



# ALGAE-BASED AIR FILTRATION: ENHANCING INDOOR AIR QUALITY

Group 17211 | Capstone Portfolio.



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## Table of Contents

<b>Chapter 1   Present and Justify Solution Requirements .....</b>	<b>3</b>
<b>Egypt Grand Challenges.....</b>	<b>3</b>
<b>Problem to be solved .....</b>	<b>13</b>
<b>Research.....</b>	<b>15</b>
<b>Prior solutions.....</b>	<b>26</b>
<b>Chapter 2   Generating and defining the solution. ....</b>	<b>32</b>
<b>Solution and design requirements.....</b>	<b>32</b>
<b>Selection of Solution .....</b>	<b>34</b>
<b>Selection of Prototype .....</b>	<b>35</b>
<b>Chapter 3   Constructing and testing a prototype. ....</b>	<b>37</b>
<b>Material and Methods.....</b>	<b>37</b>
<b>Test Plan .....</b>	<b>41</b>
<b>Data Collection.....</b>	<b>42</b>
<b>Chapter 4   Evaluation, Reflection, Recommendations.....</b>	<b>45</b>
<b>Analysis and Discussion .....</b>	<b>45</b>
<b>Recommendations.....</b>	<b>49</b>
<b>Learning Outcomes.....</b>	<b>51</b>
<b>Citation in APA<sup>7th</sup> .....</b>	<b>53</b>

## Chapter 1 | Present and Justify Solution Requirements

# Egypt Grand Challenges

For the last few years, Egypt faced many challenges that became obstacles to its development, and the government has tried hard to solve these problems to continue in its road of success and improvements in many fields.

Defining these problems is necessary to solve them, as there are too many challenges, the economic researchers chose 12 challenges to be the main grand challenges in Egypt and to focus on solving them as they include the most important fields in Egypt.

These 12 main grand challenges are shown below:

- ❖ *Deal with exponential population growth.*
- ❖ *Reduce pollution.*
- ❖ *Work to eradicate public health issues.*
- ❖ *Improve the use of alternative energies.*
- ❖ *Reduce urban congestion.*
- ❖ *Reduce and adapt the effects of climate change.*
- ❖ *Improve the use of arid areas.*
- ❖ *Increase industrial base for Egypt.*
- ❖ *Improve sources of clean water.*
- ❖ *Increase opportunities for Egyptians to stay and work in Egypt.*
- ❖ *Recycle and retain garbage for recycling.*
- ❖ *Improve the scientific and technological environment for all.*

# Deal with population growth and its consequences

Population growth is a demographic concept that shows the increase in the population of a country. It can be represented by subtracting the number of mortalities from the number of births per year. Having a high population growth is not considered a problem, the problem comes when there is a lack of resources in the country and the population is getting higher, so there will not be enough resources for the new generations which leads to many other problems such as poverty, bad education, Unemployment, urban congestion and in some cases, it could lead to famines.

For Egypt, since the last two decades, the country has been through rapid population growth which put a large pressure on the economy and the projects of enhancing the life quality. The population growth ratio in Egypt in 2023 was 1.5. *as shown in Graph (1)* and the population was about 111 million people according to the World Bank.



Graph 1.1 (Shows the population growth in Egypt)

This increase in the population is caused by many reasons:

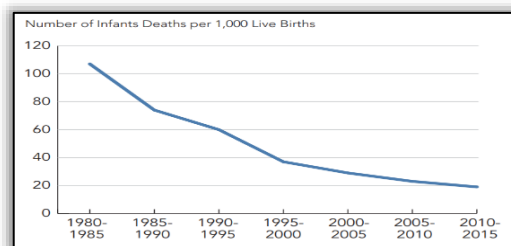
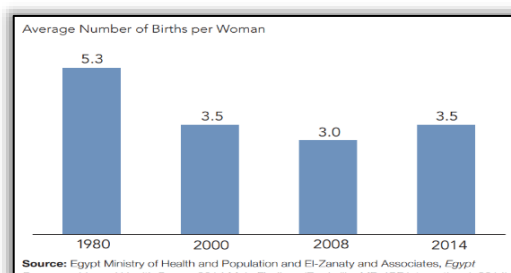
- High fertility rate.
- Low mortality rate.
- Young girls' marriage.

Egypt's population more than tripled in the second half of the 20th century, this is because of the increase in births number according to the high fertility rate (Average Number of Births per Woman), and the decline in mortality number especially in children. *As shown in Graphs (2), (3).*

Children born in Egypt today are expected to live 71 years on average, 10 years longer than those born around 1985. This is mainly because of the improvements in health care in the last few years. allowing a much larger percentage of newborns to reach adulthood and in turn have their own children. Today, Egypt's infant mortality rate is about half of the world's average.

Marriage is nearly universal in Egypt and many families still marry off their daughters at a young age. In 2014, more than half a million girls ages 15 to 19 were ever married.<sup>7</sup> For these girls, early marriage generally means early childbearing, adding momentum to the country's population growth.

Thus, the country is facing many challenges to improve the life quality of the people, every 100 people responsible for production in Egypt work to provide the needs of 60 other people, which works to reduce average incomes as well as averages of savings and investment at the state level. The demand for food has become greater than the supply, which led to the import of a large volume of basic food resources such as wheat and meat. The Egyptian state has spent in the last ten years 9 times what was spent in 2014/2015, in the field of education to create new classrooms simultaneously. The Egyptian state spent this year 13 times what was spent on investment in health 10 years ago.



Graphs 1.2 - 1.3

(show fertility and mortality rates in Egypt)

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## Recycle garbage and waste for economic and environmental purposes.

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**E**gypt is the Middle East's most populated country, with over 95 million people. In 2016, over 21.7 million tons of municipal waste were produced. Garbage generation is predicted to rise by 3.4 percent every year due to population expansion and shifting consumer patterns.

Garbage collection and infrastructure cannot keep up with the current expansion rate. Only approximately

60% of the waste produced is collected, and less than 20% is correctly disposed of or recycled. Public areas are maintained clean in certain places, but the condition is more problematic in other regions. A considerable amount of rubbish is dumped in canals, rivers, roadways, or open spaces with no environmental protection in place.

In many countries, there are standard recycling methods. Before disposing of waste, households classify it into different categories and have separate trash cans for different types of solid and organic waste. However, in Egypt, households still produce mixed waste. Therefore, pre-recycling sorting is one of the responsibilities of the waste collector and is a task that exposes it to serious health risks. Nevertheless, Cairo's garbage collectors have protested a recent decision by the city government to set up a system that encourages citizens to separate and sell their garbage. A kiosk installation is a new approach tested in some areas of Cairo. The idea is to encourage people to separate their trash, sell the solids collected through these kiosks, and donate money to selected charities. However, the city's garbage collectors rely on selling accumulated waste to earn a living. These kiosks are already located at £5 to £30 per month (\$0.25 and \$1.5, respectively). Most of Cairo's



*Figure 1.1*

garbage collectors live in the Ezbet-Elsa-Balleen district, also known as the garbage collector's village. Located on the road leading to the Mokatam district, the vehicle unloads much garbage collected by neighboring residents before sorting, processing, and recycling.

There are seven different forms of rubbish:

- 1) Liquid or Solid Household Waste.
- 2) Hazardous Waste.
- 3) Medical/Clinical Waste.
- 4) Electrical Waste (E-Waste).
- 5) Recyclable Waste.
- 6) Construction & Demolition Debris.
- 7) Green Waste.

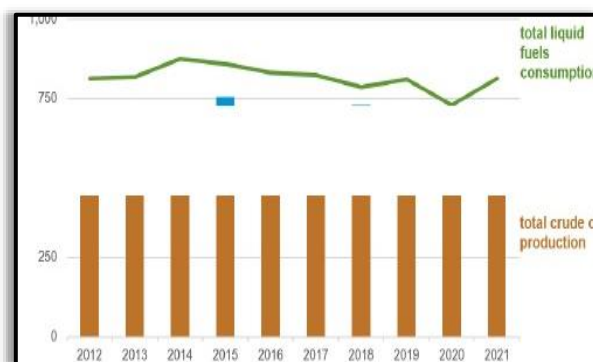
Most of the past mentioned forms of rubbish could be recycled and used to solve many problems. Recyclable wastes are from the popular forms of rubbish that have been used for recycling, as the most common types of recyclable household waste include paper, cardboard, plastic-packaged materials food containers, metal, and glass.

For that, recycling one or more of these wastes would help decrease the pollution that we suffer from, in addition to helping us solve many problems like Corrosion, replacing some materials like iron steel with more efficient materials like glass-fiber-reinforced polymer and many other solutions could be made.

# Reduce and adapt to the effects of Climate change

Climate change is a long-term change in the average weather patterns that have come to define Earth's local, regional, and global climates. These changes have a broad range of observed effects.

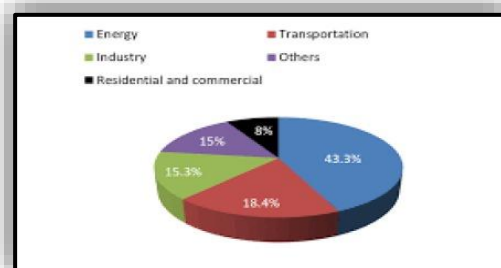
This problem of climate change has been an ongoing problem for humanity since the beginning of the Industrial Revolution as they have contributed significantly to climate change, primarily through the usage of fossil fuels such as coal, natural oil, and gas where, burning fossil fuels releases greenhouse gases that wrap around the Earth like a blanket, trapping the sun's heat and increasing temperatures.



Graph 1.4 (Egypt's annual production and consumption of liquid fuels)

## Causes of climate change:

- Generating power: Generating electricity and heat from fossil fuels causes a large problem with that. Most electricity is still generated by burning coal, oil, and gas which produces most of the carbon dioxide and nitrous oxide- powerful greenhouse gases that blanket the Earth and trap the sun's heat. Globally, a bit more than a quarter of the comes from wind, solar, and other renewable sources which, as opposed to fossil fuels, emit little to no greenhouse gases or pollutants into the air.



