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A Review on Atmospheric Dispersion System for Air Pollutants Integrated with GIS in Urban Environment

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ABSTRACT

The objective of this article is to present comprehensive findings and analysis of studies performed on air pollutant dispersion in urban environments. It captures India's rising environmental pollution due to urbanization, industrialization, and population growth. Dispersion of pollutants due to the wind in the lower Atmospheric Boundary Layer (ABL) is a major concern nowadays. The dispersion field around the buildings is a critical parameter to analyze and it primarily depends on the correct simulation of the wind flow structure. Therefore, studies performed on this in past years are being reviewed. Additionally, a brief review of different air dispersion models that are integrated with the Geographic Information System (GIS) has been studied in this article to assess the exposure. The results of these studies provide the urban air dispersion model aligning to three sub-models i.e., Emission, Weather Prediction, and Dispersion models. Various factors like wind speed, wind direction, cloud cover, traffic emission, disposal of waste, transportation, and others are considered. This study also captures the problems and risks being faced while creating a model, and its possible mitigation approaches.

INTRODUCTION

Ambient air pollution is estimated to cause 7 million deaths per year (WHO 2018). Air pollution has been linked to a variety of health problems according to several epidemiological reports. Several studies since March 2020 have also revealed that COVID-19 development was substantially higher in cities or regions where certain air contaminants were detected at comparatively higher levels and are the main cause of traffic and industrial pollution (Domingo et al. 2020).

In 2010, the Central Pollution Control Board (CPCB) created the Comprehensive Environmental Pollution Index (CEPI), a system for measuring air, water, and soil pollution in the country's industrial clusters. In collaboration with the Ministry of Environment and Forestry, CPCB established 43 critically polluted CEPI-based industrial clusters after reviewing the environmental conditions in 88 industrial clusters across India (CPCB 2016). Contributions to vehicle emissions are primarily urban (on-road), but rural areas can also be affected by off-road agricultural sources (Guttikunda et al. 2014). Emissions of primary particulate from residential combustion sectors are more common in rural and low-income urban areas, where people depend more on traditional biomass for cooking and heating.

The 2014 Intergovernmental Panel on Climate Change (IPCC) reveals that the total emission of greenhouse gases from 1970 to 2010 increased by 78% from manufacturing processes and fossil fuel combustion. Since the 1970s, CO_2 emissions have more than doubled, and have risen by 40% since 2000. Even though CO_2 emissions remained stable from 2013 to 2016, they increased by 1.5% in 2017 and are continuing to rise, led by China, India, and the European countries (Anwar et al. 2020). Another major global concern is Polyaromatic Hydrocarbon (PAH) as it gets linked to PM2.5 and ultrafine fractions of airborne particulates cause severe health risks (Mohanraj et al. 2011).

In urban areas, pollutant dissemination in the lower Atmospheric Boundary Layer (ABL) by the wind flows is a major concern. The dispersion of pollutants represents a very important environmental drawback with respect to human health. Depending on their chemical and physical properties (e.g., chemical structure, water solubility, etc.), these air pollutants may travel hundreds, even thousands of kilometers from their release worldwide.

To save human lives and reduce economic losses, computer models of air pollutant dispersion are being developed to explain and predict the result of such events and incidents.

The goal of the model-driven work represented during this paper is to develop a decision support system to cut back the impact of pollution caused by road traffic. Such a simulation coming up with a system consists of a comprehensive air-quality prediction model supported by data management, a mathematical model, and a friendly interface, integrated with GIS that uses spatial coordinates to explain the structure of urban areas, road networks, and waste product distribution within the atmosphere (Gualtieri & Tartaglia 1998). The use of a GIS integrated system is very common in research on a regional-local scale (Gulliver & Briggs 2011).

ATMOSPHERIC BOUNDARY LAYER OVERVIEW

Structure of Atmospheric boundary Layer and Turbulence

In meteorology, the lowest component of the atmosphere is the ABL, also known as the Planetary Boundary Layer (PBL), and its action is directly affected by its interaction with a planetary surface (Bonner et al. 2010). ABL can change both in space and time, depending on the orography. Also, it changes with surface cover, season, daytime, and weather (Gifford 1976). It experiences a daily cycle of changes in temperature, humidity, wind, and pollution variations in response to various fluxes in the air (Stull 2017).

Oke (1976) initially proposed a simple and two-layer model of the urban atmosphere, which recognizes the Urban Canopy Layer (UCL) and the Urban Boundary2 Layer (UBL) respectively. The first layer, called the Urban Canopy, consists of air in between the urban roughness elements (mainly building). The second layer, located directly above the first, is referred to as the urban boundary layer. This is the phenomenon that exists in local or mesoscale concepts (Oke 1976). A Roughness Sub-Layer (RSL) near the ground, also known as the Transition layer, and an Inertial Sub-Layer (ISL) above it make up this layer (Fisher et al. 2006).

The turbulence induces vertical mixing between horizontally moving air at one stage which is important in the dispersion of pollutants (Stull 2017). The ABL height is crucial in the dispersal of air pollution. The main environmental factors of urban turbulence are the roughness of the urban surface, buildings, trees, and other large structures (Roth 2000). There is a need of modelling the flow as a homogeneous flow essentially by well reproducing the turbulence profiles including the wind velocity profile (Cai et al. 2014). The relationship between wind speed and height is called the wind profile. It can be expressed as:

$$\frac{du}{dz} = \frac{u_*}{l} \quad \ldots(1)$$

u_*- the local friction velocity (proportional to the square root of the local Reynolds stress)

l - the length scale (function of the state of the atmosphere and height)

Turbulent mixing in the atmosphere is induced by wind shear and buoyancy. Defining categories including radiation parameters, surface roughness, wind intensity, and cloud cover is an easy method for measuring turbulence parameters. Pasquill's commonly used approach describes six stability levels from the extremely unstable (6) to the relatively stable (1) based on wind direction, sunrise, and cloud cover (Turner 1997, Pasquill 1961) (Figs. 2 and 3).

