Figure 1: Outdoor air quality in urban areas (European Environment Agency)

OUTDOOR AIR QUALITY ANALYSIS

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SUMMARY

Our team has been tasked with analyzing raw data received regarding the air quality in Ontario and constructing a solution while accounting for stakeholders in the process, which is our objective of the project. The project consists of tasks that will aid us in the successful completion of the project, which are conducting analysis and comparisons of the raw data and regulation standards and discovering potential causes and solutions as well. As a result, initially, our group discovered regulation standards of many compounds, such as benzene and ozone, for many periods within Ontario, such as 24 hour daily averages and 8 hour averages as well from 3 different standards, the NAAQOs, AAQC and the CAAQS. Afterwards, observations and analysis were made from the raw data in order to grasp a better understanding of the data, which found that benzene concentration was abnormally high during the months of January, February and December, while Ozone was consistently average throughout the year. Based on this process, our team created potential solutions to the issues at hand. Firstly, autonomous vehicles could bring fuel efficiency up by 15 to 40%, through improved driving patterns and less human error with braking and acceleration. Secondly, gas to liquid is a method of conversion involving natural gas to usable liquid products, such as fuels and oils, which reduces local emissions through lacking the impurities found in crude oil, as natural gas is the cleanest burning fossil fuel. Thirdly, dimethyl ether (DME) is a synthetically produced alternative to diesel. DME burns cleanly and quietly and can help reduce carbon dioxide emissions by 68-101%, Fourthly, E-Drones fitted with a variety of gas sensors can autonomously monitor the air quality at a specific location, detect the presence of pollutants like O3, CO, NO2, CO2, SO2, NH3, and PM, calculate their concentrations, and then implement a suitable abatement option if required to eliminate these pollutants. Lastly, smog free towers are large air purifiers that can be placed in urban areas where high amounts of smog are experienced. The tower is around 7 meters high and can clean 30,000 m^3 of polluted air per hour, while using as much electricity as a water boiler. In conclusion, these solutions all are effective in solving the issues at hand. However, the optimum method of solving the issue is the incorporation of all the solutions together in order to discover and construct a strong balance that allows for the most effective method of solving the issue.

INTRODUCTION

PROBLEM DESCRIPTION

As a project team, we have received crude information from an air examination across a metropolitan area in Ontario and have been tasked with dissecting and deciphering that information for regional neighbourhoods and parties of interest. Furthermore, as a group, we must analyze information from an air analyzing installation in a prominent territory. This region has extremely high attention from nearby stakeholders, such as local area individuals, industry, and government who are in fear that the quality of air is influencing their wellbeing. Additionally, the obtained crude information is with regards for benzene and ozone as well as particulates, which will be utilized for our examination, understanding and analysis. Adding on, we have been tasked with creating a report and a video clarifying the aftereffects of the air observations over the previous year and how the outcomes identify and compare with the significant surrounding air examination required standards to maintain health, such as the Canadian Ambient Air Quality Standards. Interestingly, the targeted viewing crowd for our presentation incorporates the stakeholders of the project, such as local area individuals, the district, and industry agents. As a result, our report is required to precisely address the information, investigation and obtained knowledge in a presentable and justifiable path for the intended interest group to graspy clearly. Finally, we will utilize a programming software in order to both analyze the raw data effectively while also presenting it efficiently to the audience in order to successfully present our points clearly to our intended crowd, which is the end goal of the project as a whole.

OBJECTIVE

The objective of this project for us as a group is to investigate, decipher and dissect the provided information and data given by the air analyzation station. Moreover, our group is required to perform an examination and make suggestions dependent on designing standards and judgment including correlation of alternatives. Also, we must gain experience working in multi-disciplinary groups that may incorporate partaking designing understudies from different foundations as well as understand the proficient and moral duty to address the public necessities. Additionally, developing the capacity to conduct professional research in order to discover data important for finishing the current venture is a crucial objective for this project. Also, we are tasked with developing a capacity to utilize the procedures, abilities and current designing instruments vital for designing practice. Lastly, the improvement of the relational abilities of our group is a significant objective and key to the measurement of the success of this project by constructing and

diligently arranging this report as well as introducing and discussing this project before colleagues and documenting the effort conducted on different parts of the task at hand. Furthermore, this objective can also be achieved through recording choices in justified and transparent manners and also conducting routine and regular meetings with fellow peers.

PROJECT TASKS

The tasks of this project entail the analyzation of data and conducting the comparison of standard regulations for health conditions with the provided raw data in order to perform an interpretation of data and understand the health and safety regulations of the air in the metropolitan area within Ontario. Aside from comparing data to regulations, our project team has been tasked with finding potential causes to the issue and also finding potential preventions and potential solutions to the problem as well as.

