

Ambient Air Quality of an Industrial Estate- Mandi Gobindgarh

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DECLARATION

I hereby declare that the work embodied in thesis entitled, "**Ambient Air Quality of an Industrial Estate- Mandi Gobindgarh**", is an original piece of work and was conducted in the Department of Biotechnology and Environmental Sciences, Thapar University, Patiala under the guidance of Mr. Amit Dhir (Assistant Professor, Department of Biotechnology and Environmental Sciences). The matter presented in this thesis has not been submitted in part or full, to this or any other University/Institute for any degree or diploma.


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ABSTRACT

With an increased pace of industrialization especially in developing countries, environmental problems have also increased. At the same time, with growing population and economic development, there has been a rapid rise in air pollution sources. Due to this, a number of pollutants are released in the ambient air deteriorating its quality. The health effects caused by air pollution may include difficulty in breathing, wheezing, coughing and aggravation of existing respiratory and cardiac conditions.

The project investigates the concentration of the pollutants PM 10, PM 2.5, Sulphur Dioxide, and Nitrogen Dioxide from various sources like automobiles, industries over the ambient air quality of the Mandi Gobindgarh, As it is one of the 24 critically polluted area identified by CPCB so selected for the study. 11 sampling sites were selected including 7 industrial, 2 residential, 1 agricultural within the study area on the basis of different parameters like population density, meteorological data, industrial clusters identified by PPCB. With the help of meteorological data, Windroses and impact area diagrams were plotted. Impact area for a period of 12 month was also calculated to know dilution factor of pollutants over the study period. At each site all 4 pollutants were monitored twice a week using PM 2.5/10 sampler for particulates and High volume Sampler with gaseous attachment for SO₂ and NO₂.

PTFE filters of 47mm diameter and whatman filters of diameter 37mm were used for collection particulates of diameter less than 2.5um whereas whatmman filters of diameter 47mm were used for PM 10. For SO₂ sampling, H₂O₂ was used as an absorbing solution whereas solution of Sodium Hydroxide and Sodium Arsenite was used for NO₂ sampling.

In order to calculate the level of pollutants in air, Air Quality Index (AQI) was calculated by using methodology suggested by CPCB, on the basis of concentrations of different pollutants within the studied area. AQI was calculated for each site to know the area with worst air quality which was found to be site near village Kumbh, Amloh road. Pollutant responsible for this AQI was found to be PM 10. Sites at GT road, Talwara road, Prem Nagar were also found to be critically polluted.

Overall AQI was also calculated on the basis of two different methodology, named as IND-AQI, USEPA-AQI. The results demonstrated that the AQI level measured within the studied area comes under 'Very Poor' category which reflects that the impact of pollutant on human health is at extreme level.

Ratio of SO_2/NO_2 was also calculated to observe the impact of vehicles on to air pollution. Least impact of moving vehicle was found to be at Talwara road means air quality there was mainly due to industrial emissions.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Air pollution due to anthropogenic sources, is a matter of concern in whole world. The urban areas may be viewed as dense sources of enormous anthropogenic emissions of pollutants, which can alter the atmospheric composition, chemistry and life cycles in its down wind regimes, extending over several hundred kilometers (*Gupta et al., 2008*). Moreover, worldwide epidemiological study on the effect of air pollution has revealed that gaseous pollutants and particulate matter has enough potential to cause severe health effect like respiratory, cardiovascular diseases and cardio pulmonary mortality. Modernization and industrialization of developing countries has led to the increased use of fossil fuels and their derivatives. As such, developing countries are confronted with the great challenge of controlling the atmospheric pollution especially in the rapidly growing mega cities. Hence a systematic monitoring programme all over the world especially in urban cities is urgently needed.

India, a developing country, is one of the first ten industrial countries of the world (*Sharma, 2007*). Because of the enhanced anthropogenic activities (*Goyal and Sidhartha, 2003*) in India, air pollution problems have become a topic of intense debate at all platforms. According to a study released by World Economic Forum in Davos, India has the worst air pollution in the entire world, beating China, Pakistan, Nepal and Bangladesh. Of the total 132 countries whose environmental assets were surveyed, India ranked dead last in the 'Air (effects on human health)' ranking (<http://envirocenter.yale.edu/news/237/56/India-s-Air-the-World-s-Unhealthiest-Study-says/d,newsDetail>). The World Health Organization estimates that about two million people die prematurely every year as a result of air pollution, while many more suffer from breathing ailments, heart disease, lung infections and even cancer.

