**ASSESSING AIR QUALITY DISPARITIES: A COMPARATIVE STUDY OF DELHI AND LUDHIANA**

**MAJOR PROJECT**

SUBMITTED BY

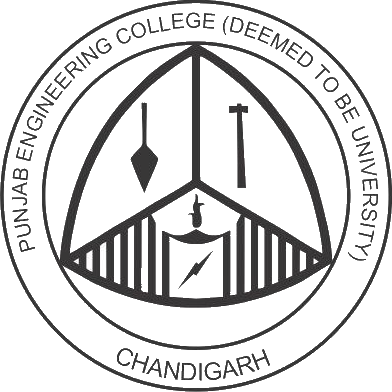
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UNDER THE GUIDANCE OF

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DEPARTMENT OF CIVIL ENGINEERING

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CHANDIGARH



# CANDIDATE’S DECLARATION

I hereby certify that the work presented in the dissertation entitled **“ASSESSING AIR QUALITY DISPARITIES: A COMPARATIVE STUDY OF DELHI AND LUDHIANA”** in the partial fulfillment of the requirements for the award of the Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering of the Punjab Engineering College (Deemed to be University), Chandigarh, is an authentic record of my work carried out during the first half of the year 2023 under the supervision of **Dr. Geeta Arora**, Associate Professor, Civil Engineering Department in Punjab Engineering College, Chandigarh.

I have not submitted the matter presented in this dissertation for the award of any other degree or any other University/Institute.

Date: Akashdeep (19102024)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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Words are often less to reveal one’s deep regard with an understanding that work like this can never be the outcome of a single person. I take this opportunity to express my profound sense of gratitude and respect to all those who directly or indirectly helped me through the duration of this work.

We would like to express our sincere regards and heartfelt appreciation to our BE Minor Project Supervisor, **Dr. Geeta Arora** (Associate Professor, Civil Engineering Department, Punjab Engineering College, Chandigarh) for her tremendous help, encouragement, invaluable guidance, and meticulous attention during this whole work. She has always pointed us in the right direction during difficulties by investing their valuable time, advice, and cooperation. It has been a great pleasure and honor to work with her.

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|  |  |  |
| --- | --- | --- |
| PM2.5  PM10  NO2  SO2  CO  O3  NAAQSDEFRA  WHO | :  :  :  :  :  :  :  :  : | Fine Particulate Matter  Particulate Matter  Nitrogen Dioxide  Sulphur Dioxide  Carbon Monoxide  Ozone  National Ambient Air Quality Standards  Department for Environment, Food & Rural Affairs  World Health Organization |
| NIH  IPCC  GDP  UNHCR  CPCB  AQI  NCT  NCR  UNCCD  COP  PPCB  CI  IS  BPLO  BPHI  AQILO  AQIHI | :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  : | National Institutes of Health  Intergovernmental Panel on Climate Change  Gross Domestic Product  United Nations High Commissioner for Refugees  Central Pollution Control Board  Air Quality Index  National Capital Territory  National Capital Region  United Nations Convention to Combat Desertification  Conference of the Parties  Punjab Pollution Control Board  Concentration of the pollutant  Sub-index of the pollutant  The breakpoint of the concentration ≤ CI  The breakpoint of the concentration ≥ CI  The AQI value corresponding to BPLO  The AQI value corresponding to BPHI |

**ABSTRACT**

Air pollution has serious implications on human health. The levels of pollutants in the air have increased significantly over the years and have deteriorated the health condition of individuals. A decade of rapid industrialization and urbanization has resulted in the increased level of air pollutants in the Indian air. However, the national restrictions in 2020 due to the outbreak of COVID-19 pandemic have brought temporary relief to the environment, along with controlling the spread of virus. The air quality improved across the globe, and India too had positive impacts of the restrictions, as there was significant reduction in the level of air pollutants.

The major project includes a comparative analysis between Delhi and Ludhiana to access difference of air quality in both cities. For this purpose, various graphs of air quality are drawn for last five years. Further the concentration level of pollutants (PM2.5, PM10, NO2, SO2, CO and O3) in each criterion city during last five years is compared with the National Ambient Air Quality Standards (NAAQS).

