AEROPURE TYRES

Group 10213

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STEM High School for Boys - 6th of October

Grade 11 - Semester 1 | 2024 - 2025

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Chapter 1: Present and Justify a Problem and Solution Requirements.

Introduction

Egypt confronts significant obstacles referred to as "Grand Challenges," **illustrated in Figure 1**. These challenges contribute to the decline of its economic, scientific, cultural, and technological foundations. Egypt aims to address these issues as part of its Vision 2030 plan, with hopes of achieving solutions by 2030.

Figure 1:

Egypt's Grand Challenges

Recycling garbage and water leads to both the reduction of pollution in the air, water, and soil and decreasing health problems from contaminated water. The burning of garbage in landfills and its decomposition can lead to the release of greenhouse gasses such as methane and carbon dioxide, leading to climate change and pollution. Pollution coming from fossil fuel, as well as landfill, burning causes health problems in the respiratory system. Large populations, specifically in high densities, lead to increased garbage and air pollution. They can, in addition to warmer climates, lead to increased disease transmission among communities.

Egypt Grand Challenges

Recycle Garbage and Waste for Economic and Environmental Purposes

Egypt faces a serious problem of waste management. Rapid population growth and urbanization play a primary role in this problem. Recent studies indicate that the country's waste production is growing at an alarming rate, currently increasing by about 3.4% annually, this is mainly because Egypt's population grows by around 2 million people each year. This increase in waste generation is beyond Egypt's recycling capabilities. The global standard of recycling is 40-60% of waste, **as shown in Figure 2**. Unfortunately, Egypt's infrastructure is still undeveloped enough to achieve this percentage, it only recycles about 15-20% of its waste. The insufficient infrastructure makes it harder for the country's management systems. In addition, many of them are either improper or illegal.

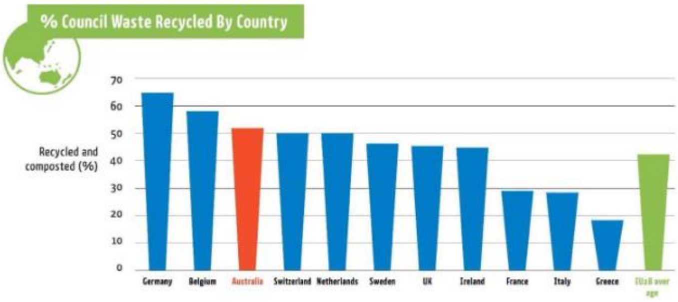


Figure 2:

Global rate of recycling.

Egypt currently has about 30 formal recycling sites, which are not enough to process the massive amount of solid waste being generated, which is estimated to be 26 million tons of solid waste and increasing, **as shown in Figure 3**. Moreover, despite efforts to establish waste sorting and recycling facilities, the country lacks a comprehensive waste collection and segregation system. Only about 9% of Egypt's households have access to formal recycling services, leaving the majority of waste either burned or dumped into illegal landfills. Additionally, a lack of public awareness and educational campaigns means that many Egyptians are unaware of the benefits of recycling, with participation rates in recycling programs hovering around 8-10%. This combination of factors underscores the urgent need for Egypt to develop a more robust and efficient recycling system to address the growing waste crisis.

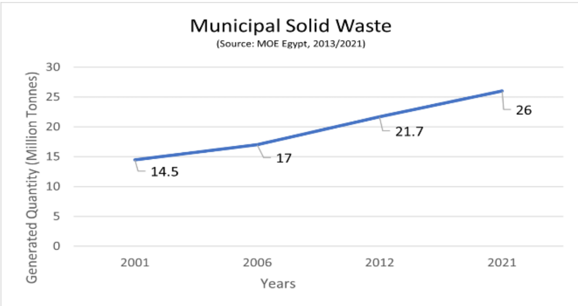


Figure 3:

Solids wastes in Egypt.

Causes

Rapid Growth in Waste Generation

Egypt is currently experiencing huge urbanization and population growth. This growth is accompanied by an increase in waste generation. Now Egypt produces about 26 million tons of solid waste annually, expected to increase to 50 million tons by 2030 if the problem isn't solved. The population is expected to increase to 160 million by 2050 with the rate of urbanization expected to increase to 69%, **as shown in Figure 4**, this will increase the waste produced by the urban areas and not being recycled.

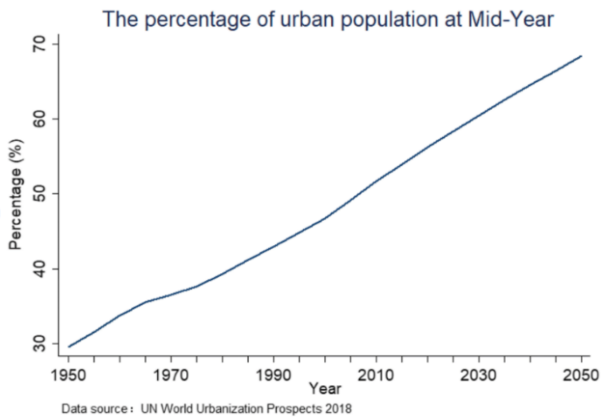


Figure 4:

Urbanization rate in Egypt.

Insufficient Waste Management Infrastructure

The lack of proper infrastructure is a primary cause of the problem of Egypt's recycling challenges. The country generates around 26 million tons of waste annually, but only 12-15% of this waste is recycled, **as shown in Figure 5**. Most of the waste is being dumped in dumpsites or landfills. Most of these landfills aren't equipped with advanced recycling technologies. A 2021 report indicated that about 3,000 illegal dumpsites are spread across the country, contributing to environmental decay, and limiting the recovery of recyclable materials. This undeveloped infrastructure has improper funding, which has led to has led to inefficient waste collection and processing systems. There are illegal garbage collectors who manage to recycle up to 80% of the waste they collect, but due to the absence of formal recognition and support, they are unable to scale up their efforts.

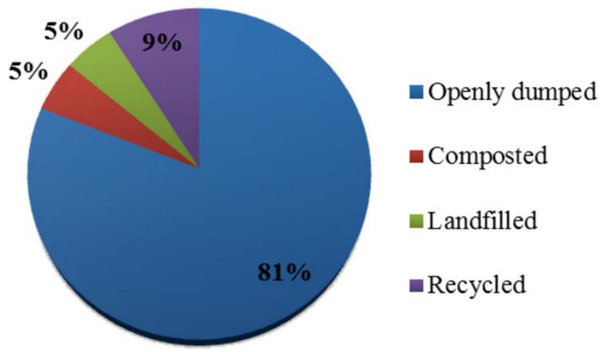


Figure 5:

Fate of waste in Egypt.

Weak Regulatory Framework

Few government policies encourage recycling, and existing regulations are not enforced effectively. For example, only 1-3% of Egypt's hazardous waste is safely treated, and the rest is often improperly removed, including toxic medical waste and industrial by-products. There is no national recycling law, and the recycling programs are primarily managed by local governments with limited capacity to enforce policies or expand infrastructure.

In addition, there is a low awareness of the importance of recycling among people. Surveys reveal that 60% of Egyptians do not engage in any recycling practices, and many are unaware of the environmental and economic benefits of recycling. Furthermore, there are very few public recycling bins or collection services, especially outside urban centers, which makes it difficult for people to recycle even if they are willing to do so.

Impacts

High Organic Waste Composition

The huge amount of organic waste in Egypt is considered a serious problem. **As shown in Figure 6**, according to EEAA, about 56% of Egypt's total solid waste is organic, equivalent to around 45 million tons generated annually. Organic waste has many forms, for example, food scraps, agricultural residues, and yard waste. This waste is left in landfills, thus producing methane gas. Methane gas is considered a greenhouse gas. According to the World Bank, Methane gas is about 25 times more harmful than carbon dioxide over a 100-year period. If this organic waste is recycled, there will be less methane which will significantly reduce greenhouse gas emissions.

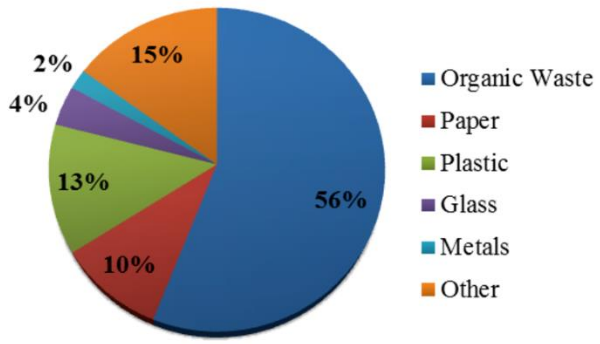


Figure 6:

Composition of solid waste in Egypt.

Environmental and Public Health Concerns

Waste management in Egypt results in significant environmental health problems. Studies reveal that improper dumping of waste is linked to respiratory diseases, waterborne illnesses, and other health problems. Around 20% of the total waste in Egypt is considered hazardous and very dangerous, including medical waste, electric and electronic waste, and industrial by-products, which add additional risk of not being handled well. The results of poor recycling in Egypt include soil contamination, air pollution from burning waste, and the degradation of natural habitats. By increasing the recycling rate, Egypt will experience fewer problems and a more friendly environment.

Economic Loss

There is a lot of economic loss due to the lack of recycling in Egypt. The 90 million tons of Egypt contains valuable materials such as plastics, metals, and organic waste, which could generate an estimated 1.5 billion dollars per year.

The management system of waste in Egypt affords high costs for landfill operations. An estimated cost of 2.5 billion dollars annually is due to poor waste handling practices, environmental damage, and healthcare costs related to pollution. Since the recycling sector in Egypt is still undeveloped, it adds additional costs for unemployed people. Increasing the recycling industry will add thousands of job opportunities. For example, the informal recycling sector already employs over 1 million people, but better infrastructure could increase this significantly.

In addition, Factories in Egypt import raw materials which costs billions of dollars. Plastic is an example of these raw materials, in 2020, Egypt spent over 2 billion dollars to import plastic only. This cost could be reduced by recycling the existing plastic waste. All these losses together emphasize the need to improve the recycling process in Egypt to reduce the financial strain.

Address and Reduce Pollution Fouling Our Air, Water, and Soil

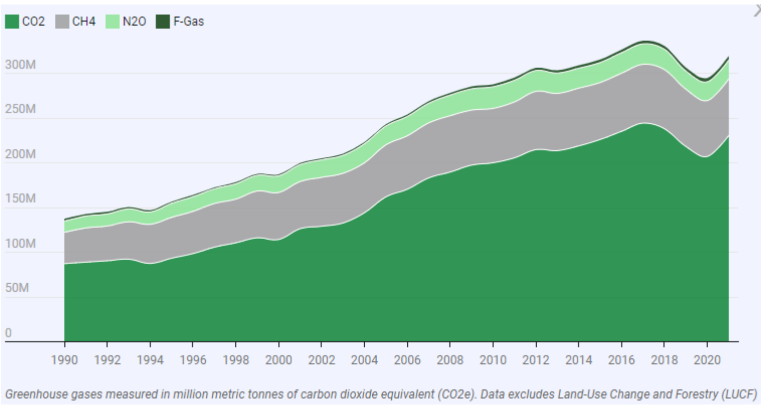


Figure 7:

Greenhouse emissions in Egypt.

Pollution is the introduction of harmful materials into the environment. These harmful materials are called pollutants. Air pollution has been a problem for Egyptians for decades, particularly in large cities such as Cairo. Egypt is the 9th country in the world according to the level of air pollution in 2023. Pollution in Egypt has many forms including air, soil, and water pollution. This pollution threatens many sectors in Egypt including agriculture, health, and others.

Air pollution is an obvious problem, especially in industrial cities. **As shown in Figure 7,** The amount of greenhouse gases in Egypt is increasing, which indicates that air pollution is getting more serious every day. According to the World Health Organization (WHO), Cairo is one of the most polluted cities in the world in terms of air quality, with particulate matter (PM2.5) levels frequently exceeding safe limits.

Water pollution is also an important problem. The Nile River, Egypt's main source of drinking water, is severely polluted with industrial wastes, agriculture runoff, and untreated sewage. According to the Egyptian Environmental Affairs Agency (EEAA), a significant portion of the Nile is contaminated, impacting drinking water quality and reducing agricultural productivity in the Nile Delta, which is the most important agricultural area.

Soil pollution is another serious problem due to the wide use of fertilizers and chemical pesticides. The Food and Agriculture Organization (FAO) highlights that soil degradation in Egypt threatens food security as arable land is gradually lost to pollution.

Causes

The Quality of Diesel Fuel

Most of the pollution, specifically air pollution, in cities, comes from the burning of fossil fuels as means of transport. According to the Egyptian Environmental Affairs Agency (EEAA), diesel-powered vehicles account for around 70% of total vehicular emissions in major cities like Cairo. Diesel fuel in Egypt usually contains a relatively high amount of Sulfur. The burning of diesel fuel with Sulfur in it leads to the reaction of Sulfur with Oxygen in the air, resulting in the evolution of Sulfur dioxide (SO_2), which is considered a greenhouse gas that leads to an increase in air pollution.

During rain, some of this sulfur dioxide gas dissolves in the water droplets, leading to the formation of acidic rains. When these rains fall on waterways, they cause water pollution. If this waterway is a river or a groundwater source, drinking this water can be poisonous. When watering the soil with polluted water, it causes soil pollution and thus affects the quality of the crops.

The Improper Disposal of Plastic Waste

According to the Egyptian Ministry of Environment, the country generates 90 million tons of waste annually, just 20% of it being properly treated or recycled. The remaining 80% is usually dumped or managed in open landfills. This huge amount of waste leads to the spread of pollutants that cause soil and water contamination.

One of the most polluting wastes is plastic. According to the United Nations Environment Program (UNEP), Egypt produces about 970,000 tons of plastic waste every year. 42,000 tons of them are being dumped in the Mediterranean Sea, which makes Egypt the largest polluter in the Mediterranean countries, **as shown in Figure 8**. This plastic threatens marine life because large items of plastic can capture and entangle marine mammals and fish and stop them from escaping, usually leading to starvation, injury, and predator vulnerability. This is why plastic causes water pollution.

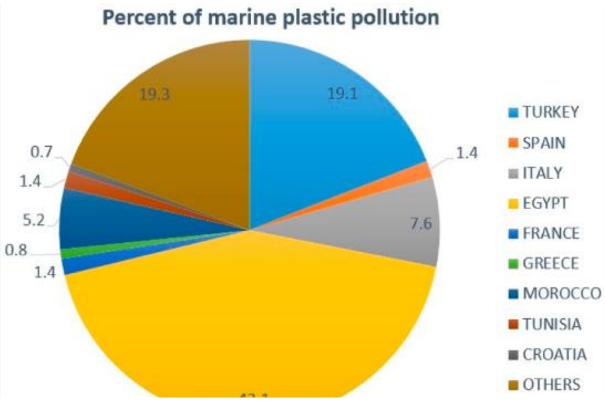


Figure 8:

Percentage of plastic leakage into the Mediterranean Sea.

