SIMULATION FOR ATMOSPHERIC POLLUTION BY VEHICULAR EMISSION:CASE STUDY FOR DELHI

PREPARED UNDER SUPERVISION OF

DR. SHIBANI KHANRA JHA

ASSOCIATE PROFESSOR,

DEPARTMENT OF CIVIL ENGINEERING,

BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE,PILANI

PREPARE BY

VARUN SAINI - 2020A7PS0144P

SHREYAS KETKAR - 2020A7PS0075P

KARI JYOTHI PRAKASH - 2020A2PS1741P

ADITYA JAISWAL - 2021A4TS2201P

ABSTRACT

PROBLEM STATEMENT

The intensifying air pollution in Delhi due to rising vehicle emissions has made a sophisticated modelling method necessary for a thorough examination. The complex dynamics of air pollution brought on by vehicle emissions in Delhi's distinct urban setting are examined in this research using COMSOL Multiphysics.

EXPECTATIONS

By utilising COMSOL Multiphysics sophisticated capabilities, the study expects to get accurate insights into pollution dispersion patterns. With the use of variables including traffic patterns, sources of emissions, climate, and topographical characteristics, the research intends to create focused plans for reducing air pollution and enhancing Delhi's air quality.

SIGNIFICANCE

COMSOL Multiphysics is used to improve the study's accuracy and comprehensiveness, which makes it a useful tool for environmental agencies, policymakers, and urban planners. The results are intended to close the knowledge gap between theoretical research and real-world applications by providing useful information for sustainable urban development in the face of air pollution issues.

KEY WORDS
Cosmol Multiphysics, Contaminant transport,
Convection, Diffusion, Vehicular emission, Air pollution

HIGHLIGHTS

- Designated a specific 50km x 50km zone covering Delhi for focused research.
- Employed advection-diffusion model to understand pollutant dispersion patterns.
- Leveraged Comsol Multiphysics for visualizing pollutant distribution in a defined Delhi area.
- Analyzed CO emissions from vehicular sources using Comsol Multiphysics within the specified zone.
- Assessed vehicular emissions impact on air pollution dynamics in the defined area.

TABLE OF CONTENTS

1. INTRODUCTION

Air pollution is a significant global issue affecting people's health and the environment worldwide. Harmful substances released into the air from various sources like industries, vehicles, and household activities contaminate the air we breathe. This pollution leads to severe health problems, including respiratory diseases, heart conditions, and even premature deaths. Additionally, it poses a threat to the environment, impacting ecosystems, water quality, and biodiversity.

Understanding air pollution is crucial for several reasons. Firstly, it directly affects human health, causing a range of illnesses that can have long-term consequences. Secondly, it damages the environment, impacting plants, animals, and natural habitats. Lastly, it has economic implications, increasing healthcare costs and reducing productivity due to sickness. Focusing on Delhi becomes imperative due to its unique challenges. The city grapples with rapid urbanization, population growth, and a staggering rise in vehicular traffic. Vehicles are a major contributor to Delhi's air pollution, accounting for a significant portion of the city's harmful emissions. This high level of pollution has dire consequences for public health, leading to a surge in respiratory diseases and posing a threat to the overall well-being of the population.

Delhi spans 1,484 square kilometers, comprising 783 square kilometers of rural areas and 700 square kilometers of urban space. The city experiences rapid population growth, leading to a surge in vehicle numbers without a proportional increase in road infrastructure. With over 6 million registered vehicles and substantial traffic influx from neighboring states, vehicles account for a significant 64% of Delhi's pollution. Other contributors, like power plants, industries, and domestic sources, contribute 16%, 12%, and 8%, respectively. Vehicular emissions, notably carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter (PM), exceed permissible levels set by the Central Pollution Control Board (CPCB). This rising pollution has dire health implications, increasing the incidence of respiratory diseases, cancer, and heart ailments. Alarmingly, Delhi's poor air quality is linked to approximately 18,600 premature deaths annually.

Between 2003 and 2009, Delhi witnessed a notable increase in the number of vehicles per kilometer of road, soaring from 128 to 191. Surprisingly, despite a rise in total available road space from 30,698 to 31,373 lane kilometers during the same period, this surge in vehicles persisted. The city experienced a sharp annual growth rate of 7.40% for private vehicles and 9.15% for commercial vehicles, resulting in significant transportation and environmental challenges.

Air pollution poses a significant global threat, impacting both human health and the environment on a worldwide scale. Emanating from various sources like industries, vehicular emissions, and everyday household activities, harmful substances contaminate the air we breathe. This pollution significantly contributes to severe health complications, including respiratory diseases, heart conditions, and premature deaths. Moreover, it casts a looming shadow over ecosystems, water quality, and biodiversity, indicating its pervasive impact on the environment.

Understanding the complexities of air pollution is pivotal for several reasons. Its direct influence on human health leads to a spectrum of illnesses with long-term implications. Simultaneously, the environmental degradation it causes impacts plant and animal life, disrupting natural habitats. Notably, the economic repercussions emerge through increased healthcare expenses and reduced productivity attributed to sickness.

Delhi, amidst rapid urbanization and an escalating population, faces a distinctive challenge—an exponential rise in vehicular traffic. Vehicles stand out as a significant contributor to the city's air pollution, accounting for a substantial portion of harmful emissions. Despite efforts to expand road infrastructure, the surge in vehicles remains disproportionate, culminating in a staggering 64% contribution to Delhi's pollution. Other sources like power plants, industries, and domestic activities also play a part, contributing 16%, 12%, and 8%, respectively. Notably, vehicular emissions exceed permissible levels set by the Central Pollution Control Board (CPCB), consisting primarily of carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter (PM). This heightened pollution has dire health implications, correlating with a surge in respiratory diseases, cancer, heart ailments, and an alarming rate of approximately 18,600 premature deaths annually.

Between 2003 and 2009, Delhi witnessed a substantial escalation in vehicles per kilometer of road, surging from 128 to 191, despite an increase in available road space from 30,698 to 31,373 lane kilometers during the same period. This sharp increase, marked by a 7.40% annual growth rate for private vehicles and 9.15% for commercial vehicles, has led to significant transportation and environmental challenges.

Our research initiative zeroes in on Delhi's vehicular traffic as the primary pollution source. Leveraging the advanced capabilities of Comsol Multiphysics, specifically the Transport of Diluted Species module, our endeavor is to comprehensively analyze and simulate the intricate dynamics of air pollution stemming from vehicular emissions. Through this study, we aim to delve deeper into understanding the impact of vehicular emissions on air quality and public health in Delhi. Our ultimate goal is to harness the potential of this advanced modeling tool to propose targeted strategies and effective interventions, thereby mitigating the adverse effects of vehicular pollution. This holistic approach seeks to foster a healthier and sustainable environment for the residents of Delhi.

Various Emissions Emitted by Vehicles

Crankcase Emissions, also known as running loss emissions, refer to unburnt or partially burned fuel components that escape from the combustion chamber under pressure, passing through the pistons and entering the crankcase. This mixture, termed blow-by, primarily consists of HCs and can make up 13–25% of total emissions. Diesel engines, compressing only air, yield blow-by with notably low pollutant levels.

Evaporative Emissions involve HC vapors continually lost to the atmosphere due to the volatile nature of petrol. These vapors mainly originate from fuel lines, the fuel tank, and the carburetor, influenced by factors like fuel composition, engine and ambient temperatures. Approximately 20-32% of total emissions, notably higher in petrol compared to diesel, result from evaporation losses, with HCs as the predominant constituents. Hot Soak Emissions, arising when a hot engine stops, stem from the carburetor.

Exhaust Emissions from automobiles represent the largest contributor, constituting roughly 60% of total emissions. This exhaust encompasses a wide array of pollutants, ranging from basic to carcinogenic substances. Notable elements include Hydrocarbons (Unburnt), Carbon Monoxide, Nitrogen Oxides (NOx), Lead Oxides, Particulate Matters like lead, carbon, alkaline compounds, iron oxide, tar, oil mist, as well as traces of aldehydes, esters, sulfur dioxide, and various other compounds like benzene, 1,3 butadiene, Poly Aromatic Hydrocarbons (PAH), metal dust, asbestos fiber, dioxin, furan, ammonia, organic acids, chlorofluorocarbons (CFCs), among others.