**CHAPTER 1 – INTRODUCTION**

* 1. **Introduction**

Clean air is essential to ensure human health and well-being. Poor air quality has been identified as the single largest environmental risk to public health and well-being (DEFRA, 2017). The earth’s atmosphere is full of air which contains gases such as Nitrogen, Oxygen, Carbon Monoxide, and traces of some rare elements. Humans need an atmosphere of air that is free from contaminants. This is very crucial for human life and health. Any change in the natural composition of air may cause grave harm to life forms on earth. Air pollution is the presence of one or more contaminants in the atmosphere such as gases in a quantity that can harm humans, animals, and plant (Arun et al. 2017).

Exposure to air pollution is not public choice but is often a consequence of daily living. Where people work, where people live and how they travel determines their level of exposure. Air pollution is not a visible problem, cannot be heard or smelt and therefore has been described as an ‘invisible killer’ (WHO, 2017). Public awareness and perception of air pollution is an important consideration to ensure those most vulnerable can take steps to reduce their exposure. There are many health effects which have been linked to exposure to air pollution from traffic including respiratory illnesses, cardiovascular illnesses, diabetes, and cognitive development impairment. The strongest evidence exists in relation to respiratory and cardiovascular illnesses (Royal College of Physicians, 2016).

The environment issues in India are increasingly becoming more serious owing to the recent boom in its industries, with little or no environmental education, massively growing infrastructure development accompanying excessive deforestation (Yadav, 2013). According to a report by World Health Organization (WHO) more than seven million people across the world lose their lives due to diseases linked with PM2.5 pollution (WHO, 2015). India, being a rapidly developing country with increasing population is suffering from severe air pollution; as among the world's 10 most polluted cities, nine of them lie in India (WHO, 2016). The increasing air pollution in most of the Indian megacities over last few decades and its consequential human health impacts (such as asthma and cardio-respiratory illness) have drawn prominent attention in recent years (Gautam et al., 2020).

Hence, this project will analyse the trend of air quality and level of concentration of pollutants in Delhi and Ludhiana. Data was collected for following six pollutants i.e., PM2.5, PM10, NO2, SO2, CO and O3, from the official Central Pollution Control Board (CPCB) website from 1st January 2018 to 31st December 2022. Therefore, the use of methods will enhance the understanding of the concentration of pollutants in air of different cities, is whether in the permissible limits as specified by National Ambient Air Quality Standards (NAAQS) or not.

**1.2 Air Quality Index**

According to CPCB, Air Quality Index is a tool for effective communication of air quality status to people in terms, which are easy to understand. It transforms complex air quality data of various pollutants into a single number (index value), nomenclature and colour. The AQI is divided into six categories. Each category corresponds to a different level of health concern. Each category also has a specific colour. The colour makes it easy for people to quickly determine whether air quality is reaching unhealthy levels in their communities. To make it easier for people to understand quickly the significance of these air pollution levels, the AQI scale is further divided into six levels of health concern and assigned a specific color to each category:

* "GOOD or HEALTHY" - This AQI value between 0 and 50 is considered satisfactory and air pollution poses little or no risk. No cautionary actions are prescribed to the general public. This is indicated with green colour.
* "SATISFACTORY" - This AQI value between 51 and 100 considered is acceptable for general public. However, unusually sensitive people should consider limiting prolonged outdoor stays. This is indicated with light green colour.
* "MODERATELY POLLUTED" - This AQI value between 101 and 200 is considered borderline unhealthy, particularly for members of sensitive groups. This means they are likely to be affected at lower levels than the general public. Some people may be sensitive to more than one pollutant. This is indicated with light yellow colour.
* "POOR" - This AQI value between 201 and 300 is considered for most of the public where everyone may begin to experience some level of discomfort. Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor stays. This is indicated with light pink colour.
* "VERY POOR" - This AQI value between 301 and 430 can trigger a health alert, meaning everyone may experience more serious health effects. Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor stays. This is indicated with orange colour.
* "SEVERE" - This AQI value of over 450+ trigger health warnings of emergency conditions. The entire population is likely to be affected. This could be due to a combination of the pollutants or a single pollutant such as PM. This is indicated with red colour.

