Aquatech

AquaTech

Portfolio

STEM October High School for boys – 6th of October
Grade 11 Semester 1 (2021 - 2022)

Group 221

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Chapter 1

Grand Challenges

Egypt faces many grand challenges that affect it socially, environmentally, and economically. These challenges form an obstacle that delays the development of Egypt. So, Egypt considered them as challenges that it should beat. Then, the Egyptians had divided these challenges into parts to start solving them.

These challenges, as shown in Figure 1.1, are reducing pollution, improving sources of clean water, increasing the industrial base of Egypt, improving the use of arid areas, improving the use of alternative energies, dealing with exponential population growth, reducing urban congestion, increasing the opportunities for Egyptians to stay and work in Egypt, eradicating public health issues, and recycling and retaining garbage for recycling.

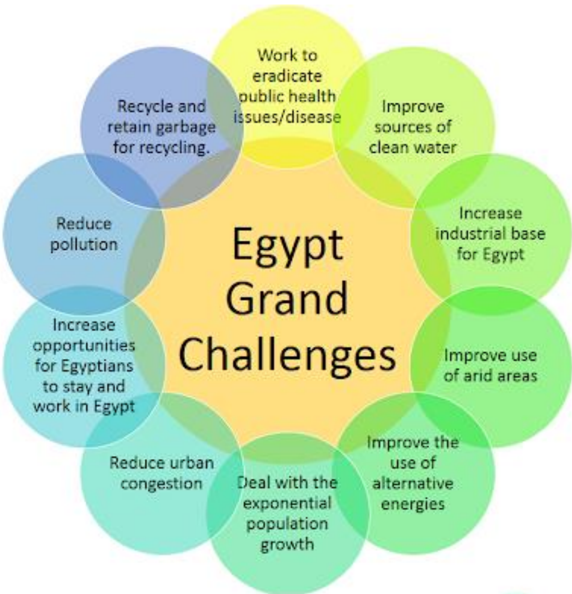


Figure 1.1 Egypt's Grand Challenges

Egypt tries to find alternative ways to solve these problems to avoid the risks and problems that they cause.

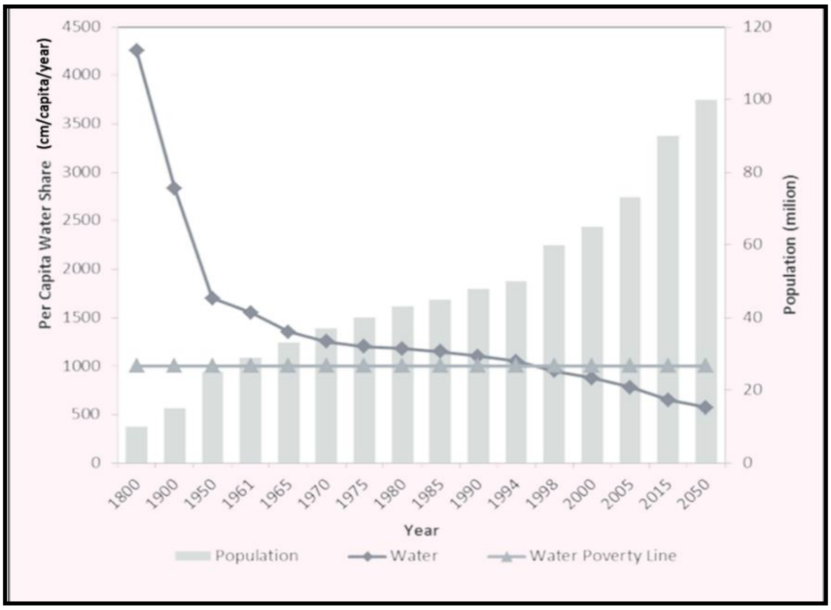
The four main grand challenges that this project relates to are: improve sources of clean water, reduce pollution, reduce urban congestion, and work on eradicating public health issues.

Improve sources of clean water

Water shortage will become one of the most pressing resource issues of the 21st Century, especially in Egypt. The major challenge facing Egypt now is the strong need to develop and manage the limited water, land, and energy resources available to meet the needs of population growth. The structure of water management in Egypt comprises several components that interact with social, economic, and environmental processes, which are often complex and uncertain.

Egypt has reached a phase where the amount of water is imposing restrictions on its economic development. There is a steady decrease in the per capita water share.

According to a study at the AUC in Egypt, the per capita share of water has decreased from 1972 m^3 in 1970 to about 570 m^3 in 2018, and the predictions tells that it is going to fall to 390 m^3 by 2050, as shown in Graph 1.1. These small numbers, according to the international standards, mean the presence of “Water Scarcity” (cannot reach the “Water Poverty Line”).



Graph 1.1 The changes of the per capita share of water in Egypt

The main source of fresh water in Egypt is the River Nile, where it contributes with the largest amount of water available in Egypt. But there are other sources of water that provide the country with fresh water such as groundwater, rainfall water, desalination of seawater (along the 2 coasts), the reuse of agricultural drainage water, and the reuse of treated domestic wastewater. Table 1.1 shows

Water Resource	Volume (billion m3/year)
Nile water (High Aswan Dam)	55.50
Deep Groundwater	2.1
Rainfall \ Flash Floods	1.30
Desalination of sea water	0.35
Shallow Groundwater (Delta)	7.5
Re-Use of Ag. Drainage Water	13.5
Total Water Resources	**80.25 BCM/Year**

Table 1.1 volume of water provided by each water source in Egypt in 2015

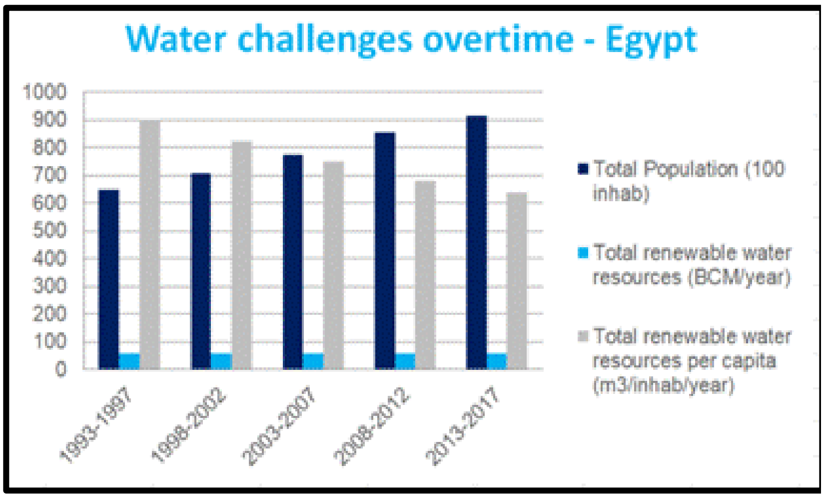
the volume of water provided by each source of water in Egypt in 2015 as an example. In that year, the River Nile provided Egypt with about 70% of the whole fresh water the county had.

So, the challenge that Egypt is facing now is the need to manage its limited water sources available to meet the needs of population growth and to help its economy continue improving, and meanwhile try to develop new technologies to make the other sources of getting water less expensive (like desalination of sea water).

Causes

❖ Overpopulation

In Egypt, the primary source of water is the river Nile. But today some big problems are facing Egypt by relying on the River Nile. First, is the massive increase in the population of Egypt for the last few years, because this overpopulation consumes a lot of pure water, which is already decreasing gradually. As Graph 1.2 shows, the annual increase in Egypt's population is so huge where the predictions say that it is going to increase from about 80 million people in 2010 up to 160 million in 2050, with a rate of increase of about 2% each year.



Graph 1.2 Water challenges overtime in Egypt (population and sources of water)

❖ Political problems

Another big problem is the Grand Ethiopian Renaissance Dam, which Ethiopia had started building in March 2011. This dam will prevent Egypt from getting its complete share of the Nile's water which is going to affect the Egyptian economy where Egypt depends on the Nile River to secure almost 95% of the water needed for different purposes as drinking, household uses, agriculture, fishing source, water transportation, tourism, electricity generation from the High Dam and industry. According to the analyzed data, Egypt's water share should be reduced by no more than 5 – 15%.

❖ Water pollution

One other huge problem about relying on the river Nile is the pollution of its water by municipal waste and industrial waste, the dumping of dead animal carcasses, and the release of industrial and hazardous chemical waste into the river, as Figure 1.2 shows.

Figure 1.2 The pollution of river Nile in

Industrial waste led to the presence of minerals in the water, which poses a great threat not only to human health but also to animal health and agriculture. High levels of ammonia and lead cause poisoning where large numbers of fish die from it. Using untreated water for irrigation has affected the quality and quantity of agricultural output as the bacteria and metals in the water influence the growth of the plant, in the Nile Delta, in particular, where pollution is highest.

Impacts

❖ Increasing urban congestion

Because of the shortage of water resources and their concentration in specific areas, this leads to urban congestion around this source of water and overpressure on it. According to UNICEF, almost all of Egypt's population lives only on 7.7% of its land, which has a total area of approximately one million square kilometers (1×10^6 km^2).

❖ Disappearing of green lands

As a result of the limits of water resources, and the gradual decrease in the Nile's water, desertification of agricultural lands, lack of fertility, and quality of production of the soil problems start to appear. This leads to a shortage of food supplies in the country, which affects the agricultural production of Egypt.