2.BACKGROUND

ABOUT AIR POLLUTION

The presence of contaminants in the air in significant amounts over extended periods of time is referred to as air pollution. Particles in the air might include hydrocarbons, CO, CO2, NO, NO2, SO3, and scattered particles. Lead, sulphur oxides, nitrogen oxides, carbon monoxide, particle pollution, and ground-level ozone are the six main air pollutants that the World Health Organisation (WHO) monitors. Air pollution may have a catastrophic impact on soil, groundwater, and other environmental elements. It also presents a significant risk to living things. since these pollutants are linked to more serious and pervasive issues with human health and environmental damage. There are significant ecological effects of acid rain, global warming, the greenhouse effect, and climatic changes on air pollution.

CAUSES OF AIR POLLUTION

- Utilising Fossil Fuels

A significant amount of sulphur dioxide is released during the burning of fossil fuels. Air pollution is also caused by carbon monoxide, which is generated when fossil fuels are not burned completely.

- Automobiles

The atmosphere is contaminated by the gases released by automobiles like lorries, buses, and jeeps, among other types of vehicles. These are the main contributors to greenhouse gas emissions and cause illnesses in people.

- Farming Operations

One of the most dangerous chemicals released during agricultural operations is ammonia. The atmosphere is contaminated by the toxic compounds released into the atmosphere by fertilisers, pesticides, and insecticides. Crop leftovers are burned by farmers in some agricultural practises following harvest. Significant volumes of particulate matter and other pollutants are released into the sky during this burning. Despite its negative effects on the ecology, this practise is still carried out in some areas.

- Industries and Factories

The primary sources of hydrocarbons, chemicals, organic compounds, and carbon monoxide are factories and other industrial facilities. The air is contaminated when they are discharged into it.

- Mining Operations

Large pieces of machinery are used in the mining operation to extract minerals from the soil. In addition to polluting the air, the dust and chemicals generated throughout the process harm the health of neighbouring residents and workers.

- Domestic Sources

Toxic chemicals included in paints and home cleaning goods are discharged into the air. The fragrance coming from the freshly painted walls is that of the paint's chemicals. In addition to contaminating the air, it makes breathing difficult.
In this study, we are considering the air pollution due to vehicular emissions as a cause.

EFFECTS OF AIR POLLUTION

The following are some of the harmful impacts of air pollution on the environment:

- Illnesses

  Human heart disease and a number of respiratory ailments have been linked to air pollution. Over the past few decades, there has been a rise in lung cancer incidences. Asthma and pneumonia are more common in kids who live close to contaminated places. Each year, a large number of individuals pass away as a direct or indirect result of air pollution.

- Global Warming

The air's gaseous composition is unbalanced as a result of greenhouse gas emissions. The earth's temperature has increased as a result of this. Global warming is the term used to describe this rise in earth's temperature. Sea levels have increased and glaciers have melted as a result.

- Acid Rain

  When fossil fuels are burned, airborne pollutants like sulphur and nitrogen oxides are released. When water droplets come into contact with these contaminants, they react to form acid rain, which harms plant, animal, and human life.

- Depletion of ozone layer

  The primary cause of the ozone layer's thinning is the atmospheric emission of hydrochlorofluorocarbons, halons, and chlorofluorocarbons. People who live in areas where the ozone layer is thinning may experience skin and vision issues as a result of the sun's damaging UV radiation.

- Impact on mammals

  Aquatic life is impacted by the air contaminants that are suspended in water bodies. Animals are often forced to relocate from their natural environment due to pollution.

DIFFERENT APPROACHES FOR AIR POLLUTION MODELS

This review provides an overview of current mathematical methods used in air quality studies, based on recent surveys. It focuses on key modeling topics:

1. Meteorological Models: Two types—prognostic models for predicting atmospheric system development and diagnostic models for mass-consistent wind flow calculations, especially in difficult terrain.

2. Plume Rise Models: Addressing the early dispersion stage of contaminants, these models consider thermal buoyancy and vertical momentum, utilizing sophisticated and semiempirical formulas.

3. Gaussian Models: Predominantly employed, Gaussian plume models assume separate horizontal and vertical Gaussian distributions, recommended by the U.S. EPA. Modifications accommodate special dispersion scenarios.

4. Eulerian Approach: Grounded in the conservation of mass, Eulerian methods solve pollutant species equations numerically using grids, like the finite-difference approach.

5. Lagrangian Approach: Describing fluid elements following instantaneous flow, Lagrangian models, especially particle modeling, offer accurate transport predictions without introducing artificial numerical diffusion.

6. Stochastic Models: Relying on statistical or semiempirical methods, stochastic models estimate pollution evolution, analyzing patterns and inter-relationships between air quality and atmospheric observations.

7. Optimization Techniques: Commonly used for monitoring network design, optimization models aid in determining the ideal number and placement of stations for monitoring ambient air quality.

8. Statistical Techniques: Quantitative and qualitative statistical methodologies assess the performance of dispersion models by comparing predictions with actual observations, emphasizing the importance of accurate data for model calibration and testing.

GOVERNING EQUATION

The diffusion model is used to represent the behavior of air pollutant concentration. We shall consider the three-dimensional advection-diffusion equation as follows:

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + \mathrm{V}\frac{\partial C}{\partial y} + w\frac{\partial C}{\partial z} = D_x\frac{\partial^2 c}{\partial x^2} + D_y\frac{\partial^2 c}{\partial y^2} + D_z\frac{\partial^2 c}{\partial z^2}$$

Where; u is a constant wind velocity in the x-direction (m/sec), v is a constant wind velocity in the y-direction (m/sec),w is a constant wind velocity in the z-direction , D_x is a constant dispersion coefficient in the horizontal direction (m2 /sec) , D_Y is a constant dispersion coefficient in the Y-direction (m2 /sec) and D_z is a constant dispersion coefficient in the the z-direction (vertical) (m2 /sec).

We are solving the above the mentioned equation with the following two approaches:

1. GAUSSIAN PLUME MODEL

ASSUMPTIONS:

1.Steady-state conditions: $\frac{\partial c}{\partial t} = 0$(No change in concentration with time).

2. Continuous and stable point source: Q is the emission rate of the pollutant.
3. Homogeneous and unbounded atmosphere.
4. Neglect vertical dispersion: *w*=0 (Vertical velocity component is ignored).
5. Steady-state and uniform wind: u is constant. so,diffusion is unimportant in x-direction.

$$u\frac{\partial c}{\partial x} = D_y\frac{\partial^2 c}{\partial y^2} + D_z\frac{\partial^2 c}{\partial z^2}$$

BOUNDARY CONDITION:

$$Q = \int\int uCdy\,dz$$

Mass flow through a vertical plane downwind must equal to emission rate Q.
The above equation can be solved for a point source using advanced mathematical techniques. Thankfully, it has been solved for us and the solution is:

$$c(x,y,z) = \frac{Q}{2\Pi u\alpha_z\alpha_y}\cdot exp\,exp\left(\frac{-y^2}{2\alpha_y^2}\right)\ [exp\,exp\left(\frac{-(z-H)^2}{2\alpha_z^2}\right)+exp\,exp\left(\frac{-(z+H)^2}{2\alpha_z^2}\right)\ ]$$

Where ; $\alpha_y^2 = \frac{2\cdot Dy\cdot \varkappa}{u}$ $\alpha_z^2 = \frac{2\cdot Dz\cdot \varkappa}{u}$

