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Chapter 1: Present and justify a problem and solution requirements

Introduction

The entire world faces many challenges nowadays. Humanity must strive to solve these problems as effectively as possible to save itself from such a fate. These challenges resemble walls that stop every country, especially Egypt, from progressing onward. The Egyptian government's "Vision 2030" hopes to solve these problems before the year 2030. These grand challenges are known as Egypt's Grand Challenges. **They are as shown in Figure 1.**

For instance, climate change leads to decreases in the overall amount of water, climate change also leads to increased forest fires which causes pollution. Climate change leads to the formation of arid areas, which in turn forces people to move to other farmable regions, which leads to urban congestion. Arid areas can cause air pollution due to the death of green plants, which would decrease oxygen. Urban congestion leads to increased pollution too. Urban congestion also leads to poor management of waste and a laxk of recycling which can pollute water further decreasing the amount of consumable water. From thus we can conclude that, It's clear that the grand challenges are highly affected by each other and dealing with one of them contributes to solving the other challenges. To deal with these issues, it is a must to see them as difficulties that must be worked hardon it to overcome. To do this, creative solutions to these issues must be considered and developed.

Figure 1 shows the Grand Challenges

Egypt's Grand Challenges

Address and reduce pollution fouling our air, water, and soil.

Pollution occurs when harmful substances, known as pollutants, are introduced into the environment. In Egypt, pollution is a significant concern, with the country ranked 27th out of 117 cities surveyed for pollution levels. This high ranking highlights the severity of the issue in Egypt. For instance, New Cairo alone ranks 507th among the world's most polluted cities, with its pollution levels increasing by over 67% in the past two years. Cairo's pollution problem is not new; in fact, it was recognized as the most particulate-polluted city globally back in 2009, as reported by the World Bank (nd), **as shown in Figure 2.**

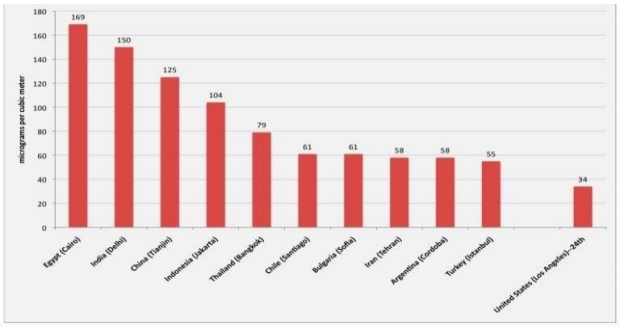

Figure 2shows the most polluted cities in the world

Pollutants in Egypt can be classified into two types, natural and unnatural. Natural pollutants include earthquakes and hurricanes. Unnatural pollutants include human beings and wastes from factories. These harmful substances affect the environment terrribly. Industrial production and commercial service will be found as the main solid pollutants with 41.4% and the oil industry accounts for 14.1% of pollutants (EEA, 2017) **as shown in Figure 3.**

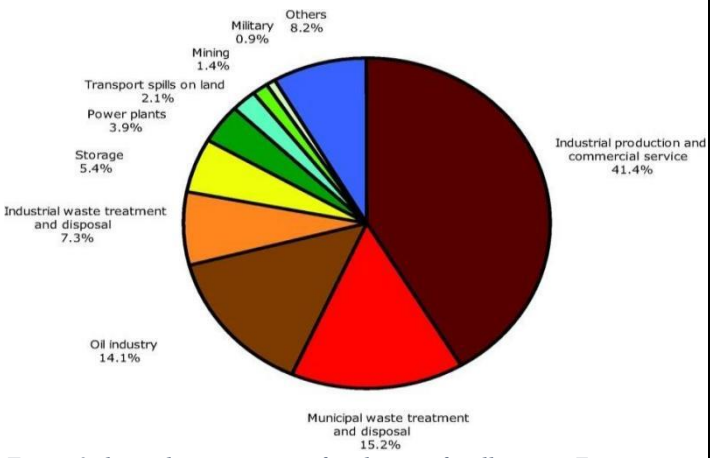

Figure 3 shows the percentage of each type of pollution in Egypt

When talking about air, Egypt will be found in 27th place in air quality among the world countries in 2021, for example, in 2019, Egypt was experiencing "Moderate "air quality with a US AQI reading of 63.

Not all pollution is air pollution as Egypt also suffers from soil pollution. Agriculture soil in Egypt suffers from a big problem which is represented in chemical pesticides (EC, 2018) **as shown in Figure 4**. Also, Egypt's soil is polluted by heavy metals like the Assanahrah area which is in El-Beheira governorate. It is mostly polluted by sodium and chromium elements.

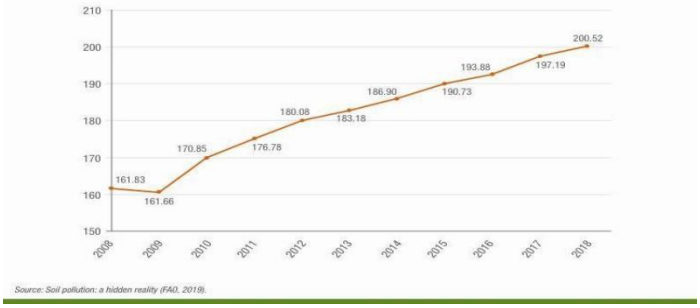

Figure 4 shows fertilizers consumption per year

Causes:

Industrial wastes:

Industrial wastes are the wastes that are made from industrial processes. The types of industrial waste are cafeteria garbage, dirt and gravel, concrete, and other things. It is estimated that 60 million tons of solid waste are made by Egypt every year. Only 30 to 60 % 0f wastes are collected while the others are thrown without treatment.

In rural areas, there are not much of landfill sites, as the place, there is an agricultural one owned by the farmers so the wastes there are not treated.

Greenhouse gases:

Due to the burning of fossil fuels, harmful gases are produced that have severe effects on the environment. These gases, which include methane, carbon dioxide, and nitrous oxide, are known as greenhouse gases. Egypt relies heavily on fossil fuels, which account for approximately 90% of the country's energy production, to power factories and large organizations. Additionally, the use of coal for electricity generation in many factories has increased the concentration of greenhouse gases. **As shown in Figure 5**, carbon dioxide has the highest percentage of greenhouse gases in Egypt's atmosphere at 72%, followed by methane at 19%, and nitrous oxide at 9%.

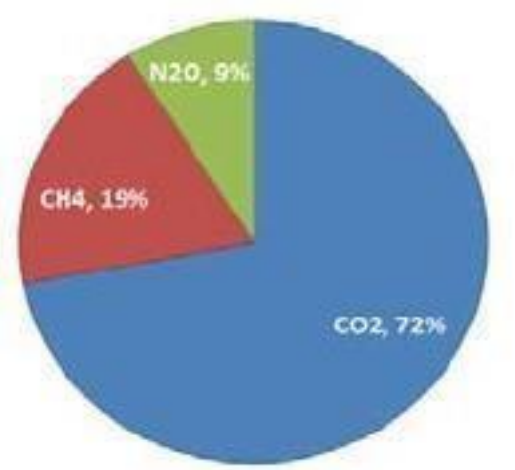

Figure 5 shows the percentage of greenhouse gases in Egypt's atmosphere

Traffic congestion:

Traffic congestion is a primary contributor to pollution in urban areas. The constant idling of vehicles in crowded streets leads to the emission of harmful pollutants, including gases and particulates, which degrade air quality. Among the pollutants released are nitrogen dioxide, carbon monoxide, and particulate matter, all of which stem from the combustion of fuel in vehicles. Traffic also generates significant noise pollution, impacting residents' quality of life in congested cities. According to studies, cars are the largest source of these emissions, producing 56% of polluting gases, followed by motorcycles at 26%, and trucks and tractors at 15% (Moussa, 2022). Prolonged traffic congestion not only increases fuel consumption but also raises the concentration of pollutants in the air, worsening health risks for city dwellers.

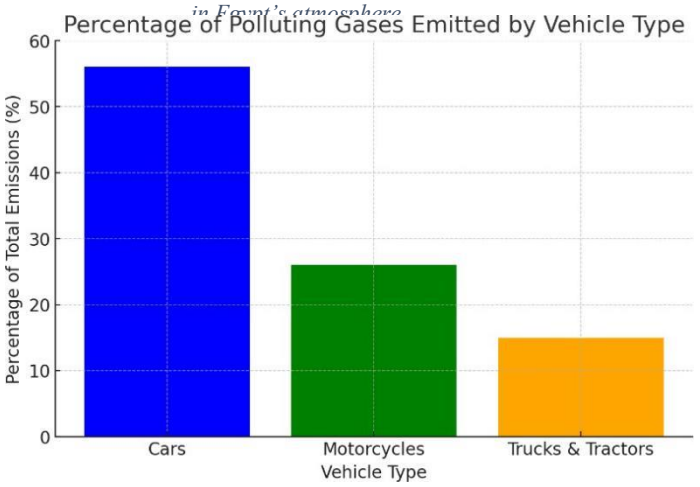

Figure 6 Percentage of Polluting Gases Emitted by Vehicle Type in Urban Traffic.

As shown in **Figure 6**, cars, motorcycles, and trucks and tractors vary in their contributions to polluting emissions.

Impacts:

Reduced water quality

Studies show that about 17,000 children die every year from diarrhea. One reason for that is the water drunk quality. A study made by the Health Ministry showed that half a million people in Assiut drink water that was unfit for humans. In 2007 water in a village, in North Giza, became so dark that 79% of the families couldn`t find clean water sources. The types of water in Egypt through the few previous years are shown in **Figure 7.**
(Tawfik, 2018)

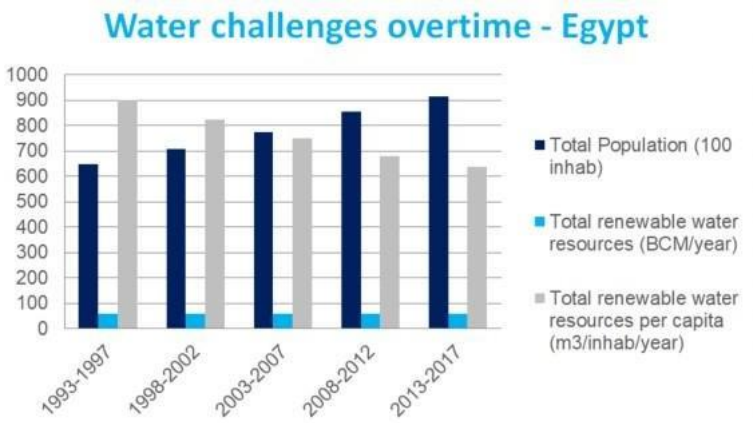

Figure 7 shows the challenges that face water over time in Egypt

Deterioration of public health

Pollution in Egypt has significantly impacted public health, with an average life expectancy of about 72 years being affected by high levels of air pollution from traffic congestion and industrial emissions. People exposed to pollutants from traffic and factories due to fossil fuel burning face increased risks of serious health issues, including respiratory problems, cardiovascular disease, and lung cancer.

Long-term exposure to air pollution is particularly harmful, as it can lead to chronic respiratory diseases like asthma and chronic bronchitis, as well as heightened risks of lung cancer and heart disease. Short-term exposure, on the other hand, can cause more immediate symptoms such as coughing, shortness of breath, and eye and throat irritation. While short-term effects are often temporary, long-term exposure results in cumulative and sometimes irreversible health damage, especially for those with preexisting health conditions.

The constant presence of traffic congestion exacerbates these issues, as vehicle emissions continuously contribute to high levels of pollutants in urban areas, putting fragile populations at an even higher risk of serious health complications.

Climate change

Pollution is a significant contributor to climate change, primarily due to the emission of greenhouse gases such as carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). These greenhouse gases trap heat in the atmosphere, creating a "blanket" effect known as the Greenhouse Effect, which leads to an increase in the Earth's temperature. Since the late 19th century, the global average surface temperature has risen by approximately 1.1 degrees Celsius (°C), representing an approximate 8% increase compared to the pre-industrial average temperature. This rise in temperature has far-reaching consequences for ecosystems, weather patterns, and human health.

Acid Rain

Acid rain is any kind of precipitation that contains high levels of acids with a pH level between 4.2 and 4.4, while normal rain has a pH of 5.6. Acid rain is caused by sulfur dioxide (SO_2) and nitrogen oxides (NO_x) when they are emitted into the atmosphere and carried by wind currents. The SO_2 and the NO_x react with water (H_2O), oxygen (O_2), and other substances in the atmosphere, forming nitric acid (HNO_3) and sulfuric acid (H_2SO_4), which then fall to the ground. Acid rain can kill trees, remove minerals and nutrients from the soil, and leach aluminum (Al) from the soil.

Reduce and adapt to the effects of climate change

Climate change is a global challenge that can be caused by both natural processes and human activities. While the Earth has experienced natural climate changes before, such as ice ages where average temperatures were around 8ºC, the appearance of the industrial revolution caused a significant turning point. During this period, human activities began to release harmful greenhouse gases from factories and car engines at unprecedented levels, increasing the temperature of the planet. As a result, climate change has transformed from a natural phenomenon into a pressing issue that demands fast action.