Each of these categories is decided based on ambient concentration values of air pollutants and their likely health impacts (known as health breakpoints). Air quality sub-index and health breakpoints are evolved for eight pollutants (PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Pb) for which short-term (up to 24-hours) National Ambient Air Quality Standards are prescribed. Based on the measured ambient concentrations of a pollutant, sub-index is calculated, which is a linear function of concentration (e.g., the sub-index for PM2.5 will be 51 at concentration 31 µg/m3, 100 at concentration 60 µg/m3, and 75 at concentration of 45 µg/m3). The worst sub-index determines the overall AQI. As per CPCB, AQI categories and health breakpoints for the eight pollutants are as follow:

Table 1.1: Breakpoints for AQI Scale 0-500

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **AQI**  **Category** | **AQI** | **Concentration range\*** | | | | | | | |
|  |  | **PM10** | **PM2.5** | **NO2** | **O3** | **CO** | **SO2** | **NH2** | **Pb** |
| **Good** | **0 - 50** | **0 -**  **50** | **0 - 30** | **0 - 40** | **0 - 50** | **0 - 1.0** | **0 - 40** | **0 -**  **200** | **0 -**  **0.5** |
| **Satisfactory** | **51 - 100** | **51 -**  **100** | **31 -**  **60** | **41 -**  **80** | **51 -**  **100** | **1.1 - 2.0** | **41 -**  **80** | **201 -**  **400** | **0.6 -**  **1.0** |
| **Moderately polluted** | **101 - 200** | **101 -**  **250** | **61 -**  **90** | **81 -**  **180** | **101 - 168** | **2.1 - 10** | **81 -**  **380** | **401 - 800** | **1.1 - 2.0** |
| **Poor** | **201 -**  **300** | **251 -**  **350** | **91 -**  **120** | **181 -**  **280** | **169 -**  **208** | **10 - 17** | **381 -**  **800** | **801 -**  **1200** | **2.1 -**  **3.0** |
| **Very poor** | **301 – 400** | **351 -**  **430** | **121 - 250** | **281 - 400** | **209 - 748\*** | **17 - 34** | **801 -**  **1600** | **1200**  **-1800** | **3.1 - 3.5** |
| **Severe** | **401 -**  **500** | **430**  **+** | **250+** | **400+** | **748+\*** | **34+** | **1600+** | **1800+** | **3.5+** |
| **\* CO in mg/m3 and other pollutants in µg/m3; 24h-hourly average values for PM10, PM2.5, NO2, SO2, NH3, and Pb, and 8-hourly values for CO and O3.** | | | | | | | | | |

**1.3 Need of the Study**

The need of the study is to mitigate the disastrous impacts of air pollution including airborne disease, rise in average temperature of earth, heat waves, rise in sea level leading to floods, climate change, etc. The following issues can be resolved with effective management of air pollution:

* **Airborne Diseases:** As per National Institutes of Health (NIH), the prevalence of asthma in India is about 3% (30 million patients), with a prevalence of 2.4% in adults aged >15 years, and between 4% and 20% in children.
* **Global Warming:** As per Intergovernmental Panel on Climate Change (IPCC): 6th assessment report, the average increase in earth’s temperature is 1.1oC above the pre-industrial level.
* **Heat Waves:** India is consistently experiencing heat waves which has led to decrease in productivity of labour, thus impacting the growth rate of GDP of the nation.
* **Disasters:** The rise in temperature has led to unprecedent disasters like cyclones, sea floods, leading to large scale rehabilitation of communities, as per United Nation High Commission for Refugees (UNHCR) about 5 million people in India are internally displaced due to disasters.
* **Ecological Imbalance:** Air pollutants have a negative impact on plant growth, primarily through interfering with resource accumulation,thus impacting the very first trophic level of food web leading to ecological imbalance.

**1.4 Objective of the Work**

The objective of this project are as follows:

* To analyse variation of six criterion pollutants (PM2.5, PM10, NO2, SO2, CO, and O3) using comparative analysis for past five years i.e., 2018-2023 and figure out major causes.
* To study the past behaviour of air pollutants in Delhi and Ludhiana, suggesting preventions accordingly.
* To compare outcomes of Delhi and Ludhiana, further accessing their reasons & suggest solutions respectively.

