spring potential energy	
ES.2.01	Earth Science	• Measuring and calculating different physical properties of water, managing the water supply in an area and using models to understand how water is distributed in various reservoirs on Earth. • Analyzing how different environmental changes would impact the water cycle and	• The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. • These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand	• We learned about the properties of water and how environmental changes can impact the water cycle and the concentration of microplastics in reservoirs. • We learned about the infiltration process. Therefore, we could develop a solution "rapid sand filter" that depends on infiltration to remove microplastics.

	availability of water	upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. • The oceans contain 97 percent of Earth's water. This means that only three percent of Earth's water is fresh water. Fresh water is an important resource for many purposes. Most fresh water is locked up and frozen in ice caps and glaciers at	

			high latitudes and altitudes.	
ES.2.02	Earth Science	• Modeling factors which affect water stored in surface and in groundwater reservoirs. • Collecting data about the water use in different areas, compare them and measure domestic water use. • Determining the amount of water used for different purposes (industry, irrigation, drinking…). • Collecting and interpreting water	• Water is a vital earth resource that flows through the Earth system and can be stored in natural or human constructed reservoirs, either on the surface, or as groundwater.	• We learned about the factors that affect surface and groundwater reservoirs and contaminations concentrations in them. • It helped us to determine the amount of water used for different purposes therefore determining the best purpose for the filtered water.

		analysis data for different surface and subsurface samples		
ES.2.03	Earth Science	• Using the collected and available data sets to explore different methods to conserve water.	• Many processes transfer water between stores. ‣ Most water supplies are withdrawn from either surface water or groundwater. • Water management methods attempt to distribute freshwater resources more evenly through the use of dams, aqueducts, and wells.	We learned about different methods to conserve water therefore we used some of these methods as low flow faucet during filtering water from microplastics.

ES.2.04	Earth Science	• Investigating the vulnerability of water resources to pollution by both human use and natural cycles or processes. • Constructing models of water-treatment processes. Constructing a groundwater model to infer how pollutants reach the groundwater table and move with groundwater flow. • Investigating how extracting water from a groundwater well influences the	• Pollutants released into the environment can contaminate both surface water and groundwater supplies. • Surface water generally has more varied pollutants. • Many kinds of substances can pollute water. Most of them fall into one of two categories: organic or inorganic. • Evaporation, condensation and bacterial activities are naturally	We learned about pollution caused by human use and natural cycles of water and how to treat this water to reuse it. Therefore, our project focused on treating water to be suitable for different usages.

		movement of pollution in groundwater.	occurring processes of water purification. • Waste water treatment involves a series of steps which can vary by locality.	
MA.2.01	Mathematics	• Revealing and explain different properties of the algebraic function and its graph. • Modeling real-world situations using polynomial and absolute value functions. • Performing operations with	• Polynomial • Absolute value, • Inverse of a function • Algebraic function • Operations with polynomials	We learned about functions, especially polynomial functions, and their use in modelling real-life situations. Therefore, this LO was used to model the rate at which our project removes microplastic particles from water using the means of functions.

	polynomials. Finding the roots of polynomial equations algebraically. • Constructing a polynomial curve through specific points on a horizontal line. • Understanding how the degree of the function determines the attributes of a graph. (turning points, symmetry, even/odd). • Finding the inverse graphically and algebraically of a function.	• Roots of polynomial equations • Polynomial curve • Polynomial functions. • Degree of the function • Attributes of a graph. (turning points, symmetry, even/odd)	

		• Identifying and using the reciprocal function and the absolute value function.		
PH.2.02	Physics	• Explaining the repulsion and attraction force between two charges. • Explaining methods of electrification. Identifying the type of accumulated electric charge on an object by using electroscope. • Comparing electrostatic force between two objects to the	• Static electricity • Coulomb's Law • Electric Field • Conservation of electric charge. • Repulsion and attraction of electric charges. • Methods of electrification • Electroscope • Field Lines	We learned about charges and their effect on each other. That helped us in understanding how flocs are formed during electrocoagulation process.

	gravitational force between them. • Determining direction of total electrostatic force on a charge in presence of other charges using vector addition. • Determining direction of total electrostatic field at a point in space in presence of electric charges using vector addition. • Describing electric field near a dipole qualitatively. Drawing field lines near a charge distribution.		

		• Determining where (if any) field-free regions exist near a charge distribution.		
PH.2.03	Physics	• Explaining the required conditions for continuous flow of electric charge. • Measuring some physical quantities as Voltage, current intensity and ohmic resistance of a conductor. • Verifying Ohm's law practically and draw V-I graph. • Using the previous graph to find the EMF of the cell.	• ‣ Dynamic electricity • Electric current • Current density • Potential difference & voltage • Electrical resistors • Electromotive force (emf) • Resistivity & conductivity • Ohm's law	• We learned about the flow of electricity in wires and about the factors that affect the current density. • Therefore, we could determine which current to use with which voltage and intensity.

