STEM EGYPT

MINISTRY OF EDUCATION AND TECHNICAL EDUCATION

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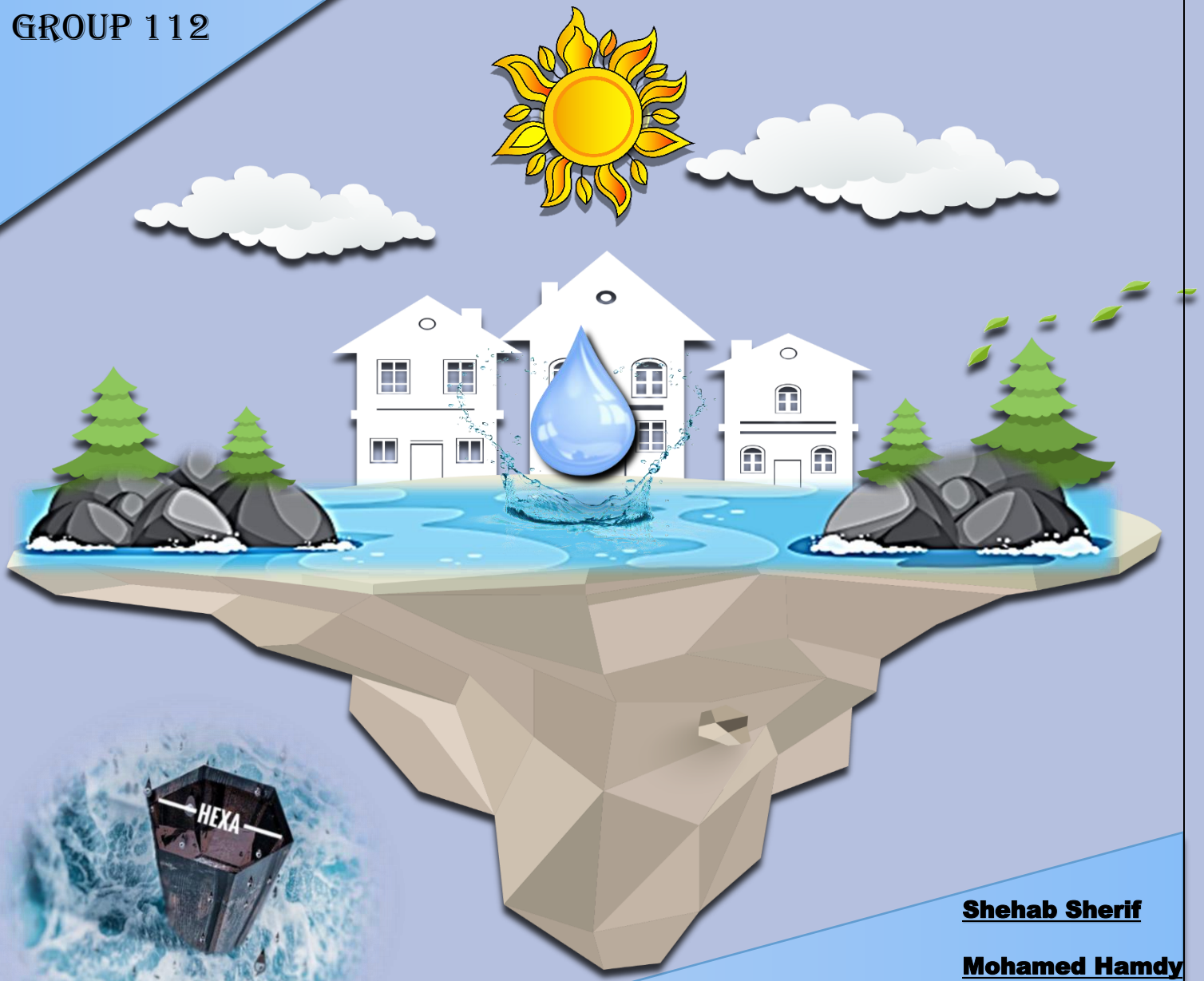
# HEXA

## GROUP 112

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# Grand challenges

# Arid areas

Egypt is struggling with the problem of arid areas. Arid areas are areas that does not support continues vegetative ground cover. More than of **90%** of Egypt consists of arid areas **as shown in figure (1).** leaving only a small percentage available for people so only 4% of Egypt is occupied by population, which results in the problem of urban congestion.

Figure (1) shows the arid areas in Egypt.

In order to solve the problem of arid areas land reclamation projects must be carried out which emphasizes on the great need of water. Water can change the topography of a desert landscape completely. Which will also increase the area of agricultural lands.

One of the main aspects of arid areas is the lack of services, as a result many people migrate from rare areas to major cities searching for jobs and better life opportunities. This leads to an increase in urban congestion and arid areas. To solve this problem new settlements must be constructed such as hospitals, schools and factories to convince people to migrate to the new lands as the Egyptians through centuries have lived on the Nile.

The financial problem also influences the problem of arid areas because the reclamation of land and building new facilities requires huge investments and Egypt's dept rose to **$112.67 billion.** But it is worth solving the problem as the arid areas have very promising resources like the solar energy, precious materials and tourism.

## Causes: -

- Water: Finding water resources is essential for solving arid areas problem because land reclamation is based on it.
- Remoteness: as arid areas have natural barriers which increase the cost of transportation.
- Decrease of opportunities: Almost of half of the opportunities is concentrated around greater Cairo so new opportunities must be generated.
- Deficiency of special technology because land reclamation of desert needs special technologies.
- Livestock overgrazing leads to reduction of land cover and soil erosion increases the percentage of arid areas in Egypt.

## Impacts: -

- The problem of arid areas also introduces desertification as It is the extreme deterioration of land in arid and semi-arid-areas.
- Increase the pollution due to concentration of people around the Nile and delta.
- Health problems and increasing the spreading of diseases due to the concentration of people in one place.
- Decrease of the amount of water available for each person and increasing the problem of water.

# Water Shortage

Water shortage is one of the major problems in Egypt as it affects all the other activities. Egypt has limited water resources and it will be under underwater stress by the year **2030.** New water resources must be used to decrease the impacts of water shortage. rainwater harvesting is one of the possible sources. The Nile water is the main and primary source of clean water in Egypt. However, the demand of water in Egypt exceeds the available water resources in Egypt. Egypt has a water deficit of **30 billion cubic meters** annually. As the population is increasing the problem of water shortage is increasing significantly because the water resources are not increasing and are fixed to the share of the Nile. The amount of clean water decreases gradually each year. That's leading to Increasing the severity of the problem.

## Causes: -

- Primitive agriculture**:** Egypt uses approximately **77% of water** for agriculture **as shown in figure (2)**, and the Egyptian people use approximately **90%** of this percentage in traditional agriculture, which is based on flooding agricultural lands with water for a period that usually exceeds an hour, which leads to a great loss in water.

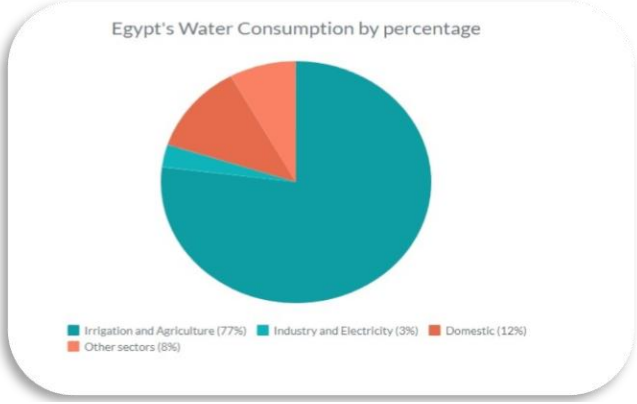



Figure (2) sectors of water use in Egypt

- Drinking water: The drinking water sector is the second most consuming sector of water in Egypt. Egypt consumes the equivalent of **13.4%** in drinking water, which is more than **10 billion** cubic meters of water.
- Spraying water: In Egypt, spraying behaviors of streets, sidewalks and cars are widespread, causing the consumption of **1.5 million** liters of clean water .
- Leak pipes: The presence of a malfunction in the water and pipes system causes a large amount of water loss .

- Contamination of water due to uncontrolled increase in agricultur and industry.

# Impacts:-

- Impeding development: because of water shortage most agricultural and industrical activities will be greatly affected and will also prevent their development.