Fig. 2 & 3: Pasquill stability class: unstable (1), slightly unstable (2), neutral (3), slightly stable (4), stable (5), and very stable (6) boundary layer. Neutral (3) class has been used for overcasting conditions and within one hour after sunrise/before sunset (Luna & Church 1972).

Flow of Wind Around Buildings

Wind currents over buildings are inherently complicated, exhibiting a wide variety of physical phenomena such as

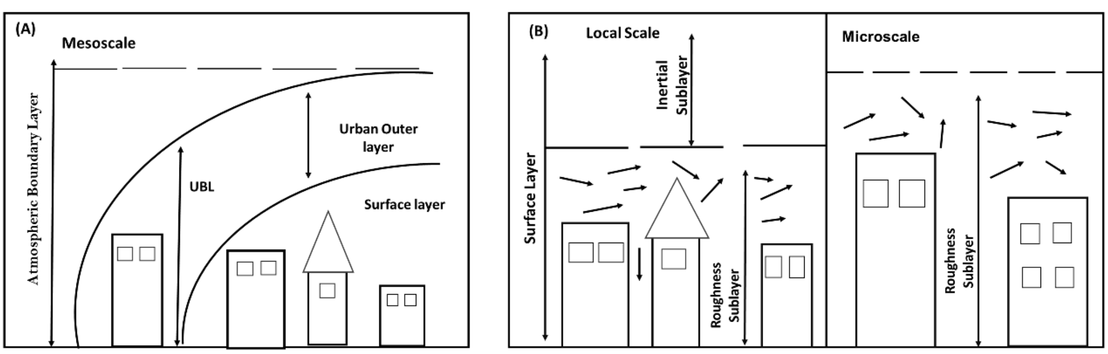

Fig. 1: Diagrammatic representation of the urban boundary-layer (A, B) (Adapted from Piringer et al. 2007).

high-pressure gradients, large low-speed fields, three-dimensional impacts, turbulent flow zones, and boundary layers (Deck 2005). It is obvious that proper modeling of pollutant dispersion within a group of buildings continues to be a very complex issue, as wind movement in a metropolitan environment can have significant effects on pollutant dispersion across buildings (Zhang et al. 2005). Moreover, the issue becomes more complicated due to the diversity and complexity of the mixture of emission sources, such as industries, automobiles, generators, domestic fuel combustion, roadside dust, construction activities, etc. Therefore, a precise concentration forecast of contaminants released into the urban environment is needed to understand the mechanisms regulating the pollutants' dispersion (Tseng et al. 2006). Several methods along with GIS have been widely used to research the pollutant dispersion around urban buildings.

GIS Overview

A GIS is a computer application that captures, stores, analyzes, and displays data about locations on the Earth's

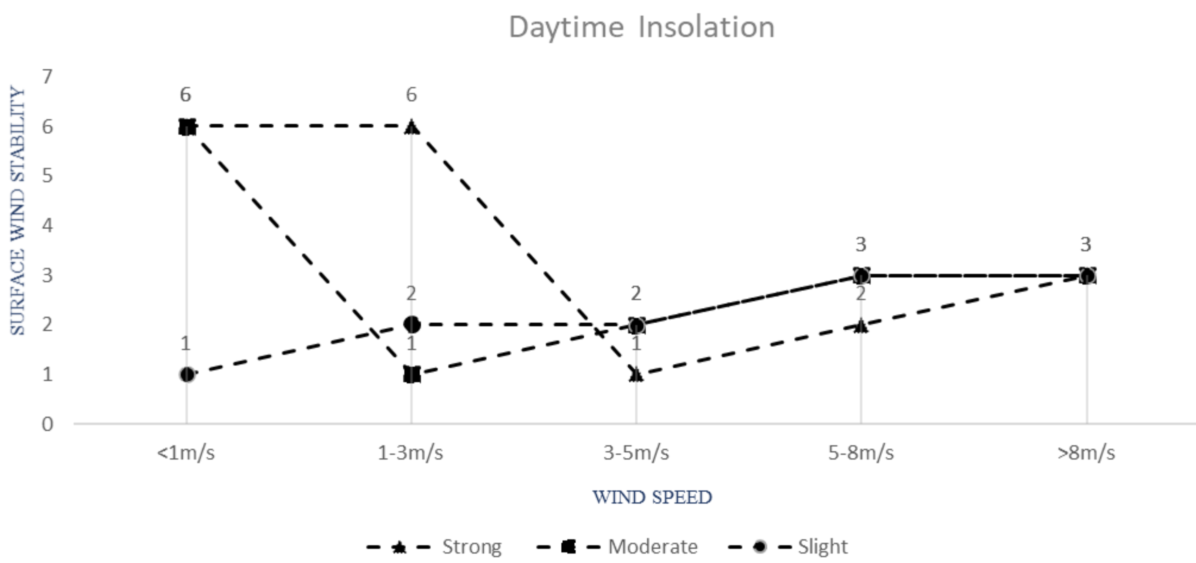

Fig. 2: Daytime insolation.