Industrial Emissions

Industry in Egypt has been growing exponentially. The factories have waste that is often harmful to the environment. According to the Egyptian Environmental Affairs Agency (EEAA) in 2023, industrial activities are responsible for approximately 30% of the total air pollution in Egypt. Some harmful gases, such as sulfur dioxide (SO_2), Carbon dioxide (CO_2), Nitrogen oxides, and many others. These gasses decrease the quality of the air and cause air pollution.

Another form of pollution caused by factories is water pollution. Also, according to EEAA, 60% of industrial facilities in Egypt don't treat their wastewater before dumping it into the seas or the Nile River. This causes contamination in the drinking water in the Nile River or even destroys marine life in the seas.

Impacts

The Health Toll of Air Pollution

Air pollution, in all forms, affects the public health obviously. It is responsible for more than 6.5 million deaths each year globally, a number that has increased over the past two decades. Egypt faces severe health problems because of air pollution. According to the World Health Organization database, air pollution-related illnesses responsible for premature mortality in Egypt in 2016 included heart disease (57.9%), stroke (17.7%), and pulmonary and lower respiratory diseases and cancer (24.4%).

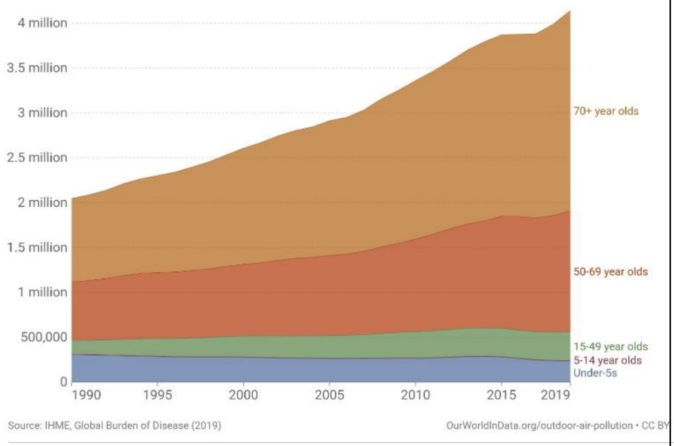


Figure 9:

Deaths caused by air pollution.

The impacts of air pollution on Egyptian health aren't limited to just illness, sometimes the disease develops leading to death. According to the Institute for Health Metrics and Evaluation, about 12% of deaths in Egypt, which is counted to be 4.2 million people, in 2019 because of air pollution, **as shown in Figure 9**. This percentage is more than the average death caused by air pollution in the world, which is about 11%. That's why it's a serious impact that should be considered.

The Economic Burden of Air Pollution in Egypt

Pollution causes economic loss due to its consequences. According to the World Bank in 2019, Pollution in Egypt costs about 47 billion dollars annually, which is approximately 4.4% of the country's Gross domestic product (GDP). For example, an estimated amount of 22 billion dollars is being paid for pollution-caused diseases including surgical operations for cardiovascular diseases and others. Evidence is that according to the World Health Organization (WHO), air pollution-related health issues are responsible for approximately 40,000 premature deaths annually in Egypt.

According to The Food and Agriculture Organization (FAO), There are economic losses of about 2 billion dollars annually in agriculture due to reduced crop quality, which pollution contributes to the large cause of it. Also, according to the EEAA report in 2020, air pollution leads to increased healthcare costs, with 30% of hospital admissions in urban areas linked to air quality problems.

Effect of Water Pollution on Marine Ecosystems

Rising pollution levels in waterways have severe consequences on marine life. Increasing the percentage of pollutants like heavy metals or agricultural wastes, containing fertilizers and pesticides, can kill some fish species, thus decreasing the biodiversity of marine life. The United Nations Environment Program (UNEP) in 2020 reports that nearly 30% of the species native to the Nile are threatened due to pollution and habitat degradation. According to the WHO in 2021, fertilizers and pesticides specifically have negative results on the food of the fish as they allow harmful blooms to grow thus consuming oxygen and decreasing its percentage in water bodies.

Reduce and Adapt to the Effect of Climatic Change

Climate change, according to the United Nations (UN), is defined as the changing of the atmosphere's composition due to natural causes such as solar activity, volcanoes, and anthropogenic causes. The last of which started from the 1800s forward due to the industrial revolution's generation of power coal burning and fuel.

The ND-GAIN index, which ranks countries based on vulnerability to Climate Change, considers Egypt the 93rd most vulnerable country to Climate Change. **As shown in Figure 10,** the annual mean temperature increase went from ~ 0°C in 2009 to 0.7°C in 2024. This adds to Egypt's already hot and dry climate, where desert area temperatures can fluctuate from 7°C to 44°C. It's expected by the year 2050, if climate change is not addressed, that temperatures increase to 6°C above pre-industrial levels.

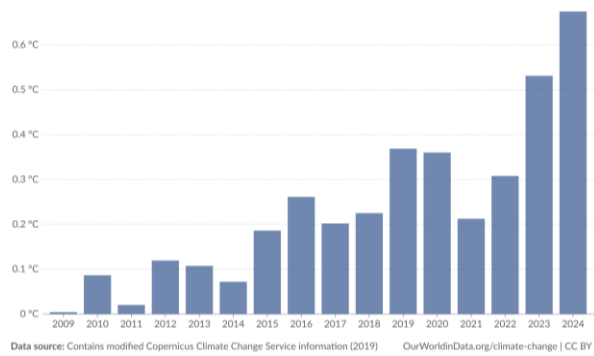


Figure 10:

The annual mean temperature.

Air pollution is very linked with climate change. Fine air pollution particles, or aerosols, (PM2.5) include black carbon, ground-level ozone, and hydrofluorocarbons among other gasses. **Figure 11** shows black carbon emissions in Egypt during the last 80 years. According to WorldBank.info, they are responsible for 6.4 million deaths annually, caused by diseases such as ischemic heart disease, stroke, lung cancer, and pneumonia. PM2.5 is also a major contributing factor to climate change. Methane is 80 times more potent than the commonly known carbon dioxide over a 20-year time span.

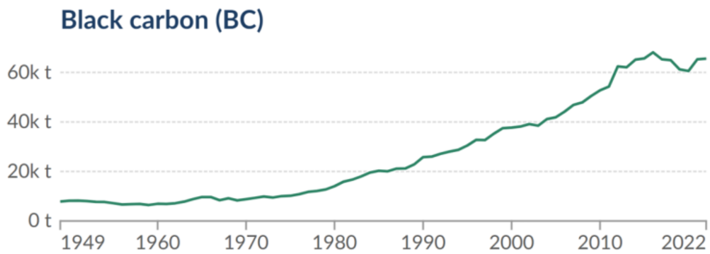


Figure 11:

Black carbon emissions in Egypt.

Causes

Energy Industry

Temperature increases resulting from Climate Change ensure the importance of decreasing fossil fuel usage, which produces Greenhouse gasses. According to our World in Data, in 2022, nearly 88%, **as shown in Figure 12,** of Egypt's electricity came from fossil fuels, where 71% of the energy produced from fossil fuels comes from gas, which is Egypt's main energy source, producing 121 million tons of Carbon Dioxide Gas.

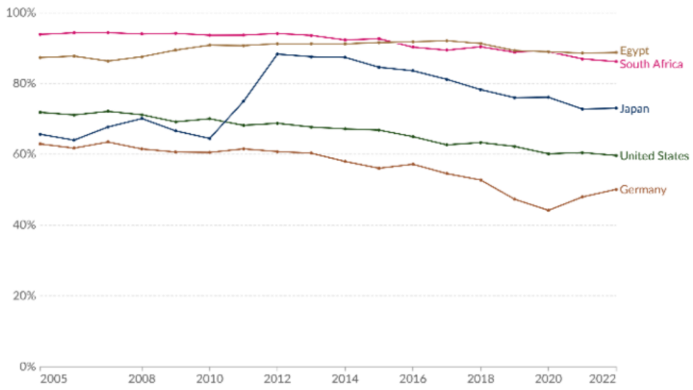


Figure 12:

Sources of Egypt's electricity.

Fertilizers

Until Nitrous oxide becomes synthetic to be absorbed by plants when fertilizing with manure, a lot escapes due to its mobility. It stays in the atmosphere for over 100 years and is also 300 times better at trapping heat than carbon dioxide. Agriculture has produced over 15 million tons of nitrous oxide, **as shown in Figure 13,** which equates to 4500 million tons of carbon dioxide.

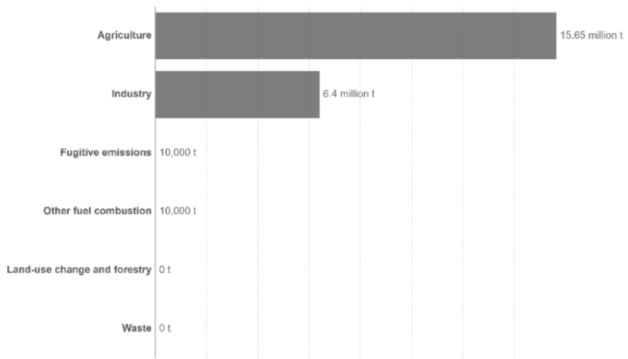


Figure 13:

Nitrous oxides Emissions in Egypt.

Fugitive emissions of Methane

Fugitive emissions are caused by the leakage of substances like natural gas, where natural gas consists of a minimum of 75% methane gas. Fugitive emissions have led to the emission of approximately 29 tons of methane gas **as shown in Figure 14**.

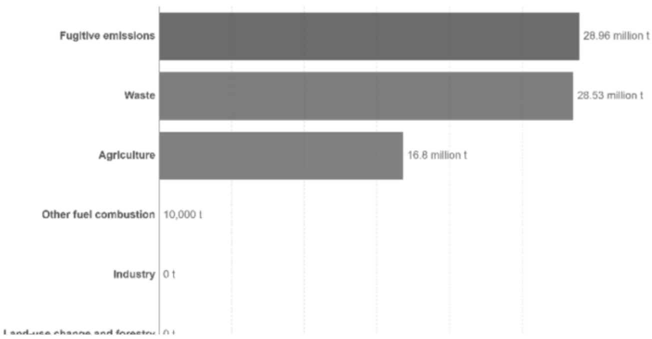


Figure 14:

Methane emissions in Egypt.

Impacts

Decrease in the Amount of Precipitation

Climate change has led to a decrease in precipitation rates over time, this is exclusive to northern Africa, where no other countries have shown decreased precipitation rates due to climate change. This could cause droughts leading to the death of many plants, and thus huge supply deficiencies, possibly turning into an economic crisis.

Rising Sea Levels

Figure 15 shows what areas are expected to be under sea level if climate change gets to certain degrees. Furthermore, almost 15% of the population of Egypt lives around the coastlines. Additionally, The Nile is especially prone to flooding from the melting of the polar regions, as one-fourth of the Nile Delta would be flooded. Additionally, one-fifth of Egypt’s workforce is in the Nile Delta, where the Delta is responsible for 12% of Egypt’s GDP.

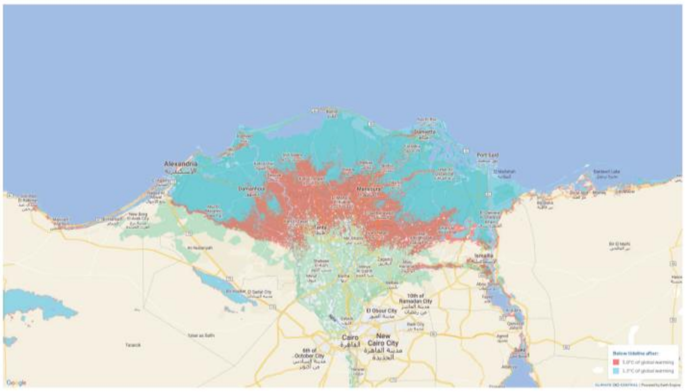


Figure 15:

Threatened areas by climate change.

Food Insecurity

Food production and supply would be affected by the flooding of agricultural land. By the time the Mediterranean Sea level rises by one 1 meter due to the melting of the ice in the two poles, 12% of the Nile Delta would be flooded. This puts Egypt’s agricultural production at risk, where nearly half of Egypt's crops, including wheat, bananas, and rice, are grown in the Nile Delta. The remaining areas that are not underwater would also be affected by salt water from the Mediterranean Sea contaminating aquifers, which are used for consumption. It could also contaminate clean water, which is used for agriculture, leading to more food scarcity.

Work to Eradicate Public Health Issues and Diseases

The public health issues in Egypt are enormous, as they grapple with communicable and non-communicable diseases, inequalities in access to health care, environmental threats, and high population growth. Levels of maternal and child health care have improved relative to where the country was five years ago as well as the published prevalence rates of Hepatitis C infection, however the burden of health care shifts to non-communicable diseases such as heart diseases, cancer, and diabetes which is on the rise. Equity in the delivery of health care services remains a challenge, particularly between the rural and urban areas with the latter having a comparatively higher infrastructure and services.

Severe air pollution and poor water sanitation represent other environmental health hazards that further stress the health system by aggravating respiratory and diarrheal diseases. The state, among other health system reforms, has adopted the 2018 Universal Health Insurance Law which is a goal geared to provide health services for every citizen, while also promoting various health campaigns such as that against Hepatitis C. There are also active collaborations with many international organizations and institutions including the WHO, UNICEF and the World Bank that help Egypt in these issues. Despite these initiatives, the country faces ongoing challenges as gradually seeks to improve healthcare infrastructure, manage environmental threats, and aim at providing all the regions in the country with services for the increasing population, focusing on the areas which are less populated with facilities. Here too the country's attention stands to bear upon many population factors.

Causes

Polluted Air

From every 10 people, there are 9 breathing polluting air caused by many things such as burning fossil fuel, the smoke from the factories, and burning trash instead of recycling it such as plastic which produces carbon dioxide heavily. Air pollution in Cairo is a matter of great concern. Air pollution in central Cairo is 10 to 100 times higher than acceptable world standards. The dark side of Cairo lies in that the city has high-rise buildings and narrow streets, creating a bowl effect (poor oxygenating and trapped pollutants). Egypt's biggest air pollution problem is particulate matter. The main sources of dust and small particles are transportation, industry, and outdoor waste incineration facilities. Another important source of dust is the wind blowing from the dry areas around Egypt.

Population Density

Egypt suffers from a high population percentage and this caused many problems such as the transmission of many diseases because of the daily handling like influenza, Egypt's population increased by 1.6 million in 2022 to reach 104.4 million in December, up from 102.8 in January, according to the Central Agency for Public Mobilization and Statistics (CAPMAS) and the population increases by 1.67% every year, **as shown in Figure 16**, that explained the population increasing from 2018 to 2028.