- Food scarcity: Because there is not enough water to be used in agriculture which is major problem due to the growth rate of the population.

- Employment opportunities will be significantly reduced as a result of being affected by the industrial and agricultural fields due to the shortage of water

- Spent a lot of money on seawater desalination plants and wastewater purification

# Urban congestion

Urban congestion can be defined as a growth and concentrating of people within the main cities that can have adverse effects on efficiency within any industrial activities, the local environment, accessibility, sustainability, economic regeneration, and equity.

Urban congestion is one of the biggest problems facing Egypt. As the population within Egypt has been growing for. But this is not the problem, the main problem is the wrong population distribution that leads to urban congestion.

All people in Egypt live in the main cities around Nile and sources of water through the ages. This is because water is the main source of life, and also because the cities around the Nile have better services than other cities further from the Nile.

Because of the spread of many good job opportunities, and this causes people to travel to big cities. Which causes crowding and urban congestion .as all of these will be mentioned in causes and impacts.

# Causes:

- Arid areas spread, the spread of arid areas has led to congestion in many cities, this is because it is natural that many people do not prefer arid areas and prefer cities. This is due to the lack of services in arid areas

People used to live near the Nile Valley, because it is the main source of water in Egypt. And that's lead to urban congestion. If we study the distribution of the population in Egypt specifically, we will find that More than **95%** of the country's population lives on the banks of the Nile and the Delta as shown in figure (3)

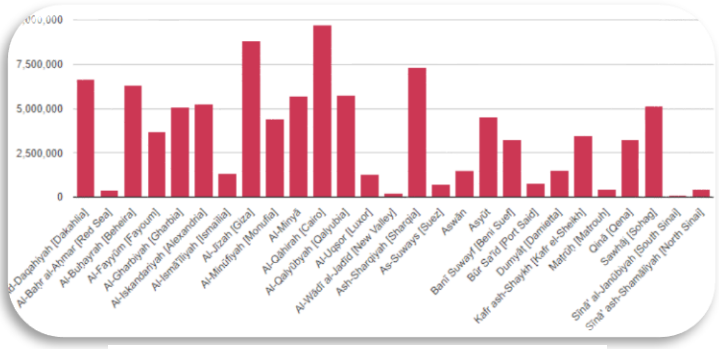



Figure (3) showing the population in Egyptian cities

- Taking the capital of Egypt on the Nile River throughout the ages since the ancient Egyptians

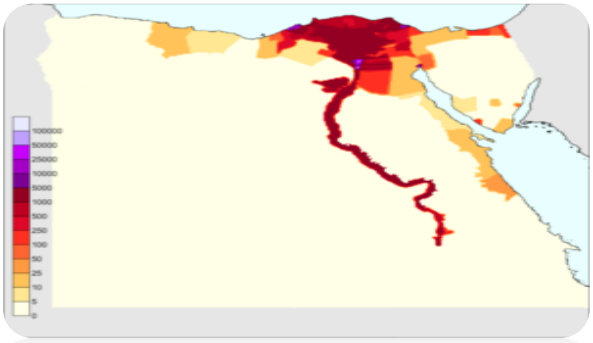


Figure (4) showing places of concentration of population in Egypt

- People crowding to live in cities that have services and job opportunities. **as shown in figure (4)** The proof of this is that Cairo is classified as one of the most densely populated cities in the world.

## Impacts: -

- The spread of pollution and diseases in Egypt, the easy transmission of bacteria and viruses due to overcrowding
- The traffic congestion problem appeared which led to many problems such as reckless driving. This can lead to many deaths, Pollution from many cars and transportation vehicles
- Many economic problems such as unequal prices due to the unequal distribution of the population
- The emergence of the problem of unemployment in the areas of urban congestion due to the lack of jobs.
- Noise pollution resulting from urban crowding, due to the sounds of machines, cars, and people.

# Pollution

Pollution in Egypt is one of the most affecting problems in life, it is not just having bad effects on humans, it also affects animals, the environment, aquatic life, water, and air. This pollution happens due to causes the human is used doing it since the last century. This pollution has impacts and effects on the environment and health in general. There are water pollution and air pollution for each of them it's negative sequences.

There are many types of pollution but **two of them** will be mentioned **which are:**

# 1-water pollution: -

Water pollution is the effect of human activities on water bodies which cause changes in water's combination that affects the viability of water, solid wastes which are dropped in rivers and lakes affect the public health with many diseases **as shown in figure (5)**. Chemical pollution effects can damage the nervous system and cause dangerous diseases like cancer. Polluted water leads to the death of a lot of people each year. Water pollution often happens when microorganisms, chemicals, plastic materials animal, and human wastes are dropped in the water. It is easily polluted because the water can dissolve any substance more than any liquid. also, groundwater can be polluted by fertilizers and pesticides. approximately one-third of our rivers and lakes are polluted and is not suitable for drinking, fishing, swimming.

Figure (5)

# Causes of water pollution: -

- **Agricultural:** agriculture runoffs frequently contain pollutants from pesticides and herbicides, which have negative effects on the river and the people using it.

- **Plastic pollution:** dropping plastic wastes into water is considered a bad type of pollution because the water dissolves the plastic into microplastic and people drink it with water, which causes cancer diseases.

- **Hunting by explosions:** some fishermen tend to hunt fishes with bombs to collect more fish easily, which affects the quality of water with high pollution.

- **Petroleum transportation:** ships that transport oil, coal, petroleum pollutes the Nile river, especially the accidents that a ship of coal and oil is drawn.

## Impacts of water pollution: -

- **Diseases:** many diseases result from polluting water as cancer disease, malaria disease which is infectious disease and might lead to death.

- **Aquatic life:** it has big effect on fish and all aquatic living organisms which return back with diseases for human and affect the environment, plants and ecosystem.

## 2-Air Pollution: -

Air Pollution happens due to the pollutants such as factories gases and car fumes **as shown in figure (6)**. it is one of the biggest kinds of pollution as **9%** of deaths in **2017** were because of air pollution. **95%** of world's population is breathing polluted, unsafe air and the hardest areas are in Africa and Asia.

Figure (6) shows air pollution

# Causes of air pollution: -

- **Cars fumes:** In **2017**, the number of registered passenger vehicles in Egypt amounted to **4.71 million** vehicles, cars emits carbon dioxide gas and other green house gases which cause global warming. It also emits nitrogen oxide which damage the human respiratory system and cause lung diseases.

- **burning of fuel:** factories depend mainly on the energy from burning non- renewable resources as coal, natural gas, petroleum and oil which produce greenhouse gases as carbon dioxide and Sulphur trioxide .Also factories drop its wastes in rivers and canals which affects the water with huge pollution . approximately **50%** of pollution in Egypt is from industry **as shown in figure (7)**

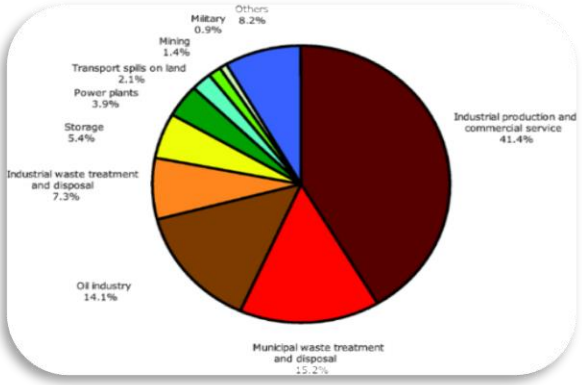



*Figure (7) percentage of pollution in Egypt*

# Impacts of air pollution: -

- **global warming:** air pollution that contains carbon dioxide and methane gases make global warming which is a world grand challenge.

- **acidic rains:** polluted air pollute the rain water which make acidic rains that affects the collected rain water, soil and plants and oceans, rivers water.

# Public Health

Public health is an extremely dangerous problem in Egypt. Egypt takes care of public health in order to have citizens with good health and to eliminate number of disease cases, especially during pandemics as shown in figure (8). But, Egypt, like many other developing countries, does not always achieve that goal due to many reasons. The main reason is the insufficient amount of resources.

