**Capstone Project**

## Automating PM10 source apportionment data analysis using Python.

**Section 1: Abstract**:

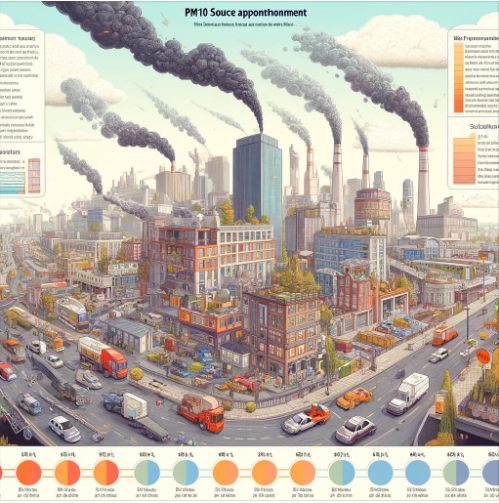
Significant health risks and environmental concerns are associated with airborne particulate matter (PM) pollution, especially in urban areas like Queen Street, Auckland's major business district. The goal of this capstone project, which is focused on PM10 source apportionment, is to determine and measure the relative contributions of different sources of pollution to Queen Street's PM10 levels. By applying cutting-edge techniques like Positive Matrix Factorization (PMF) and receptor modelling, the study aims to improve our comprehension of the intricate dynamics of PM10 pollution in this urban setting.

Based on an extensive study of the literature that includes studies from France, Switzerland, New Zealand, Iran, India, and other countries, the project tackles the difficulties, shortcomings, and gaps in information related to PM10 source apportionment. It examines how seasonal fluctuations, anthropogenic activity in the area, and meteorological circumstances affect PM10 concentrations, with a particular emphasis on the special qualities of Queen Street’s ‘Street canyon habitat’.   
  
The project's main conclusions identify the Port of Auckland, construction activities, vehicle emissions, and industrial processes as the main causes of PM10 pollution on Queen Street. The project offers useful information for focused mitigation methods and policy initiatives geared at enhancing public health and air quality by estimating the relative impacts of different sources.   
  
The initiative has practical implications for public health policy, environmental management, and urban planning. Through the incorporation of cutting-edge methodologies like as receptor modelling and PMF analysis into air quality management protocols, interested parties can devise pre-emptive strategies to tackle new sources of PM10 contamination and advance ecological sustainability in metropolitan regions.   
  
Prospective avenues for investigation encompass enhancing and verifying PM10 source apportionment techniques customised for street canyon settings such as Queen Street, as well as carrying out cross-national comparisons with other global cities. In order to reduce PM10 pollution and protect public health in urban areas, effective methods including researchers, policymakers, and industry stakeholders must be developed in tandem.   
  
To sum up, this research contributes significantly to our knowledge of the dynamics of PM10 pollution in urban settings, which has consequences for environmental sustainability, public health, and urban planning techniques.

**Keywords:**

Air pollution, Source apportionment, Particulate matter (PM10), Positive Matrix Factorisation, Air Quality, Emissions from industry, Effects on health.

**Section 2: Introduction:**

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One of the biggest environmental problems facing the world today is air pollution, which has a direct impact on ecosystem health and population health. In developing countries, rapid industrialisation and urbanisation have increased pollution levels to the point that they are above legal limits and seriously endanger public health (Brauer et al., 2012). Particulate matter (PM10), defined as particles with an aerodynamic diameter of less than or equal to 10 µm, is a major air pollutant that originates from both natural and man-made sources. Its composition influences the pollutants found in the atmosphere (Dockery et al., 2009). The need for focused measures to reduce pollution sources is highlighted by the significant contribution of anthropogenic activities to PM10 emissions (Liu et al., 2020).

The effects of PM10 concentrations on global climate, visibility, and human health emphasise how urgent it is to combat air pollution (U.S. EPA, 2004; Andreae and Rosenfeld, 2008). Studies show that populations are becoming more sensitive to PM10 exposure, which is associated with a higher prevalence of respiratory and cardiovascular diseases (Chowdhury et al., 2018; Marzouni et al., 2017). Adverse health consequences have been linked to even brief exposure to PM10, especially in sensitive populations like children (Mahapatra et al., 2020).