RELATIVE STANDARDS AND REGULATIONS

The first Canadian air quality standard was the National Ambient Air Quality Objectives (NAAQOs). They were developed in the 1970s as the benchmark for the impact of human activities on air quality. They were also used to check if emission policies at the time were sufficient to protect human health and the environment. (Environment Canada)

Later in May 2013, the Canadian federal government published the Canadian Ambient Air Quality Standards (CAAQS). This set of standards sets a guideline for outdoor air quality in Canada. Specifically, it monitors the number of certain pollutants in the air. As of 2020, air quality is indicated by the chart below. (Government of Ontario)

Indicator	Definition	Concentration unit
Average $PM_{2.5}$	Annual average of the daily 24-hour average concentrations	$\mu g/m^3$
Peak $PM_{2.5}$	Annual 98th percentile of the daily 24-hour average concentrations	$\mu g/m^3$
Average O_3	Annual average of the daily maximum 8-hour average concentrations	ppb
Peak O_3	Annual 4th-highest of the daily maximum 8-hour average concentrations	ppb
Average SO_2	Annual average of the hourly concentrations	ppb
Peak SO_2	Annual 99th percentile of the daily maximum 1-hour average concentrations	ppb
Average NO_2	Annual average of the hourly concentrations	ppb
Peak NO_2	Annual 98th percentile of the daily maximum 1-hour average concentrations	ppb
Average VOC	Annual average of the daily 24-hour average concentrations	ppbC

The chart above aggregates all volatile organic compounds (VOCs) together, including one featured in our raw data: Benzene. For a specific target for Benzene concentrations, we look at a list of Ambient Air Quality Criteria (AAQC) published before CAAQS, by the Ontario Ministry of the Environment, Conservation and Parks (MOECP).

AAQC values are not meant to serve as a regulatory standard, they are meant to serve as an upper limit for the safety of human health or the environment. As such, they are commonly used for air quality studies and annual reporting. Since they are based on health effects, more dangerous pollutants that can cause short term or long term damage have shorter averaging times. (MOECP)

Depending on the data, this may affect analysis, but for this project, they are sufficient.

The standards relevant for the data analysed in this project are listed in the chart below. Most of these values are the CAAQS 2020 standard, while Benzene is the older AAQCs.

Pollutant	**Averaging time**	**Standard Reference**
Average $PM_{2.5}$	Annual average of the daily 24-hour average concentrations	$8.8\mu g/m^3$
Peak $PM_{2.5}$	Annual 98th percentile of the daily 24-hour average concentrations	$27\mu g/m^3$
Peak O_3	Annual 4th-highest of the daily maximum 8-hour average concentrations	$124\mu g/m^3 = 62ppb$
Average Benzene	Annual average of the daily 24-hour average concentrations	$0.45\mu g/m^3 = 0.14ppb$
Peak Benzene	Annual average of the daily maximum 8-hour average concentrations	$2.3\mu g/m^3 = 0.72ppb$

All values were converted to $\mu g/m^3$ if originally ppb. (Danish Nationalt Center for Miljø og Energi)

ANALYSIS

MEASURED DATA

The file provided to us had some corrupted data, that is, there was data that was interfering with the continuity of the graphs produced. For example, for some of the hours on certain days, we assume that there was a power fail because the given value for that hour was 'pwrfail'. Similarly, we have had several data points that we had to filter, with which our data would not appear to be continuous. We also converted the data for Ozone and Benzene from Parts per Billion (ppb) to Micrograms per metre cubed ($\mu g/m^3$).

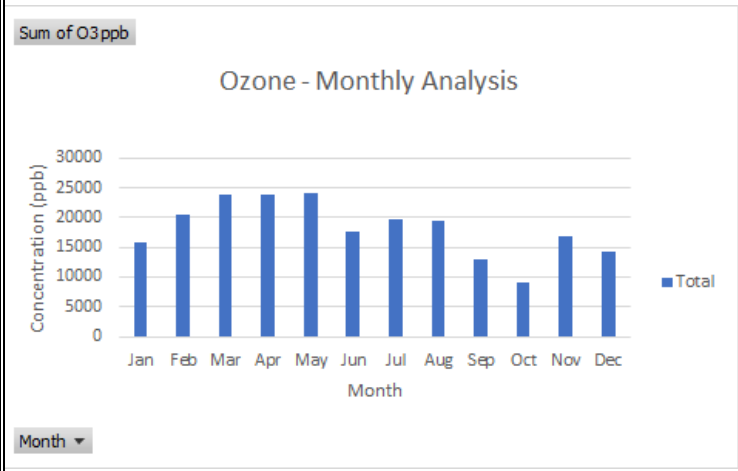
TYPES OF PERFORMED ANALYSIS

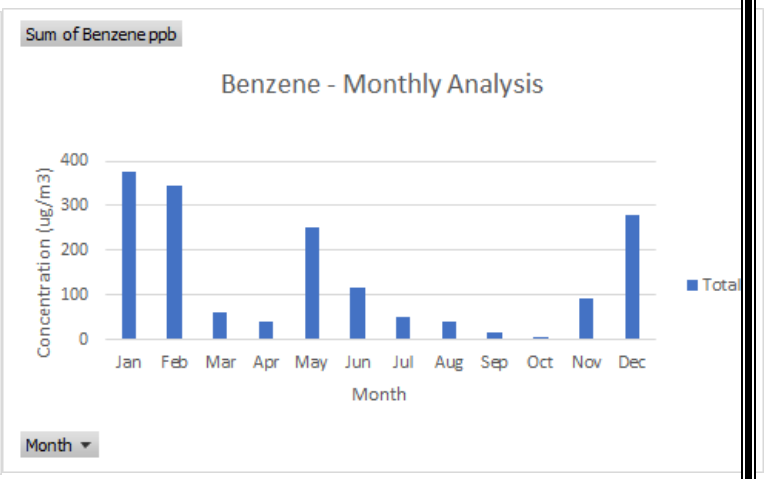
Several analyses were performed by reading the given threshold values for each pollutant on a 24-hour and an annual basis. There were certain environmental standards that we could not find, so we decided to use data from the United States of America's Environmental Standards, or the European Environmental Standards. For example, the values we decided for on Ozone was 2 $\mu g/m^3$ per ppb. Similarly, for Benzene, we decided to use 3.24 $\mu g/m^3$ per ppb. (Environmental Protection Agency)