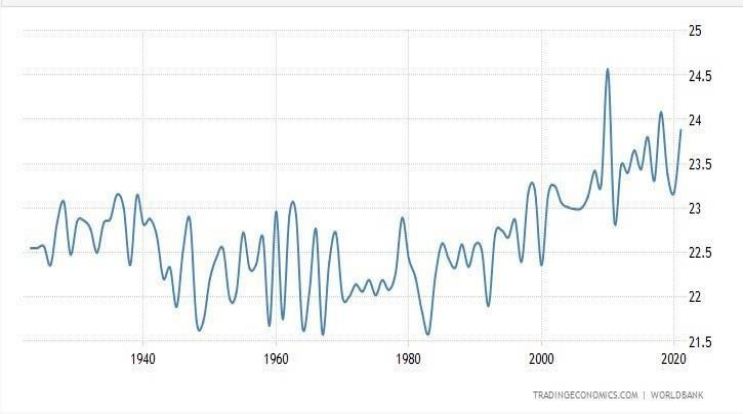

Figure 8 the change in the average temperature in Egypt

In Egypt, the consequences of climate change are increasingly obvious, with rising temperatures and shifting weather patterns leading to severe impacts, as shown in figure 8. According to UNICEF, average annual temperatures in the region have risen by approximately 0.53 degrees Celsius per decade. This increasing warming contributes to more frequent and intense heat waves, as well as dust storms along the Mediterranean coast, endangering both human health and agricultural activities. Furthermore, projections for the twenty-first century indicate that the flow of the Nile River may deviate by as much as 50 percent due to climate change, resulting in a heightened risk of floods. These changes will cause significant threats to water security, food production, and the livelihoods of millions of Egyptians. To fight these challenges, it is important for governments, organizations, and communities to work on strategies for mitigation and adaptation, ensuring a sustainable future in the face of a changing climate.

<u>Causes:</u>

Generating electricity

Egypt generates a big quantity of energy. Egypt produced about 183,475,540 MWh (megawatt-hour) in 2016 (Worldometer, nd.). Most of the produced electricity in Egypt pollutes the Environment and has many harmful impacts. 22% of it is produced from oil, and about 19% of the produced energy is from gas and other types of electric sources (Gokcek, 2010) **as shown in Figure 9.** Generating electricity from gas, oil, coal, etc. harms the environment and affects climate change. That's because this type of produced energy causes large greenhouse gases such as carbon dioxide, methane, and other greenhouse gases.

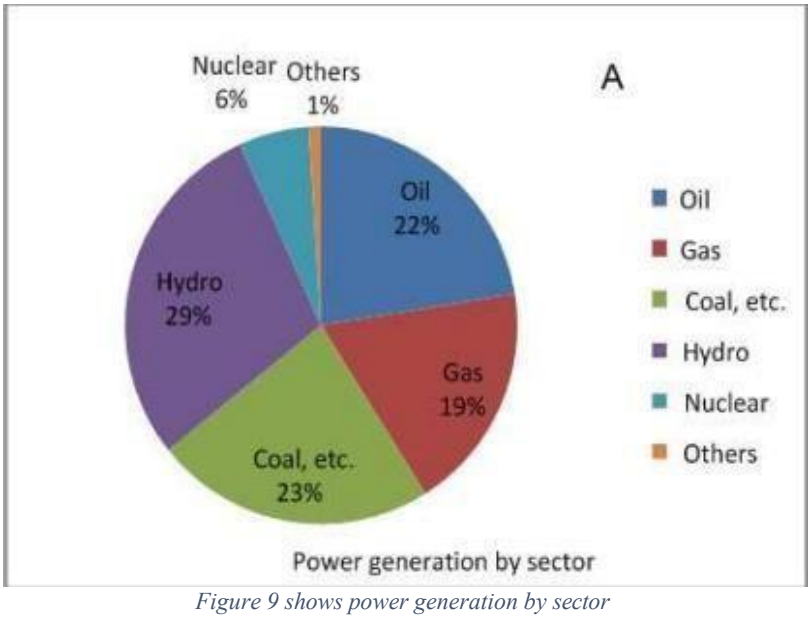

Figure 9 shows power generation by sector

Increase the number of private transportation methods

There are two types of transportation. The first one is public transportation. Public transportation is less harmful than private transportation not because it consumes less fuel than private cars, but it is because in public transportation such as public buses the number of passengers in the bus is less than the number of passengers in one car. Transportation in private cars represents 63% of types of transportation (Samaha & Mostofi, 2020) **as shown in Figure 10.**

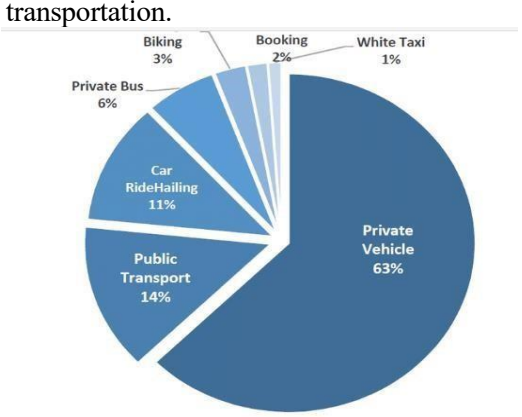

Figure 10 show types of transportation in Egypt

Using nitrogenous fertilizers

Climate change has many reasons, one of which is the use of fertilizers. Egypt used about 473.4 kilograms per hectare in 2020 (Knoema, nd.). The gases emitted from nitrogenous fertilizers include ammonia (NH_3), nitric oxide (NO), and nitrous oxide (N_2O). Nitrous oxide is one of the most harmful gases to the climate, representing 4% of the harmful gases in Egypt, as shown in Figure 11. Nitrous oxide (N_2O) is 256 times more effective at trapping heat than carbon dioxide (CO_2).

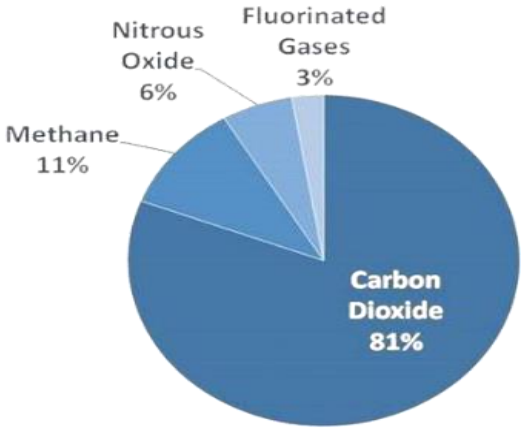

Figure 11 shows the percentage of harmful gases in Egypt

Greenhouse gases

The greenhouse effect is one of the leading causes of climate change. This phenomenon involves the trapping of heat in the Earth's atmosphere and is caused by gases known as greenhouse gases. These gases include carbon dioxide (CO_2), chlorofluorocarbons (CFCs), methane (CH_4), and nitrous oxide (N_2O). In 2021, CO_2 emissions for Egypt were 259.3 million tonnes. Notably, approximately **20% to 25%** of Egypt's total greenhouse gas emissions come from vehicles, highlighting the significant impact of the transportation sector. Greenhouse gases are emitted by cars, factories, and other sources, contributing to the ongoing climate crisis.

Impacts:

Agricultural change

Egypt's climate change will cause higher temperatures and decrease the percentage of rainfall, affecting the crops that grow in Egypt. By 2050, it is estimated that the food crops to be decreased by a percentage of 10%. There are many affected crops such as potatoes and maize.

Rise of sea levels

Sea level rise poses a severe threat to coastal life across the planet. Floods will occur, severe storms will be more powerful, and coastal locations will sustain damage. Both vulnerable animal regions and dense populations are regularly seen here. North coast deterioration Global warming is exacerbated by ice melting. Due to their deeper hues, the ocean and land absorb more solar energy, which they then release as heat into the atmosphere. Global warming thus gets worse. Since 1880, sea levels have risen an average of over 8 inches (23 cm), with nearly three of those inches coming in the past 25 years. The sea level increases further each year. 13.5 inches (3.2 mm.) (National Geographic, 2022) The estimated rate of sea level rise is expected to increase by a foot in 2050.

Droughts

Warmer temperatures cause more evaporation, which reduces surface water in closed seas and dries out the soil and vegetation, resulting in drought. Dry spells, therefore, linger longer than they would in cooler weather. Climate change is also affecting the timing of when water is available. It is predicted that in 2022, the average global temperature would be 1.15 [1.02 to 1.28] °C higher than it was between 1850 and 1900.

As a result, Egypt experiences less rainfall, **as depicted in Figure 12** (Nada, 2014)

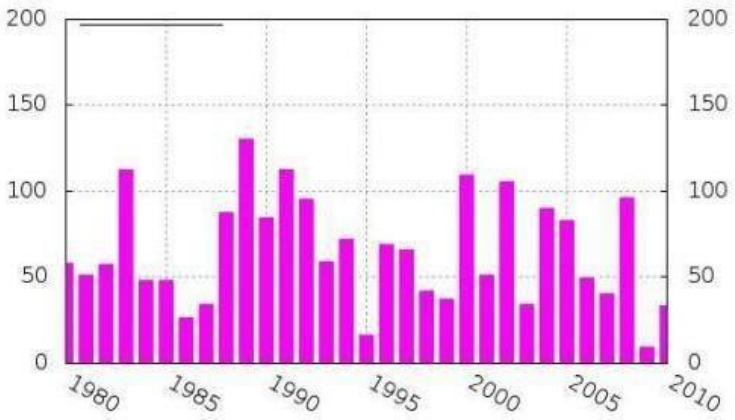

Figure 12 shows annual rainfall in Egypt

Recycle garbage and waste for economic and environmental purposes.

Waste management has become a major concern since few years ago. Egypt produces a tremendous waste **as shown in Figure 13**. Consequently, Egypt produces 90 million tons of solid waste annually and 20 million tons of which are municipal or agricultural solid waste. The amount of municipal waste of the governorates of the Republic was up to 76.6 thousand tons per day. The recycling problem was occasioned by obstacles in recycling projects and processes. Recycling process includes many steps: it starts with collecting garbage, sorting, preparing garbage for the initial recycling phase, and

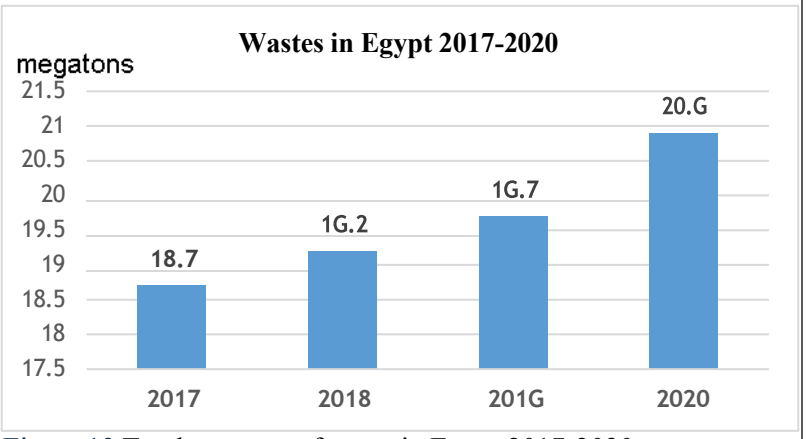

Figure 13 Total amounts of waste in Egypt 2017-2020 (megatons/year).

treatments. The last step is to turn garbage into usable materials. Some recycling gaps and problems cause lack in our need for new raw materials and reduce our consumption of energy materials, which have a significant impact on the environment.

Achieving sustainability and conserving materials, it will be assured that environment will regain its balance. Solid waste is the major known waste in addition to canals and drains waste, municipal waste, demolition and construction waste, and industrial waste. According to a report issued by the Information Center calls for a decision to be taken by the Council of Ministers shows that the percentage of solid waste in Egypt equals 22 million ton to 25 million ton every year and 50 thousand to 76 thousand per day nationwide. The reason for this is that solid waste includes many types of other wastes that share different percentages of total solid waste.

Causes:

Poor waste management

Egypt suffers from low solid waste management leading to environment and health effects. There are large economic costs that are spent on the disposal of waste. This budget can be estimated to be from 30 to 75 USD per ton and the amount of garbage is estimated to be 22 million tons annually. Egypt produces approximately 90 million tons of solid waste annually that amounts to 55,000 tons daily. Municipal solid waste, considering the most influential, is around 21 million tons of total solid waste. About 47% of the solid waste is generated from four governorates (Greater Cairo Governorates) **as shown in figure 14**, but only 12% of household solid waste is recycled in addition to 81% that is randomly disposed. The remaining is disposed in sanitary landfills. More than 95 million tons of solid waste have been generated from various sectors in Egypt, but most of them was not recycled totally.

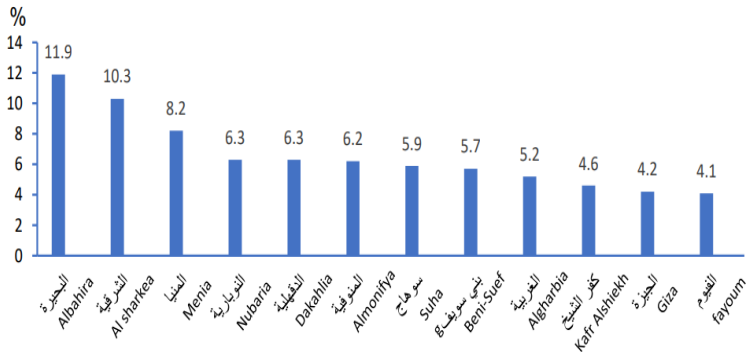

Figure 14 Agricultural waste recycling rates for some Governorates of Egypt in 2021

Unrecycled Household and Agricultural waste

Household waste is post-consumer waste that includes consumer products and household chemicals and more. With the continuous increase in population, the amount of household waste increases as generated solid waste in Egypt reached nearly 75 million tons as published by AUC (American University in Cairo) and this number of wastes can lead to a great impact on the environment and that will be costly to recycle. Eventually, the cost of solid-waste management services, which includes collection, transportation, and completion of basic waste treatment, is $35 – 150$ per ton. Agricultural waste recycling percentage for twelve governorates of the Republic ranged between 4.1% to 11.9% in 2021.