Graph 1.5 (causes of climate change)

- Manufacturing and industry produce emissions, mostly from burning fossil fuels to produce energy for making things like cement, iron, steel, electronics, plastics, clothes, and other goods. Mining and other industrial processes also release gases, as does the construction industry. Machines used in the manufacturing process often run on coal, oil, and plastics, are made from chemicals sourced from fossil fuels. The manufacturing industry is one of the largest contributors to greenhouse gas emissions worldwide.
- Producing food causes emissions of carbon dioxide methane and other greenhouse gases in various ways, including through deforestation and clearing of land for agriculture and grazing, digestion by cows and sheep, the production and use of fertilizers and manure for growing crops, and the use of energy to run farm equipment or fishing boats, usually with fossil fuels. All this makes food production a major contributor to climate change and greenhouse gas emissions also come from packaging and distributing food.
- Most cars, trucks, ships, and planes run on fossil fuels. That makes transportation a major contributor to greenhouse gases, especially carbon dioxide emissions. Road vehicles account for the largest part, due to the combustion of petroleum-based products, like gasoline, in internal combustion engines. But emissions from ships and planes continue to grow. Transport accounts for nearly a quarter of global energy-related carbon dioxide emissions.

#### Effects of climate change:

- As greenhouse gas concentration rises, so does the global surface temperature which is evident from the fact that the last decade has been the warmest decade in human history on record. Nearly all land

areas are seeing more hot days and heat waves which increases the risk of heat-related illnesses and makes working outdoors more difficult than it already is.

- Destructive storms have become stronger and more frequent in many regions. As temperatures rise, more humidity evaporates, which causes extreme rainfall and flooding, causing more destructive storms.
- Climate change is changing water availability, making it scarcer in more regions. Global warming causes shortages of water in already water-stressed regions and is leading to an increased risk of agriculture droughts affecting crops. sand and dust storms that can move billions of tons of sand across continents. Deserts are expanding, reducing land for growing food. Many people now face the threat of not having enough water regularly.
- Climate change is the single biggest health threat facing humanity. Climate impacts are already harming health, through air pollution, disease, extreme weather events, forced displacement, pressures on mental health, and increased hunger and poor nutrition in places where people cannot grow or find sufficient food. Every year, changing weather patterns are expanding diseases, and extreme weather events increase deaths and make it difficult for healthcare systems to keep up.

# Work to eradicate public health issues and diseases

**Egypt's new Constitution 2014** powerfully addresses health as a fundamental human right and declares commitment to covering the whole population with quality health services. Egypt's progress towards universal health coverage (UHC) has been spurred recently by approving the Social Health Insurance (SHI) law, ensuring adequate and sustainable funding for health and reducing out-of-pocket expenditures. The new law has been approved by the government and parliament and authorized by the president for initiating implementation.

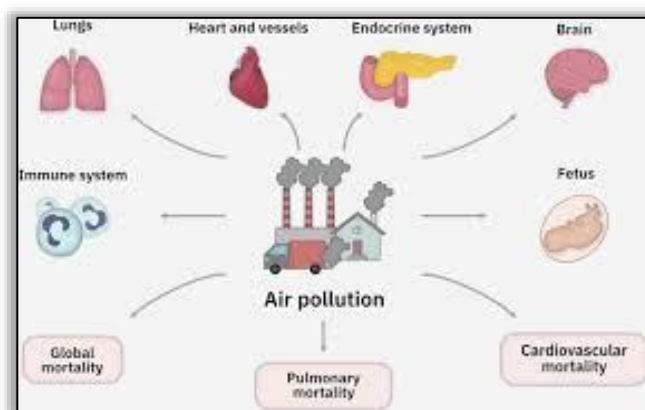


Figure 1.2 (shows the effect of air pollution on human health.)

Egypt has a long experience developing and implementing health system reforms and engaging with development partners. It has an elaborate network whereby 95% of the population lives within a 5 km radius of a given health facility. Commitment to the family practice program has expanded to cover 50% of primary care facilities and developed a national plan for scaling up family practice. The health information system within MoHP handles a multitude of indicators generated by the health sector with complete civil registration and vital statistics (CRVS) system. Sustained health system support has helped achieve high immunization coverage, Schistosomiasis control, and elimination of polio, diphtheria, pertussis, and lymphatic filariasis, besides improvement towards the achievement of MDG goals. Noncommunicable diseases (NCDs) constitute a significant burden on the health system in Egypt and are considered a substantial challenge for

socioeconomic development in the country. About 84% of total mortality in Egypt is attributed to NCDs, mainly Cardiovascular diseases, Cancer, Chronic Lung diseases, and Diabetes. Also, the prevalence of main behavioral and biological risk factors for these diseases is very high (Tobacco use, physical inactivity, unhealthy diet, obesity, hypertension, and hypercholesteremia).

Microplastics entering the human body via direct exposures through ingestion or inhalation can lead to an array of health impacts, including inflammation, genotoxicity, oxidative stress, apoptosis, and necrosis, which are linked to a variety of adverse health outcomes including cancer, cardiovascular diseases, and a lot of other conditions also other negative health issues that the plastic reasoned in are Direct toxicity as in the cases of lead, cadmium, and mercury

Also, Carcinogens, as in the case of diethylhexyl phthalate (DEHP), so in a way to decrease these problems, recycling the plastic polymers and taking them from the environment to insert them for improving particular industries will reduce the health issues and diseases caused by this plastic lead to a healthier hygienic environment.

Cutting down on the sources of pollution is important. Governments should make stricter rules for factories, vehicles, or any machine that increases air pollution, the government should encourage cleaner options like electric cars and renewable energy, such as solar and wind power. Cities can be designed with more green spaces and better public transportation to reduce pollution, and monitoring air quality in real-time can help people make better decisions for their health.

We also need more research to develop technology that reduces pollution and to find better treatments for diseases caused by it with stronger policies, cleaner energy, and public awareness, we can reduce the harmful effects of air pollution and make communities healthier.

# Problem to be solved

## Air pollution

For the past 2 to 3 centuries, the environment has been deteriorating in the form of climate change and different kinds of pollutants- at a rapid rate due to the usage of fossil fuels and not recycling waste causing a lot of public health issues and diseases, especially with the ongoing rise in population growth, the consequences of these problems are going to get amplified. This project addresses one of the consequences of these problems which is air pollution.

Air pollution has been an ongoing problem for humanity since the beginning of the Industrial Revolution. This is because unclean and non-renewable sources of energy such as fossil fuels were used which when burnt produced a plethora of harmful pollutant gasses like CO, CO<sub>2</sub>, and NO<sub>2</sub>. These pollutants caused a lot of diseases and lowered the quality and the life span of humanity especially when considering the fact that the Industrial Revolution started about 250 years ago where little information about how harmful these gasses were known at the time.

The usage of fossil fuels isn't the only factor contributing to air pollution as waste produces about 20% of the human-driven methane emissions globally due to burning said waste to get rid of it or naturally emitted gases from the waste deteriorating and rotting. This amount of air pollution would be non-existent if the waste was recycled and used for other things which would also mean that the factories would need to manufacture less of the materials resulting in less fossil fuel consumption.

If the problem is solved:

- ❖ Improved cognitive and neurological abilities and lower cancer and cardiovascular disease risks.
- ❖ Improved air and water quality, restoration of ecosystems, protection of the ozone layer and slow climate change.
- ❖ Reduced healthcare costs boosted agricultural yields, and increased labor productivity.
- ❖ An overall improved quality of life in the form of better mental well-being, greater outdoor enjoyment and enhanced health and longevity.

If the problem isn't solved:

- ❖ There will be a widespread range of different kinds of diseases such as cancer, cardiovascular diseases, and neurological effects.
- ❖ The environment will be negatively affected in the form of climate change, acid rain, damage to wildlife and ozone depletion.
- ❖ Due to the widespread diseases and the terrible air quality, there will be an increase in the cost of healthcare, a decrease in labor productivity, and the potential damage to infrastructure due to acid rain.
- ❖ It will induce a negative impact on the daily life of individuals as air pollution, especially in the form of smog decreases visibility potentially leading to more road accidents.

# Research

## Case Study: Air Pollution in Cairo, Egypt

Cairo, Egypt, has been facing significant air pollution challenges for decades, primarily due to rapid urbanization, industrialization, and increasing vehicles on the road. Emissions from vehicles, industrial activities, and open burning of agricultural waste primarily cause air pollution in Cairo. In addition, the city's geographic location in a desert area means that it is frequently exposed to dust storms, exacerbating the pollution problem.



*Figure 1.3 the black cloud that happens due to air pollution*

One of the most notorious air pollution events in Egypt is the annual occurrence of the Black Cloud which happens during the fall season, typically from September to November. This event is largely attributed to the burning of rice straw after the harvest season, creating severe smog over the city and surrounding regions.

There are 4 main causes for Black cloud:

- 1- Agricultural Waste burning: farmers in the Nie Delta region leftover rice straw after the harvest, releasing large amounts of smog and particular matter into the air.
- 2- Vehicle emissions: Cario has a rapidly growing population, leading to heavy traffic. These vehicles use low-quality fuel and produce high levels of exhaust emissions containing nitrogen oxides, sulfur dioxide, and particulate matter

- 3- Industrial emissions: factories and industrial plants located near Cairo release Pollutants like sulfur dioxide, carbon monoxide, and other toxic gases. This adds to the overall poor air quality in the city.
- 4- Dust storms: Egypt is near to the desert which causes dust and sand in storm to pollute the air

Because of air pollution in Egypt specifically, Cairo, there are serious impacts that faces Egypt such as health consequences, economic impact, and tourism.

- 1- Health consequences: Cairo's air pollution levels frequently exceed the World Health Organization (WHO) guidelines. This has led to an increase in respiratory diseases, such as asthma and bronchitis, especially among vulnerable populations like children and the elderly. Long-term exposure to polluted air increases the risk of heart disease, lung cancer, and stroke. It is estimated that air pollution in Egypt is responsible for approximately 90,000 premature deaths annually.
- 2- Economic impact: Poor air quality affects Egypt's economy due to lost productivity from workers suffering from pollution-related illnesses. The healthcare costs associated with treating air pollution-related conditions are also substantial.
- 3- Tourism: Cairo is one of the most visited cities in the Middle East and home to iconic landmarks like the Pyramids of Giza. However, persistent air pollution has negatively affected the city's reputation as a tourist destination, with visitors often complaining about the smog and poor visibility.