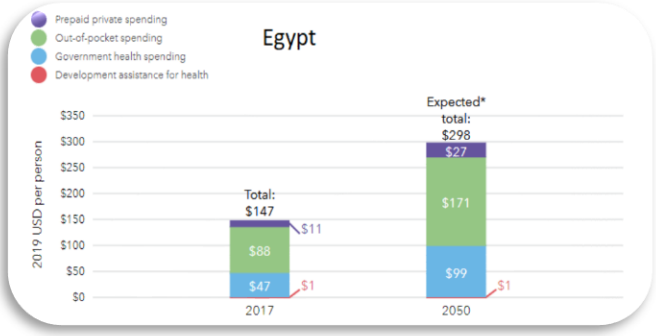



Figure (8) Money spent on a person for health in Egypt

We can increase the share of health in the national income to solve the problem of in-sufficient resources. Also, we can make people aware of health instructions.

If we solve the problem of public health, we will have a a healthy generation of young people.

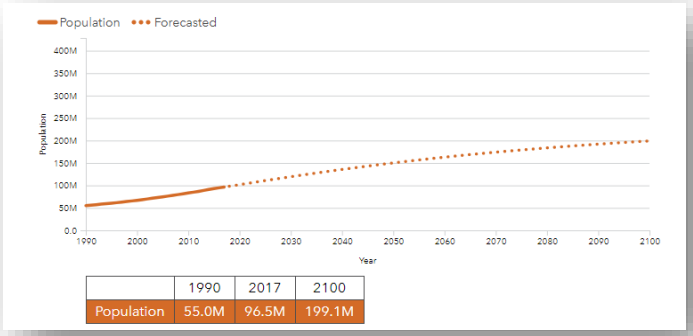
## Causes: -

1-**Weak health budget:** Egypt cannot spend too much money on citizens' health. Egypt spends about 147$ on each citizen while another country as Germany spends about 5110$ on each citizen.

2-**Un-equipped hospitals:** many hospitals in Egypt are not big enough to receive all patients visiting it, also many hospitals don't have air conditioning, so hospitals become a diseases center instead of being a place for making people feel better.

3-**Urban Congestion:** Having many people centered in a small area increases the risk of many diseases. Heart diseases are one of those diseases where they are caused due the massive amounts of car exhausts as CO, $CO_2$, $NO_2$ and $SO_2$.

4-**Over Population:** Egypt's population is too big and it is increasing very fast as shown in fagiure(9), so government can't provide citizens with enough equipment and can't spend proper amounts of money on them.




| | 1990 | 2017 | 2100 |
|---|---|---|---|
| Population | 55.0M | 96.5M | 199.1M |

population is too big and it is increasing very fast as shown in figure (9)

# Impacts:

- Little national income: It is well known that a healthy worker works better than a sick worker. Also, a worker with good health concentrates in his/her work. That's why, countries with citizens suffering bad health have less production and a bad economy. Also, while there are pandemics, people don't go to work or decrease work hours which affects the production.

- Weaker academic achievement: Students having bad health usually suffer bad concentration and a weaker mind. That is why, many countries with bad health insurance have bad academic achievements. Also, during pandemics, many students didn't study well as going to schools was prohibited to avoid getting sick.

# Problem to be solved

## Introduction: -

- Rainwater harvesting aims to collecting rainwater falling from roofs, buildings, etc. Then aims to either storing or utilizing water in fields that benefit humans and serves their daily-life requirements in home, work, etc. Rainwater harvesting aims to provide clean water not dirty water whether it is stored or used once it is collected.

- Rainwater harvesting is so important and all countries in the world, especially Egypt, try to save it as it has many positive effects that we cannot be given them away. Egypt did not save it, so there are so many negative effects as desertification, urban congestion, over population and drought problems present in Egypt and those negative effects will be discussed in detail down.

## Positive consequences: -

- **Decreasing usage of water in houses:** People use huge amounts of water daily in many activities as: washing clothes, flushing toilets, washing cars, watering plants and flowers in gardens and in washing the outside of buildings. Rainwater is suitable for all those activities.
- **Overcoming droughts**: many scientists assume that many rivers, lakes and other water sources may suffer a huge decrease in their water level in the next years. So, rainwater may be a resource that we can rely on.
- **Decreasing costs:** Rainwater collecting is much cheaper than paying water as no one owns rainwater or can make you pay taxes. Collecting water may be the best solution for poor people.
- **Decreasing houses' harms:** collecting water from roofs and ceiling may decrease the rate of erosion of surfaces, so many houses will stand still for long times. A great number of people die because of buildings falling accidents.
- **Decrease of urban congestion**: Many people in Egypt are concentrated in only **6%** of land in Egypt. This area is the Nile Valley as it is full of resources and services, especially water. If we solved that rainwater problem. We will be able to convince as many people as possible to leave the River Nile.
- **Decreasing of arid areas:** Many places in Egypt does not contain enough resources of water as Nile does not move in it. That's why, rain water harvesting may be one of the most wonderful solutions to solve the problem of arid areas as it will provide water to those dry places.

**Maintaining better health:** As mentioned before rain water provides clean water where dirty water is the cause of many diseases as

# Negative consequences: -

- **Urban Congestion:** If we don't solve that rain water problem, people will continue living at a high concentration around the Nile Valley. That brings us again to the urban congestion problem.
- **Arid Areas:** Many places in Egypt does not contain enough resources of water as Nile does not move in it. That's why, rain water harvesting may be one of the most wonderful solutions to solve the problem of arid areas as it will provide water to those dry places.

1. **Health problems:** Polluted water is the most suitable environment for the spread of many diseases as typhoid, cholera, encephalitis, poliomyelitis, hepatitis, skin infection and gastrointestinal diseases. Percentage of hepatitis in Egypt is **12% in 2016 as shown in figure 1.10** which is a massive percentage that we cannot ignore as may other European countries have a percentage less than **2%** which is **also shown in figure (1.10)**

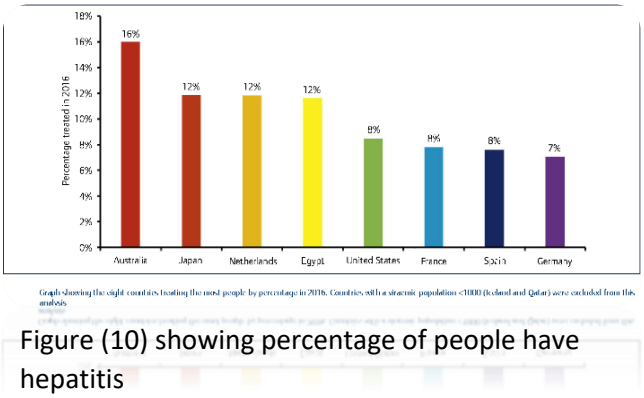



Figure (10) showing percentage of people have hepatitis

# Research

# Topics Related to problem

## Floods

Floods falling on Egypt is can either be useful or harmful .The water from floods can be the solution to the scarcity of water. Waters from floods can be collected by using dams. But, floods can also cause massive destruction where it can destroy houses and kill people. So, the floods should be controlled.

The water falling on Egypt increases the level of water in the Nile and north areas every year. It caused big floods in the past.

**In 1887**, A big flood happened and caused **150 billion** cubic meters of water to descend into Egypt.

**In 1954**, a flood happened in Qena governorate, which caused crops to be destroyed and population activity stopped due to the water .The happening of heavy rains in Egypt in **2019** led to an expectation of flooding in Egypt **2020/2021**.

## Acidic rains

Acid rains are caused by the chemical action of sulfur dioxide and nitrogen oxide in the air. These gases come from cars, factories, and other human activities or natural phenomena **as shown in figure (11)**

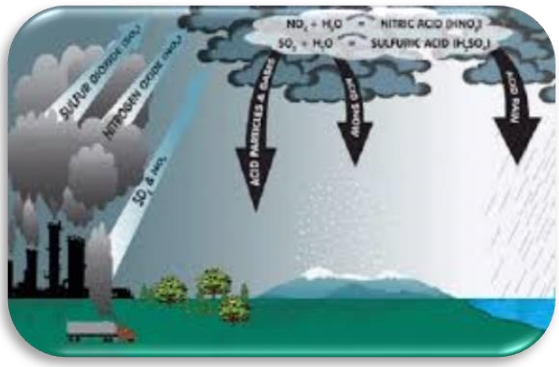



Figure (11) acid rains resulting from harmful gases

Acidic rains damages planets and destroys forests. Acidic rains have negative impacts on health and the

aquatic ecosystem. The PH of most lakes and streams is around **6.5**, but the acid rain has caused the levels of many water bodies to drop too much, killing the aquatic animals. The chemicals found in acid rain can cause paint to peel and stone statues to begin to appear old and worn down, which reduces their value and beauty.