Air pollution is a global problem that affects many places, including Auckland, New Zealand. It transcends national boundaries. Auckland's residents suffer severe health and economic consequences from air pollution, which exceeds national and international norms despite the city's advantageous geographic location (Dirks et al., 2017; Kuschel et al., 2022; Sridhar, 2013; Talbot and Crimmins, 2020). Because particulate matter, especially PM2.5, can enter the circulation and lung tissues deeply, it becomes a serious health hazard (Chen and Hoek, 2020; Nel, 2005).   
  
The Auckland Council (AC) tracks a range of pollutants, such as PM10, PM2.5, nitrogen dioxide (NO2), black carbon, carbon monoxide (CO), and sulphur dioxide (SO2), in accordance with national environmental standards in order to address these issues. (MfE and Stats NZ, 2021). But knowing where air pollutants originate from need for more sophisticated methods than just measuring bulk quantities. In order to identify and quantify pollution sources, receptor modelling techniques like Positive Matrix Factorization (PMF) analysis are essential. These methodologies provide useful insights for evidence-based decision-making in air quality management (US EPA, 2021).   
  
With the use of advanced techniques like PMF analysis, this study seeks to identify the sources of air pollution in Auckland and determine the relative contributions of different contaminants. In addition to helping Auckland and the rest of the world tackle air pollution issues, our research aims to improve evidence-based decision-making and air quality management methods by offering useful insights. Research from other areas, such as those that relate industrial emissions to the effects on public health and developments in monitoring technologies, add to our knowledge and offer important perspectives for reducing air pollution globally (Pope, 1996; Kumarathasan et al., 2018; de Jonge, 2018, 2019, 2020; Furger et al., 2020).

The remainder of this paper is organized into sections as follows: In section II we will describe the literature review regarding this project which covers various studies conducted globally on-air pollution, especially Particulate Matter on source apportionment techniques, health impacts, regulatory standards, air quality management practises. In section III we will discuss about the methodology, sampling and instrumentation, analysis methods e.g. PMF and Receptor modelling whichever technique is more useful, results obtained from source apportionment. In section IV we will conclude the project.

**Section 3: Project Questions:**

1. **Problem Questions:**

How can advanced source apportionment techniques like receptor modelling and Positive Matrix Factorization (PMF) be efficiently used to identify and measure the various pollution sources that contribute to airborne particulate matter in Queen Street, Auckland CBD?  
  
**Sub-Questions:** a. What are the main sources of airborne particulate matter pollution on Queen Street, Auckland CBD, and what is their relative influence?   
  
b. How do site-specific factors on Queen Street, such as construction activities, vehicular traffic, and urban growth, impact the composition and spread of airborne particulate matter?   
  
c. What are the possible health, environmental, and regulatory consequences of the identified sources of pollutants on the inhabitants, businesses, and tourists of Queen Street?   
  
**Project Scope:** The main goal of this study is to apply modern techniques, such as receptor modelling and PMF analysis, to investigate the origins of airborne particulate matter on Queen Street, Auckland CBD.   
  
- The data collected from air quality monitoring stations situated on and around Queen Street will be examined for a specific timeframe to determine and measure the sources of pollution.   
  
The study aims to evaluate the impact of local factors such as construction activities, vehicular traffic, and urban growth on the levels of airborne particulate matter on Queen Street.   
  
The findings of this study will offer valuable understanding of the precise elements that contribute to air pollution on Queen Street. This will facilitate the creation of focused actions and strategies to reduce and manage the issue.   
  
This project seeks to improve public health outcomes, increase environmental quality, and assure regulatory compliance in the Queen Street area by addressing the intricate business demands associated with air quality management.

**Section 4: Literature Review:**  
  
In order to gain a better knowledge of the intricacies of air pollution and to develop successful strategies for its mitigation, the literature on source apportionment methodologies offers significant insights. In order to identify and quantify the sources that contribute to airborne particulate matter, research that has been carried out in a variety of nations has utilised a variety of methodologies. This has resulted in an improvement in our understanding of the dynamics of air quality and has made it easier to implement targeted interventions.   
  
Multiple Linear Regression (MLR) and Positive Matrix Factorization (PMF) have been utilised in research carried out in France in order to identify correlations between oxidative potential (OP) measurements and the sources of PM that have been found. Researchers are able to get more profound understandings of the inherent OP of each source by including PMF-derived source contributions through MLR analysis (Refs. France research). Further, the utilisation of Weighted Least-Square Regression (WLS) assists in taking into consideration the uncertainties that are present in OP measurements, which ultimately results in an improvement in the accuracy of the analysis.  
  