Government's response to the problem was represented in the following 4 actions:

- 1- Air quality monitoring: the Egyptian environmental African Agency (EEAA) has established a network of air quality monitoring stations across Cairo to measure pollution levels and provide real-time data.
- 2- Regulation of agricultural waste burning: In recent years, the Egyptian government has taken steps to reduce rice straw burning by encouraging farmers to use it for other purposes, such as producing biofuels and fertilizers. Additionally, stricter enforcement of penalties for illegal burning has been implemented.
- 3- Vehicle emissions standards: The government has been working to implement stricter emissions standards for vehicles and promote the use of cleaner fuels. There has been a push to shift towards natural gas-powered vehicles and electric transportation.
- 4- Public awareness campaigns: Environmental awareness campaigns have been launched to educate citizens about the health risks of air pollution and the importance of sustainable practices, such as reducing waste burning and vehicle emissions.

Carbon dioxide (CO<sub>2</sub>) has emerged as one of the most significant contributors to environmental degradation and directly affects humanity as a whole. With increasingly high CO<sub>2</sub> concentration in the Earth's atmosphere, the world is currently plagued with numerous stressors that impact the ecosystems, climate change, the well-being of humanity, and even world order. CO<sub>2</sub> belongs to the family of greenhouse gases (GHG) which are lid donate bog-dot. Such a greenhouse effect has always existed in the biosphere and is vital for retaining the temperatures on the planet supporting life, but due to increased levels of CO<sub>2</sub> emissions caused by human activities, the greenhouse effect has worsened leading to global warming. There is

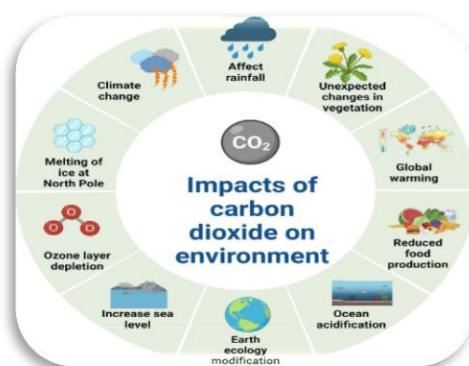
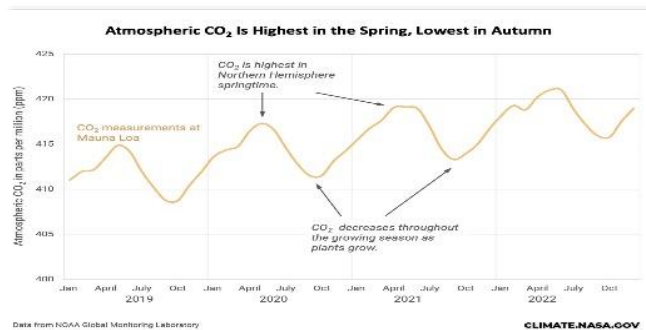


Figure 1.2 (impacts of carbon dioxide on the environment)

an unequal distribution of this warming; it sets off a chain of interrelated processes that are already changing the planet in a more permanent way.

The most immediate impact of higher levels of CO<sub>2</sub> gas in the atmosphere is the disintegration of the polar ice caps and glaciers. These large freshwater reservoirs that have survived for many thousands of years are easily getting wiped away with the heat. The melting of glaciers leads to an increase in sea water level, which poses danger to low lying areas. Such low-lying areas comprise many islands and very populous cities which are relatively close to ocean bodies. The change is apparent; areas which weren't submerged are now under water owing to increased flooding. Besides loss of areas, few other issues that arise from the destroyed habitats are increase in sea levels which



Graph 1.6(Carbon dioxide in the atmosphere)

endanger habitats and their ecosystems. Wading birds, fish species that spawn in estuaries and other organisms that depend on them have this territory now taken from them. As a result, humans face the adverse consequences of this situation that include much more than simply losing some animal and plant species. This is also strength and unrest that is usually kept at bay by nature's own constructions is now in jeopardy.

It's not only the ice melting that contributes to the warming caused by CO<sub>2</sub>. It is also altering weather patterns around the world. With climate change, the amount of water vapor in the atmosphere increases leading to the rise in frequency of climatic extremes. The intensity and amount of rainfall associated with hurricanes and typhoons has increased as have maximum sustained wind speeds. The duration of heatwaves is increasing and their intensity is also becoming more severe which places great pressure on energy systems

as people seek to escape the heat by using air conditioning. There are extended dry spells pushing some areas to become arid with water resources and food supplies becoming scarce. On the other hand, in some areas, there are too hot and too many rains with flooding which wash away crops and houses. This unpredictability in weather patterns creates doubt among the farmers and communities who depend on moderate temperatures and weather patterns for their survival.

More CO<sub>2</sub> means stress on ecosystems. Although plants initially grow better — faster and larger — when given more CO<sub>2</sub>, given the effects of climate change, notably heat stress, and water scarcity, and as seasons shift, they lose their resilience. Forests, an essential sink for making O<sub>2</sub> and taking in CO<sub>2</sub>, are under attack by wildfires, pests, and diseases, exacerbated by warming.



*Figure 1.5 (Industrial CO<sub>2</sub> emissions)*

Bleaching and dying coral reefs, which host a quarter of all marine life, let them down as Earth's oceans absorb CO<sub>2</sub> and turn more acidic. This upends marine ecosystems, threatening fish and species. These environmental changes contribute to losses of food, income, and cultural resources for coastal communities.

High levels of CO<sub>2</sub> exposure are psychologically and physiologically harmful to humans. Respiratory and cardiovascular diseases are caused by air pollution, CO<sub>2</sub> being one of the major pollutants. Urban cities are not immune from high pollutant concentrations that form smog and heat islands around the cities. These are major contributors to health stress, especially for children, the elderly, and the ill.

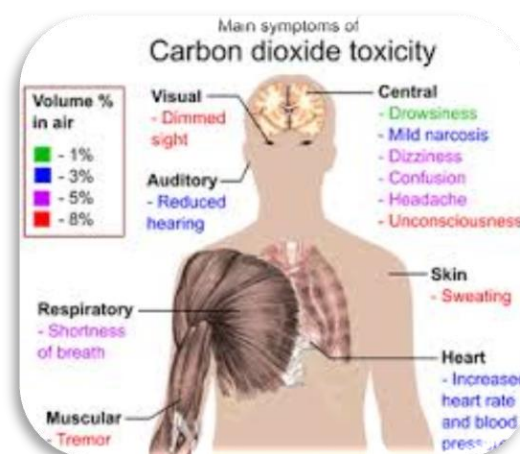


Figure 1.6 (carbon dioxide toxicity on human body)

As temperature increases, health risks related to heat rise and the deaths associated with hot spells rise with them, as for instance in long heatwaves. The food crisis is also one of the impacts of changing weather conditions. Agriculture is economically sensitive to changes in temperature, rainfall, and soil conditions in general. Some crops, like wheat, rice, and maize, might be unable to cope with the extremes of weather, resulting in loss of yields, which will ultimately affect the food security of millions in areas where agriculture is the main source of income and sustenance. Food prices increase with dwindling food supply, aggravating hunger and malnutrition levels especially in the poorer communities.

High ambient CO<sub>2</sub> levels have the most immediate psychological and physiological consequences on humans. Moreover, respiratory and cardiovascular diseases are caused by air pollution, CO<sub>2</sub> being one of the major pollutants. Urban cities are not immune from such high pollutant concentrations, which form smog and heat islands around most cities. East of smog is characterized by health stress, particularly for children, the elderly, and those already ill. Further, it raises risks related to health and heat, whereas the death toll associated with some hot spells rises with it, as for instance during long heatwaves. The most directly related factor was food security. Agriculture is economically sensitive to changes in local temperatures, Rainfall, and soil conditions. In addition, some crops, like wheat, rice, and maize,

may not keep up with the extremes of weather so that yields dwindle, which in the end can pose serious threats to the food security of millions in those areas where agriculture happens to be the main source of income and sustenance. Food security would be threatened because of increased prices due to decreasing supplies of food, thus heightening levels of hunger and malnutrition, especially in poorer communities.

Rising CO<sub>2</sub> concentrations have direct psychological and physiological negative effects on humans. Even more so, air pollution through CO<sub>2</sub> and other pollutants causes respiratory and cardiovascular diseases. Urban cities bask under smog of heat-islands due to the concentration of emissions. This contributes to an exacerbation of health issues, especially among children, the elderly, and those with pre-existing conditions. As the mercury rises, these acute heat-related conditions and the resultant heat-associated deaths tend to increase, particularly with extended spells of high heat. Health issues aside, the food crisis is another impact on the changing patent weather conditions. Agriculture is economically sensitive to any changes in temperature, rainfall, and soil conditions in its generality. Some crops, such as wheat, rice, and maize, may cope with the extremes of weather poorly, resulting in losses in yields that would have food security implications for millions living in areas where agriculture is the main source of income and sustenance. That means raising food prices as supplies dwindle; meanwhile, levels of hunger and malnutrition are aggravated, especially in poorer communities.

Even though increasing CO<sub>2</sub> can be shown to have short-term psychological and physiological effects on humans, it can actually cause respiratory and cardiovascular disorders due to air pollution from CO<sub>2</sub> and other pollutants. The issue becomes more complicated in urban cities, where people suffer with smog and heat islands made by the concentration of emissions. These become major culprits in

health stress, especially for children, the elderly, and the ill. This coupled with the rise in temperature also increases the health risks associated with heat, and more deaths associated with some hot spells rise along with it, such as during long heatwaves. Food insecurity also was among the primary impacts of the current changing weather conditions. Agriculture is the most economically susceptible to the alterations in temperature, rainfall

Sea-level rise that makes storms more drastic is a disaster for many of the coastal communities. Entire communities would be uprooted by displacements, turning millions into environmental refugees. Most villages and towns are relocating, and the inhabitants above are given the fate of becoming uprooted populations. This conversion alters the way of life and also puts a great deal of pressure on the area in which people are moving. Too many people vying for jobs and being overwhelmed by infrastructure make it possible for the majority of them to experience social tensions and economic instability.