**1.5 Scope of the Work**

The scope of the project is summarized below:

* The present study incorporates two cities of India i.e., Delhi and Ludhiana for which the air pollutants data will be assessed from Central Pollution Control Board.
* Analyzing variations of air pollutants for above mentioned cities from 2018-2023 i.e., past five years using comparative analysis on Excel through various graphs.
* Suggesting preventive measure after understanding outcome of above analysis and permissible limits of air pollutants with its effect.
* The scope of the project is an eye opener for all of us to study the parameters governing the quality of air and make actions which our sustainable to the environment and act as responsible citizens.

# 1.6 Organization of the Project

The project presents the methodology, analysis, results, and discussion obtained from a time series graphical report of air quality. The project is divided into five chapters which are given below:

* Chapter 1 briefly introduces air pollution, its effect on environment, reason why it is being studied. Further, it explains objective, scope of the study, and the organization of the project respectively.
* Chapter 2 includes detailed literature review of previous studies regarding the monitoring of concentration of air pollutants carried out by various researchers have been studied.
* Chapter 3 focuses on the study area, providing an overview of the air quality conditions in Delhi and Ludhiana.
* Chapter 4 refers to application/software that are used in the study and comparative analysis was followed in this study. It explains the procedure of method used in the study.
* Chapter 5 refers to the application of comparative analysis to compare the concentration of air pollutants in different cities in last five consecutive years. Accordingly, the comparison between the air quality and performance attributes are discussed in detail.
* In chapter 6, conclusions are driven according to the results provided in chapter 5. In addition, recommendations for future works are provided in the light of the study

CHAPTER 1

INTRODUCTION

Stage 1:

Theoretical Research

CHAPTER 2

LITERATURE REVIEW

CHAPTER 3

STUDY AREA

Stage 2:

Empirical

Research

CHAPTER 4

METHODOLOGY

CHAPTER 5

RESULTS & DISCUSSION

Stage 3:

Result &

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CHAPTER 6

CONCLUSION

Fig 1.1: Project outline

**CHAPTER 2 – LITERATURE REVIEW**

## 2.1 Literature Review

Air quality is a critical environmental concern that has significant implications for human health, ecosystems, and the global climate. The quality of the air we breathe is determined by various natural and anthropogenic factors, such as emissions from industrial and transportation sources, agricultural practices, and natural processes like wildfires and volcanic eruptions. The impacts of poor air quality are wide-ranging and can result in detrimental effects on human health, including respiratory and cardiovascular diseases, as well as negative impacts on crops, ecosystems, and climate change. Therefore, understanding the literature on air quality is crucial in order to assess the state of the environment, identify sources of air pollution, and develop effective strategies for air quality management and mitigation. In this literature review, we will explore the current knowledge and research findings related to air quality, including the main sources of air pollution, the impacts on human health and the environment, as well as emerging technologies and strategies for improving air quality.

Pallavi et al. (2018), regulatory monitored landscape in India, and included a discussion on measurement methods and other available government data on air pollution. Coarse particulate matter (PM10) concentration data from the national regulatory monitoring network for 12 years (2004–2015) were systematically analysed to determine broad trends. Less than 1% of all PM10 measurements (11 out of 4789) were found to meet the annual average WHO Air Quality Guideline (20 μg/m3), while 19% of the locations were in compliance with the Indian air quality standards for PM10 (60 μg/m3). Further efforts are necessary to improve measurement coverage and quality including the use of hybrid monitoring systems, harmonized approaches for sampling and data analysis, and easier data accessibility.

Huixiang Liu et al. (2019), have taken two different cities Beijing and Italian city for the study purpose. They have forecasted the Air Quality Index (AQI) for the city Beijing and predicting the concentration of NOx in an Italian city depending on two different publicly available datasets. The first dataset for the period of December 2013 to August 2018 having 1738 instances is made available from the Beijing Municipal Environmental Centre which contains the fields like hourly averaged AQI and the concentrations of PM2.5, O3, SO2, PM10, and NO2 in Beijing. The second dataset with 9358 instances is collected from Italian city for the period of March 2004 to February 2005. This dataset contains the attributes as Hourly averaged concentration of CO, Non-Methane Hydrocarbons, Benzene and NOx. But they focused majorly on NOx prediction as it is one of the important predictors for Air Quality evaluation. They used Support Vector Regression (SVR) and Random Forest Regression (RFR) techniques for AQI and NOx concentration prediction. SVR shows better performance in prediction of AQI while RFR gives the better performance in predicting the NOx concentration.