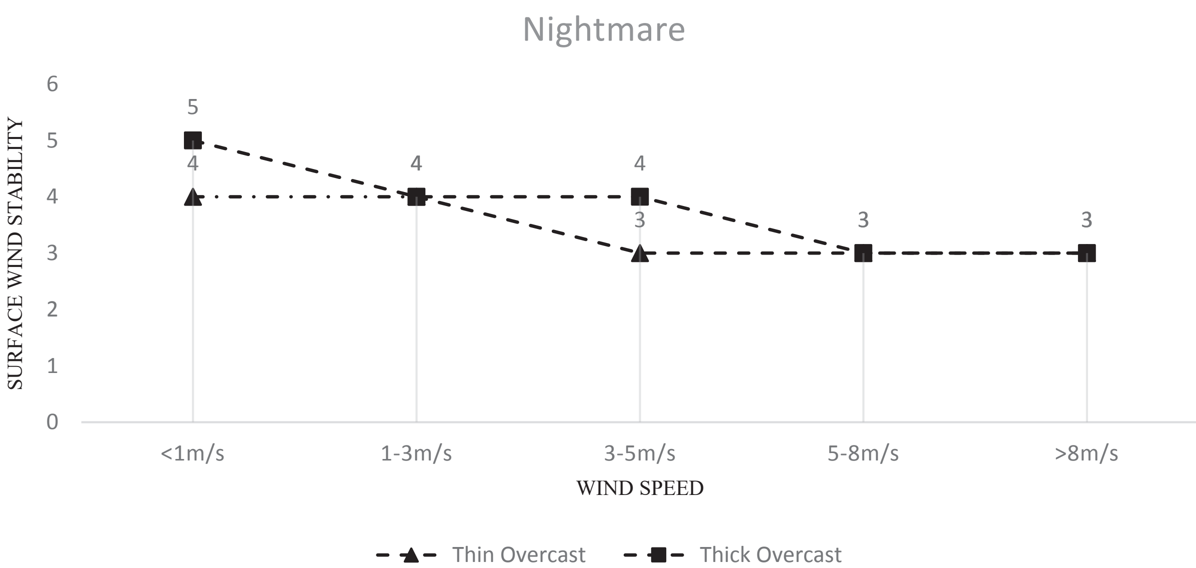

Fig. 3: Nightmare.

surface. It is a multi-layered approach to representing data from multiple sources and connecting spatial and non-spatial information. The analysis of spatial data and handling of massive spatial databases are the advantages of GIS over other information systems. There is a vast amount of data that can help deal with air pollution (Gualtieri & Tartaglia 1998).

MODEL STRUCTURE

The GIS integrated air dispersion model consists of the whole database and mathematical models. These models work in a cascade manner that has different parameters. These can be used as an input for the emission model and its output in turn is necessary to stimulate pollution levels of the dispersion models. It consists of 3 different sub-models i.e., emission, weather prediction, and dispersion models (Gulliver & Briggs 2011). Each of the mandatory model components and related data is described, separately below.

Emission Model

The emission model has been developed on the idea of the consequences shown by Joumard et al. (1992), Eggleston et al. (1991), and Tartaglia (1995). There are multiple sources of pollution in urban areas, where traffic, manufacturing industries, and the open burning of waste contribute significantly to it.

The emission model can calculate traffic-associated pollutants like - Carbon Monoxide (CO), Hydrocarbons (HC), Nitrogen Oxides (NOx), and others. It represents the number of released pollutants and the activity associated with the release of pollutants. The formula is used to calculate total pollutant emission Q provided by traffic flow 'f' for N vehicular groups.

$$Q = \sum_{g=1}^{N} \frac{Cg}{100} \text{ x } E_g(V_m) \text{ x } f \qquad \ldots(2)$$

Where:

C_g - the percentage of vehicles in category g in terms of vehicle feet.

E_g -The emission factor due to road vehicles belonging to group g-traveling in the typical road and environmental conditions & is expressed as the mass of pollutant per unit length (m.L^{-1}) as a function of the average travel speed V_m (Gualtieri & Tartaglia 1998).

Most emissions emitted by manufacturing industries are due to the use of fossil fuels, a major source of emissions from the manufacturing sector. Overall, the share of emissions during the period varies between 65% and 75%; and was found that carbon emissions represent nearly 70% of total fuel consumption emissions. The formula used to calculate the emission is as follows.

$$Egas = Afuel * C.Vunit * C.Vfuel * E.Fgas * GWPgas \qquad \ldots(3)$$

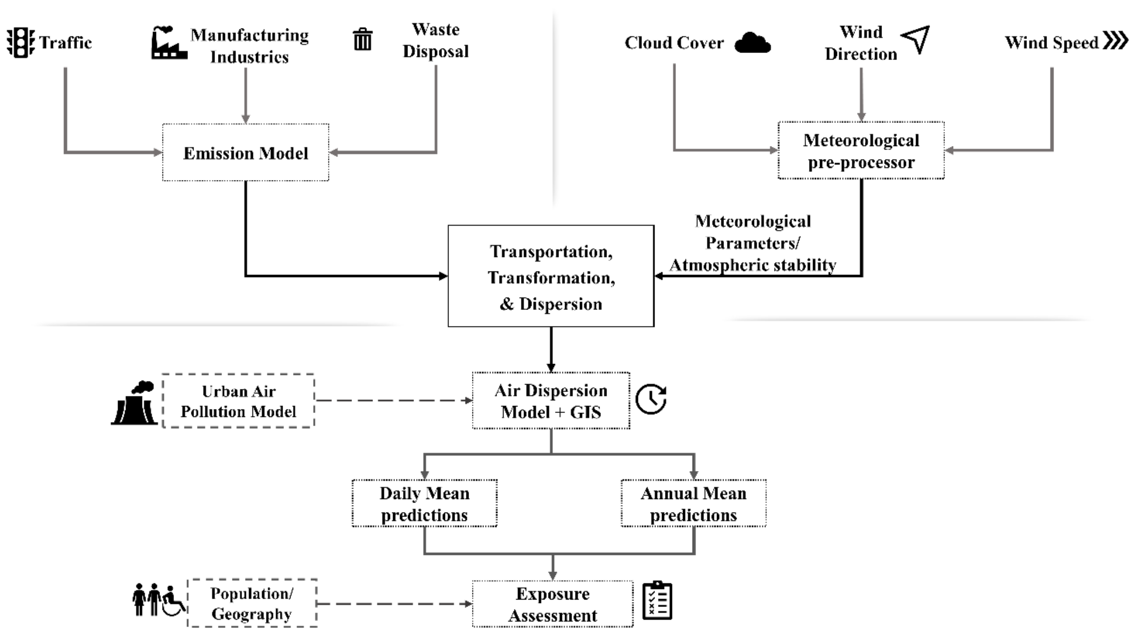

Fig. 4: The GIS-based dispersion model (based on Gullliver & Briggs 2011).