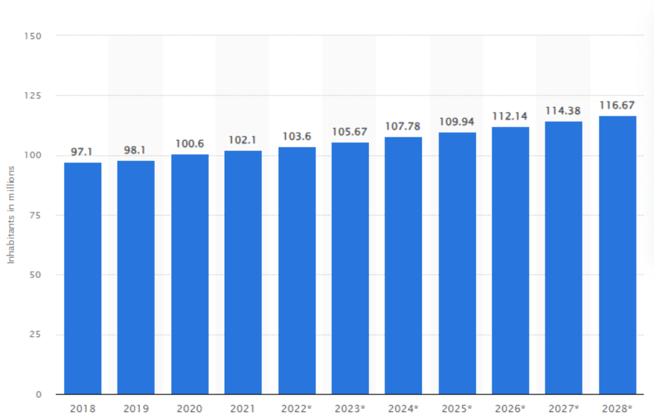


Figure 16:

Egypt's population.

Lack of Awareness

There is a lot of Egyptians, especially in the villages don't know the importance of getting a vaccination against diseases and ignore it, some of them don't secure themselves if he has any issues like wearing a mask if they have a cold and there is also Poor hygiene considered as the lack of awareness, lack of sanitation facilities, and improper disposal of waste can contribute to the spread of diseases, especially those transmitted through contaminated water or surfaces.

Polluted Water

It is any physical or chemical change in water quality, directly or indirectly, that negatively affects living organisms, or renders the water unfit for the required uses. Water pollution has a great impact on the life of the individual, the family, and society. Water is a vital requirement for humans and other living things. Water may be a major reason for ending life on Earth if it is polluted. Some polluted water looks muddy, smells bad, and has garbage floating in it. Some polluted water looks clean, but it is filled with harmful chemicals you can't see or smell.

Impacts

Lack of Productivity

One of the negative effects of health problems is reduced work productivity. If the person has a long-term illness, such as kidney failure caused by polluted water, he will not be able to do his job well which negatively affects the community.

Illness and Diseases

According to the CIA fact book, the four most common diseases in Egypt are bacterial diarrhea, typhoid fever, hepatitis A and schistosomiasis, and kidney diseases caused by the polluted water and polluted air that cause lung cancer, furthermore, Crowded places with high population density, such as cities or crowded events, can facilitate the rapid transmission of diseases due to close contact between individuals. According to the Centers for Disease Control and Prevention **in Figure 17** the top 10 causes of death in Egypt.

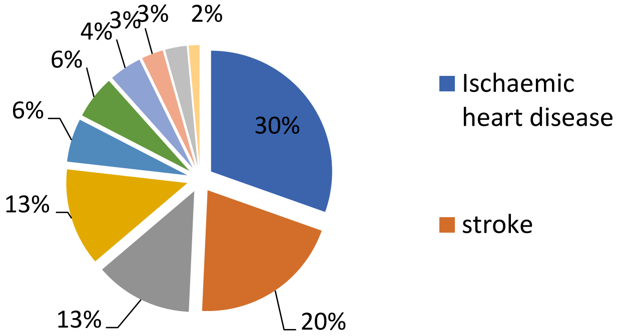


Figure 17:

Top 10 causes of death in Egypt.

Hepatitis C Epidemic

For many decades and until very recently, Egypt was among the countries with the highest prevalence of Hepatitis C in the world. The disease's transmission was mainly associated with unsafe healthcare practices. Most of the infections were among elderly people, **as shown in Figure 18**, which significantly affected the number of deaths and made a high increase in it. In this context, in Egypt, efforts to eradicate the disease commenced with the most recent campaign of hepatitis C elimination, which emulsified remarkably, solving the healthcare needs of over 2 million people by 2020. As a result of this action, the number of patients who had hepatitis C dropped significantly, restoring health for many populations, and providing a blueprint for designed vandals to save people from chronic VHD. Regardless of what has been achieved, there remains a necessity for further surveillance and proactive controlling approaches, which would guarantee that the disease will not make a comeback.

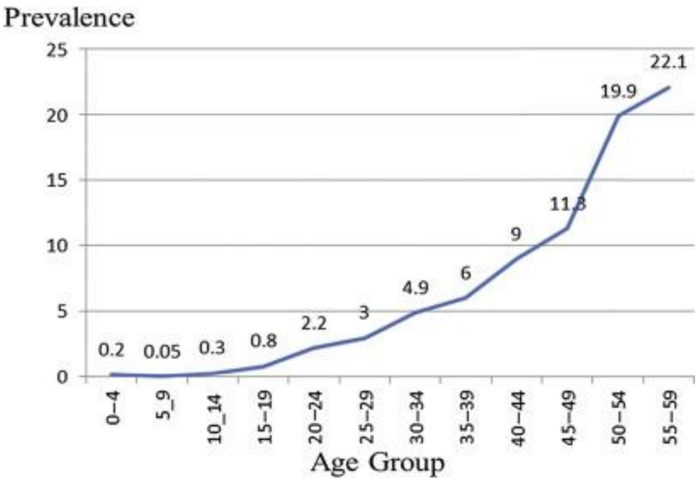


Figure 18:

Number of the prevalence in each age group in Egypt.

Deal with Population Growth and Its Consequences

Egypt is the third country in Africa in terms of population, following Nigeria and Ethiopia, and the first in the Middle East. Over the past decades, Egypt's population has been rising at a high rate compared to the global rate of approximately 0.9%, as stated by the World Bank. The population rose from 43.7 million in 1980 to 114.5 million in 2024. The annual growth rate is 1.57% in 2024, which is equivalent to 1.8 million individuals per year, whereas it was 2.44% in 1980, about 1 million. Although the rate is decreasing, the number added to the population is becoming greater. According to the World Population Prospects 2024 by the United Nations, it is estimated that Egypt's population will increase to 160 million by 2050, **as shown in Figure 19**.

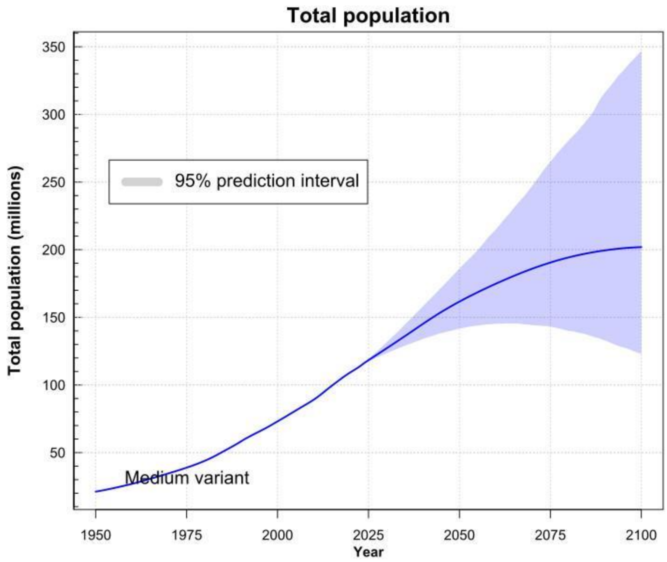


Figure 19:

Predicted Population of Egypt till 2100.

Egypt's population distribution is extremely uneven, **as shown in Figure 20**. In 2023, approximately 43.1% of the total population was urban, often in crowded conditions, while the rural population was 56.9%. As of 2022, the total inhabited land in Egypt represented only 10.5% of its total land area, which equals 1,002,000 square kilometers. The actual population density, the total population divided by the inhabited area, is about 1,700 persons per square kilometer, whereas the expected density, the total population divided by the total area, is 115 p/km².

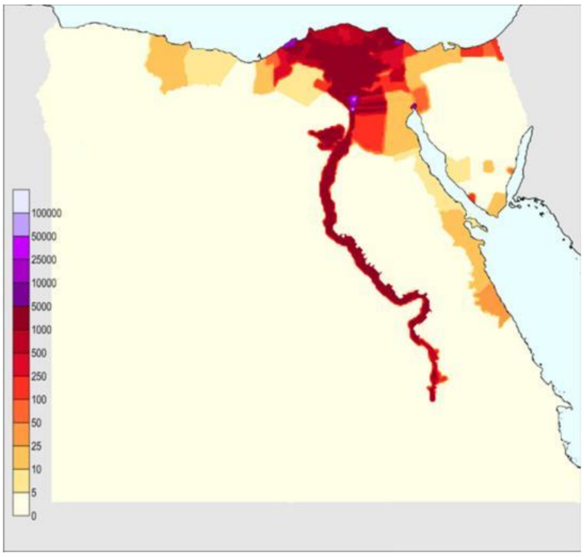


Figure 20:

Map of population concentrated areas.

Cairo, Alexandria, and Giza are the main metropolitan areas in Egypt. Cairo is one of the most overcrowded cities in the world, where its population density is approximately 19,000 people per square kilometer. Population density exceeds 100,000 p/km² in some areas of Cairo and Alexandria. **As shown in Figure 21,** a study by Statista indicated that three Egyptian cities—specifically Tanta, El-Mahallah Al-Kubra, and Al-Mansura—are among the world's 12 most densely populated cities, with densities of 31,360, 25,979, and 23,962 inhabitants per square kilometer, respectively.

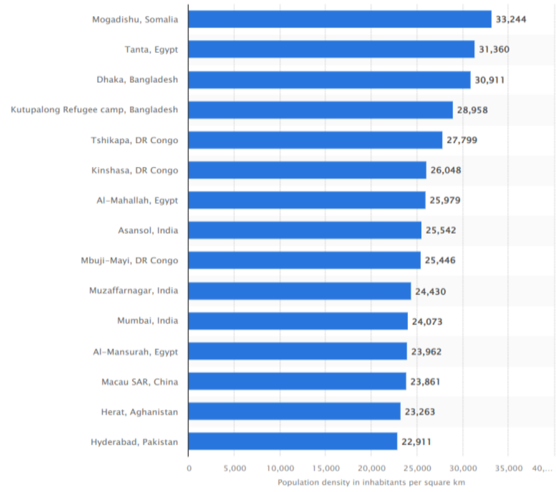


Figure 21:

Population density in inhabitants per square km.

Egypt's resources are limited compared to its huge population. The environment and natural resources are strained by the fast population growth, which demands more production to meet the basic needs and employment of the people.

Causes

High Fertility Rate

The fertility rate is the average number of children born to a woman in her reproductive years. According to the United Nations Population Fund (UNFPA), Egypt's fertility rate is 2.8 children per woman as of 2023. This means that 2,448,253 children are born annually. Although this rate has been declining since 1980, **as shown in Figure 22**, it is still higher than the replacement-level fertility rate of 2.1 children per woman, which is the rate at which the population can maintain its size without migration. The huge number of annual newborns, in addition to increased life expectancy and a low rate of mortality, **as shown in Figure 23,** causes the population to grow rapidly. The high fertility level is due to some key factors, including traditions, education, and poverty. For example, rural and Upper Egypt is still dominated by ideas and beliefs that

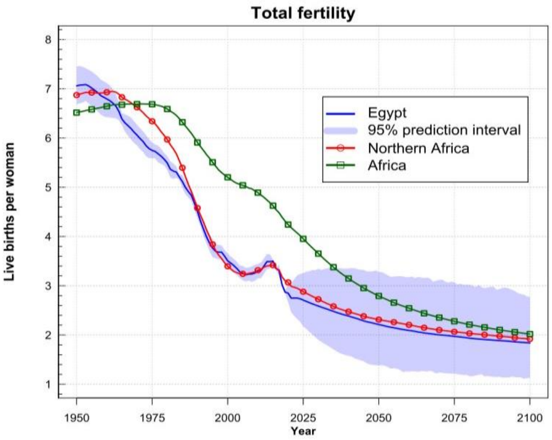


Figure 22:

Total fertility.

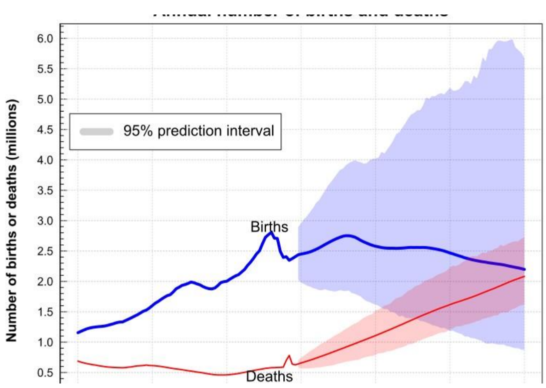


Figure 23:

Number of births and deaths in Egypt.

emphasize the importance of families with an increasing number of children. These beliefs relate to the fact that large families can employ their children at an early age to help in agriculture, thus representing their economic power.

Forced Displacement and Migration

According to the United Nations High Commissioner for Refugees (UNHCR), forced displacement occurs when individuals and communities are forced or obliged to flee or leave their homes or places of habitual residence. This is in order to avoid the effects of events such as armed conflict, generalized violence, human rights abuses, natural or man-made disasters, or development projects. In 2022, the International Organization for Migration (IOM) estimated the total number of international migrants residing in Egypt to be 9 million migrants and refugees, accounting for about 9% of the total population. The outbreak of armed conflict in Sudan on April 15, 2023, led to the fleeing of large numbers of civilians to Egypt and neighboring countries. **As shown in Figure 24**, the total number of newly arrived refugees from Sudan is 460,000 as of January 31, 2024, according to UNHCR. Egypt also hosts 154,794 Syrian refugees and 114,230 from various nationalities.

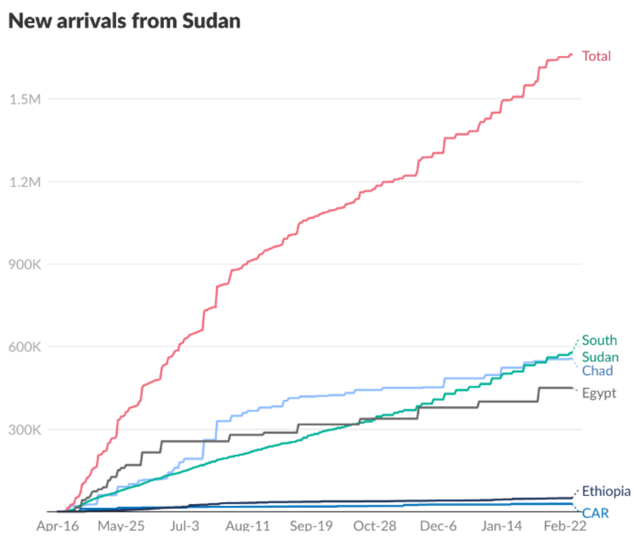


Figure 24:

Number of new arrivals from Sudan.