Resource-poor and poorly planned, countries then have their governments scrambling to find solutions for these displaced populations. What lives and homes bring to the individuals and families losing homes, livelihoods, or even a sense of place cannot be measured, although it very much adds a human dimension of what is seen as an environmental problem.

The degradation is not just physical. It is also going to encroach upon the systems on which humanity now depends for its survival. Forests, wetlands, and related ecosystems as natural buffers against climate change have been compromised. These ecosystems house vital services, such as carbon storage, water purification, and biodiversity, but the current rate of destruction is alarming. Every time one of these natural systems crumbles, humanity loses one of its important allies in the battle against climate change. Indeed, economic systems are also being stressed. The numbers on these natural disasters, infrastructure rehabilitation, and adaptation to new realities of the

environment are huge and thus starve other needs like education and healthcare.

Above all the increased effects of CO<sub>2</sub> concentration are intimately related and extensive in the impacts on life in total on Earth. From the melting of ice caps to the disruption of ecosystems or even human health, the consequences are staggering in terms of their actual extent and often the irreversibility of their consequences. This has become urgent action from every sector from the individual to governments and all multinationals. Reducing baseline CO<sub>2</sub> levels or avoiding CO<sub>2</sub> emission in the first instance while conserving ecosystems and converting to renewable energy sources are among the immediate steps to this crisis. Failure to act now, or to act effectively over time, will only add to the daunting consequences of rising CO<sub>2</sub> for the future of both planet and men. Understanding how grave the issue is and taking action around it is not only an environmental imperative; it is also a moral one that requires a collective commitment to safeguarding the Earth for generations to come.

The consequences of increasing levels of carbon dioxide (CO<sub>2</sub>) are huge: if nothing gets done about them, they proceed into very serious negative impacts. Neglect will mostly have very serious and extensive negative impacts. Prominent among the negative impacts will be that of acceleration in global warming. Increasing levels of CO<sub>2</sub> will strengthen the greenhouse effect and result in higher average global temperatures. This will cause heat waves more frequently and with increased severity, which can seriously affect human health, especially among vulnerable groups. Many ecosystems will be laid to waste as they try to adapt to the changes, and there will also be significant losses in biodiversity.

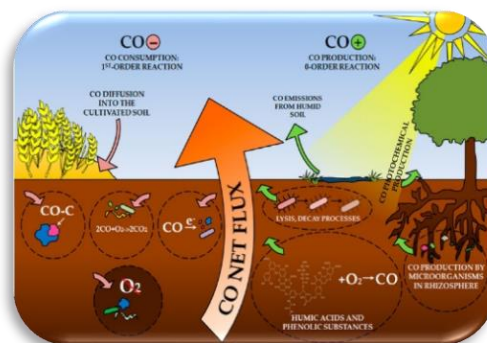
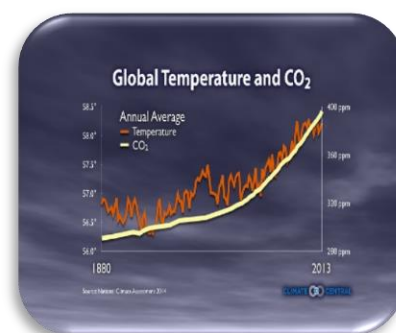


Figure 1.7(CO<sub>2</sub> impact on habitat)

The other significant aspect to consider is that the seas are still rising. Melting of polar ice caps and glaciers due to the effect of increasing temperatures will submerge coastal regions, displacing millions of population apart from the havoc wrecked. The coastal ecosystems like mangroves and wetlands will also be lost along with their indispensable services, which include protection from storms and habitat for marine lives. This will increase the vulnerability of communities living along coastal areas to flooding and extreme weather events if nothing is done about it. More extreme and erratic weather systems, such as intensified hurricanes and typhoons, as well as floods, strain agricultural systems, resulting in poor yields, insufficient food supplies, and economic malaise. The consequences will also exert pressure on healthcare systems as the number of cases related to heat and vector-borne diseases increases, thereby increasing the spread of diseases by vectors such as malaria.

On the other hand, tackling the increasing level of CO<sub>2</sub> would bring substantial positive results. By controlling emissions, global temperatures can be stabilized and minimized in the intensity of heatwaves, thereby creating a healthier setting globally for people. By better protecting populations at risk, ecosystems are also given a fighting chance to adapt to the resulting changing climate changes while also saving biodiversity and essential ecosystem services, such as air and water purification. Rising-sea coastal areas and ecosystems vulnerable to sea-level rise are mitigated, hence avoiding the uprooting of millions of humans and protecting vital habitats that are coastal in nature.

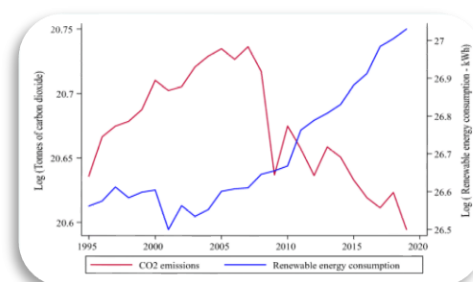
It is only by tackling CO<sub>2</sub> emissions that frequency and intensity of extreme weather events could be reduced and more stable agricultural conditions achieved. This combination would guarantee food security and minimize crop failures and price fluctuations, especially in areas highly prone to adverse effects of climate change. Well, farmers



Graph 1.7 (CO<sub>2</sub> effect on temperature)

would have better conditions under which, with less havoc wrought by unpredictable weather, to maintain their livelihoods while contributing to global food production. Needless to say, public health would also greatly benefit since better air quality associated with this moderation will reduce respiratory and cardiovascular diseases due to pollution. Further minimization of the heat island effect in urban areas leads to livable environments that would otherwise avoid heat stress illnesses.

As a matter of fact, it is the solution to the CO<sub>2</sub> problem that triggers active development in renewable energy technologies and innovation in creating jobs and industries. The move would also encourage economic development while diminishing reliance on fossil fuels, thus lessening emissions and breaking the cycle of environmental destruction. Therefore, reducing CO<sub>2</sub> emissions, not only will it clean up the environment but also create a more resilient, sustainable, and prosperous future for everyone.



Graph 1.8 (CO<sub>2</sub> emissions and renewable energy consumption relationship)

Rising levels of CO<sub>2</sub> have deep scars on the environment, climate, human health, and world order. If left unchecked, these negative impacts bring catastrophes-everything from rising oceans and severe weather to food insecurity and public health crises. However, if immediate and sustained action is taken to cut CO<sub>2</sub> emissions, the upside is very high. The poor effects can change to stabilization in climate, protection of ecosystems, improved health, and new goals for securing economic growth. It is vital for GATEN to develop as a synonym for Man-an-IN-it Hour.

# Prior solutions

## Electric vehicles

Transportation is a major source of air pollution and the largest source of heat-trapping emissions in the United States. Vehicles that burn fossil fuels to move emit more than half of nitrogen oxides in our air, and are a major source of heat-trapping emissions in the US. A solution that was developed for this problem is to use a green source of energy in transportation, The electricity.

The design of electric cars has been developed since 1800, it was the first birth of cars run by electricity, the developments were just single projects and weren't made for commercial purposes.

Electric vehicles ran into a race with fossil-fueled vehicles in the early 19<sup>th</sup> century to see which will show more reliability, and at this time the fossil-fueled vehicles showed more reliability, as using fossil fuels as a source of energy actually showed reliability in other fields like powering factories, agriculture and other transportations like trains, so it was the direction of scientists to construct cars.

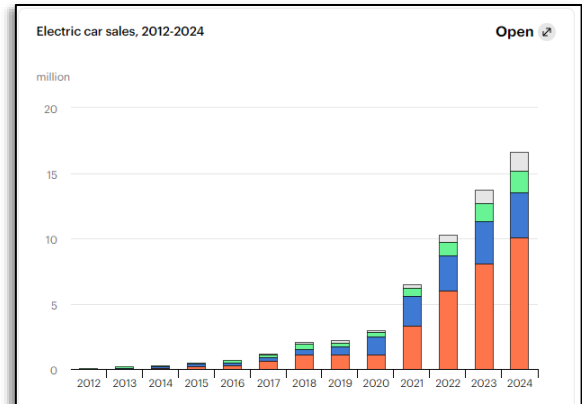
The late 1960s and early 1970s. Soaring oil prices and gasoline shortages. Created a new challenge for the United States to lower the country's dependence on Fossil fuels energy, which led to increase the use of EVs instead of other vehicles.

for the last few decades, a lot of campaigns have been made to



*Figure 1.8 (shows an old design for an electric car in 1901)*

aware people of the consequences of air pollution and how burning fossil fuels affects our air, these campaigns worked as advertisements for electric cars companies, which led to a huge increase in the usage of electric vehicles and huge development in the designs of electric cars. And this was the biggest grow for the EVs *as shown in Graph(1)*.



Graph 1.9 (shows the increase in the usage of EVs)

### Advantages:

- **Environmental Friendliness:** EVs produce zero emissions, reducing air pollution and greenhouse gas emissions.
- **Energy Efficiency:** EVs generally have higher energy efficiency compared to internal combustion engine (ICE) vehicles, resulting in lower fuel costs over time.
- **Lower Maintenance Costs:** EVs have fewer moving parts, leading to reduced maintenance requirements and costs.
- **Quiet Operation:** EVs are significantly quieter than ICE vehicles, providing a more peaceful driving experience.

### Disadvantages:

- **Limited Range:** While EV range has improved significantly, it may still be a concern for long-distance travel or those without access to charging infrastructure.
- **Charging Time:** Charging an EV, especially for a full charge, can take longer than refueling an ICE vehicle. However, rapid charging stations are becoming more common.
- **Higher Initial Cost:** EVs often have a higher upfront cost compared to ICE vehicles, although this gap is narrowing.