Where:

Egas: Emission of greenhouse gas(es) in a ton

Afuel: Activity data of fuel (in L.kg.ton^{-1})

C. Vunit: Conversion factor(s) to convert activity data to ton (please refer to Appendix 1)

C.V. fuel: Calorific value of fuel (a ton of energy in Tera Joule (TJ) per ton of fuel

E. Fgas: Emission factor of GHG gas due to combustion of the fuel (a ton of gas.TJ^{-1} (gas.TH^{-1} of energy input)

GWPgas: Global warming potential of gas

Open burning of waste is a possible nonpoint source of emissions, causing major concern, particularly in urban areas, and pollutants that are released are Carbon monoxide, Particulate matter, Sulphur dioxide, Nitrogen oxide, etc. Waste produced depends on factors such as population, livelihood, season, way of life, topography, and industry. The equation used to estimate the emission of pollutants was given as shown below (NEERI 2010).

Amount of Pollutant emitted (P) = SWB x EF …(4)

Where:

P = Amount of pollutant emitted (Kg.day^{-1}, g.day^{-1}, or µg.day^{-1})

SWB = Solid Waste Burned (MT.day^{-1})

EF = Emission Factor (Kg.MT^{-1}, g.MT^{-1}, or µg.MT)

Meteorological Pre-Processor and Weather Prediction Models

The weather forecast refers to the use of science and technology to estimate the future condition of the environment in relation to a specific area or location (pressure, temperature, etc) (Yerramilli et al. 2011). While various methods are available, quantitative weather forecasts are provided by numerical models alone. Such models employ a closed system of mathematical equations based on mass, momentum, and water vapor conservation, as well as the equation of state and thermodynamic energy for differential temperature. To solve these equations mathematically, the study area should be formulated in a rectangular shape with an evenly spaced horizontal intersecting grid in the horizontal direction and appropriate vertical levels for numerical solution.

Due to limitations in mathematical formulation, numerical setup, and computing tools, the horizontal grid resolution is limited to a few miles. As the atmospheric model comprises dynamic and physical components, it is important for these processes such as planetary boundary layer, atmospheric radiation, convection, face physics, and cloud microphysics must be parameterized on a smaller scale.

Anomalies in weather forecasting and a rise in errors as prediction progress are caused by measurement errors, model grid interpolation, flaws in the presentation of physical processes, and mistakes due to numerical solution methods. Rapid developments in computational resources have resulted in the design and implementation of atmospheric models as suitable for real-time weather forecasts of different weather phenomena with scales from a few kilometers to thousands of kilometers. There are many weather prediction meteorological models available and the mainly used ones are the RAMS, MM5, and WRF (Yerramilli et al. 2011). The following is a summary of these models.

Dispersion Model

Air pollution models are the only tool that quantifies the deterministic relationship between emissions and concentrations or depositions, including the effect of past and future scenarios and determining the efficiency of reduction strategies. Measurements of air pollution provide information on atmospheric concentrations and deposition at specific places and times, but they do not provide clear guidance on identifying the causes of the air quality issue. Transport, absorption, chemical transformation, and ground deposition all play a role in determining the atmospheric concentrations of substances. Atmospheric pollutants are carried over longer distances by large-scale atmospheric wind currents and then released into the atmosphere by small-scale turbulent

Table 1: List of different weather prediction models.

Model	Developer Name	Features	Function
RAMS	Colorado State University	Highly versatile numerical code	To simulate and forecast meteorological phenomena
MM5	Written in Fortran and developed at Penn State and NCAR	Non-hydrostatic, Terrain-following sigma-coordinate model	To simulate mesoscale atmospheric circulation (Grell et al. 1995) To predict weather forecasts and climate projections
WRF	National Centre for Atmospheric Research (NCAR)	The prognostic variables and completely compressible non-hydrostatic equations	

Note. RAMS: Regional Atmospheric Modelling System; MM5: Mesoscale Model; WRF- Weather Forecasting and Research flows, where they mix with the environment. The turbulence dynamics and turbulent diffusion are commonly considered intractable, even under laboratory conditions (Yerramilli et al. 2011). The atmospheric dispersion is influenced by weather factors, as transport is driven by wind flows and dispersal by air stability, vertical mixing, and mesoscale winds. There is no general full formula describing the physical relationship between the atmospheric air emission concentrations and the meteorological causative factors and processes. Overall, modeling data reduces the expense of continuous monitoring over vast areas and over longer periods of time.

Box Model

The mass-conservation principle is used in box models. The site is treated like a box that releases toxins and undergoes physical and chemical processes. It needs simple meteorology and emissions input, and it allows contaminants to flow into and out of the box. The inside of the box is not specified, and the air mass is handled as if it is well mixed with uniform concentrations (Holmes & Morawska 2006). This model, on the other hand, simulates the accumulation of contaminants inside the box after initial conditions are entered, but it does not include any details about the pollutants' local concentrations. For this reason, they are inappropriate for modeling particle concentrations in a local environment where concentrations and therefore particle dynamics are highly influenced.