## • Desertification

Desertification is the process by which fertile land becomes desert **as shown in figure (12).** Desertification has many causes. One of them is flood irrigation where farmer flood the land with water. That causes two main problems the first is water shortage because of the big amount of water that is wasted in these lands, the second problem is desertification. Another cause is acidic rain which is typically because of factories emissions. Increasing the temperature by climate change and excessive use of fertilizers and pesticides also causes desertification. Desertification increases the percentage of arid areas making the problem of urban congestion much worse.

Figure(12) Desertification

## • Damaging plants

Excess water can damage plants severely. If the excess water is not collected the plants will die and this will decrease the green areas. Floods can also destroy plants and trees if not controlled. An illustration **is shown in figure (13)**

Figure (14) shown destroy plants and trees

# Topics related to solution

## The location: -

The place of the rain water collector is one of the most important factors of the project, the rain water collector must be in a rainy place, for example the north cost, the rainiest places are the coasts.

## Filtration: -

Filtrating water after collecting is important because the rain is polluted the dust particles and also by factories emissions. Filtration also increases the quality of collected rain water. It can also prevent many diseases. Also, the first flush of water should be removed which is the first collected amount of water as it is mostly contaminated and contain pollutants.

## Isolation: -

The tank and the pipes should be isolated. Isolation prevents the collected rain water from evaporation in hot areas and also prevents it from freezing in cold areas. This can increase the efficiency of the collector and provide more water.

## Material of the collecting surface: -

The rain water collecting surface should be made of insulating materials as stainless steel to maintain the water quality and prevent it from pollution, as if the surface is made of a rocky layer or a layer that contains vegetation. It also should be made of materials that withstand high pressure so that it is not broken in places where rain fall heavily.

## Container’s capacity: -

The capacity of the container should be suitable for the amount of rain falling. So, in a place with heavy rain a large container must be used so that it does not overflow. In a place with light rain a small container should be used to decrease evaporation effect.

## Surface area of the collector: -

The collector should have a sufficient surface area to collect an enough amount of water.as the surface area of the collector increases the amount of water increases.

# prior solutions

## Roof top: -

## Project mechanism

One of the most important methods that are used to collect rainwater is the rooftop water harvesting method. it is extensively used in Latin America, Caribbean and Honduras America.

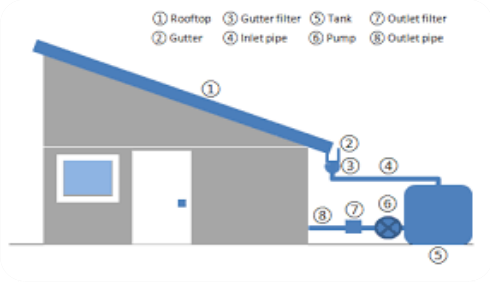



Figure (14) rooftop harvesting system

## Mechanism: -

The rooftop water harvesting system consists of collecting surface, transporting system and collecting system as shown in figure (14)

- Collecting surface: the main mechanism is to use the roof as a collecting surface of rainwater. The roof is made from hard materials to prevent the contamination of water.
- Transporting system: The water is then transported by a guttering system that is installed below the edge of the roof. The guttering system should also be kept clean to prevent water contamination.
- Filtration system: Then comes the filtration system which is an essential part to further clean the water. The last part is the storing system which is usually a tank with an isolating system.

## Advantage:

- Ease of design for the project and no dependence on expensive materials
- Purified and cleansed water by placing a water filter before it entered the tank.

- The water is not dirty due to the use of metal roof, not a rocky one.
- Cheap and predictable in performance as it is a simple system.
- Delivering water directly to households so it decreases the need of carrying water specially, for children and women.
- The system is flexible it can be built to meet almost any requirement.

## Disadvantages: -

- If the roof is thatched or made of mud and bricks as in places with high poverty the water will get contaminated when passing through the roof.
- Possible decaying of the roof if it is made of decaying of materials or not well isolated.
- The transmission of diseases transferred by vectors like rats, lizards and insects directly entering the water tank.
- The possibility of presence of dead bodies of animals on the roof causing many health problems.
- In underground water tanks the leakage of a near sewage pipe line can cause the presence of nitrite in water or water-borne disease like diarrhea and blue baby syndrome.
- The water must be filtered periodically which is hard in developing countries.

# Ground catchments

In areas with limited water resources or limited rainfall or limited water resources ground catchments are more suitable to provide water for several families or a small community. It is more practical for small communities than roof top system.

## Mechanism: -

In the simplest form of ground catchments, the surface is simply cleaned and smoothed. Natural compacted clay soils are considered good surfaces for catching water, because they need little treatment to close their pores. Cement can also be used to reinforce the collecting surface as shown on figure (15). The catchments surface must have a proper slope to ensure continuous run-off of water and minimum loss of water in evaporation or transmission as shown in.

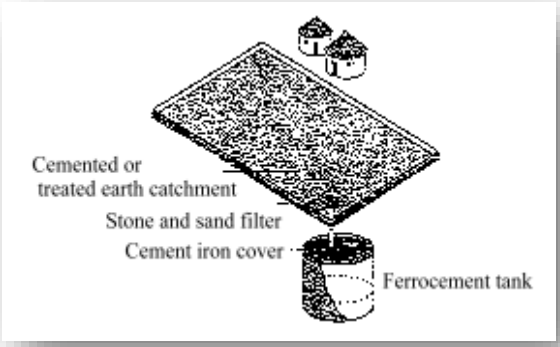



Figure (15) cement enforced ground catchment

The water is then collected in a tank underground and then retrieved by hand or by a power pump. The tank should be isolated to prevent evaporation of water inside the tank.

## Advantages: -

- It has a larger catchments area so it can collect a good amount of water with little rain fall.
- It is more useful for a small community rather than individual systems like roof-top system.

## Disadvantages: -

- Ground catchments are generally more difficult to design.
- Building ground catchments need skilled labor.

- High cost of installing an underground tank also it needs to be reinforced and a pumping system should be installed.
- If there is a crack in the tank its maintains can be very hard.
- Possible contamination of water during its flowing on the sloping surface due to animal wastes or corpses of small animals.

# Rainwater harvesting in situ brazil

In arid and semi-arid areas where the precipitation is low or infrequent in dry seasons, rainwater must be collected in wet seasons in sufficient amounts, especially for domestic and agricultural use.

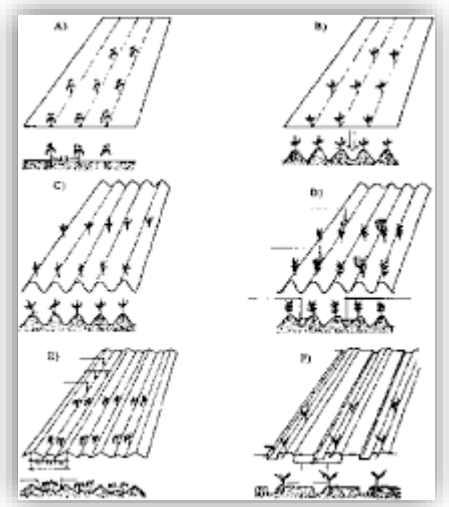


Figure (16) showing the process of building furrows in the land

In areas that have a low topography is best for in situ harvesting. this method is used in arid and semi-arid areas in northeastern Brazil, Paraguay and Argentina. It is mainly used in irrigation.

## Mechanism: -

Any rain collector has a collection area, conveyance system and collecting facility. The collection and storage are provided within the landscape where the agricultural land is designed in a way that allows rainwater collection and the depression of land prompts collecting rainwater. The land is served by distribution canals that transfer water from storage area to area of use as shown in figure(16) In most cases, the land is impermeable as it is underlain by clay soil that minimizes infiltration. The collection and storage area must have a fence to protect water from contamination by animals.

This method also is usually combined with clay tanks. the rainwater is delivered from in situ rainfall collection area to the storage tank.