A similar approach has been taken by researchers in Switzerland, who have utilised the Xact technology to collect data on the elemental composition of PM2.5 and PM10 particles. The use of elemental data into PMF analysis makes it possible to precisely identify the origins of particulate matter (Refs. Switzerland research). It is possible to improve source identification by combining PM2.5 and PM10 information, particularly for sources that release coarse particles at greater quantities.   
  
Reference New Zealand research data reveals that the primary focus of New Zealand's study is on receptor modelling analysis. More specifically, the country used Positive Matrix Factorization (PMF) with EPA PMF 5.0 in order to identify the sources of particulate matter. The identification of wind directions that are related with high source contribution values can be aided by statistical methods such as conditional bivariate probability function (CBPF) analysis.

In Iran, the focus of research is on gaining a knowledge of sand and dust storms (SDSs) and the impact that they have on the quality of the air. Simulations of SDS events, measurements of dust emissions, and evaluations of dust contributions to PM10 concentrations are all carried out with the use of the Comprehensive Air Quality Model with Extensions (CAMx) in the research. Additional assistance in identifying and quantifying dust sources is provided by dust modelling tools and receptor models that are based on trajectories.   
  
It is necessary to establish effective pollution control measures in order to address the present air quality problems in India, which are made worse by the rapid industrialisation and urbanisation that is occurring in the country (Refs. India research). In regions that have a wide variety of emission sources, doing exhaustive source identification studies is absolutely necessary.   
  
The significance of these findings lies in the fact that they highlight the necessity of utilising sophisticated source apportionment approaches and automation tools in order to appreciate the complex characteristic of air pollution. Both the incorporation of data from a wide variety of sources and the utilisation of sophisticated modelling techniques make it possible for researchers to precisely quantify the contributions of sources and to develop tailored plans for the management of air quality.   
  
Researchers have the ability to effectively handle the complex difficulties that are posed by air pollution if they make use of these approaches and instruments. Furthermore, the insights that were acquired from these research provide useful information for policymakers and stakeholders in the process of developing individualised solutions to reduce air pollution and protect public health and the environment.

**Section 5: Discussion with possible solutions:**

Queen Street, which is located in the heart of Auckland's bustling central business district, is the key focal point of this project. In order to conduct an investigation that is both efficient and effective into the factors that contribute to airborne particulate matter (PM10), it is very necessary to address the specific difficulties and complications that are linked with this particular area.

**Challenges:**  
**1. Complex atmospheric dynamics:** The street canyon form of Queen Street, along with the placement of tall buildings, leads to the accumulation of turbulence and swirling, which hinders the dispersion of PM10 pollutants. This is one of the challenges that must be overcome.

**Possible Solution:** The solution that has been proposed is to make use of sophisticated computational fluid dynamics (CFD) modelling to predict airflow patterns and PM10 dispersion within the roadway canyon. This has the potential to offer useful insights into the spatial distribution of PM10 sources and aids in identifying regions with elevated PM10 concentrations for the purpose of implementing targeted mitigation measures.  
  
**2. Inadequate Data Coverage:** It is difficult to get appropriate data sources for PM10 analysis in Queen Street because there may be limits in the data coverage and representativeness of the data.  
  
**Possible Solution:** The solution that has been proposed is to improve the gathering of PM10 data by installing additional monitoring stations in Queen Street and the areas surrounding it that are equipped with PM10 sample monitors. To make the most of the infrastructure that is already in place and to broaden the geographical coverage of PM10 monitoring networks, cooperation with local authorities and stakeholders is required.  
  
**3. Methodological Uncertainties:** The inherent uncertainties that relate to methodological methods to the apportionment of PM10 sources have the potential to contribute biases or inaccuracies into the evaluation of PM10 sources.  
  
**Possible Solution:** The solution that has been proposed is to carry out exhaustive sensitivity assessments in order to evaluate the robustness of the conclusions regarding the apportionment of PM10 sources to modifications in model parameters and assumptions. Utilise a variety of PM10 source apportionment approaches, such as Positive Matrix Factorization (PMF) and receptor modelling, in order to improve the dependability and precision of the PM10 source identification process.  
  