2. FINITE DIFFERENCE METHOD

The prediction of pollutant from a stationary source can be calculated to solve the air pollution problem in the industrial areas. we get the concentration of C at each time T_{n+1} from $Tn = n\Delta T$, n=0,1,2,3,------,P when ΔT is a time increment. The solution of pollutant concentration at (X,Z,T) is denoted by $C(X_i,Z_j,T_n) = c_{i,j}^n$. The considered domain is meshed by the grid spacing ΔX and ΔZ where $X_i = i\,\Delta X$, i=0,1,2,3,---,N , and $Z_j = j\,\Delta Z$, j=0,1,2,----,M . The finite difference method is chosen as proper equipment for estimating solutions. we use the forward time central space (FTCS) scheme. In the transient term, we used the forward difference for

$$\frac{\partial c}{\partial T} = \frac{c_{i,j}^{n+1} - c_{i,j}^{n}}{\Delta T}$$

The advection and diffusion terms are substituted by using the centered difference in space by

$$\frac{\partial c}{\partial x} = \frac{c_{i+1,j}^{n} - c_{i-1,j}^{n}}{2\Delta x}$$

$$\frac{\partial c}{\partial z} = \frac{c_{i,j+1}^{n} - c_{i,j-1}^{n}}{2\Delta z}$$

$$\frac{\partial^2 c}{\partial x^2} = \frac{c_{i+1,j}^{n} - 2c_{i,j}^{n} + c_{i-1,j}^{n}}{(\Delta x)^2}$$

$$\frac{\partial^2 c}{\partial z^2} = \frac{c_{i,j+1}^{n} - 2c_{i,j}^{n} + c_{i,j-1}^{n}}{(\Delta z)^2}$$

respectively. On substituting the values in the governing equation gives

$$\frac{c_{i,j}^{n+1} - c_{i,j}^{n}}{\Delta T} + \mathbf{u}\left(\frac{c_{i+1,j}^{n} - c_{i-1,j}^{n}}{2\Delta x}\right) + w\left(\frac{c_{i,j+1}^{n} - c_{i,j-1}^{n}}{2\Delta z}\right) =$$

$$\mathbf{D_x}\left(\frac{c_{i+1,j}^{n} - 2c_{i,j}^{n} + c_{i-1,j}^{n}}{(\Delta x)^2}\right) + \mathbf{D_z}\left(\frac{c_{i,j+1}^{n} - 2c_{i,j}^{n} + c_{i,j-1}^{n}}{(\Delta z)^2}\right)$$

Thus, the finite difference form of the advection-diffusion equation becomes

$$c_{i,j}^{n+1} = (d_x - A_x)\, c_{i+1,j}^{n} + (d_x + A_x)\, c_{i-1,j}^{n} + (1 - 2d_x - 2d_y)\, c_{i,j}^{n} + (d_z + A_z)\, c_{i,j-1}^{n} + (d_z - A_z)\, c_{i,j+1}^{n}$$

Where;

$$A_x = \frac{u\Delta T}{2\Delta x},\ A_z = \frac{w\Delta T}{2\Delta z},\ d_x = \frac{D_x \Delta T}{(\Delta x)^2},\ d_z = \frac{D_z \Delta T}{(\Delta z)^2}$$

LITERATURE - RESEARCH INSIGHTS

The article (Joseph et al.,2020) attempts to balance computing economy and accuracy by addressing the incompatibility of Gaussian plume and computing Fluid Dynamics models for particulate dispersion. It is specifically addressed that the trade-off inherent in these models, emphasizing practical applicability in environmental impact assessments. The paper likely delves into validation, calibration, and sensitivity analysis, examining the integration of meteorological factors and discussing model limitations transparently. Practical implementation considerations and a comparative analysis with traditional models are likely discussed, providing insights for regulatory frameworks. The conclusion may highlight specific directions for future research, refining integrated models and exploring diverse contexts.

In the paper on leakage source location using a Gaussian plume diffusion model with a near-infrared sensor (Weilin Ye et al.,2020),the focus lies on developing a method for pinpointing the source of a leak. The study incorporates a near-infrared sensor for detection and utilizes the Gaussian plume diffusion model for accurate dispersion analysis. Weilin Ye and colleagues likely detail the experimental setup and methodology, emphasizing the effectiveness of near-infrared sensors in detecting and locating leaks. The integration of the Gaussian plume model suggests a sophisticated approach to understanding the dispersion pattern, enhancing precision in source identification. This paper likely provides a significant contribution to the field of leak detection and environmental monitoring, offering a reliable and precise methodology based on advanced sensing technologies and established diffusion models.

In comprehensive study spanning from 2000 to 2019, (Youchen Shen et al.,2022), employ geographically weighted regression to model air pollution levels across Europe. The research utilizes advanced statistical techniques to analyze and map the spatial variations in air quality. It indicates a nuanced approach, likely considering diverse environmental factors. This paper not only captures the temporal evolution of air pollution but also offers a nuanced understanding by employing geographically weighted regression, acknowledging the geographical heterogeneity in pollution sources and impacts. The involvement of experts like Jørgen Brandt and Jesper H. Christensen suggests a strong foundation in atmospheric science. Overall, this research provides a valuable Europe-wide perspective on air pollution dynamics, crucial for informing targeted environmental policies and public health initiatives.

In the paper (Chang Liu et al.,2022), introduce a gas diffusion model that builds upon an enhanced Gaussian plume model, specifically designed for inverse calculations of source strength. This study likely refines the traditional Gaussian plume model to improve accuracy in estimating the emission source strength. The involvement of multidisciplinary approach, potentially combining expertise in atmospheric science and mathematical modelling, may indicate an application-oriented perspective. This research is expected to contribute significantly to the field of air quality modelling, offering an advanced tool for inverse calculations that can enhance our ability to identify and quantify pollution sources. The improved Gaussian plume model introduced in this paper likely provides a more nuanced and accurate representation of gas diffusion, crucial for environmental assessments and regulatory measures.

In the paper (Sha He et al., 2023), the focus is on modeling optimal control strategies for air pollution to mitigate the prevalence of respiratory diseases. This research likely employs mathematical modeling techniques to assess and optimize strategies aimed at reducing air pollution and subsequently lowering the risk of respiratory illnesses. It suggests a comprehensive examination of control measures, potentially encompassing epidemiological and environmental perspectives and implies a potential interdisciplinary approach, incorporating insights from ecology or public health. This paper is anticipated to contribute valuable insights into the development of effective strategies for air quality management, providing a basis for informed decision-making in public health and environmental policy to alleviate respiratory health challenges.

physics-based reduced order model for predicting urban air pollution is published in a reduced order model (ROM) based on physics (Moaad Khamlich et al.,2023) to anticipate urban air pollution. Using the ideas of reduced order modelling, this model seeks to effectively simulate and forecast air pollution levels in metropolitan contexts. Through the integration of physical rules guiding the dynamics of air pollution, complicated urban air quality situations may be represented more computationally efficiently.

The influence of vehicle emissions on air pollution is examined in this study (Jianlei Lang et al.,2021). The study focuses on the regional transport dynamics in the Beijing-Tianjin-Hebei area of China. The study most likely takes a comprehensive approach, taking into account regional air conditions, transportation networks, and emission trends. The authors want to offer a comprehensive knowledge of how vehicle emissions affect air pollution at the regional level by using a case study technique. For environmental scientists and politicians looking for practical solutions to address and alleviate air quality concerns in heavily industrialised and inhabited areas like the Beijing-Tianjin-Hebei Region, this research is essential. In the context of regional transport dynamics, the results may guide targeted efforts to lessen the environmental effect of vehicle activity.

In the paper Improving traffic-related air pollution estimates by modelling minor road traffic volumes (Miguel Alvarado-Molina et al.,2023), goal of the work is to simulate small road traffic volumes in order to improve the precision of air pollution estimations connected to traffic, which emphasises how crucial it is to take small-scale road traffic into account when evaluating air pollution. In order to give a more thorough and accurate depiction of traffic-related air pollution, the authors use sophisticated modelling approaches to include small amounts of road activity into their projections. The results of the study provide important new information for improving evaluations of air quality, especially in cities where little roads frequently account for a large portion of total traffic emissions. The findings of this study have significance for enhancing public health outcomes and developing urban development plans that lessen the effects of air pollution.

