STUDY AND ANALYSIS OF EFFECTIVENESS OF STACK IN THE DISPERSION OF AIR POLLUTANTS BY USING GAUSSIAN'S PLUME MODEL AT INDO GULF FERTILIZERS LTD., JAGDISHPUR, U.P., INDIA

A
Project Report Submitted
In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF TECHNOLOGY

In
Environmental Engineering

By

Rishi Yadav
(1170470009)

Under the Guidance of

Dr. Arif Siddiquie
Department of Civil Engineering
Babu Banarasi Das University, Lucknow
2018-2019

CERTIFICATE

Certified that Rishi Yadav (1170470009) has carried out the research work presented in this project entitled **"STUDY AND ANALYSIS OF EFFECTIVENESS OF STACK IN THE DISPERSION OF AIR POLLUTANTS BY USING GAUSSIAN'S PLUME MODEL AT INDO GULF FERTILIZERS LTD., JAGDISHPUR, U.P., INDIA"** for the award of **Master of Technology in Environmental Engineering** from Babu Banarsi Das University, Lucknow under my supervision. This project embodies result of original work and studies carried out by student and the contents of the project do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

Signature	Signature
Dr. Arif Siddiquie	Mr. Anupam Mehrotra
(Project Guide)	(Head of the Department)
Department of Civil Engineering	Department of Civil Engineering
BBD University	BBD University

DECLARATION

I hereby declare that the project work entitled **"STUDY AND ANALYSIS OF EFFECTIVENESS OF STACK IN THE DISPERSION OF AIR POLLUTANTS BY USING GAUSSIAN'S PLUME MODEL AT INDO GULF FERTILIZERS LTD., JAGDISHPUR, U.P., INDIA"** is a record of an original work done by me under the guidance of Department of civil Engineering, **BABU BANARSI DAS UNIVERSITY, LUCKNOW**. This project work is done in the fulfillment of the requirements for the master's degree. This is a bona fide work carried out by me and the results provided in this project report have not been copied from any source. The results provided in this have not been submitted to any other University or Institute for the award of any degree or diploma.

Date: 13/04/2019

Place: Lucknow

Rishi Yadav

(1170470009)

Civil Engineering Department

BBDU, Lucknow.

ABSTRACT

The main objective is to analyse the **effectiveness of stack in the dispersion of air pollutants** (at the desired location of **Indo Gulf Fertilizers Ltd.,** situated at Jadishpur, U.P.), emitted under different conditions of mass flow rate at the exit and ambient cross flow velocity by using Gaussian’s plume model. Main focus is to find out whether stack can disperse atmospheric pollutants away from city or surroundings where the boiler is installed.

Dispersion modeling includes means of calculating ambient ground level concentrations of emitted substances, considering the information like meteorological data, pollutants flow rates and terrain data of area. This modeling is done to assess that the Ground level concentrations (GLC) of atmospheric pollutants owing to emissions from boiler stack are less than applicable ambient air quality standards.

ACKNOWLEDGEMENT

During project work in the month of August 2018 to April 2019, I have attained useful experience, knowledge and guidance for our future career. The work was very informative during operation and management done in the analysis.

I Would Like To Express My Faithful Thanks To My **Head Of Department** Of Civil Engineering **Mr. Anupam Mehrotra** For Extending All The Department Facilities Without Slightest Hesitation.

I Would Like To Thanks To My **Project Guide** of civil department, **Dr. Arif Siddiquie** for his extremely valuable guidance and encouragement throughout the project.

I offer my special thanks to **Invigilation Panel** of Civil Department to approve my project and to give correct guidelines during project reviews.

It is a great pleasure for me to acknowledge and express my gratitude to my classmates and friends for their understanding, unstinted support and endless encouragement during the study.

Lastly, I thank all those who are directly or indirectly involved in the completion of project work.

CONTENTS

LIST OF FIGURES, TABLES AND CHARTS

NOMENCLATURE

Δh = plume height of stack in m

v_s = stack gas velocity in m/s

D = inside exit dia of stack in m

u = wind speed in m/s

P = atmospheric pressure in milli-bars

T_s = stack gas temperature in °K

T_a = air temperature in °K

h = height of stack in m

C = the concentration of pollutant in g/m^3

Q = the pollutant emission rate in g/sec

x and y = downwind and cross-wind horizontal distances, respectively in m

σ_y = Plume's standard deviation in cross-wind direction in m

σ_z = Plume's standard deviation in downwind direction in m

H = Effective height of stack

CHAPTER 1

INTRODUCTION

1.1 AIR POLLUTION

Air pollutants are introduced in the surrounding from the variety of sources that changes the composition of the atmosphere and affect the living species of environment. The concentration of the air pollutants depend not only on the quantities which are emitted from pollution sources but also depends upon the ability of the atmosphere to either absorb or disperse these pollutants. The concentration of air pollutants vary spatially and temporarily causing the air pollution to change with different positions and time due to changes in meteorological and topographical condition. The sources of air pollutants are automobiles, industries, domestic sources and natural sources. Due the presence of high amount of air pollutants in the air, the health of the people and the property is getting adversely affected. In order to capture the deterioration in air quality, Govt. of India has approved Air (Prevention and Control of Pollution) Act in 1981. This responsibility has been further improved under Environment (Protection) Act, 1986. The most important atmospheric conditions are wind speed, wind direction, and the vertical temperature structure of the local atmosphere. If the temperature decreases with height at a rate higher than the adiabatic lapse rate, the atmosphere is in unstable equilibrium and vertical motions are enhanced. This is to keep pollution concentrations moderate or weak at ground level. But, if the temperature decreases with height at a rate lower than the adiabatic lapse rate (stable atmosphere) or increases with height (inversion), vertical motions are reduced or damped. This will lead to potentially high pollution concentrations. Atmospheric air quality dispersion models are usually used to estimate just how much reduction has occurred during the transport of pollutant from an industrial source, and consequently to project the pollution concentration at ground level. Dispersion models usually incorporate meteorological, terrain, physical and chemical characteristics of the effluent and source design to simulate the formation and transport of pollutant plumes. Strict environmental regulations worldwide is behind the growing concern about the validity and reliability of air quality dispersion models.

The ambient air quality monitoring observing system includes estimation of various air contaminations at number of areas in the nation to meet targets of the checking Air quality checking system additionally includes choice of poisons, determination of areas, fixation and the kind of toxins in the environment through different normal sources, called regular urban air toxins, for example, Suspended Particulate Matter (SPM), Respirable Suspended Particulate Matter (RSPM), Sulfur dioxide (SO2), Oxides of Nitrogen (NOx), and Carbon Monoxide (CO) and so on.

1.2 AIR (PREVENTION AND CONTROL OF POLLUTION) ACT 1981

Administration of India made the law of Air (Prevention and Control of Pollution) Act 1981 to compute the deterioration in the air quality all around. The act prescribes different capacities for the Central Pollution Control Board (CPCB) at the peak level and State Pollution Control Boards at the state level.

1.3 NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

The targets/gauges of ambient air quality are essential for creating project for compelling administration of surrounding air quality and to lessen the harming impacts of air contamination. The goals of air quality measures are: -

- To show the levels of air quality essential with a sufficient margin of safety to protect the public health, vegetation and property.
- To aid in creating needs for reduction and control of pollutant level.
- To give uniform measuring stick for evaluating air quality at national level.

1.4 GAUSSIAN'S DISTRIBUTION

The Gaussian model which uses the Gaussian distribution equation to simply calculate the variations of pollutant concentrations away from the centre of the plume. This equation calculates the ground level pollutant concentrations depend upon time-averaged atmospheric variables (e.g. wind speed and temperature).

Gaussian distribution equation:-

$$c(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z u}\exp\left(\frac{-y^2}{2\sigma_y^2}\right)\left(\exp\left(\frac{-(z-h)^2}{2\sigma_z^2}\right)+\exp\left(\frac{-(z+h)^2}{2\sigma_z^2}\right)\right)$$

1.5 INDO GULF FERTILIZERS LTD., JAGDISHPUR:

Type: Fertilizer Plant (Ammonia-Urea Plant)

Area: Uttar Pradesh

Annual Production: 1.08 million tonnes of Urea

Owner: Indo Gulf Fertilisers Limited

Shareholders: Aditya Birla Nuvo Limited

Activity Since: 1988

Figure 1.1: Indo gulf plant view

Indo Gulf, the agri input business of Aditya Birla Nuvo, manufactures and markets urea, agricultural seeds and agrochemicals. Indo Gulf Fertilisers is the 8th largest urea manufacturer in India. The goal of the business is to become a 'total agri solutions provider' offering a full range of agri inputs - fertilisers, seeds, agrochemicals and specialties from sowing to harvesting.

Birla Shaktiman Urea - Neem coated and Gold continued to remain the products of first choice,for the farmers. Birla Shaktiman enjoys a market leadership position in entire zone of Uttar Pradesh, Bihar, Jharkhand and West Bengal, through excellent product quality and customer servicing. It is fulfilling aspirations of millions of farmers who reap a rich harvest of crops.

Indo Gulf's state-of-the-art manufacturing facility at Jagdishpur in Uttar Pradesh is considered one of the most energy efficient plants in the country. It's location at Jagdishpur - in the middle of the agricultural heartland of the Indo-Gangetic plains, gives it access to a large and growing market. The plant is operating at more than 100 per cent capacity utilisation and manufactured 10,21,447 tonnes of urea in 2014-15. Indo Gulf's marketing activities span the entire Indo-Gangetic plain - from Punjab in North to Odisha in the East. A strong marketing, distribution and customer service network that includes the wholesalers' network, Birla Shaktiman accredited retailers and Birla Shaktiman service centres, helps the company sustain its leadership position.

CHAPTER 2
LITERATURE REVIEW

2.1 OVERVIEW

Adel A. Abdel Rahman (October 2008)

As an air pollutant is transported from a source to a potential receptor the pollutant disperses into the surrounding air so that it arrives at a much lower concentration than it was on leaving the source. Strict environmental regulations worldwide resulted in an ever growing concern about the validity and reliability of air quality dispersion models. The present work is a try to evaluate the applicability of dispersion models from an industrial source. Two examples of the air quality dispersion models are considered here; the classical Gaussian plume model by Sutton and PRISE (Plume Rise) model by Henderson-Sellers and Allen.

Ankita Shukla, Rajeev Kumar Mishra, Dr. M. Parida (December 2010)

This paper mainly deals with the measurement of air quality by observing the concentration of pollutants in the atmosphere namely suspended particulate matter, NOx and SO2 at five different selected locations in Lucknow city. The locations for the study have been chosen on the basis of land use pattern. Each pollutant has been observed by 12 hours from 8:00 to 20:00 hours. According to air quality scale, the air quality status has been measured at each location and zone. From the study it is found that the residential zone has highest air quality index in comparison to other zones.