## Advantages: -

- It requires minimal additional labor
- The flexibility in construction as furrows can be constructed before or after planting
- In permeable lands, it can renew the groundwater
- It is compatible with agricultural practices.
- It does not require expensive maintenance as it is periodically done during everyday agriculture by removing vegetation from canals
- It is cost-effective as digging canal does not require much money

## Disadvantages: -

- It is not suitable in every place as it needs land with a suitable slope
- Areas which contain rocks or trees must be cleaned and trees must be removed.
- The effective of storage is low because water might evaporate between periods of rain falling

# Runoff collection from paved and unpaved roads

It is a technology used in Argentina and Brazil where they have a semi-arid climate with the amount and frequency of precipitation is small and variable. So, it is important to capture the runoff water for later use.

## Mechanism:

Paved and unpaved roads tend to drive water to their edges water to their outside edges because they are cambered. The runoff can be captured in underground tanks or dams. the components include a collection area, drainage system, storage area, and distribution system as shown in figure(17). The run-off water can then be used to irrigate trees along the roadsides.

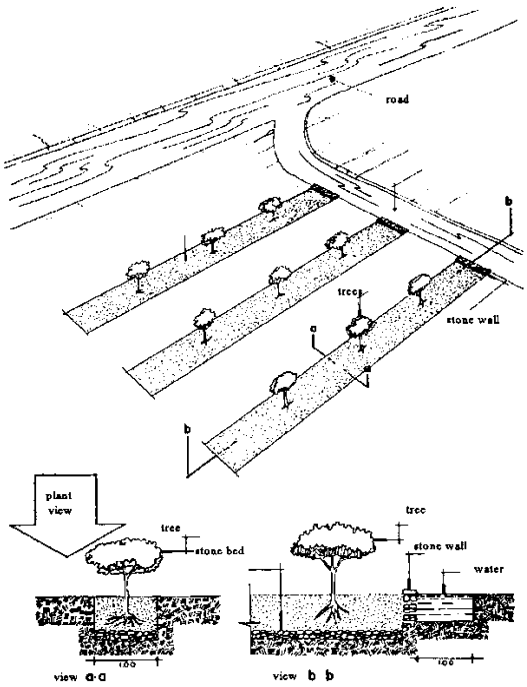



**Figure (17) Shawn Runoff collection from paved and unpaved roads mechanism**

## Advantages:

1)It has a simple mechanism and the cost of constructing the project is relatively low

2)it can enable cultivation in arid and semi-arid areas

3)its maintenance does not require much money and is fairly easy

## Disadvantages:

1) Plants may require irrigation from another source during dry periods
2) The water quality is low and can become contaminated from the wastes on the road
3) The water can not be used for drinking purposes as it has a very low quality

# CH.2
# Solution Requirement

## Location

A study must be conducted to find a suitable location for building the rainwater collector. A suitable location is a location that has continuous rain throughout most of the year or at least has enough amount of water falling to satisfy the consumers need.

The location of the collector should be in a shaded area or an area that does not have direct sunlight hitting it, especially in hot regions. If the area is very hot a cover should be constructed for the collector. The reason for avoiding direct sunlight is to avoid the evaporation of water collected and to maximize the amount of collected water.

## Selection of location

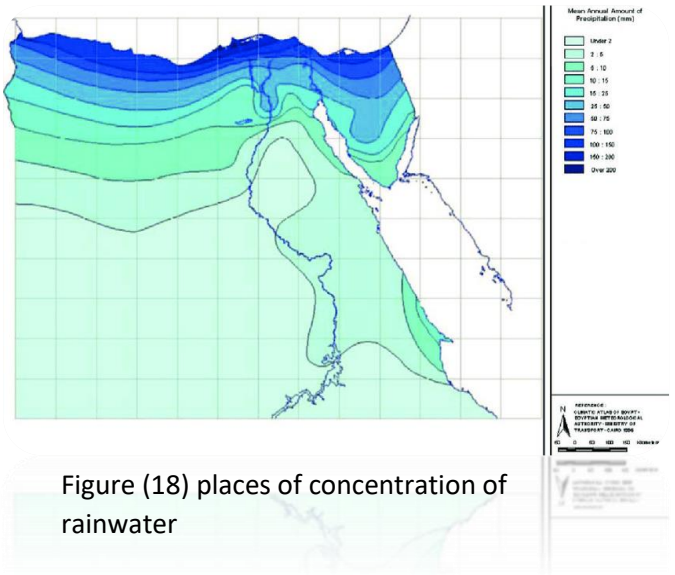


Figure (18) places of concentration of rainwater

Rainfall in Egypt is very scarce and falls mostly in winter in the form of scattered showers. The rain is concentrated in the northern part of Egypt and decreases in the southern part of it as shown in figure (18). The places that get the most rain is the north coast especially Alexandria and parts of the Red Sea. So the best place to place the collector will be in one of those places.

## Sustainability

The sustainability of the materials used in the prototype should be researched. Also, its effect on the natural system and the environment. Eco-friendly material is preferred to be used. Also, greenhouse emissions during the construction of the prototype can be reduced by using modern technology. Some alternative materials like bamboo tubes would also be a choice.

# The cost

The cost is an essential aspect of the collector. The cost of the collector must be moderate and the quality of the collector must not be affected. The collector could be made of local materials so that the cost does not increase by importing materials. The expensive material should be changed with cheaper local materials while taking into consideration the quality of the materials. A project with a low-cost will be easier to implement on a large scale and will be suitable for most people.

# The quality

While working on a specific project, the quality of the materials used must be taken into consideration .Because the damage of a part of the collector can affect the other parts or the collector as all.

The quality of the material used to make the collection system is very important. If poor materials are used this might lead to the contamination of the water. So, metallic or plastic collection systems are generally better. Also, the material used to make the tank should be durable and hard to prevent the leakage of water.

# Distribution system

The effectiveness of the collector is greatly affected by the distribution system the energy can be saved by using the potential energy of the water as shown in figure (19). The collector should be placed in a high place so that the water is transferred by potential energy to the collector. This decreases the needed energy to pump water to the collector.

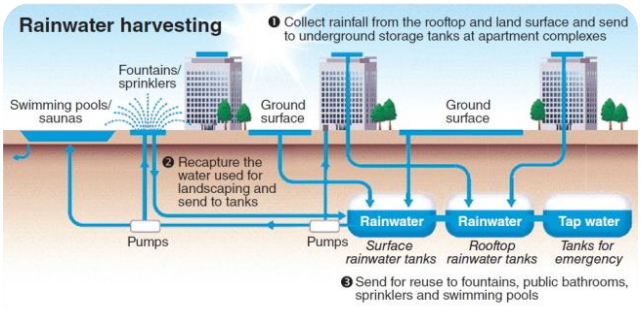



Figure (19) Pumping water by potential energy

The effectiveness of the collector is greatly affected by the distribution system. The energy can be saved by using the potential energy of the water as shown in figure (19). The collector should be placed in a high place so that the water is transferred by potential energy to the collector. This decreases the needed energy to pump water to the collector.

# Availability: -

The materials used to make the prototype should be available worldwide. This will make it easier to implement the project in any place and will also reduce the cost of constructing the project.

# Filtration

Rainwater harvesting system distributes water for many purposes like washing clothes, toilets' flushing and drinking. Some processes as washing clothes and toilets' flushing need a minimum sterilization process as using chlorine which is the classical way. Drinking requires a higher level of sterilization as rainwater is objected to many ways of pollution as dust which may be collected by rainwater and end up in the tank or container. The filtration system is especially important in Egypt because the rainwater is polluted by factories emissions and generally has low quality. Also, the first flush of water should be removed which is the first collected amount of water.

# Design Requirements

**Achieving the maximum rate of collecting water:** that means the collector has to collect the maximum amount of water in the shortest time. Where a shower is placed 1.5 meters above the collector. the time needed to collect 200ml, 400ml, 600ml, 800ml and 1000ml is collected. This data is represented in a graph and the rate of collection in ml/min is measured.

**Minimizing the materials used:** the materials must be decreased as possible by weight. All the used materials must be calculated. The weight must be decreased as much as possible. The attempts to decrease the materials of the prototype must be declared and shown.

# Selection of solution

Lack of water resources leads to the concentration of people around the Nile which is the primary source of water in Egypt. This lead to the problem of urban congestion where the mass of the Egyptian population is concentrated around the Nile. People cannot move away from the Nile because most of the other lands are arid. So, the root of the problem which is the lack of water should be solved. Reclamation processes of arid areas could be possible if a new water resource is used. After research, there were two water resources: groundwater and rainwater. Rainwater was preferred because it was generally cleaner and easier to collect.