In the paper Street-scale dispersion modelling framework of road-traffic derived air pollution in Hanoi, Vietnam (Khoi Quang Ngo et al.,2023), aims to evaluate road-traffic-derived air pollution in Hanoi, Vietnam, by using a street-scale dispersion modelling framework. The study attempts to offer a thorough grasp of local air quality in an urban environment. The framework that the authors develop is customised to the distinct features of Hanoi's road network through the application of sophisticated dispersion modelling techniques. This street-scale method takes into account the unique dynamics of traffic emissions in the city and enables a more detailed examination of air pollution trends.

In the paper Development and evaluation of Vehicular Air Pollution Inventory model (B.R. Gurjar et al.,2012), have worked together to create and assess a model called the Vehicular Air Pollution Inventory. The goal of the project is to develop a thorough model that will evaluate and quantify air pollution caused by vehicles. To build the inventory model, the authors probably combine traffic statistics, emission factors, and other pertinent variables. The accuracy and dependability of the model are tested during the review process, maybe using data on actual air quality. Understanding how vehicle emissions contribute to air pollution is important because it will help researchers, politicians, and urban planners develop practical solutions to lessen the negative effects of vehicle pollution on public health and air quality.

In this case study led by (Xinping Yang et.al,2023) , the authors investigate the reduction potential of vehicular emissions in Chengdu, China, focusing on the context of the COVID-19 pandemic. The study likely explores changes in air quality and vehicular emissions during the lockdown measures implemented in response to the pandemic. By analyzing this unique period, the authors aim to quantify the impact of reduced vehicular activity on air pollution levels in Chengdu. The findings of this research contribute valuable insights into the potential environmental benefits of mobility restrictions and have implications for urban planning and pollution control strategies in the context of public health emergencies.

"Roadside Measurements of Nanoparticles and Their Dynamics in Relation to Traffic Sources in Delhi: Impact of Restrictions and Pollution Events (Kanagaraj Rajagopal et al., 2023)", likely investigates nanoparticle levels along Delhi roadways in relation to traffic sources. The authors may explore the impact of traffic restrictions on nanoparticle concentrations and assess variations during pollution events. This research contributes insights into the dynamics of nanoparticles in urban air, particularly in the context of traffic-related pollution, and evaluates the efficacy of control measures in Delhi.

3.METHODOLOGY

- A domain of the study area 50km x 50km covering Delhi and surrounding regions has been selected.

- Height of Boundary: 300m[LINK]
- Average wind speed in Delhi is 2.4m/s.[LINK]
- **Initial co concentration =** 2.856 × 10^-5 mol/m³[LINK]
- **Estimation of CO emission from vehicles[LINK][LINK][LINK]**

1. Average Distance Travelled by Vehicles in delhi (km) (1)

2Wheelers: 12000/365 = 32.87

4Wheelers: 11000/365 = 30.13

Bus/Truck : 43800/365 = 120

2. Fuel Efficiency Per Vehicle Type (km/litre) (1)

2Wheelers:44
4Wheelers: 14
Bus/Truck: 5

Number Of daily Vehicles of Each Type (3)
2Wheelers:127000
4Wheelers: 307000
Bus/Truck: 32500

Average Fuel Emission Factor of CO (g/km) (4)
2Wheelers:15.7
4Wheelers: 20.9
Bus/Truck: 30

Two-Wheelers (2W):
Total distance traveled by all two-wheelers = Average distance traveled by one two-wheeler * Number of daily two-wheelers
Total distance = 32.87 km * 127,000 = 4,174,490 km

- **Total CO emissions from two-wheelers = Total distance * Emission factor per kilometer** = 4,174,490 km * 15.7 g/km =65539493 g = 65,539.43 kg

Four-Wheelers (4W):
Total distance traveled by all four-wheelers = Average distance traveled by one four-wheeler * Number of daily four-wheelers
Total distance = 30.13 km * 307,000 = 9,249,910 km

- **Total CO emissions from four-wheelers = Total distance * Emission factor per kilometer** = 9,249,910 km * 15 g/km = 184998200 g = 184,998.2 kg

Buses/Trucks:

Total distance traveled by all buses/trucks = Average distance traveled by one bus/truck * Number of daily buses/trucks
Total distance = 120 km * 32,500 = 3,900,000 km

Total CO emissions from buses/trucks = Total distance * Emission factor per kilometer = 3,900,000 km * 30 g/km = 117,000,000 g = 117,000 kg

Converting these total CO emissions from kilograms (kg) to moles (mol) we get:

<u>For Two-Wheelers (2W):</u>

Moles of CO emitted = Mass of CO emitted / Molar mass of CO

Moles of CO emitted = 65539.43 kg / 28.01 g/mol = 2340693.92 mol

<u>For Four-Wheelers (4W):</u>

Moles of CO emitted = 184998.2 kg / 28.01 g/mol = 6607078.57 mol

<u>For Buses/Trucks:</u>

Moles of CO emitted = 117,000 kg / 28.01 g/mol = 4178571.42 mol

Finally, calculate the total moles of CO emitted daily in Delhi:
Total moles of CO emitted = Moles emitted by 2W + Moles emitted by 4W + Moles emitted by buses/trucks
Total moles of CO emitted = 13126343.91 moles
Area Considered=50,000 m×50,000 m = 25 x 10^8 m^2
Flux of Co emitted in mol/m^3 = total moles of co emitted/ Area considered for study
We get 5.25 x 10^(-5) mol/m^2

- **For calculation of dispersion coefficients, we have used gaussian dispersion model discussed above**.

First we have find α_x, α_y and α_z under unstable, stable and neutral conditions and we have taken average of all the three conditions. Then, we need to substitute the values in the following equations :

$$\alpha_x^2 = \alpha_y^2 = \frac{2 \cdot Dy \cdot \varkappa}{u}, \; \alpha_z^2 = \frac{2 \cdot Dz \cdot \varkappa}{u}$$

On substituting the values of x and u we got,

D_X=D_Y= $0.133[0.2x^{0 \cdot 42} + 0.02x^{0 \cdot 39}]^2$

D_Z = $0.133[0.53x^{0 \cdot 23} + 0.15x^{0 \cdot 2} + 0.05x^{0 \cdot 11}]^2$

Where, x is downwind distance.

4.RESULTS

CASE STUDY: A Numerical Simulation of a Three-dimensional Air Quality Model in an Area Under a Bangkok Sky Train Platform Using an Explicit Finite Difference Scheme

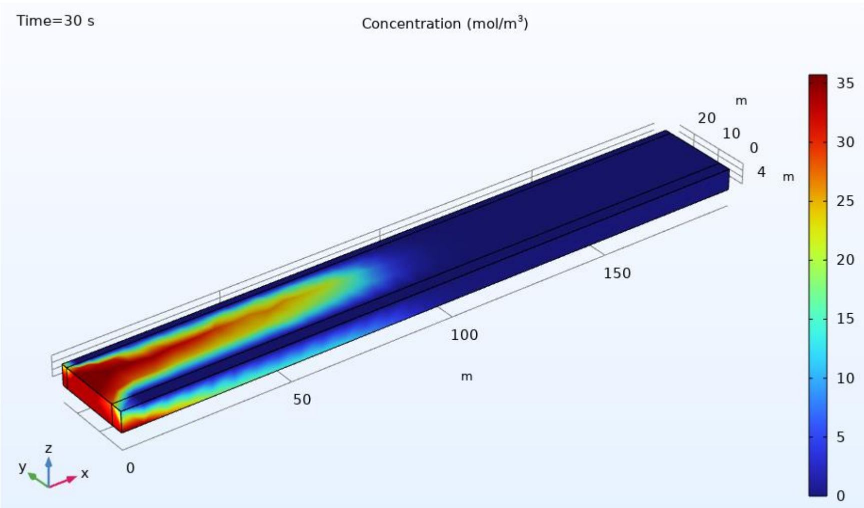
A region covered by Bangkok Transit System's Sky Train (BTS). We assume that there is just wind input in the x-direction for Cases I and II.

Case II is comparable to Case I, except it includes the tunnel's boundary requirements for impediments. We suppose that there is wind input in both the x and y directions for Case III.