Child Marriage

Cultures and traditions are key factors that affect the fertility rate, contributing to population increase. Child marriage refers to children who get married before the age of 18, as agreed in the International Convention on the Rights of the Child. Although the Egyptian Child Law, passed in 2008, prevents marriage under 18 years for both genders, child marriage is still being practiced in some regions of the country, especially in Upper Egypt. According to a 2017 census by the

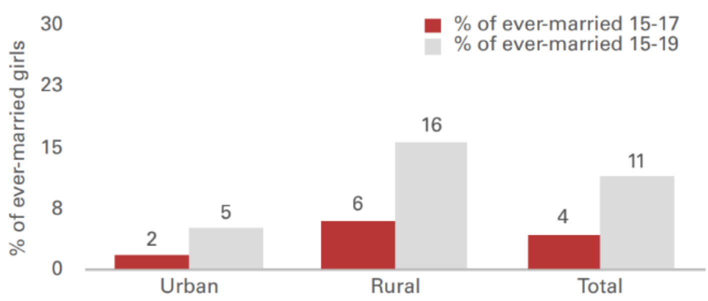


Figure 25:

Number of married people in Egypt under 19 years.

Central Agency for Public Mobilization and Statistics (CAPMAS), nearly 4% of girls between the ages 15 to 17 and 11% of adolescent girls aged 15 to 19 years, are either currently married or were married before, **as shown in Figure 25**. Marriage at an early age is associated with a longer period of exposure to the possibility of pregnancy and thus higher fertility levels.

Impacts

Unemployment

The labor force is the number of people aged 15 to 60 who are working, not working, or searching for work. Unemployment refers specifically to those who are jobless or seeking a job within the labor force. The labor force of Egypt in 2022 was 32.6 million, with an unemployment rate of 7.2%, **as shown in Figure 26.** Such a high unemployment rate is due to rapid population growth accompanied by few available job opportunities. Economic deterioration has also affected the unemployment rate. Egypt's economy has faced a foreign exchange crisis and fiscal pressure due to global shocks. These challenges have forced Egyptian businesses to reduce employment. Thus, the number of job opportunities remains approximately constant while the population continues to increase.

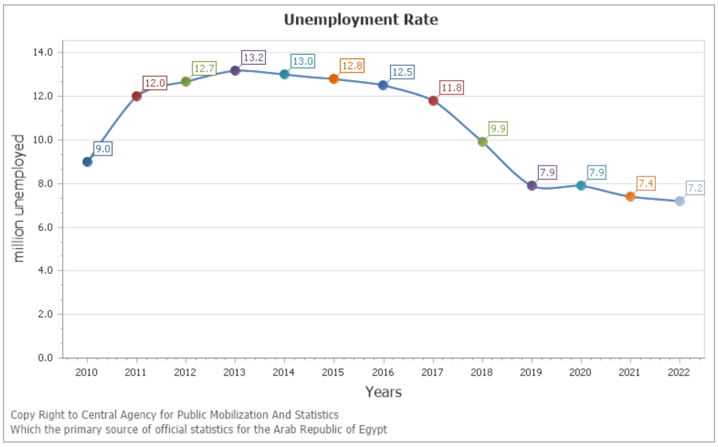


Figure 26:

Unemployment rate in Egypt.

Poverty

In 2020, Egypt's national poverty line, the estimated minimum level of income needed to secure the necessities of life, stood at 10,300 Egyptian pounds. The projected poverty rate in 2022 was 27.3% of the total population, **as shown in Figure 27**. Population growth causes overpopulation, which increases demand over supply for consumable

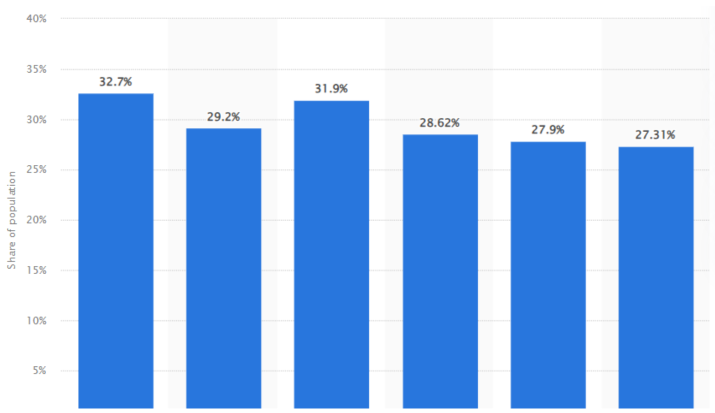


Figure 27:

Poverty rate in Egypt.

products, forcing Egypt to import, which in turn raises prices. Rising prices, combined with unemployment, and decreasing salaries, push a significant percentage of Egyptians below the poverty line. For instance, the inflation rate in 2023 was 33.9%, according to CAPMAS, leading to high prices and increasing poverty.

Slums

Due to rapid population growth, people migrate from rural areas to urban cities in search of job opportunities and better living conditions. This has led to increased urban poverty, overcrowding, and thus the emergence of slum areas. According to the UN-Habitat, a slum is a contiguous settlement whose inhabitants are described as having inadequate housing and basic services. A slum household lacks either safe drinking water access to improved sanitation and other basic infrastructure, or both. It is also characterized by overcrowding, hazardous locations, and insecurity of tenure. Slums mainly exist around urban cities in Egypt and constitute about 38% of the total area of urban communities.

Problem to be Solved

Reducing Nitrous Oxide Emissions from Fertilizers in Al-Mena Safour

Reducing certain air, water, and soil pollutants -nitrous oxides, carbon dioxide, and methane- can decrease the effect of climate change. Additionally, Pollutants, such as ozone and mercury, can lead to many health issues from stroke to lung cancer.

Since the 1960s worldwide, land dedicated to farming has increased by 15%. In contrast, fertilizer use has increased by 570% from 20.69 kilograms per hectare to 118.62 in 2021. The need for fertilizers is explained by the increase in demand for food by 135% from an average of 2181 kilocalories per person to 2959 worldwide in 2021. In Egypt, more specifically, Fertilizer use has reached 414.16 kilograms per hectare in 2021, with 330.41 kilograms per hectare of nitrogen.

Nitrogen is considered essential for plants to grow. Before being taken by plants, it is first changed by organisms living in the soil. Using fertilizers, or manure, to increase nitrogen in soil increases efficiency, but also leads to the escapement of large amounts of nitrogen into the atmosphere, mostly in the form of nitrous oxides.

Fertilizers lead to nitrous oxide emissions. Manure is often used in addition to provide plant nutrients, by mixing with soil, which can lead to methane and nitrous oxide emissions. Additionally, moving soil, or tilling, can lead to the release of trace amounts of carbon dioxide from organic matter, which accumulates over time.

According to the Egyptian Journal of Agriculture Research, agriculture led to the emission of 2.57 million tons of carbon dioxide in 2018. And according to ourworldindata it led to the emission of 9.95 million tons of methane and 12.78 million tons of nitrous oxide in 2020.

From the aforementioned data, it is apparent that nitrous oxide is the most pressing issue, both in quantity and, as will be shown later, in severity for both climate change and health. Thus, the chosen problem to be solved is nitrous oxide emissions in Al-Mena Safour, Sharqia.

Positive Consequences

Reduced Soil Degradation

Decreasing artificial nutrient usage leads to better stability in soil, increasing its long-term productivity. This also creates a positive feedback loop, where better soil stability requires less fertilizers, and thus decreases costs needed for the farmlands, which also decreases emissions. Additionally, following sustainable clean methods will open more job opportunities in soil conservation.

Cleaner Drinking Water.

Nitrogen can escape into water in the form of nitrates, leading to nutrient pollution and algal bloom. This can lead to dead zones in water bodies, specifically ponds, impacting fish populations (which is important since locals like to go fishing in nearby streams). Lower nitrogen concentrations in drinking water will also protect infants from methemoglobinemia.

Negative Consequences

Contributing to Climate Change

According to the IPCC (Intergovernmental Panel on Climate Change) in its scientific assessment of climate change, one kilogram of nitrous oxide is equivalent to 273 kilograms of carbon dioxide in terms of climate change. According to worldbank, 4% of land in Egypt is dedicated to agriculture, equating to 4040000 hectares. Since 330.41 kilograms per hectare of nitrogen are used on average, it's estimated that 1334856400 kilograms of nitrogen are used annually for agriculture. According to Our World In Data, two thirds of used nitrogen is released, equating to 889904267 kilograms. When turned into carbon dioxide equivalent, this is equal to 242943864891 kilograms.

Health Risks

According to a website made by the Australia government, breathing in nitrous oxide can lead to impaired memory, blackouts, depression, hallucinations, paranoia, and most severely, vitamin B12 inactivation. Vitamin B12 deficiency can lead to weakness, constipation, brain damage, muscle weakness, and loss of sensation of in the hands and feet. Nitrous oxide can also lead to anemia, heart attack, low blood pressure, and breathing difficulties.

Economic crisis.

Overuse of fertilizers to maximize production could, in time, lead to reduced crop yields due to soil degradation and water pollution. The community will also have to spend more on water purification infrastructure to make it safe for people to drink.

Research

Topics Related to the Problem

Effects of Fertilizer and Pesticide Usage on Air Quality

The overuse of fertilizers and pesticides for agricultural purposes is considered a great factor in air pollution. They produce mainly Nitrous oxide (N2O), which greatly increases the greenhouse effect. The production of N2O gas is increasing, **as shown in Figure 28**. According to the U.S. Environmental Protection Agency (EPA), Nitrous Oxide (N2O) is more effective 273 times than CO2 for a 100-year timescale in trapping heat in the atmosphere and not being reflected to space. Public health is being affected by these emissions and air pollution. According to the WHO, about 6.5 million premature deaths each year are mainly due to air pollution. In agricultural communities, long-lasting exposure to these pollutants increases the risk of respiratory diseases, such as chronic obstructive pulmonary disease (COPD) and asthma, by 15-20%. In Al-Mena Safour, the common usage of nitrogen-based fertilizers can result in the escape of about 50% of the nitrogen into the atmosphere, which increases local air quality issues.

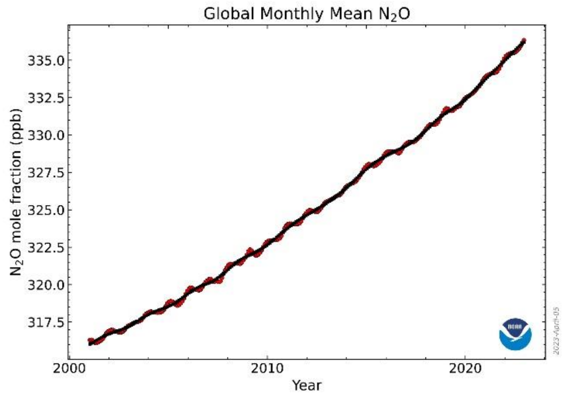


Figure 28:

N_2O emmitions.

Agricultural Waste Burning

Burning agricultural waste is a significant contributor to local air pollution and poses serious environmental and health risks. Farmers, usually, burn crop remains such as leaves to clear agricultural fields. This releases harmful pollutants like particulate matter (PM2.5), carbon monoxide (CO), and various volatile organic compounds (VOCs). In addition to air pollution, these pollutants help in the formation of ground-level ozone. This ozone contributes to respiratory systems serious diseases. The smoke produced from burning agricultural waste contains extremely small particulate matter that can penetrate deep into the lungs, leading to chronic respiratory issues and cardiovascular diseases. In addition, burning these crops increases greenhouse emissions especially CO2, because the carbon stored in plant materials is burnt and released back into the atmosphere. This increases the problem of climate change and pollute the local air which affect the biodiversity and the ecosystem in agricultural areas.

To mitigate these issues, alternative waste management practices, such as composting or pyrolysis, is used.

The Air Quality Index (AQI)

The air quality index is a scale that measures air pollution levels. The scale ranges from 0 to 500, where higher values indicate more air pollution and health risks. The AQI is mainly used to detect 5 pollutants: ground-level ozone, particulate matter (PM2.5 and PM10), carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). Usually, the concentrations of these pollutants are measured in micrograms per cubic meter (µg/m³) or parts per million (ppm). The concentrations are then converted into AQI values using standardized formulas, **as shown in Equation 1**. Where Ip is the index of the pollutant p, Cp is the truncated concentration of pollutant p, BP_{Hi} is the concentration breakpoint that is greater than or equal to Cp, BP_{Lo} is the concentration breakpoint that is less than or equal to Cp, I_{Hi} is the AQI value corresponding to BP_{Hi}, and I_{Lo} is the AQI value corresponding to BP_{Lo}. The Air Quality Index is **shown in Figure 29**.

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} \left(C_p - BP_{Lo}\right) + I_{Lo}$$

Equation 1:

AQI calculation formula.

Air Quality Index		
AQI Category and Color	**Index Value**	**Description of Air Quality**
Good Green	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Moderate Yellow	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups Orange	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Unhealthy Red	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy Purple	201 to 300	Health alert: The risk of health effects is increased for everyone.
Hazardous Maroon	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Figure 29:

Air Quality Index.

In agricultural areas, the AQI is often a little more than 150 due to the emissions resulting from fertilizers, which is in the "unhealthy" category. The burning of the crop remains and the release of nitrous oxides (N_2O) from fertilizers are major contributors. For example, high levels of PM2.5 from burning can raise the AQI to over 200, falling into the "very unhealthy" category, where long-lasting exposure can increase respiratory disease risks by up to 30%.

Topics Related to the Solution

Adsorption

Adsorption is the process by which molecules or ions from a fluid phase, such as gasses or liquids, adhere to and accumulate on the surface of a solid material, **as illustrated in Figure 30**. The substance being adsorbed is referred to as the adsorbate, while the solid material is known as the adsorbent. This process is driven by the attractive forces between the adsorbate and the adsorbent, which can be either physical or chemical in nature. Physical adsorption, or physisorption, relies on van der Waals forces—weak intermolecular forces—that attract and hold the molecules onto the surface of the adsorbent. Physisorption is reversible and is influenced by temperature and pressure. In contrast, chemical adsorption, or chemisorption, involves the formation of chemical bonds, which requires energy to overcome the activation energy barrier. The rate of chemisorption is governed by rate constants that also depend on temperature and pressure. An example of physisorption is the adsorption of gasses on activated charcoal, which is extensively used in air purification systems, gas masks, and medical applications to adsorb toxins and odors from the air.