Aaron Daly and Paolo Zannetti (2007)

His chapter presents a brief review of air pollution modeling techniques, i.e., computer methods for the simulation of air quality processes. The review includes models developed or recommended by governmental agencies for regulatory applications. Both non-reactive (e.g., plume models) and reactive (e.g., photochemical models) are discussed. We also provide Web sites where the reader can download modeling software.

Ben Bella S. Tawfik & M. M. El-Gazar (June 2013)

In this work, a computer program has been constructed for investigating the factors affecting the dispersion of stack emissions. These factors are wind speed, wind direction with respect to source, wind direction with respect to receptor, ambient air temperature and atmospheric stability conditions. The analysis is done via a 3-D graphical model which simulate the reality. A case study is applied for four stacks. The results indicate that the effect wind speed on total concentration, from the four stacks, is directly proportional to the increase of wind speed, while the distance of maximum concentration is inversely proportional to it. Also it is found that the total concentration is inversely proportional to the increase of wind angle direction with respect to receptor, while the distance of maximum concentration is shifted towards the source location. Total concentration is directly proportional to the increase of ambient air temperature, while the distance at which the maximum concentration occurs is almost constant. With regards to atmospheric stability conditions, the study indicates that Stability classes E and F give higher concentration than other classes while stability classes C and D give the lowest concentration.

Chandrasekar, Rajendran, Bharath, (April 2017)

Done an analysis on dispersion of air pollutants in the coastal site due to thermal power plant and other various type of industries located in inland terrain is one of the major environmental pollution issue. Sulphur dioxide is the dominant air pollutant from thermal plants which are easily converted into sulphur trioxide, sulphuric acid and sulphur particles. This leads to the various environmental and health impacts to the humans. Dispersion model are the tool to predict the environmental conditions and the concentration in the downwind environment. Thus in this study, the Dispersion model was developed for the dispersion of sulphur dioxide concentration in the environment using Gaussian Plume Model.

Dr. Akshey Bhargava (April 2016)

Stack Plume Rise is a conceptual phenomenon which is mainly dependent on two forces, namely, Buoyant and Momentum force. Buoyant forces are governed by temperature, heat emission rate of the stack exit gases whereas Momentum forces are governed by Stack exit gas velocity. Plume Rise is also dependent on various factors like Atmospheric wind speed, Atmospheric stability condition, and Atmospheric turbulence besides some other internal parameters like Stack gas temperature, Heat emission rate, Stack Height and Stack gas exit velocity. The Plume Rise is an important parameter in the overall air pollution control mechanism which directly interferes the dispersion of pollutant over a period of time and space, the more is the plume rise, the better would be the dispersion of air pollutants resulting into less ground level concentration of air pollutants. An effort has been made in the present research paper to optimize the Plume Rise using various equations that are employed to estimate the Plume Rise under different stability conditions, and also Effect of changes of Stack Exit Velocity and Gas Temperature.

Dr. Dipak Prasad and Dr. Srabani Sanyal (2016)

Erudite groups of people, scientists, planners, and policy-makers of different countries have come to realise that quality of environment is not necessarily a simple function of nature as in primitive earth. Today nature's self-regulatory functions are inoperative. All the developed and developing countries are deeply concerned to make balance between their environmental anxiety and their economic development. Dreadful environmental conditions are affecting the biological segment of the ecosystem of these areas. Human being, 'one of the most precious component in biosphere, have regular predicament situation with accretion of sullied air, water, and soil degradation. Though water and land pollution is extremely dangerous, air pollution has its own peculiarities, due to its trans-boundary dispersion of pollutants over the entire world. The effect of air pollution on health is very complex as there are many different sources and their individual effect varying from one to other. It is not only the ambient air quality in the cities but also the indoor air quality in the rural and urban areas that are causing concern. The study is confined with the health impact of deteriorating air quality in Lucknow city.

Dorin Carstoiu, Gabriel Gorghiu, Carmen Leane Nicolescu (2010)

An analysis of the pollution status is performed in Dambovita County for the most important pollutants with a major influence on population health (CO, NO, NO2, SO2 and PM10 dusts). The analysis is made by the MEMDUR management system, designed in the frame of the National Research project: "Sustainable Management System of Resources Used for

Monitoring and Evaluating the Environmental Risks in Order to Prevent the Negative Effects and to Manage Crises Situations". In this case, for determining the zones were the pollution level generated by the stationary pollution sources reaches the maximum values, a Gaussian mathematical model is used (Nicolescu *et al.*, 2008). The model takes into account the source-related factors and the meteorological ones for estimating the pollutant concentration from the stationary sources, using an exponential equation (Abdel-Rahman, 2008). The wind speed represents the core parameter of the model due to its influence on the dispersion (Straja, 1994). But this model makes possible also to determine the ground level concentrations at any receptor point in the analyzed region. The distribution of the concentration becomes available by computing the corresponding values registered at various receptors and summarizing the recorded values.

G. Grigoras, V. Cuculeanu, G. Ene, G. Mocioaca, A. Deneanu (July 2010) Carried out air quality assessment in a polluted area with specific and complex terrain features situated in the north-western part of Romania was made using The Air Pollution Model (TAPM). This is a 3D prognostic model that solves the fundamental fluid dynamics and scalar transport equations to predict both meteorological data and air pollution concentrations. In order to properly assess the concentrations of air pollutants in the studied area, there were taken into account not only the emissions from the activities on the premises of the main industrial platform, but also the contribution from the other pollution sources from the area of interest, such as other industries, residential heating, traffic, dump heaps. The mathematical modeling results, displayed as air pollutant dispersion maps, showed the significant influence of the complex terrain features and of the other pollution sources on the concentration levels in the region, usually associated with the emissions of the main industrial platform.

Geetika Saluja (2017)

The human behaviour over the last few decades has changed the global atmospheric condition. The emission from automobiles, industrial emission, urban development, intensification of agricultural practices has escalate the levels of the harmful gases like CO2, CO, SO2, NO and Particulate Matter(PM) which probably changing the condition of the atmosphere and in turn harming us. The study aims at assessing the rate of air pollution in Lucknow with the focus on the Particulate Matter 10, Particulate Matter 2.5, Sulphur Dioxide and Nitrogen Dioxide. The study also reveals the major cause of the air pollution in Lucknow; the areas of Lucknow which are severely under pollution threats and monitoring the tracking mechanisms which has been set up; lacking equipments and the reason behind the same and little focus on the implemented awareness method among Lucknow is on air pollution. The study accounts the data of the recent months and the comparison to evaluate the increasing amount of level of pollution from last years.

I.R. Ilaboya, E. Atikpo, L. Umukoro, F.E. Omofuma and M.O. Ezugwu (February 2011)
Done a research work was to study the various factors that affect plume dilution and dispersion. Some of the factors that were studied include; the effects of mixing height, the effects of plume rise and the effects of terrain in addition to momentum and buoyancy on the overall dispersion of plume released from a stack of known effective height. Data on temperature versus altitude was collected using an infra-red thermometer at different height of a telecommunication mast under construction. The highest temperature for the month was noted and the validity of the recorded data was done using correlation analysis. Mathematical analysis was then employed to determine the mixing depth which represents the effective height of any stack that must be placed in such location in other to allow for complete dispersion/dilution of any form of pollutant released from any source. Result obtained shows that the effective height of stack that can be erected in such location that will allow for effective dispersion of any pollutants was shown to be 1700m. Any stack below this height will lead to ground level pollution. Also discussed in this research paper is the application of Gaussian Plume model in the evaluation/analysis of the horizontal dispersion of pollutants released from a height (h).

Khaled Sadek Mohamed Essa, Mohamed Magdy Abd El-Wahab, Hussein Mahmoud ELsman, Adel Shahta Soliman, Samy Mahmoud ELGmmal, Aly Ahamed Wheida (2014)
The advection diffusion equation (ADE) is solved in two directions to obtain the crosswind integrated concentration. The solution is solved using separation variables technique and considering the wind speed depends on the vertical height and eddy diffusivity depends on

downwind and vertical distances. Comparing between the two predicted concentrations and observed concentration data are taken on the Copenhagen in Denmark.

Khaled S. M. Essa, Soad M. Etman And Maha S. El-otaify (April 2014)

An analytical solution of the three dimensional advection- diffusion equations has been formulated to simulate the dispersion of pollutants in the planetary boundary layer. The solution is based on the assumption that the concentration distribution of pollutants in the crosswind direction has a Gaussian shape and the wind speed is constant. The analytical solution has been obtained in two cases where, the vertical eddy diffusivity is taken to be dependent on: (a) the downwind distance x only and (b) the vertical height z only. The dry deposition of the diffusing particles on the ground is taken into account throughout the boundary conditions. The resulting analytical formulae have been applied to calculate the concentration of I-131 using data collected from the experiments conducted to collect air samples around the Research Reactor. Statistical measures are utilized in the comparison between the predicted and observed concentrations. The results are discussed and presented in tables and illustrative figures.

Kulshresth Singh (2018)

Industrial chimney releases pollutant to the environment which causes air pollution. As an air pollutant is transported from a source to a potential receptor the pollutant disperses into the surrounding air so that it arrives at a much lower concentration than it was on leaving the source. Air pollution modeling helps to determine the mathematical relationship between the effects of source emission of the pollutant on ground level concentration. Many dispersion models have been developed and used to estimate the downwind ambient concentration of air pollutants from sources such as industrial plants, vehicular traffic or accidental chemical release. Air Pollution emission plume i.e., the flow of pollutant in the form of smoke released into the air. Throughout many dispersion models, Gaussian Dispersion Models perhaps the oldest (circa 1936) and perhaps the most commonly used model type. The primary algorithm used in Gaussian modeling is the Generalized Dispersion Equation for a continuous point source plume.

Mavhungu Sydney Muthige (September 2013)

Lephalale Municipality is a predominantly rural Municipality with 38 villages, two townships (Marapong and Onverwacht) and one town, Lephalale. Lephalale, formerly known as Ellisras, is a town situated in the "heart of the Bushveld" in Limpopo province. The town is growing rapidly and more industries are becoming concentrated within this small town. The construction of Medupi power station which is underway and other projects such as the expansion of Grootegeluk mine (coal 3 and 4 projects), and road developments in the area; have led to concern about the ambient air quality of the area. Other possible future projects are the Coal to Liquid project by Sasol and the Coal Bed Methane project by Anglo American Thermal Coal. The purpose of this study is to determine the ambient air quality impact of the Matimba power station in the Lephalale area. The AERMOD model and ambient air quality data obtained from Eskom's Grootstryd and Marapong monitoring stations were used to assess the ambient air quality of Lephalale. Sulphur dioxide and Nitrogen oxides were investigated. Both the model's results and the ambient air quality monitoring data indicated that the power station contributes to high -ground level concentrations of Sulphur dioxide. AERMOD simulated the nitrogen oxides results as nitrogen dioxide. From the study it is concluded that the power station is not the only source of nitrogen oxides. Nitrogen oxides concentrations were associated with low-level sources. The relationship between the criteria pollutants in this study was assessed. The study found that there is no relationship between sulphur dioxide and nitrogen oxides. This finding was used to support the idea that sulphur dioxide and nitrogen oxides are from different sources. It was also established that seasonality has an influence on the ground level concentrations of pollutants in the area.