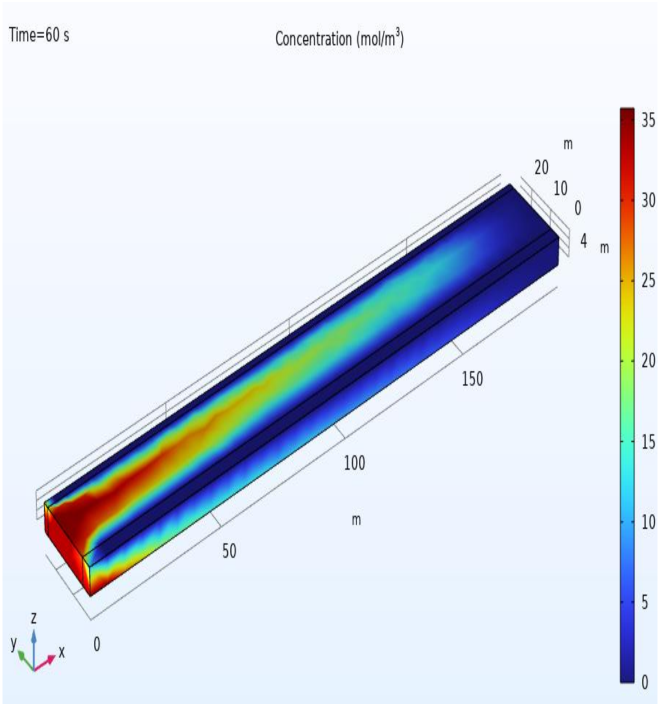
We take into account that the tunnel is 192 metres long, 26 metres wide, and 6 metres tall. Then, Ω = {(x, y, z); 0 ≤ x ≤ 192, 0 ≤ y ≤ 26, 0 ≤ z ≤ 6} is the issue domain.

CASE 1 To make the problem more realistic, the domain is expanded to include the parallel gaps that run down the tunnel between the ceiling and the buildings on both sides. The pace of change is thought to be slowed at the exit gate and parallel gaps. We address the three-dimensional advection-diffusion equation found in Eq, assuming that A = 4, B = 24, and c1 = 1.

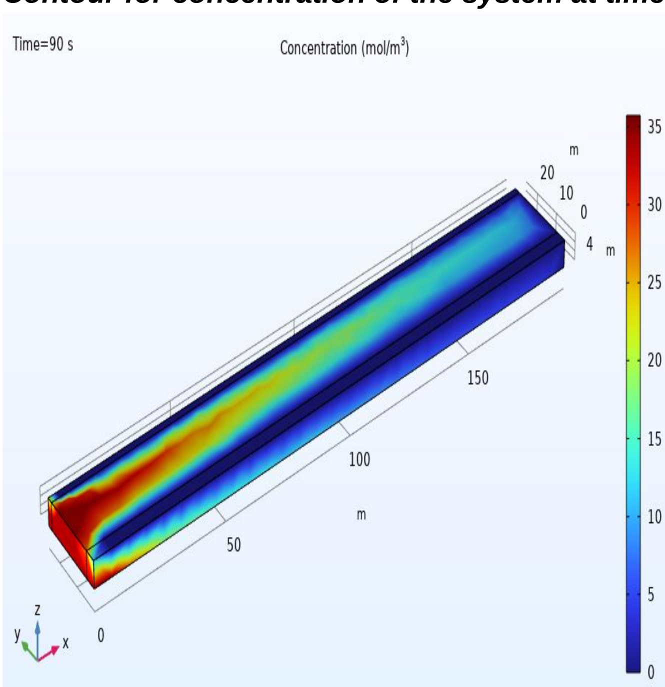
The concentrations of air pollutants after 30 seconds are displayed in contour and surface plots, respectively. Figures display the levels of air pollution after 120 seconds in both surface and contour plots. The numerical answers for Case I are displayed in those figures, where u = 2.7778 m/sec; v = 0 m/sec; z = 4 m; Δx = Δy = Δz = 2 m; Δt = 0.06 sec; Dh = 0.1592 m2 /sec; Dv = 0.05 m2 /sec. Our system's pollutant concentration will decrease as we give it more time.



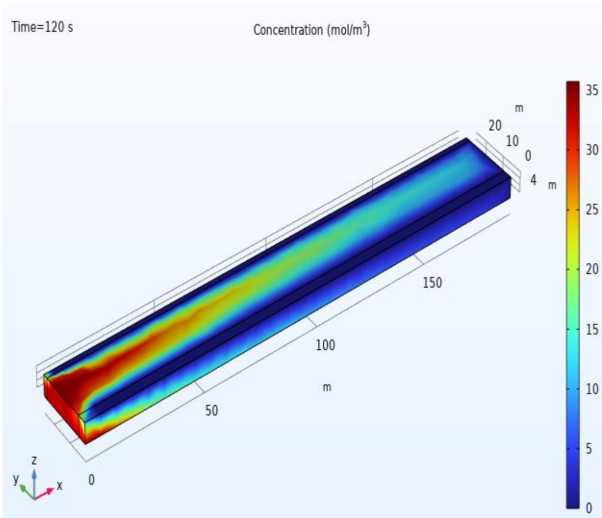
Contour for concentration of the system at time t=30sec

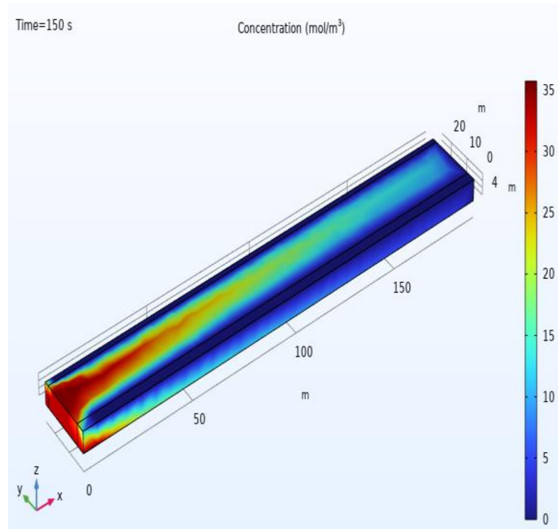


Contour for concentration of the system at time t=60sec



Contour for concentration of the system at time t=90sec





Contour for concentration of the system at time t=120sec

Contour for concentration of the system at time t=150sec

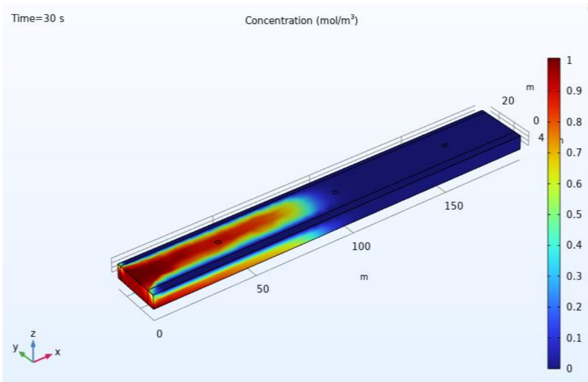
<u>**CASE-2**</u>

In actuality, there are barriers like columns. Thus, we shall include the barriers' border conditions in the tunnel. No rate of change is thought to exist at the columns. Assuming that $c1 = 1$, $c2 = c3 = -0.01$, $A = 4$, $B = 24$, $D1 = 41$, $D2 = 101$, $D3 = 161$, and $E = 14$, we examine the three-dimensional advection-diffusion equation . The air pollutant concentration levels after 30 seconds are displayed in contour plot and surface plot, respectively, in Figures . The concentration levels of air pollutants in contour and surface plots, respectively, are displayed after 120 seconds in Figures , respectively.