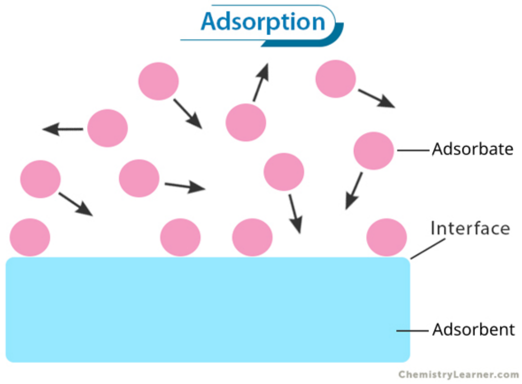


Figure 30:

Adsorption of matters.

Bioremediation

Bioremediation is the process of utilizing living organisms, primarily microorganisms, to remove the pollutants or hazardous components of environmental waste to convert them into CO2, H2O, microbial biomass, and metabolites. Microorganisms degrade these pollutants during their metabolic reactions and utilize them for their growth. The factors affecting the biodegradation process encompass: the favorable environmental conditions, pollutant type and solubility, and the bioavailability of the pollutant to the microbes. These factors are controlled to allow sufficient

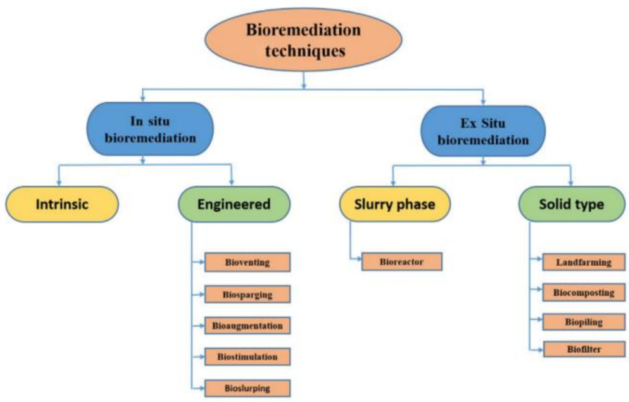


Figure 31:

Bioremediation Technique.

microbial growth and thus enable fast and effective biodegradation. Bioremediation is divided into three types: biostimulation, bioaugmentation, and intrinsic bioremediation, depending on the mechanism used. Another classification of bioremediation technique types is **shown in Figure 31**.

Electrostatic Precipitator (ESP)

An electrostatic precipitator, invented by Frederick Gardner in 1907, is a device that uses an electric charge to remove certain impurities, either solid particles or liquid droplets, from air. ESPs can capture fine particles, smaller than 2.5 micrometers, which are especially dangerous if released because they can be drawn deep into the lungs and can trigger inflammatory reactions. An electrostatic precipitator operates using two sets of electrodes: negative wire mesh and positive plates, arranged alternately, **as shown in Figure 32**. High voltage from a DC source ionizes gas-borne particles, such as ash, giving them a negative charge that attracts them to the positively charged collector plates. A maintained distance between the electrodes creates a high voltage gradient, facilitating ionization in the air medium. The system, enclosed in a metallic container, allows flue gasses to enter and exit filtered. Free electrons interact with dust particles, causing them to become negatively charged and fall off due to gravity, resulting in clean flue gas discharged into the atmosphere.

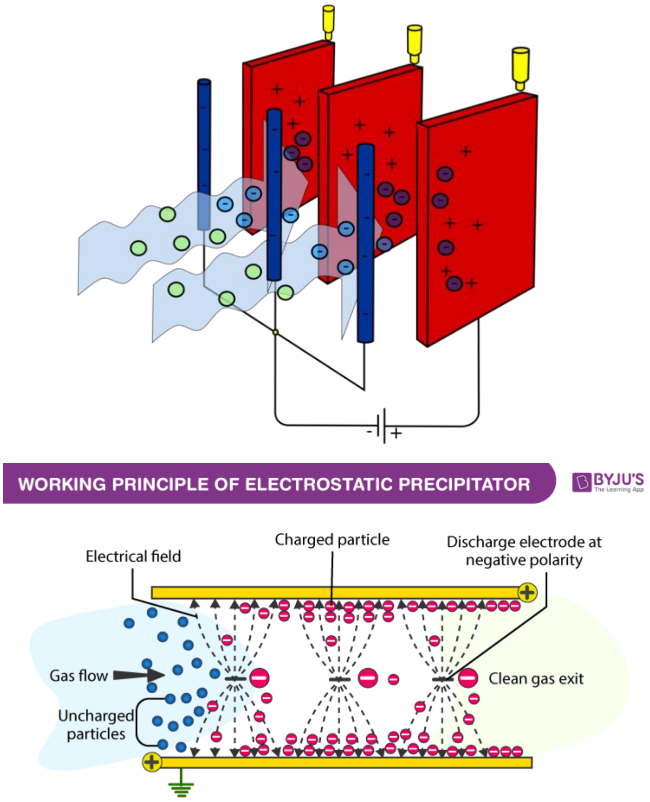


Figure 32:

Electrostatic precipitator.

Other Solutions Already Tried

Smog Free Tower

Figure 33:

The Smog Free Tower.

Created by the Dutch designer Daan Roosegaarde, the Smog-Free Tower, **shown in Figure 33**, is the first outdoor air purifier in the world designed to deal with urban pollution on a micro-level. About 7 meters tall, the tower uses positive ionization technology to grab and remove PM2.5 and PM10, the most dangerous ingredients of smog, from the air; it can clean up to 30,000 cubic meters of air per hour. The structure primarily operates at low energy consumption, mostly deriving its energy from renewable sources, such as solar or wind energy. Each jewelry piece made from the trapped particles rings or represents the removal of pollutants from 1,000 cubic meters of air. The tower was originally constructed in Rotterdam and has since been deployed in other major cities such as Beijing, Tianjin, and Kraków, where air pollution is at its worst. The Smog Free Tower is not only a practical environmental technology but also a public art installation, which is able to raise people's awareness of air pollution and at the same time promote innovative sustainable practices. Its futuristic look is so smooth that that it no longer looks like a building in the middle of the city, but rather a "clean air area" that ensures real air quality improvement for a healthy life.

Mechanism

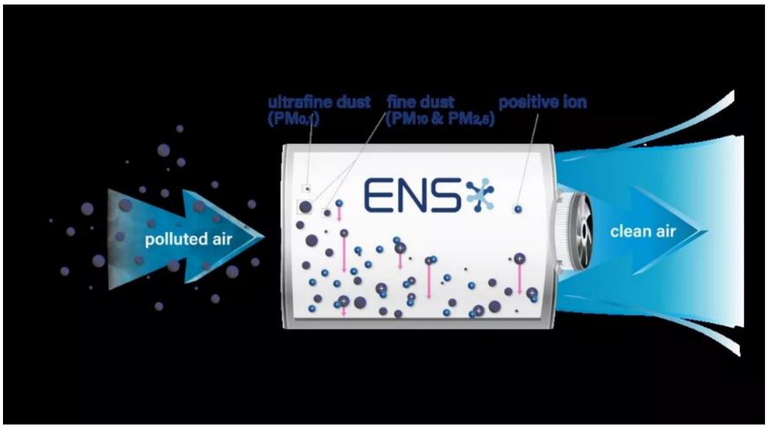


Figure 34:

Positive ionization process.

The Smog Free Tower, a product of Daan Roosegaarde's innovation is the best armor against outdoor pollution using ionization technology, also known as the positive-ionization process **as shown in Figure 34**. At the beginning of the process, the tower attracts the surrounding polluted air, where dangerous particulate matter such as PM2.5 and PM10 are contained. These particles are then charged with ions through the ionization process, positive ions are emitted into the air, and the particles attach themselves causing the fine dust particles to acquire opposite charges. The ionized pollutants are then mixed with the negative plates inside the tower, a process which is known as electrostatic precipitation. With the help of this, the pollutants, thus, are taken out of the air, thus only clean air is among the components of the released air. This tower can purify up to 30,000 cubic meters of air in an hour, with only one million one hundred seventy watts of energy consumption, which is only equivalent to that of a small home appliance. Besides, it gets its power from renewable energy sources like solar or wind, for which its sustainability is significantly depressed. The remaining particles which are mainly carbon, are trapped in the tower which is subsequently converted to small cubes for the production of jewelry such as rings and cufflinks add the phrase Smog Free Jewelry, drawing attention to them particularly. The ten jewelry pieces bear the same value as 1,000 cubic meters of fresh air, the output of which is a vivid and memorable evaluation of the initiative. This technique, especially the projection of the cities that are currently grappling with severe air quality issues, definitely assists the people in creating a better environment, and the icing on the cake is that it's both non-toxic and no embers are released during the process. Through public interactive activities such as the Smog Free Tower and related community events, this idea enhances action, and is a point of departure for more thorough conversations on issues of pollution, sustainability, and shared green technology initiatives.

Points of Strength

Effective Local Air Purification

The plant can refine even 30,000 cubic meters of air per hour and cleaning off the microparticles (PM2.5 and PM10) which are the essential elements of smog, makes the air quality in the nearby location significantly better.

Energy-Efficient Operation

It operates on a small amount of electricity, normally fed from solar or wind generators, therefore the solution does not require expensive energy and is environmentally sustainable. The tower forms localized “clean air” bubbles in heavily polluted areas, hence it can produce immediate advantages for people who live or work nearby.

Innovative Recycling of Smog Particles

It compresses the gathered smog particles (mainly carbon) into Smog Free Jewelry, and people can wear them as pieces demonstrating a contribution to cleaner air, promoting circular, environmentally friendly cooperation.

Points of weakness

Limited Coverage Area

While the tower has a capability of 30,000 cubic meters of air clean-up per hour, the zone of the tower's effectiveness is limited to the surrounding area, and it can't be a solution for the whole city's pollution. Only its impacts are site-specific, and the problem of overall pollution still exists.

Scalability Challenges

While it may work well on a local basis it can be a challenge to expand the Smog Free Tower to cover larger urban areas or multiple cities because of the cost, energy consumption, and difficulties in installation and maintenance.

Installation High Cost

Building and installing the Smog Free Tower from scratch comes with a high cost in the beginning. Talk about advanced technology and infrastructure making them sufficient, hence this will be expensive for deployment in large and poor urban areas with limited budgets for environmental projects.

Air-Ink

Figure 35:

The Kaalink device.

The project called Air-Ink, which was implemented by Graviky Labs in Bengaluru - India, was led by Anirudh Sharma, is a revolutionary project that converts air pollution into ink for drawing. The project aims to collect soot, which is one of the most dangerous pollutants created by burning fossil fuels and use it to make high-quality black ink for artistic and commercial purposes. The Kaalink device, **shown in Figure 35**, which is a core part of the project, is fitted around the exhaust pipes of vehicles and industrial machines to trap PM and prevent it from being released into the air.

This soot is then harvested and treated to become Air-Ink, an ink suitable for filling pens, markers, spray paints, and screen printers. For instance, the manufacturing of 30 ml of Air-Ink produced has a corresponding equivalence of emission of about 45 minutes of exhaust from a car, hence concrete reduction of that surface air pollution. This novel form of inky recycling assists in eliminating the substance of air pollution in the form of waste ink products.

Besides the ecological concerns of the project, it is also culture oriented. The Air-Ink Project gives inks made from polluted air to the artist so that people are engaged in the issue of air pollution in a more creative manner. Air-Ink has been utilized in the form of public art in the works of street art and advertisement, highlighting the issue of urban suffocation with smog and providing a relevant solution that is artistically and environmentally pleasing.

The scheme has gained global acclaim including collaborations with some key players such as Tiger Beer brand and is regarded as an ink-optimistic sustainable model of printing processes. The Air-Ink project strives to tackle pollution issues through creative means whilst advocating for change, showing a balanced ratio between environmental poise and artistic construction.

Mechanism

The device, designed by Graviky Labs, captures particulate matter from vehicle and industrial exhaust systems under its Air-Ink project. It is installed directly on the tailpipes of vehicles or the exhaust of machines running on fossil fuels. As the fumes of the exhaust gases pass through it, Kaalink filters the carbon-rich soot particles, PM2.5 and PM10, from the emissions. These particles are the by-product of the incomplete combustion of fossil fuels and also happen to be one of the major contributors to air pollution within urban areas.

A combination of filtration and centrifugal force by the Kaalink device traps as much as 95% of the particulate matter emitted by the exhaust. Inside, the filter collects soot particles without affecting engine performance or drastically changing the efficiency of the emission system. It would work quite efficiently and require minimum maintenance; attachment and removal from the exhaust system can also be done rather effortlessly.

Figure 36:

Air-ink process.

Soot picked from the equipment after collecting particulate matter is treated at the plant of ENS. These metals and other toxic component parts are then taken out through purification, leaving just the pure form, which is carbon, **as shown in Figure 36**. Further processing of the carbon with the soluble SYN leading to the formation of the ink printing it on various surfaces and in various outlets is done. This system turned the harmful pollutants into reusable ink. It is very eco-friendly and reduces the air pollution as well. Moreover, it creates amazing things like ink.

Points of Strength

Recycling of Soot by a New Process

Air-Ink is a way of turning harmful emissions into a commodity that provides a sustainable manner of reuse for the pollutants. The resulting ink can be used in various artistic works, commercial printing, and other forms, thereby changing waste to a creative material.

Public Awareness and Engagement

Air-Ink employs art and art installations to depict the many adverse effects of air pollution. It has worked with international artists, creating a platform for the use of art for environmental education.

Ability to Grow and Adapt

Kaalink universal device is designed to be mounted on any kind of exhaust system be it automotive or industrial equipment. Such applications and effects can be imagined in cities and industrial regions across the globe.

Points of weakness

Limited to Particulate Matter (Soot)

The project targets trapping highly carbonaceous particulate matter and this kind does not cover nitrogen oxide-oxides (NOx), sulfur dioxide (SO2), or greenhouse gas CO2, thus, it is a limitation to the broader environmental impact of the project.

Small Scale Impact (Per Unit)

Every Kaalink device has the capability to extract a limited amount of soot from the individual drives. That is commendable on its own but it can only be a small portion of the solution considering the immeasurably large emissions globally. A considerable scaling-up effort would be required to have a notable environmental influence.

Maintenance and Collection Process

The soot that Kaalink has gathered has to be cleaned out and taken to a processing plant which could possibly endure some challenges. This might limit its flexibility in some areas, especially as that would require regular cleaning regularly.

Electrostatic and Activated Carbon Combo Units

Air cleaner filtration technology has evolved too additionally. By their very nature and design, electrostatic precipitators such as Electrostatic and Activated Carbon Combo Units, **shown in Figure 37**, work by using an electric charge to enable an airborne particle to be “attached” to a collector that is oppositely charged. Electrostatics is especially good at collecting small particles like dust, pollen, or smoke, which may be much more intricate for the conventional filters to work on. In that process, beyond trapping the particulate pollutants present in the air, a considerable reduction in allergy-caused airborne irritants can be achieved with respect to the indoor comfort level.

Figure 37:

Electrostatic and Activated Carbon Combo Units.