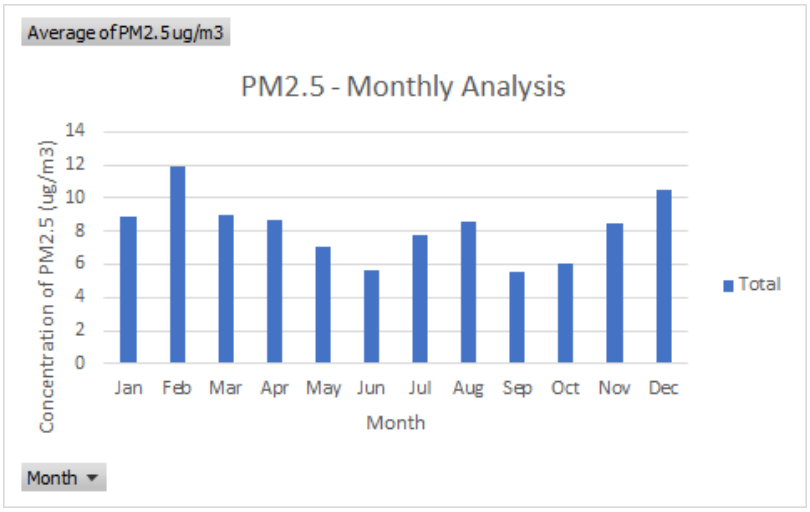
INTERPRETATION OF ANALYSIS

The analyses performed, as mentioned above, is based on a 24-hour and an annual basis, and on a timely basis. We generated graphs that gave us the maximum emission of given pollutants during certain times of the year, and graphs that gave us the annual average emission rate, which we then compared with the available environmental standards. We also found trends about the certain time of the day at which the emission rate is maximum, and we generated those graphs and compared it with these trends. With these interpretations, we were able to confirm or deny several trends that were available by discussing the changes that occurred within the years, and how these changes could affect the environment in the future.
(Environmental Protection Agency)