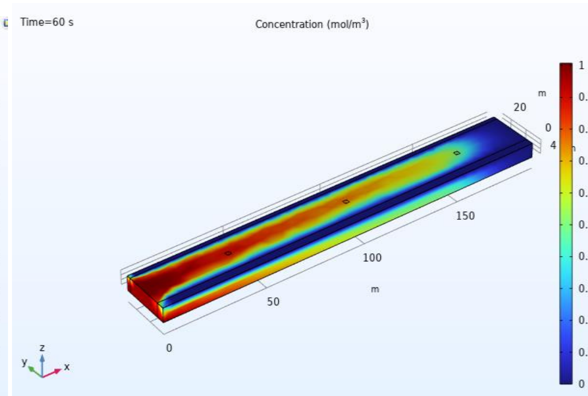
In Case II, where $\Delta x = \Delta y = \Delta z = 1$ m; $\Delta t = 0.06$ sec; $Dh = 0.1592$ m2 /sec; $Dv = 0.05$ m2 /sec; $u = 2.7778$ m/sec; $v = 0$ m/sec; $z = 4$ m, those figures depict the numerical answers. The findings are satisfactory; the concentration of pollutants decreases with distance from the source.

Contour for concentration of the system at time t=30sec

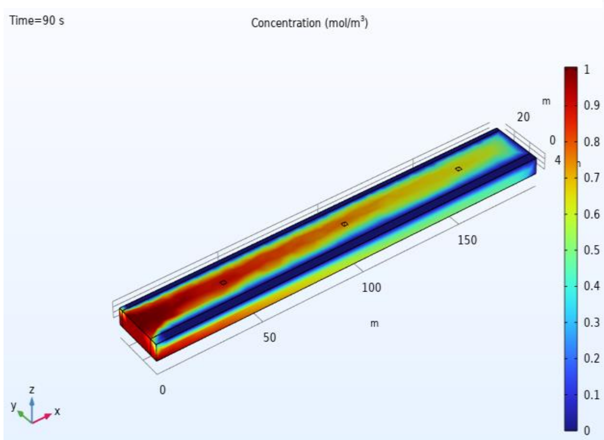
Contour for concentration of the system at time t=30sec



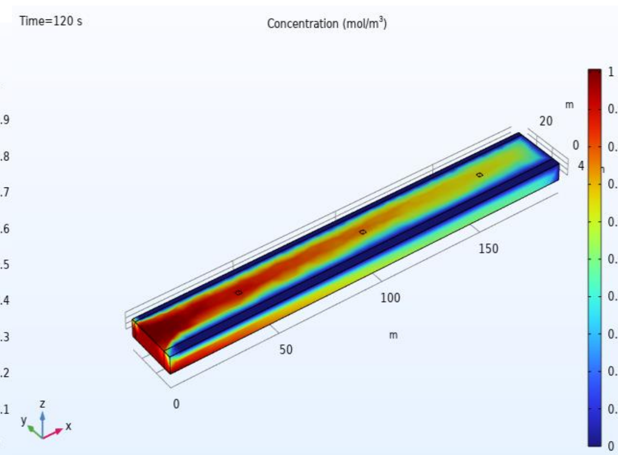
Contour for concentration of the system at time t=30sec



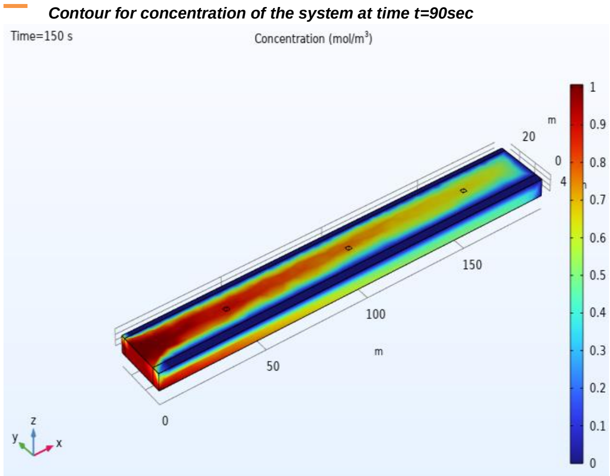
Contour for concentration of the system at time t=0sec



Contour for concentration of the system at time t=90sec



Contour for concentration of the system at time t=120sec

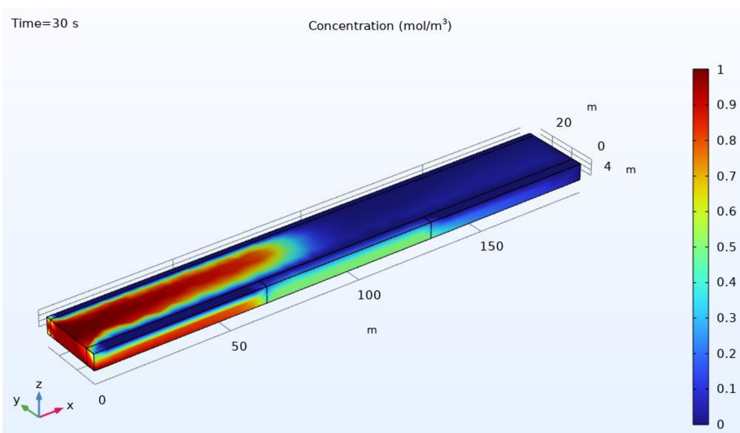


Contour for concentration of the system at time t=150sec

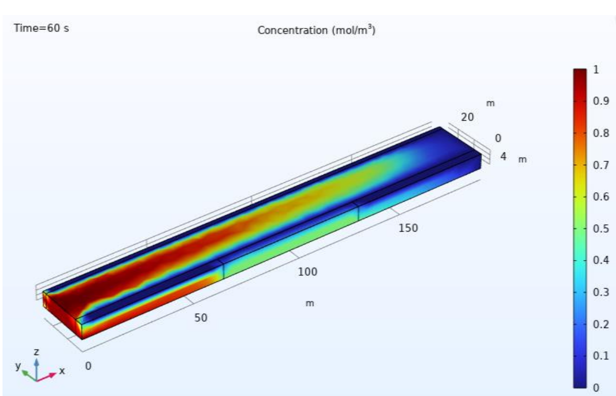
CASE-3

In this case, the wind input is taken into account in both the x and y directions. Put another way, we'll add u in the x direction and v in the y direction. We take into consideration the three-dimensional advection-diffusion equation found in Eq. (2), with the following assumptions: A = 4, B = 24, F = 64, G = 129, and c1 = 1. The air pollutant concentration levels after 30 seconds are displayed in contour plot and surface plot, respectively, in Figures. Figures depict the concentration levels of air pollutants in a contour plot and surface plot, respectively, after 120 seconds.

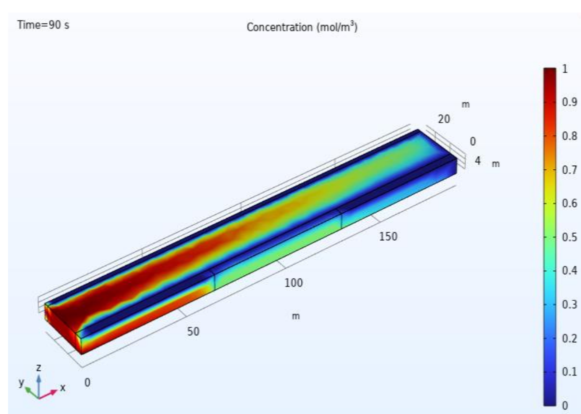
The numerical answers for Case III are displayed in those figures, where u = 2.7778 m/sec; v = u 20 m/sec; z = 4 m; $\Delta x = \Delta y = \Delta z = 2$ m; $\Delta t = 0.06$ sec; Dh = 0.1592 m2 /sec; Dv = 0.05 m2 /sec. The pollutant concentrations are calculated to decrease with proximity to the source, yielding appropriate results.