Overpopulation

Overpopulation caused a great rise for waste, making the recycling process more expensive. The rapid population growth leads to an increase for plastic waste, especially single-use products leading to a significant issue in increasing pollution. **As shown in figure 15**, Cairo has the greatest population in Egypt and the greatest amount of waste. The excessive consumption due to overpopulation is associated with an increase in energy demands. It is estimated that for each.

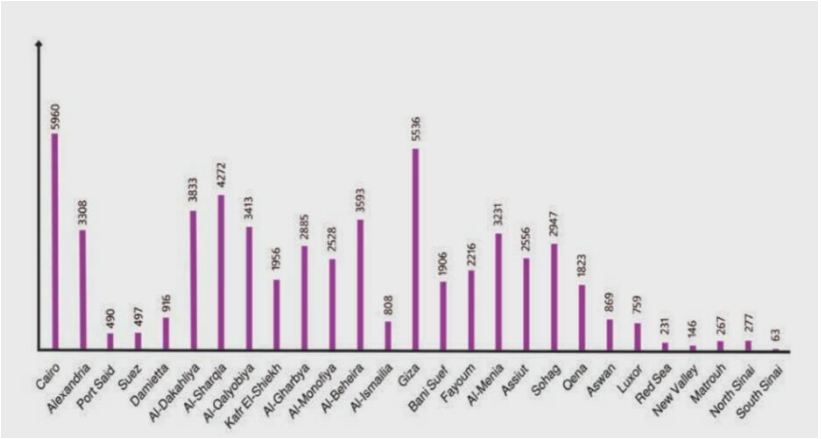

Figure 15 the amount of waste generated in Egyptian governorates

Impacts:

Greenhouse gases increasing and pollution

The Spread of waste can include dangers to the environment as involved in increasing diseases such as yellow fever and plague. In a polluted environment, the risk of infection with cancer increased to 113.4 per 100,000 population in 2020 according to WHO (World Health Organization). It is expected that the percentage of cancer will increase to 341 per 100,000 in 2050. According to this information, it can be concluded that the percentage of cancer is increased due to increasing of waste and decreasing of recycling.

Loss of valuable materials

The economic result for the lack in recycling processes is that there are many precious materials lost **as shown in Figure 16**. For example, food wastes cost much money more than eaten food in the world, but food wastes are not proper for recycling and reusing again. Recycled metal is more versatile in uses ten times more energy than molten metal from raw materials. E-waste production and mining contribute to emissions of carbon dioxide that is 80% per unit of gold. Substituting mining valuable minerals and geological materials from the ground by recycling waste metals will minimize economical loss as looking for materials in the earth core is expensive. Solid Waste from canals and drains reached 9.2 million cubic meters, while the amount of demolition and construction waste reached 4.7 million tons in 2021. Achieving tremendous rates per year, solid wastes acquire a high economic supply either for the waste disposal or for recycling of it. The economic result for the lack in recycling processes that there are many precious materials.

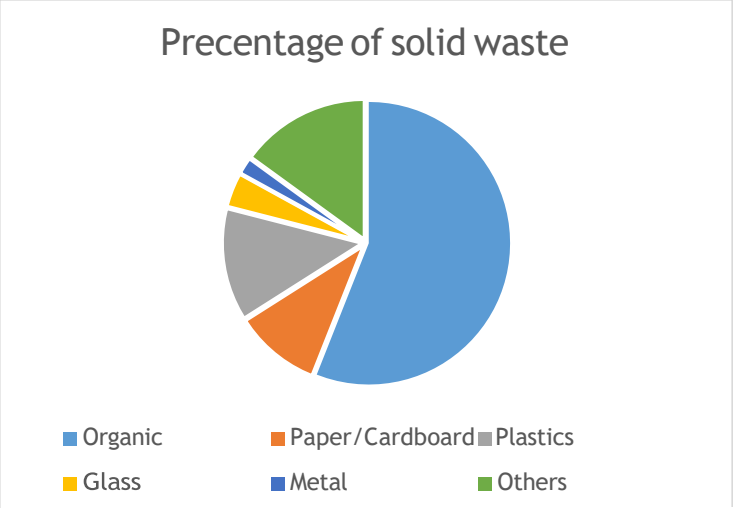

Figure 16 shows solid waste percentages in Egypt.

Health problems and disease spread

As a result of infiltration of wastes to water resources or agricultural soil, contaminated resources like water and plants lead to health problems and disease spread in Egypt. About thirty-eight million Egyptians drink from sewage-contaminated water which cause diseases like cholera, typhoid, schistosomiasis, and hepatitis. Furthermore,

8.4 million people have inadequate sanitation in rural regions. Pollution and wastes caused a variety of diseases including respiratory diseases, skin diseases, and cancer. Resulting from burning wastes, approximately 40,000 deaths are recorded annually. Air pollution is the reason for 2,400 deaths, 1,500 cases of acute bronchitis, 329,000 cases of respiratory infections, and eight million asthma attacks annually. Solid wastes and disposal cause environmental and health problems in the urban areas. Wastes and disposal are leading to significant environmental problems. Including soil, air water, and aesthetic pollution as environmental problems, solid wastes deposal are associated with human health disorder.

Deal with population growth and its consequences.

Egypt faces a great problem in dealing with the huge continuous growth of its population which puts pressure on the country's economy and environment and is threatening the health and well-being of its people. The major problem is that the development of local facilities and the number of exploited resources cannot meet the population's needs thus hindering the country's development. The real reason behind the rapid population growth is a declining death rate, and a constantly high birth rate and this means that Egypt is now in the heart of a transitory demographic stage. It progresses towards the stage of maturity at which the birth rate goes down and the death rate reaches its usual minimum. As of 1 January 2024, Egypt's population stood at 105.8 million, up from 104.4 million in 2022 to 102.8 million in 2021, according to the Central Agency for Public Mobilization and Statistics (CAPMAS) population clock. The number of births in Egypt reached 2.4 million in 2023 and based on the official data, the birth rate in 2023 reached 5,599 per day. Egypt's birth rate has declined over the past five years, dropping from 3.5 to 2.85 per woman. However, **as shown in Figure 17** This didn't solve the problem, and the country's population is expected to reach 192 million people by 2052 if current growth rates continue.

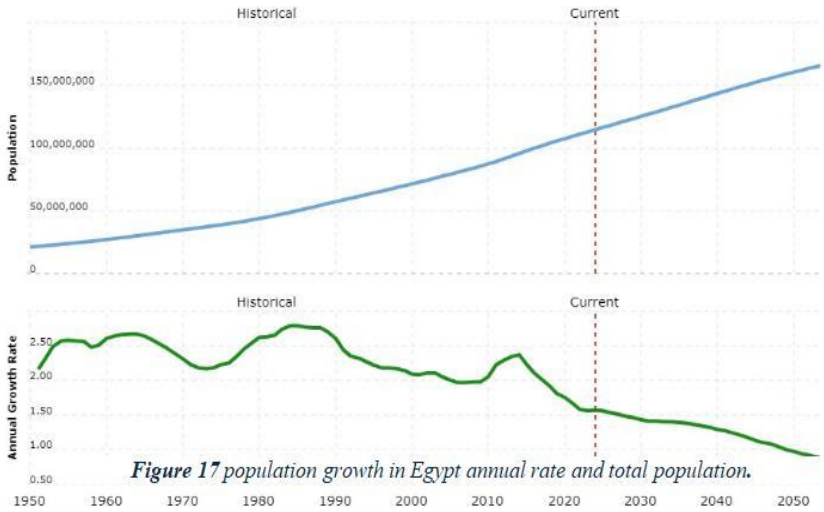

Figure 17 population growth in Egypt annual rate and total population.

Recently, the country has launched several campaigns and programs to curb runaway population growth, spending over EGP 100 million (approximately $5.2 million) annually to provide birth control for free or at lowered prices. In September 2023, Egypt, currently the 14th most populous country worldwide, launched the National Population and Development Strategy (2023-2030), the latest in a series of steps to address the population issue.

Causes:

High fertility rates in Egypt

Egyptians are known for their pride in big families and children, especially boys. Egyptian families used to consist of up to 9 or 8 children and their parents. The fertility rate in Egypt has been declining in recent years, from 3.5 births per woman in 2014 to 2.85 births per woman in 2021 as shown in **Figure 18**. However, the annual birth rate is still high, at around 2.2 million. The illiteracy of women is one of the main reasons for the high fertility rate in Egypt. There are some villages in Egypt where the illiteracy rate for girls is up to 50%. Egyptians lack knowledge about the effects of such a problem. This leads to many problems notably child labor, illiteracy, and poverty causing an even bigger chain of challenges.

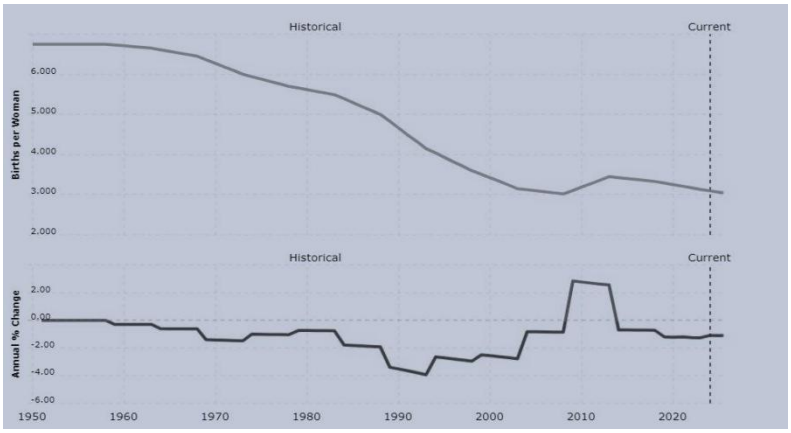

Figure 18 Fertility rate in Egypt and its annual change.

Child marriage

Child marriage is a big problem in Egypt, and it is a crucial reason for the increase in fertility rate and population growth problem in Egypt .17% of girls in Egypt are married before their 18th birthday, and 2% are married before the age of 15. Child marriage is particularly common in Upper Egypt, which is rural and has high levels of poverty and low levels of literacy. A 2017 World Bank/ICRW study estimated that ending child marriage in Egypt would generate an additional USD 2,893 million approximately through gains in earnings and productivity. The main reasons for child marriage are poverty, low education level, and some cultural practices.

The improvement of healthcare

The development of healthcare in Egypt is a great achievement that helped develop a better life for Egyptians. However, it is one of the main reasons causing the population growth problem to develop in Egypt. This is because the population problem is not only affected by the birth rate but also the death rate where the growth rate is the difference between the death and birth rate. **As shown in Figure 19** healthcare in Egypt has caused the number of deaths per birth to decrease notably and led to a great increase in the life expectancy at birth, which is the average number of years that a newborn could expect to live, in Egypt **as shown in Figure 20.**

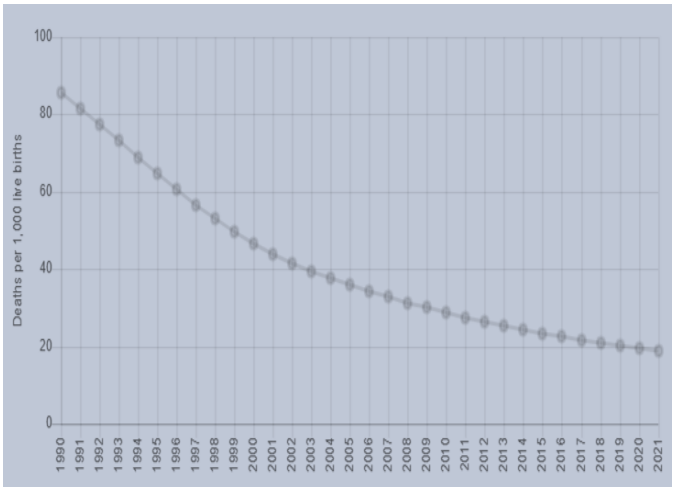

Figure 19 Graph representing the death rate in Egypt per 1000 births.