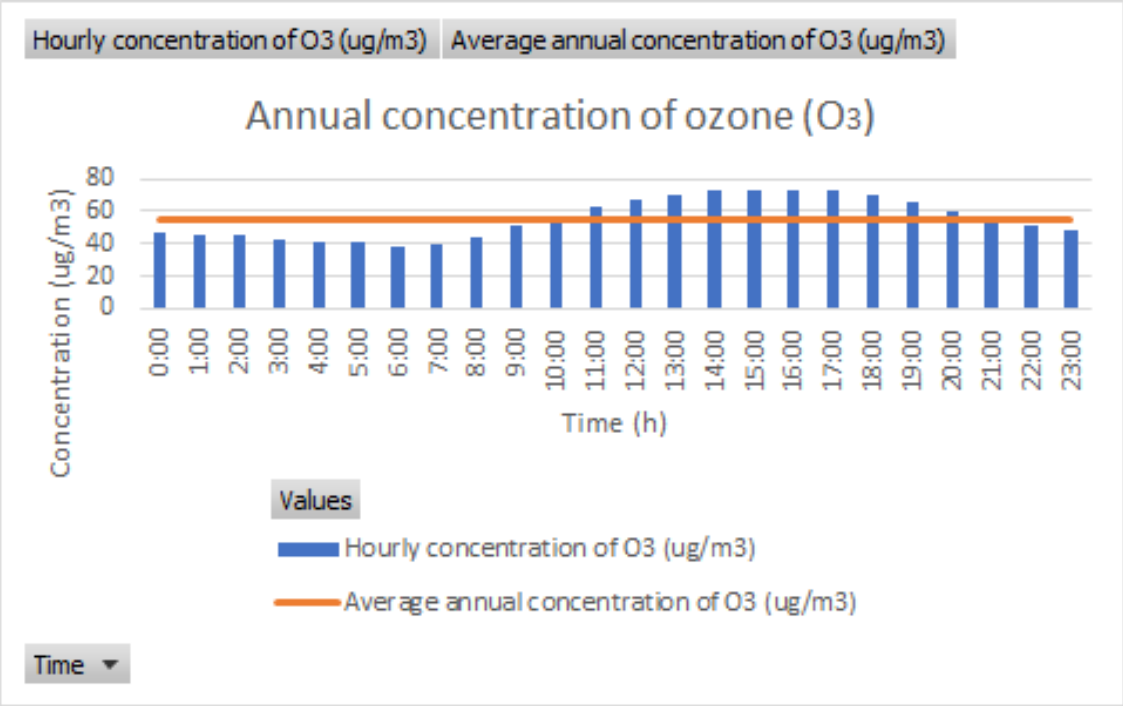
OBSERVATIONS FROM DATA AND CAUSES



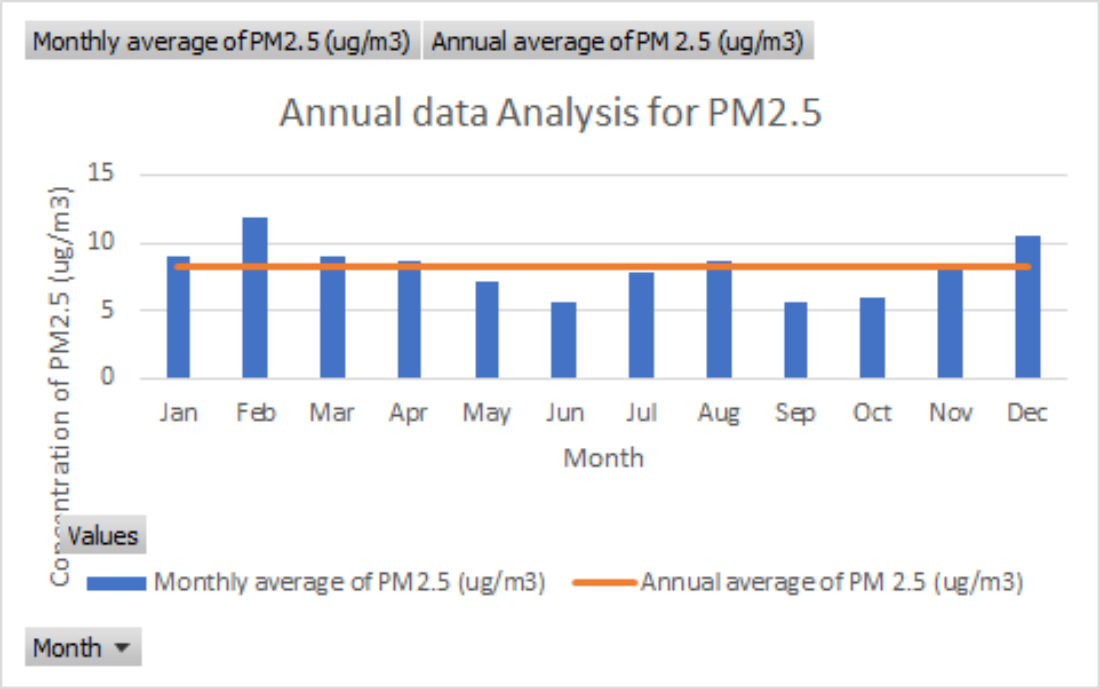




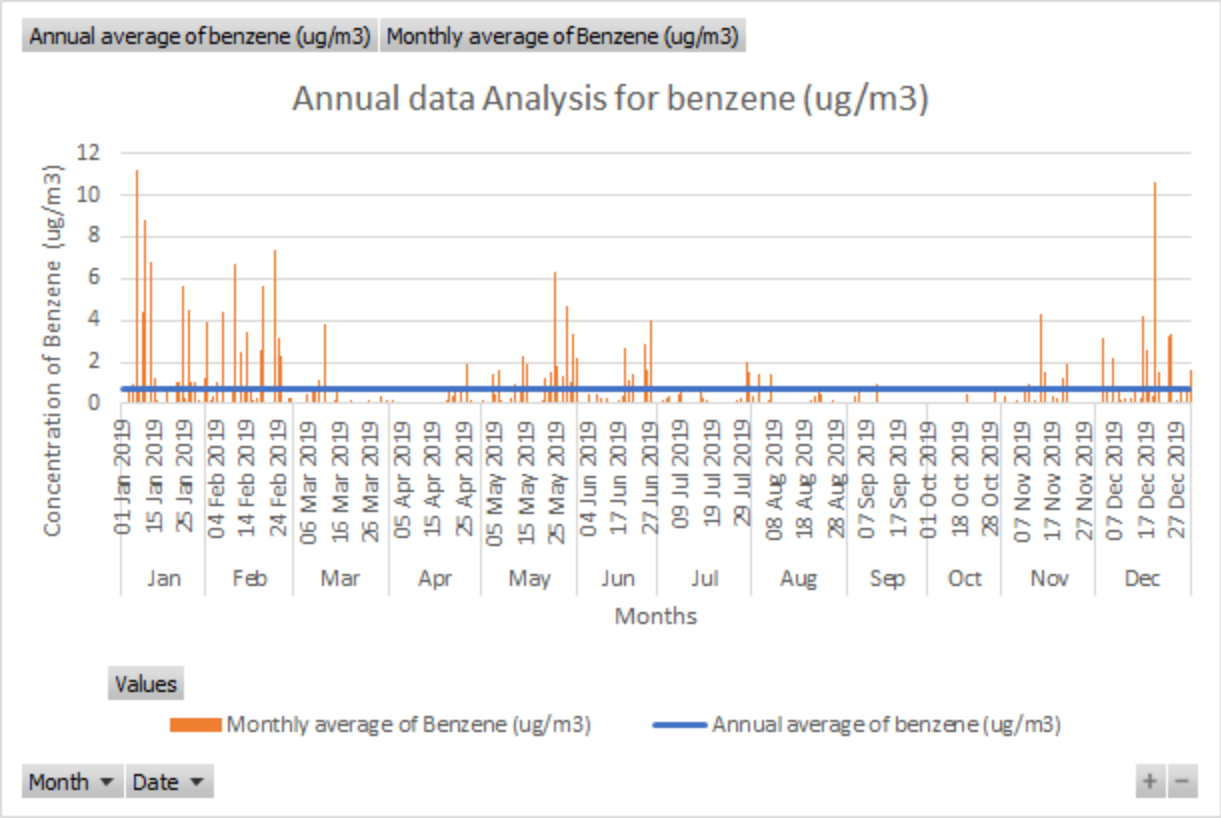
The graphs shown above are the monthly analyses of Ozone, Benzene and Particulate Matter emissions over the course of the year 2019. The given data for Ozone and Benzene, as mentioned above, has been converted to µg/m^3. Benzene concentration levels are highest in winter. More sunlight and higher temperatures lead to higher chemical removal reaction rates. The chemical removal of benzene by OH radicals act slowest during winter. As noticed from the graph, high ozone levels are detected between May and September. As noticed from the graphs above, the Ozone levels are highest from noon to early evening. Summer ozone, however, continues to exceed the Ontario AAQC during the warmer months and remains a challenge in areas of the province. (Human Toxicology and Air Standards Section) (Atabi, Mansouri and Alesheikh)