Air pollution in India has increased rapidly because of intensive population growth, increase in the numbers of vehicles, use of fuels with poor environmental performance, badly mentioned transportation systems, poor land use pattern, industrialization, and above all, ineffective environmental regulations (*Chattopadhyay et al., 2010*). In most of the 23 Indian cities with a

million-plus population, air pollution levels exceed World Health Organization's (WHO) recommended health standards. In every city, the levels are getting worse because of rapid industrialization, growing number of vehicles, energy consumption, and burning of wastes. Several cities face severe air pollution problems, with annual average levels of total suspended particulates (TSP) at least three times as high as the WHO standards. A study conducted by the World Bank indicates premature deaths of people in Delhi owing to high levels of air pollution (CPCB, 2003).

1.2 Air Quality Monitoring Program in India

The air quality monitoring program in India was started in 1967 by the National Environmental Engineering Research Institute (NEERI) (then named CIPHERI, Central Public Health Engineering Research Institute). The monitoring was expanded to include regular monitoring at three stations in 1978. The CPCB initiated the National Ambient Air Quality Monitoring (NAAQM) program in the year 1984 with seven stations at Agra and Anpara. Subsequently, the program was renamed as National Air Monitoring Programme (NAMP). The number of monitoring stations under the NAMP has increased, steadily, to 295 by 2000-2001 covering 99 cities/towns in 28 States and 4 Union Territories (CPCB, 2003).

Under NAMP, four air pollutants, viz., sulphur dioxide (SO₂), oxides of nitrogen as NO₂ and suspended particulate matter (SPM) and respirable suspended particulate matter (RSPM/PM 10), have been identified for regular monitoring at all the locations. Besides this, additional parameters such as respirable lead and other toxic trace metals, hydrogen sulphide (H₂S), ammonia (NH₃) and polycyclic aromatic hydrocarbons (PAHs) are also being monitored in 10 metro-cities of the country since 1990.

The monitoring of meteorological parameters such as wind speed and direction, relative humidity and temperature were also integrated with the monitoring of air quality. Further, for real time data collection, automatic monitoring stations at few places had also been installed. Ambient air quality monitoring was carried out manually using high volume samplers and respirable dust samplers with gaseous attachments. The samples were analyzed in the laboratory and sent to the Pollution Assessment Monitoring and Survey (PAMS), division of CPCB.

A number of agencies and institution involved in monitoring activities are:

- (i) Central Pollution Control Board, Headquarters, Zonal and Regional Offices
- (ii) State Pollution Control Boards, in respective states
- (iii) Pollution Control Committees in respective Union Territories
- (iv) National Environmental Engineering Research Institute (NEERI), Nagpur in 10 metro cities
- (v) Visveshwarya Regional College of Engineering, Nagpur
- (vi) Pune University, Pune
- (vii) KTHM College, Nasik
- (viii) Walchand Institute of Technology, Solapur

The objectives of the N.A.M.P. are as follows:

- To determine status and trends of ambient air quality;
- To ascertain the compliance of prescribed ambient air quality standards;
- To Identify non-attainment Cities where air pollutants are exceeded prescribed standards.
- To develop preventive and corrective measures and
- To understand the natural cleansing process undergoing in the environment through pollution dilution, dispersion, wind based movement, dry deposition, precipitation and chemical transformation of generated pollutants.

National Ambient Air Quality Standards, prevailing during year 2007 and revised standards notified in November 2009 are annexed for reference (*Annexure I and II*).

1.3 Air Pollution Affected Areas

Air pollution in India is mainly caused by three sources, namely, vehicles, industrial and domestic sources. It is mainly concentrated in the following three areas:

- (i) **Major cities:** The problem of air pollution is in major cities where the prominent sources are vehicles and small- and medium-scale industries. These cities include Delhi, Kolkata, Mumbai, Chennai, Ahmedabad, Bangalore, Hyderabad, Pune, Kanpur, etc.