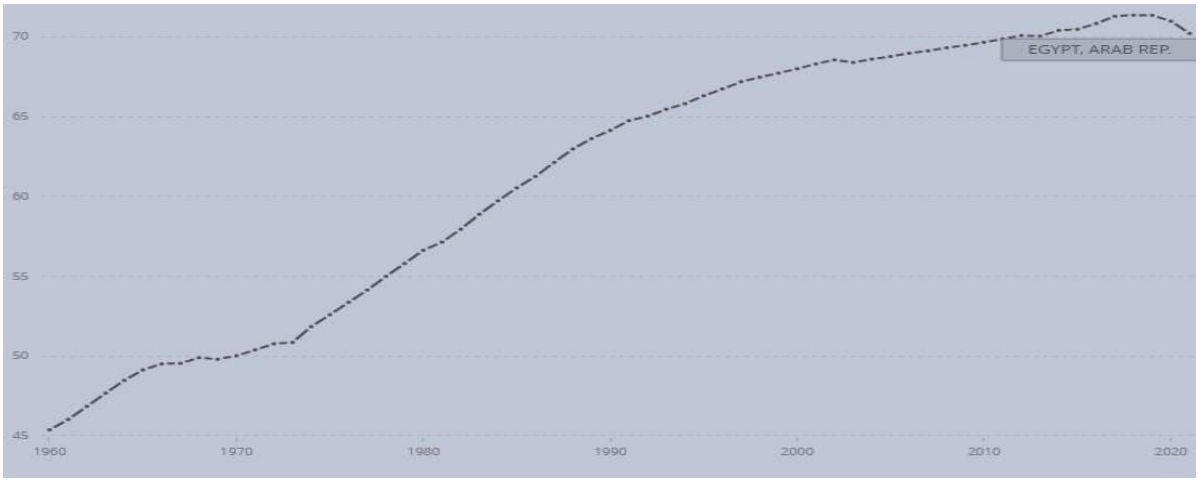

Figure 20 Life expectancy at birth in Egypt, 2000 - 2019.

Impacts:

Urban and Traffic congestion

Cairo itself has a population density of 19,376 people per square kilometer, which ranks 37th in the world as **shown in the opposite Figure 21.** This, together with the population crises, affects the quality of life of Egyptians, by causing many problems like traffic congestion. This is dangerous since Urban Congestion deals with much more than just the cost of burning fuel, wasting time, and car maintenance as it affects drivers' attitudes, health, and work performance. The overcrowding of Egyptians in cities puts great pressure on public services especially schools and hospitals decreasing the quality of these services and contributing to many major problems like unemployment and pollution. This is because while the number of people in a certain area is huge and quickly increasing, the services on the other hand are limited by various factors which when combined make it more complicated for the government to make development projects or address rising problems.

Figure21: population density in Egypt

Increase resources consumption

The continuous increase in the population of Egypt made it much harder for the country to save its citizens the necessary resources for a decent life like food, healthcare, facilities in general, sources of energy, and jobs. This is not just because the population is increasing but also because the consumption of everyone is increasing while production is not developing or coping with the local needs. Overpopulation plays an important role in this because the country cannot focus on any development projects because they need to develop facilities and local needs first like food and water. **As shown in Figure 22** this costs Egypt a huge amount of money due to the deadly

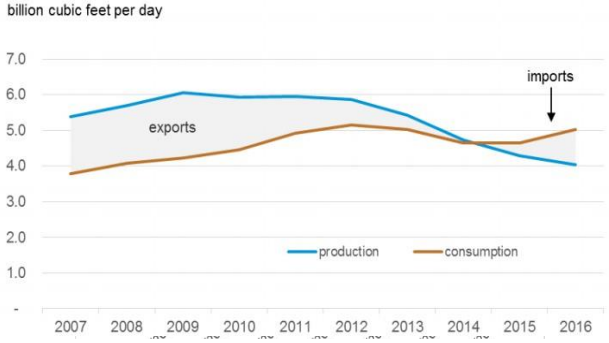

Figure 22 Egyptian Annual Petroleum & Other Oil-Products Production, Consumption.

decrease in its production and makes it more dependent on other countries which weakens its infrastructure and strength. This leads to an overall low standard of living increasing the poverty rates **as shown in Figure 23** and causing overpopulation to accelerate.

Increase Pollution

Population growth problem in Egypt is a main reason for pollution in cities as it increases Urban congestion which has many impacts that increase pollution and affect public health. Since many people live in the same place, many pollution types are spread in these places with high population density. Due to high traffic congestion and the concentration of factories and citizens in a relatively small area, pollution has greater impacts on food, water, and spreading diseases. The high concentration of residents in the same area leads to many factories, cars and traffic, smokers, and many other dangerous gases. Not to forget, a lot of solid wastes are dumped by these factories causing the problem to be evaluated at a higher rate.

Work to eradicate public health issues and diseases

The spread of diseases and epidemics has become a pressing problem. Recently, diseases have been mutating and spreading rapidly, for example there are around a billion cases of seasonal influenza annually, including 3–5 million cases of severe illness. It causes 290 000 to 650 000 respiratory deaths annually. Even simple diseases such as influenza can sometimes turn into fatal diseases, especially in Egypt, because Egypt is one of the countries with a highly concentrated population distribution, meaning that its population density is high, reaching the population density of Egypt in 2022 was 110.83 people per square kilometer, a 1.58% increase from 2021. Although Egypt has begun to pay attention to health issues **as shown in figure 24,** it is still one of the average countries in terms of health care **as shown in Figure 25**. For example, Egypt is one of the countries that witnessed a large-scale epidemic of highly pathogenic avian influenza in poultry caused by the influenza A (H5N1) virus. Since 2006, Egypt has reported more than 100 human cases of avian influenza A (H5N1) and dozens of deaths (Table 1).

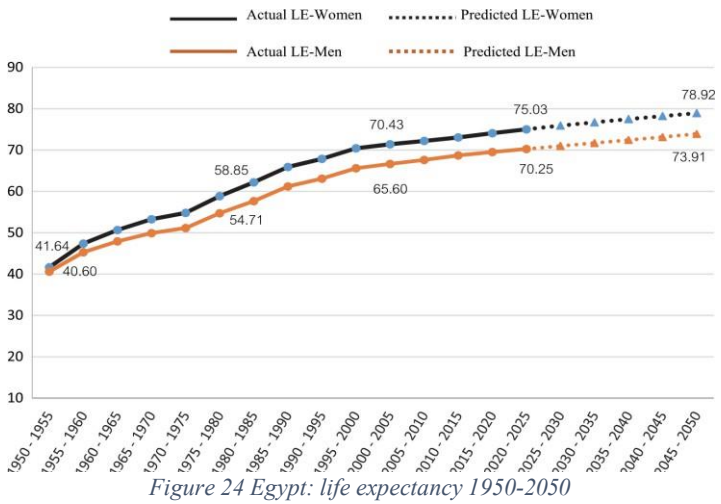

Figure 24 Egypt: life expectancy 1950-2050

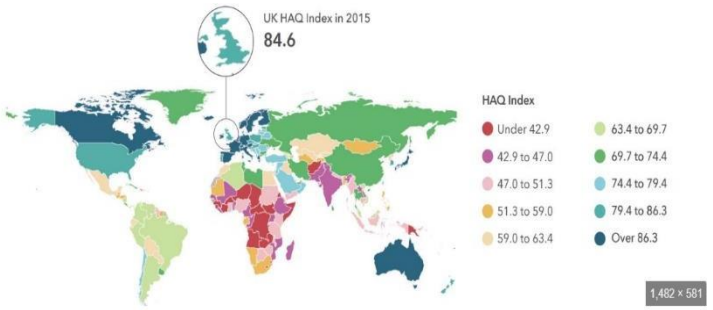

Figure 25 quality and accessibility of healthcare around the world.

Before the avian flu crisis, about 2.2 to 2.5 million chickens were being produced daily in Egypt by about 75,000 licensed breeders. Another example is that Egypt ranks among the top countries in the world to underreport the number of deaths related to COVID-19. According to the World Bank report, which focuses on socio-economic trends and public health systems in the Middle East and North Africa, Egypt's ratio of excess mortality to reported COVID-19 deaths stood at 13.1 as of November 30, 2020, by far the highest undercount ratio in the Middle East and North Africa, and the

fifth highest in the world **as shown in the figure 26.** This indicates that even though Egypt's interest in public health is constantly increasing, it is still average.

Country	Undercount Ratio	Data until
Egypt	13.1	Nov 30, 2020
Iran	2.4	Sep 21, 2020
Lebanon	1.2	Apr 30, 2021
Oman	0.9	May 31, 2021
Qatar	1.4	Apr 30, 2021
Tunisia	0.6	Feb 14, 2021

Figure 26 Ratio between Excess Mortality and the Reported Covid Deaths

Causes:

highly concentrated population distribution

Population density of Egypt in 2022 was 110.83 people per square kilometer, a 1.58% increase from 2021, Which helps in the rapid spread of infection or disease. For example, Cairo itself has a population density of 19,376 people per square kilometer (50,180/sq mi), which ranks 37th in the world. Therefore, Cairo Governorate had the highest number of Corona cases in Egypt **as shown in figure 27.** For all this, it can be said that the relationship between population concentration and the commodity of the spread of the epidemic or disease is a direct relationship **as shown in igure 28.**

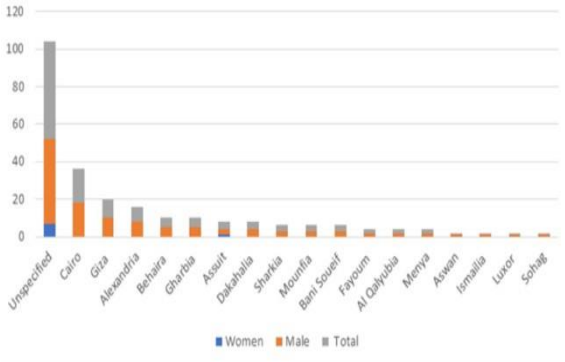

Figure 27 coronavirus fatalities per governorates

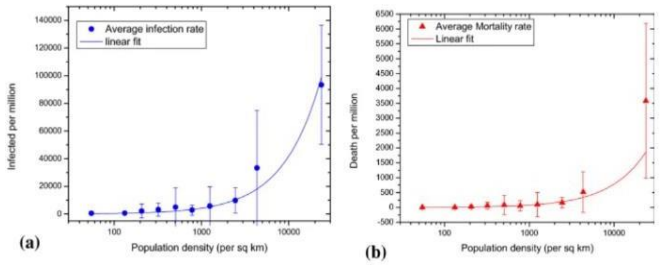

Figure 28 Variation of averaged infected and death rate due to Covid-19 with population density for the whole country

Lack of doctors and hospitals

In 2020, Egypt registered 432,273 healthcare professionals in total, including dentists, pharmacists, human physicians, and nursing staff. Furthermore, there were 6.6 times more public and private healthcare professionals. This means that for every 1,000 people in Egypt, there are approximately 5 medical staff (physicians, nurses and midwives) as Egypt's population in 2020 was 107.5 million. Although the ratio of medical stuff is higher than the WHO target of at least 2.5 medical staff (physicians, nurses and midwives) per 1,000 people, it is low compared to countries such as Germany, Ireland and the United States. In addition, there is many medical stuffs that travels abroad. For example, more than 11,500 Egyptian public health workers moved to the UK between the years 2019 and 2022, seeking better prospects abroad.

Lack of financial support for the health sector

The latest statistics from the Information and Decision Support Center of the Council of Ministers indicate that the total value of public spending on the health sector in the budget for the fiscal year 2021/2022 reached about EGP 108.8 billion, with an increase rate of EGP 15.3 billion (about 16%) over the allocations. Even if this spending rate is high, it is very small compared to the United States, where U.S. health care spending grew 4.1 percent in 2022, reaching $4.5 trillion.

Impacts:

Weaken the economy

The global and Egyptian economies have weakened during periods of illness. For example, during the Corona period, the economy weakened significantly as Egypt began imposing a health lockdown and preventing social activity, which led to a weakening of transportation in addition to the closure of many factories whose workers were infected with Corona. In addition, the Central Bank of Egypt reduced policy interest rates by 400 basis points during 2020—with the overnight deposit rate cut from 12.25 percent to 8.25 percent—to help support economic activity and alleviate pressures in domestic financial markets.

Social effects

In times of diseases and epidemics such as Corona, Egypt will be required to take many steps such as imposing a health quarantine and preventing people from physical contact or touching each other. Therefore, diseases and epidemics lead to a decline in the health status of the population, which leads to a weakening of their feelings and their aversion to work.

psychological impacts

A high prevalence of depression (67.1%), anxiety (53.5%), stress (48.8%), and inadequate sleeping (23.1%) among the public in Egypt during the pandemic was observed **as shown in figure 29.** We could also determine many sociodemographic associations with severe to very severe forms of depression, anxiety, and stress. Which caused sleep problems, stress, and difficulty in dealing with others, which negatively affected Egypt and its internal and external dealings.