Rathore et al. (2020), conducted the study to estimate the reduction in the level of pollutants such as, PM10, PM2.5, NO2, SO2, CO and O3 by descriptive statistics. Correlation among the air pollutants and AQI was evaluated, using the Pearson correlation. The cities considered for the analysis were Delhi, Mumbai, Bengaluru, Chennai, Jaipur, Hyderabad, Kolkata, and Lucknow. The results showed a maximum reduction in AQI for Bangalore and Lucknow i.e., 52%. The cities such as, Lucknow, Delhi, Mumbai, Kolkata, Mumbai, and Hyderabad show significant reduction in PM2.5 (49%), PM10 (57%), CO (75%), NO2 (68%), SO2 (48%) and O3 (29%), respectively. The authors further suggest, implications of such lockdowns every month can help restore the environment and improve ambient air quality.

Bedi et al. (2020), conducted a study to know the impact of lockdown on the air quality. The study areas considered were Delhi, Chennai Kolkata, and Mumbai. As per the results of the study the lockdown measures were effective in bringing down the concentration level of several pollutants whereas, significant decrease around 70% was obtained for NO2. However, insignificant reduction was obtained for SO2. The concentration of O3 was increased in all the cities, but not in Mumbai. This scenario was explained by the author, as the level of NOx decreased in the atmosphere the use of O3 in the in photochemical reaction also decreases.

Singh et al. (2021), analyses the PM2.5, NO2, O3, CO and SO2 along with meteorological parameters (humidity, temperature, and wind speed) at a tropical coastal station Chennai for March-May 2019 and 2020 at five locations: Alandur Bus depot, Velachery, Manali, Teynampet and U.S. Embassy Chennai. Though overall PM2.5 values decreased for the lockdown (ranging from ~32–187%), weekly analysis shows the variation in reduction/increase. SO2 and O3 values were found increasing for two sites: Teynampet (~40% in SO2 and ~48% in O3) and Velachery (~42% in SO2 and ~5% in O3), but decreasing for Alandur (~30% in SO2 and ~50% in O3) and Manali (~247% in SO2). NOx and CO were reduced during the lockdown (~47–125%) for all the sites. The source regions examined by concentration weighted trajectory analysis were found to change for transporting pollution to the site. The analysis shows there are local scale variations in the air pollution for the city during COVID-19 lockdown.

The investigation of multiple studies work has revealed a consistent trend wherein increased levels of pollutants were observed prior to lockdown periods, while reduced levels of pollutants were observed during lockdown periods. Based on these findings, it is imperative to conduct a comparative analysis of air quality data for the past five consecutive years to gain insights into the behavior of air quality. Such an analysis can inform and guide the development of appropriate measures by the relevant authorities to improve air quality, with a particular focus on addressing the sources of air pollutants. Implementation of appropriate measures can effectively mitigate the impact of air pollution, safeguard public health, and protect the environment.

**CHAPTER 3 – STUDY AREA**

**3.1 Introduction**

The present study incorporates two cities of India i.e., Delhi and Ludhiana for which the air quality will be assessed. The rationale behind selecting these cities is their location, both cities are in northern India and have been experiencing significant air pollution issues. The comparison between Delhi and Ludhiana helps in understanding the severity of air pollution in different regions of northern India and the measures required to improve air quality. It also helps in identifying the sources of pollution in these cities and developing targeted strategies to address them. Additionally, availability of data from the public domain was considered as a criterion for selection of above-mentioned cities. Further, understanding the geographical background and environmental factors that contribute to air pollution in these cities is crucial for developing effective solutions to this pressing issue.