For foul air or gas control, activated carbon filters are employed. These types of filters encompass the use of carbonaceous porous materials of high space areas in combination with the ability to suck in and hold volatile organic compounds (VOCs), noxious fumes, and unpleasant odors. Combining the essence of the socialistic precipitator of aerosols with the merits of the carbon filter, the integrated system can remove both particle and gas-phase contamination indoors.

Mechanism

The Electrostatic and Activated Carbon Combo Units work using a two-stage filtration process that removes both particulate matter and gaseous pollutants; thus, it is highly efficient in cleaning indoor air. The following is a comprehensive description of the process:

1. Electrostatic Precipitation:

   The allergen extermination itinerary is started by the electric precipitation of the air. When the air passes through an ionizing part, it is attracted to the ionizer electric field at high voltage, **as shown in Figure 38**. This electric field makes the particles in the air, which are mainly dusty, pollen, smoke, and other micro-particles, charged.

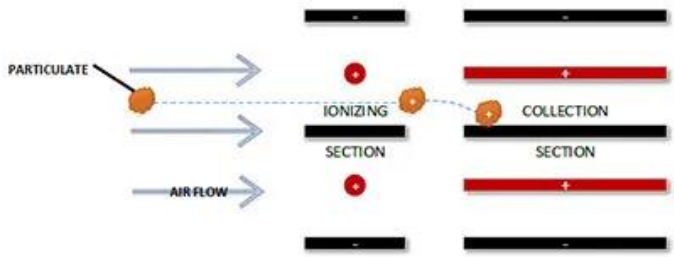


Figure 38:

the process of the electrostatic filtration.

Afterward, through electrostatic attraction, opposite charges attract, and the particles are attached to the plates. As a result, there is no airflow, and they are smoothly moved from there. This method is able to capture even sub-micron particles, which are the traditional mechanical filters' weak side, down to sizes as small as 1 µm. The panels get dirty and need to be cleaned after some time, which in the long run provides steadily low operational costs as the plates are reusable.

2. Activated Carbon Filtration:

When the air has passed through the electrostatic part, it continues to run over an activated carbon filter, **shown in Figure 39**. Activated carbon is a spongy matter that has got a huge area, and this allows the work to be completed through the method of adsorption. In the process of adsorption, gas-phase pollutants such as volatile organic compounds (VOCs), chemical fumes, and stinky smells are attached to the carbon's surface. This way, not only gases but also odors are removed, improving the quality of the air indoors. Nevertheless, as the adsorption capacity of carbon decreases and it ultimately gets to a saturated state over time, the gas removal process less intensifies. In contrast, the performance of the filter is affected. Filter replacement is therefore the key to such maintenance, and the duration of replacement relies on the quantity of the gaseous contaminants in the surroundings.

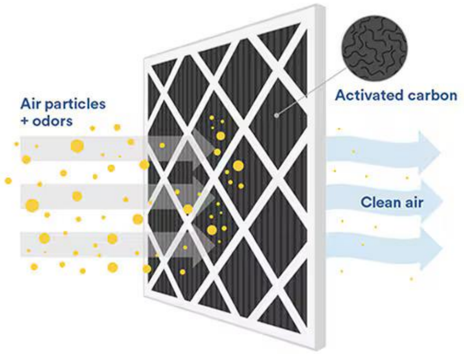


Figure 39:

Filtration of activated carbon.

Air purification by the electrode collection precipitator and the carbon filter is of great strength. First off, the dust is separated, and then in the second stage the gas is the target. This is so-called the sequential means of cleaning whereby the air is purified in a way that is the most efficient. Thus, air is delivered to a space that is clean and healthier than ever.

Points of Strength

Customizable Configuration for Target Pollutant Removal

These combo units can be configured to meet specific air quality needs. In particulate-dominant environments, the electrostatic module can be further enhanced while settings with odors or VOCs can call for more activated carbon. This flexibility enables each unit to be configured for such diverse spaces as hospitals, offices, or industrial plants for optimal air purification and targeting of different pollutants in various setups.

Energy-Efficient with Minimal Pressure Drop

The electrostatic components ensure only marginal resistance against the airflow thus rendering the units comparatively energy-efficient far beyond the conventional filtration systems. Because they have minimal fan power utilization for air circulation, these units save on energy expenses over time. The passive adsorption of VOCs done by the activated carbon filter requires minimum energy; thus, again, this unit becomes an energy-efficient and eco-friendly solution.

Points of Weakness

Limited Effectiveness Against Biological Contaminants

Although they have been shown to be effective in capturing particles and adsorbing gases, they do not address human pathogens, such as bacteria and viruses. They may need additional technologies, such as UV lights or antimicrobial coatings, to be effective in environments where controlling biological contaminants is essential, such as hospitals or labs. Without these features, the units may fall short in settings emphasizing sterilization.

Less Effective in High-Humidity Environments

Humidity will impact both electrostatic and carbon components appreciably, making them less efficient. Highly humid conditions may cluster smaller mighty particles into larger masses, thus the inability of the charged particles to work electrostatically. Moisture in itself saturates activated carbon very fast, which has a further fouling limit for gas. They will need more frequent maintenance; thus, the cost of operation may also increase and shorten the life span.

Quattro Corti Photocatalytic Cement Project

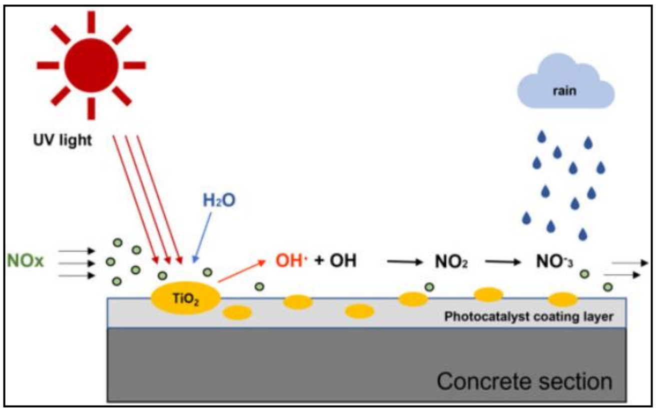


Figure 40:

The idea of Quattro Corti Photocatalytic building.

One notable project aimed at decreasing the levels of NOx air pollution took place in Milan, Italy. The city used photocatalytic cement on pavements and public territories in the Quattro Corti premises. Photocatalytic cement enables beneficial processes in the presence of sunlight and the implementation of titanium dioxide (TiO_2) into cement mixes helps to mitigate the environmental threats from sulphur and particularly nitrogen oxides (NOx) pollution. Heavy motorized vehicle traffic, like in many cities, is another contributing factor of NOx air pollution problem in Milani (James, 2020). The main aim of that undertaking was to help reduce air pollution in the city, especially encouraging the use of environmentally friendly, self-cleaning materials in areas where people congregate, **as show in Figure 40**. This initiative has attracted some notice marker in practice because of its passive nature and low active maintenance required for the air purification, which adapted well to most areas where pollution abounds. Post-implementation studies have reported that the concentration of NO_x in band as with applied photocatalytic cement reached as high as 45% decrease in optimal conditions, which had a positive effect on the quality of ambient air (Graham, 2020). There have been similar initiatives with this technology in cities like Mexico City and even in Tokyo where it indicates the concept is flexible to use in varied urban environments. These real-life instances provide validation that, as offered in many countries these days, utilize photocatalytic materials as an aspect of an urbanism strategy to curb pollution from vehicles and factories.

Mechanism

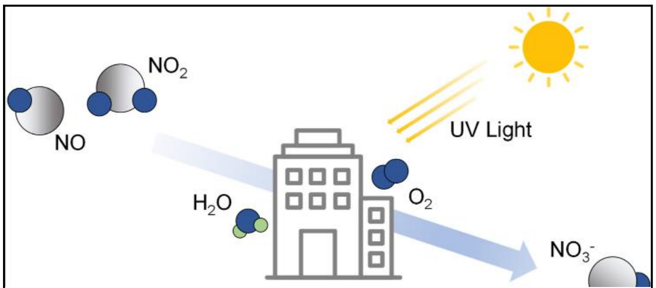


Figure 41:

The mechanism of titanium dioxide to mitigate of NOx.

The Milan Project incorporated photocatalytic cement, otherwise known as cement with titanium dioxide (TiO_2) implemented in its structure, for the treatment of nitrogen oxides (NO_x) pollution via photocatalytic processes. The process starts by shining sunlight on the concrete, this time the UV component.

Embedded in the concrete is the mineral TiO_2 which performs a significant function, absorbing the UV rays and elevating the electrons inside it to its higher states generating charged particles, electrons and holes. These pools of electronic and hole charge carriers in turn come into contact with water and air's oxygen to produce extra atoms, reactive oxygen species (ROS) in particular, such as OH and superoxide O_2. The ROS interacts with the NO_x molecules leading to the cleavage of NOx into less harmful nitrate groups NO_3 and others **as show in Figure 41**. The nitrates are then formed on the surface of the cement which is easily washed off with rains ensuring that such nitrates do not get back to encircle the atmosphere. This process is beneficial as the reactant, TiO_2 is not used up and hence the above air purification process can be sustained over a longer period. According to research, photocatalytic cement could lower NO_x levels by 20-70% (Julian, 2021) with respect to the environmental conditions such as sunlight and airflow velocity. The project illustrated how a very basic, non-mechanical alteration of properties could prove to be of benefit for the ecology for quite a prolonged period of time.

Points of Strengths:

Requiring Little Upkeep

An essential benefit of the Milan photocatalytic cement project is the fact that it can purify the air passively for extended durations without any active maintenance or power sources. Once the photocatalytic cement is applied on surfaces, it becomes functional as long as there is sunlight. There is TiO_2 in the cement which acts as a catalyst in converting NOx gas to other less toxic elements like potassium which is then washed away by rains. This makes it better suited to places that suffer high concentrations of NOx gases emissions like inner city areas and even road sides. Some results from the project reported a decrease in the levels of NOx in the areas with concentrations of up to 45%. The self-sustaining nature of this technology indicates that it will be useable for several years without having to replace it. This is in sharp contrast to traditional air filters that require regular maintenance. Hence, it brings down both the efficiency costs and the ecological costs over a period of time with great sunlight.

Scalable Urban Solution

The photocatalytic cement has the added advantage of being easily scaled which enhances its possibilities for application in diverse urban infrastructures like roads, sides and public areas. The scale of the project is that it can fit in the urban fabric of a city without making any major changes in the existing structures. This feature enables the cities to embrace the technology in steps or aim at specific areas. In the case of the Milan project, the cement was put on many different surfaces and the results showed a decrease in the NOx levels in the whole city ranging from 20-45%. The aspect of scalability is also favorable economically for urban planners since such enables an increase in the area coverage over time while assessing the outcome of the initiative. Also, cities such as Tokyo and Mexico City have carried out projects of this kind, proving that photocatalytic coatings are not limited to only a set of cities making it possible to serve anyone from anywhere.

Sustainable and Environmentally Friendly

Photocatalytic cement represents an environmentally friendly innovation for ensuring clean air. It makes use of solar energy alone, which enables chemical processes that decompose various toxins without using additional energy. TiO_2 contained in the cement is remarkably cheap, non-invasive, and does not pose any danger to the environment, which qualifies this technology as an eco-friendly one. Milan project showcased how such materials can combat the effects of air pollution and do not generate toxic wastes in the process. Eventually, the nitrogen oxides through a photocatalytic process are transformed into harmless pheromones, ready to be washed away with the rain and causing no damage to the environment. In addition, this project helps in the overall reduction of the city's carbon footprint because it does away with air purification machines which consume a lot of energy. In the report of the project carried out in Milan, in some parts of the city with heavy traffic, the concentration of nitrogen dioxide decreased by 30-50%. Thus, it can be considered as an environmentally sound and yet effective method of addressing the problem of air pollution in urban centers while ensuring that ecosystems degrade minimally.

Points of Weakness

Low Light Conditions - Limited Effectiveness

Photocatalytic cement is a surface material whose efficiency is influenced specifically by UV light. In shaded places or in conditions with less sunlight (including cloudy days or winter), the photocatalytic reaction takes place to a very small extent. This leads to a drop in its efficiency in removing NOx. It was reported in Milan that during the months of winter and in the conditions where the hours of sunlight were limited, there was nearly a 50% decrease in efficiency in reducing NOx levels, therefore the technology is of limitation in seasons or geographical areas where sunlight is scarce.

Accumulation of By-products

Over the course of time, the byproducts that come from the decomposition of NOx in the form of nitrates settles at the top of the photocatalytic cement layer. These byproducts, in the absence of cleaning solutions or rain that would rinse them off, could compromise the layer's ability to capture more chemicals (Mano, 2022). As a consequence, it has been observed in the city of Milan that photocatalytic performance declined by almost 10-15% after few months due to nitrate accumulation in areas with low rainfall. It has been observed that such window cleaning services are required at regular intervals.

Initial Cost of Implementation

The cost of photocatalytic installation is much higher than for normal cement, where the normal cement is relatively inexpensive due to its simplicity of installation. The use of TiO_2 nanoparticles in the adhesive resin contributes to a higher cost of production, and this becomes a limiting factor when it comes to implementation especially in the cases of developing countries. In Milan, the cost for installation was also predicted to be 20 to 30% above that of normal cement, thus making the risk associated with large scale use without extra funding or long-term benefits assessment unwarranted.

Chapter 2: Generating and Defending a Solution.

Solution Requirements

Cost Effectiveness

The chosen solution should be cost-effective, meaning it generates savings or revenue that exceed its initial investment. This can be achieved by utilizing affordable and efficient materials.

Eco-friendliness

The solution must minimize negative environmental impacts during both construction and operation. The construction methods and operational mechanisms should not emit harmful substances or pollutants. Additionally, the materials used should be natural, recycled, or recyclable.

Availability of Materials

The materials and methods employed in the solution should be widely accessible to ensure applicability in various regions around the world. This will facilitate addressing the prescribed problem in multiple countries, not just in Egypt.

Safety

The solution should be user-friendly and safe for all users. It must not emit any toxic gases, and measures should be in place to prevent leaks or explosions. Furthermore, extreme temperatures associated with the solution should not pose a risk to users.

Sustainability

The solution should be designed for long-term operation with minimal maintenance requirements, thereby reducing overall costs. It should also maintain its efficiency regardless of varying weather and environmental conditions.

Scalability

The solution should be scalable, allowing for easy expansion and adaptation to meet growing demand. Modular design enables components to be added or removed as needed. It should integrate with existing infrastructure and facilitate replication in various regions, optimizing resource use and minimizing costs.

Design Requirements

- The solution must reduce the concentration of Nitrous Oxide by 20% or more in a period of 10 minutes or less.
- The air sample used in the purification should be with volume of at least 600 ml and up to 1500 ml.
- The efficiency of the solution should be at least 20%.