- **Infrastructure Limitations:** The availability of charging stations, especially in rural areas or for long-distance travel, can be a limitation.
  - **Battery Concerns:** Battery technology is constantly evolving, but there are still concerns about battery life, safety, and recycling.
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## **Photocatalytic Oxidation: A Cutting-Edge Approach to Air Quality Improvement**

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In the pursuit of enhanced air quality and healthier indoor spaces, photocatalytic oxidation (PCO) has emerged as a significant technological advancement for the effective degradation of organic pollutants and volatile organic compounds (VOCs). This process employs a photocatalyst, predominantly titanium dioxide ( $\text{TiO}_2$ ), which is activated by ultraviolet (UV) light, providing a novel mechanism for air purification by transforming harmful substances into less detrimental compounds. This paper examines the operational principles, applications, benefits, and constraints of PCO, emphasizing its potential contribution to alleviating air pollution.

### **Mechanism of Photocatalytic Oxidation:**

The PCO process initiates when UV light strikes titanium dioxide, functioning as the photocatalyst. The energy from the UV light excites electrons within the  $\text{TiO}_2$ , resulting in the formation of electron-hole pairs. These energized electrons and holes engage with moisture and oxygen present in the atmosphere, generating reactive oxygen species (ROS) such as hydroxyl radicals ( $\bullet\text{OH}$ ) and superoxide ions ( $\text{O}_2\bullet^-$ ). These reactive species are instrumental in the degradation of various pollutants.

As these reactive species oxidize and decompose organic contaminants—including VOCs, bacteria, mold spores, and unpleasant odors—they convert these hazardous compounds into less toxic byproducts, primarily carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O). The air that traverses the PCO system is purified and subsequently released back into the environment, leading to enhanced indoor air quality.

### Applications of Photocatalytic Oxidation:

The applications of PCO technology are extensive across diverse environments. One of its main implementations is in indoor air purifiers, which cater to residential, office, and commercial settings. By significantly diminishing airborne pollutants and odors, these purifiers improve overall air quality and foster a healthier living atmosphere.

Beyond standalone air purifiers, PCO technology can also be incorporated into heating, ventilation, and air conditioning (HVAC) systems, thereby treating the air circulated throughout these systems.

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## Atmospheric algae purification project: LIQUID 3

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**Overview:** The "LIQUID 3" project is an innovative urban photo-bioreactor. Developed by the Institute for Multidisciplinary Research of the University of Belgrade, it utilizes microalgae in purifying air and absorbing carbon dioxide emissions from urban ambient simultaneously. The system has been carefully designed to deal with challenges that come when there are high levels of pollution, as is the case in highly populated areas.



Figure 1.9(liquid 3 photo-bioreactor)

**How It Works:** The LIQUID 3 system operates using a six hundred-liter aquarium filled with water and algae, mainly *Chlorella vulgaris*. This species of microalgae is known for its high efficiency in photosynthesis; hence, it absorbs CO<sub>2</sub> and releases oxygen. The process initiates with the drawing of air into the bioreactor, which passes through a filtration system that removes particulates before entering the algae chamber. In this context, algae harness solar energy to transform carbon dioxide into oxygen while simultaneously sequestering additional gaseous contaminants.

### **Advantages of Using Algae:**

**Efficiency:** Microalgae have a significantly higher photosynthesis and CO<sub>2</sub> absorption efficiency compared to traditional trees. They are estimated to be 10 to 50 times more productive.

**Space-Saving Solution:** With the scarcity of green spaces in urban areas for tree planting, LIQUID 3 is compact, making it an ideal solution to be placed in small urban pockets.

**Minimal Maintenance Requirements:** The system necessitates limited maintenance; the biomass generated by the algae can be collected at regular intervals and utilized as fertilizer.

### **Disadvantages of using algae:**

#### **1) Temperature Sensitivity:**

LIQUID 3 units require specific temperature conditions for optimal functioning; they need heating when temperatures drop below five degrees Celsius. This dependency on external energy sources (both solar and grid electricity) raises concerns about their efficiency during colder months and their overall sustainability.

**2) Energy Consumption:** The LIQUID 3 units rely on energy sources for their operation, particularly for heating during colder months. This reliance on energy can lead to increased operational costs and may counteract some of the environmental benefits they provide by contributing to greenhouse gas emissions if non-renewable energy sources are used. The overall carbon footprint of operating these units could diminish their intended purpose of improving air quality.

The LIQUID 3 has many functions: it is an air-purifying system, a bench with integrated solar panels, which allow the bench to light up during nighttime and even charge portable electronic devices with its charging ports. Such a design increases its usefulness in public spaces while furthering environmental awareness.

**Impact on Urban Air Quality:** Such integration of systems can significantly improve air quality and public health outcomes within the urban environment. The LIQUID 3 project is an example of how biotechnology can be applied to sustainable urban development through the use of natural processes for environmental remediation.

## Chapter 2 | Generating and defining the solution.

# Solution and design requirements

## Solution requirements:

- ***Sustainability***

The solution must be highly sustainable, which means that it needs to meet the needs of the present without compromising the ability of future generations to meet their own needs. ensuring the clearness of the future environmental impacts of the solution.



Figure 2.1

- ***Low cost***

The solution must offer the lowest cost that ensures the best efficiency, making it affordable for the vast majority of people. This can be done by using recycled low-cost materials.



Figure 2.2

- ***Availability***

The chosen materials must be widely available through lots of regions to ensure the availability of the solution.



Figure 2.3

- ***Flexibility***

The flexibility of the solution is how the solution could be used in different areas and environments having the same efficiency.



Figure 2.4

- ***Efficiency***

The solution must be highly efficient, meaning that it needs to outcome the best quality with the least cost, time, and effort. The better performance the solution gives by the least cost, time, and effort, the higher efficient the solution be.



Figure 2.5

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## **Design requirements**

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There are a few design requirements that are put into place to ensure that the design is applicable in real-world settings:

- 1) The waste-derived material can reduce the concentration of the targeted air pollutant (CO<sub>2</sub>) by at least 20%. This reduction should be done using an air sample between 600 and 1500 ml, within a timeframe of 10 minutes or less.
- 2) The prototype must incorporate components that maintain a temperature range of 20 to 30 Celsius and the PH must also be within the range of 7 to 9 on the PH scale. This is to ensure that the chlorella is of the highest efficiency and completely optimized for reproduction and CO<sub>2</sub> absorption through its photosynthetic cycles.

# Selection of Solution

For our solution, we decided to develop an algae-based air purification system, because it's natural efficiency in absorbing carbon dioxide (CO<sub>2</sub>) and producing oxygen through photosynthesis, making a sustainable and eco-friendly solution to improve air quality. This approach leverages the algae's ability to capture CO<sub>2</sub>, a major greenhouse gas, making it an economically viable option given the low-cost materials and simple growth requirements like sunlight, polluted water, and nutrients.

The solution involves a closed and controlled system in which the PH, temperature, sunlight and the nutrients of the bacteria are being controlled to optimize their reproduction and photosynthetic cycles. A container that allows the light to pass through it where air circulates through the algae -filled bioreactors designed to maximize the surface area for algae exposure to light and Co<sub>2</sub>. Air is continuously pumped through these bioreactors, allowing the algae to absorb co<sub>2</sub> and release oxygen, while integrated sensors monitor the level of co<sub>2</sub> and oxygen to ensure efficient operation.

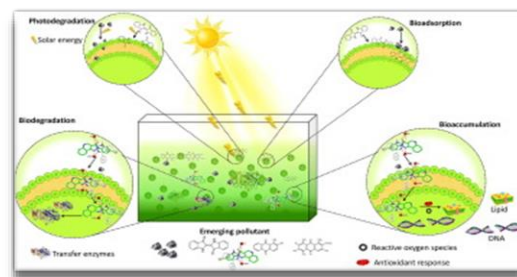


Figure 2.6 (algae system)

The water for algae planting can be periodically refreshed to keep optimal growth conditions, boosting the system overall performance this innovative method not only decreases air pollution but also offers the potential to produce valuable byproducts such as biofuels and biomass, contributing to a circular economy. By making this algae-based air purification prototype, we aim to create a sustainable and effective solution to reduce Co<sub>2</sub> emissions and improve air quality, thereby addressing environmental concerns while exploring the benefits of renewable resources.

# Selection of Prototype

The project's prototype should represent the main function of the project, reducing the concentration of carbon dioxide (CO<sub>2</sub>). In addition to meeting the design requirements.

The project's prototype consists of several parts, each of it has its own function, which is discussed in detail above.

- The container of the algae

This part consists of a glass container box that allows sun light to pass through it. The container has 2 holes in its ceiling, one for polluted gas entry and the other for treated air removal. It contains an amount of water which represents the environment that the algae live in, supplied with some nutrients needed for the algae to perform its metabolic and reproduction functions. An extra function in this part is Ph adjustment. This is done by measuring the pH scale of the water containing the algae every 1 to 3 days, ensuring that the pH scale of the water is between 7 and 9. Whenever the water becomes more acidic by the effect of the CO<sub>2</sub> gas, a solution of sodium bicarbonate is added to the water making it more basic.

- Temperature adjustment part

This part consists mainly of two devices, a water temperature sensor, and a water heater, these two devices are connected using the Arduino Uno board, the board gets the readings of the sensor in Celsius and allows a 220V AC current to go through the heater using a 5V DC relay module in case that the temperature gets lower than needed. This allows the prototype to adjust the temperature of the algae environment automatically.

- Air Quality testing part

This part's function is to calculate the concentration of the pollutant ( $\text{CO}_2$ ) in the Air sample inside the container at different times, this part consists mainly for applying the test plan and for collecting the data and the results of the project. This part contains a carbon dioxide gas sensor (MQ-135) connected to the Arduino board for reading the results. This part contains also 3 LEDs of different colors (green, yellow, and red) each representing the level of  $\text{CO}_2$  concentration inside the container as 20%, 50%, and 80% respectively.