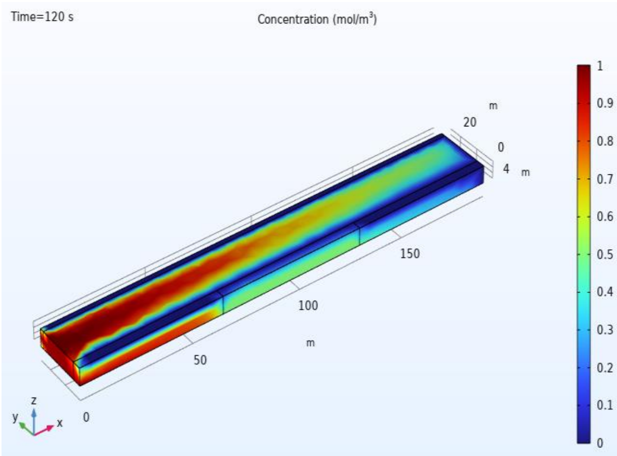
Contour for concentration of the system at time t=30sec



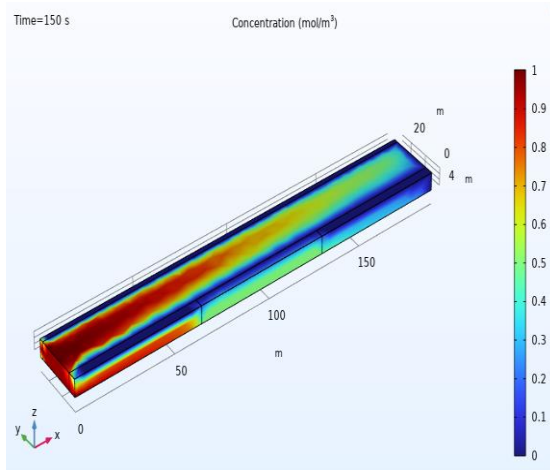
Contour for concentration of the system at time t=60sec



Contour for concentration of the system at time t=90sec

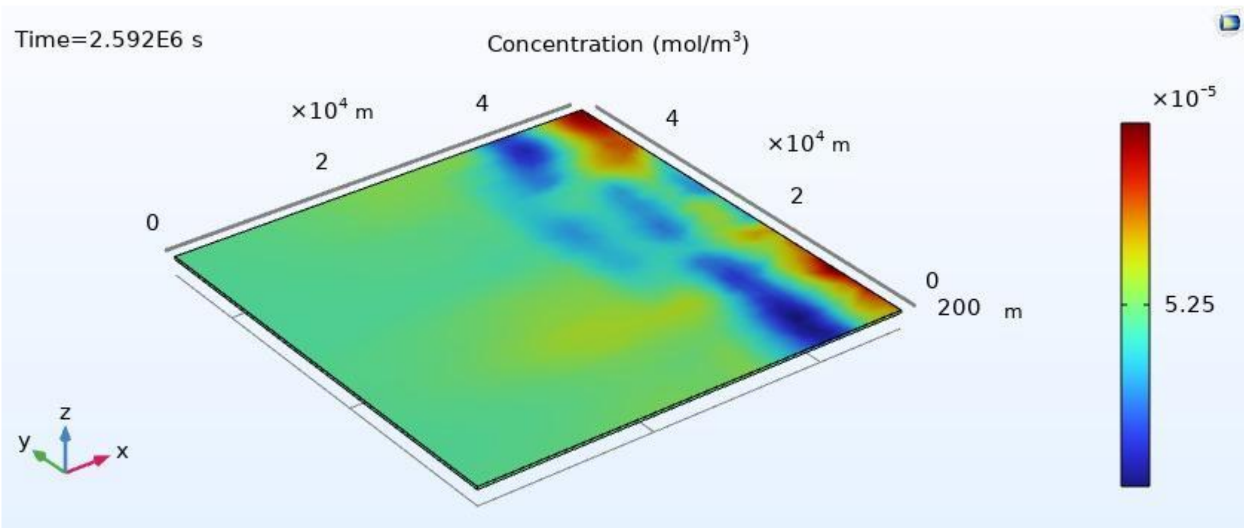


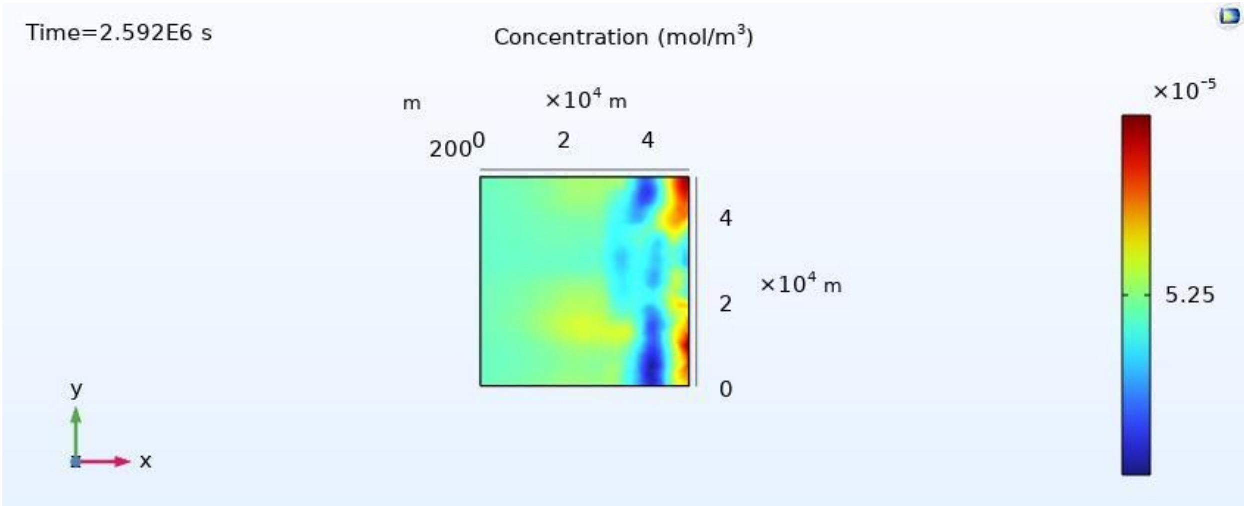
Contour for concentration of the system at time t=120sec



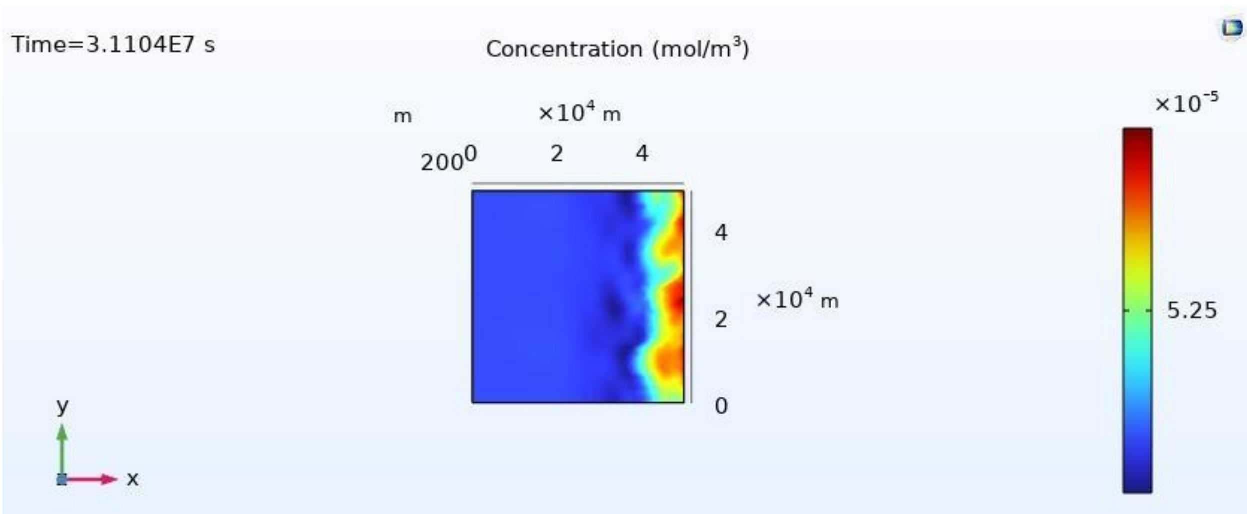
Contour for concentration of the system at time t=150sec