Lettau (1970) proposed for the first time a simple urban air quality box model, in which the concentration decreases exponentially and reaches its balance value. It is calculated as:

$$\mathrm{c} = \mathrm{b} + \frac{\mathrm{ql}}{\mathrm{uH}} \qquad \ldots(5)$$

Where:

c - Pollutant concentration in air living box

b - Pollutant concentration in entering air

q - Pollutant mass emission rate per unit area in the city

l - Length of the box in direction of the wind

u - Wind speed

H - Mixing Height

Gaussian Model

The Gaussian plume model is the air emission dispersion model most used. This fits well with the majority of field and laboratory evidence while there are frequent non-systemic variations from a Gaussian distribution. This model is commonly used in atmospheric dispersion modeling, especially for regulatory purposes, and is frequently "nested" in Lagrangian and Eulerian models (Leelossy 2014). Under steady-state conditions, these models are based on a vertical and horizontal Gaussian distribution of the plume (Zhang et al. 2000) And are described as follows:

$$C(x,y,z,h_e) = \frac{Q}{2\pi\sigma_y\sigma_z}\exp\left(-\frac{1}{2}\left(\frac{y}{\sigma_z}\right)^2\right)\left(\exp\left(-\frac{1}{2}\left(\frac{z-h_e}{\sigma_z}\right)^2\right)+\exp\left(-\frac{1}{2}\left(\frac{z+h_e}{\sigma_z}\right)^2\right)\right) \qquad \ldots(6)$$

Where:

C - Concentration level (ug.m^{-3}, or as a ratio in fraction or ppm),

x – Distance downwind from the source (m),

y - Distance perpendicular from the source(m),

z - Elevation of the destination point (m),

h_e - Elevation of the source (m),

Q- Release rate of pollutant (mass emission rate – g.s^{-1}, or volumetric flow rate -m^3.s^{-1}),

u - Average wind speed (m.s^{-1}),

σ_y and σ_z - Diffusion parameters in the y and z directions (both in m)

The term $\frac{Q}{(2\pi\sigma_y\sigma_z)}$ is the centreline concentration; $\exp(-\frac{1}{2}\left(\frac{y}{\sigma_z}\right)^2$ accounts for off-axis location; $\exp\left(-\frac{1}{2}\left(\frac{z-h_e}{\sigma_z}\right)^2\right)$ accounts for the source elevation above the ground surface; and $\exp\left(-\frac{1}{2}\left(\frac{z+h_e}{\sigma_z}\right)^2\right)$ treats the ground surface as a perfect reflector, absorbing none of the pollutants.

The plume width is determined by σ_y and σ_z, which are defined either by stability classes (Pasquill 1961, Gifford 1976) or travel time from the source.

Since plume models use constant approximations, they do not account for the time taken for the pollutant to migrate to the receptor, which is a significant limitation in terms of particle dispersion modeling (Yerramilli 2011). Although most Gaussian models still consider the diffusion and advection of contaminants, moreGifford advanced Gaussian models have recently been established that include physical processes such as deposition and rapid chemical reactions. Further disadvantages of the Gaussian approach include the fact that it is unable to model dispersion under low wind conditions or at locations close to the source, i.e., distances less than 100 m.

Lagrangian Model

The formulation of air dispersion can vary significantly from one model to another. The Lagrangian and Eulerian solutions are the most known methods (Holmes & Morawska 2006). Lagrangian models are like box models and describe a region of air as a box containing an initial pollutant concentration (Leelossy 2014). This approach is focused on the estimation of wind trajectories and the transport of air parcels along the paths. In source-oriented models, trajectories are calculated over a period after the source releases an air parcel containing contaminants (forward trajectories from a fixed source) before it reaches the receptor location. The trajectories in receptor-oriented models are calculated backward in time from the arrival of an air parcel at a suitable receptor (backward trajectories from a fixed receptor). This model works well over flat terrain for both uniform and stationary conditions (Tsuang 2003) as well as for non-uniform and unstable media conditions for complex terrain (Jung et al. 2003). Meteorological data are used to measure the variance of wind velocity variations and the Lagrangian autocorrelation function. Because Lagrangian particle models measure diffusion characteristics by producing semi-random numbers, they are not limited to stability groups or sigma curves, as is the case with Gaussian dispersion models (Holmes & Morawska 2006).

Eulerian Model

The 3-dimensional atmosphere in the Eulerian system is divided into horizontal and vertical grid cells. Each grid cell defines changes to the times and thus is called "grid models". This modeling has been adopted for ozone studies (Reynolds et al. 1973) and SO2 studies (Shir & Shieh 1974) in urban areas. Reynolds' modeling experiments on the Los Angeles basin formed the basis for Model-UAM, the well-known Urban Air shed. This model was used by Holmes and Morawska (2006) to estimate long-distance transport and dispersion.

Computational Fluid Dynamic Models

The Computational Fluid Dynamic (CFD) model forecasts the wind speed and pollutant concentration profiles in real three-dimensional environments, enabling an analysis of gas dispersion effects of complex terrain (Tsuang 2003). These models provide complex fluid flow analysis based on mass and momentum conservation by solving Navier – Stokes's equation using three-dimensional finite differential and finite volume approaches (Lettau 1970). It is formulated as:

$$\frac{\partial \vec{v}}{\partial t} + (\vec{v}\nabla)\vec{v} = -\frac{1}{\rho}\nabla p - \vec{g} + v_T \nabla^2 \vec{v} \qquad \ldots(7)$$

Where:

$\vec{v}$ is the wind field,

ρ is the density,

V_T is the eddy viscosity,

p is the pressure,

$\vec{g}$ is the acceleration vector due to gravity

Given that CFD models are mostly used for complex geometry, explicit measuring up to a very small scale of turbulence requires a fine grid resolution that leads to very high computational costs. Subgrid-scale instability, though, also must be measured and assumed isotropic. Models of CFD street canyons are commonly used for forecasting air quality in industrial and urban areas (Yamada 2004). Different types of models are mentioned below:

Photochemical modeling, Particle models, Statistical models, Odor models, Deposition modules, and Plume Rise models are among the various modeling approaches available and described in Table 3.