❖ Ecosystem imbalance

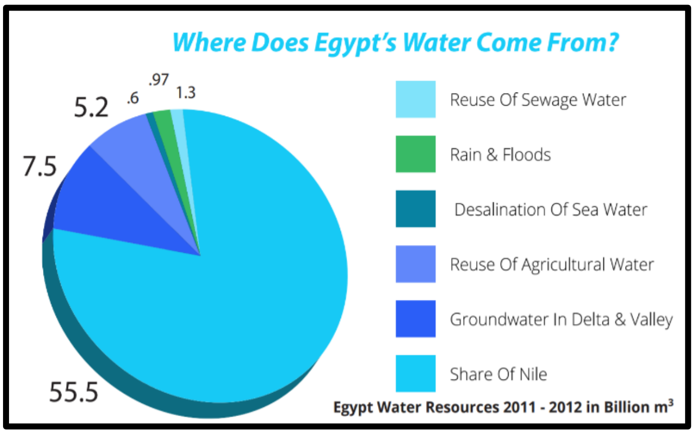
The lack in the resources of water means that not everyone can have fresh water available. This means fresh water may not reach a whole habitat of some species of an organism, which endangers this species and expose it to the danger of extinction, which causes a new imbalance in the ecosystem. That is because in an ecosystem each one is a member that completes the ring, which means everyone is dependent on the other.

Reduce Pollution

Pollution is the change of a medium, such as air, water, or soil, in such a way that it becomes harmful to humans or the environment. Pollutants are the materials (or things) that cause pollution, like chemicals, dust, noise, and radiation. These contaminants come from a variety of places. Some of these sources are diffuse, such as transport or agriculture, whereas others, are linked to a specific location, such as a factory or power plant.

Water pollution

Egypt has many sources of water, but the Egypt's main source of fresh water is the river Nile, as shown in Graph 1.3, about 55.5-billion-meter cubes of water are collected from the Nile.



Graph 1.3 Shows the sources of water in Egypt

As known that there's a lot of factories get rid of their industrial wastes in the Nile because it's one of the cheapest ways to get rid of their wastes. Mercury (Hg), Ammonia (NH_4), oil products and other harmful materials are thrown in the Nile. Also, the agricultural wastewater is thrown in the Nile. Those pollutants harm the living organisms in the Nile and cause a lot of diseases among the people.

The annual cost of the health effects resulted from drinking inadequate water, sanitation, and hygiene is about LE 26 billion to 56 billion in the year 2016/2017. This costs Egypt about 0.75% to 1.61% of its GDP that year.

Causes

❖ Human activity and Industrial wastewater discharge

There are about 700 factories along the river Nile in Egypt. The wastewater resulting from various industrial process contains harmful pollutants that is impossible to be separated from water like asbestos,

Figure 1.3 Shows the pollution caused by the factory in Luxor along the River Nile

lead (Pb), mercury (Hg), cadmium, arsenic (As), sulfur (S), oils, and petrochemicals. Also, radioactive materials like cesium and uranium can be found in wastewater as a result of ore processing and weapons production. As shown in Figure1.3, one of the factories that pollutes the river in Luxor along river Nile.

❖ Domestic sewage and agriculture wastewater pollution

Along the Nile valley, between Cairo and the High dam, there are about 43 towns and approximately 2500 village. Those population are about 20 million citizens; all these citizens need to get rid of their wastewater. So, according to CAPMAS 2010/2011 statistics, only 24.7% of the rural population was connected to a sewage system. On the other hand, the other 88% in urban areas don't have sewage system. Those who are linked to a sewage tank, will empty their tanks into the Nile or onto ground where the water source especially the underground water and the soil are polluted.

In turn, the bad sanitation extends to drinking water, making it untreated, about 95% of the Egyptian population drink untreated water. The World Health Organization (WHO) report in 2008 saying: "Safer Water, Better Health" shows that 5.1% of all deaths and 6.5% of all disabilities (disease and injury) in a year in Egypt are because of unsafe drinking water, unsuitable sanitation capacity, insufficient hygiene, and a wrong management of water resources.

❖ Oil spill accidents

Many accidental oil spills had happened in the River Nile. They are always caused by cargo ships. There is a study made on three places which are Helwan, Aswan and Naj Hammadi that shows the effect of the oil on the River Nile. This study depends on the pH of the water, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), oil and grease, total coliform count (TC) and fecal coliform count (FC). All these parameters have been carried out by American Public Health Association (APHA, 2012). The results were as shown in Table 1.2. The results show that there is a big change in water quality between the water before the accident and after the accident.

Parameter	Unit	Helwan case 2008		Aswanc 2010		Naj Hammadi case 2012		Low 48/ article 60
		Helwan normal Nile water	Helwan polluted water	Aswan normal Nile water	Aswan polluted water	Naj Hammadi normal Nile water	Naj Hammadi polluted water	
Oil & grease	mg/l	0.3	426	0.07	109	0.09	2.92	0.1
pH		7.76	7.68	7.51	7.65	7.62	7.96	7 - 8.5
EC	mmhos/cm	0.366	0.394	0.286	2.89	0.299	0.311	
TDS	mg/l	234	252	225	238	222	227	500
BOD	mg/l	15	130	5	76	4	30	6
COD	mg/l	18	550	7	230	7	98	10
Total Coliform	CFU/100 ml	8000	5000	900	600	2800	1600	
Fecal Coliform	CFU/100 ml	1000	600	20	8	500	200	

Table 1.2 The results of checking the water parameters after three different cases of oil spill

Impacts

❖ Water-based diseases

Water-based diseases come from hosts that either live or spend part of their life cycle in water. These diseases are passed to humans when they are ingested or contacted our skin. The most famous example in this category is bilharzia disease and this disease is shown in Figure 1.4, which happens due to contact with snails which serve as hosts for this disease.

Figure 1.4 Bilharzia worm

There are many governorates in Egypt depend on Nile water as the primary source of drinking water, so determining of the prevalence of water-borne protozoa in water sources is important.

In Egypt, sewage is usually treated primarily and discharged into seas, rivers, lakes, and canals. Therefore, the population will be infected by Cryptosporidium, Giardia and other protozoa with significant chances. Sewerage water in the middle districts of the Nile Delta is far from being drinkable and ideal. Biological agents, especially the neglected protozoal infections such as giardiasis and cryptosporidiosis, set up a real risk factor for the population.

❖ Effect on the aquatic life

Most of living creature have died because of the oxygen scarcity in water because of the cooling the nuclear reactors, also most of the fishes are being polluted by the mercury which exists from the industrial wastes. All of this affects the aquatic creature and affect our health when drinking this water, and when eating the fish that is supposed to all of these pollutions.

❖ Decrease in water quantity and availability

Pollution and poor water quality affect the quantity and availability of water in several ways. First, the polluted water which can't be used for bathing, drinking, industrial purposes, and agriculture will reduce the amount of water in the region. The more polluted water the more difficult to treat it to be useful for human proposes, and high costs of treat it. The poorer water quality of the source of water, the greater level of treatment that will be needed to bring it to a practical standard, and less clean water will result from treatment. Also, high level of water pollution requires a high amount of energy to treat.

Improve public health

Public health is the overall quality of health and life in a specific region (a country for example). The goal of public health improvements is to improve the health of populations and increase life expectancy, which is the average time and organism is expected to live. The whole purpose of improving the public health is protecting and improving the health of people and their communities through preventing and mitigating diseases, injuries, and other health conditions.

The challenge of improving the public health in Egypt had arisen when the spread of a big number of diseases became remarkable in which they begin to affect the country as a whole in different fields, like the economy. According to the CIA World Factbook, the four most common diseases in Egypt, in 2017, were bacterial diarrhea, typhoid fever, viral hepatitis, and schistosomiasis (bilharzia).

These diseases are a result of other problems (grand challenges) that Egypt faces, like urban congestion and pollution. For instance, as shown in Figure 1.5, hepatitis C, which is a type of viral hepatitis, mainly transmits when someone comes into contact with blood from an infected person, which happens when sharing drug-injection equipment, for example. Besides, these diseases can easily spread among people because of the very high density of people in very small areas of land, and that is the urban congestion. The main reason in Egypt for urban congestion is the lack of different clean water resources, where people gather around the main water resource of the country which is the River Nile in Egypt.

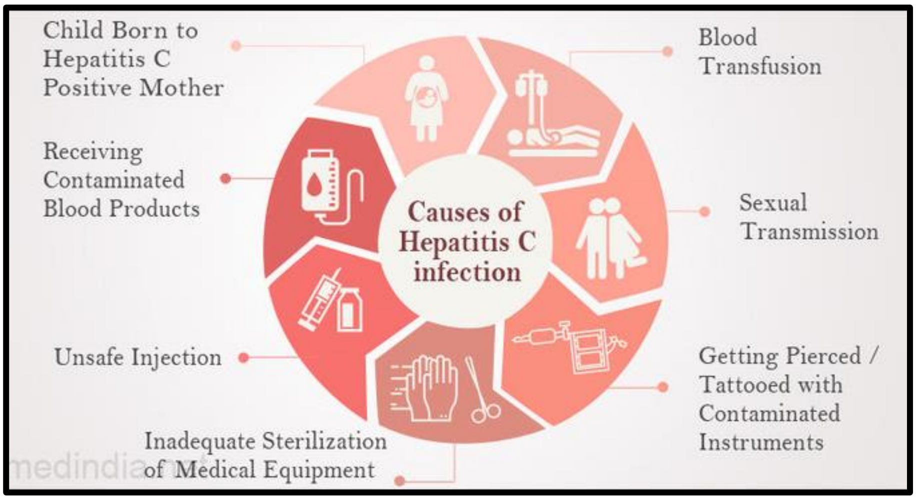


Figure 1.5 Causes of hepatitis C infection

Causes

❖ Pollution

The main cause of public health problems is the wide spread of diseases. And the primary factor, that helps diseases spread more, is pollution. As mentioned before, pollution is the presence of contaminants or harmful materials in the environment. This means that water, which is supposed to be the elixir of life, can be very harmful due to water pollution. And that is the case in hepatitis A, which is another type of viral hepatitis, where it is mainly transmitted through ingestion of contaminated for or water.

Also, pollution has contributed to the spread of many other diseases. But the most remarkable one in Egypt was hepatitis C, where in 2015 its prevalence in the total population of Egypt was around 4.5% to 6.7%. From the main reasons of its epidemic in Egypt was the pollution inside the hospitals themselves, as it was transmitted through the contact with blood with infected people by sharing needles, syringes, … etc. without sterilization.