Neha Mumtaz, Anshika Yadav, Tabish Izhar (May 2017)

Air pollution is one of the foremost and grave public health and environmental anxiety in most of evolving countries. Due to increase in immense number of vehicles, industries and manufacturing units has resulted in excess assembly of pollutants in air making air pollution as a state of national emergency across various cities around the country. Lucknow is a fast growing city. During the last many years, researchers from the city have studied various aspects of air pollution and identified particulate matter is one of the main air pollutants in the city. The objective of this review article is to analyze the ambient air pollution status of city, associated with the environmental and health impacts and possible control measure presented in the studies on Lucknow from the available literature. Particulate matter; PM2.5, PM10 and SPM were observed to be exceed the National ambient air Quality Standards (NAAQS) limits in most of the studies but oxides of sulphur and nitrogen (SO2 and NOx) were within the limit of National ambient air Quality Standards (NAAQS). Particulates and associated toxic chemicals (metals and PAHs) and gaseous pollutants have found to be toxic to human and plants in Lucknow. The exposure of these pollutants is associated with cardiovascular and respiratory diseases, neurological impairments; increased risk of preterm birth and even mortality and morbidity. Air pollution level at control site (village or low traffic density area) was lower than the other urban sites of the city**.**

Neha Mumtaz, Anshika Yadav, Tabish Izhar (July 2017)

The objectives of this study is to assess the ambient air quality with respect to Particulate Matter (PM2.5 & PM10) and heavy metal lead (Pb), nickel (Ni) & the preliminary information of the study area and principal source of pollution & to study trends of pollutants over a period of time, to create a database for future use and space. In the last few decades, the human behaviours have changed the global atmospheric condition, the present study deals with the quantitative effect of vehicular emission on ambient air quality during Dec2016- Feb 2017 in three locations viz. Aliganj (Residential area), Gomtinagar (Commercial cum traffic area), Talkatora (Industrial area) of Lucknow city. The air quality was based on measuring four air pollutants namely Particulate Matter (PM2.5 & PM10), and Heavy Metal Lead (Pb) & nickel (Ni). The PM2.5 level at all the locations were higher than the NAAQS limits .The PM10 levels at all the monitoring locations were higher than the NAAQS limits. The concentrations of the Heavy Metal Lead (Pb) and Nickel (Ni) higher at all locations than the NAAQS limit. Heavy vehicular density and construction activity at road side, unpaved road is the causes of increase particulate matter in atmosphere.

Seema Awasthia, Mukesh Khareb and Prashant Gargava (2006)

Gaussian-based dispersion models are widely used to estimate local pollution levels. The accuracy of such models depends on stability classification schemes as well as plume rise equations. A general plume dispersion model (GPDM) for a point source emission, based on

Gaussian plume dispersion equation, was developed. The program complex was developed using Java and Visual basic tools. It has the flexibility of using five kinds of stability classification schemes, i.e., Lapse Rate, Pasquill Y Gifford (PG), Turner, Y and Richardson number. It also has the option of using two types of plume rise formulations Y Briggs and Holland's. The model, applicable for both rural and urban roughness conditions, uses meteorological and emission data as its input parameters, and calculates concentrations of pollutant at the center of each cell in a predefined grid area with respect to the given source location. Its performance was tested by comparing with 4-h average field data of continuous releases of SO_2 from Dadri thermal power plant (Uttar Pradesh, India).

Tan Mei Wen Michele (2011)

In his study, an inexact chance-constrained optimization model (ICCLP) was developed for air quality management under uncertainty. The ICCLP was formulated by integrating the inexact linear programming (ILP) and the chance-constrained programming model (CCP). The ICCLP allows the left-hand side (LHS) random variables to be expressed as interval numbers while letting the righthand side (RHS) constraints to be expressed as probabilistic functions. In this way, the highly random RHS constraints will be satisfied at predetermined confidence levels, providing a more flexible and in-depth tradeoff analysis when applied to air quality management.

Ted Stathopoulos and Bodhisatta Hajra (2008)

This report investigates the use of the various air-dispersion models, which have been approved by the Environmental Protection Agency (EPA), in modeling dispersion of effluents from stacks located on roof tops to determine their concentrations at various areas of the roofs with these stacks. In this context the effects of roof top structures and the varying directions of wind have been taken into account. Comparisons of the wind tunnel and field data with the results obtained from various dispersion models were made. It was observed that the EPA models, which mostly use the Gaussian equations, are more appropriate for longer rather than shorter distances within the vicinity of the building under consideration. In such cases of proximity of the stack with the points of interest on the roof, the ASHRAE model and wind tunnel data can be more reliable, to predict dispersion or concentration of pollutants.

Tansen Patel1, P Udayakumar (2016)

Wireless Sensor Networks are very popular technology to monitor environmental conditions consists of distributed independent sensors. Air pollution in heavily populated and industrialized areas is a serious problem. WSNs prepared with different sensors have been actively used for air quality monitoring. The air pollution monitoring system contains sensors to monitor the concerned pollution parameters in environment. In this paper, several technologies of a WSN based air pollution monitoring system and air quality model for air pollutions have been discussed. Various types of air pollutants with its effects on health and environment are discussed initially. It includes an overview of operating systems and simulators specifically designed for WSNs with various design approaches, and investigation of the current wireless sensor motes concerning towards performance metrics. Finally, this study reviews existing atmospheric dispersion model specifically the Gaussian plume model and its equations for air pollution**.**

Verma A. K., Saxena A.1, Khan A. H. and Sharma G. D. (June 2015)

Urban air pollution is one of the major environmental problems faced by the developing countries. Studies in large Indian cities revealed that ambient air pollution concentrations are at such levels where it can cause serious health impacts. Lucknow, a fast growing city is not an exception to this. Researchers from the city have studied various aspects of air pollution during the last one and half decades, identified particulate matter as the main air pollutant in city. A few studies of indoor environment in households due to various type of fuels used in cooking from urban and nearby rural areas have also identified particulates and associated PAHs as major indoor air pollutant. The objective of this review article is to analyze the air pollution status of city, associated environmental and health impacts and possible control measures presented in studies on Lucknow from the available literature. Particulate fractions viz.; PM2.5, PM10 and SPM were reported to be exceeded the National Ambient Air Quality Standards (NAAQS) limits in most of the studies but oxides of sulphur and nitrogen (SO2 and NOx) were within the limit of 80 µg/m3. Lack of dispersion of pollutants in winter season was reported to be the main reason for highest air pollution during this season and minimum in monsoon due to washout by rains. Commercial areas with high traffic volume recorded higher air pollution levels than residential and industrial areas with low traffic density. Vehicular traffic was identified the major source of air pollution in the city. Air pollution level at control site (village or low traffic density area) was lower than other urban sites. Particulates and associated toxic chemicals (metals and PAHs) and gaseous pollutants have found to be toxic to human and plants in Lucknow. The exposure of these pollutants is associated with cardiovascular and respiratory diseases, neurological impairments, increased risk of preterm birth and even mortality and morbidity. A few studies focusing roadside air pollution have shown high air pollution concentration as well as adverse impact on chlorophyll content of roadside plants. Authorities have been sensitized from the findings of these studies and initiated measures to control vehicular pollution, create awareness and better control of traffic by traffic police. However the efforts made so far are inadequate to maintain good air quality. In view of the rapid growth of Lucknow city in term of area, population and number of registered vehicles, planning and implementation of suitable air pollution control measures are necessary to protect the health of its citizens.

CHAPTER 3
METHODLOGY

3.1 STACK DESIGN

Pollutants are thrown into the atmosphere in a number of different ways. For example wind dust is blown off into the air by the wind. When any plant material decays, methane is released. Pollutants are emitted by the Automobiles, trucks and buses engine exhausts and during refuelling. Electric power plants and home furnaces emits pollutants as they are tried to satisfy mankind's need for energy. One method of releasing the pollution has received more attention than any other –pollution released from stationary point sources, i.e. stacks. Stacks used to come in all sizes –for a small vent on a building's roof to a tall stack. Their function is to release the pollutants high enough above the earth's surface so that the emitted pollutants can effectively disperse in the atmosphere before coming to the ground level. All else being equal, taller stacks disperse the pollutants better than the shorter stacks because the plume has to travel through a greater depth of the atmosphere before it reaches to the ground level. As the plume travels it disperse and spreads.

3.2 PLUME BEHAVIOUR AND DISPERSION

Gases which are emitted from stacks are generally pushed out by fans. As these turbulent exhaust gases comes out from the stack they mix with ambient air. This mixing of ambient air inside the plume is called **entrainment**. As the air is entrained into the plume, the plume diameter grows wider as it travels downwind. These exhaust gases are having momentum as they enter into the atmosphere. Moreover these gases are heated and are warmer than the surroundings air. In such cases the emitted gases are less dense than the surroundings air and are therefore buoyant. A combination of the exhaust gases' momentum and buoyancy causes the gases to rise. This is known as **plume rise** and also allows the air pollutants emitted in this gas stream to be lofted higher in the atmosphere. As the plume is going higher in the atmosphere and at certain distance from the ground, the plume will disperse more before it reaches ground level.