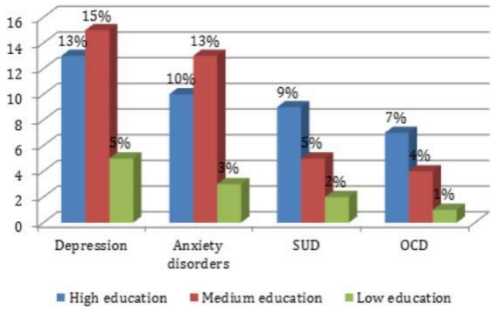

Figure 29 Psychological effects during pandemics

Problem to be solved

Cardiovascular and respiratory diseases in Downtown Cairo

Egypt has been constantly suffering from population problems. These problems cause a high increase in pollution rates and contribute significantly to climate change decreasing the quality of life of Egyptians and causing the widespread of a variety of diseases and health problems. This is especially recognized in industrial cities and urban areas with high traffic congestion like in Cairo. Cairo is considered the 9th most polluted city in the world where PM2.5 concentration in Cairo City is currently 9.5 times the WHO annual air quality guideline value. Having high traffic activity and being in the middle of the popular sites of Cairo, Downtown Cairo suffers greatly from high concentrations of dangerous pollutants like sulfur oxides, nitric oxide, and different types of particulate matter (pm) like kerosene and VOCs. SO2 emission from fuel combustion in Cairo reaches 251,646 tons annually according to researched data in 1998. Transportation in Cairo may emit 18,489 tons per annum. NOx emissions from motor vehicles in Cairo are estimated to be 10 600 tons in the year 2000. In Cairo, CO emissions from cars and buses have been estimated to be 223,000 tons per annum in the year 2000 which is a more than threefold increase from 1980. This is dangerous since Air pollution indirectly affects most of the body's organs especially the respiratory tract hence several air pollutants are absorbed by blood and consequently reach other parts of the human body. For example, Sulphur dioxide was found to increase mortality at high concentrations, and at lower concentrations, it causes bronchitis and respiratory illness in children. In Egypt, non-communicable diseases, including cardiovascular and chronic respiratory illnesses, account for 82% of all deaths, with 67% being premature deaths. These pollutants are also the core reason for global warming, climate change, and acidic rains which are seriously affecting the quality of life in Egypt. The problem to be solved is the

respiratory and cardiovascular diseases in Downtown Cairo and the main idea of our project is to design an air purification system that can decrease the level of sulfur dioxide, nitric oxide PM, and VOCs using locally grown waste materials through treating air made by car exhausts.

Positive Consequences (If solved):

Reduce air pollution-related illness

Air pollution-related diseases are diseases caused by harmful pollutants in the air or the aggravation of a pre-existing disease due to air pollutants. Therefore, it has become urgent to solve the problem of high values of AQI. Reducing the AQI means reducing all pollutants in the air, including CO, which is a toxic substance, in addition to the fact that it interferes with the delivery of oxygen to the tissues by binding to haemoglobin, the protein in red blood cells that carries oxygen, as more than 400 people die from it annually, in addition to the side effects that contribute to the death of others. The advantages of reducing the AQI do not stop there, but it also means reducing the percentage of nitric acid, which causes acid rain. The evidence is that the maximum contributions of nitric acid to the acidity of perception in summer are 73 and 31% in summer and in winter are 59 and 61%, respectively. Moreover, reducing the percentage of nitric acid will lead to a decrease in asthma, which affects more than 8.2 and 6.7% among children and adults, respectively. Moreover, the combined effects of ambient air pollution and household air pollution are associated with 6.7 million premature deaths annually. Therefore, air pollution is a major contributor to premature deaths worldwide. Cleaner air can significantly reduce these numbers.

Boosting economic productivity & psychological state

Reducing the AQI will reduce the spread of diseases such as asthma and natural disasters such as acid rain, which in turn will raise the psychological state of employees and workers and make them at the highest levels of production and efficiency, which will in turn result in an increase in the economy and an increase in quality and sales, benefiting all segments of Egyptian society. In addition, the decrease in diseases will help increase interest in economic fields and the establishment of factories instead of searching for ways to treat patients and searching for means to combat infection.

Developing relationships

Reducing diseases and pollutants will make the streets, clubs and gathering places full again as people will go to these places to find fresh air without any pollutants or anything like that which in turn will lead to developing relationships between people and help them to become cooperative and loving with each other.

Environmental Benefits

Many pollutants in the air, such as greenhouse gases, contribute to climate change. **As shown in the following 30**, carbon dioxide (CO2) and nitrogen oxides (NOx) are among the most important greenhouse gases contributing to climate change. Carbon dioxide (CO2) accounts for about 76 percent of total greenhouse gas emissions. Emissions of nitrous oxide, the third most important human-made greenhouse gas, rose 40 percent from 1980 to 2020, according to a new report by the Global Carbon Project. Reducing these gases in the air will help reduce climate change and global warming significantly and effectively.

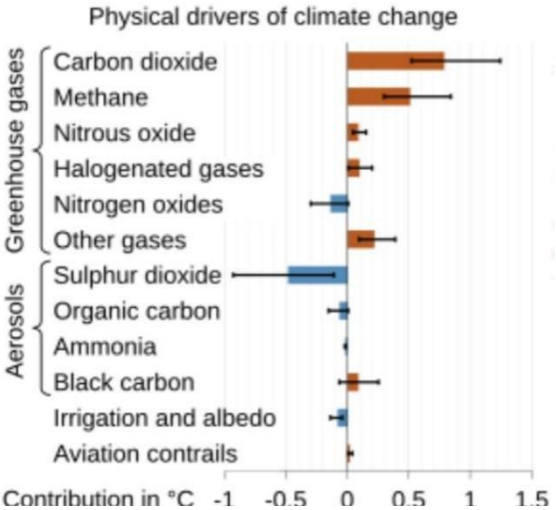

Figure 30 Physical drivers of climate change

Negative consequences (if not solved):

Extended periods of high AQI levels

Extended periods of high AQI levels, including PM2.5: NOx, SOx, and VOCs (volatile organic compounds), have a great impact on the health of the Egyptian population. Air pollution contributes to approximately 16% of all deaths in Egypt. In 2019, air pollution was responsible for 90,559 premature deaths. Cairo, with AQI level of 118, is particularly affected with approximately 40,000 people dying annually from pollution-related issues. Long-term exposure can lead to severe respiratory problems, such as asthma and chronic bronchitis, as well as cardiovascular diseases, including heart attacks and strokes. The WHO guidelines recommend that levels should not exceed 10 µg/m³ annually. In many Egyptian cities, the average concentration of PM2.5 concentration in Egypt is 8.5 times the World Health Organization's standard air quality, rising AQI in Cairo to 118 AQI US, especially during dust storms and winter months when industrial emissions and vehicular traffic increase. In Egypt, the high levels of PM2.5, associated with rising AQI levels, are exacerbated by factors such as dust storms, increased vehicular traffic, and industrial emissions.

Spatial Disparities in Air Quality

Spatial disparities in Air Quality means the uneven distribution of air pollutants across different neighborhoods and districts. These disparities affect the public health of residents in specific regions. Persistent differences in air quality levels across various neighborhoods and districts within Greater Cairo. Individuals who live consistently in residents with poorer air quality are at higher risk of health problems. In Egypt, Heart disease (57.9%), stroke (17.7%), and pulmonary and lower respiratory diseases and cancer (24.4%) is considered high stated by World Health Organization in 2018. Citizens living in areas with poor air quality are at a higher risk of being infected with asthma, bronchitis, and other respiratory ailments. Some studies have proved that exposure to air pollution can increase risk of strokes, heart attacks, cancer, and other cardiovascular conditions.

Weather Change

Due to the presence of a large percentage of pollutants in the air, including fluor chlorocarbon gases (CFCs), which affect the weather and make it difficult to predict weather changes and whether a storm will blow or not. Egypt faced many changes due to climate change, with noticeable increases in

heat waves, dust storms along the Mediterranean coast, and severe weather changes in temperature and phenomenon. The rise in temperature has been documented over the last 30 years. It was estimated that the average annual temperatures increasing by 0.53 degree Celsius each decade. That is because the annual nationwide average PM2.5 concentration in 2019 was 13.6x times greater than the World Health Organization recommended concentration levels, which influences flights that fail because of changes in the weather, as weather changes are linked to the failure of more than 11% of flights. In addition, climate change resulting from increased air pollutants leads to hurricanes, lightning and tsunamis, which are destructive to cities and cars, leading to thousands of accidents.

Research

Topics related to the Problem:

Government's environmental policies and targets

Government policies has stepped up climate action but needs to further strengthen institutional capacity. Despite of sector-specific targets to reduce emissions, on no more international financial support, it is still facing implementation challenges related to its current policies and prospect. The organizations of environmental management which began in 1982 in Egypt with the establishment of the Environmental Affairs Agency as the authority responsible for promoting and protecting the environment. The government did not take several measures to improve air quality such as regulating industrial emissions, improving solid waste management, upscaling electric public transport. As Egypt hosted the COP27 in 2022, Egypt has limited some environmental groups' ability to carry out independent policies, which are essential to protecting the Human public health and the environmental policies. In contrast, many of these sector-specific targets, which was to reduce emissions: -37% for electricity, -7% for transport and -65% for oil and gas by 2030, were not totally achieved. It has started planning for the National Climate Change Strategy 2050.

Effects of excessive greenhouse gases on public health

As a major cause of trapping heat and respiratory diseases from smog, greenhouse gases have wide-range environmental health effects. In Egypt, the rise in greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), poses serious public health risks, exacerbating air pollution and climate-related illnesses. According to Egypt's Ministry of Environment, air pollution contributes to approximately 90,000 premature deaths annually, primarily due to respiratory and cardiovascular diseases linked to high levels of particulate matter and ground-level ozone caused by GHG emissions. Additionally, heatwaves driven by climate change have become more frequent and intense in Egypt, leading to a 20% increase in heat-related illnesses in the last decade, particularly among vulnerable populations such as children and the elderly. Moreover, a study conducted by the American University in Cairo (AUC) found that the prevalence of asthma and other respiratory diseases has risen by 30% in Egypt's urban centers, directly correlating with increased air pollution from GHGs.

Smog's rise as an impact on the usage of excessive transport emissions

Smog rise contributes to temperatures rising leading to heatwaves and increases the risk of heatstroke, dehydration, and cardiovascular diseases. Climate change, because of smog rise, can disrupt rainfall patterns, leading to water scarcity and affecting public health. Resulting from excessive transport emissions of greenhouse gases, these emissions can exacerbate air pollution, contributing to respiratory diseases such as asthma and cardiovascular problems. Warmer temperatures can expand the range of disease-carrying insects like mosquitoes, increasing the prevalence of malaria, dengue

fever, and other vector-borne illnesses. The stress and uncertainty associated with climate change can negatively affect mental health, leading to anxiety, depression, and post-traumatic stress disorder.

Topics related to the Solution:

Water electrolysis

Water electrolysis, also called electrochemical splitting of water, is a process that is used to store electricity. It happens by breaking down the water molecule into an oxygen atom and a hydrogen atom. Electrolysis uses DC electricity in this process to obtain a hydrogen atom and then store it. After storing the energy comes the turn of the photoelectrochemical cell process (PEC). This is a device made from an electrolyte and a photoactive semiconductor electrode. The semiconductor is made from materials like those used in making photovoltaic cells. But the difference is that semiconductor is immersed in a water-based electrolyte, where sunlight gives energy to the water splitting process thus producing energy by the solar generation of hydrogen. The process of electrolysis **is shown in Figure 31.**

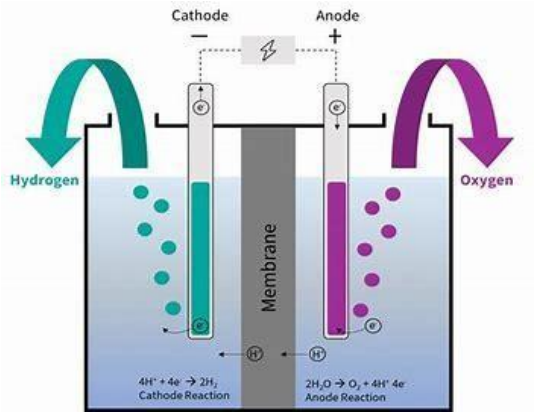

Figure 31 shows the process of electrolysis

Carbon Capture and Storage (CCS)

Carbon Capture and Storage (CCS) is a vital technological solution aimed at significantly reducing carbon dioxide (CO2) emissions from industrial sources and power plants. The process begins with capturing CO2 emissions before they enter the atmosphere, employing techniques such as absorption, adsorption, or membrane separation. As of 2023, there are 31 large-scale CCS facilities worldwide with the capacity to capture over 40 million metric tons of CO2 annually, a number projected to grow significantly to meet the International Energy Agency's estimate of needing to capture around 1.7 billion metric tons of CO2 per year by 2050 to achieve net-zero emissions. Following capture, the CO2 is compressed into a liquid state for transport, usually via pipelines, and then injected into geological formations, such as depleted oil and gas fields or saline aquifers, for secure, long-term storage. The world possesses the potential to store over 2,000 gigatons of CO2, which could be more than 60 times the annual global emissions. While capturing CO2 typically costs between $50 to $100 per ton, innovative technologies could lower this to around $30 to $40 per ton by 2030. Moreover, CCS could contribute to reducing about 80-90% of CO2 emissions from hard-to-abate sectors, such as cement and steel production, which account for approximately 20% of global emissions. Overall, CCS not only mitigates climate change but also has the potential to create around 1.3 million jobs in the U.S. by 2030, highlighting its role in achieving global climate goals and enhancing economic opportunities.

Biochar Production

Biochar is a special product made from organic waste, and it can help reduce air pollution. The process of making biochar involves heating materials like agricultural leftovers, municipal waste, or

forestry scraps at high temperatures without oxygen. This creates a stable form of carbon that can be added to soil.

Using biochar has many benefits. It can improve soil health, help the soil hold onto water, and make nutrients more available for plants, all of which can lead to better crop yields. Additionally, biochar can trap harmful pollutants from the air, such as heavy metals and chemicals, which helps clean up the atmosphere.