The solution is to build a rainwater collector in the shape of a hexagonal frustum and through achieving the design requirement of collecting the maximum amount of water in the shortest time the problem can be solved and a new water resource will be introduced. This will provide the ability of the reclamation process of arid areas and constructing new lands so people can migrate away from the Nile solving the problem of arid areas and urban congestion.

# Selection of prototype

## The angle of slope

the angle is 45 degrees it was chosen to increase the speed of water where the slope of the angle and the speed of water are in direct variation. So, by increasing the angle to 45 degrees the speed of water will be suitable. The chosen angle did not exceed 45 degrees so that the area of the base of the collector does not decrease which will lead to a loss in water.

## Shape

The chosen shape is a hexagonal frustum where it has a hexagonal base. The hexagonal base is suitable because the hexagon is a compacted shape so it has a high area to perimeter ratio. This is very important as it has a large surface area that water can fall into relative to a small perimeter. This with increasing the speed of water because of the 45degrees angle will lead to collecting the greatest amount of water in the shortest amount of time.

# Dimensions

The dimensions were calculated by using the given area **0.36 m2**, the slope angle **45º,** knowing that the total area for the hexagonal pyramid is **0.36** $\boldsymbol{m^2}$ and using learning outcome from mathematics. From that and by using some mathematical calculations the dimensions will be as follows: Lengths of the two bases of one face are **31.5 cm** and **3.6 cm**, the height of one face = and depth = **25.5 cm**.

# Materials

The main material used for building the prototype is craft sticks. The craft sticks were glued together by using yellow PVA glue (carpenter's glue) where it is a very strong glue used for gluing wood and also it causes the least expansion in craft sticks. Pu sealant was used to stick the faces of the prototype together where it is water-resistant and easy to use. Then the prototype was covered with a coating material which is kemapoxy 150. It is a coating material that can withstand acids like acidic rain. Also, it has numerous mechanical advantages and does not easily react with other chemicals.

# CHAPTER:3

# Materials: -

| Name | Quantity | Description | Image | Cost |
|---|---|---|---|---|
| Craft Sticks | 10 Boxes | They are made of wood where they are 1.7 cm wide, 15cm length and 0.1 cm thick |  | 10 L.E. |
| Yellow PVA | One | Yellow PVA is the adhesive material that joins craft sticks together. |  | 20 L.E. |
| Polyurethane Caulk | One | PU caulk is the adhesive that is used to glue the faces together. |  | 40 L.E. |
| Kemapoxy150 | One | Kemapoxy150 is the coating material that is used to protect the craft sticks from water, etc. |  | 190 L.E. |
| Rough and Smooth wood sandpaper | One - One | It is used to make the edges and the body of the sticks smooth. |  | 10 L.E. 5 L.E. |
| Hardpoint Tenon Saw Straight Handle Serrated Normal | One | It was used to cut the craft-sticks rectangular faces into trapezoidal faces of the prototype. |  | 35 L.E. |
| paintbrush | One | It was used to cover all the prototype with kemapoxy150 |  | 10 L.E. |

# Methods

## Section one: Preparation

Figure (20) shows the craft sticks after cutting.

**1st Step:** The round edges of the craft sticks were cut by the scissors and the body of the stick was glazed as shown in figure (4).

**2nd Step:** Many samples were made to try the glue and the coating material which helped to choose the suitable materials for each use as shown in figure (5).

Figure (21) shows a sample for the materials.

**3rd Step:** The sticks were glued together by the yellow PVA to form rectangular faces **40x60cm**, where some sticks are put as horizontal rows and another layer with vertical rows of sticks.

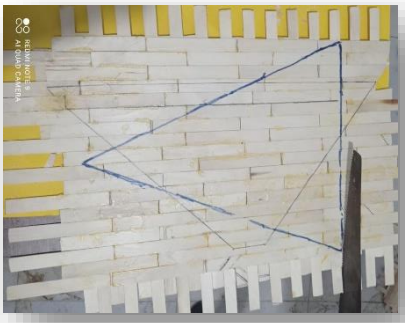


Figure (22) shows a rectangle face which was cut in a triangle face

## Section two: Execution

**1st Step**: Rectangular faces were cut into triangles with dimensions **31.5cm** base and **38.6cm** height as shown in figure (21).

**2nd Step:** The produced triangles were cut into trapeziums with dimensions **31.5cm** and **3.6cm** bases and **34.09cm** height by removing a small triangle with an area **$8.33cm^2$** that makes the area of each resulted trapezium = **$600cm^2$**.

Figure (23) shows the faces after putting them together by PU sealant.

**3rd Step:** The trapeziums were made smoother by using sanding papers.

**4th Step**: The trapeziums were put together and then glued to make the hexagonal pyramid frustum by the PU sealant **figure (22).**

**5th Step:** The prototype was supported by gluing some sticks on the external of the prototype to hamper PU sealant's flexibility, then all the external of the prototype was covered by PU sealant to fill spaces between the craft sticks as shown in **figure (23).**

Figure (24) shows the supported prototype after covering by PU sealant and Kempoxy 150.

**6th Step:** The prototype was covered externally and internally by Kempoxy150 (Epoxy Risen) as shown in **figures (23) and (24**).

Figure (25) shows the internal of the prototype after covering by Kempoxy 150.

## Section three: Test plan

Our design requirement was having a high rainwater collection rate, so a small test station was made by performing these steps:

**1st Step:** A water bottle with a capacity of **1.2L** was attached to the prototype, where it had a mark each **0.2L** to facilitate indicating the time interval indicated to collect **0.2L**, **0.4L**, **0.6L**, **0.8L** and **1.0L**.

**2nd Step:** The shower, which is the water source, was attached at the height of **1.5m** above the prototype and the diameter of the shower was calculated and was equal to 6.5xcm.

**3rd Step:** The time intervals of collecting each 0.2L were calculated carefully and recorded in a sheet of paper.

## Safety Precautions:

1. Direct contact with Chemical materials like kemapoxy and PU sealant was prevented as they may be toxic.
2. Taking into consideration not to breathe harmful odors like the odors that comes out from kemapoxy.
3. Flammable materials where stored carefully to prevent fire.
4. Sharp tools like the scissors and the where used carefully and covered after usage.
5. Gloves and glasses where used for protection during the construction of the prototype.
6. Following the safety precautions of covid-19 and maintaining a safe distance during working.

# Data Collection & Results:

## Negative Results:

During the test plan, there was a problem facing us. The pressure of the shower's water, which is the water source, wasn't stable. The pressure levels were variant, odd and random, where the pressure must be a controlled variable in the test plan and must be the same during the test plan. That gave us positive results.

## Positive Results:

After correcting that mistake, the results became positive. First a quantity of 0.2L was dropped into the prototype using the shower and the time was collected. Those steps were repeated for every 0.2L until a liter was dropped. The results were competitive and encouraging for each of 0.2, 0.4, 0.6, 0.8, 1L as shown in table (1). The results remained competitive and gave an average of a liter per 29seconds as

shown in graph (1). That is due to the prototype's great way of construction. That result supports the fact that the prototype can perform good or even better in any real-life application. Also, if the people in Egypt used the prototype, the problem of urban congestion will be eradicated and solved completely

| Quantity | 1st trial | 2nd trial | 3rd trial |
|---|---|---|---|
| 0.2L | 6 ±1sec | 7 ±1sec | 7 ±1sec |
| 0.4L | 13 ±2sec | 12 ±2sec | 12 ±2sec |
| 0.6L | 18 ±3sec | 16 ±3sec | 17 ±3sec |
| 0.8L | 24 ±4sec | 21±4sec | 22 ±4sec |
| 1.0L | 31 ±5sec | 26 ±5sec | 28 ±5sec |

figure (26): shows the time taken to collect 200, 400, 600, 800, 1000ml in the two trials.


figure (27): Shows the visualization of the average time interval to collect 1liter.

# CHAPTER:4

# Analysis & Discuss

## Analysis

The analysis is one of the major aspects of any project to know the scientific background behind the chosen materials and the obtained results. Also, it helps to know the scientific concepts used in the project which will all be shown in this section.

### Prototype overview

| Percent | Degrees/min/s |
|---|---|
| 0.5 | 0°17'10" |
| 1 | 0°35' |
| 2 | 1°08'40" |
| 5 | 2°51'40" |
| 10 | 5°42'40" |
| 20 | 11°18'36" |
| 30 | 16°42' |
| 40 | 21°48'05" |
| 50 | 26°33'55" |
| 100 | 45° |

Figure (28) shows conversion of slope units from percent into degrees.