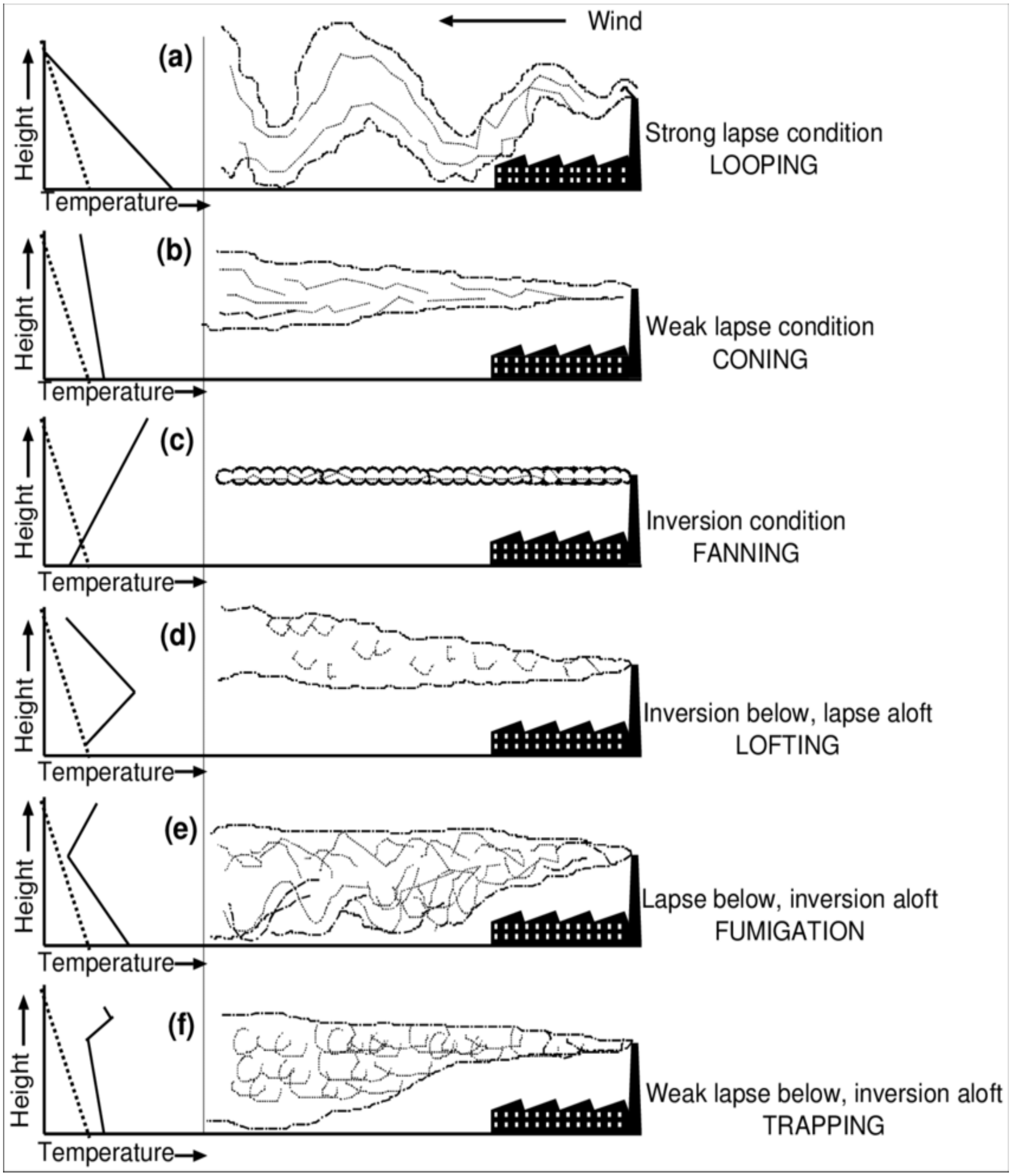


Figure 3.1: Behaviour of plume

The actual height of the plume, is referred as the effective stack height (H), it is the sum of the physical height of stack (hs) and the plume rise (Δh). Plume rise is basically calculated as the distance to the imaginary centreline of plume rather than to the lower or upper edge of the plume. Plume rise actually depends upon the stack's physical characteristics and also on the effluent's (stack gas) characteristics. The difference in the temperatures between the exhaust gases (Ts) and ambient air (Ta) determines the plume density which affects the plume rise. Also, the velocity of the stack gases is a function of the stack diameter and the volumetric flow rate of the gases determines the plume's momentum.

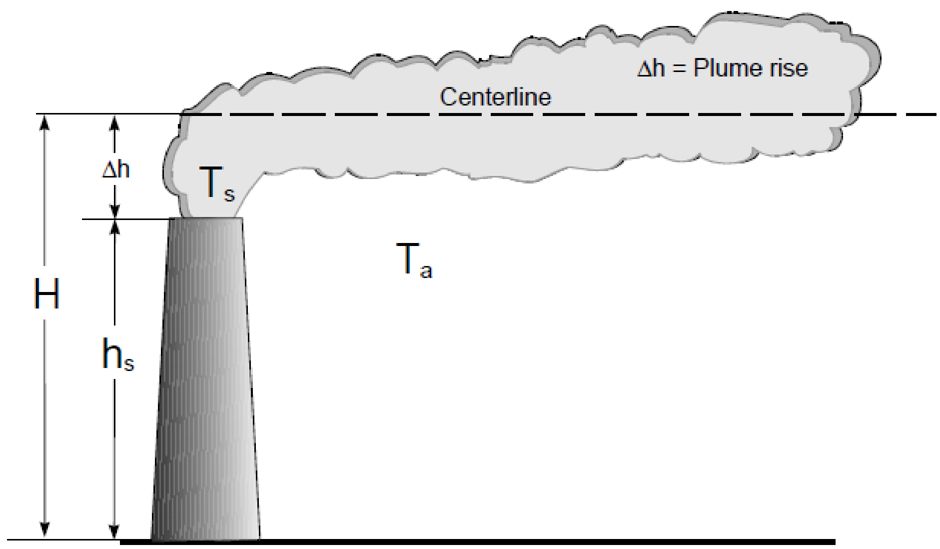


Figure 3.2: Plume rise

3.3 MOMENTUM BUOYANCY

The atmosphere conditions, including the winds and temperature profile, will largely determine the plume's rise along the path of the plume. Two plume characteristics which influences the plume rise: momentum and buoyancy. The velocity of the exhaust gases leaving from the stack generally contributes to the rise of the plume in the surrounding. This momentum carries the effluent gases out of the stack to the point where the atmospheric conditions begin to affect the plume. Once emitted, the initial velocity of the plume is quickly reduced by entrainment as the plume acquires horizontal momentum from the wind. This causes the plume to bend over. The greater the wind speed is, the more horizontal momentum the plume acquires. Wind speed usually increases with distance above the earth's surface. As the plume continues upward the stronger winds tilt the plume even further. This process continues until the plume may appear to be horizontal to the ground. The point where the plume looks level may be a considerable distance downwind from the stack. The speed of wind is important in blowing the plume over. As the wind is stronger, the faster the plume will tilt over.

Plume rise is due to the buoyancy is a function of the temperature difference between the surrounding atmosphere and the plume. The atmosphere when it is unstable, as the plume rises the buoyancy of the plume increases, finally increasing the plume height. In an atmosphere which is stable, as the plume rises buoyancy of the plume decreases. Finally, in the neutral atmosphere, the buoyancy of the plume remains unchanged.

The Buoyancy is taken out from the plume by the same mechanism that tilts the plume towards the wind. As shown in Figure 3.3, due to the mixing of the plume it pulls the atmospheric air into the plume. As the wind speed is very high, the faster is the mixing with outside air takes place. The ambient air is entrained into the plume by the wind "robs" the plume due to its buoyancy, so that on the windy days the plume does not goes very high above the stack.

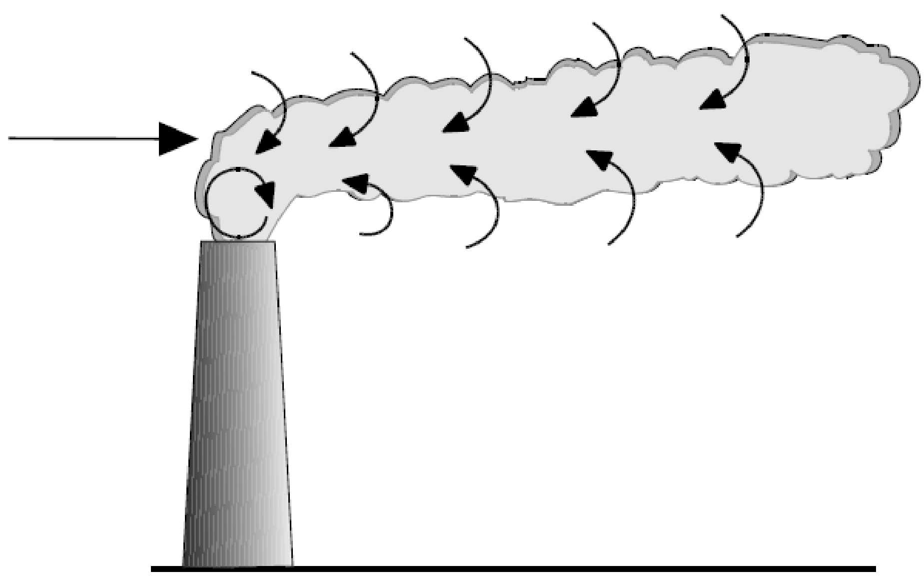


Figure 3.3: Wind effecting entrainment

3.4 EFFECTS OF SOURCE ON PLUME

Due to the physical structure of the stack or the adjacent buildings, this plume may not rise up freely into the atmosphere. Due to Some aerodynamic effects the wind moves around the stack and the adjacent buildings which can force the plume towards the ground and instead of allowing it to go up in the atmosphere.

Stack tip downwash occurs when the ratio of the stack gases exit velocity to wind speed is small. In this case, low pressure wake is formed behind the stack which may cause the plume to be drawn towards downward behind the stack. Dispersion of pollutant is reduced when this mechanism occurs and thus lead to elevated pollutant concentrations immediately to the downwind of the source.

As the air moves over and around the buildings and other structures, turbulent wakes are generated. The plume can be pulled down into this low pressure wake area which depends, upon the release height of a plume (stack height). This is known as aerodynamic or building downwash of the plume and which can lead to elevated pollutant concentrations immediately downwind of the source.