Producing biochar is a great way to store carbon, helping to combat climate change, and it also offers a valuable resource for sustainable farming. Studies suggest that if farmers widely adopt biochar, it could reduce greenhouse gas emissions by up to 1.8 billion metric tons each year.

Other Solutions Already Tried

Activated Carbon Filters from Coconut Shells

Activated carbon filters made from coconut shells are a great way to clean air and water. These filters use coconut shells, which are easy to find and good for the environment. To make activated carbon, the shells are heated in a special process that creates tiny holes in the material. These small holes allow the carbon to trap harmful substances.

These filters are effective in removing many harmful pollutants. For water treatment, they remove things like chlorine, heavy metals, pesticides, and chemicals, making the water safer to drink. For air purification, they help get rid of bad odors, harmful gases, and other pollutants, making the air cleaner and healthier. Coconut shells are widely available in tropical areas, making these filters a smart and affordable choice for reducing pollution **as shown in figure 32.**

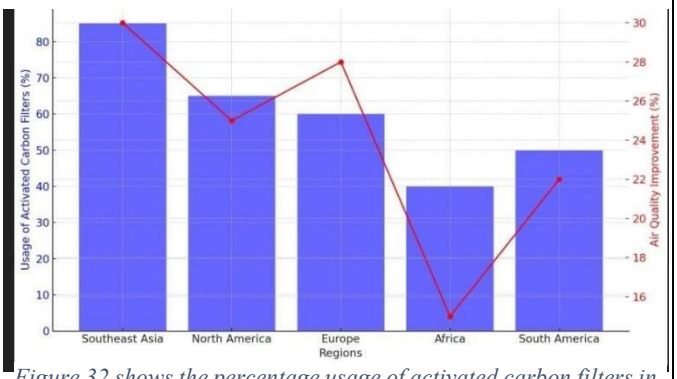

Figure 32 shows the percentage usage of activated carbon filters in various regions and the resulting air quality improvements.

Mechanism:

The process begins with gathering coconut shells, which are often leftover from the food industry in tropical regions. The shells are then treated through chemical or steam activation, where they are heated to 600-900°C. This high heat treatment makes the material very porous, which greatly improves its ability to trap pollutants.

After activation, the carbon is used in air filters for industrial buildings. As polluted air flows through, the activated carbon traps harmful substances like volatile organic compounds (VOCs), sulfur dioxide (SO_2), and nitrogen oxides (NO_x). Sensors monitor pollutant levels before and after filtering to ensure that the system is working effectively **shown in figure 33.**

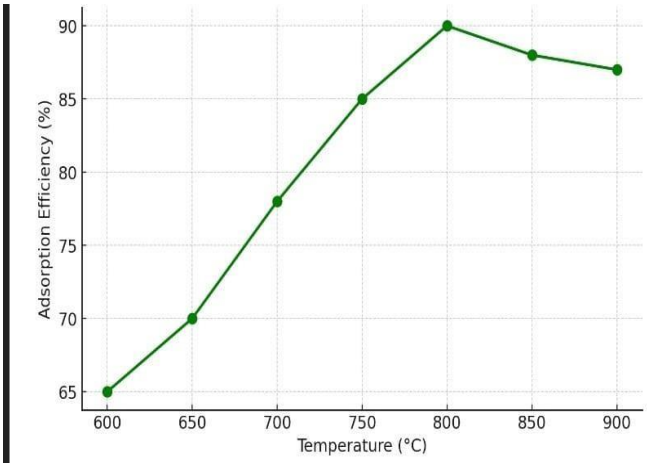

Figure 33 shows how the efficiency increases with temperature, peaking around 800 C

Points of Strength:

High Adsorption Efficiency

Activated carbon filters are known for their excellent ability to adsorb pollutants. They can effectively remove up to 90% of volatile organic compounds (VOCs) and about 75% of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from industrial emissions. This level of efficiency not only improves air quality but also helps industries meet environmental regulations, which can prevent fines and contribute to better public health outcomes. The effectiveness of these filters in reducing harmful pollutants **is shown in Figure 34.**

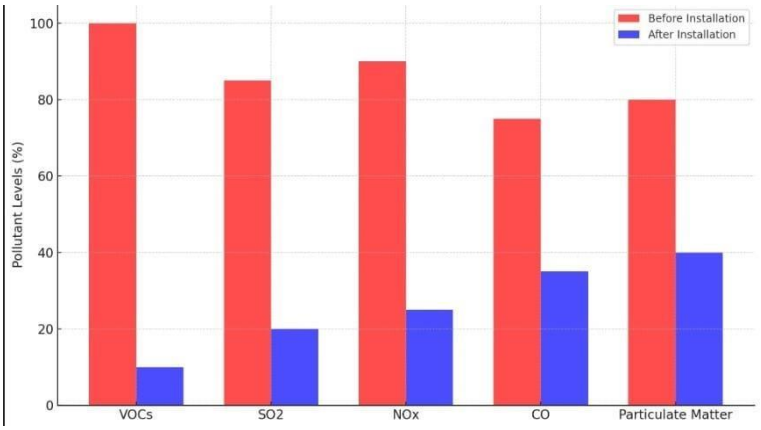

Figure 34 compares the pollutants levels before and after filter installation.

Sustainable and Abundant Raw Materials

Activated carbon filters are mainly made from coconut shells, which are a valuable byproduct of the coconut industry, especially in tropical regions. Each year, about 25 billion coconuts are produced globally, resulting in a large amount of shells that would otherwise be discarded. By using these shells, we not only help reduce waste but also provide an eco-friendly alternative to synthetic materials, **as shown in Figure 35.**

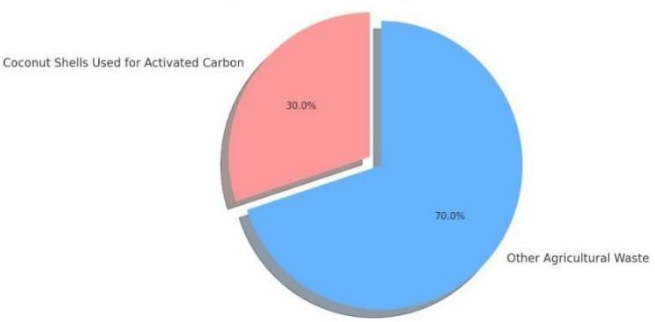

Figure 35 shows the reduction in agricultural waste

Long Filter Lifespan

Typically, activated carbon filters have a lifespan of 12 to 18 months before they need to be regenerated or replaced. This long duration helps minimize maintenance frequency and lowers its costs. Therefore, these filters can be seen as a cost-effective option for industries, ensuring continuous management of air quality, **as shown in Figure 36.**

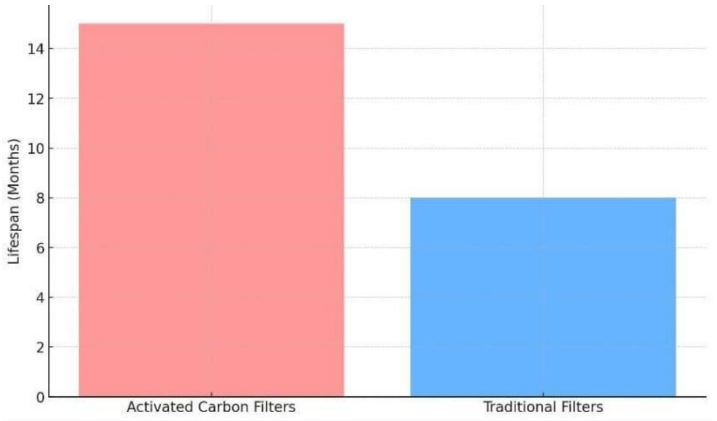

Figure 36 shows lifespan comparison of filters

Points of Weakness:

High Initial Cost

The installation of activated carbon filtration systems can be quite expensive, with costs ranging from $50,000 to $100,000 for large facilities. This upfront investment may deter smaller businesses or those in developing regions from implementing such systems, limiting their ability to improve air quality, as illustrated in Figure 6.

Energy-Intensive Activation Process:

The production of activated carbon requires an essential energy input, consuming approximately 3,000 MJ (megajoules) of energy per ton produced during the activation process. This high energy demand can increase the overall carbon footprint of the system, particularly if non-renewable energy sources are utilized. For instance, using fossil fuels for activation can result in carbon emissions of around 800 kg of CO2 per ton of activated carbon, which can counteract some of the environmental benefits.

Decreased Efficiency Over Time

As activated carbon filters become saturated with pollutants, their adsorption efficiency worsens over time. Typically, after 12 to 18 months, the filters require regeneration or replacement, which adds to its costs. This decline in efficiency over time **is shown in Figure 37.**

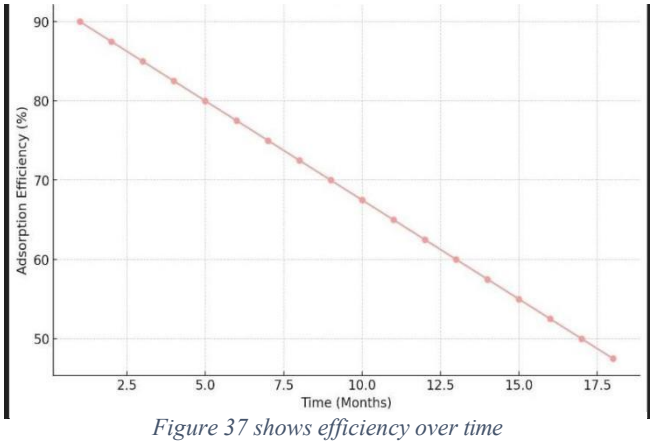

Figure 37 shows efficiency over time

Catalytic Converters in vehicles

The history of the catalytic converter dates to the late 19th century, when some prototypes were developed in France. In the mid-1950s, Eugène Houdry, a French mechanical engineer, patented his research into developing catalytic converters for gasoline engines. Catalytic converters were further developed and became more widespread after emissions control regulations began in the early 1960s. The first production catalytic converter was built in 1973 at the Engelhard Corporation, and widespread use of the part began around 1975, due to EPA regulations on toxic emissions reductions. Without catalytic converters, vehicles release hydrocarbons, carbon monoxide, and nitrogen oxide into the atmosphere. These gases are the largest source of ground level ozone, which causes smog, acid rain. Catalytic converters can be found in generators, buses, trucks, and trains. almost everything with an internal combustion engine has a form of catalytic converter attached to its exhaust system. The position of catalytic converter in vehicles is **shown in figure 38.**

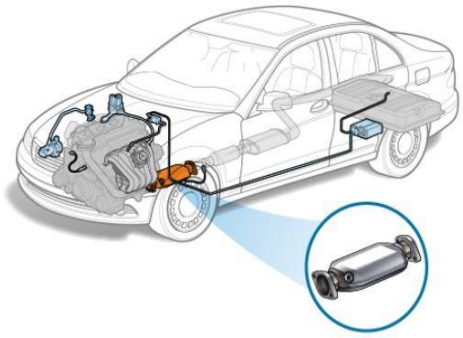

Figure 38 Catalytic converter in car

Mechanism:

A catalytic converter is a simple and relatively small device, about the size of a loaf of bread, with a capacity of 1.6 liters. The function of catalytic converter is converting harmful and toxic outputs into less harmful outputs and has proven highly effective by converting 98% of harmful outputs into less harmful outputs. The catalytic converter consists of a metal shell with a ceramic honeycomb inside, to increase the reaction surface area and thus increase the rate of the chemical reaction, with insulating layers. This inner honeycomb contains thin-walled channels coated with a layer of aluminum oxide. And contains precious metals such as platinum, rhodium and palladium. In a single solution, 4-9 grams of these precious metals are used. The structure of the catalytic converter is **shown in figure 39.** This device relies primarily on redox reactions, reducing nitrogen oxides and oxidizing carbon monoxide and hydrocarbons. As a reminder, oxidation is the process of losing electrons and reduction is the process of gaining electrons. Precious metals such as palladium, rhodium and platinum enhance the transfer of electrons, thus converting toxic fumes. The final section of the converter controls the fuel injection system, where this control system is assisted by an oxygen sensor that monitors the amount of oxygen in the exhaust stream, which in turn tells the engine computer to adjust the air-fuel ratio, keeping the catalytic converter operating at the stoichiometric point and near 100% efficiency.