Another form of pollution that is involved in most public health issues is the air pollution. Due to the excessive use of vehicles and factories emissions, the air that people breathe became unhealthy. This can lead to chest problems especially for elderly people. And that is why solving the pollution problems will solve most of the public health issues.

❖ Poverty

Many people, especially in developing countries, suffer from extreme poverty. In 2021, the poverty rate was projected at 29.3 percent in Egypt. These people are often not even able to afford basic items like enough food and drinks. This in turn often leads to diseases since their immune system is weakened due to their poor living conditions and malnutrition.

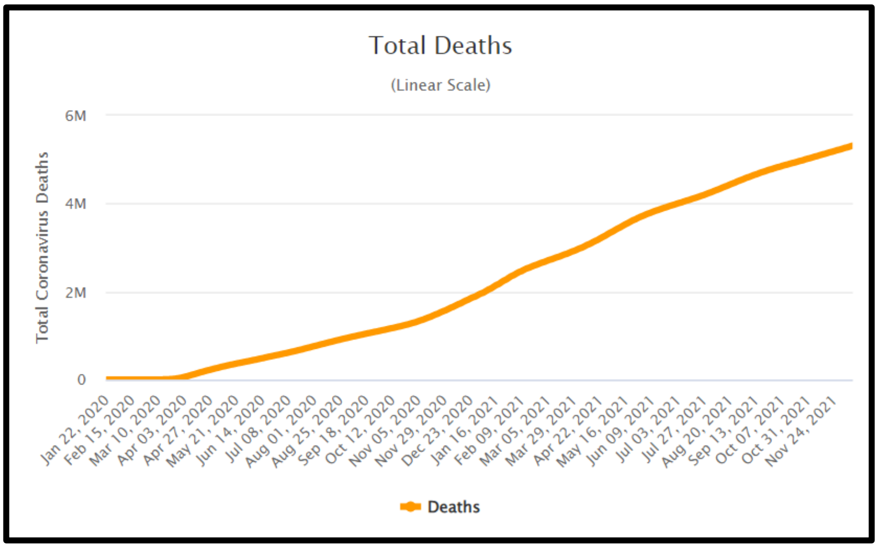
❖ Lack of education

The lack of education also plays a role in several public health issues. The level of education of a person has a big impact on his attitude towards life. This encompasses both his or her consumption behavior and social behavior. Due to the lack of education, people are prone to be unconcerned about their environmental behavior since they do not understand how their daily actions effect our environment. The lack of education also adds to public health problems since uneducated people are more prone to drink and smoke, resulting in negative health consequences.

Impacts

❖ Pandemics

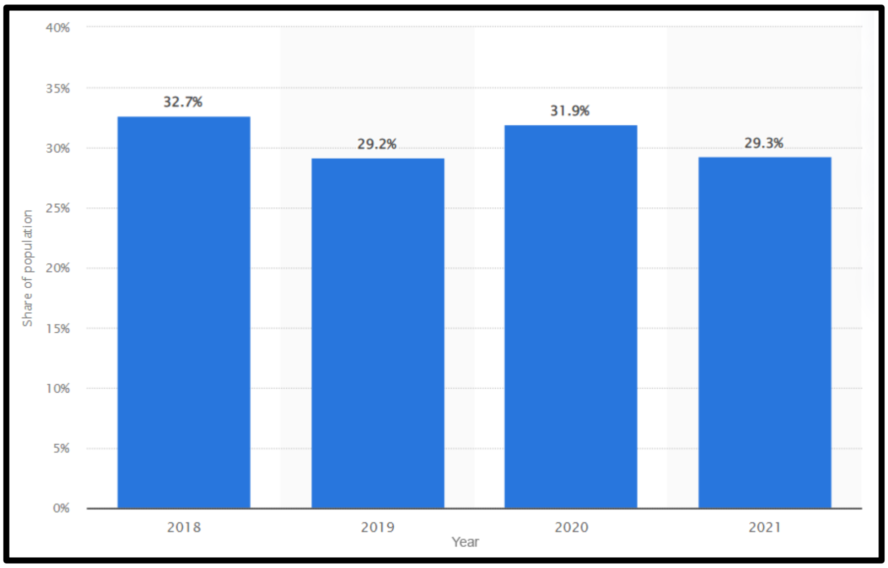
Some public health issues may also lead to pandemics, which is the worldwide spread of a new disease. For example, the pandemic of COVID-19 that the whole world (including Egypt) is going through right now and it is causing death to many people (about 5 million people until now worldwide as shown in Graph 1.4). And COVID-19 is not the first pandemic that the world has faced, and here is the problem where the consecutive public health issues like this affects other areas (or fields) in the country.



Graph 1.4 Total number of deaths from COVID-19 pandemic

❖ Economic disturbances

One of the things that public health issues greatly affect is the economy of the country, where these issues may cause a huge number of deaths that affects the standards of the country's economy due to the stopping of a big number of working institutions and individuals. For instance (as shown in Graph 1.5), in 2018, in Egypt, the poverty rate was about 32.7%, and it was moving in a good path where it reached 29.2% in 2019. But, because of the COVID-19 pandemic, the rate of poverty in Egypt has increased again to 31.9% in 2020.



Graph 1.5 The rate of poverty in Egypt

Urban Congestion

Urban congestion can be defined as an abnormal increase in the amount of settled and residing people in someplace like cities, states, or provinces. Cairo has more than 10 million inhabitants, which means that this huge number is condensed in a small area of land, as illustrated in Figure 1.6.

Figure 1.6 Urban congestion in Egypt

This problem has affected Egypt in several ways where the greenhouse gases will be emitted more due to the increase in industry and traffic, this will result in an increase in pollution, which will also lead to a lack in services due to the increase of the demands as the number of people increases.

Urban congestion has many causes, but its main ones are overpopulation, and the high population density which is the concentration of a lot of people in a very small space of land. An example for this cause is Egypt where the concentration of the population in the Nile valley and delta area is very high because Egypt as a country depends on the Nile River as a main source of water.

Causes:

❖ Immigration from territories and villages

The immigration to the big cities from the other places of the country plays a great role in the existence of the problem of urban congestion. People immigrate from territories and villages to the cities and mainly to Cairo, this happens because the ignorance of the governorate in providing services and projects and work opportunities in the villages and territories, besides the great population there due to the ignorance of the importance of birth control.

❖ Concentration of the population around the Nile valley

Egypt is considered the most populous country in the Arab world, and the most populous region in it is the Cairo Metropolitan Area, which is the home of nearly 21 million residents, about 10 million of them live in the city of Cairo itself.

Egypt covers one million square kilometers with about 96% of it is desert, which leads most of the population to live on about 7.7% of the country's total area, which is concentrated in the fertile basin of the River Nile, as shown in Figure 1.7. As a result, the population density often exceeds 40,000 people per square kilometers in the teeming capital.

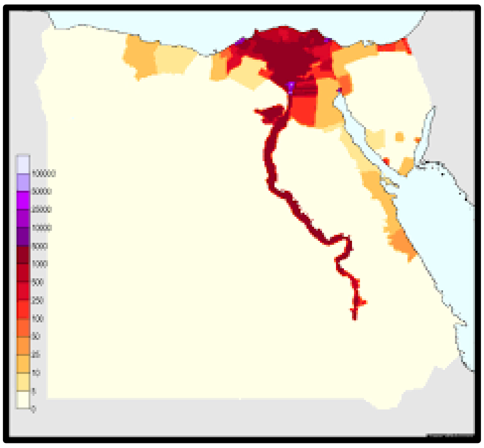


Figure 1.7 Population centers and density map in Egypt

❖ Overpopulation

Overpopulation can be considered as a cause of the problem of urban congestion. The population in Egypt is ignorant of the importance of birth control and the consequences of the overpopulation, this leads to a problem like urban congestion, which leads to the lack of water resources due to the increase of consumption and increase of the pollution due to the traffic congestion. Egypt's population still grows each year by approximately 1.5 million people, or the equivalent of the population of a country the size of Kuwait, for example. The predictions indicate that the population will grow from 100 million in 2010 up to 160 million by 2050.

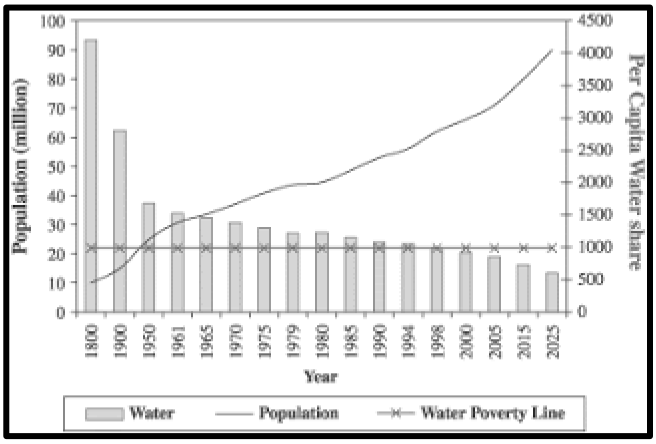
Impacts:

❖ Decrease in sources and services efficiency

The massive growth of the population in some area obviously leads to decrease of the sources in this place. For example, the concentration of the population in the Nile valley and delta leads to water crisis due to the dependence on the River Nile only.

❖ Decrease in the per capita share of water

The problem of urban congestion is caused by the overpopulation, which is the massive increase in the number of populations, and this problem leads to the decrease in the per capita share of water, as shown in Graph 1.6, because the available water is not increasing with the same rate of the increase in population.



Graph 1.6 The relation between the per-capita water share and the water poverty line

❖ Pollution

Air pollution is also resulted by the traffic congestion as the greenhouse gases are emitted in a specific area with massive amounts by vehicles. Also, the industrial activity will also increase which will increase the negative effects like air pollution due to the emissions of the factories, and water pollution due to liquid emissions.