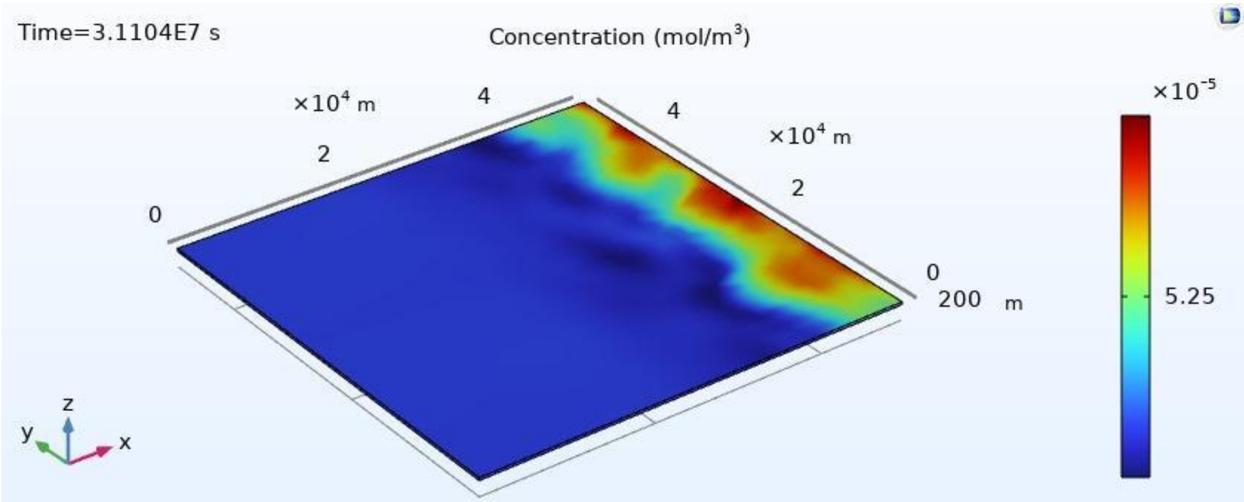
CASE STUDY FOR DELHI AIR POLLUTION DUE TO VEHICULAR EMISSION





Top & isometric view of the Delhi pollution case study simulation @ different times





5.CONCLUSION AND RECOMMENDATIONS

The simulation of atmospheric pollution from vehicular emissions in Delhi provides valuable insights into the distribution and concentration of pollutants. Findings reveal specific areas with elevated pollution levels, emphasizing the urgent need for comprehensive mitigation measures.

The analysis indicates that vehicular emissions significantly contribute to air quality deterioration in Delhi, impacting public health and the environment. The simulation acts as a crucial tool for understanding the dynamics of pollution, aiding policymakers and stakeholders in informed decision-making.

Recommendations:

1. **Promote Public Transportation:** To minimise total emissions, lower the number of private automobiles on the road by encouraging the use of public transportation.

2. **Implement Strict Emission limits**: To guarantee a cleaner fleet on the roads, impose stringent emission limits for automobiles and periodically check and enforce compliance.

3.**Adopt Electric cars:** Encourage the use of electric cars to lessen the dependency on conventional fossil fuel-powered vehicles, which will lower emissions and air pollution.

4. **Traffic Management Strategies**: Reduce traffic congestion and idle hours, which are major contributors to emissions, by implementing sophisticated traffic management systems to optimise traffic flow.

5. **Green Spaces and Urban design:** To lessen the effects of pollution, expand the amount of green space in the city and use urban design techniques that give priority to sustainable development.

6.REFERENCES

- G.M.D. Joseph , D.M. Hargreaves , I.S. Lowndes . Reconciling Gaussian plume and Computational Fluid Dynamics models of particulate dispersion. Atmospheric Environment: X 5 (2020) 100064.
- Weilin Ye , Bo Zhou , Zihan Tu , Xupeng Xiao , Jingwen Yan , Tao Wu , Fupei Wu , Chuantao Zheng, Frank K. Tittel. Leakage source location based on Gaussian plume diffusion model using a near-infrared sensor. Infrared Physics & Technology 109 (2020) 103411.
- Youchen Shen, Kees de Hoogh, Oliver Schmitz , Nicholas Clinton , Karin Tuxen-Bettman, Jørgen Brandt, Jesper H. Christensen , Lise M. Frohn , Camilla Geels , Derek Karssenberg , Roel Vermeulen, Gerard Hoek . Europe-wide air pollution modeling from 2000 to 2019 using geographically weighted regression. Environment International 168 (2022) 107485.
- Chang Liu , Ru Zhou , Teng Su , Juncheng Jiang . Gas diffusion model based on an improved Gaussian plume model for inverse calculations of the source strength. Journal of Loss Prevention in the Process Industries 75 (2022) 104677.

- Sha Hea , Sanyi Tanga , Qimin Zhang , Libin Rongc , Robert A. Cheke . Modelling optimal control of air pollution to reduce respiratory diseases. Applied Mathematics and Computation 458 (2023) 128223.
- Miguel Alvarado-Molina , Ariadna Curto , Amanda J. Wheeler , Rachel Tham , Ester Cerin , Mark Nieuwenhuijsen, Roel Vermeulen, David Donaire-Gonzalez. Improving traffic-related air pollution estimates by modelling minor road traffic volumes. Environmental Pollution 338 (2023) 122657.
- Khoi Quang Ngo, Le Anh Hoang, Bang Quoc Ho , Neil R.P. Harris , Gillian H. Drew , Mohammed Iqbal Mead . Street-scale dispersion modelling framework of road-traffic derived air pollution in Hanoi, Vietnam. Environmental Research 233 (2023) 116497.
- Ajay Singh Nagpure , B.R. Gurjar . Development and evaluation of Vehicular Air Pollution Inventory model.Atmospheric Environment 59 (2012) 160-169.
- Jianlei Lang , Xiaoyu Liang , Shengyue Li , Ying Zhou , Dongsheng Chen , Yanyun Zhang , Lanting Xu .Understanding the impact of vehicular emissions on air pollution from the perspective of regional transport: A case study of the Beijing-Tianjin-Hebei region in China.Science of The Total Environment 785 (2021) 147304.
- Moaad Khamlich , Giovanni Stabile, Gianluigi Rozza, László Környei , Zoltán Horváth. A physics-based reduced order model for urban air pollution prediction . Computer Methods in Applied Mechanics and Engineering 417 (2023) 116416.
- Ioannis Manisalidis, Elisavet Stavropoulou, Agathangelos Stavropoulos, and Eugenia Bezirtzoglou. Environmental and Health Impacts of Air Pollution: A Review. Front Public Health (2020) 8: 14 .
- Pravitra Oyjinda and Nopparat Pochai. Numerical Simulation to Air Pollution Emission Control near an Industrial Zone. Qualitative and Quantitative Techniques for Differential Equations Arising in Mathematical Physics (2017) 5287132.
- Paolo Zannetti Failure Analysis Associates, Inc., 149 Commonwealth Drive, Menlo Park, California 94025, USA. Numerical simulation modeling of air pollution: an overview. WIT Transactions on Ecology and the Environment 1 (1993) 9.
- Xinping Yang , Hefeng Zhang, Wei Li , Hong Tian , Yongdong Wang , Jing Zhou , Ze Bao , Xiaorui Chen , Teng Xiao , Yunjing Wang, Mingliang Fu, Xian Wu, Han Jiang , Hang Yin , Yan Ding. Reduction potential of vehicular

emission in Chengdu, China: A case study of COVID-19.Urban Climate 51 (2023) 101607.

- Kanagaraj Rajagopal, S. Ramachandran , Rajeev Kumar Mishra. Roadside measurements of nanoparticles and their dynamics in relation to traffic sources in Delhi: Impact of restrictions and pollution events. Urban Climate 51 (2023) 101625.
- Goel, R., & Guttikunda, S. K. (2015). Evolution of on-road vehicle exhaust emissions in Delhi. Atmospheric Environment, 105, 78-90.
- Jaiprakash, Habib G, Kumar A, Sharma A, Haider M. On-road emissions of CO, CO2 and NOX from four wheeler and emission estimates for Delhi. J Environ Sci (China) 53 2017 39-47.
- Goyal, P., Mishra, D. & Kumar, A. Vehicular emission inventory of criteria pollutants in Delhi. SpringerPlus 2 (2013) 216.