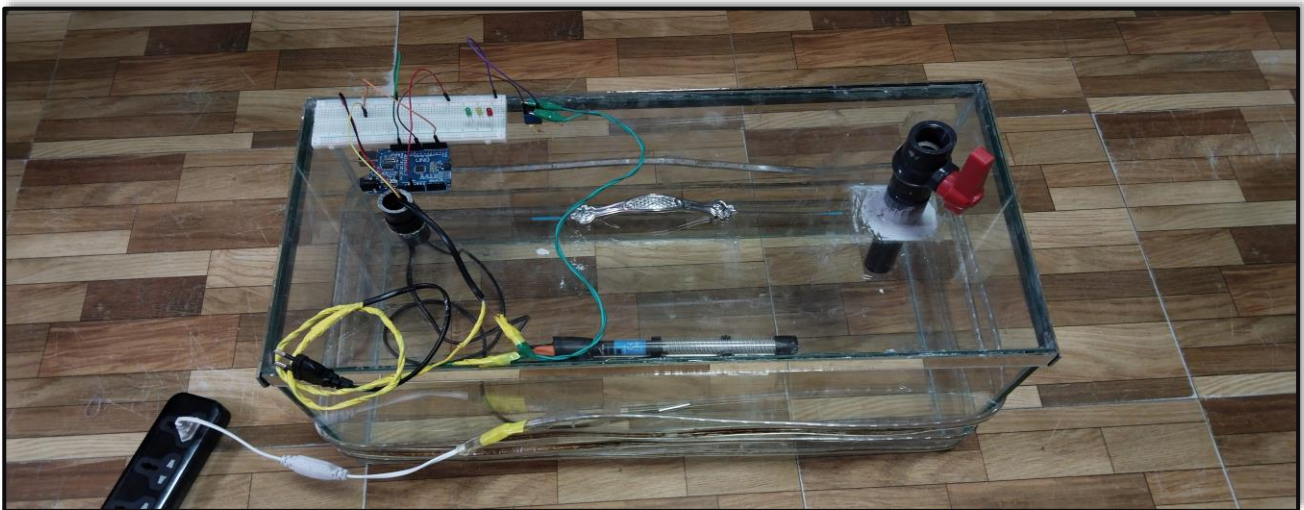


Figure 2.7 (a photo of all parts of the prototype after construction)

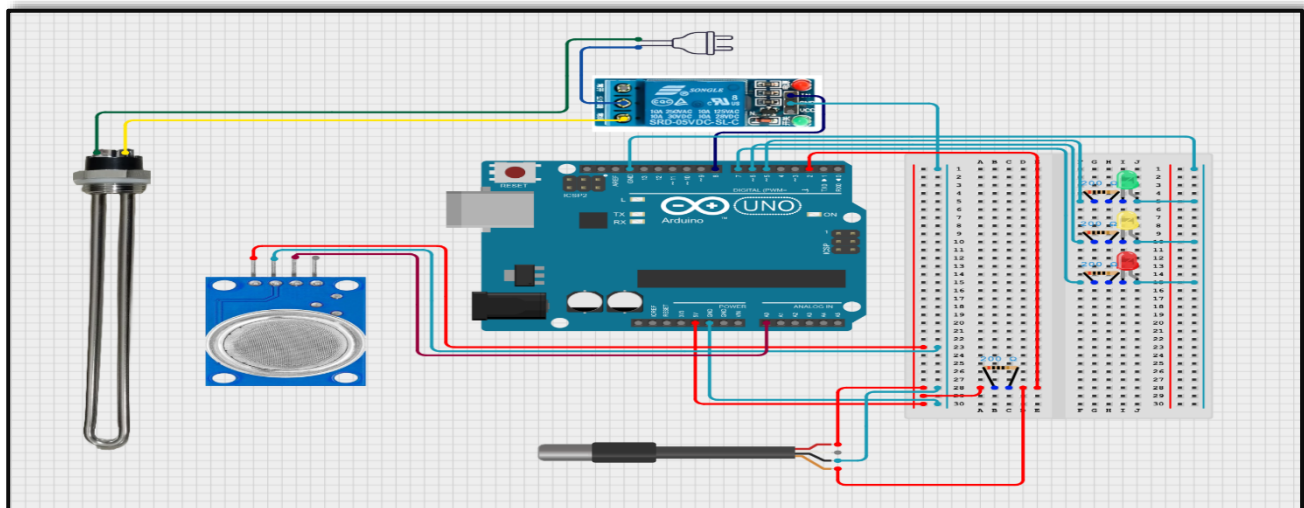










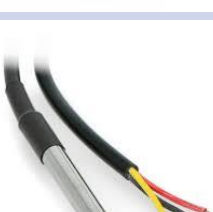

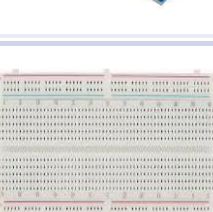


Figure 2.8 (a diagram that shows different circuits and connections of devices connected to the Arduino board)


## Chapter 3 | Constructing and testing a prototype.

# Material and Methods

Table 3.1 (the materials used in the

Item	Amount	Description	Usage	Cost	Source of purchase	Picture
Algae sample	75 ml	A water sample containing an amount of algae organisms	Used as the first sample in the reproduction of the algal system	—	Faculty of Science, Zagazig University	
Glass container	1	A container made of glass	Contains an environment made for the algae	530 LE	Glass store	
pipe	50cm	A plastic pipe with a diameter of 32 mm	Cutten into pieces to be used as bathes for the gas	30 LE	Plumbing shop	
valve	1	A plastic piece connected to the pipe	Opens and closes the paths for the gas	35 LE	Plumbing shop	
Purple LED strip	2 m	A lightning strip with a purple color of a wavelength between 500 and 600	Used to increase the light intensity of the system increasing the efficiency	40 LE	electronics shop	
Water heater	1	A device uses 220v AC electricity to heat water, usually used as an Aquarium heater	Used to control the water temperature to be between 25° and 35°	100 LE	electronics shop	

Arduino uno R3	1	A microcontroller that controls the project	Used to control the main functions of the project like turning the heater on/off and sensing the gasses.	300 LE	Electronics shop	
CO <sub>2</sub> sensor (mq-135)	1	A device that senses the concentration of CO <sub>2</sub> gas in air.	Connected to Arduino board to sense the concentration of CO <sub>2</sub> gas in the air sample	55 LE	Electronics shop	
Temperature sensor (DS18B20)	1	_____	Connected to the Arduino board to sense the temperature of the water	50 LE	Electronics shop	
Relay module	1	An electronic device that switches high voltage circuits using low volts input	Connected to the Arduino board for switching the heater on and off	15 LE	Electronics shop	
Bread board	1	A board with multiple connections	Used to connect several parts and wires in the project in circuits	25 LE	Electronics shop	
Jumper wires	15	Small wires for connections between parts	Used to connect the project parts with each other in circuits	1x15 LE	Electronics shop	
LEDs	3	Low voltage LEDs	Shows 3 different colors representing the concentration levels of CO <sub>2</sub>	1x3 LE	Electronics shop	

resistor	4	Electronic parts used to reduce the circuit current	Used to reduce the current flow through the LEDs to avoid burning it	1x4 LE	Electronics shop	
Total Cost	1202 LE					

### Methods of construction:

The prototype was made through many steps of construction, these steps are listed above.

- The glass container is made by cutting the sides by lengths and installing them to create a box, then making two holes each of diameter 3cm in the top ceiling of the container.
- The next step was to cut the plastic pipe into a 20 cm piece, which is placed in one of the two top holes, and used in getting the CO<sub>2</sub> gas into the container. And another 10 cm piece was placed in the other hole, used for getting the replaced air out of the container, and connected to a valve.
- After finishing the container, the electric parts used for controlling the system were set to perform their functions. Having the Arduino board and the bread-board installed outside the container. The water heater was stuck in the container wall from the inside, the temperature sensor was installed inside the container, and the heater was connected to the sensor through the Arduino board. The CO<sub>2</sub> sensor was installed inside the container, connected to the Arduino board, and the 3 LEDs. The LED strip was installed all around the container to increase the light intensity.
- The next step was to write the code for the Arduino board the perform all the parts functions, this step included using the

Arduino IDE (Integrated Development Environment), to compile the code and upload it into the Arduino board.

- The last step was to fill the container with water, adjusting the temperature of the water to be between 25° and 35°, ensuring that the pH of the water is between 7 and 9, and then inserting the needed nutrients for the algae, and filling the water with a number of algae, and waiting for the algae about 2 to 3 days for reproduction.

After constructing the prototype, it is time to perform the test plan on it, to ensure the efficiency of its pollution absorption.

### Safety procedures:

**Wearing gloves:** Hand gloves ensure not being affected or getting any infection while dealing with types of bio-organisms like algae. It also provides some safety from getting injuries while dealing with sharp materials like glass.

**Wearing goggles:** This protects the eye from any damage could happen to it, such as algae water sprays.

**Wearing coats:** This ensures that your clothes and your body are safe from spilling any unwanted chemical on it.

**Experts' supervision:** All the steps made were done under the experts' supervision, such as school teachers, teachers reviewed the used circuits to avoid any short circuits happen, and supervised dealing with the high AC voltage to avoid getting shocked.

# Test Plan

The purpose of the test at any project is examining if the project could solve the problem and meet the design requirements that determined previously so, the test plan should ensure if the prototype meets the design requirements or not. therefore, we have listed them and test each one.

- The CO<sub>2</sub> capture capabilities
- The temperature control capabilities
- The pH control capabilities

## ➤ The CO<sub>2</sub> capture capabilities:

There will be 2 stages for this test:

- 1) Preparing the CO<sub>2</sub> sample: This will be done by putting yeast and sugar in a balloon then leaving it for an hour, after said hour the balloon will be filled with CO<sub>2</sub>.
- 2) Inserting the CO<sub>2</sub> sample into the container: Putting the balloon inside the intake type then put a timer for 10 minutes in which the CO<sub>2</sub> concentration would be calculated beforehand and after hand. Then calculating the percentage of  $\frac{c_2}{c_1}$  which would be measured by using MQ135 sensor. This would be divided by the amount of time (10 minutes)

## ➤ The temperature control capabilities of the prototype:





This will be tested by cooling the prototype to a temperature below 20 Celsius then checking if the heater automatically heats it up to 27 Celsius then turns off.

## ➤ The pH control capabilities of the prototype:

The pH control capabilities of the prototype: Periodically over the day, the pH will be monitored making sure that it stays within the range of 7 to 9.