Selection of Solution

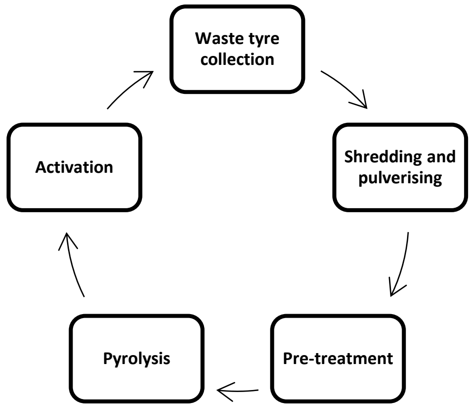


Figure 42:

Steps of converting waste tires into activated carbon.

The traditional disposal techniques of waste tires, landfilling and burning, cause environmental and health issues including soil pollution due to leakage of chemicals, release of methane gas into the air causing air pollution, providing a breeding ground for mosquitoes, and moreover taking up a lot of space by piling up in landfills and junkyards. Among these techniques, pyrolysis, which is eco-friendly and recovers from 30 to 40% by weight of pyrolytic char, transforms waste tires into useful organic compounds in the absence of oxygen at high temperatures. Activated Carbon can be produced using the recovered pyrolytic char in the presence of steam or CO_2 at high temperatures.

The steps involved in the production of activated carbon are **shown in Figure 42** and listed as follows:

1. Collection of waste tires from retailers or waste depots.
2. Shredding and pulverizing the waste tires to form granules in addition to removing steel and reinforcing fabric.
3. Pre-treating the granulated tires using an acid solution.
4. Converting the waste tire into carbon black and other by-products by carrying out pyrolysis.
5. Activating the carbon black using physical or chemical processes to obtain the activated carbon.

Waste tires are made up of nearly 200 compounds, including both natural and synthetic rubbers, along with 5–22% carbon by weight, 16 to 25% steel, 5% textile materials, and various additives such as ZnO, sulfur, TiO_2, and SiO_2. Thus, carbon black (68–75 wt%) is one of the main components of tire rubber. After the raw material is washed with deionized water, dried, sized, and pre-treated, it is impregnated with a reagent such as methanol, acid, or base. The material then undergoes a carbonization process, or pyrolysis, resulting in the formation of carbon.

Pyrolysis involves heating the raw materials at a temperature below than 800C in the absence of air, resulting in a solid porous carbon material. Then, other elements such as nitrogen, sulfur, hydrogen, and oxygen are removed through the gasification process and only the pyrolytic char is left. Then, the pyrolytic char is again washed, dried, and impregnated with another reagent. The activation process is then carried out.

The activation of pyrolytic char can be either physical or chemical. Physical activation entails treating pyrolytic char by subjecting it to gasification with CO_2 or steam at temperatures between 800 °C and 900 °C. The use of CO_2, which is preferred due to its ease of handling and cleanliness, enhances the pore structure, while steam helps to expand the micropores. The chemical activation process is a one-step procedure that involves the use of chemicals like NaOH, KOH, H_3PO_4, and $ZnCl_2$, followed by pyrolysis in an oxygen-free environment at temperatures ranging from 500 to 900 °C. This type of activation reduces the formation of tar and by-products and increases the yield and pore volume.

The chemical activation process is more advantageous than the physical activation process. However, it is important to exercise caution when handling chemicals like ZnCl2, KOH, and NaOH, as they are corrosive, toxic, environmentally harmful, and can pose challenges in waste disposal.

In case of waste tire-derived activated carbon, physical activation using steam is regularly used as it was reported that steam-activated carbon had higher surface areas (1000 m^2/g) than CO_2-activated carbons (270 – 980 m^2/g). Moreover, it was found to be two to three faster than CO_2 activation.

The overall process for producing activated carbon (AC) from waste tires consists of two steps. The first step involves thermal pyrolysis, which occurs at low temperatures ranging from 400 °C to 700 °C in the presence of nitrogen or helium to minimize the cross-linking of carbon atoms. The second step is the activation process, where an activating gas (either steam or CO_2) is used at temperatures between 800 °C and 1000 °C to create a specific surface area and porosity. The degree of activation, the activation temperature, and the type of activating gas (steam or CO_2) significantly influence the properties of the resulting carbon.

Selection of Prototype

The proposed solution involves the development of an air filter utilizing activated carbon derived from waste tires. A 3D model of the prototype is **shown in Figure 43**. The prototype consists of two interlocking containers of the same size, each featuring multiple drilled holes to facilitate airflow. The second container is filled with tire-derived activated carbon, which effectively adsorbs pollutants, particularly nitrous oxides, thereby purifying the air. To prevent the escape of activated carbon, a non-metal window screen will be employed to reduce the size of the holes. Additionally, a 12V DC fan will be installed at the top of the filter to actively draw air through the system, ensuring efficient circulation and filtration.

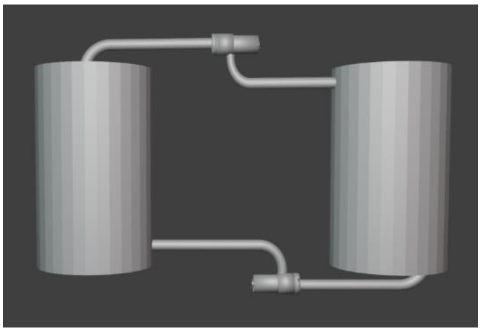


Figure 43:

3D model of the prototype.

As air enters the filter, nitrous oxide and other pollutants adhere to the surfaces of the activated carbon particles. Activated carbon is particularly effective for this purpose due to its high ratio of micropore volume to total pore volume, as well as its extensive surface area. These properties make it suitable for adsorbing various air pollutants, including NO_x, SO_2, and CO_2. Once the air has passed through the activated carbon, the fan expels it back out of the filter, maintaining continuous circulation. This process ensures ongoing filtration of the air, effectively reducing the concentration of harmful pollutants.

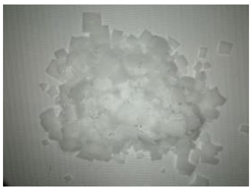
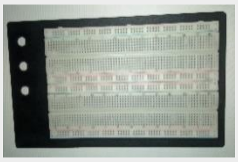
The materials required for constructing the prototype include two plastic buckets of different volumes to serve as the containers, a roll of non-metal window screen to contain the activated carbon, and a 12V DC fan to regulate airflow. Waste tires will be treated to create the activated carbon.

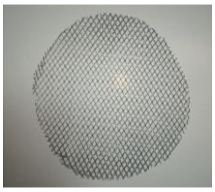
Chapter 3: Constructing and Testing a Prototype

Materials and Methods

Table 1:
The used materials in the prototype.

Item	Quantity	Description	Cost	Source	Picture
Waste tire	1 tire	A waste tire was utilized as the source of carbon black, which was subsequently processed to produce activated carbon.	25 EGP	Car mechanic Shop	
Syringe	1 syringe (60 ml)	Polluted air was injected into the container using a syringe.	10 EGP	Medical equipment shop	
3-way stopcock	2 stopcocks	Two stopcocks served as valves to regulate the airflow within the system.	20 EGP	Medical equipment shop	
Micro air pump	2 pumps	Two micro air pumps were utilized to facilitate airflow through the two containers.	300 EGP	Electronics shop	
MQ-135 sensor	1 sensor	An MQ135 sensor was employed to measure the concentration	100 EGP	Electronics shop	

		of nitrous oxide pollutants.			
Silicon tube	2 tubes	Silicon tubes were utilized to link the two containers.	20 EGP	Medical equipment shop	
Plastic jar	2 jars	Two plastic jars were used as containers: one for polluted air and the other for the filter.	90 EGP	Online	
Potassium hydroxide	240 g	Potassium hydroxide (KOH) was utilized in the pretreatment process of the waste tires.	24 EGP	Detergent shops	
HC-05 Bluetooth module	1 module	A Bluetooth module connected the sensor to a mobile application to collect measurements.	Owned	–	
Arduino UNO	1 board	An Arduino UNO was utilized as the central control unit for the system of sensors and pumps.	Owned	–	
Breadboard	1 board	A breadboard was employed to assemble the electric circuit.	Owned	–	

Jumpers	20 jumpers	Jumpers were used to connect the different components of the circuit.	25 EGP	Electronics shop	
Glue sticks	2 sticks	Glue sticks were utilized to adhere various components of the prototype together.	10 EGP	Stationery	
Stainless steel mesh	15-cm-diameter circle	A steel mesh was employed to support the layer of activated carbon within the filter.	17.5 EGP	Paint shop	

Methods

Prototype Construction.

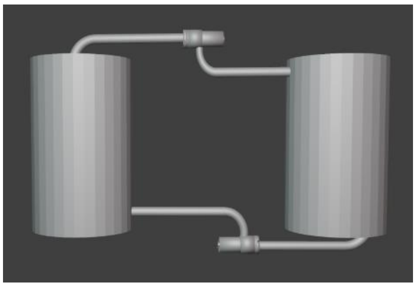


Figure 44:

A 3D model of the prototype.

1. Initially, a 3D model of the prototype, **depicted in Figure 44**, was created to aid in the construction process.
2. Holes were drilled into the plastic containers at air entry and exit points, with two holes per container. An additional hole was made in the polluted gas container to insert a stopcock to introduce the gas.
3. The two pumps were connected to the containers using silicone tubes, **as shown in Figure 45**, to facilitate gas circulation between the containers.
4. The steel mesh was secured in the filter with wax to support the activated carbon layer and the sensor was installed in the gas container to measure the concentration of pollutants.

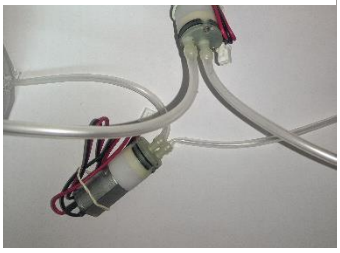


Figure 45:

The two air pumps connected to the containers through silicon.

Waste Tire Treatment.

1. Prior to treatment, the tire was shredded into small particles approximately 0.5 cm in size, **as shown in Figure 46**, rinsed with water to remove any residual dust or clay, and subsequently dried.

Figure 46:

Tire shreds of size range from 0.5 cm to 1 cm.

2. In chemical pretreatment, a solution of KOH was prepared by dissolving 240 g of KOH in 800 ml of water. 120 g of shredded tires were then stirred in this KOH solution, **as depicted in Figure 47**, at a temperature range from 80°C to 100°C for 3 hours at an impregnation ratio of 2:1 KOH to tires. The tire-KOH slurry was then dried.

Figure 47:

The tire shreds while stirring in the KOH solution.

3. The pre-treated tire shreds were pyrolyzed in an underground hole to yield the carbon **shown in Figure 48**. The process involved heating the sample to a temperature range of 100°C to 280°C for 1 hour, followed by cooling the resulting residue.
4. After cooling, the products were stirred in 250 ml of 0.5 N HCl at 85°C for 30 minutes, **shown in Figure 49**, followed by filtration. The sample was then leached with 250 ml of distilled water at 85°C, with repeated filtration until the pH exceeded 6. Finally, the leached sample was dried to give the final carbon products.

Figure 48:

The carbon product from the pyrolysis of waste tires.

Air Quality Control System.

1. The MQ-135 gas sensor, two micro air pumps, and an HC-05 Bluetooth module were integrated with an Arduino UNO board. The sensor was coded to measure the concentration of pollutants while the pumps were used to control the airflow and circulation through the filter.
2. An Android application, connected to the Arduino using the Bluetooth module, was developed using Android Studio and Kotlin to control the system and monitor the sensor readings.

Figure 49:

The carbon products stirred in the HCL solution.

Safety Precautions.

Some precautions were used during prototype building and material treatment to ensure our safety. Lab coats and gloves were worn during all the chemical reactions and processes to ensure protection from any material spills. Masks were used for any resulting harmful gas during any chemical reaction. Eye goggles were worn to protect our eyes from any splinters.

Test Plan.

A comprehensive set of criteria was established to ensure the feasibility of the prototype to meet the design requirement, reducing nitrous oxides concentration by at least 20%, facilitating enhancements in areas identified as potential weaknesses.

1. Nitrogen dioxide gas was produced through the redox reaction of nitric acid with copper, **as shown in Figure 50**. This reaction yielded aqueous copper nitrate, nitrogen dioxide gas, and water, as represented by the chemical equation:

$$Cu_{(s)} + 4HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$$

Figure 50:

The reaction of nitric acid with copper.

The resulting gas was captured and inserted into the contaminated-air container. The prototype was then operated for 8 minutes. The initial and final concentrations of nitrous oxide, denoted as C_i and C_f respectively, were recorded. The percentage reduction of the nitrogen dioxide was calculated using the formula:

$$\frac{C_i - C_f}{C_f} \times 100\%$$

Data Collection.

Measuring Tools.

A graduated beaker was used to measure the volume of the used liquids with an uncertainty of ± 25 ml. A sensitive balance was used to measure the mass of used solids with an uncertainty of ± 5×10-3 g. A ruler was used to measure the diameter of the mech with an uncertainty of 5×10^{-2} cm.

Negative Results.

The containers used in the prototype were initially not perfectly sealed, resulting in gas leakage. To address this issue, Teflon (polytetrafluoroethylene) was applied to seal the containers effectively, preventing any further leaks. In initial trials, the MQ-135 showed illogical concentration readings due to missing calibration.

Positive Results.

Following an 8-minute operation of the prototype, the initial concentration C_i was determined to be 256.72 parts per billion (ppb), while the final concentration C_f was calculated to be 49.252 ppb. **Figure 51** illustrates the NO2 concentration, measured at 5-second intervals, whereas **Table 2**shows the readings of the sensor every minute. According to the formula specified in the test plan, the percentage of pollutants removed was calculated to be 80.81%.