(ii) **Critically polluted areas:** In India, there are as many as 24 areas which have been designated as ‘Critically Polluted Areas’ w.r.t. air, water pollution by CPCB. These areas are as follows:

Table 1.1: Problem Areas in India (CPCB, 2003)

S.No.	Problem Areas in India	Problem Area Type of Industry
1	Singrauli	Power Plants, Mining, Aluminium Industry
2	Korba	Power Plants, Aluminium Industry, Mining
3	Vapi	Chemical Industries
4	Ankaleshwar	Chemical Industries
5	Greater Cochin	Oil Refineries, Chemical, Metallurgical Industries
6	Visakhapatnam	Oil Refinery, Chemical, Steel Plants
7	Howrah	Foundry, Rolling Mills
8	Durgapur	Chemical Industries, Power Plants, Steel Plants
9	Manali	Oil Refineries, Chemical Industry, Fertilizer Industry
10	Chembur	Refineries, Power Plant, Fertilizer Industry
11	Mandi Gobindgarh	Secondary Steel Industry
12	Dhanbad	Mining, Coke Oven
13	Pali	Cotton Textile, Dyeing
14	Nagafgarh	Drain Basin Power Plants, Vehicles
15	Angul-Talcher	Mining, Aluminum Plants, Thermal Power Plants
16	Bhadravati	Iron and Steel, Paper Industry
17	Digboi	Oil Refinery
18	Jodhpur	Cotton Textile, Dye
19	Kala-Amb	Paper, Electroplating
20	Nagda-Ratlam	Viscose Rayon, Caustic, Dyes, Distillery
21	North Arcot	Tanneries
22	Parwanoo	Food Processing Unit, Electroplating
23	Patancheru – Bollaram	Organic Chemical, Paints Petrochemical Industry
24	Tarapur	Chemical Industry

Among those, the critically polluted areas with regard to Air Pollution are Mandi Gobindgarh, Durgapur, Digboi, Greater Cochin, Visakhapatnam etc.

(iii) **Rural areas:** Indoor air pollution exists in rural areas with domestic fuel as the main source of air pollution. In rural areas cow dung and wood sticks are used as fuel in household. Kitchens are without any proper ventilation, resulting in the buildup of air pollutants in the houses. Indoor air pollution exists in rural areas due to lack of proper ventilation and absence of exhaust fans/ electric chimneys.

1.4 General Description of the Study Area

Mandi Gobindgarh is a town and a municipal committee in Fatehgarh Sahib district in the Indian state of Punjab and also known as 'Steel Town of India' as various categories of steel manufacturing units are operating in this town. This town is located on National Highway-I. The town is spread over an area of 10.64 Sq. Kms. and accommodates a population of 55,416 as per 2001 census. Geographically, Mandi Gobindgarh falls in District Fatehgarh Sahib, which is situated in Malwa region of Punjab. It lies between north latitude 30°-37'-30" and 30°-42'-30" and east longitude 76°-15' and 76°-20'. It shares common boundaries with several districts such as Mohali, Patiala, Sangrur, Ludhiana and Rupnagar, and is well connected by rail and road (*PCB, 2010*).

The topography of the District Fatehgarh Sahib is typical representative of an Alluvial plain; it owes its origin to the aggravation work of the Sutlej River. The climate of the District Fatehgarh Sahib is characterized by dryness except a brief spell of monsoon season in a very hot summer and a bracing winter. The winter season is from middle of November to the early part of March. The succeeding period up-to the end of June is the hot season. July, August and half of September constitute the south west of monsoon, the period of mid September to about the middle of November may be termed as post monsoon or transitional period. About 70% of the rainfall is received during the period July to September. Hot and scorching dust laden winds blow during summer season. The mean daily temperature varies in the range of 5.8 °C to 41.2 °C. The average annual rainfall is 681 mm. As per Central Ground Water Authority data, the depth of water level in district Fatehgarh Sahib ranges between 10 to 20 meters below ground level.

After analyzing the Environmental Status of Industrial Clusters of the country, Central Pollution Control Board in consultation with the Ministry of Environment & Forests has identified 88 critically polluted industrial clusters, of which Mandi Gobindgarh is one of them in the State of Punjab. The Ministry of Environment & Forests vide office memorandum No.J-11013/5/2010-IA.II(I) dated 13/1/2010 has imposed a temporary restriction of 8 months on the establishment of the projects in the said critically polluted industrial clusters, which are covered in Schedule-I appended to the EIA notification dated 14/9/2006.

1.5 Motivation for the Study

Mandi Gobindgarh city is one of the highly industrialized towns in Northern India. The predominant industries operating in the city are induction furnace units, re-rolling mills and cupola furnaces having high air pollution potential. The Punjab Pollution Control Board has identified following 6 industrial clusters within the jurisdiction of critically polluted area of Mandi Gobindgarh. The identified clusters of Mandi Gobindgarh area are shown in Table 1.2.