		• Solving physics problems that require use of Ohm's law. • Differentiating between Ohmic and non-Ohmic materials Giving some examples of superconductor applications. • Understanding how length and cross-sectional area of a wire affects resistance.	• Ohmic vs. non-Ohmic materials. • Superconductors • Electric energy and power	
PH.2.04	Physics	• Determining the net resistance of series and parallel combinations of	• Connections of resistors (series & parallel) • Kirchoff's current law	We learned about the resistance facing the current in series and parallel connections. Therefore, we could decide which

	resistors in a DC circuit. • Analyzing a DC circuit containing only series and/or parallel resistors to predict current, power and voltage through all devices. • Designing an electric circuit to obtain the largest value and smallest value of combination of the group of resistors. • Using Kirchoff's Laws to solve for current, voltage, power in a multi-loop circuit.	• Kirchoff's voltage law • internal resistance • terminal voltage	connection to use in electrocoagulation process.

PH.2.08	Physics	• Determining total impedance of an AC circuit made up of series and parallel combinations of resistors. • Understanding difference between peak-peak voltage and current measurements and RMS measurements.	• AC circuits • Impedance • rms voltage, current, power	We learned about the difference between the AC and the DC and their characteristics that affect the reaction rate. Therefore, we decided to use the AC due to its higher efficiency in our project.
CH.2.01	Chemistry	• Using simple distillation to separate soluble salt. • Using filtration to separate insoluble salt.	• solutions and aqueous solutions • solubilities of salts (temperature impact) • solubilities curves	• We learned about different characteristics of solutions. Therefore, we could deal with water according to its properties to get the

	• Using carbon to remove tastes and colors. • Calculating rates of chlorination to disinfect the water. • Comparing between chemical, biological and physical treatment. • Determining the concentration of solutes by different methods. • Comparing between qualitative and quantitative analysis.	• ppm • molarity • molality • normality • mole fraction • mass percentage • TDS • Strength • titration • Dissolved Oxygen (DO) • the different ions percentage which the human body need them daily • resins	highest filtration efficiency. • We learned about different ways to measure and calculate concentrations. Therefore, we could use these measurements to know the microplastics concentration in water.

	• Using analytically equipment correctly. • Interpreting the analytical data and results.	• EDTA (including ion exchange) • Electrodialysis • simple distillation • filtration • adsorption • sedimentation / alum • biological treatment • oxygenation • osmosis and reverse osmosis • dissolved oxygen • quantitative analysis • qualitative analysis	

CH.2.02	Chemistr y	• Identifying naturally occurring dissolved and suspended materials in water sources (mineral salts; oxygen; organic matter). • Describing pollutants, their origins and the chemical interactions that make them harmful (metal compounds; sewage; nitrates from fertilizers; phosphates from fertilizers and detergents; harmful microbes). • Developing chemical	• water in the environment • properties and types • measuring densities, conductivity, pH, boiling points. • effect of solutes on physical properties • colligative properties • elevation in B.P. • depression in F.P. • Osmotic pressure.	• We learned about dissolved and suspended materials in water. Therefore, we could develop a solution to remove microplastics as they do not dissolve in water.

		explanation for the role of beneficial chemicals in water (e.g. oxygen and mineral salts for aquatic life).		
CH.2.03	Chemistry	• Describing the general rules of solubility for common salts to include nitrates, chlorides (including silver and lead), sulfates (including barium, calcium and lead), carbonates, hydroxides, Group I cations and ammonium salts. • Suggesting a method of preparing a given salt from suitable	• acids • the nature of acids and bases • acid strength • the pH scales • Bases • polyprotic acid • acid -base properties of salts • The Effect of Structure on	• We learned about the acidity and alkalinity in solutions. Therefore, we could measure the PH change before and after filtration.

		starting materials, given appropriate information.	○ Acid–Base Properties ○ Acid–Base Properties of Oxides • The Lewis Acid–Base Model	
CH.2.04	Chemistry	• Determining the rate of chemical reaction by monitoring: 1. change of concentration of reactant or product. 2.volume of gas evolved 3. change in PH 4. change of weight of the reactants.	• order • molecularity • rate of chemical reaction • law of mass action • determination of rate of reaction	• We learned about the rate of chemical reactions and the factors affecting this rate. Therefore, we could calculate the rate of dissolution of the electrodes in the electrocoagulation process.

CH.2.06	Chemistry	• Illustrating and explaining whether changes in concentration, pressure or temperature or the presence of a catalyst affect the value of the equilibrium constant for a reaction. • Deducing expressions for equilibrium constants in terms of concentrations, Kc and partial pressures, Kp. • Calculating the values of equilibrium constants in terms of concentrations	• Chemical equilibria • reversible reactions • dynamic equilibrium • Factors affecting chemical equilibria • equilibrium graphing • Equilibrium constants • The Haber processes • the Contact processes	• We learned about chemical equilibrium and reversible reactions; therefore, we could determine the equilibrium point of the electrocoagulation reaction and we could affirm that it is an irreversible reaction.

		or partial pressures from appropriate data. • Calculating the quantities present at equilibrium, given appropriate data.		
CS.2.01	Compute r science	• creating a data table • creating a form and query to database tables.	• Field • record • table and database • primary and foreign key • data types • field properties • relation types.	We learned about how to record and represent data using a database. This technique was used while recording the outcomes of the test and representing the results.

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