Table 2: Different models and their examples.

Models	Examples
Box models	CPB, AURORA, and PBM
Gaussian models	HIWAY2, OSPM, CAR-FMI, CALINE4, CALPUFF, UK-ADMS AEROSOL, SCREEN3, and AERMOD
Lagrangian/ Eulerian Models	TAPM, GRAL, ARIA Regional
CFD models	ARIA Local, MICRO-CALGRID, MISKAM

MAPPING RESULTS BASED ON GIS

Most GIS packages have many ways to quickly and efficiently view and show data in a map layer. They can zoom into and out on the map layer, highlight the features selected in the map layer by the selection, classify them based on certain criteria, and then display them in a variety of coded colors (Tippichai 2017).

PROBLEMS AND CHALLENGES

I. The format adopted by the GIS and by the atmospheric dispersion models are vector and tabulated text data respectively which is a serious problem (Teggi 2017)

II. There are several problems with urban air pollution mapping. Because of the multiple emission sources and their uncontrolled dispersion processes in an urban setting, the air pollution levels usually differ over very short distances, often just a few tens of meters (Hewitt 1991).

Table 3: Different dispersion models.

Model	Function	Applicable	Examples
Photochemical models	Models that predict the changes in atmospheric pollutant concentrations using a series of mathematical equations and describe the physical and chemical processes of the atmosphere.	At a wide range of different spatial clusters from local to global.	Community Multi-scale Air Quality (CMAQ), WRF/Chem, Urban Airshed Model (UAM), Comprehensive Air quality Model with extensions (CAMx), etc.
Particle models	The source is simulated by releasing many particles throughout the fire. Each particle's trajectory is calculated, as well as a random component that simulates atmospheric turbulence. Instead of following the parameterized spatial distribution pattern, a particle cluster will extend into space according to atmospheric turbulence patterns.	The most effective way to simulate levels at any time, but restricted to single point sources with single chemical or sources that have essential components, such as toxins, which must be monitored accurately	HYSPLIT
Statistical models	The model focused on non-deterministic statistical data analysis of measured atmospheric concentrations, which do not clarify or predict the cause-and-effect relationship, or the relationship between pollution and environmental concentrations.	Techniques for forecasting air pollution patterns a few hours ahead of time so that the public can be alerted.	Chemical Mass Balance (CMB)model
Odor models	The model provides instant or semi-instantaneous algorithms for simulating concentrations, as odors are instantaneous for human sensations.	At Local scales	
Deposition modules	Computer module to measure the amount of plum deposited in the ground due to the phenomenon of dry and wet deposition.	At Local scales	
Plume rise models	Models typically assume stable conditions, which means wind speed, wind direction, and emission rates are all relatively constant.	Close to the source or for a limited period, with land use or topography restrictions	PRIME in HYSPLIT and AERMOD

III. In addition to inherent uncertainties related to the stochastic processes (for example turbulence) in the atmosphere, all models generate primarily two forms of uncertainties: (i) structural and (ii) parametric (Holmes et al. 2009). The use of unpredictable input values (e.g., wind speed and direction, number of emission factors, etc) for model calculations cause parametric uncertainty. These can be caused by the lack of significant data sets (e.g., local weather data), data inconsistencies (e.g., instrument calibration, measurement conditions instability), or lack of understanding of key parameters (e.g., emission factors) (Kumar et al. 2011). The determination of emission factors is one of the most important problems in the Emission model. As a result, emission inventory has certain limitations and uncertainties, when it is performed (Collet et al. 2012)

CONCLUSION

The issue of air pollution needs to be addressed systematically with an all-government approach that includes preparation for short, and long-term air quality management strategies. Some of the approaches to control this include the adoption of renewable power sources for public transport, industrial activities, and initiatives to minimize road traffic. Additional approaches include increasing taxes on fuel and car parking, levying congestion charges, developing free zones & cycling paths, use of solar lighting, and encouraging vegetation on the roadside. For long-term control, many of these updates will be motivated by improvements in the Numerical Air Prediction Model in operation.

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APPENDIX 1: CONVERSION FACTORS USED FOR DIFFERENT FUEL TYPES.

Description	Unit Conversion
Anthracite (raw coal)	1
Benzol	1
Briquettes and similar solid fuels manufactured from coal, n.e.c.	1
Briquettes, coal, coal dust	1
Briquettes, coke	1
Coal	1
Coal (under sized)	1
Coal ash	1
Coal bed Methane	1
Coal compressed (middling's)	1
Coal consumed	1
Coal for carbonisation	1
Coal gas	1
Coal gas, water gas, producer gas and similar gases, other than petroleum gases and other gaseous hydrocarbons; n.e.c	1
Coal rejects	1
Coal slack	1
Coal tar by-product	1
Coal tar crude	1
Coal tar Oil	1
Coal tar peat	1
Coal tar processed	1
Coal tar product	1
Coal tar, crude	1
Coal tar, pitch	1
Coal washed	1
Coal, not agglomerated, n.e.c.	1
Coke and semi-coke of coal, of lignite or of peat; retort carbon n.e.c	1
Coke breeze	1
Coke cp	1
Coke dust	1
Coke hard	1
Coke mixed	1
Coke peat	1
Coke seme	1
Coke soft	1
Diesel	0.837520938
Fuel oils n.e.c	0.9765625
Fuel, aviation turbine	0.798722045
Furnace oil	0.000976563
Gas compressed natural	0.000711238
Gas oils	0.856164384
Gas, n.e.c	1
High speed diesel	0.826446281
Kerosene	0.798722045
Kerosene n.e.c	0.798722045
Kerosene type jet fuel	1
Light petroleum oil	0.862068966
Lignite briquettes	1
Lignite, agglomerated	1
Lignite, not agglomerated	1
Liquid or liquid gas fuel for lighter	1
Liquefied petroleum gas (LPG)	1
Liquified natural gas	0.000711238
Medium petroleum oil, n.e.c.	0.825082508
Motor spirit (gasoline), including aviation spirit n.e.c	0.734214391
Natural gas	1
Oil, coal tar	1
Other coal tar oil pitch products, n.e.c.	1
Other gaseous hydrocarbons	1
Other light petroleum oils and light oils obtained from bituminous minerals n.e.c	0.862068966
Other than petroleum gas	1
Peat, hard/medium	1
Peat, n.e.c.	1
Peat, other than hard/medium	1
Petrol / motor spirit/ gasoline	1
Petrol, diesel, oil, lubricants consumed	1
Petroleum coke	1
Petroleum coke calcined	1
Petroleum products obtained from bitumen n.e.c.	1
Pitch other than hard/medium	1
Pitch, hard/medium	1
Propane and butanes, liquefied, n.e.c.	1
Regasified liquefied natural gas	1
Shale Oil	1
Spirit type (gasoline type) jet fuel	0.8
Superior kerosene	0.778210117
Tar from Coal or Lignite	1
Water gas	1