Problem to be solved

Managing and increasing the sources of clean water:

Finding a new source of water is not an easy job, especially when it is needed to be clean to use in domestic, agricultural, or even in industrial uses, that's because there are many factors that affect the quality of the water source, such as what type of uses its water can be used for, the cost needed to get water from that source, but the really important factor is the quality of the water it provides. The quality of the water affects all the other factors, where it requires special treatments according to the type of elements it contains. Also, it should be cost-efficient where the amount of water it provides is not too small compared to a very high cost it needs.

In 2015, a statistic showed that the total amount of water that Egypt has every year is 80.25 billion m^3, but there is a significant increase in the population in the last few years as it reached more than 100 million people. In addition, the amount of water needed by the populations every year is about 105-110 billion m^3. This means that there is a water shortage problem, in which about 30 billion m^3 of water that are being imported from outside of the country. Also, the water of agriculture needs a lot of water as it consumes alone 70% of water.

In addition, finding alternative water sources only is not enough because the water they provide should be clean and pure, too. One of the solutions to that problem is the desalination of the seawater, but unfortunately, it costs a lot of money in which the cost to desalinate $7m^3$ of seawater costs about 4 LE and it is a relatively very high cost as there are about 30 billion m^3 of water needed above what we have which will cost about 20 billion LE and this is a huge cost that will be heavy on the Egyptian economy. But fortunately, this cost problem can be solved by using other technologies which cost less money than the other ways of desalination.

If solved (Positive Consequences):

Environmentally:

Water is the secret of life so, if there is enough water available the planted agricultural lands will increase, also the forests will be everywhere so, most of the animals will feed on it, the birds and all the animals so, the number of animal species which are endangered (about to extinct) will significantly decrease. This will help the environmental balance to be stable.

Socially:

Water is the most important thing for any person as if there is no water, there is no life. If there is a sufficient amount of water, the agricultural and green areas will increase. This will help the farmers to produce more products so, they will gain more money and the economy of Egypt will increase which will lead to an increase in personal income. So, there will be more jobs opportunities in agriculture and industry. All this will help the people increase their productivity and they will not have to migrate to find water.

Economically:

Due to increasing the available water sources, there could be big amounts of water left after using the regular domestic uses of the people, it will be very easy for farmers to plant new lands which increase the agricultural production, also the investors to build new factories. These products suffice the needs of the people, and the rest can be exported to other countries, which leads to the growth of the country's economy.

If not solved (Negative Consequences):

Environmentally:

The water is the main source of life on earth so if the populations continue in growing so, the water won't be enough for the people also, for agriculture as the water needed for agriculture is about 77% of Egypt's water so, the plants will die and most of the organisms that fed on the plants and tree leaves will die causing environmental imbalance. But this is not the end of the road, the people will live in starvation and most of them will die.

Socially:

Since the water scarcity continues increasing the governments will not be able to provide the people with the needed amounts of water, which leads to decreased productivity of the people. So, this will lead to conflicts among the people to get their need of water which will cause the deterioration of the economy.

Economically:

Because water is being used in almost all the country's productions from agriculture to industry, if the amount of water decreases, we will not be able to grow the crops which will lead to the deterioration of agriculture. The deterioration of agriculture means that we cannot produce the food that suffices the people's needs, which means that we can't export. Instead, we need to import the food which will lead to deterioration of the economy, in which our country will be from the importing countries.

Research

Topics related to the problem

❖ Building Dams:

Dams are huge buildings built to hold back water and boost up its level, forming a reservoir used to generate electricity or as a water supply. These buildings are often built on rivers or narrow waterways because they have very high-water flows. Dams can be very useful for the one who is building them where he can use them to generate electricity, irrigate his green lands, save his land from getting covered with water from floods, and even more benefits. But unfortunately, building dams is a double-edged sword in which they can be beneficial for some people, but it is also deadly for others. That’s because dams incredibly decrease the flow of water so, in the long run, this water cannot go very far to the people who used to rely on it.

For Example, the Egypt and the Grand Ethiopian Renaissance Dam, for Egypt, the Grand Ethiopian Renaissance Dam (GERD) stands as one of the country’s most pressing water issues, where Ethiopia has built this dam on the course of the River Nile (as illustrated in Figure 1.8), which is the main source of water in Egypt. Unfortunately, this dam has very bad impacts on Egypt, for example, according to research from Ain Shams University, impounding of GERD at Normal flow through 6, 3, and 2 years will decrease the active storage of Lake Nasser by 13.3, 25.4, and 37.3 BCM per year, which will significantly affect the country’s economy through agriculture, electricity production, and even more.

Figure 1.8 The Grand Ethiopian Renaissance Dam (GERD)

For that reason, many countries are now trying to find new ways to get clean and pure water, as they can be prevented from their current resource of water at any time by building only one building.

❖ Water Impurity:

Water impurities are the negative components dissolved in water. These impurities are the main factor in identifying the suitable use of the water, where the water needed for agriculture, as an example, doesn't have to be as clean as the water needed for domestic uses. There are many types of water impurities, as shown in Figure 1.9, such as dirt, dust, harmful chemicals, radiological contaminants, biological contaminants, and total suspended solids (TSS) - total suspended solids are visible particles that make water appear cloudy or hazy.

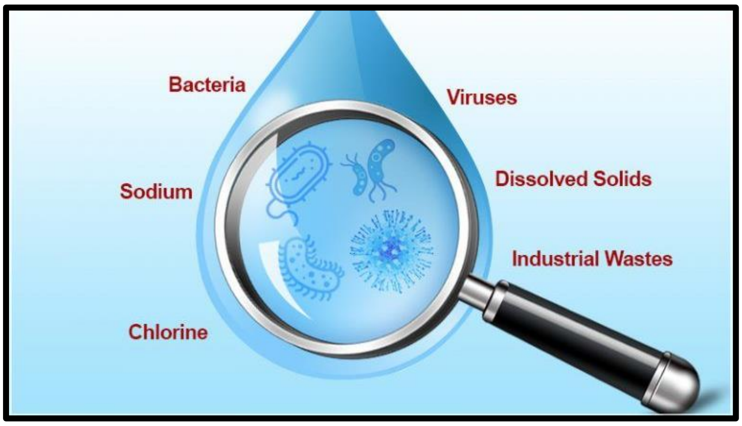


Figure 1.9 Some Types of the impurities in water

Water impurity can be caused by a variety of conditions. Rainfall water, streams, and wells can pick up harmful chemicals in the environment like acid and metallic elements. Biological components in water can include bacteria, algae, amino acids, organic waste, pathogens, microbes, viruses, and parasites. They reach water because of the contact with industrial sewage and wastewater, agricultural waste and runoff, decomposing waste in water bodies, and imbalances in water chemical profiles that promote the proliferation of microbes. Each of these conditions must have a type of filter or technique to purify the water from it, so it becomes suitable for any type of use, where it is almost impossible to return the water to be 100% pure at a reasonable cost.

❖ Water pollution:

Water scarcity is one of the biggest problems that faces Egypt. As there is significant decrease in water so, the water will not suffice the populations demands and this forced the governments to recycle the wastewater. The problem of using recycled water is that not all the pollutants can be removed from water like organic materials. So, the people will drink the water with a percent of pollution which will lead to long-term effect on their body. On the other hand, the government has to clean and purify the Nile water as there is about of 150 million tons of industrial wastes are dumped in it every year.

Topics related to the solution

❖ Liquid iodine treatment:

Liquid iodine, which is shown in Figure 1.10, can be used to kill toxic substances, bacteria and viruses in water. It is very strong disinfectant and also more effective than water filtration. On the other hand, it may leave unpleasant taste at your mouth while drinking. It is easy to be used; if the water is clear, use a medicine dropper to put 5 drops of 2% liquid iodine solution on each quarter gallon, but if the water is turbid put 10 drops.

Figure 1.10 Some Types of the impurities in water

❖ Ultraviolet water purification:

UV purification process is one of the most effective ways to purify the water. UV light works in a way to destroy the pathogens' and bacteria's genetic core (DNA), this mean prevent their productivity. There are some good points about the (UV purification) is that it doesn't change the taste of the water, also chemicals like chlorine and bleach aren't used and uses very low energy as it works only with (UV bulb), as shown in Figure 1.11, and it takes the same as 60-watt bulb, but (UV purification) is not enough to purify drinking water but it can be used for industrial and agriculture proposes.

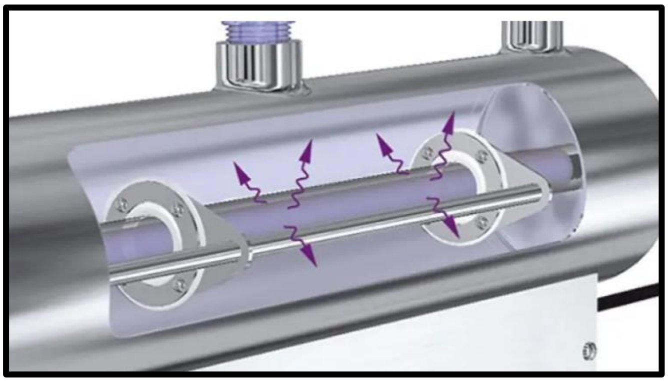


Figure 1.11 UV water filter

❖ Physical water filtration:

Physical filtration is one of the simplest ways to purify the water. Its idea revolves around putting paper and cotton on glass cup and then pour the water, as illustrated in Figure 1.12. So, any solid particle or dirties in water will not been penetrated. This method can't be used at homes or for purifying the water because some small bacteria and pathogens will penetrate, but this method used only in danger position where if you don't drink you will die.