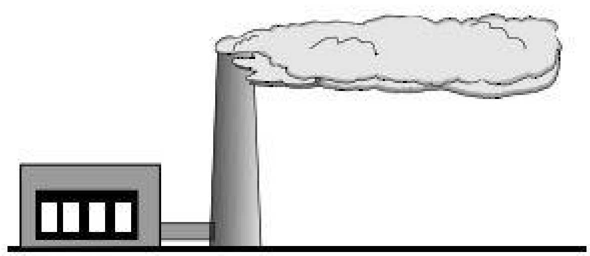


Figure 3.4: Stack dip downwash

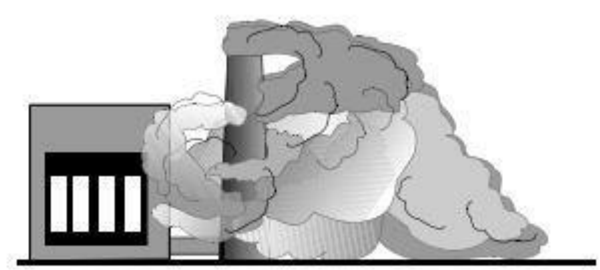


Figure 3.5: Building downwash

3.5 GAUSSIAN'S DISPERSION MODEL

Theory and limitations of Gaussian models,

The turbulent diffusion equation is a partial differential equation that can be solved with various numerical methods. Assuming a homogenous, steady-state flow and a steady-state point source, equation can also be analytically integrated and results the well-known Gaussian plume distribution.

$$c(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z u}\exp\left(\frac{-y^2}{2\sigma_y^2}\right)\left(\exp\left(\frac{-(z-h)^2}{2\sigma_z^2}\right)+\exp\left(\frac{-(z+h)^2}{2\sigma_z^2}\right)\right)$$

Where c is a concentration at a given position, Q is the source term, x is the downwind, y is the crosswind and z is the vertical direction and u is the wind speed at the h height of the release. The σ_y, σ_z deviations describe the crosswind and vertical mixing of the pollutant, thus they are constructed from the K_h, K_z values of equation. Equation describes a mixing process that results a Gaussian concentration distribution both in crosswind and in vertical direction, centered at the line downwind from the source. The last term of equation expresses a total reflection from the ground, therefore this formula does not count with dry and wet deposition. Adding a third vertical component to the equation, total reflection from an inversion layer can also be computed. Gravitational settling and chemical or radioactive decay are neglected.

One can observe that the x downwind distance from the source does not appear in equation. It originates from the obvious assumption that advection is more dominant than diffusion, that, however, can cause large error in situations with low wind speeds where a three-dimensional diffusion dominates. Unfortunately, these situations proved to have been the most dangerous ones in real-life atmospheric dispersion problems as they were often connected to stably stratified atmosphere or low-level inversions.

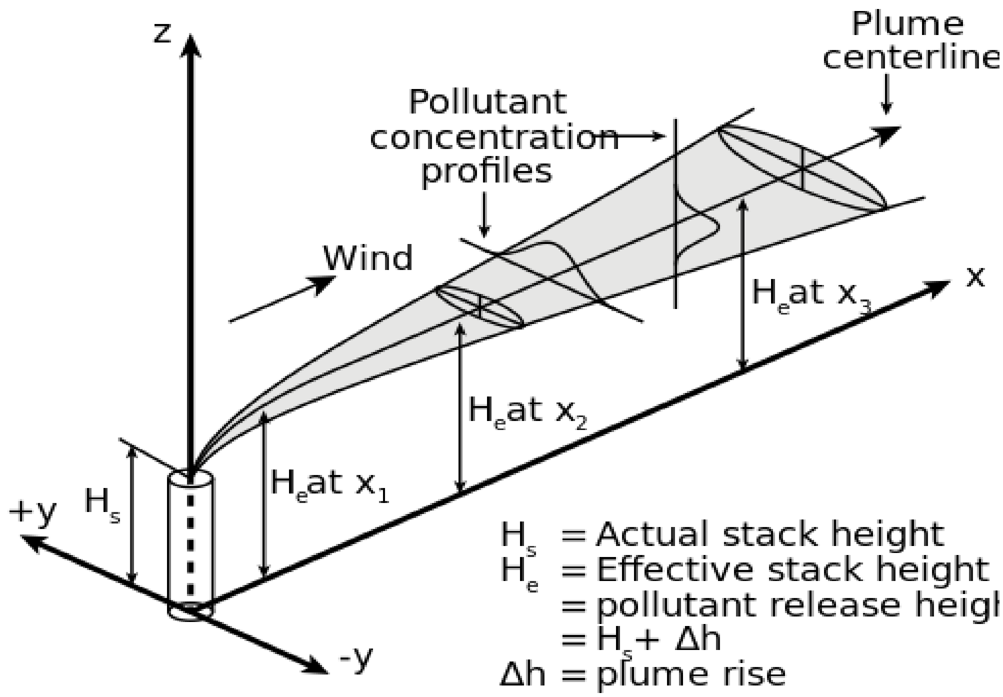


Figure 3.6: Schematic figure of a Gaussian plume.

Besides turbulence, the elevation of the source, often referred to as stack height is a key parameter of a Gaussian model, because ground concentrations are computed in an analytical way assuming the maximum concentration in the stack height. If buoyant pollutants are present, the horizontal advection starts from considerably higher than the stack's top due to the buoyant rise of the released gas. It led to the definition of the effective stack height that is the stack height added to the buoyant plume rise. Both empirical and theoretical formulas exist to compute the plume rise using the temperature, specific heat capacity, release speed and flux of the material as input data, which can be successfully used even in extremely buoyant cases like pool fires. We note that in situations where buoyant pollutants and a low-level thermal inversion are present, more sophisticated simulations are required to estimate the penetration of the inversion layer by the plume.

Table 3.1: Features and assumptions of most Gaussian dispersion models

Represented in most Gaussian models	Not represented in most Gaussian models
Advection	Wind shear
Horizontal turbulent diffusion	Change of wind over time
Vertical turbulent diffusion	Change of source parameters over time
Reflection from ground	Wet and dry deposition
Reflection from inversion layer	Gravitational settling
Elevated source	Chemical reactions
Buoyancy (effective stack height)	Radioactive decay
Multiple source points	Complex terrain

Following graphs shows the plume's standard coefficients with respect to downwind distance:

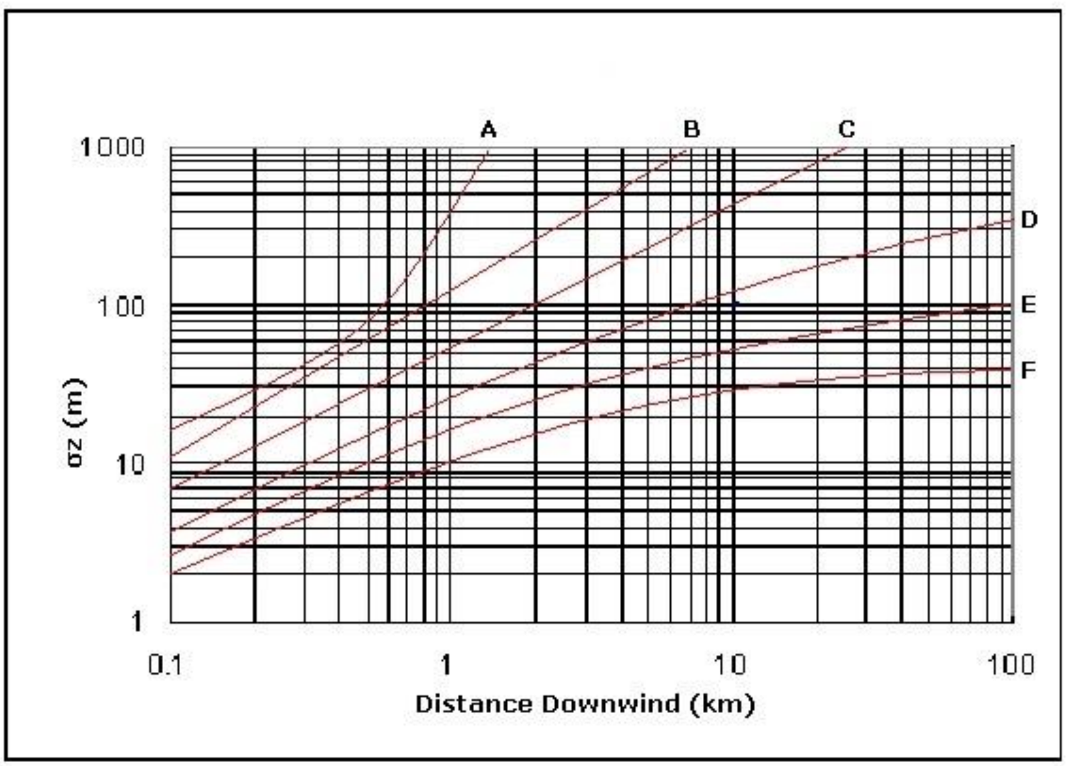


Figure 3.7: Graph of plume's standard coefficient in vertical direction

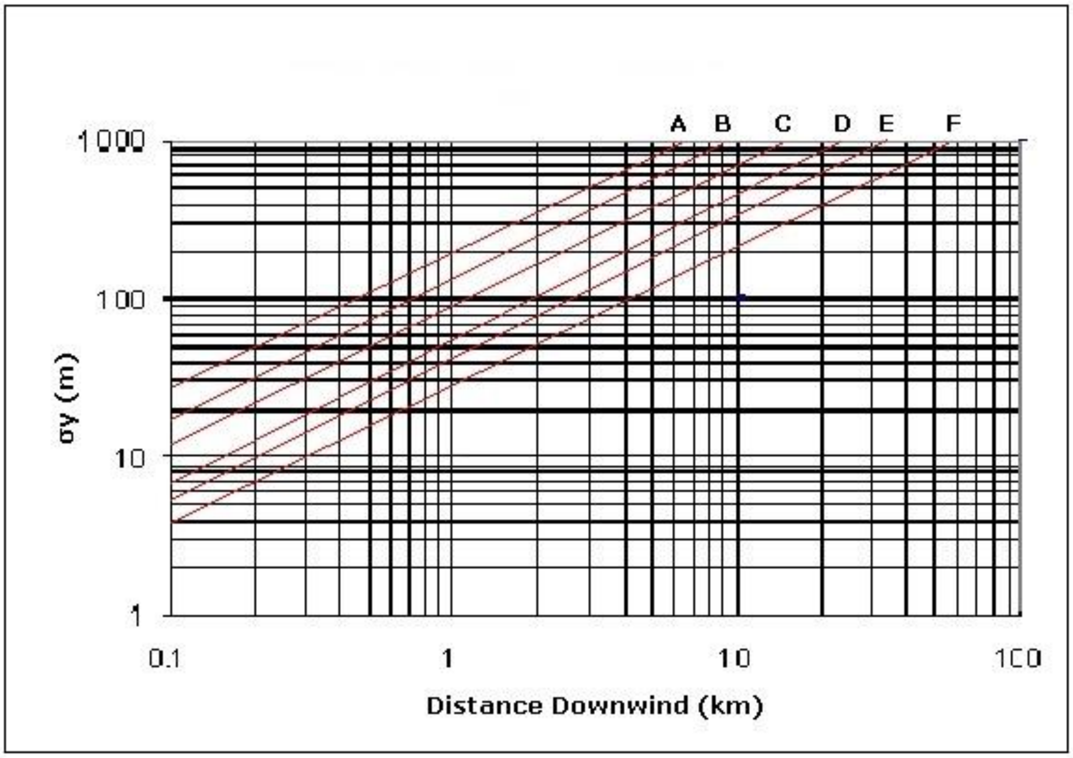


Figure 3.8: Graph of plume's standard coefficient in cross-wind direction.