Source: -CEEW

REFERENCES

Anwar, A., Younis, M. and Ullah, I. 2020. Impact of urbanization and economic growth on CO_2 emission: A case of Far East Asian countries. Int. J. Environ. Res. Public Health, 2020; 17: 2531. doi:10.3390/ijerph17072531.

Bonner, C.S., Ashley, M.C.B., Cui. X., Feng, L., Gong, X., Lawrence, J.S., Luong-Van, D.M., Shang, Z., Storey, J.W.V., Wang, L., Yang, H., Zhou, X. and Zhu, Z. 2010. The thickness of the atmospheric boundary layer above dome A, Antarctica, during 2009. Astronom. Soc. Pac., 122: 1122-1131. https://doi.org/10.1086/656250

Cai, X., Huo, Q., Kang, L. and Song, Y. 2014. Equilibrium atmospheric boundary-layer flow: computational fluid dynamics simulation with balanced forces. Bound. Layer Meteorol.,152: 349-366. DOI: 10.1007/s10546-014-9928-0

CPCB 2016. Central Pollution Control Board, Environmental Assessment of Industrial Clusters. https://cpcb.nic.in/comprehensive-environmental-pollution-index-cepi/

Collet, S., Kidokoro, T., Sonoda, Y., Lohman, K., Karamchandani, P., Chen, S.Y. and Minoura, H. Air quality impacts of motor vehicle emissions in the south coast air basin: Current versus more stringent control scenario. Atmos. Environ., 47: 236-240. doi: 10.1016/j.atmosenv.2011.11.010.

Deck, S. 2005. Zonal-detached-eddy simulation of the flow around a high-lift configuration. AIAA J., 43(11): 2372-2384. https://doi.org/10.2514/1.16810

Domingo JL, Marques M, Rovira J. Influence of airborne transmission of SARS-CoV-2 on COVID-19 pandemic. A review. Environmental Researc.188 (2020) 109861. https://doi.org/10.1016/j.envres.2020.109861.

Eggleston, H.S., Gaudioso, D., Gorissen, N., Joumard, R., Rijkeboer, R.C., Sameres, Z. and Zierock, K.H. 1991. CORINAIR Working Group on Emission Factors for Calculating 1990 Emissions from Road Traffic. Vol. I., Methodology and Emission Factors. Final Report, Contract n.B4/3045(91) IOPH, Directorate Generale XI. European Environmental Agency Task Force, Commission of European Communities, Bruxelles, Belgium.

Fisher, B., Kukkonen, J., Piringer, M., Rotach, W. and Schatzmann, M. 2006. Meteorology applied to urban air pollution problems: Concept from COST 715. Atmos. Chem. Phys., 6(2): 555-564. https://doi.org/10.5194/acp-6-555-2006.

Gifford, F.A. 1976. Consequences of effluent releases. Nucl. Safety, 17(1): 68-86.

Greenhouse Gases Emission Estimates from the Manufacturing Industries in India State level estimates: 2005 to2013, Council on Energy, Envir-ronment and Water (CEEW).

Grell, G. A., Dudhia, J. and Staufer, D.R. 1995. A Description of the Fifth Generation PennState/ NCAR Mesoscale Model (MM5), NCAR Technical Note, 6-1995.

Gualtieri, G. and Tartaglia, M. 1998. Predicting urban traffic air pollution: A GIS framework. Transp. Res., Part D, 3(5): 329-336. https://doi.org/10.1016/S1361-9209(98)00011-X

Gulliver, J. and Briggs, D. Stems-air: a simple GIS-based air pollution dispersion model for city-wide exposure assessment". Sci. Total Environ., 409: 2419-2429. DOI: 10.1016/j.scitotenv.2011.03.004

Guttikunda, S.K., Goel, R. and Pant, P. 2014. Nature of air pollution, emission sources, and management in the Indian cities. Atmos. Environ., 95: 501-510. https://doi.org/10.1016/j.atmosenv.2014.07.006

Hewitt, C.N. 1991. Spatial variations in nitrogen dioxide concentration in an urban area. Atmos. Environ., 25B: 429-434. https://doi.org/10.1016/0957-1272(91)90014-6.

Holmes, K.J., Graham, J.A., McKone, T. and Whipple, C. 2009. Regulatory models and the environment: practice, pitfalls, and prospects. Risk Anal., 29: 159-170. doi: 10.1111/j.1539-6924.2008.01186. x.

Holmes, N.S. and Morawska, L. 2006. A review of dispersion modeling and its application to the dispersion of particles: An overview of different dispersion models available. Atmos Environ., 81: 40: 5902-5928. https://doi.org/10.1016/j.atmosenv.2006.06.003.