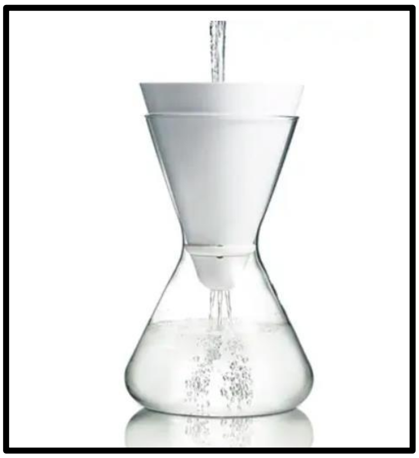


Figure 1.12 Physical water filtration example

❖ Electrodialysis:

Electrodialysis is an electrochemical method that separates salt from water through ion transfer. It works only with substances that are able to be ionized; for example, salt (NaCl) dissolves into ions of Na^+ and Cl^- ions in solution. (On the other hand, because silica, for example, does not ionize, it is not removed by electrodialysis.) When electrodes are immersed in a salt solution and linked to an appropriate direct current supply, current flows, carried by the ions. Cations are ions that have a positive charge and are attracted to the negative cathode. Anions with a negative charge flow towards the positive anode. Filters or membranes selectively impermeable to cations or anions are alternately placed between the electrodes in electrodialysis, as shown in Figure 1.13. Cation filters allow anions to get through but prevent positively charged cations from doing so. On the other, the anion filter, on the other hand, keeps anions out while allowing cations to get through. Ions will gather in various sections of the tank as their flow is monitored by an appropriate filter. As a result, cells with increasing salt content alternate with cells with decreasing salt concentration. Water that has been properly desalinated is extracted from the suitable compartments.

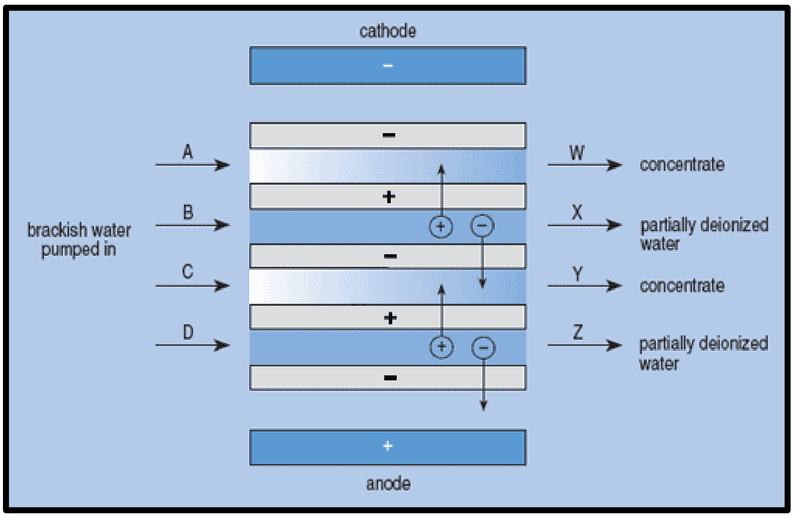


Figure 1.13 The electrodialysis process

Prior Solutions

Water desalination plant

The desalination of sea water is the most obvious source of producing fresh water for cities suffering from overpopulation. For example, when the population increased in the sunbelt areas of the U.S., the consumption of the limited fresh water sources will increase, and this can make a problem of water crisis. A lot of solutions have been suggested but they were too expensive. The sea water desalination was the most realistic solution for the problem because it is not expensive and has more efficiency compared to the other solutions.

Figure 1.14 Machinery in the desalination plant for Catalina Island

The first full-time public desalination plant in the United States was just off the coast of California, Catalina Island. It can produce more than 132,000 gallons of freshwater from the Pacific Ocean per day.

More plants were constructed in different places after Catalina Island. a 40$ million plant was constructed by the city of Santa Barbara in 1992 which can produce 8 million gallons of freshwater every day. In 2012, another one was opened by the southern California city of Carlsbad which can produce 50 million gallons of freshwater per day.

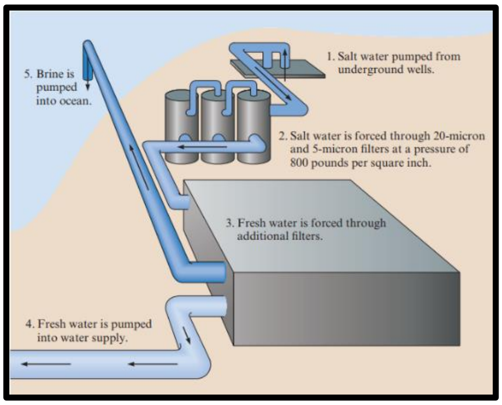


Figure 1.15 Residents of Catalina Island are benefiting from a desalination plant that supply 132,000

Mechanism

The desalination plant main idea depends on the idea of reverse osmosis. Reverse osmosis is when we put a solution; which is sea water in our case, in contact with a pure solvent with a semipermeable membrane (a membrane that allows the solvent to pass through and prevent the solute), then a pressure is applied on the solute to remove the solute particles from the solution which is more than its osmotic pressure, therefore the molecules of the solution will go to the pure solvent more than the molecules that which go from the pure solvent to the solution, so a net flow of solute particles will exist.

In the case of Catalina Island, powerful pumps are used to force the seawater through synthetic semipermeable membrane in order to filter it from salts. Then the water is forced to another filter to apply additional filters to make the water 100% clean and ready for the human consumption.

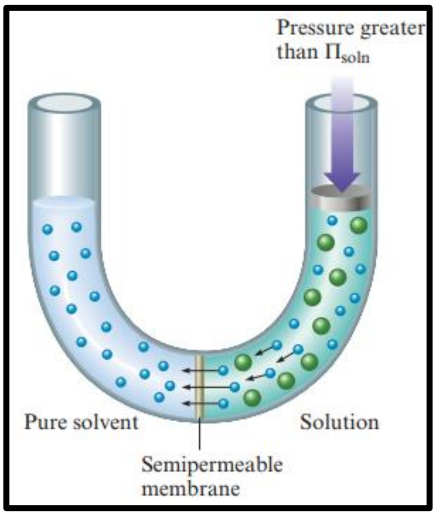


Figure 1.16 A pressure greater than the osmotic pressure of the solution is applied to filter the solute from the solvent

Advantages

- **Provide accessible drinking water**

It provides drinkable water to the cities facing freshwater crisis. A place like Saudi Arabia gets 70% of freshwater via this process.

- **Help with habitat protection**

Because these plants treat salty water from seas and ocean rather using freshwater sources which preserve habitats of endangered species.

- **Provide water to agricultural industry**

Desalination provides portable water which is safe for usage in irrigation of plants and livestock drinking. They are great for arid regions where there is no direct source of fresh water.

Disadvantages

- **Consumes a large amount of energy**

Reverse osmosis uses a large amount of energy to overcome the natural osmosis process and remove large particles from seawater by using a semipermeable membrane.

- **High cost to build and operate**

Desalination plants can be expensive to build and to operate. These costs can run from 30 to 240 million to build and operate, which may not include equipment and worker training. They can also be expensive to maintain, and these costs are affected by the energy price changes.

- **The environmental impact can be high**

While desalination plants can help to stop species endangerment, it can also have a negative environmental impact. The salt has to be removed, and in this large volume, it can be highly difficult to be removed.

Slow Sand Filtration

Also known as (Bio Sand filter), this solution has many designs but the most known one consists of (Fine sand, Coarse sand, Gravel, Diffuser plate) and a plastic container approximately 0.9 meters tall and 0.3-square-meters, the water level should be maintained from 5 to 6 cm so the bioactive layer can grow on the top of the sand helps in decreasing of disease-causing organisms, and the diffuser plate is used in preventing the disruption of bioactive layer in water and the water is poured from the top of the container and the water comes out from a pipe over time, and if the water is more turbid the flow rate decreases and the time taken to drain all the water increases, the flow rate can be maintained by cleaning the filter through agitating the top level of sand, or by pre-treating the turbid water before filtration.

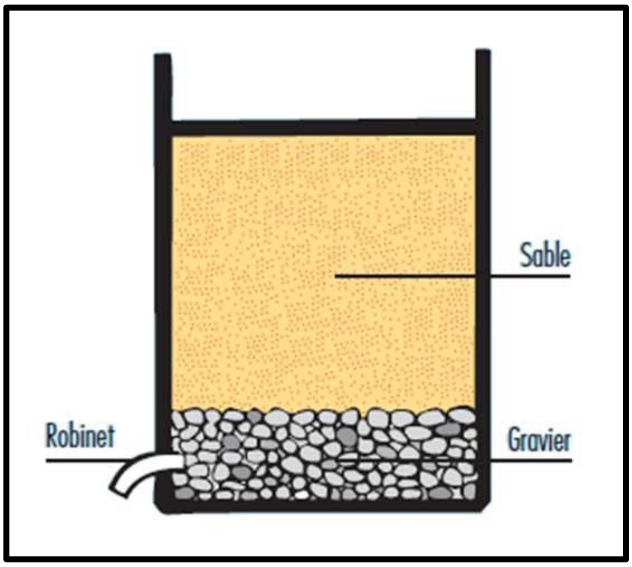


Figure 1.17 Sand Filter

Effectiveness

Slow sand filtration is an effective way to filter water as it has 99.98% protozoan, 90-99% bacterial, E. coli removal rates 80-98%, diarrheal diseases removal 44-47% in a mature biolayer.

Advantages

- High percentage reduction of protozoa and most bacteria
- High flow rate of up to 0.6 liters per minute
- Simplicity of use and acceptability
- Visual improvement of the water
- Production of sufficient quantities of water for all household uses
- Local production (if clean, appropriate sand is available)
- One-time installation with low maintenance requirements
- Long life (estimated >10 years) with no recurrent expenses

Disadvantages

- Is not that effective against viruses
- Leads to recontamination due to the absence of chlorine
- Routine cleaning can harm the biolayer and decrease effectiveness and will lead to increasing the infection rate
- Difficult to transport due to weight, as shown in Figure 1.18, and it has a high initial cost

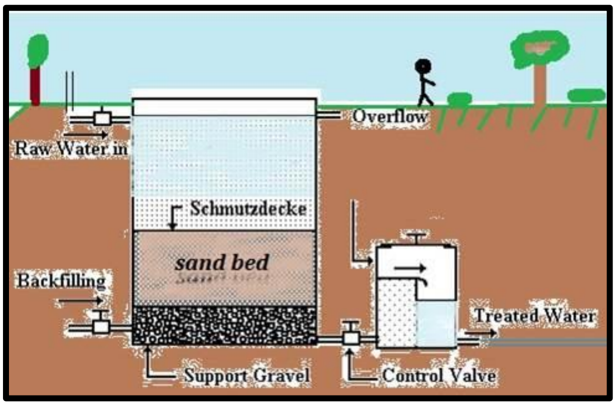


Figure 1.18 Sand filtration system

Cost

The cost of the slow sand filter is (15-60) $ depending on where the materials came from and (2-10) $ for repairing and the overall cost is about 100$ This means that if someone has a liter of water filtered from Slow Sand Filter is about 0.068 $ and this is a cost as the daily usage of water is (10-20) liters approximately which is from (0.6-1.2) $ per day for water only without the other expenses of life.