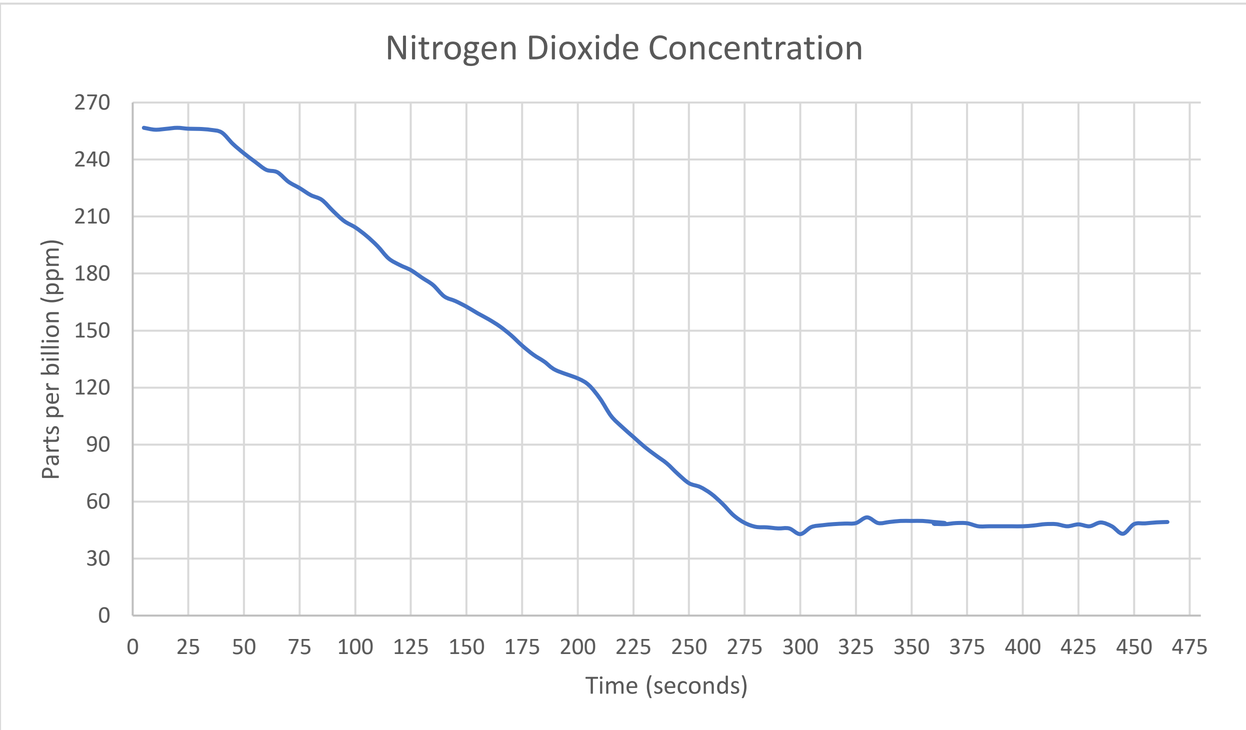


Figure 51:

Nitrogen dioxide concentration VS time graph.

Table 2:
Sensor readings every minute in the test plan.

Time (minutes)	Parts per billion
0	256.716
1	234.613

2	184.514
3	137.367
4	80.124
5	47.569
6	49.260
7	47.009
8	49.252

CHAPTER 4: Evaluation, Reflection, Recommendations

Analysis and Discussion

Analysis

Material Sciences & Environmental Impact

Material	Car/passenger	Truck
Rubber/elastomer	41-48	41-45
Carbon Black	22-28	20-28
Metal/steel	13-16	20-27
Textile	4-6	0-10
Additives	10-12	7-10

Table 3:

Composition of tires according to type.

Tires represent a major source of pollution worldwide. Around 11% of old tires are thrown in landfills, making good homes for pests such as rodents. They are also commonly used by mosquitoes as breeding grounds due to their heat insulation, which can increase the spread of diseases like malaria. Additionally, sometimes, fires can result.

Pyrolyzing tires, instead of natural decomposition which lasts many years, helps reduce the pollution effect while producing valuable products. Pyrolysis produces pyrolytic oil, used as a fuel or as a feedstock for making chemicals, synthetic gas, primarily hydrogen, and carbon monoxide, which can be used as an industrial fuel, and carbon black or char (Smith & Jones, 2022). Moreover, tires have on average a composition favoring carbon black, **as shown in Table 3**. Thus, they were chosen as the carbon precursor for activated carbon production. Activated carbon is an adsorbent material able to remove several types of air pollutants, facilitating in achieving the design requirements.

Adsorption

Adsorption refers to the attraction of molecules, atoms, or ions, called absorbates, to the surface of another substance, called absorbent (Aljamali et al., 2021). To achieve optimal results, the filtration material was chosen with adsorption properties rather than absorption. In the case of NO_x, adsorption, compared to absorption, produces no liquid waste, has higher purification efficiency, and requires only simple equipment. While it does require large initial investment in comparison to absorption, this isn't a problem for the proposed solution (Zhu & Xu, 2022).

The prototype utilizes physisorption specifically to trap pollutants. Physisorption is caused by the one-sidedness of the Van der Waal forces acting between the outermost and second layer of absorbent materials, which results in an attraction force to the absorbent .

Activation of Carbon

The activated carbon was acquired from wasted tires using chemical methods. Alkaline hydroxides were chosen mainly due to their low ash content and high adsorption capacity (Linares-Solano et al., 2012, p.63). KOH was chosen as an activating agent as it can lead to activated carbon with high microporosity (Heidarinejad, Dehghani, Heidari, & et al., 2020, p.11), and thus surface areas up to $4000\frac{m^2}{g}$ (Gao et al., 2020, p.34). Additionally, it is less corrosive and environmentally threatening than alternatives, and thus safer for use in the prototype (Heidarinejad, Dehghani, Heidari, & et al., 2020, p.11).

Wet methods were used to mix the KOH with tires. The optimal ratio of KOH to water to form the activating solution was found to be $30 : 200\ w/w$ respectively from older papers (Özbaş, Balçık, & Özcan, 2019, p.79). Previous papers have stated that the mixing of carbon precursors in activating agents increased surface area, total pore volume, and mesopore volume until the 5th hour (Gao et al., 2020, p.21). Due to lab regulations, the process was forced to stop in the 3rd hour.

Sensor Calibration

As studied in CH.2.01, the parts per million/billion property of a solute in a solution is used to describe the concentration of substances normally present in trace amounts. There are many different types of parts per billion, including volume-to-volume, mass-to-volume, and mass-to-mass. Volume-to-volume was chosen due to its ease of calculability.

To get accurate NO_2 ppb readings from the MQ-135 sensor, it first had to be calibrated. The calibration graph in the official datasheet of the sensor contains functions relating pollutant ppm to a resistance ratio to ease calibration for most gasses, excluding NOx. Thus, to calibrate the sensor, a function had to be first derived.

First, the sensor resistance is measured using the following equation (Kinnera, Subbareddy, & Luhach, 2019):

$$R_S = \frac{5 * R_l}{V_{rl}} - R_l = \frac{5 * 20}{V_{rl}} - 20$$

Where R_l is the resistance load, which is equal to 20 kilohms (derived from the datasheet). To calibrate, R_s in normal atmospheric air, known as R_0, was measured 100 times and averaged, equating to 581.76471.

Secondly, 3 samples of known NO_2 ppb were prepared and diluted to different ppbs using the redox reaction of copper with nitric acid, shown in the following equation:

$$Cu_{(s)} + 4HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$$

Then, for each of the samples, 100 sensor resistance readings were taken and averaged to obtain 3 R_s values, which turned out to be $R_{s1} = 618.2325$, $R_{s2} = 599.0540$, and $R_{s3} = 592.1692$. Each sample resistance was then paired with its ppb in the form $(ppb, \frac{R_S}{R_0})$:

$$(47085.89, 1.063), \qquad (15317.27, 1.029), \qquad (4984.87, 1.018)$$

The functions used to model pollutants in MQ-135 sensors are logarithmic functions. Thus:

$$\log(y) = m * log(x) + b$$

The slope of the conversion function of NOx can be calculated using the following equation:

$$m = \frac{\log(y_2) - \log(y_1)}{\log(x_2) - \log(x_1)} = \frac{\log(1.029) - \log(1.063)}{\log(15317.27) - \log(47085.89)} = 0.0289$$

Where y_2, x_2, y_1, and x_1, are the first two ppb and resistance ratios aforementioned.

Now, substituting in the function with the third (x, y) pair to obtain b, or the y intercept:

$$\log(y) = 0.0289 * \log(x) + b,$$
$$b = \log(1.018) - 0.0289 * \log(4984.87) = -0.0992$$

Thus, the function is:

$$\log(y) = 0.0289 * \log(x) - 0.0992$$

Where y is the $\frac{R_s}{R_0}$ ratio and x is the NO_2 ppb.

HEPA Filter

As studied in ES2.04, Sieves are used as semi-permeable membranes to clear large flowing particles. Thus, in the same way, High-Efficiency Particle Arresting filters, known as HEPA filters, were used to capture relatively large airborne particles. HEPA filters can capture at least 99.97% of airborne particles as small as 0.3 microns (μm). Incorporating HEPA filters in air filtration systems can reduce respiratory-related diseases by up to 20% in urban environments, particularly where PM2.5 levels are high (Zhao et al. 2015).

In this project, surgical face masks were used to include the activated carbon inside. The typical face mask can capture in the range of 300 nm to 5 µm in size (Walawalkar et al., 2021) Particularly, the third layer of the mask was used as it contains pores of 0.5 µm. On one hand, this ensures the carbon particles are held without penetrating the mask. On the other hand, it increases the lifetime of the carbon as it prevents large particles, like dust, from mixing with the carbon, which can decrease the area susceptible to physisorption. Estimates vary, but the use of a HEPA filter can approximately double the effective lifespan of an activated carbon filter, depending on the specific environmental conditions and pollutant load.

Conclusions

The selected problem to be solved through this project was the reduction of nitrous oxide (NO_x) emissions caused by the overuse of fertilizers in agriculture. Activated carbon, known for its high efficiency in adsorbing air pollutants, was chosen to be the solution. Waste tires were used as the raw material to produce the activated carbon, undergoing pretreatment using potassium hydroxide (KOH), followed by pyrolysis, thermal decomposition under high temperature, and finally activation process, also using KOH. Despite some negative results, the prototype, successfully, has proven to meet all the design requirements, achieving a reduction of 80.81% in NO_2 concentration within 8 minutes. Compared to previous solutions, like Smog Free Tower, this project uses easily accessible recycled materials and is eco-friendly and more cost-effective. By combining the strengths of earlier methods while addressing their limitations, this project delivers a practical and sustainable alternative for reducing NO_x emissions, offering significant potential for environmental improvement.

Recommendations

Real-life Application

The recommended location for implementing the project is Al-Mena Safour, **shown in Figure 52**. Al-Mena Safour, situated in Sharqia, is a rural area where agriculture predominates and serves as the primary source of livelihood for the residents. The

Figure 52:

Location of Al-Mena Safour.

extensive use of nitrogenous fertilizers to achieve high crop yields has significantly contributed to nitrous oxide emissions in the region, necessitating immediate attention. The real-life project will replicate the prototype's filter, designed for household use to reduce pollutant concentrations. The activated carbon layer should be integrated into a porous material, allowing for easy replacement when necessary.

Chemical-Thermal Reactivation of Spent Activated Carbon (SAC)

Reactivation, or regeneration, involves removing impurities adsorbed on the surface of spent activated carbon (SAC) while preserving its porous structure. This process allows AC to be reused across multiple cycles, reducing the need for new AC production and minimizing waste generation. Among the various reactivation methods, past studies have concluded that combining acid-washing (chemical) with thermal reactivation of SAC is essential for achieving a higher reactivation degree (Toledo et al., 2020). While acid-washing removes impurities through dissolving, thermal reactivation eliminates organic waste by thermal decomposition. According to the study, the optimal experimental conditions for reactivating SAC were achieved through acid washing with HNO_3 at 20% v/v at 50°C for 30 minutes, followed by thermal reactivation at 850°C for 1 hour.

Microwave Pyrolysis

Microwave pyrolysis, first introduced by Tech-En Ltd., involves mixing scrap tire crumbs with a microwave-absorbent material and heating it in a microwave bed, **as shown in Figure 53**. The material captures thermal energy, heating the waste tires to produce volatile material and char. The volatile material condenses into pyrolytic oil, while the char remains, ideal for activated carbon production. A key advantage is its efficiency in producing solid char, though scaling up remains a challenge. Experiments show the yield of pyrolysis oil and char ranges between 30-44% and 40-65% by weight, respectively. This process produces the highest percentage of solid char, optimal for activated carbon production (Liang et al., 2023).

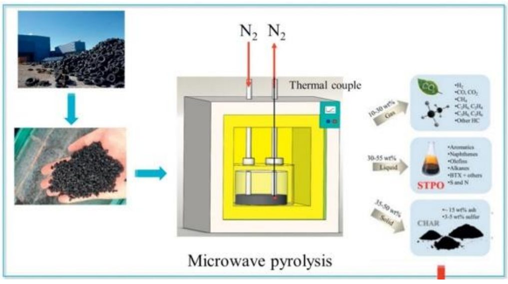


Figure 53:

Demonstration of microwave pyrolysis of waste tires.

Recommendations to Future Teams

For the team undertaking the advancement of our prototype, we recommend digging deeper into the pyrolysis process, considering the parameters affecting it like temperature, pretreatment, residence time, and activation methods to enhance the carbon's adsorption capacity. Develop a scalable, modular filter design that allows easy integration into air purification systems. Develop a detailed project plan, outlining timelines, milestones, and resource requirements. Try to avoid the negative results we faced in our project. Search for advanced technology like hybrid materials.

Project's Positive Influence

Our team at STEM school has had a real-life changing event while designing and constructing a real-life project and a prototype for an air filter. This project has not only helped us to understand scientific and engineering concepts profoundly, but it has also improved our abilities to work together and communicate effectively. This project has opened up a whole new world of scientific exploration, encompassing fields such as physics, chemistry, and the combination of them both. We had a better understanding of adsorbent materials and how to improve the future of this field. The project also improved our soft skills such as communication, creativity, and teamwork.

Learning Outcomes

L.O.	Description
ENW.2.1.2	ENW.2.1.2 in English discusses how to write a process analysis essay, which was used during the discussion of the project.
CH.2.04	In CH.2.05 we learned the factors that affect the chemical reaction, which helped us during performing the chemical reactions.
PH.2.03	In PH.2.03 we explored the electric circuits and others, which helped us build the sensor circuit.
ES.2.04	In ES.2.04 we learned more about pollution, the steps of filtration, and their order. This helped us while designing the prototype's body.
CH.2.03	In CH.2.03, acids and their properties were studied which helped us determine which acid is more suitable according to its properties, like its PH.
CH.2.01	In CH.2.01 we studied the concentration of particles in many ways which was used in the project while measuring the concentration of NOx in air in ppm.
CH.2.02	In CH.2.02, reverse osmosis was studied which was used while integrating the HEPA filter of the face mask into the prototype.
CH.1.01	CH 1.01 explains how to deal with uncertainties and significant figures, which were essential to decreasing measuring errors and calculating multimeter errors.

MA.1.02	This L.O. showed different types of graphs, and which one is suitable for each data. This helped us to represent the graph of the NOx concentration in air before and after filtration.
ES.2.01	This L.O. discusses various properties of water which was used in other materials like activated carbon which has a high adhesion force ability which is known as the adsorption process.

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