This graph shows the average annual concentration of Ozone (O3) in Metropolitan. The blue part indicates the hourly concentration of ozone in ($\mu g/m^3$) in the air which is from 12 am to 11 pm in terms of time. It is shown in the form of bars. The orange line on the other hand indicates the average of all the blue bars and is the average value for the whole year. The average concentration of ozone throughout the year is approximately 55.33 $\mu g/m^3$. The average as given by the Ontario Air Ambient Quality Data is 165 $\mu g/m^3$. We can therefore observe that the condition in terms of Ozone emissions is far better than the given threshold value in Ontario. (Human Toxicology and Air Standards Section)



This graph shows the average annual concentration of $PM_{2.5}$ in the province of Ontario. The bar graph indicates the monthly concentration of $PM_{2.5}$ in $\mu g/m^3$ in the air from January to December. It is shown in the form of bars. The orange line indicates the annual average value of $PM_{2.5}$ in the year 2019. The average concentration of $PM_{2.5}$ is approximately 8.20 $\mu g/m^3$. The target value as described by the Ontario Air Ambient Quality Criteria was 8.8 $\mu g/m^3$ by the year 2020. We can therefore observe that the target value has been met, and we have done better than it in the year 2019, which is great news, considering that the target value for the year 2015 was 10 $\mu g/m^3$. (Human Toxicology and Air Standards Section)



This graph above shows the average annual concentration of Benzene in µg/m^3. The bar graph here shows the daily Benzene emissions. The blue line represents the average value of the Benzene emissions in µg/m^3. The annual average of Benzene in µg/m^3 is 0.69 according to the graph shown above. The target annual average of Benzene in µg/m^3 is 0.45. The observed average appears to be more than the standards set by the Ontario Air Ambient Quality Criteria. So, there is work that needs to be done to reduce Benzene emissions and to meet the air quality standards so that these emissions do not affect human health in a critical way. (Human Toxicology and Air Standards Section)

SOLUTIONS AND OTHER ALTERNATIVES

Some non-technological solutions include carpooling, using public transportation, bike, or walking whenever possible, keeping cars, boats and other engines properly tuned. Moreover, stricter testing and controls of vehicles, mulching or composting leaves and yard waste, using environmentally safe paints and cleaning products whenever possible, avoiding excessive idling of your automobile, and promoting electric and hybrid vehicles.

Technological solutions:

Autonomous vehicles:

Studies have shown that autonomous vehicles could improve fuel efficiency by 15% to 40% (Howard). This is possible because efficient driving patterns would help reduce repeated braking and acceleration and allow vehicles to travel closer together which is known to improve aerodynamics (Robinson). Improving fuel economy would also mean lower CO_2 emissions (Watson).

GTL fuels:

Gas to Liquid technology converts natural gas, which is the cleanest burning fossil fuel into high quality liquid products like transport fuels, motor oils, etc. These products contain almost none of the impurities that are found in crude oil. GTL fuels can reduce local emissions (eg. PM, NOx, hydrocarbons and carbon monoxide). GTL fuel by Shell is a cleaner alternative fuel for use in diesel engines. Also, based on operability studies conducted by Shell, It was found that these fuels can be used in existing heavy-duty diesel vehicles without modifications, which makes it a more attractive option to choose over diesels as it would allow easy switchover. Shell's GTL fuel has similar physical characteristics to crude diesel but has a much higher cetane number which is a measurement of the quality or performance of diesel fuel, has a higher mass calorific value, lower levels of sulphur and aromatics and a lower density (Shell Global).