Joumard, R., Hickmann, L., Nemerlin, J. and Hassel, D. 1992 Model of Exhaust and Noise Emissions and Fuel Consumption of Traffic in Urban Areas. INRETS, Lion-Bron, France. https://doi.org/10.1155/2013/736285

Jung, Y.R., Park, W.G. and Park, O.H. 2003. Pollution dispersion analysis using the puff model with numerical flow field data. Mech. Res. Commun., 30(4): 277-286. doi:10.1016/S0093-6413(03)00024-7

Leelossy, J.M. 2014. Dispersion modeling of air pollutants in the atmosphere: A review. Cent. Eur. J. Geosci., 6(3): 257-278. https://doi.org/10.2478/s13533-012-0188-6

Kumar, P., Ketzel, M., Vardoulakis, S., Pirjola, L. and Britter, R. 2011. Dynamics and dispersion 826 modeling of nanoparticles from road traffic in the urban atmospheric environment - A review. J. Aeros. Sci., 42(9): 580-603. doi: 10.1016/j.jaerosci.2011.06.001

Lettau, H.H. 1970. The physical and meteorological basis for mathematical models of the urban diffusion process. Proc. Symp. on Multiple-Source Urb. Diff. Mod., 86: 2-26

Luna, R.E. and Church, H.W. 1972. A comparison of turbulence intensity and stability ratio measurements to Pasquill stability classes. J. Appl. Meteorol., 11: 663-669. https://www.jstor.org/stable/26175715

Mohanraj, R., Dhanakumar, S. and Solaraj, G. 2012. Polycyclic aromatic hydrocarbons bound to PM 2.5 in urban Coimbatore, India with emphasis on source apportionment. Sci. World J., 98: 843. https://doi.org/10.1100/2012/980843.

National Environmental Engineering Research Institute (NEERI). 2010. Air quality assessment, emissions inventory, and source apportionment studies. Mumbai. Central Pollution Control Board (CPCB), New Delhi.

Oke, T.R. 1976. The distinction between canopy and boundary-layer urban heat islands. Atmosphere, 14: 268-277. https://doi.org/10.1080/00046973.1976.9648422

Pasquill, F. 1961. The estimation of the dispersion of windborne material. Meteorol. Mag., 90(1063): 33-40

Piringer, M., Joffre, S., Baknalov, A., Christen, A., Deserti, M., De-Ridder, K., Emeis, S., Mestayer, P., Tombrou, M., Middleton, D., Baumann-Stanzer, K., Dandou, A., Karppinen, A. and Burzynski J. 2007. The surface energy balance and the mixing height in urban areas - activities and recommendations of COST-Action 715. Boundary-Layer Meteorol., 124(1): 3-24. DOI: 10.1007/s10546-007-9170-0

Reynolds, S., Roth, P. and Seinfeld, J. 1973. Mathematical modeling of photochemical air pollution. Atm.Env., 7. https://doi.org/10.1016/0004-6981(73)90214-X.

Roth, M. 2000. Review of atmospheric turbulence over cities. Q. J. R. Meteorological Soc. 126, 941-990.

Shir, C.C. and Shieh, L.J. 1974. A generalized urban air pollution model and its application to the study of SO2 distribution in the St. Louis Metropolitan area. J. Appl. Met., 19: 185-204. DOI: https://doi.org/10.1175/1520-0450-13.2.185

Stull, R. 2017. Practical Meteorology: An Algebra-Based Survey of Atmospheric Science, Version 1.02b. University of British Columbia, Vancouver, BC, Canada.

Tartaglia, M. 1995. Relationship between polluting emissions and speed of road vehicles. Rail. Eng., 5: 337-346

Teggi, A. 2017. GIS-based atmospheric dispersion model for pollutants emitted by complex source areas. Sci. Total Environ., 610-611: 175–190. doi: 10.1016/j.scitotenv.2017.07.196.

Tippichai, A. 2017. Applications of GIS for analyzing air pollution from urban road traffic (Thai). KKU Res. J., 10(4): 201.

Tseng, Y.H., Meneveau, C. and Parlange, M.B. 2006. Modeling flow around bluff bodies and predicting urban dispersion using large-eddy simulation. Environ. Sci. Technol., 40(8): 2653-2662. https://doi.org/10.1021/es051708m.

Tsuang, B.J. 2003. Quantification on the source/receptor relationship of primary pollutants and secondary aerosols by a Gaussian plume trajectory model: Part I theory. Atmos. Environ., 37(28): 3981-3991. https://doi.org/10.1016/S1352-2310(03)00471-0.

Turner, D.B. 1997. The long lifetime of the dispersion methods of Pasquill in U.S. regulatory air modeling, J. Appl. Meteorol., 36: 1016-1020

WHO 2018. World Health Organization releases new global air pollution data. https://www.ccacoalition.org/en/news/world-health-organization-releases-new-global-air-pollution-data

Yamada, T. 2004. Merging CFD and atmospheric modeling capabilities to simulate airflows and dispersion in the urban area., Comput. Fluid Dyn. J., 13: 329-341

Yerramilli, A., Dodla, V.B.R. and Yerramilli, S. 2011.Air pollution, modeling, and GIS-based decision support systems for air quality risk assessment. Eur. J. Oper. Res., 10(4): 220. DOI: 10.5772/22055.

Zhang, A., Gao, C. and Zhang, L. 2005. Numerical simulation of the wind field around different building arrangements. J. Wind Eng. Indus. Aerodyn., 93(12): 891-904. DOI: 10.1016/j.jweia.2005.09.001.

Zhang, J., Hodgson, J. and Erkut, E. 2000. Using GIS to assess the risks of hazardous materials transport in networks. Eur. J. Oper. Res., 121: 316-329. DOI: 10.1016/S0377-2217(99)00220-9.