# Data Collection

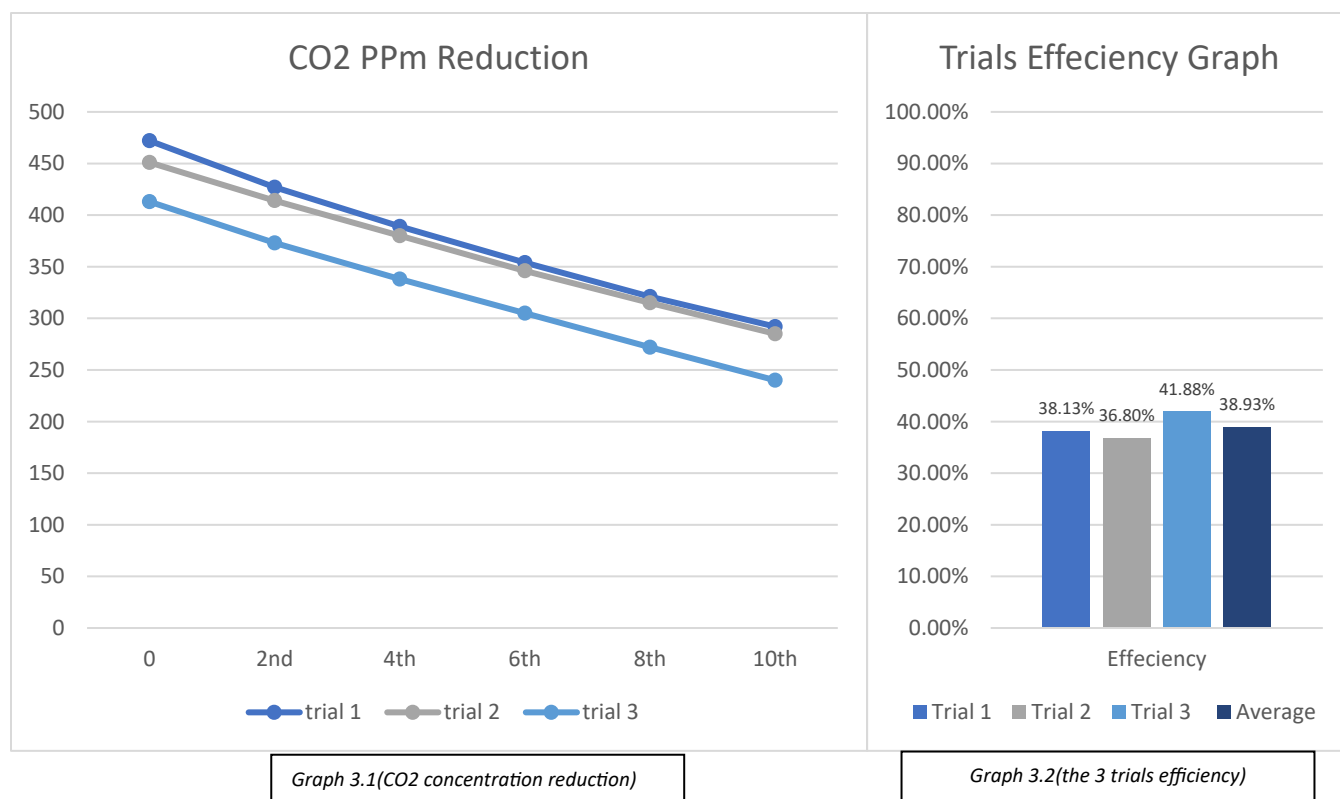
Applying the test plan to the prototype after construction requires several tools and measurement instruments.

	<p><b>litmus paper</b></p> <p>A specific type of paper that indicates the pH scales of a solution, it was used to determine the pH scale of the algae environment.</p>
	<p><b>MQ-135</b></p> <p>A gas sensor that detects the concentration of the CO<sub>2</sub> gas in air, this was used to calculate the efficiency of the project.</p>
	<p><b>DS18B20</b></p> <p>A temperature sensor that measures the temperature of the algal system.</p>
	<p><b>Measuring tape</b></p> <p>Used to measure the lengths of several parts in the prototype such as the container sides and the Cutten pipes</p>

The gas analyzer was turned on to measure the concentration of CO<sub>2</sub> during a 10-minute period within the algae-based bioreactor. The analysis is based on a gas analyzer calibrated with a precision of  $\pm 1$  mL and a margin of error of  $\pm 2\%$ . The microalgae were initially entered into the system, and 3 prepared air samples each of volume 1500 ml with a high concentration of CO<sub>2</sub> were entered into the system performing 3 trials to the prototype, the reduction of the concentration was watched over the 3 trials. Measurements were taken after every one minute. Data were associated into an age-based system where each two-minute interval referred to a specific stage of the algae CO<sub>2</sub> absorption process.

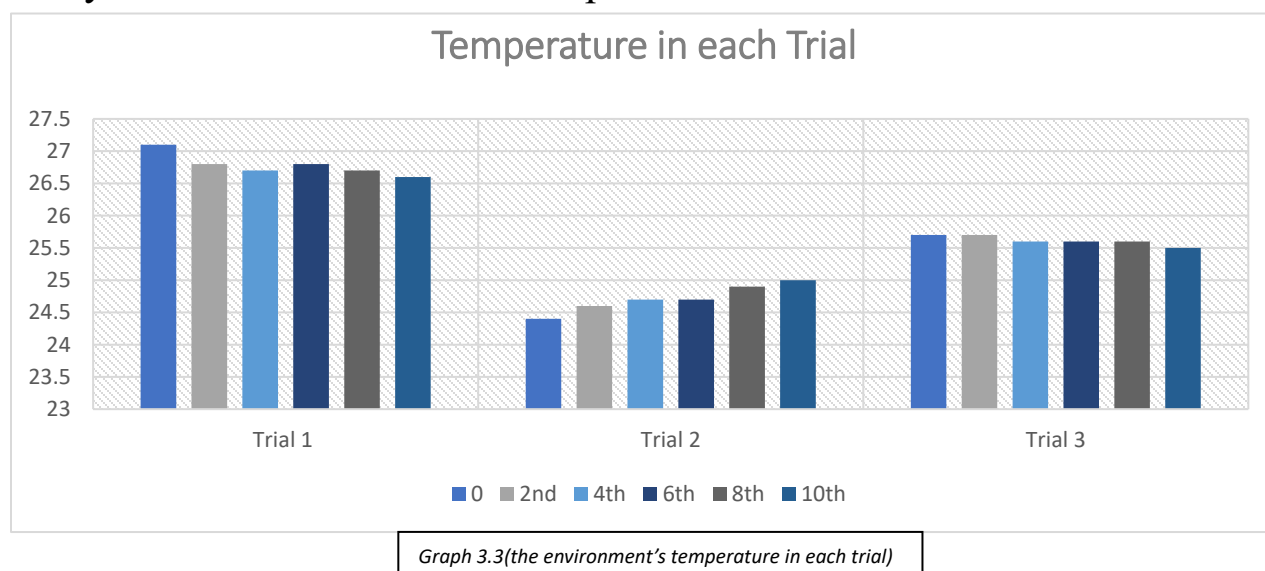
Table 3.2 (CO<sub>2</sub> Reduction rate)

Time (minutes)	CO <sub>2</sub> PPM		
	Trial 1	Trial 2	Trial 3
0	472 $\pm$ 9.44	451 $\pm$ 9.02	413 $\pm$ 8.26
2 <sup>nd</sup>	427 $\pm$ 8.54	414 $\pm$ 8.28	373 $\pm$ 7.46
4 <sup>th</sup>	389 $\pm$ 7.78	380 $\pm$ 7.6	338 $\pm$ 6.76
6 <sup>th</sup>	354 $\pm$ 7.08	346 $\pm$ 6.92	305 $\pm$ 6.1
8 <sup>th</sup>	321 $\pm$ 6.42	315 $\pm$ 6.3	272 $\pm$ 5.44
10 <sup>th</sup>	292 $\pm$ 5.84	285 $\pm$ 5.7	240 $\pm$ 4.8
Efficiency	38.13%	36.80%	41.88%
<b>AVG Efficiency</b>	<b>38.93%</b>		



This representation is systematic in that it clearly shows the efficiency of the algae in driving down levels of CO<sub>2</sub>.

The temperature of the environment was collected through the 3 trials using the temperature sensor DS18B20, ensuring that the temperature stays in the range of 20 - 30 degree Celsius, the data were collected every 2 minutes in each trial as represented above:



## Analysis and Discussion

Considering the test findings, the prototype achieved the design requirements, exhibiting a positive impact on the grand challenges addressed, and the major problem of air pollution.

It's no secret that Egypt is facing an environmental crisis namely the deterioration of air quality, and this is due to the large amount of contaminated gasses emissions from the burning of non-clean energy (fossil fuels). As a way to combat this deterioration of air quality, Egypt is looking to decrease the concentration of those harmful gasses and these efforts are presented in the various air filters that are in Egypt like the Daikin air filtration units and the arabo filters, though these projects aren't keeping up with the recent emissions. If Egypt succeeds in making the rate of emissions equivalent to or less than the rate of air filtration, it will result in improving the environmental situation, and the overall health conditions of the Egyptian citizens.