**4. Logistical Constraints:** The deployment of current PM10 monitoring equipment and extensive field measurements has the potential to be hampered by resource restrictions and logistical obstacles in the urban context of Queen Street.  
  
**Feasible approach:** In order to gain access to cutting-edge PM10 monitoring technology and expertise, a feasible approach would be to establish strategic alliances with academic institutions, research groups, and industry stakeholders. In order to overcome logistical obstacles and improve the spatial and temporal coverage of PM10 measurements, it is recommended to make use of modern technologies for monitoring PM10, such as remote sensing and mobile monitoring platforms.

**Gaps:**  
For the purpose of enhancing the understanding and management of PM10 pollution in Queen Street, it is essential to respond to the issues that have been discovered and to put the solutions that have been presented into action. Nevertheless, there are still gaps in knowledge that need to be addressed and resolved:  
  
**1. More Recent Studies on the Methodologies Concerning the Source Apportionment of PM10:** In order to develop and test PM10 source apportionment methodologies that are specifically designed for street canyon situations like Queen Street, additional study is required. To do this, it is necessary to investigate novel approaches to the distribution of PM10 sources and to use sophisticated modelling tools in order to enhance the precision and dependability of PM10 source identification.  
  
**2. A Comprehensive Evaluation of the Health and Environmental Impacts:** It is vital to conduct exhaustive investigations in order to determine the long-term health and environmental impacts of exposure to PM10 pollution in urban environments, particularly in densely populated business districts such as Queen Street.  
  
Through the addressing of difficulties, the implementation of viable solutions, and the bridging of information gaps, the purpose of this project is to improve our understanding of the dynamics of PM10 pollution in urban settings, notably Queen Street. Establishing a basis for evidence-based decision-making and improving PM10 pollution management in urban areas are both possible outcomes that can be achieved through collaborative efforts and innovative ways.

**Section 6: Conclusion with Future Direction:**

In summary, the complex problem of PM10 source apportionment in Queen Street, Auckland's central business district, has been the main emphasis of this research. We've come a long way in identifying the precise sources of airborne particulate matter pollution in this metropolitan area by using sophisticated techniques like Positive Matrix Factorization (PMF).  
  
**Key Findings and achievements:** The analysis we conducted has clarified the main causes of PM10 pollution on Queen Street, which include the Port of Auckland, continuous construction projects, automobile emissions, and industrial operations. We've measured the relative contributions of these sources using data from ambient air quality monitoring sites and incorporated knowledge from earlier studies, offering useful information for focused mitigation initiatives (Resource: Key Findings).   
  
Furthermore, our research has emphasised how crucial it is to consider the particulars of Queen Street’s ‘Street canyon environment’, which is distinguished by its towering buildings and intricate airflow patterns. Urban planners and regulators may now make more informed decisions by using this information to pinpoint PM10 concentration hotspots and properly estimate air pollution levels (Resource: Atmospheric Dynamics in Urban Environments).   
  
**Practical Implications:** Queen Street and other comparable metropolitan areas will need to control air quality considering the project's results. Through the identification and quantification of the primary causes of PM10 pollution, we have established the foundation for focused actions aimed at enhancing air quality and protecting public health. Stricter emission regulations, traffic congestion-reducing urban planning strategies, and dust-emissions-reducing construction site management techniques are a few examples of these interventions (Resource: Practical Implications).   
  
Our work also emphasises the significance of continuous PM10 pollution monitoring and assessment in urban settings. We can improve our capacity to recognise new sources of pollution and create preventative strategies to deal with them by incorporating cutting-edge methods like receptor modelling and PMF analysis into air quality management procedures (Resource: Innovative Techniques).   
  
**Future Directions:** In light of this, studies in the future ought to concentrate on improving and confirming PM10 source apportionment techniques designed especially for street canyon contexts such as Queen Street. Studies that draw comparisons with other global metropolises can yield important information on the most effective ways to regulate PM10 pollution in urban environments. Furthermore, to create practical plans for lowering PM10 pollution and advancing environmental sustainability in cities, researchers, legislators, and industry stakeholders must continue to work together (Resource: Future Directions).   
  
To sum up, this research contributes significantly to our knowledge of the dynamics of PM10 pollution in urban settings, which has consequences for both environmental sustainability and public health. We've set the stage for future study and action targeted at boosting air quality and the standard of living for both locals and visitors by tackling the intricate issues of PM10 source apportionment in Queen Street.