In physics, the angle of slope and the speed of water are in direct variation, so by increasing the angle the speed of water increases. To achieve the goal of collecting the maximum amount of water in the least amount of time, the suitable angle is 45$^{o}$. Because the percent of the slope at this angle is 100% as shown in table (28). Also, if the angle increased by more than 45 degrees this will decrease the amount of water collected as the base of the prototype will decrease. The reason for choosing the hexagon shape is that it is compacted, which means it has a high area to perimeter ratio. This property is especially important for our prototype. As the design requirement was achieving the maximum collection rate, so by choosing the hexagon the maximum area for water to fall into can be achieved to collect more water while reducing the material used effort and

Figure (29): shows the hexagonal structure of honey comb.

cost. This idea is symbolized in the honey comb where bees use the hexagon shape to store maximum honey with the least material used to build it as shown in figure (29). By using the angle, 45°, and given area, 0.36m$^2$, the dimensions of the prototype were measured as what will be described.

The side of the hexagonal base was named (a), the depth of the hexagonal pyramid was named (d) and the height of the side of the hexagonal pyramid was named (h).

From learning outcome (3) in mathematics, it is known that the depth (D) of the prototype with (45°) angle of slope is equal to the vertical distance from the center of the hexagon base on any side of the hexagonal pyramid. Both of them make right isosceles triangle and its hypotenuse is the height of any face of the hexagonal pyramid. All of these are shown in figure (29). From that: $h = \sqrt{d^2 + d^2} = \sqrt{2d^2} = \sqrt{2}d$

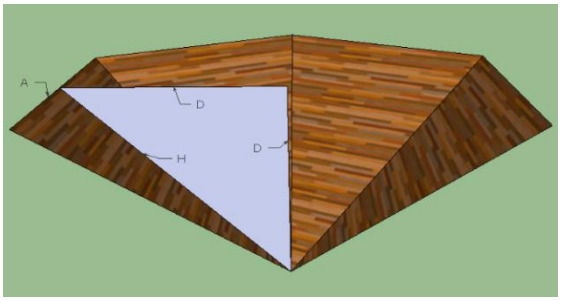



Figure (29): shows a section from 3D shape of the prototype and the given notes from studying that.

On the hexagonal base, there is an equilateral triangle whose side is equal to a and its height is equal to d. It can be concluded that:

$$d = \sqrt{a^2 - \left(\frac{1}{2}a\right)^2} = \sqrt{a^2 - \frac{1}{4}a^2} = \sqrt{\frac{3}{4}a^2} = \frac{\sqrt{3}}{2}a \quad \text{and} \quad h=\sqrt{2}d=\sqrt{2} \times \frac{\sqrt{3}}{2}a = \frac{\sqrt{6}}{2}a$$

The total area of the faces of the hexagonal pyramid frustum is 3600cm$^2$. So, the total area of the hexagonal pyramid frustum was put as 3650cm$^2$. The area of the one triangular face is $\frac{1}{2} \times a \times h = \frac{1}{2} \times a \times \frac{\sqrt{6}}{2}a = \frac{\sqrt{6}}{4}a^2$

To make the triangular face trapezoidal, a small triangle must be cut out of each face and the total area of the small triangles must be 50cm2. The height was named (k) and the base was named (f). The area of one triangular face is $\frac{1}{2}fk$ and the the total area of the triangular faces is $6 \times \frac{1}{2} \times f \times k = 3 \times f \times k = 50$ From the biggest hexagonal pyramid, it appears that. So that,

By using the calculator, f = 3.6cm and $k = \frac{\sqrt{6}}{2} f$

Knowing that the dimensions of the hexagonal pyramid frustum are expressed by both the dimensions of each trapezium and the depth of the prototype as follows: the length of each base is 31.5 cm and 3.6 cm. The height was h - k = 38.6 - 4.51 = 34.09 cm and the depth = 25.5 cm.

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# Materials Analysis

## Kemapoxy

The coating material used is epoxy coating. An epoxy coating is a compound of two distinct elements. One is epoxy resin and the other is polyamine hardener. When mixed, the resin and hardener engage in a chemical reaction that creates cross-linking of the elements as it cures, where epoxy resins are formed of the reaction of Bisphenol A with Epichlorohydrin as shown in figure (12). When it is fully cured, the resulting product is durable, rigid plastic with numerous mechanical and

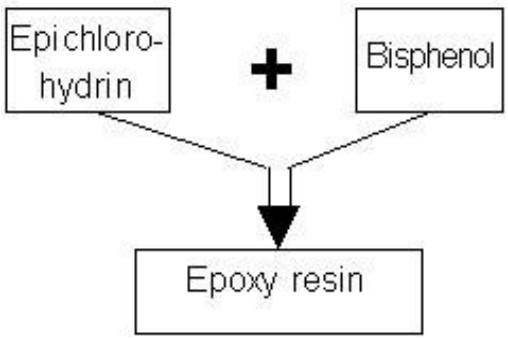



Figure (12): shows the elements forming epoxy resins.

chemical advantages. It is also chemical resistant which is an important property withstand acidic rain. It is also anti-fungus and anti-bacterial.

## Polyurethane sealant (PU)

Polyurethane is a polymer formed of the reaction of a isocyanate $(R-(N=C=O)_{n\geq 2})$ which has two or more isocyanate $(N=C=O)$ groups and a polyol $(R`-(O-H)_{n\geq 2})$ containing two or more hydroxyl group$(OH)$ as shown in figure (13)

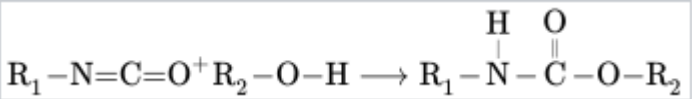



Figure (13): The general form of the reaction forming Polyurethane from two compounds, one with an isocyanate group and the other with a hydroxide group.

Polyurethane is affected by the polyol and the isocyanate forming it, where long chains give a flexible polymer and chains with a lot of cross-linking gives a rigid polymer. Polyurethane is characterized by its flexibility and a good level of rigidity as it consists of long chains with intermediate cross-linking. Also, PU is recyclable and environment friendly and it does not soften or melt by heating. It is compatible with wood, too, which makes itself one of the best choices to use.

## PVA glue

PVA is usually nontoxic thermoplastic adhesive prepared by the polymerization of vinyl acetate. PVA is a rubbery synthetic polymer with the formula $(C_4H_6O_2)_n$ as shown in figures (14 and 15). Polyvinyl acetate is a component of a widely used glue type. It refers to variously as wood glue, white glue, carpenter's glue. Yellow PVA which used is Special as it is water resistant and that made it suitable for water collection system. It is considered to be the best wood adhesive as it dries with dehydration and porous materials as wood help to fasten dehydration.

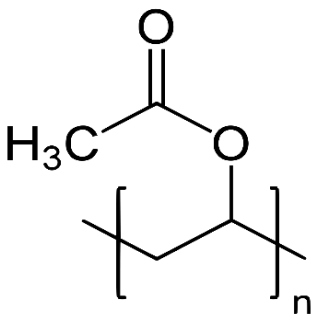
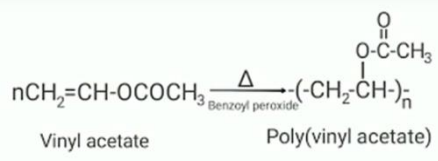



Figure (14): shows Polyvinyl acetate formula




Figure(15): shows the chemical reaction of formation of PVA.

# Conclusion

According to the results and analysis, the prototype showed high efficiency by achieving the design requirements and collected high amount of water. Also, building it with a large scale can provide the needs of each family in Egypt, which leads to solving the grand challenge.

# Recommendation

## Materials Recommendation

After completing the project testing and analyzing the results, we concluded that there are materials that can be used that may lead to a better result.

## Fiberglass

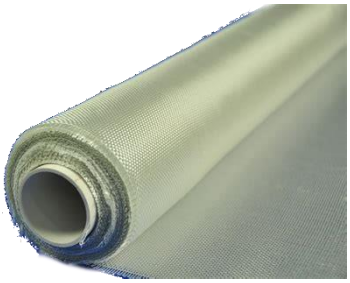


Figure (16) illustrates fiberglass.