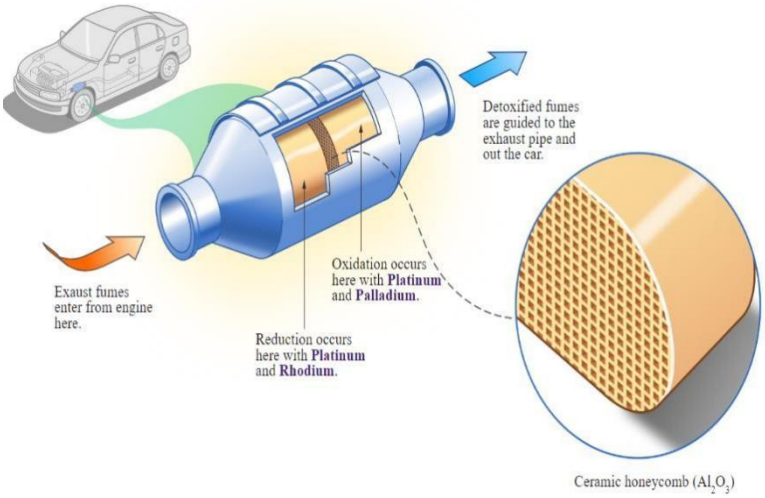

Figure 39 The structure of the catalytic converter

A three-way catalytic converter has three main reactions:

1. Reduction of nitrogen oxides into elemental nitrogen and oxygen:

$$NO_x \rightarrow N_x + O_x$$

2. Oxidation of carbon monoxide to carbon dioxide:

$$CO + O_2 \rightarrow CO_2$$

3. Oxidation of hydrocarbons into carbon dioxide and water:

$$C_xH4_x + 2_xO_2 \rightarrow xCO_2 + 2xH_2O$$

Points of Strength:

Lowering the number of toxic pollutants emitted

Nitrogen oxides (NO_2) are compounds in the same family as nitric acid and nitrous oxide. The reason NO is dangerous is that it reacts with organic compounds in the air under the influence of sunlight, producing smog, which is one of the most dangerous pollutants and has harmful effects on children's lungs. The evidence is that about 4,000 people were known to have died because of the fog, but it could be many more. In addition, NO can react with sulfur dioxide (SO_2) to form acid rain, which corrodes cars, plants, buildings, and national monuments, and pollutes lakes and streams, poisoning animals that drink from them, in addition to the acidity that is not suitable for fish. NO can also bind to ozone to create biological mutations (such as smog) and reduces light transmission. Therefore, the presence of a catalytic converter in cars to convert NO to NO_2 is an urgent issue. The

catalytic converter also works to convert carbon monoxide into carbon dioxide, which in turn converts the toxic substance into a less harmful substance.

Longer engine life & Improved fuel efficiency

Reducing harmful effects will improve engine performance, which can extend the life of your vehicle's engine. Declining fuel efficiency: If a catalytic converter becomes clogged, it can reduce the amount of airflow through your engine. To compensate, your engine might start to burn more fuel than usual, resulting in a noticeable drop in fuel efficiency.

Reducing noise pollution

Catalytic converters can help reduce the noise emitted by vehicles, making for a quieter driving experience and contributing to a more peaceful environment.

Points of Weakness:

Catalytic Converter Theft

Catalytic converters are one of the most vulnerable to theft. For example, 27,609 catalytic converters were stolen in the United States, with nearly half of those stolen in California, according to the National Insurance Crime Bureau. The reason for this is the precious metals in the ceramic coating inside the body. The reason why catalytic converters are so easy to steal is because they are in an easily accessible location, specifically on the outside of the car, at the bottom. A thief can easily slide under the car, cut the connecting pipes at each end, and walk away with the catalytic converter. The selling price of a catalytic converter depends on the amount and type of precious metals inside, but it is usually worth about $200.

High cost

Catalytic converters are expensive devices because they contain many precious metals such as palladium, platinum, and rhodium. Because of this price increase, it becomes very difficult to install the catalytic converter, or in other words, it prevents its use by all individuals, as it is only used in modern cars, as the Catalytic Converter Replacement Cost is between $1,000 and $2,500.

Susceptibility to Damage

The catalytic converter is an easily damaged device due to its sensitivity to many factors. First, if it is exposed to excessive heat, the high temperature will lead to the deterioration of the catalytic converter. Second, if it contains low-quality fuel with many impurities, it will clog the catalytic converter. The third reason is that it is sensitive to accidents or collisions.

Boundary Dam CCS project

The Boundary Dam CCS project, in Canada, is the first post-combustion coal fired carbon capture and storage project started in 2014. **As shown in figure 40**, the project is connected to the factories and facilities related to the boundary dam. Its purpose to reduce greenhouse gas emissions from the Boundary Dam Power Station, a coal-fired power plant. To achieve that purpose, the CCS project, with capturing capacity of 1 million tons of CO_2 annually, depends on the low temperature CO2 capture technologies, often called cryogenic carbon capture. Cryogenic carbon capture (CCC), which captures at most 90% CO_2 emissions, is a potential solution to reduce carbon dioxide emissions from industrial emitters. Furthermore, Cryogenic carbon capture (CCC) could emerge by offering high CO2 recovery rates and purification levels. The CCS, in boundary dam, captures over one million metric tons of CO_2 per year, demonstrating a 90% CO_2 capture rate for 139 MW coal-fired unit. CCS project captured and reused most of the heat-trapping CO_2 from its exhaust while the boundary dam generated electricity for 100,000 homes. In 2016, SaskPower stated that Boundary Dam CCS successfully captured 83,497 tons of CO_2 have been captured in a month in addition to a total of 757,000 ton of CO2 since 2014.

Figure 40 shows the Boundary Dam Carbon Capture and Storage (CCS) that was launched in Canada, 2014.

Mechanism:

The Boundary dam CCS project depends on Cryogenic capture technology. The CCS uses the gas that needs to remove CO_2 by process, which can effectively reduce impurities and remove, and ensure the progress of the subsequent carbon capture process, like desulfurization, denitrification and dust removal treatment **as shown in Figure 41**. CCC procedures are gas conditioning, cooling, CO_2 separation, and storage and utilization. Gas conditioning process includes removal of impurities at which inserted gas is purified to remove impurities like sulfur oxides (SOx) and nitrogen oxides (NOx). Moisture removal, after removal of impurities, involves removing water vapor from the gas to prevent ice formation while cooling. The second stage is cooling consisting of compression, heat exchange, and cryogenic cooling. The gas is compressed, after conditioning and purifying, to rise its pressure enhancing efficiency of cooling process. The compressed gas is passed through heat exchangers to cool the gas to a normal temperature. Consequently, the gas is cooled down to extremely low temperature, -100°C using refrigeration like nitrogen, helium, or hydrogen. To separate CO_2, the gas is condensed into a liquid or solid state after high heat. The condensed CO_2 is

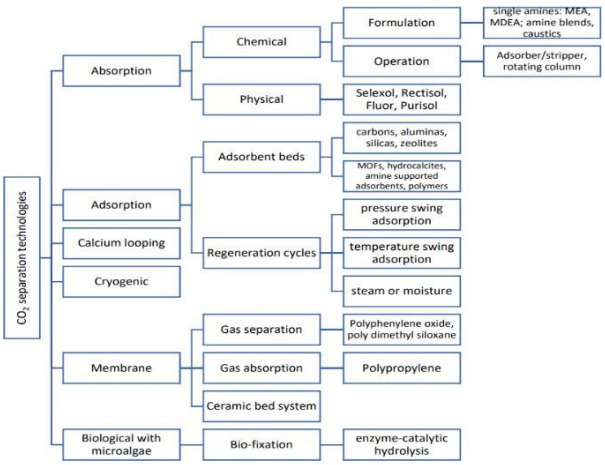

Figure 41 shows the separating technologies for CO_2.

separated from the remaining gases, such as nitrogen and oxygen, by using distillation or absorption. The captured CO2 is stored in underground formations like gas fields or depleted oil, or in saline aquifers. CCC sublimation can capture low-concentration CO_2 at a rate of 99.9% at 13.5 vol%. CCC technology provides less cost and efficiency benefits compared with other carbon capture technologies. The process **is shown in figure 42.**

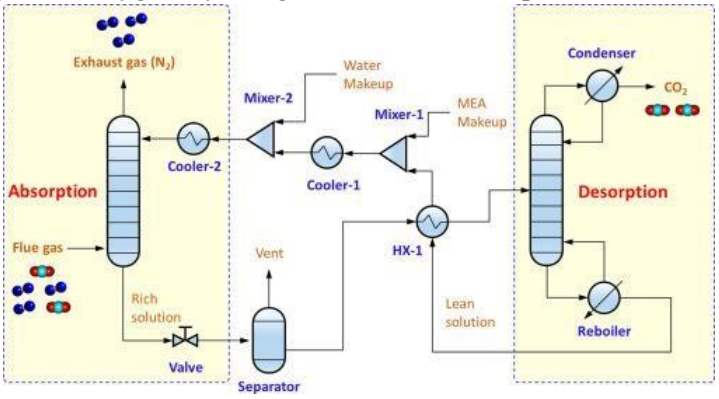

Figure 42 shows a map of Cryogenic carbon capture procedures and flow.

Point of strength:

High purity of captured CO2

The concentration of pollutants in the effluent gas for a coal-fired flue gas exiting a CCC system is 90% removed. After the gas cools to near-cryogenic temperatures, molecules that have vapor pressures greater than the CO_2 vapor pressure will be captured along with the CO2. Including heavy metals such as Hg, As, Pb, etc. and other pollutants like SOx, NO2, and particulates, these pollutants are captured efficiently by CCC. activated carbon beds for Hg removal, and selective catalytic reducer (SCR) units for NOx reduction. Carbon monoxide (CO) as well as any other compounds which **are shown in Figure 43**. High-level PFD of the CCC process showing to main sub-systems of the process. GHGT-15 Baxter-2 4 lighter than CO2 will not be captured by the CCC process.

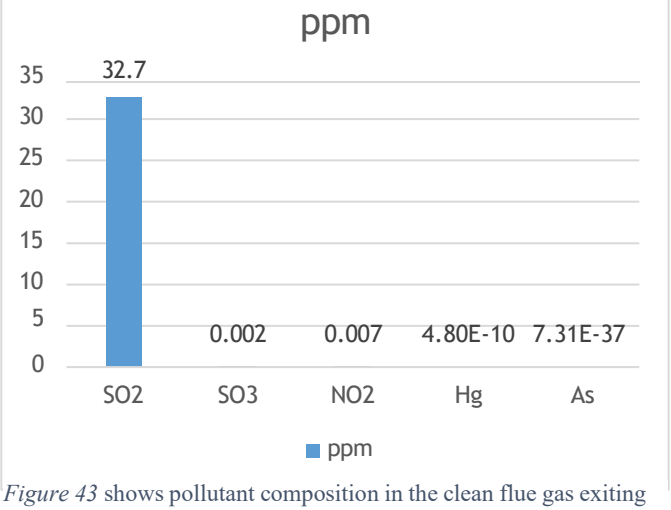

Figure 43 shows pollutant composition in the clean flue gas exiting the CCC process when capturing 90% of the inlet CO2.

Large-Scale Capture and Environmental impact

CCC projects present a new opportunity for large-scale, inexpensive, and high-efficiency energy storage. The pure hydrogen with 90–98% purity can be constructed in large-scale production plants through cryogenic distillation with 96% hydrogen recovery **as shown in figure 44**. Cryogenic Carbon Capture (CCC) can achieve high CO2 capture rates, making it suitable for industries and affordable for large-scale.

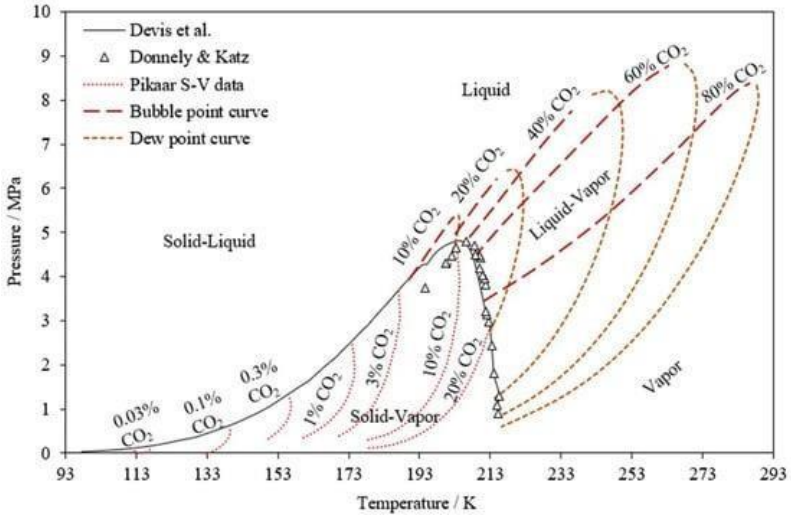

Figure 44 shows the dew and bubble curves and solid–vapor data for CO2–CH4 mixtures with varying CO2 content.

Sustainable low-emission electricity with high efficiency

CCC and CCS technology provide moderate cost and high efficiency benefits compared with other carbon capture (CC) technologies. By 2030, China's expected CO_2 capture cost will be 13–57$ per ton. It will cost 3–19$ per ton in 2060, showing that with developing technologies of CCC or Carbon Capture and Storage. The total abatement, combining fixed costs and operating costs, cost is 65$ per ton CO_2. In Japan, the

cost of CCC is 54$ per ton CO_2 and 60–193$ per ton CO_2 in Australia. By 2060, the CO_2 emission reduction ratio of carbon capture, utilization, and storage (CCUS) will be about 10% of the total reduction of the emissions. Moreover, modern technology development is going to increase the efficiency of the system energy consumption barriers.

Point of weakness:

High operating cost:

Cryogenic carbon capture projects cannot be always constructable due to initial cost and investments, causing it to be not cost-effective. The specialized equipment and infrastructure needed for cryogenic processes are not affordable and expensive to build and maintain. Constructing pipelines, storage facilities, and monitoring systems for Carbon Capture and Storage (CCS) projects represents a significant financial challenge at the construction phase, after which the return is satisfying.

High energy requirement for regeneration:

The energy required for carbon capture can reduce the overall efficiency of power plants, leading to higher energy costs. While CCS can be used to capture CO2 from fossil fuel power plants, it does not address the underlying issue of reliance on fossil fuels. Concerns about potential environmental risks and the long-term viability of storage can hinder public acceptance and support for CCS projects. The process of cooling gases to extremely low temperatures require substantial energy input, often from fossil fuels. This can offset the environmental benefits if not carefully managed. Transporting and storing captured CO2 can also be energy-intensive, particularly over long distances.