DME fuels:

Dimethyl Ether (DME) is a synthetically produced alternative to diesel. DME burns cleanly and quietly and can help reduce carbon dioxide emissions by 68-101%, depending on which renewable raw material is used. It is also sulphur free and burns with no particulate matter. DME can also help transport hydrogen fuels. DME is dense in hydrogen and can be easily reformed into pure hydrogen due to its chemical structure. Thus DME could be used to make hydrogen at fueling stations, on board vehicles or can even power a fuel cell directly.

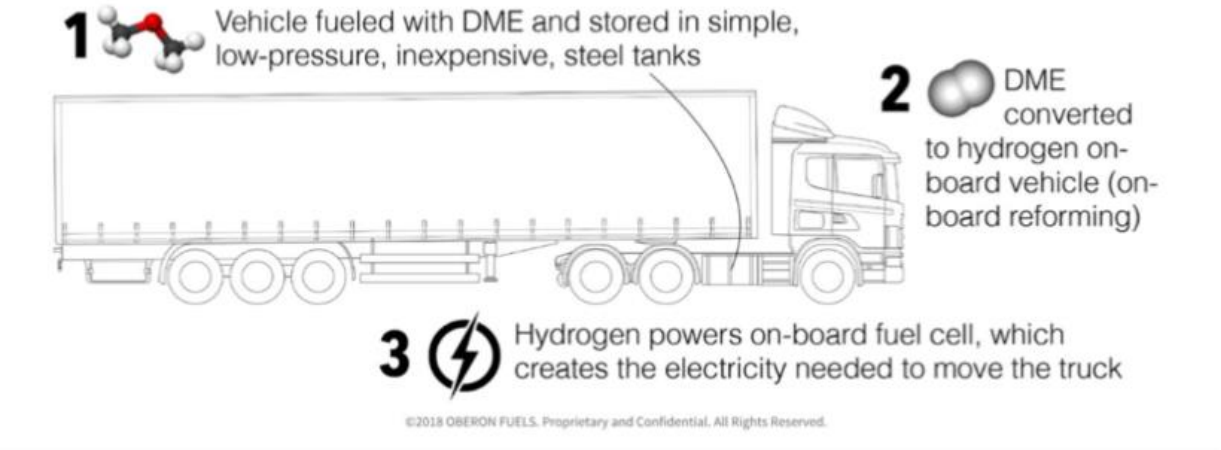


Figure 1: On-board conversion of DME to Hydrogen.

Hydrogen-powered fuel cell electric vehicles do not emit any pollutants, they only emit water (H20) and warm air (Oberon Fuels).

Environmental Drones (E-Drones):

E-Drones fitted with a variety of gas sensors can autonomously monitor the air quality at a specific location, detect the presence of pollutants like O3, CO, NO2, CO2, SO2, NH3, and PM, calculate their concentrations, and then implement a suitable abatement option if required to eliminate these pollutants. The drone can carry the abatement solutions onboard like for example, one of the abatement options for NO2 used a scrubbing solution containing Hydrogen Peroxide and Nitric Acid with a volume of 500 ml. And then this solution was discharged by means of a nozzle and a motor coupled with a pump.

The drones can also help in generating AQHI maps by sending the data collected to computers at the monitoring stations on ground. These drones can be very useful in monitoring and controlling air pollution at specific places (Rohi et al.,2020)

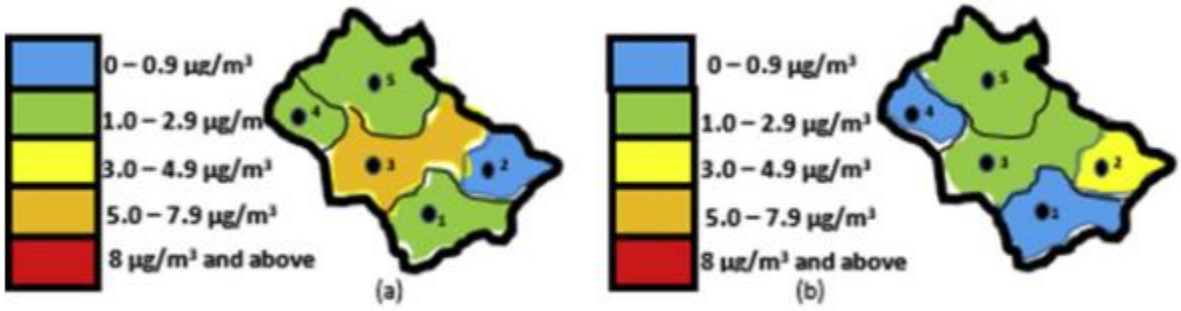


Figure 2: AQHI maps by E-Drones in Ontario, New Brunswick. (a) AQHI O3 (b) AQHI PM.

Smog Free Towers:

Smog free towers are large air purifiers that can be placed in urban areas where high amounts of smog are experienced. The tower is around 7 meters high and can clean 30,000 m^3 of polluted air per hour, while using as much electricity as a water boiler. The tower uses ENS's positive ionization technology which captures fine (PM10 and PM2.5) dust and transforms it into coarse dust, which is not air-borne and hence cannot be inhaled. This leaves behind clean air to breathe. The air purification technology also does not require filters. This helps reduce energy consumption and also reduces maintenance cost since we do not have to purchase or replace filters.