**3.2 History**

Delhi, officially the National Capital Territory (NCT) of Delhi, is a city and a union territory of India containing New Delhi, the capital of India. Straddling the Yamuna River, primarily its western or right bank, Delhi shares borders with the state of Uttar Pradesh in the east and with the state of Haryana in the remaining directions. Located in northern India, Delhi is a centre of culture, politics, and commerce, and is home to over 18 million people. The city is a melting pot of different cultures and religions, and is known for its ancient landmarks, modern architecture, and bustling markets. Despite its many challenges, including air pollution, traffic congestion, and social inequality, Delhi continues to be an important hub of innovation, creativity, and enterprise. The city is home to some of India's top universities, research institutions, and startups, and attracts millions of visitors each year from all over the world. Whether you are interested in exploring ancient monuments, sampling delicious cuisine, or experiencing the energy of a modern megacity, Delhi has something for everyone. From the bustling streets of Old Delhi to the modern skyscrapers of New Delhi, this city is a true reflection of India's rich cultural heritage and vibrant spirit.

Ludhiana, located in the northern Indian state of Punjab, is a major industrial hub and an important centre of commerce and culture. With a population of over 1.5 million people, Ludhiana is the largest city in Punjab and the fifth largest in India's northern region. The city is renowned for its thriving textile industry, which produces a wide range of products including hosiery, woollen garments, and cotton clothes. Ludhiana is also a major centre for the manufacturing of industrial goods, including machine tools, auto parts, and agricultural equipment. In addition to its industrial importance, Ludhiana is also a city of rich cultural heritage. It is home to several historic monuments and landmarks, including the famous Lodhi Fort and the Maharaja Ranjit Singh War Museum. The city is also known for its vibrant Punjabi culture, with a rich tradition of music, dance, and cuisine. Overall, Ludhiana is a city with a rich history, diverse culture, and a thriving economy. Whether you are interested in exploring its industrial heartland or experiencing its vibrant cultural scene, Ludhiana is a city that offers something for everyone.

**3.3 Area and Population**

Delhi is in Northern India, at latitude of 28.61°N and longitude of 77.23°E. It is situated at an altitude of approximately 216 meters (709 feet) above sea level. The city is bordered on its northern, western, and southern sides by the state of Haryana and to the east by that of Uttar Pradesh (UP). Two prominent features of the geography of Delhi are the Yamuna flood plains and the Delhi ridge. According to UNCCD COP 14, the National Capital Territory of Delhi covers an area of 1,484 km2, of which 783 km2 is designated rural, and 700 km2 urban therefore making it the largest city in terms of area in the country. It has a length of 51.9 km and a width of 48.48 km. According to the 2011 census, Delhi's city proper population was over 11 million, while the NCT's population was about 16.8 million. Delhi's urban agglomeration, which includes the satellite cities Ghaziabad, Faridabad, Gurgaon, and Noida in an area known as the National Capital Region (NCR), has an estimated population of over 28 million, making it the largest metropolitan area in India and the second-largest in the world (after Tokyo).

  
Fig 3.1: Location map of Delhi

Ludhiana is a centrally located city of Punjab, which is on the Grand Trunk Road from Delhi to Amritsar at latitude 30.55o North and longitude 75.54o East in Northern India. Ludhiana is the most centrally located district in the Malwa region of the state of Punjab. For administrative purposes, it has been placed in the Patiala Division. The average elevation of Ludhiana is about 262 meters (859 feet) above sea level. The terrain of Ludhiana is relatively flat, with some low hills in the surrounding areas. The city is bordered by the Shivalik Range to the north and the Himalayas to the northeast. The total area covered by Ludhiana is approximately 310 km2 (120 mi2). The city is the largest in Punjab and covers a significant portion of the state. It is divided into five zones and has a total of 95 wards. Ludhiana is a highly populated city with a population density of over 5,200 people per km2. As of the 2011 Census of India, the population of Ludhiana was 1.6 million. Since then, the population of Ludhiana has continued to grow steadily. According to recent estimates, the population of Ludhiana in 2022 is around 2.2 million people. Ludhiana is the largest city in the state of Punjab and is a major economic and cultural center in the region.