High possibility of process blockage:

Carbon Capture and storage projects are not always applicable technology; however, there are feasible applications where cryogenic separation has advantages compared to other technologies. Ensuring efficient and safe operation at extremely low temperatures can be complex and requires advanced engineering solutions. Preventing leakage from storage sites and ensuring long-term stability of CO2 deposits are ongoing technical challenges.

Smog Free Tower

The Smog Free Tower was designed by the Dutch artist Daan Roosegaarde and **is shown in Figure 45**. The tower is 7 meters tall and functions as a huge air purifier. The tower is made to be able to clear 30,000 cubic meters of air per hour. It has been placed in various countries, including China, South Korea, the Netherlands, and Poland where it showed its effectiveness in solving the air pollution problem. The tower's design and operation are based on advanced positive ionization technology, which removes harmful particulate matter (PM) from the air. In addition to air purification, the Smog Free Tower project includes a recycling system that uses the collected smog particles.

Figure 45: A real picture representing the smog free tower

Mechanism:

The Smog Free Tower utilizes the patented positive ionization technology, which **is shown in Figure 46**, according to the following steps:

The tower draws in polluted gases from the surrounding environment through multiple vents in its body. These vents are controlled and can open or close according to the needs. They are also designed to increase the volume of air processed by the tower. Once inside the tower, the air passes through a series of filters that utilize positive ionization technology. This process involves the generation of positive ions that attach to airborne particulate matter, such as PM2.5 and PM10. The positively charged particles are then attracted to negatively charged collection plates within the tower. This electrostatic attraction causes the particles to adhere to the plates. After the particulate matter is removed, the purified air is released back into the environment through the tower's exhaust vents. The tower then repeats the process continuously allowing for less polluted air in the environment. The tower also uses the collected particles, which are then used to create jewelry, such as rings. Each piece of jewelry represents 1,000 cubic meters of clean air, turning pollution

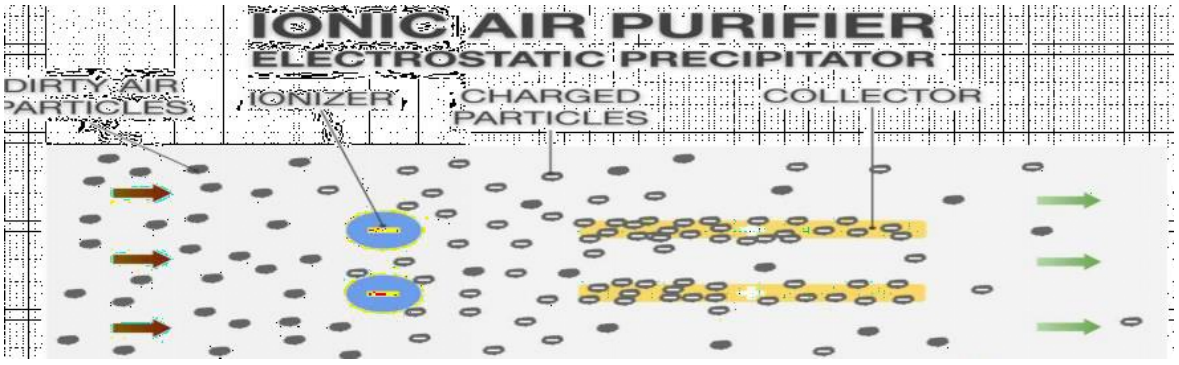

Figure 46 Figure representing the ionic air purification process

Points of Strength

Improved Air Quality

By capturing PM2.5 and PM10 particles, the tower helps to decrease the health risks associated with air pollution, such as respiratory and cardiovascular diseases. Studies conducted by

the Eindhoven University of Technology have proved the tower's effectiveness in decreasing the mentioned pollutants emphasizing its advantages.

Energy Efficiency

This is achieved by low-energy fans and efficient ionization technology. The tower's energy consumption is comparable to that of a household appliance, making it a sustainable solution for cities looking to improve air quality without increasing their energy consumption and thus saving energy.

Public Awareness and Engagement

The presence of the tower in urban areas raises public awareness about the issue and encourages citizens to take action to reduce their contributions to air pollution. The tower's design and the jewellery made from collected smog particles also provide a clear connection to the problem since people are usually attracted to observable progress.

Points of Weakness:

Limited Coverage Area

This is because while the tower can purify a significant volume of air, its impact is restricted to the immediate vicinity. To achieve city-wide improvements in air quality, multiple towers would need to be deployed, which could be costly and challenging. The effectiveness of the tower also diminishes with distance, making it less suitable for large-scale applications without extensive planning.

Maintenance Requirements

The filters and ionization components of the Smog Free Tower require regular maintenance and replacement to ensure optimal performance. These frequent maintenance costs may cause a challenge for cities and countries with low budget. The need for skilled technicians to perform maintenance tasks also adds to the total costs.

Temporary Solution

This is because while the tower can decrease pollution rates in the surrounding areas, it doesn't address the root cause of these pollutants. Solutions for the pollution challenge require decreasing the gaseous waste of restaurants, factories, and vehicles.

Chapter 2: Generating and defending a solution

Solution and design requirements

Solution requirements

Sustainability and Flexibility

The solution and the prototype overall should be sustainable, easy to maintain and the ability to build anywhere, so the solution was chosen as it can work in almost all environments, and it is easy to utilize. The project also uses recycled materials which make sustainability for production and use. Being greatly helpful for the project, flexibility is a significant requirement that should be considered, as the device absorbs excess emissions and makes advantage of them reducing the overall danger and solving the problem. The solution should be made from waste materials not harming the environment. An example of sustainability as a requirement was that waste materials should be used. Furthermore, and filtration procedures should meet the requirements.

Engineering Quality

Engineering quality, including efficiency, is a study to ensure the ability of the device to be constructed correctly without negative impacts. In other words, it is developing and upgraded or introducing new products. Engineering quality, in any project, determines success that will happen in the global marketplace. So, the solution will consider some functional, structural factors such as the solidity of the tools from which the device is made and the extent of their ability to withstand outside effects or damages. Legal and regulatory requirements permit, licenses, and safety standards adherence are legal and regulatory requirements that apply to devices being permitted to be used. Applying that in our solution, this strengthens the solution qualification to construct the real-life project.

Cost-effectiveness

Solution requires materials that is completely based on treated waste materials in addition to recycled building materials. To achieve the requirements, materials should be cheap materials. Appropriate cost gives the possibility to initiate the solution anywhere despite poverty. Since cost is a considerable marketing factor for our solution, it will also determine the spread of its applications in Egypt. Population growth inhibits the solution spread and availability. Our solution provides poor countries, which suffer from poverty, with methods to reduce excessive emissions.

Eco-friendly

The project being built from recyclable materials will help the environment immensely, it will also be built from recyclable that isn’t harmful to the environment. For example, only types of plastic that are sustainable will be allowed to help the environment in the long term. Furthermore, by using recyclable materials we will clean the environment by removing this waste from it and using it. The device should be environmentally friendly to minimize harm and waste.

Design Requirements

Efficient Pollutant Oxidation via Water Spray

The system must be capable of efficiently oxidizing SO_x and NOx pollutants by exposing them to a water spray in an enclosed chamber. This process should lead to the formation of sulfuric and nitric acids without the need for additional chemical or thermal reactions.

Ammonia Injection and Salt Formation

The system must incorporate a controlled ammonia (NH_3) injection mechanism that ensures the reaction between the acids and ammonia, leading to the formation of ammonium sulfate and ammonium nitrate salts. This reaction must occur at ambient temperature and pressure, with no requirement for external heating.

Coffee Ground-Based Filtration System

The system must include a cylindrical filtration component filled with spent coffee grounds. The coffee residue must have sufficient adsorptive capacity to absorb ammonium salts (ammonium sulfate and ammonium nitrate) and other residual pollutants, thus purifying the air before release. The filtration process should be scalable and designed for easy maintenance and replenishment.

Selection of solution

Reducing AQI values is an essential goal for Egypt. AQI values in Egypt have constantly increased over the years. As of now Cairo, Egypt's capital and most condensed city with more than a fourth of the country's citizens taking residence in it, is considered the 9th most polluted city in the world where PM2.5 concentration in Cairo City is currently 9.5 times the WHO annual air quality guideline value. This imposes many difficulties for Egypt's authorities since it causes great health risks to Egypt's public health and the climate, especially with Egypt's high population growth values. In Egypt, non-communicable diseases, including cardiovascular and chronic respiratory illnesses, account for 82% of all deaths, with 67% being premature deaths.

The chosen solution to solve the problem of Cardiovascular and respiratory diseases in Downtown Cairo is to develop a system that can take in the polluted air from its surroundings and release it after purifying it from pollutants where it doesn't affect public health or contribute to climate change. The system will be able to decrease pollution problems significantly in the target areas, especially in long-term usage.

The system used in this air treatment consists of an intake pipe connecting to the main chamber in which the pollutant values are measured through a sensor. The air will then pass through multiple chambers that utilize chemical, biological, and physical processes that will decrease the concentration of PM and some chemicals according to data provided by the sensor and then release the purified air from the system through a chamber that contains a device which forces air to flow from the main chamber, across the purification chambers and finally to the release chamber.

To ensure the efficient operation of the system it is provided with a precise monitoring system that provides data crucial for controlling the system's processes. The monitoring system consists of multiple sensors that can show the amount of target pollutants and provide live data that can be used to provide the minimum amount of chemicals needed to perform purification processes.

The chosen location to implement this system is Downtown Cairo (Tahrir Square and Ramses Square). This location was chosen due to the high traffic congestion which is a result of it being in the middle of the most crowded places in Cairo. The target pollutants of our project are NOx and Sox which are produced by the different means of transportation used in this area and different PM and VOC pollutants that contribute to the AQI values.

Selection of prototype

The prototype will consist of four identical containers connected to each other by two identical pipes and one tap so that fresh air can exit **as shown in figure 46**. The first container is cube-shaped with a side length of 25 cm and a volume of 15625 cm^3 to contain highly polluted air so that the prototypes can be tested under the highest levels of pollution. Then the polluted air will pass through a pipe number 1 which has the shape of a medium size tap to control the flow rate of polluted air. Then the air will move to container 2, empty container, to test the and determine the amount of SO,NO, and VOCs in aire usingq-135 sensor. After that polluted air will pass through a pipe 2, has the shape of a cylinder with a base of radius 25 and a height of 10, which will be completely filled with coffee to reach container 3, which contains ammonia (NH_3). Then a pipe 3, identical to pipe 2 in shape, components, and containg coffee, will be connected to container 4, which will contain filtered air.

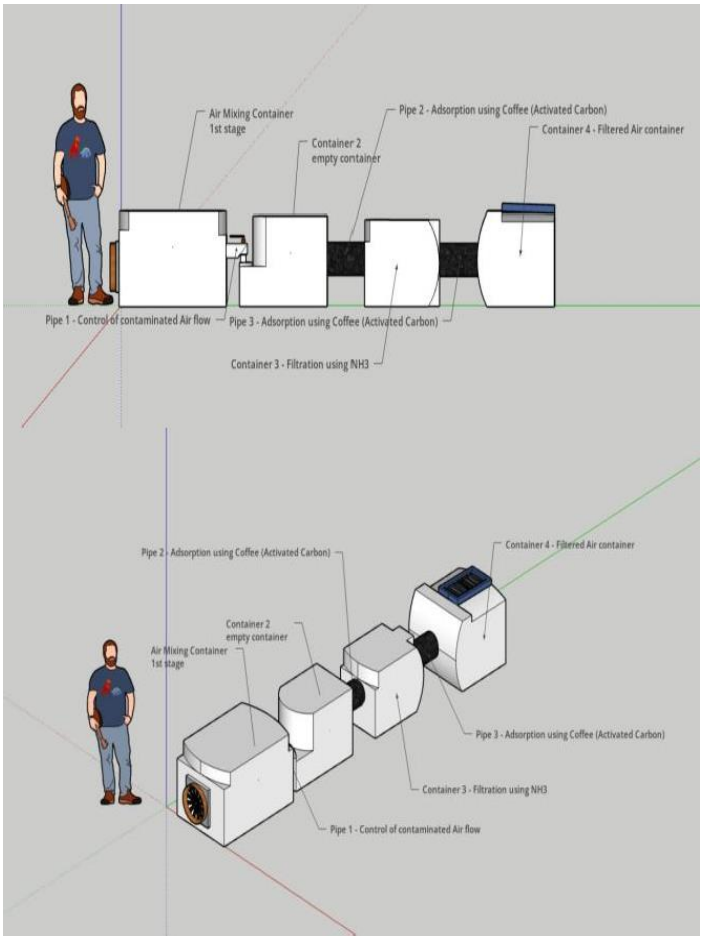

Figure 47 shows the 3D design of the prototype

The opening and closing process of the pipes will be supervised by the presence of medium size pipe 1 or tap. When the reaction in container 3 complete, pipe 3 will be opened and pipe 2 will be closed. A sensor will be placed in container 2 to measure the percentage of each gas, and a sensor in container 4 to know the change in the amount of harmful gases and to ensure the success of the process