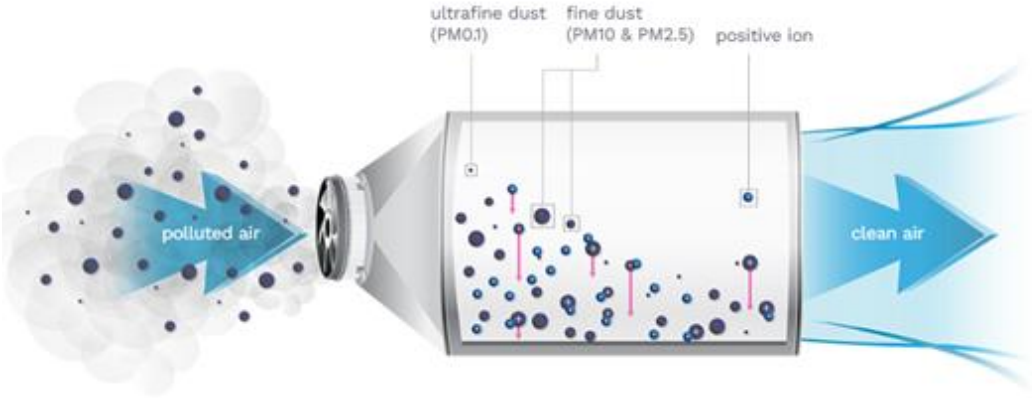


Figure 3: ENS technology.

The smog free tower was tested in Beijing and Tianjin and the functioning of the tower was also examined by Eindhoven University of Technology, which confirmed that tower eliminates up to 70% of the incoming PM10 and 50% of the incoming PM2.5 (ENS).

CONCLUSION

Some non-innovative arrangements incorporate carpooling, utilizing public transportation, bicycle, or strolling at whatever point conceivable, keeping vehicles, boats and different motors appropriately tuned. Besides, stricter testing and controls of vehicles, mulching or treating the soil leaves and yard squander, utilizing naturally safe paints and cleaning items at whatever point conceivable, dodging inordinate standing by of your car, and advancing electric and half and half vehicles. Studies have shown that independent vehicles could improve eco-friendliness by 15% to 40%. This is conceivable on the grounds that productive driving examples would help diminish continued slowing down and speed increase and permit vehicles to travel nearer together which is known to improve optimal design Improving mileage would likewise mean lower CO2 outflows. Gas to Liquid innovation changes over gaseous petrol, which is the cleanest consuming non-renewable energy source into top notch fluid items like vehicle fills, engine oils, and so on These items contain practically none of the contaminants that are found in unrefined petroleum. GTL fills can diminish neighborhood discharges (eg. PM, NOx, hydrocarbons and carbon monoxide). GTL fuel by Shell is a cleaner elective fuel for use in diesel motors. Likewise, in view of operability examinations led by Shell, It was tracked down that these fills can be utilized in existing substantial diesel vehicles without alterations, which makes it a more appealing choice to pick over diesels as it would permit simple switchover. Shell's GTL fuel has comparative actual attributes to rough diesel yet has a lot higher cetane number which is an estimation of the quality or execution of diesel fuel, has a higher mass calorific worth, lower levels of sulfur and aromatics and a lower thickness. Dimethyl Ether (DME) is an artificially created option in contrast to diesel. DME consumes neatly and discreetly and can help diminish carbon dioxide outflows by 68-101%, contingent upon which inexhaustible crude material is utilized. It is likewise sulfur free and ignites with no particulate matter. DME can likewise help transport hydrogen powers. DME is thick in hydrogen and can be effortlessly improved into unadulterated hydrogen because of its synthetic construction. Consequently, DME could be utilized to make hydrogen at energizing stations, on board vehicles or can even power an energy unit straightforwardly. E-Drones fitted with an assortment of gas sensors can self-rulingly screen the air quality at a particular area, identify the presence of poisons like O3, CO, NO2, CO2, SO2, NH3, and PM, compute their fixations, and afterward execute an appropriate reduction choice whenever needed to dispose of these pollutants.The robot can convey the decrease arrangements locally available like for instance, one of the decrease choices for NO2 utilized a scouring arrangement containing Hydrogen Peroxide and Nitric Acid with a volume of 500 ml. And afterward this arrangement was released through a spout and an engine combined with a siphon. The robots can likewise help in producing AQHI maps by sending the information gathered to PCs at the observing stations on ground. These robots can be exceptionally valuable in observing and controlling air contamination at

explicit spots. Exhaust cloud free pinnacles are enormous air purifiers that can be put in metropolitan regions where high measures of brown haze are capable. The pinnacle is around 7 meters high and can clean 30,000 m3 of contaminated air each hour, while utilizing as much power as a water heater. The pinnacle utilizes ENS's positive ionization innovation which catches fine (PM10 and PM2.5) dust and changes it into coarse residue, which isn't air-borne and thus can't be breathed in. This gives up clean air to relax. The air cleansing innovation additionally doesn't need channels. This lessens energy utilization and furthermore diminishes support cost since we don't need to buy or supplant filters.The brown haze free pinnacle was tried in Beijing and Tianjin and the working of the pinnacle was likewise analyzed by Eindhoven University of Technology, which affirmed that pinnacle dispenses with up to 70% of the approaching PM10 and half of the approaching PM2.5. In conclusion, these solutions all are effective in solving the issues at hand. However, the optimum method of solving the issue is the incorporation of all the solutions together in order to discover and construct a strong balance that allows for the most effective method of solving the issue. Both non technological and technological solutions should be incorporated to experience the decreased cost of non-technological and the effectiveness of technological solutions as well in order to find a balance between the two and tackle all areas of the issue effectively.