It will be better to replace the epoxy insulation with fiberglass (illustration shown in figure (16)). It is a type of plastic that is used as a water-proofing material, which will permit collecting more water with less leakage. Fiber glass reinforced plastics are used in a wide variety of piping system applications, Firefighting systems, drinking water systems and gas distribution systems. But among the flaws, that fiberglass becomes damaged by the effect of sun and UV rays.

# Epoxy Adhesive

Epoxy (illustration shown in figure (17)) can be used as a coating material as in our prototype or as a glue, where it is water- proof and some types have very short drying intervals. It has many positive points as it is both water and solvent resistant, fills gaps and have short bonding time intervals varying from very short time intervals to 24 hours. But, its high price was a great issue preventing its use as glue.


Figure (17) illustrates Epoxy.

# HDPE

HDPE (illustration shown in figure (18)) material will be more useful than craft sticks, as the craft sticks are made of wood and absorb water, on the other side (HDPE) is a water-resistant material. HDPE (High Density Polyethylene) has many positive points as they are safe for drinking water, characterized by long-term reliability, resists corrosion, deposits, flexible during speed installations and is both lightweight, easy to transport and healthy, where most milk bottles are made of it.

Figure (18) illustrates HDPE.

It is recyclable, environment-friendly and suitable for a roof-top collector, due to its heat resistance. In spite of the advantages of HDPE, it is still harmful to humans. But it is the best type of plastic to use as it has the least damage among other types of plastic.

## Real-life Application

In Egypt, the recommended region for the rain collector is the North Coast. It is the place with the largest rainwater fall rate, which is 200mm/year. It was recommended to have a rainwater collector above each roof. An individual person in the north cost uses around 47 liter per day and the average number of people per household 4.1 person. the rainwater collector should collect 192.7 liter to suffice the needs of the house. If rain will last for 5 minutes with the quantity not changing and the rain not stopping, the hexagonal pyramid frustum must collect 38.54 liter per minute. The prototype, which collects approximately 2 liters per 1 minute must get bigger to collect 47 liter per minute. This will happen by multiplying the prototype dimensions 19.27 times. So, the resulting dimensions are 6.07m for the large base, 0.6937m for the small base and around 6.56915m height. The resulting area for the collector is around 266.59$m^2$.

| LO | Key Concepts | Content | Related |
|---|---|---|---|
| MA.1.02 | *The scatter plot. | That LO gives a presentation to the various ways of representing and visualizing data. Also, it gave good way to perform some calculations in order to analyze those data. | Studying that LO was essential for making a scatter plot for the results of the test plan and to calculate the average result, which maintains the accuracy of the results. |
| MA.1.03 | *3D objects. | That LO gives a great entry for studying 3D shapes and knowing the relationship between 2D and 3D shapes by studying both rotation of 2D shapes and cross-sections of 3D shapes. | That L.O. helped to collect important information about the structure of the prototype. |
| MA.1.04 | *Similarity.<br>*Proportionality. | That LO introduces the concept of similarity and how similar shapes are related to each other. Also, it gave useful theorems for determining the similarity of some important polygons like triangles and regular polygons. | Similarity helped to determine the real dimensions of the prototype and to make the dimensions corresponding to the dimensions of the prototype. |
| MA.1.05 | *Area | That LO introduces the mechanism of calculating the area and volume of any figure, especially the composite figures. | This L.O. helped to calculate the area of the prototype and to maintain it under the $0.36m^2$ limit. |
| PH.1.01 | *International system of units.<br>*Measurement errors. | That LO introduced the principles of physics by first introducing physics as an experimental science and determining the bases of experiments from choosing the right units and maintaining the accuracy of the results. | This L.O. helped to make our units SI units, which ensured the agreement of our project with the scientific basis. It also helped to calculate the error of our prototype and to repeat the test plan with calculating the average. |
| CH.1.01 | *Relations between variables. | That LO introduced the principle of science by first defining the way of scientific thinking and then gave the principles of experiments from choosing the right units and maintaining the accuracy of the results passing by significant figures. | That L.O. helped to make the independent variables of the test plan constant to achieve precise and accurate results. |
| CH.1.05 | *Nomenclature of alkanes. | That LO gave an introduction to an important branch of chemistry, which is the "organic chemistry" by introducing the way of naming alkanes and the study of cis, trans and isomers. | That L.O. helped to understand, analyze and study the complex equations of the formation of PU and kemapoxy. |

| | | | |
|---|---|---|---|
| EN.1.02 | *Writing as the key of expressing thoughts. | That LO introduced writing as the key of expressing thoughts, ideas and explorations by tying it to STEM subjects. | That L.O. helped to write academic English as it is the suitable type for research projects. |
| CS.1.01 | *Sketchup, Structure, tools, and Styles.<br>*3D design | That LO gave the key of 3D modeling using sketch up through studying most of its tools, properties and menus. | 3D design helped to make the structure of the prototype obvious for further study and easier to share. |
| SS.1.04 | *Topography of Egypt.<br>*The Nile Valley.<br>*The strategical advantage of Egypt's surface. | That LO gave a complete picture of the shape of earth's surface and the relation between the shape of earth's surface and its relation to some properties related to the residents. | This LO helped us to know the percentage of the River Nile's water from Egypt's share of water and the places that the Nile River does not reach. |

## Literature Cited:


Serway, R. A., & Vuille, C. (2011). *College Physics (9th ed.).* Cengage Learning.

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Akindoyo, J. O., Beg, M. D. H., Ghazali, S., Islam, M. R., Jeyaratnam, N., & Yuvaraj, A. R. (2016). *Polyurethane types, synthesis and applications – a review. RSC Advances, 6*(115), 114453–114482. https://doi.org/10.1039/c6ra14525f

---

ABDEL-SHAFY, H. I., EL-SAHARTY, A. A., REGELSBERGER, M., & PLATZER, C. (2010). *Rainwater in Egypt: quantity, distribution and harvesting. Mediterranean Marine Science*, 11(2), 245. https://doi.org/10.12681/mms.75

---

Helmreich, B., & Horn, H. (2009). *Opportunities in rainwater harvesting. Desalination*, 248(1–3), 118–124. https://doi.org/10.1016/j.desal.2008.05.046

Meera, V., & Ahammed, M. M. (2006). *Water quality of rooftop rainwater harvesting systems: a review. Journal of Water Supply: Research and Technology-Aqua*, 55(4), 257–268. https://doi.org/10.2166/aqua.2006.0010

---

El Araby, M. (2002). *Urban growth and environmental degradation*. *Cities*, *19*(6), 389–400. https://doi.org/10.1016/s0264-2751(02)00069-0

---

Gad, W. A. (2017). *[PDF] WATER SCARCITY IN EGYPT : CAUSES AND CONSEQUENCES | Semantic Scholar*. SemanticScholar.Org. https://www.semanticscholar.org/paper/WATER-SCARCITY-IN-EGYPT-%3A-CAUSES-AND-CONSEQUENCES-Gad/b6bef76cb00f96dd65def3c892bcf030de164dd4

---

Abdel-Shafy, Hussein. (2002). Water issue in Egypt: Resources, pollution and protection endeavors. Central European Journal of Medicine. 8. 1-21. https://www.researchgate.net/publication/299579941_Water_issue_in_Egypt_Resources_pollution_and_protection_endeavors/citation/download

---

Allam, M. N., & Allam, G. I. (2007). Water Resources In Egypt: Future Challeges and Opportunities. *Water International*, *32*(2), 205–218. https://doi.org/10.1080/02508060708692201

---

Gado, T. A., & El-Agha, D. E. (2019). Feasibility of rainwater harvesting for sustainable water management in urban areas of Egypt. *Environmental Science and Pollution Research*, *27*(26), 32304–32317. https://doi.org/10.1007/s11356-019-06529-5

---

Organization of American States. Unit of Sustainable Development and Environment, United Nations Environment Programme. Water Branch, Organization of American States. Unit of Sustainable Development and Environment, UNEP International Environmental Technology Centre, & United Nations Environment Programme. Water Branch. (1998). *Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean*. UNEP.

---

Zumdahl, S. S., & Zumdahl, S. A. (2013). *Chemistry* (9th ed.). Cengage Learning.

---

Anwar, W. A. (2003). Environmental health in Egypt. *International Journal of Hygiene and Environmental Health*, *206*(4–5), 339–350. https://doi.org/10.1078/1438-4639-00230

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# THANKS