Solar Disinfection

Solar disinfection also known as SODIS was developed in the 1980’s to disinfect water inexpensively and this water is used in oral rehydration solution. The Swiss Federal Institute for environmental science and technology investigated SODIS in 1991 and found that it can be used by human. So, it was used in the developing countries to prevent diarrhea. The ones who use SODIS in disinfecting water use it in a certain way which is : they fill 0.2-0.3 low-turbidity water in a plastic bottle, they then shake the bottle to oxygenate, then the bottle is placed on a roof for 6 hours if the weather is sunny and 2 days if the weather is cloudy, So the combined effects of ultra-violet light (UV)-induced DNA damage, thermal inactivation, and photo-oxidative destruction inactivate disease-causing organisms as shown in Figure 1.19.

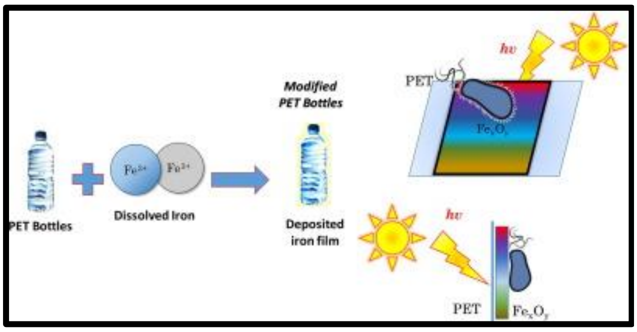


Figure 1.19 Solar disinfection method

Effectiveness

In the laboratory, SODIS has proven it is effective in disinfecting and inactivating viruses, bacteria and protozoa that causes diarrheal diseases. And from the field data it was shown that there were reduction of viruses, bacteria, and protozoa, the result from field data shown that SODIS has resulted in diarrheal diseases ranging from 9-86%.

Advantages

- Proven reduction of viruses, bacteria, and protozoa in water
- Proven reduction of diarrheal disease incidence
- Simplicity of use and acceptability
- No cost if using recycled plastic bottles
- Minimal change in taste of the water
- Recontamination is low because water is served and stored in the small narrow necked bottles

Disadvantages:

- Need to pretreat water of higher turbidity with flocculation and/or filtration
- Limited volume of water that can be treated all at once
- Length of time required to treat water
- Large supply of intact, clean, suitable plastic bottles required

Figure 1.20 Treating water with solar disinfection

Cost

The SODIS is a virtually zero technology as it only depends on the sun which is a permanent source of heat and light as shown in Figure 1.20. For 20 years SODIS has been spread by 28 countries from NGOs through training of trainers educating at the grassroots level, providing technical assistance to partner organizations, lobbying key players, and establishing information networks. The experiences gained have shown that SODIS is best promoted and disseminated by local institutions with experience in community health education. A long-term training approach and repeated contact with the community is needed to create awareness on the importance of treating drinking water and to establish corresponding changes in behavior. Both the Swiss Federal Institute of Aquatic Research and Technology External and the SODIS Foundation External provide technical assistance to NGOs implementing SODIS.

Chapter 2

Solution requirements

Sustainability and durability:

Sustainability and durability are from the most important characteristics that a filtration system should have, that's because of the huge amounts of water that will pass through in order to get filtered. Of course, this water will not be pure. Instead, it is the contaminated water that the filtration system should filter. This means that this filtration system must be built perfectly to tolerate any type of water that can pass through it and with any level of contamination.

Also, besides that the filtration system should tolerate this contaminated water without getting impacted, it should also maintain its performance for a relatively long time where the filtration system is considered a main part of the infrastructure when building a water-related project. This means that it is hard to change the whole filtration system for many times.

Eco-friendliness:

The solution that has been chosen will not affect the environment as it will be built with materials that do not harm the plants and organisms like glass. Also, it will reduce TDS of water by the method of electrodialysis which depends on the electricity and there is a lot of sources of renewable energy that will not harm the environment. Another thing that the pH will be adjusted with substances that do not harm the plants.

Availability:

The materials that will be used to build the prototype will be available and easy to be found. The electrodialysis components are any anode and cathode not only the copper and zinc. The vinegar and any acid or sodium and any basic substance can be used to adjust the pH. Therefore, the materials could be found easily because there are many alternatives for the solution's materials.

Ability to adapt for different uses:

A good filtration system must be able to filter the water to a certain level. But a better one is a one that can be easily set to filter the water to a higher level without a big change in its structure. This means that it should adjust some processes in order to get to a higher quality water. For example, a filtration system is built to filter water in order to be used in agriculture. Also, it can be even more useful if it could be easily adjusted to increase the filtration efficiency so, the water that it provides can be used for domestic uses as well.

Filtering water from all aspects:

Water is said to be usable for human activities not only if its parameters is good where there are some other aspects that a filtration system should consider, like filtering the water from microorganisms.

Filtering the water from harmful microorganisms is from the important requirements as if there any protozoan or harmful bacteria, the plants will be harmed, and the crops will be corrupted. Therefore, the sand and gravels are chosen are for our solution to kill the harmful organisms.

Also, balancing the parameters of the water is from the important factors to say that the water is filtered. As if the TDS and pH not balanced this will defect the crops and will be harmful for the soil and may cause soil pollution. Therefore, form water filtering requirements TDS balancing system such as electrodialysis, reverse osmosis or any other method, and for the pH it should be adjusted with acidic or basic substance according to its degree.

Design requirements

The main design requirement for the chosen solution is to desalinate seawater for agricultural usage.

Water parameters:

The first design requirement that was chosen for testing was the water parameters. Water parameters are certain sets that are used for deciding whether or not the water could be used for agriculture. The two most important parameters that affect the suitability of water to use are pH and total dissolved solids (TDS). These two parameters are the ones that will be tested. The first parameter is the pH. The agricultural water pH should be in the range of 6.5 to 8.4 as this is the most suitable pH for agriculture according to FAO (Food and Agriculture Organization of the United Nations). Second, the TDS of water should range from 450 to 2000 ppm. There is also a tolerance limit where the land can tolerate the water, but it may get affected after some time. The tolerance limits of pH and TDS for agricultural uses are shown in Table 2.1.

Parameters	Tolerance limit
pH	5.5–9.0
TDS	2,100

Table 2.1 The tolerance limit for agricultural uses

Efficiency:

The second design requirement chosen for testing the prototype is the efficiency. The efficiency is the ratio between the amount of water entered to the amount of water that the filtration system provides after being filtered, where we try to minimize the amount of wasted water from the process as much as possible.

Selection of solution

The required challenge is to increase the source of clean water. Therefore, the solution should be a new method of water filtering. To say that the water is filtered, the harmful microorganisms should be killed, the TDS of water (Total Dissolved Solids) should be reduced to the required level, and the pH should be neutral. These steps are to make sure that the crops, as the solution will be best used for agriculture, will be able to tolerate the water and not get harmed from it.

The chosen solution consists of three filtration stages. The first stage, a filtration stage that clean and purify the water from the impurities, protozoan and harmful micro bacteria by sand and gravels, as they have high ability to reduce these impurities. The second stage is the process of decreasing the TDS of the water where electric rods will be used to attract the ions in water towards the positive electrode (cathode) and the negative electrode (anode) to reduce the TDS (Total Dissolved Solids) of water will be used. And finally, a small system that contains acidic and basic substances that will be used to the balance the pH of water as if the water has high pH so, the water will be adjusted by an acidic material, and vice versa.

A main component that will be added and will give the solution a scene of technology is Arduino Uno, where the solution will utilize modern technologies to control the process of filtration automatically. Some devices will be connected to the Arduino to calculate the water TDS and pH. The Arduino will take these results and make a suitable filtration cycle for the water.

Selection of prototype

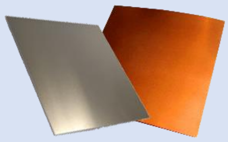
The selected prototype consists of three glass containers each one contains one process of the three processes of the solution. The dimensions of each container are 0.2m length, 0.2m width, and 0.2m height. The three glass containers have been holed at some specific places to let the water pass from a stage to another.

The first container of the prototype contains a sand filter. This filter consists of three layers: activated carbon (activated charcoal), fine sand, and gravels, ordered vertically from top to bottom. There is also a layer of cotton between each two layers to separate the materials from each other and prevent their passage with water to the next stage. The activated carbon layer is responsible for removing bad odors and tastes from the water. The sand layer is for cleaning the water from harmful microorganisms found in it. The final layer of the gravels is responsible for decreasing the speed of the water and giving the whole stage some stability. All these layers cover the whole surface area of the container so all the water that enters the prototype must pass through it. After finishing the first stage, water will pass to the second container. The second container contains the capacitive deionization process which is made using two different types of electrodes: copper and aluminum, which are connected to electricity in order run the process. Then the water will flow to the last container which contains specific materials for balancing the pH of the water.

But, before starting any process of the three, the water parameters will be tested by using specific sensors connected to an Arduino Uno board. The data collected from these sensors are used to adjust the processes so the filtration system can adapt to filter any type of water.