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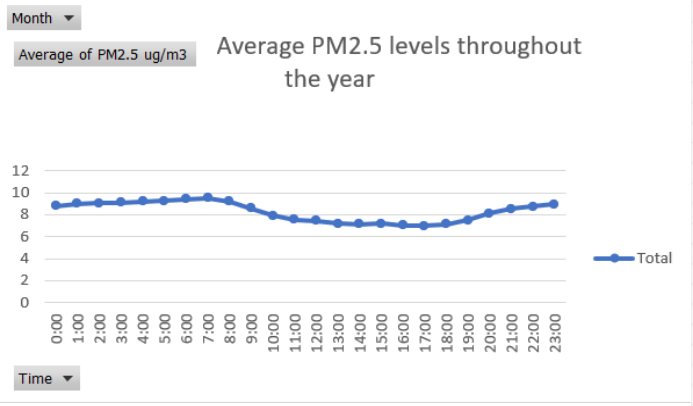
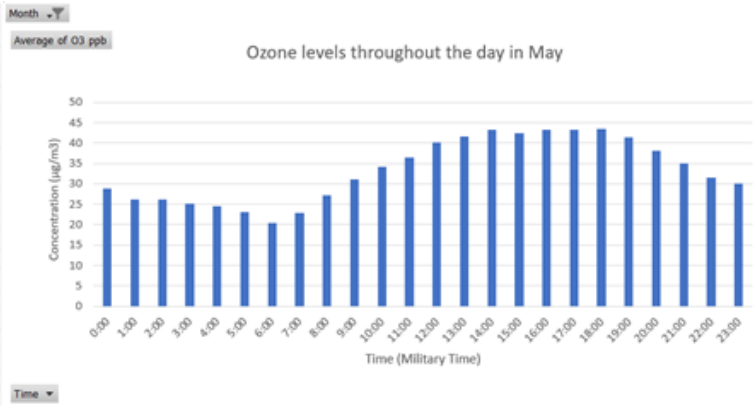
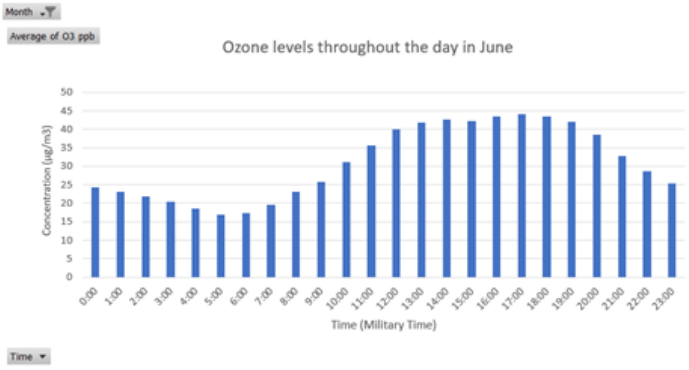
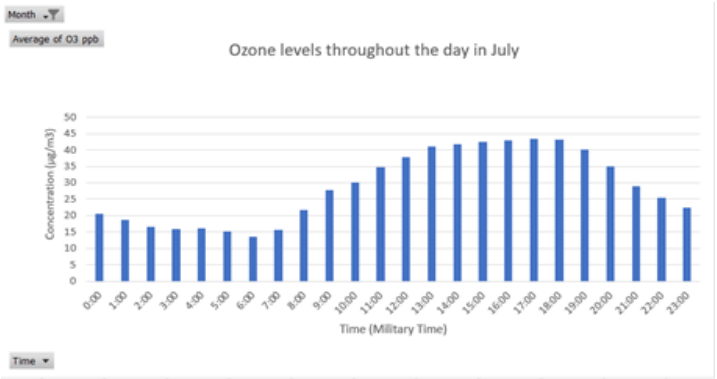
APPENDIX


Month
Average of PM2.5 ug/m3
Average PM2.5 levels throughout the year
12
10
8
6
4
2
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
Total
Time


Month
Average of O3 ppb
Ozone levels throughout the day in May
Concentration (µg/m3)
Time (Military Time)
Time


Month
Average of O3 ppb
Ozone levels throughout the day in June
Concentration (µg/m3)
Time (Military Time)
Time


Month
Average of O3 ppb
Ozone levels throughout the day in July
Concentration (µg/m3)
Time (Military Time)
Time

ATTRIBUTION TABLE

Group Member	***Contribution***	***Percentage of Overall Contribution***
Ibrahim Kenawy	Summary, Introduction, Conclusion	16.67%
Rushanshah Saiyed	Solutions and other alternatives	16.67%
Mohammed Fulwala	Analysis, Observations	16.67%
Abhirami Venugopal	Analysis, Observations	16.67%
Thanh Nguyen	Relative Standards and Regulations	16.67%
Afham Malik	Analysis, Observations	16.67%