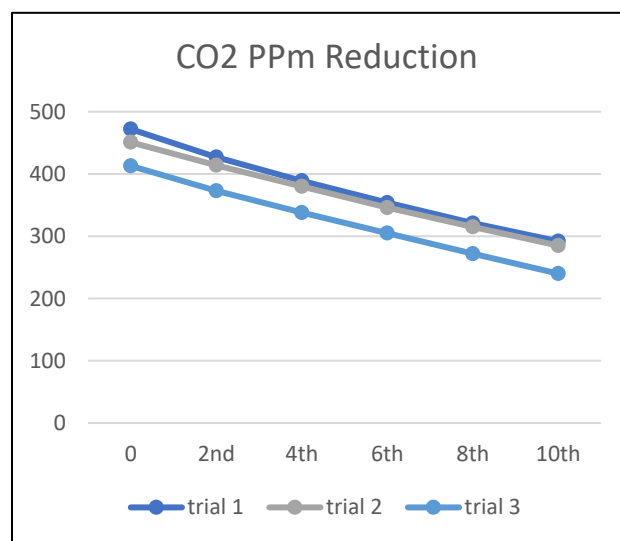
The algae biofilter (the chosen solution) aids Egypt in its journey to reach the state of equilibrium between the emissions of toxic gases and the rate of air filtration. This solution overcomes the grand challenges and solves the major problem of air pollution. This is because the biological filter filters CO<sub>2</sub> with an efficiency of 10 to 30 times more effective than a tree while also taking substantially less space and time to do said function. The reason why the biological filter was chosen as the solution is because it utilizes the algal photosynthesis process, so the algae are placed in a suitable and ideal environment maximizing both its reproduction and the rate of its photosynthetic cycles thus maximizing the efficiency of its CO<sub>2</sub> removal. Water will be used as the medium for

the algae as water needs to gain a considerable amount of energy to increase its temperature due to its high heat capacity thus making its temperature quite stable as learned in (ES.2.01).

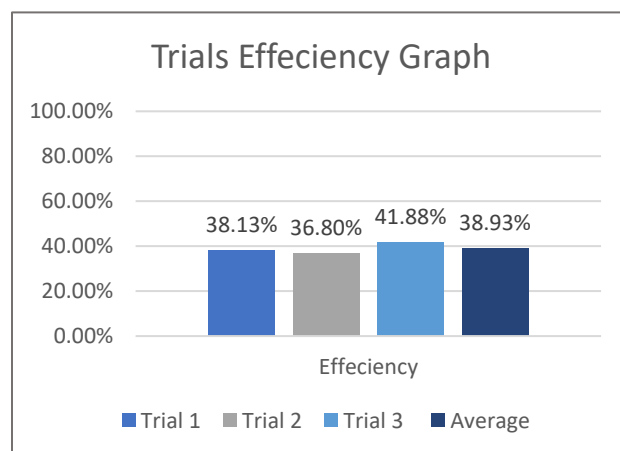
The project's strength points as illustrated from the results are that it is highly efficient in terms of decreasing the CO<sub>2</sub> concentration, space utilization, and time management especially when compared to an actual tree. It also provides the ideal living environment for the algae thus resulting in them reaching high efficiencies of CO<sub>2</sub> absorption equivalent to 39% while also utilizing contaminated water. The project's weak points are that it requires a fair amount of maintenance to function and consumes energy for the heating system and the CO<sub>2</sub> detection system while also not being able to deal well with hot temperatures.

The prototype met all the design requirements and they are as follows:

- 1) Decrease the concentration of CO<sub>2</sub> by 20% in a timeframe of 10 minutes: As shown in graphs (3.2-3.3) the prototype surpassed this design requirement as it decreased the CO<sub>2</sub> concentration by 37%. This was calculated by using the law:  $\left| \frac{\Delta c}{c_0} \right| \times 100$ . This was done by making a database using an Excel sheet of the values for 3 trials then getting the average for said trials. This type of database is called a



Graph 3.2(CO<sub>2</sub> absorption per



Graph 3.3(Trials efficiency

relational database. (CS.2.02) was essential for making the database and identifying its type.

- 2) Temperature control capabilities: The prototype showed remarkable control over its internal temperature keeping the range between 20 and 30 Celsius. This was achieved primarily due to the automatic temperature control system, where the temperature sensor gives a reading to the Arduino and if said reading drops below 20 Celsius, a submersible aquarium heater (which is connected to the Arduino using a relay) is coded to have it turn on and heat the water till it reaches a stable temperature of 25 Celsius.
- 3) pH and nutrient optimization: The pH of the prototype is meant to be in the range of 7 to 9 thus the pH of the prototype was periodically monitored and when the prototype dropped below a pH of 7, NaOH was added and this is because it had a pH of 13 which was calculated from the law that was learned in (CH.2.03) **pH of NAOH = - log (H+).**

The nutrients of the algae were provided from organic waste. We used molarity to measure how much nutrients were dissolved in the water to help algae grow. **Molality:** Tracks nutrients more accurately when temperature changes and it's calculated by using the following law: **number of moles of nutrients / liters of solution**, to ensure algae grow consistently as learned in (CH.2.01).

There are 3 mechanisms that are essential for testing the prototype and they are as follows:

- 1) Air sample preparation: Yeast will be added to sugar with varying ratios, then after waiting for an approximate time of an hour, CO<sub>2</sub> will be produced and the air sample will be complete. This is illustrated in the reaction: **C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> (aq) → 2 C<sub>2</sub>H<sub>5</sub>OH (aq) + 2 CO<sub>2</sub> (g)**. This way of CO<sub>2</sub> preparation was chosen as Ethanol (C<sub>2</sub>H<sub>5</sub>OH) is considered a nutrients for the algae.

2) The method of CO<sub>2</sub> absorption: the algae filters the CO<sub>2</sub> out of the air through its photosynthetic cycles illustrated in the following chemical equation: **6 CO<sub>2</sub> + 6 H<sub>2</sub>O + light energy → C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> + 6 O<sub>2</sub>.**

3) The automated heat system: The 220 V heater is connected to the Arduino UNO through a relay. A temperature sensor was also connected to the Arduino circuit. The circuit is coded so that if the temperature sensor gives a reading less than 20 Celsius, the heater automatically turns on, heating the prototype till it reaches a temperature of 25 Celsius ensuring that the prototype is always at optimal temperatures. The system relies on dynamic electricity to power devices such as CO<sub>2</sub> sensors, heater or LED lighting, which optimize the growth environment for algae and enhance CO<sub>2</sub> absorption efficiency which we learned to utilize in (PH.2.03).

The findings that have arisen from the performance results of the prototype indicate relative success of the project since it exceeded expectations in efficiency, durability, and user feedback. Also, the condition requiring the design to lower 20% of CO<sub>2</sub> pollutants within 10 minutes has been met, proving the system's immediacy in addressing challenges of the environment. This is substantiated by the analysis that shows the endurance of the system's operation with varying conditions, so making it reliable and easy to handle for the user. The project is thus incomparable and the most cost-effective and scalable option from other solutions made by the team on researched alternatives. Most of these solutions are either less efficient or more expensive. This addresses some significant gaps in current methods, meaning that it has the potential for application on a much broader setting. Based on all the results, the validation of the efficacy of the project in meeting its design goals specifically in reducing CO<sub>2</sub> emissions rapidly, makes it a hopeful solution in the fight against environmental pollution in various industries.

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# Recommendations

## Prototype Recommendations:

- ❖ LED lights with red and blue colors, which are best for algae growth, can be used. Light spreaders can also be added to ensure all parts of the algae get light, and a light schedule can be followed to mimic natural sunlight.
- ❖ CO<sub>2</sub> can be added directly into the system, and bubble columns can be used to spread it evenly, helping algae grow faster. CO<sub>2</sub> can even be recycled from factories, saving money and benefiting the environment.
- ❖ The temperature can be maintained by using heaters or coolers and insulating tanks to protect the algae from extreme heat or cold.
- ❖ Algae should be harvested regularly to avoid overcrowding, which can block light and nutrients. Tools like centrifuges or filters can be used to make harvesting quicker and easier.
- ❖ Contamination can be avoided by using closed systems like photobioreactors, and equipment should be cleaned regularly. A small system can be tested before scaling up, which helps spot and fix any issues early.
- ❖ The system can be automated with sensors to track things like pH and nutrients, saving time and allowing for quick adjustments.
- ❖ Algae systems can be combined with other processes, such as using wastewater nutrients or capturing CO<sub>2</sub> and heat from factories.

### **Real-life Recommendations:**

- ❖ Reflective surfaces, like mirrors or shiny materials, can be added around the algae tanks to reflect more light into the system, helping the algae get more light without using extra electricity.
- ❖ A simple system can be set up to collect CO<sub>2</sub> from nearby sources, like generators or cars, and feed it into the algae tanks. This will provide the algae with the CO<sub>2</sub> they need to grow faster.
- ❖ Rainwater can be collected to fill the algae tanks. It is clean, free, and doesn't contain harmful chemicals like tap water.
- ❖ A two-step method can be used to improve harvesting: letting algae settle naturally first, then using a filter or spinner to gather them. This saves energy and allows for the collection of more algae.

# Learning Outcomes

MA.2.01	In this learning outcome, we learned about polynomial functions, absolute functions, and graphing of functions. where we know how to calculate results precisely while having the Corrosion formula.
CH.2.01	In this learning outcome, we learned about TDS, Dissolved oxygen (DO), and mass percentage. Which helps us to measure dissolved oxygen or solid dissolved nutrients needed for algae to live.
CH.2.02	In this learning outcome, we learned about elevation in B.P and depression in F.P, which helped us in measuring and maintaining the temperature of the algae-based system.
CH.2.03	In this learning outcome, we learned about the Acid-base properties of salts which helped us in making the system more basic to raise the efficiency of algae to absorb CO <sub>2</sub> .
CH.2.04	In this learning outcome, we learned about chemical reactions and the rate of chemical reactions which helped us know the time and rate at which algae make photosynthesis to absorb CO <sub>2</sub> .
BI.2.01	In this learning outcome, we learned about genetic engineering which help us to increase

	the efficiency of algae by inserting foreign gen from effective bacteria on it.
MA.2.03	In this learning outcome, we learned about the Binomial Theorem which plays a crucial role in statistical models for capstone projects, especially when expanding probabilities to predict outcomes like the likelihood of successes or failures in a sequence of experiments.
PH. 2.03	We learned about Dynamic Electricity, which can be useful for our project. The system may rely on dynamic electricity to power devices such as pumps, CO <sub>2</sub> sensors, or LED lighting, which optimize the growth environment for algae and enhance CO <sub>2</sub> absorption efficiency.
PH. 2.02	We learned about Methods of Electrification: we learned that Friction could be used in a pre-filtering system to charge CO <sub>2</sub> molecules through contact with certain materials.
ME.2.01	we learned that Static friction affects components that remain stationary but resist movement, such as algae-support structures or tanks subjected to forces like wind or vibrations.

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