Chapter 3

Materials

Item	Quantity	Cost	Source of purchase	Picture	Description / Usage
Glass Container	3	70 L.E. each (210 L.E. total)	Glass Shop		A cubic container of edge length 0.2m. for each stage of filtration.
Sand and gravels	1 kilogram	-	Construction materials shop		
Activated Carbon	½ kilogram	30 L.E.	Chemicals shop		Used to make the sand filter of the first stage.
Cotton	½ packet (125 gm. each)	10 L.E.	Pharmacy		
Copper & Aluminum electrodes	4 electrodes of each type	70 L.E.	Blacksmith shop		The electrodes used to power the capacitive deionization process. Each one has dimensions 0.2m. length and 0.1m. width.
Arduino Uno	1	120 L.E.	Electronics Shop		The Arduino Uno board which acts as the brain of the system.

TDS meter	1	150 L.E.	Electronics shop		The device (sensor) used to measure the TDS of the water in the second stage.
pH meter	1	200 L.E.	Electronic shop		The device used to measure the pH of the water in the third stage.
Solenoid valve	3	50 L.E. each (150 L.E. total)	Electronics shop		Valves connected to Arduino that opens and closes automatically.
Breadboard	1	20 L.E.	Electronics shop		An electronic board used to make the circuits of the system.
Electric wires and resistors	4	3 L.E. total	Electronics shop		Wires used to connect the circuit and resistor to adjust the voltage of electricity.
Transistors	3	2 L.E. each (6 L.E. total)	Electronics shop		Electronic parts that are used to switch the electricity on and off for the required device.
Power Adapter	1	25 L.E.	Electronics shop		The adapter that connects the whole system to the electricity.
Total		994 L.E.			

Methods

Designing and constructing:

1) The design of the prototype was drawn on a paper in a 2D form, then it was interpreted as a 3D shape using a computer software called (Sketchup).

2) The faces of the three glass containers were cut in the required dimensions (0.2m. length and 0.2m. width). Then, they were glued together using silicon glue to form the three cubic glass containers. After they were fixed together, some faces of the containers were holed at specific places to let the water pass through them. Three pieces of wood were used to fix the three glass containers together.

3) The components of the first stage (the pre-treatment stage) were put vertically in the first glass container, as shown in Figure (1). They are put in order from top to bottom: activated carbon (AC), fine sand, and gravels. Cotton was used to make a separating layer between each two materials.

Figure (1) - The pretreatment stage

4) The copper and aluminum electrodes of the second stage (the capacitive deionization process) were fixed in the second glass container, As Figure (2) shows.

The TDS sensor was also fixed in this stage to measure the TDS of the water before it passes to the next stage. This passage is also controlled by a solenoid valve which is fixed at the bottom of the second container.

Figure (2) - The CDI treatment

5) The pH sensor was fixed at the last glass container to measure the pH of the water, as shown in Figure (3). Two solenoid valves were also fixed in this container, each one controlling the addition of either the acidic or the basic material to balance the pH of the water if needed.

Figure (3) - The pH treatment stage

6) Electric wires were used to connect the two electrodes, TDS sensor, pH sensor, and the three solenoid valves to the power source, and the required ones to the Arduino.

7) Finally, the Arduino was coded to manage the process of water filtration where it controls almost everything in the process.

Safety precautions:

1) Wear gloves while working with strange substances like gluing the glass containers with silicon.
2) Make sure that everything is connected to the right place to prevent electric shocks.
3) Make sure to clean the place after finishing work.

Test plan:

After the prototype was built, testing it was the best way to verify its success and to ensure that it has achieved the design requirements. Seawater was used to test the prototype. Since the two design requirements that was set to test the prototype are water parameters and the efficiency of the prototype, two measures were taken for the seawater: its parameters and the volume of specified amount of it. The efficiency of the prototype is the percentage of the volume of filtered water to the volume of water before filtration ($efficieny = \frac{Volume_2}{Volume_1} \times 100$).

Of course, the prototype already has the required tools to get these measures. However, the parameters of seawater (water before filtration) of the first test of the three and that of the filtered water were sent to the Desert Research Center to measure them to verify the accuracy of the results and that of our devices too.

Data Collection

The prototype has been tested and a good result have been achieved. The prototype made to be available for any agriculture crop with TDS under 1300. So, it has been tested to adjust the TDS of Mediterranean seawater (1×10^4 ppm – 7.8pH) for the tomatoes crop as the tomatoes needs (1088 ± 20) ppm and the output water is (1051 ± 20) ppm. This means that our requirement has been achieved. The same thing has been done on other two testcases which are shown in Table (2):

	The required TDS	After Treatment
Tomatoes	1088	1051
Grapes	640	658
Potatoes	704	697

Table (2) – The TDS of water after treatment

As seen that there is always an error not exceeding 20 ppm so, it is from the good points in our prototype.

As known that the acidity of the water varies as some times the atmospheric water may be acid and sea water is basic and the prototype made to work under any conditions. The agricultural water best pH should vary between 6.5 and 8.4. Table (3) shows the results after adjusting the pH for three tests of the rice, grapes and beans.

	The required pH	The pH after treatment
Tomatoes	6.0 – 7.0	7.02
Grapes	5.5 – 6.5	6.48
Potatoes	6.0 – 6.5	6.47

Table (3) – The pH of water after treatment

As seen that the results are with accuracy (7.0 ± 0.03) pH.

The second design is efficiency and it's calculated by the formula $= \frac{output}{input}$.

First, the input was 1000 ml, the output was 730 ml. Therefore, the efficiency $= \frac{730}{1000} = 0.73$ which equals 73% and this is very good efficiency as there is a big loose in the pretreatment stage.

The negative results are that the prototype was hard to build and there was a lot of errors in the Arduino code, which lead to some defects in the results.

The positive result is that the prototype now was build and succeed in the test plan with the least errors.

Chapter 4

Analysis and Discussion

The solution has been implemented in three stages. The pretreatment stage that is responsible for filtering the water from microorganisms, suspended solids, and bad tastes and odors. The two other stages are the main treatment methods. The second stage is the one that reduces the TDS of the water. And the final stage is responsible for balancing the pH of the water.

Pretreatment stage:

Sand and gravels:

Sand and gravels are used in the pretreatment stage as it helps in reducing the total suspended solids (TSS), floating and sinkable particles. Also, because sand is water permeable, as we learned in Geology LO 2.01, it can filter the water from many pathogens, such as harmful bacteria and viruses, as it prevents them from passing while letting the water pass easily.

Activated Carbon (charcoal):

Activated carbon (AC) is made of an organic material that is high in carbon, which is usually coal. Activated carbon is mainly made by subjecting the carbon to heat in the absence of oxygen. Afterwards, the carbon is exposed to some chemicals, commonly argon and nitrogen and then it is exposed to extreme heat again, but in the presence of steam and oxygen. This process creates a pore structure, and the usable surface area of the carbon greatly increases, as shown in Figure (4).

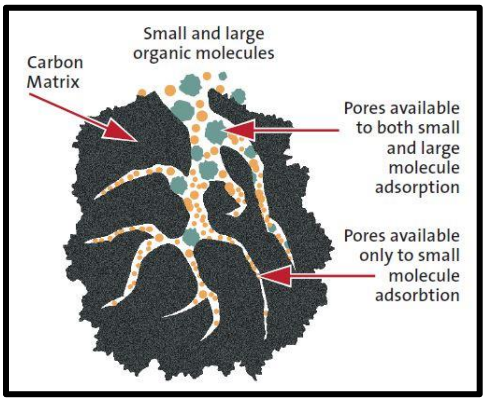


Figure (4) - The structure of activated carbon

Activated carbon filters the water from some chemicals that give objectionable odors or tastes to water such as hydrogen sulfide (H_2S) and chlorine (Cl) where it adsorbs these chemicals where they stick to the surface area of the carbon particles (adsorption means that the activated carbon makes the molecules stick to its surface.)

Treatment stages:

Aqueous solutions and dissociation of ionic compounds:

Aqueous solutions are the solutions in which the solvent is water. Since water is a polar substance, it can dissolve only polar materials (Chemistry LO 2.01), and ionic compounds are extremely polar compounds. Thus, ionic compounds get dissociated into free positive and negative ions in the water. Therefore, these ions can then be collected by the capacitive deionization process.

Capacitive Deionization:

Capacitive deionization (CDI) is a process system that removes charged ions from water using the electrical potential difference between parallel charged electrodes. Some of them are positively charged (anodes), and the others are negatively charged (cathodes). CDI process depends on the phenomenon of electrical double layer (EDL). EDL, as illustrated in Figure (5), is a structure that appears on the surface of an object when it is exposed to a fluid. For example, the electrode-solution interface, where one side is the electrode, the other side is the electrolyte solution phase (diffuse layer), and the dielectric medium between them is a layer of solvent molecules that are always adsorbed to the electrode.

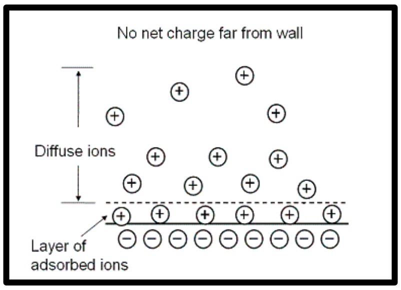


Figure (5) – The EDL phenomenon

In CDI process, the potential required for water splitting is above ~1.2V. So, when working in a lower potential with saline water the charged electrodes will adsorb the counter-ions (ions of opposite charge), by an electrostatic binding (the EDL phenomenon). The EDL capacitance, as learnt in Physics LO 2.05, is its ability to collect energy in the form of an electrical charge. It is given by Equation (1) which relates to parallel plates capacitor.

$$\boxed{C = \frac{A \cdot \varepsilon_w \cdot \varepsilon_0}{d}}$$

Equation (1) – The capacity of an EDL

In Equation (1), A is the surface area of the electrode, d is the distance between the electrodes, ε_w is the water permittivity constant, ε_0 is the vacuum permittivity constant. This means that the higher the surface area of the electrode, the higher is its capacity. So, this high surface area electrodes can adsorb a lot of ions which will decrease the TDS of the water.

pH meter:

The pH meter is a device made for calculating the pH of a substance, so the system can decide whether an acidic or basic material should be added to the water. The pH meter utilizes the electric potential that results from the migration of H^+ ions from the unknown solution, which is water in this case, to the known one inside the device to measure the pH of the water.