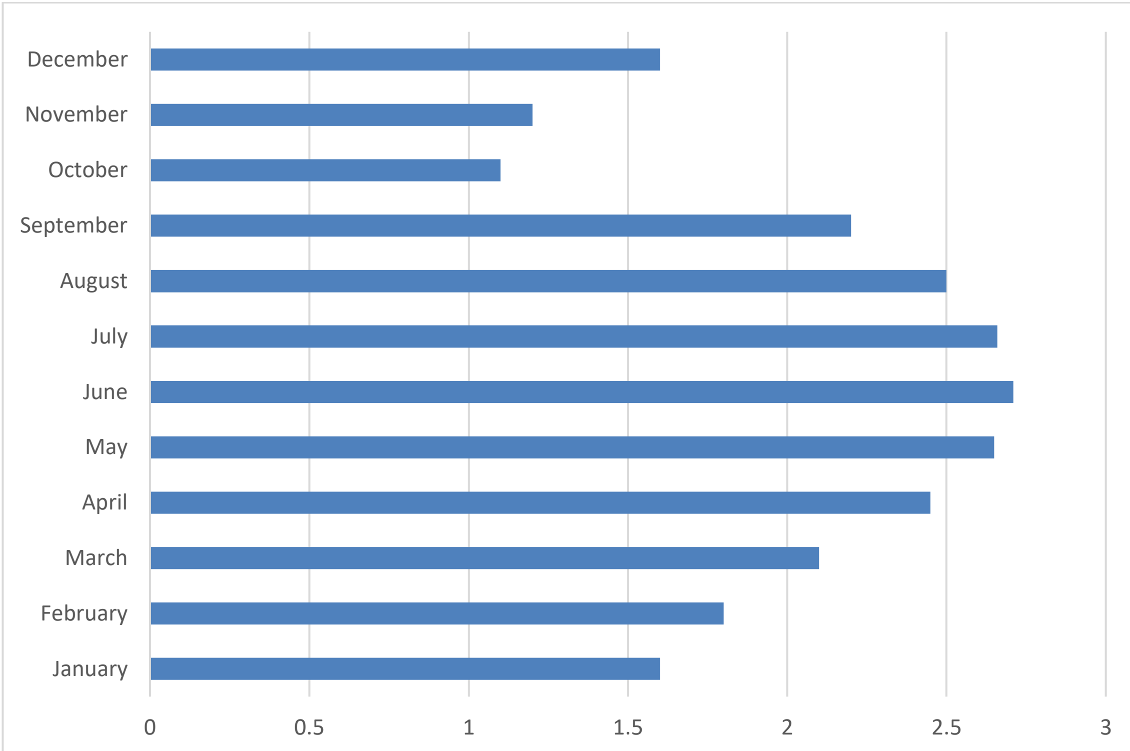
3.6 EFFECT OF METEOROLOGICAL CONDITIONS ON PLUME DISPERSION

Parameters that directly influence the dispersion of pollutants include, wind speeds and direction, atmosphere stability and mixing layer depths. Meteorological conditions that may lead to high ground level concentrations (HGC) from elevated point sources are typically either convective atmospheric stability with light winds or neutral conditions with high wind speeds. Both of these conditions lead to the plume rapidly being carried to ground level close to source. High concentrations from low elevated sources, elevated sources with building or topography effects, or virtual sources are typically due to stable conditions with light winds.

The local meteorology of the region must be characterized to evaluate the short term atmospheric dispersion and transport of emissions released by facility. The data required predicting dispersion and transport includes: wind speeds and direction, temperature, atmospheric stability and mixing layer depth.

Meteorological data is required for the dispersion modelling as it gives the data for the wind velocity, temperature.

Chart 3.1: Average wind speed of prescribed area (m/s)



Meteorological data of Jagdishpur on visit day (24th October 2018):

Temperature: 22°C to 37°C

Humidity: 71%

Wind speed: N 2km/h to 7km/h

Precipitation: 0mm

Pressure: 1013hPa to 1015hPa

Visibility: 3km

UV Index: 5

Air quality: 286 at PM 2.5 (Poor)

Data of fuel used at Indo Gulf Fertilizers Ltd.

Fuel type: 79.44% natural gas and 20.56% naptha fuel

Fuel quantity: 0.228 million standard cubic metres/day

Combustion properties of natural gas:

Ignition point: 564°C

Flammability limits: 4% to 15%

Theoretical flame temperature: 1953°C

Maximum flame velocity: 0.36 m/s

Note: Naptha is a flammable liquid hydrocarbon mixture which is being produced from natural gas condensation, petroleum distillation and the distillation of coal tar and peat.
Refined product of naptha is kerosene.

Table 3.2: Chemical composition of natural gas.

Component	**Typical analysis (mole %)**	**Range (mole %)**
Methane	93.9	87-97
Ethane	4.2	1.5-9
Propane	0.3	0.1-1.5
Iso-butane	0.03	0.01-0.3
Normal butane	0.03	0.01-0.3
Iso-pentane	0.01	Trace-0.4
Normal pentane	0.01	Trace-0.4
Hexanes plus	0.01	Trace-0.6
Nitrogen	1.0	0.2-5.5
CO_2	0.5	0.05-1.0
O_2	0.01	Trace-0.1
Hydrogen	Trace	Trace-0.02
Specific gravity	0.59	0.57-0.62
Gross heating value (MJ/m^3) dry basis	38.7	36.0-40.2
Wolbe number (MJ/m^3)	50.4	47.5-51.5

3.7 PROBLEM STATEMENT

Air pollution occurs when harmful or excessive quantities of substances including gases, particulates, and biological molecules are introduced into Earth's atmosphere. It may cause diseases, allergies and even death to humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Both human activity and natural processes can generate air pollution.

Air pollution risk is a function of the hazard of the pollutant and the exposure to that pollutant. Air pollution exposure can be expressed for an individual, for certain groups (e.g. neighborhoods or children living in a country), or for entire populations. For example, one may want to calculate the exposure to a hazardous air pollutant for a geographic area, which includes the various microenvironments and age groups. This can be calculated as an inhalation exposure. This would account for daily exposure in various settings (e.g. different indoor micro-environments and outdoor locations). The exposure needs to include different age and other demographic groups, especially infants, children, pregnant women and other sensitive subpopulations. The exposure to an air pollutant must integrate the concentrations of the air pollutant with respect to the time spent in each setting and the respective inhalation rates for each subgroup for each specific time that the subgroup is in the setting and engaged in particular activities (playing, cooking, reading, working, spending time in traffic, etc.). For example, a small child's inhalation rate will be less than that of an adult. A child engaged in vigorous exercise will have a higher respiration rate than the same child in a sedentary activity. The daily exposure, then, needs to reflect the time spent in each micro-environmental setting and the type of activities in these settings. The air pollutant concentration in each microactivity/microenvironmental setting is summed to indicate the exposure. For some pollutants such as black carbon, traffic related exposures may dominate total exposure despite short exposure times since high concentrations coincide with proximity to major roads or participation to (motorized) traffic.

In 2012, air pollution caused premature deaths on average of 1 year in Europe, and was a significant risk factor for a number of pollution-related diseases, including respiratory infections, heart disease, COPD, stroke and lung cancer. The health effects caused by air pollution may include difficulty in breathing, wheezing, coughing, asthma and worsening of existing respiratory and cardiac conditions. These effects can result in increased medication use, increased doctor or emergency department visits, more hospital admissions and premature death. The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, and the individual's health status and genetics. The most common sources of air pollution include particulates, ozone, nitrogen dioxide, and sulphur dioxide. Children aged less than five years that live in developing countries are the most vulnerable population in terms of total deaths attributable to indoor and outdoor air pollution.

Air pollution takes place due to manufacturing of fertilizer in fertilizer industry. This source of air pollution spews particulate matters and chemicals into the atmosphere. The exhaust from fertilizer industry includes oxides of carbon, sulphur and nitrogen as well as volatile organic compounds and particulates. Due to this air is polluted and this polluted air effect human health.

CHAPTER 4:
RESULTS AND DISCUSSION

4.1 EVALUATION OF READINGS

Stack is present of height 110m and diameter 3m which through the pollutants to atmosphere. Wind is flowing in positive X-direction and considering the different velocities of wind as 2km/hr, 3km/h, 4km/h, 5km/h, 6km/h and 7km/h. Different velocities of gases from stack are taken as 14.61m/s, 15.47m/s, and 16.33m/s. Mass fractions of the pollutants (N_2, CO_2) coming out from stack are known. Mass diffusivities of different pollutants with respect to air are also known. On each value of wind velocity by varying the stack velocity, different types of plume dispersion is observed. The rest of work which includes providing initial and boundary conditions etc. is done in Fluent. Thus the concentration of pollutants at different heights and horizontal distance is calculated using Gaussian's dispersion model. Tabulation and plotting is done to get an idea about the relation among the pollutants concentration and distance.

Evaluation of effective height of stack (H):

$$\Delta h = \frac{v_s.D}{u}\left[1.5 + 2.68 * 10^{-3} P.D\left(\frac{T_s - T_a}{T_s}\right)\right] \quad \text{....eq(4.1)}$$

where,

Δh = plume height of stack in m

v_s = stack gas velocity in m/s

D = inside exit dia of stack in m

u = wind speed in m/s

P = atmospheric pressure in milli-bars

T_s = stack gas temperature in °K

T_a = air temperature in °K

$$H = h + \Delta h \quad \text{....eq(4.2)}$$

where,

h = height of stack in m

Gaussian distribution equation:

$$C_{x,y} = \frac{Q}{\pi u \sigma_z . \sigma_y}\left(e^{-\frac{1}{2}\left(\frac{H^2}{\sigma_z{}^2}+\frac{y^2}{\sigma_y{}^2}\right)}\right) \qquad \text{....eq(4.3)}$$

where,

C = the concentration of pollutant in g/m^3

Q = the pollutant emission rate in g/sec

u = mean wind velocity in m/sec

x and y = downwind and cross-wind horizontal distances, respectively in m

σ_y = Plume's standard deviation in cross-wind direction in m

σ_z = Plume's standard deviation in downwind direction in m

H = Effective height of stack

When concentration is required only along x-direction, i.e. in the downwind horizontal direction along the centre line of the plume, then naturally y=0. Then equation (4.3) becomes

$$C_{x,0} = \frac{Q}{\pi u . \sigma_z \sigma_y} e^{-\frac{1}{2}\left(\frac{H^2}{\sigma_z{}^2}\right)} \qquad \text{....eq(4.4)}$$

At the indo gulf fertilizers limited the main stack is connected with two boilers by (BOILER 605 & BOILER 606) which the pollutants are flowing towards the stack, thus the readings of that boilers are as follows:

BOILER 605

T_a = 32°C = 32 + 273 = 305K

T_s = 137°C = 137 + 273 = 410K

Pressure of water vapours in stack, ΔH = 11.5, 12.3, 11.9, 11.2, 12.2, 12.3, 11.7, 12.5, 12.2, 11.2, 12.1, 12.2, 13.3, 14.2, 16.3, 17.2, 16.1, 15.2

Mean ΔH = 13.08 mmH_2O

Plume velocity, $v_1 = 0.1995\sqrt{T_s \times \Delta H}$ = 14.61m/s

BOILER 606

T_a = 32°C = 32 + 273 = 305K

T_s = 130°C = 130 + 273 = 403K

Pressure of water vapours in stack, ΔH = 14.2, 15.3, 16.9, 13.2, 17.7, 15.5, 18.2, 15.9, 18.3, 17.2, 15.1, 16.2, 18.5, 17.1, 17.9, 16.2

Mean ΔH = 16.63 mmH_2O

Plume velocity, $v_2 = 0.1995\sqrt{T_s \times \Delta H}$ = 16.33 m/s

Mean plume velocity, v_s = 15.47 m/s

Pressure = 1014 milli-bars

Fuel quantity: 0.228 million standard cubic metres/day

Density of fuel = 0.712 kg/m^3

As we know, density = mass/volume

Therefore, mass = 6764 kg/h

CO_2 produced/h = $6764 \times \frac{1}{100}$ = 67.64 kg

Nitrogen produced/h = $6764 \times \frac{5.5}{100}$ = 372.02 kg

Emission rate for N_2 = $\frac{372.02 \times 1000}{60 \times 60}$ = 103.34 g/s

Emission rate for CO_2 = $\frac{67.64 \times 1000}{60 \times 60}$ = 18.79 g/s

Height of stack, h = 110m

Diameter of stack = 3m

Wind velocities we have, 2km/h, 3km/h, 4km/h, 5km/h, 6km/h and 7km/h

The values of x and σ_y is been evaluated by the help of the value of σ_z, with the help of graph in the figures 3.7 and 3.8.

4.2 For wind velocity, u = 2km/hr

u = 0.56 m/s

by using formula,

$$\Delta h = \frac{v_s . D}{u}\left[1.5 + 2.68 * 10^{-3} P.D\left(\frac{T_s - T_a}{T_s}\right)\right]$$

we get the height of plume,

$\Delta h = 293.02m$

Effective height of stack is given by,

H = h + Δh = 110 + 293.02 = 403.02m

σ_z = 0.707*H = 284.94m

The values of x and σ_y is been evaluated by the help of the value of σ_z, with the help of graph in the figures 3.7 and 3.8 in case of slightly unstable atmospheric conditions.

x = 6000m

σ_y = 545m

by using Gaussian's equation for the cross-wind distance of the centre line of plume, i.e. y=0

$$C_{x,0} = \frac{Q}{\pi u. \sigma_z \sigma_y} e^{-\frac{1}{2}\left(\frac{H^2}{\sigma_z{}^2}\right)}$$

Therefore after solving the equation wrt given values of the unknowns we get the values,

For N_2

C_{max} = 139 µg/m^3

And for CO_2

C_{max} = 25.3 µg/m^3

4.3 For wind velocity, u = 3km/hr

u = 0.83 m/s

by using formula,

$$\Delta h = \frac{v_s . D}{u}\left[1.5 + 2.68 * 10^{-3} P. D\left(\frac{T_s - T_a}{T_s}\right)\right]$$

we get the height of plume,

$\Delta h = 197.7m$

Effective height of stack is given by,

H = h + Δh = 110 + 197.7 = 307.7m

σ_z = 0.707*H = 218m

The values of x and σ_y is been evaluated by the help of the value of σ_z, with the help of graph in the figures 3.7 and 3.8 in case of slightly unstable atmospheric conditions.

x = 4000m

σ_y = 375m

by using Gaussian's equation for the cross-wind distance of the centre line of plume, i.e. y=0

$$C_{x,0} = \frac{Q}{\pi u. \sigma_z \sigma_y} e^{-\frac{1}{2}\left(\frac{H^2}{\sigma_z{}^2}\right)}$$

Therefore after solving the equation wrt given values of the unknowns we get the values,

For N_2

C_{max} = 178 µg/m^3

And for CO_2

C_{max} = 32.4 µg/m^3

4.4 For wind velocity, u = 4km/hr

u = 1.11 m/s

by using formula,

$$\Delta h = \frac{v_s . D}{u}\left[1.5 + 2.68 * 10^{-3} P. D\left(\frac{T_s - T_a}{T_s}\right)\right]$$

we get the height of plume,

$\Delta h = 147.8m$

Effective height of stack is given by,

H = h + Δh = 110 + 147.8 = 257.8m

σ_z = 0.707*H = 182m

The values of x and σ_y is been evaluated by the help of the value of σ_z, with the help of graph in the figures 3.7 and 3.8 in case of slightly unstable atmospheric conditions.

x = 3500m

σ_y = 335m

by using Gaussian's equation for the cross-wind distance of the centre line of plume, i.e. y=0

$$C_{x,0} = \frac{Q}{\pi u. \sigma_z \sigma_y} e^{-\frac{1}{2}\left(\frac{H^2}{\sigma_z{}^2}\right)}$$

Therefore after solving the equation wrt given values of the unknowns we get the values,

For N_2

C_{max} = 179 µg/m^3

And for CO_2

C_{max} = 32.5 µg/m^3

4.5 For wind velocity, u = 5km/hr

u = 1.39 m/s

by using formula,

$$\Delta h = \frac{v_s . D}{u}\left[1.5 + 2.68 * 10^{-3} P . D\left(\frac{T_s - T_a}{T_s}\right)\right]$$

we get the height of plume,

$\Delta h = 118.05m$

Effective height of stack is given by,

$H = h + \Delta h = 110 + 118.05 = 228.05m$

$\sigma_z = 0.707*H = 161.23m$

The values of x and σ_y is been evaluated by the help of the value of σ_z, with the help of graph in the figures 3.7 and 3.8 in case of slightly unstable atmospheric conditions.

x = 2600m

$\sigma_y = 255m$

by using Gaussian's equation for the cross-wind distance of the centre line of plume, i.e. y=0

$$C_{x,0} = \frac{Q}{\pi u . \sigma_z \sigma_y} e^{-\frac{1}{2}\left(\frac{H^2}{\sigma_z{}^2}\right)}$$

Therefore after solving the equation wrt given values of the unknowns we get the values,

For N_2

$C_{max} = 212\ \mu g/m^3$

And for CO_2

$C_{max} = 38.5\ \mu g/m^3$

4.6 For wind velocity, u = 6km/hr

u = 1.67 m/s

by using formula,

$$\Delta h = \frac{v_s . D}{u}\left[1.5 + 2.68 * 10^{-3} P . D\left(\frac{T_s - T_a}{T_s}\right)\right]$$

we get the height of plume,

$\Delta h = 98.26m$

Effective height of stack is given by,

$H = h + \Delta h = 110 + 98.26 = 208.26m$

$\sigma_z = 0.707 * H = 147.24m$

The values of x and σ_y is been evaluated by the help of the value of σ_z, with the help of graph in the figures 3.7 and 3.8 in case of slightly unstable atmospheric conditions.

x = 2260m

$\sigma_y = 225m$

by using Gaussian's equation for the cross-wind distance of the centre line of plume, i.e. y=0

$$C_{x,0} = \frac{Q}{\pi u . \sigma_z \sigma_y} e^{-\frac{1}{2}\left(\frac{H^2}{\sigma_z{}^2}\right)}$$

Therefore after solving the equation wrt given values of the unknowns we get the values,

For N_2

$C_{max} = 219\ \mu g/m^3$

And for CO_2

$C_{max} = 39.8\ \mu g/m^3$

4.7 For wind velocity, u = 7km/hr

u = 1.94 m/s

by using formula,

$$\Delta h = \frac{v_s . D}{u}\left[1.5 + 2.68 * 10^{-3} P. D\left(\frac{T_s - T_a}{T_s}\right)\right]$$

we get the height of plume,

$\Delta h = 84.58m$

Effective height of stack is given by,

H = h + Δh = 110 + 84.58 = 194.58m

σ_z = 0.707*H = 137.57m

The values of x and σ_y is been evaluated by the help of the value of σ_z, with the help of graph in the figures 3.7 and 3.8 in case of slightly unstable atmospheric conditions.

x = 2100m

σ_y = 205m

by using Gaussian's equation for the cross-wind distance of the centre line of plume, i.e. y=0

$$C_{x,0} = \frac{Q}{\pi u. \sigma_z \sigma_y} e^{-\frac{1}{2}\left(\frac{H^2}{\sigma_z{}^2}\right)}$$

Therefore after solving the equation wrt given values of the unknowns we get the values,

For N_2

C_{max} = 221 μg/m^3

And for CO_2

C_{max} = 40 μg/m^3

Chart 4.1: Plume's standard deviation (m) vs wind speed (km/h)