Fig 3.2: Location map of Ludhiana

**3.4 Environmental Factors**

Environmental problems in Delhi, India, are a threat to the well-being of the city's and area's inhabitants as well as the flora and fauna. Delhi, the ninth-most populated metropolis in the world (second largest if the entire NCR includes especially Faridabad and Gurugram– Haryana, is one of the most heavily polluted cities in India (The Hindu, 2011), having for instance one of the country's highest volumes of particulate matter pollution (The Times of India, 2011). Indian cities have regularly featured among the world’s most polluted cities in recent years. And among Indian cities, Delhi has often been the worst-performing one with the dubious distinction of having been ranked the most polluted city in the world for the fourth consecutive year in 2022 (The Times of India, 2023). Air pollution is a major environmental factor in Delhi, India's capital city, with severe consequences on the health and well-being of its citizens. The sources of air pollution in Delhi are diverse and include vehicular emissions, industrial emissions, construction activities, and open burning of waste and crops. However, there is a need for sustained and concerted efforts to tackle the problem of air pollution in Delhi and improve the air quality for the health and well-being of its citizens.

Air pollution is a major environmental factor in Ludhiana as well, a bustling city in the northern state of Punjab, India. The sources of air pollution in Ludhiana are almost same as of Delhi i.e., diverse and include vehicular emissions, industrial emissions, construction activities, and open burning of waste and crops. Meanwhile, Punjab Pollution Control Board (PPCB) officials said that there were many weather and environmental-related factors behind the bad air quality in the city. City residents are forced to suffer various problems due to the air pollution (The Times of India, 2023). This has led to major rise in respiratory problems and other allied complications to the residents, especially children, aged, and those suffering from respiratory and cardiac problems, who were gasping for clean air. Another city of Ludhiana District, Khanna also figured among the top ten most polluted cities in the state (The Tribune, 2023). However, the air pollution continues to be a major problem in Ludhiana. There is a need for sustained efforts to tackle the problem of air pollution in the city, through the implementation of comprehensive measures and the engagement of communities and individuals in the effort to improve the air quality.

**CHAPTER 4 - METHODOLOGY**

**4.1 Dataset Summary**

Computation of the AQI requires an air pollutant concentration over a specified averaging period, obtained from an air monitor. Taken together, concentration and time represent the dose of the air pollutant. Air pollutants vary in potency, and the function used to convert from air pollutant concentration to respective sub-index respectively using equation 4.1. AQI is the maximum value of the sub-index, considering available pollutants for computation or minimum three parameters are required to compute in which PM2.5 or PM10 must be considered. Its air quality index values are typically grouped into ranges. Each range is assigned a descriptor, a colour code, and a standardized public health advisory**.**

Calculation of the AQI is presented below, along with the supporting data for various ranges refer table 1.1.

…………………………………………………… (4.1)

In above equation,

CI = Concentration of the pollutant

IS = Sub-index of the pollutant

BPLO = The breakpoint of the concentration ≤ CI

BPHI = The breakpoint of the concentration ≥ CI

AQILO = The AQI value corresponding to BPLO

AQIHI = The AQI value corresponding to BPHI

In this study, data for six parameters is collated for past five years i.e., 2018-2023. The pollutants selected for the study were PM2.5, PM10, CO, NO2, SO2, and O3. The reason behind selection of these pollutants is that, their main source is fuel combustion, primarily from industrial and automobile exhaust, and O3 is formed by reaction of primary pollutants. The data for each pollutant is obtained on the daily basis for past five years. The daily data of the above-mentioned air pollutants were obtained from the open-source data. Further, AQI was computed by using Microsoft Excel.

**4.2 Data Analysis**

The Data have to be according to maximum values of each parameter and have to compare them with each other, the value come to be worst is known as AQI of the period. First of all, we found out values of six parameter from January, 2018 to December, 2022. Then maximum values are found out and overall average of year is taken and compared with table 1.1 and observed relevant quality of air. Statistical analysis is done on the obtained dataset, to analyse the basic characteristics of the data. The values of mean, standard deviation, maximum and minimum were computed. The percentage difference, between January, 2018 and December, 2022 was calculated for air pollutants and AQI. The above-mentioned analysis was done using Microsoft Excel.

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