The pH meter consists of three main components, as shown in Figure (6): a standard electrode of known potential, a special glass electrode that that changes electric potential depending on the concentration of the H^+ in the water, and a potentiometer that measures the potential between the two electrodes.

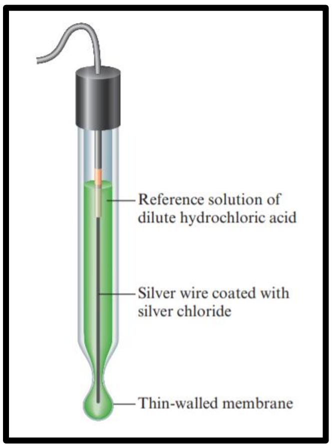


Figure (6) – The structure of the pH meter

The glass electrode contains a reference solution of dilute hydrochloric acid (HCl) in contact with a thin glass membrane which is an ion-selective electrode. Ion selective electrodes are the electrodes that are sensitive to the concentration of a particular ion. The electrical potential of the glass electrode depends on the difference in the concentration of H^+ ions between the reference solution and the water of unknown pH. So, the electrical potential varies with the pH of the water. This electrical potential is read by the potentiometer then it is converted electronically to a direct reading of the pH of the water.

TDS meter:

TDS (Total Dissolved Solids) meter is a device used to measure an approximated estimation of the TDS of the solution being tested, which is water in this project. It is used in the prototype to let the water pass to the next stage only if the TDS of the water is within the appropriate range. TDS meter is based on measuring the electrical conductivity (EC) of the water and multiplying it by the conversion factor (k_e), as Equation (2) shows.

$$\boxed{TDS = k_e \times EC}$$

Equation (2) – Calculation of the TDS from the electric conductivity (in 25°C)

The measurement of the TDS using this method is a good approximate of the TDS of the water but not the exact measurement because other factors, such as type of salt, have a small effect on the measurement.

Arduino Uno:

Arduino is an open-source electronics project that designs and manufactures Arduino boards. Arduino boards are single-board microcontrollers. This board provides all the necessary needs to do a useful control task; it can receive inputs, process the data, and perform an output as a regular computer does. Arduino boards are coded in a language called Arduino language which is based on C and C++ languages. It is used in the prototype to get the input data from a set of different devices like the TDS and pH meters and send orders to the solenoid valves.

Electric circuit:

It's from the important things to put an electric circuit in the prototype because the water valve needs volts in range of (6V – 12V) and the Arduino's emf is 5v only. So, a power supply is needed to help us to power the three water valves and a transistor is needed as it will be used like a switch to help in controlling the valve using the Arduino. Another thing is the sensors as there are two sensors are used and the Arduino obtains energy for only one. Furthermore, the most important thing is to make a suitable voltage for the capacitive deionization using resistors. The circuit is with all its connections is shown in Figure (7).

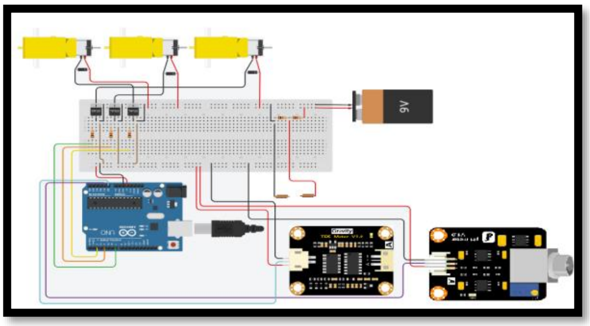


Figure (7) - The circuit of the project

Learning outcomes transfer:

Chemistry LO 2.01 & 2.02: They were used in studying the physical and chemical properties of water and studying how to measure the TDS and pH of water. Also, they were used in understanding the phenomenon of dissociation of ions in an aqueous solution.

Physics LO 2.04 & 2.05: They were used to determine the connection of the electrodes of the CDI process whether series or parallel. Also, they were used in knowing how to calculate the capacitance of the electrodes.

Geology LO 2.01: It was used in understanding the role of sand in the pretreatment stage of the filtration system and the relation between permeability and how the sand layer filters the water.

In conclusion, the main challenge that the project focused on was the lack of water resources and its consequences on the development of Egypt. The specific problem the project tried to solve was finding a new way or resource to provide the country with freshwater usable for different human activities, from domestic to industrial uses. The project has come up with a solution to utilize the unused water resources in Egypt using chemical ways controlled with modern technologies. The project consists of three stages: the pretreatment of water which filters it from harmful microorganisms, the capacitive deionization process, which decreases the TDS of water to the appropriate range, and the final stage that balances the pH of the water. Testing the prototype several times according to a specific set of design requirements has ensured the success of the project, where the prototype has successfully improved the water parameters while maintaining relatively high efficiency. These results prove that this project is a successful and viable one that can be applied in real life.

Recommendations

For the prototype:

Even if the prototype could meet the design requirements, there are even more further modifications that can be applied to the prototype to improve its performance that can make it achieve better results. An important modification to the prototype is:

Use an electrical pump:

Since the water is not always flowing into the prototype, the speed of the water is relatively slow. A further improvement that can be added to the prototype (or the real project if the flow of water in it is not continuous) is an electrical pump. An electrical pump can be added at the beginning of the process to force the water into the filtration system which increases the speed of the water flow inside the system. An electrical pump is a pump that is driven by an electric motor. It should be also connected to a power source, to provide it with energy required to work its components. Increasing the speed of the flow of water into the prototype will decrease the time taken to complete the filtration process. Unfortunately, we could not add this pump into our prototype due to its relatively high cost which will make the prototype exceed our budget.

To apply the prototype in real life:

Location:

The solution can produce filtered water with adjustable ranges of water parameters. The idea of the solution can give a lot of benefits if it is used in agriculture where we can adjust the filtration process to fit with crop we plant (as shown in the Results section). So, choosing the location of the real-life project depends on the source of the water because the project should provide the agricultural lands with the water they need for irrigation. But at the same time, the project must not be built too far away from the resource of water, as this costs a lot for transferring the unclear water to the filtration system.

From the best resources to collect the water needed for a purpose like agriculture is seawater, because seawater is a surface water which costs only the money needed for the transferring of water to the land, and it is also found in very huge amounts. In Egypt, the north coast, as an example, is a very good area for building this project, where the Mediterranean Sea can provide the lands around it with needed water. So, it can be filtered and used in irrigating the lands. In addition, there are big areas of land that are capable of agriculture in the northern coast which will make use of the filtered water. This water can also be used to reclaim new lands.

Improve the materials used in constructing the system:

As the solution can filter a lot of types of water, it can be exposed to water that may cause damage to its parts. So, when considering the materials that are getting used in the real solution, they must be chosen according to the type of water that it will deal with. Besides considering that these materials must not interact with water. For example, copper-zinc alloy and graphite, which is a non-metal conductor material, can be used as the electrodes in the second stage, as they have higher tolerance for the water and the salts in it.

Also, considering the water containers of each stage in the system, they must be made of a sustainable and durable material which can tolerate the amounts of water it will carry, such as fiber glass.

Use a soil moisture sensor:

A soil moisture sensor measures the volumetric water content in soil. It uses some properties of the soil to calculate the volumetric water content like the electrical resistance. A soil moisture sensor can be connected to an Arduino board to input the data of the soil to it. Such a sensor can be very useful for our real-life project if it is used in agriculture. After the filtration process of the water, it can be stored in tanks that are automatically controlled. Then, according to the data that the soil moisture sensor sends to the Arduino about the state of the volume of water in the soil, the Arduino can decide whether to open the irrigation system of the land or not. A small modification like this can positively affect the water used in irrigation, where there will be a lot less amounts of wasted water on irrigation that are not necessary for the agricultural land.

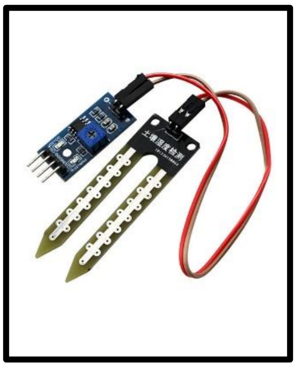


Figure (7) – The soil moisture sensor

Learning outcomes transfer

Subjects	Learning outcome	Description	Connection
Computer Science	CS 1.10	Logical operators and conditional statements	This helped us in building the code of the Arduino as there is no code not including if statement and logical operators
Computer Science	CS 1.11	Loop statements	This learning outcome helped us in understanding the function loop of the Arduino
Chemistry	CH 2.01	Calculating the molarity, molality, normality, TDS, reverse osmosis, electrodialysis and the mass percent	This Learning outcome helped us in understanding the concept of TDS and searching a little about solution of reverse osmosis and electrodialysis
Chemistry	CH 2.03	Acids and bases	This learning outcome helped us to understand the law of acid and base and in calculating the pH in the water

Geology	ES 2.01	We learned about the properties of water and its abundance in nature and the water cycle	This Learning outcome helped us to know the nature of the aquifers, sand and gravel
Geology	ES 2.04	We have learned about the pollutants that affect, their types and how to purify the water	This learning outcome helped us in understanding more about the solutions of the challenge
Math	MA 2.01	We have learned about the functions and how to use them to represent the polynomial and rational functions	This helped us in writing the function of the graphs and tables
Physics	PH 2.03	We have learned about the resistors, ohm's law and connection of resistors in series and parallel	This Learning outcome helped us a lot in building the circuit which is the prototype mainly built on
Physics	PH 2.05	We have studied about capacitance, capacitors and their connection in series and parallel	This helped us as it is the same idea like our project which is (CDI)
English	Cycle 1	We have studied in these cycles about cause effect essay and process analysis	This helped us a lot in Improving our writing
English	Cycle 2		

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