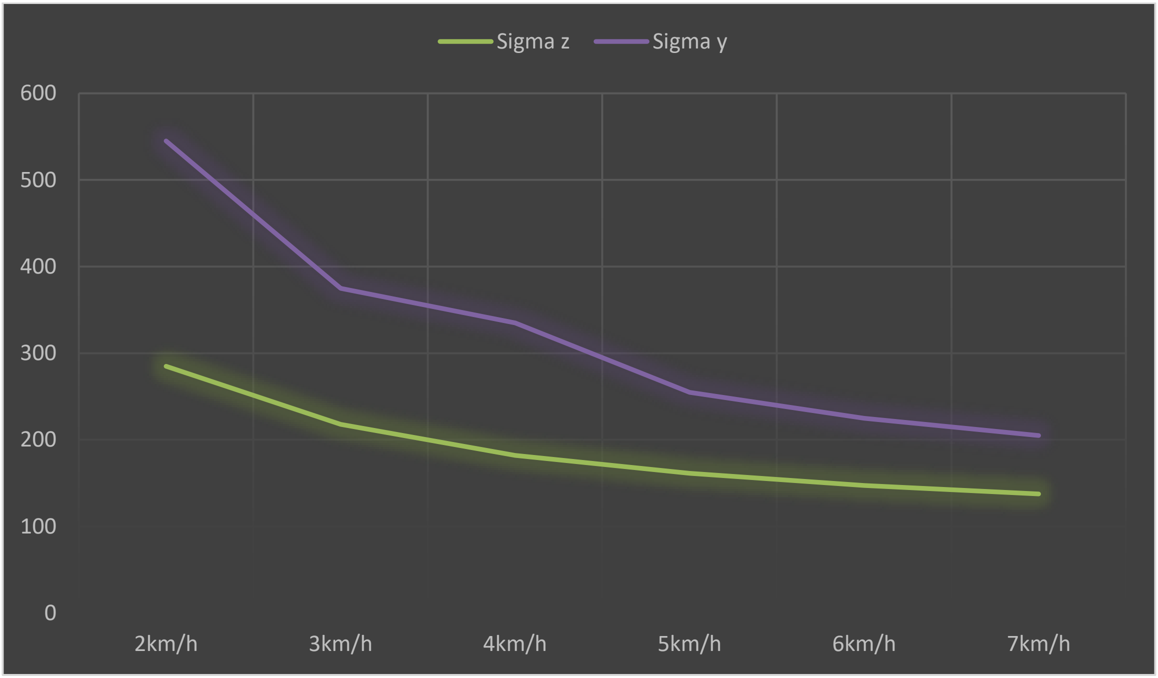
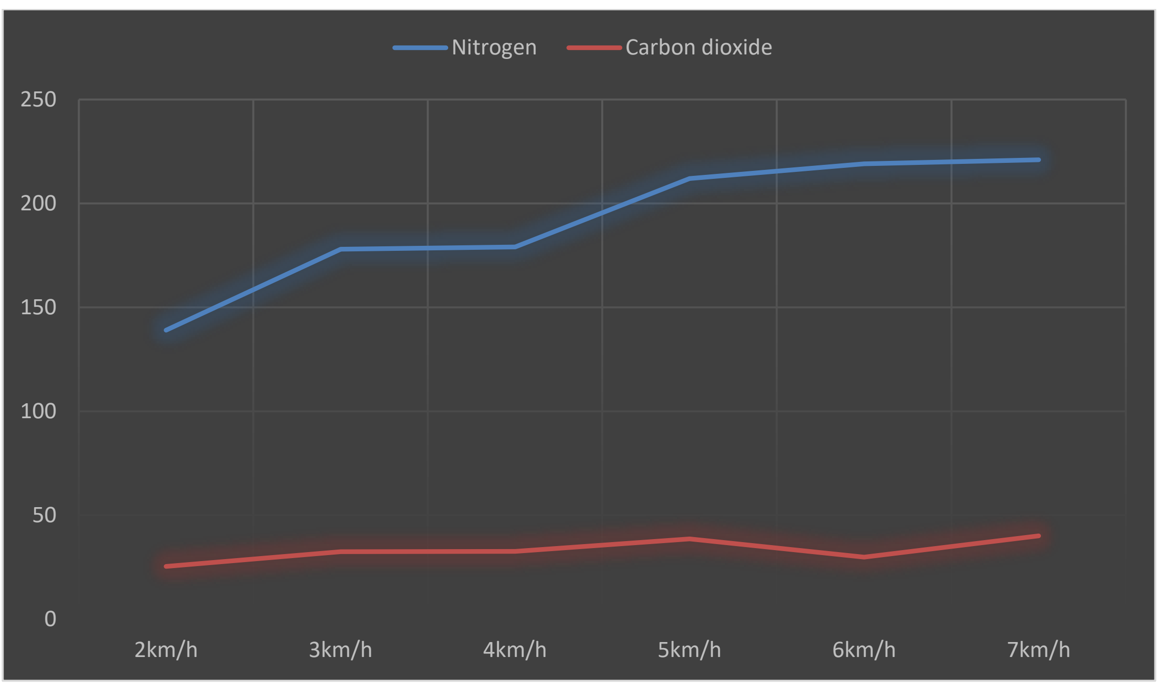


Chart 4.2: Concentration of pollutant µg/m^3 vs mean wind velocity km/h



CHAPTER 5

CONCLUSION

From the graphs plotted above at different wind velocity conditions and as well as different stack velocity conditions, the pollutant concentration is determined. When the wind velocity is low then the pollutant concentration on the ground is low and at the high wind velocity the pollutant concentration is increased easily shown in plotting's. As the engineering design is done for worst and best case, the worst condition for any stack design or the plume dispersion is when the wind velocity is very high. In this case the pollutants are dragged off towards the ground level.

To avoid this behaviour, stack velocity is to be increased in such a manner that the wind velocity should be much less than that of stack velocity. To avoid this behaviour we can also have numbers of stack in the industry of different dimensions which can give the different velocities of gases from stack as per required. Finally the best engineering work is done by providing the more turbulence in atmosphere so that there is more diffusion of pollutants and before reaching the ground surface, maximum pollutants should diffuse in environment.

REFERENCES

1. Ádám Leel″ossy, Ferenc Molnár Jr., Ferenc Izsák, Ágnes Havasi, István Lagzi, Róbert Mészáros (15 May 2014), Dispersion modeling of air pollutants in the atmosphere: a review.
2. Adel A. Abdel-Rahman (October 2008), On the Atmospheric Dispersion and Gaussian Plume Model.
3. Air Pollution Modeling – An Overview by Aaron Daly and Paolo Zannetti.
4. Assessment of Air Pollution in Lucknow by Geetika Saluja (2017).
5. A general equation for aerosol aspiration by thin-walled sampling probes in calm and moving air, by Sergey Grinshpun, Klaus Willeke and Suresh Kalatoor (Afmospheric Environment 27A, 1459-1470, 1993). Atmospheric Environmenf Vol. 28, No. 2, p. 375, 1994.
6. Ankita Shukla, Rajeev Kumar Mishra, Dr. M. Parida (2010), Estimation of Composite Air Quality Index for Lucknow.
7. Ben Bella S. Tawfik1 & M. M. El-Gazar (June 2013), Analysis of the Factors Affecting the Distribution of Chimney Emissions to the Atmosphere – Simulation Approach.
8. Chandrasekar.e, Rajendran.m, Bharath.p (April 2017), Air pollution dispersion study in the neighbourhood of coastal Super power thermal plant at Karikkuppam, Tamil Nadu.
9. Dr. Akshey Bhargava (April 2016), Effect Of Stack Exit Velocity And Gas Temperature On Plume Rise Using Different Equations.
10. Dorin Cârstoiu, Gabriel Gorghi, Carmen Leane Nicolescu (2010), A Model For Establishing The Pollutants Dispersion Implemented In Memdur System.
11. Debosree Ghosh and Pratap Parinda (November 2015), Air Pollution And India: Current Scenario.

12. Dr. Dipak Prasad and Dr. (Mrs.) Srabani Sanyal (2016), Air Quality and its Effect on Health: A Geographical Perspective of Lucknow City.
13. Eman Sarwat and F.S.Tawfik (2016), Optimizing Atmospheric Radioactivity levels Using Genetic Algorithm for Radiation Safety Aspects.
14. G. Grigoras, V. Cuculeanu1, G. Ene, G. Mocioaca, A. Deneanu (July 2010), Air pollution dispersion modeling in a polluted Industrial area of complex terrain from Romania.
15. Gabriel A. Sandler, Hannah E. Gardiner, James Baciak. Atmospheric 41Ar Plume Tracking and Model Development of the UF Training Reactor Using a Large-Volume NaI Detector.
16. Health impacts of air pollution: studies from india by Dr. Arun Kr. Sharma
17. I.R. Ilaboya, E. Atikpo, L. Umukoro, F.E. Omofuma and M.O. Ezugwu (February 2011), Analysis of the Effects of Mixing Height and Other Associated Factors on the Effective Dispersion of Plume.
18. Musalaiah Modi, Venkata Ramachandra P, Liyakhath Ahmed Sk And Zakir Hussain (2013), A Review On Theoretical Air Pollutants Dispersion Models.
19. R.L. Dennis (July 1978),The Smeared Concentration Approximation Method: A Simplified Air Pollution Dispersion Methodology For Regional Analysis.
20. Seema Awasthia, Mukesh Khareb and Prashant Gargavac (2006), General plume dispersion model (GPDM) for point source emission.
21. Steven R. Hanna and Rex E. Britter "Wind flow and Vapor cloud dispersion. At industrial and urban sites". University of Cambridge, 2002.
22. Weil J.C "An updated Gaussian plume model for all stacks". Journal of Air Pollution and control association, 1984.

IJSRD
ISSN (ONLINE) : 2321 0613
IJSRDV7I30003
No: 366765

IJSRD

INTERNATIONAL JOURNAL FOR SCIENTIFIC RESEARCH & DEVELOPMENT

CERTIFICATE OF PUBLICATION

is here by awarding this certificate to

Rishi Yadav

in recognition of the publication of the paper entitled

Analysis of Effectiveness of Stack in the Dispersion of Air Pollutants by using Gaussian,S Plume Model at Indo Gulf Fertilizers Ltd., Jagdishpur, U.P., India

published in e-journal

Volume 7, Issue 3, in May 2019

EDITOR-IN-CHIEF

EXECUTIVE-EDITOR

IJSRD
ISSN (ONLINE) : 2321 0613
IJSRDV7I30033
No: 366773

IJSRD

INTERNATIONAL JOURNAL FOR SCIENTIFIC RESEARCH & DEVELOPMENT

CERTIFICATE OF PUBLICATION

is here by awarding this certificate to

Rishi Yadav

in recognition of the publication of the paper entitled

A Review Study on Effectiveness of Stack in the Dispersion of Air Pollutants

published in e-journal

Volume 7, Issue 3, in May 2019

EDITOR-IN-CHIEF

EXECUTIVE-EDITOR

- Visit us @ www.ijsrd.com or call us @ +91 8866191212

Prakriti Consultants Services

An Approved Laboratory From MoEF, NABL & Uttar Pradesh Pollution Control Board
(An ISO 14001:2004, ISO 9001-2008 and OHSAS-18001-2007 Certified Organization)
Address: 12, Vishnupuri, Church Road, Aliganj, Lucknow-226024
E-mail: prakriti_md@rediffmail.com
Tel: 0522- 4002545, Mobile: 09415518818,

An Approved Laboratory from MoEF vide S.O. No. 1190 (E) dated 01/05/2014 and Valid up to 30/04/2019

"NABL" Accredited Laboratory Certificate No:- TC-8241 Validity 01-01-2019 to 31-12-2020

CERTIFICATE

This is to certify that **Mr. Rishi Yadav S/o Mr. V.K Yadav** student of M.Tech Environmental Engineering fourth semester **BBD University, Lucknow (UP)** has completed 3 month training during the period October 2018 to December 2018 on ***"Air Pollution Monitoring & Analysis".***

Date: 29/4/2019

Dr. Divya Misra

PERSONAL PROFILE

	Rishi Yadav (1170470009) M.Tech Environmental Engineering B.B.D. University, Lucknow (email: 12rrishi@gmail.com)