Table 1.2: Clusters identified as critically polluted area of Mandi Gobindgarh (PPCB, 2010)

CLUSTER NO.	NAME OF THE INDUSTRIAL CLUSTER
I	Area near RIMT starting from M/s Cold Drip Pvt. Ltd. to M/s JTG Alloys Ltd.
II	Area between RIMT road (upto M/s Pushpanjali Steel) to Talwara Road (upto M/s M.R. Alloys) on one side of G.T. Road and upto Rajwaha on the other side of the G.T. Road
III	Area on G.T. Road (right side - Rajpura to Ludhiana) covered between M/s IMT, M/s Gian Steel Rolling Mills, M/s Baba Balak Nath Steel Rolling Mills, M/s Bansal Iron and Steel Rolling Mills (on left side) and area starting from M/s Patiala Casting to M/s Bansal Iron upto Rajwaha.
IV	Area bound between M/s Gopal Mills, M/s Kailash Steel Rolling Mills, M/s Northern India Pvt. Ltd. and M/s Aarti Strips in Guru Ki Nagri
V	Area on both sides of Amloh Road covered between M/s Doaba Steel Rolling Mills, M/s Janta Steel & Agro Industries, M.C. disposal point, M/s Vishnu Steels and M/s R.K. Steel and Allied Industry

VI	Area on both sides of G.T. Road on Khanna side starting from M/s Ganesh Steel Industry to M/s Karam Steel to M/s Shri Ganesh Steel Rolling Mills to M/s Dhiman Steel Industry to M/s M.T.C. Steel Industry to M/s Kumar Hammer and Model Town.
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The environment of Mandi Gobindgarh has degraded a lot during the last few years due to rapid urbanization, industrialization, increase in population, vehicles and commercialization of land available within the town. The main stationary sources of air pollution are the industrial units, which are emitting particulate matter, sulphur dioxide and oxides of nitrogen etc. As per the inventory prepared by the PPCB, there are 404 air polluting industries in Mandi Gobindgarh which are using coal/furnace oil as fuel in their furnaces emitting the aforesaid pollutants, besides the process / fugitive emissions.

As per report of Central Pollution Control Board, the Cumulative Environmental Pollution Index (CEPI) with respect to air has been calculated as 62 for Mandi Gobindgarh Industrial Cluster, on the basis of which Mandi Gobindgarh has been declared as critically polluted area. CEPI is a cumulative index due to air, water, land pollution. The major contribution to the said index from air pollution is due to inadequate/ irregular operation of air pollution control systems provided by the industrial units. Industries of different categories situated in Mandi Gobindgarh are mentioned in the Table 1.3.

Table 1.3: Industries in the study area (*PPCB, 2010*)

Sr. No.	Category	Number of Industries Mandi Gobindgarh
1.	Arc Furnace	01
2.	Induction Furnaces	89
3.	Steel Rolling Mills	247
4.	Cupola Furnaces	38
5.	Refractories	13
6.	Forging Industry	13
7.	Lead Extraction Units	03
Total		404

In order to determine the status of quality of the ambient air in Mandi Gobindgarh, the PPCB is monitoring the ambient air quality of Mandi Gobindgarh for the last 15 years. The ambient air quality monitoring analysis of last 7 years (Table 1.4) reveals that the annual average concentration of Respirable Suspended Particulate Matter (RSPM) is in the range of 214 – 272 $\mu\text{g}/\text{m}^3$ against annual average prescribed standard of 120 $\mu\text{g}/\text{m}^3$ for industrial area, 60 $\mu\text{g}/\text{m}^3$ for residential, rural and other area, and 50 $\mu\text{g}/\text{m}^3$ for sensitive area. So, the concentration of RSPM in ambient air is more than the prescribed limits.

Table 1.4: Annual average concentration of Pollutants for 2003-2009 (PPCB, 2010)

Location of Ambient Air Station	Parameters	Annual Average Conc. ($\mu\text{g}/\text{m}^3$)							Permissible limits	
		2003	2004	2005	2006	2007	2008	2009	Old	New
M/s Raj Steel Rolling Mills, Guru ki Nagri, (Industrial Area)	RSPM	272	257	235	230	214.1	219	205.8	120	PM10-60, PM2.5-40
	SO ₂	11	14	17	11	11	11.6	10	80	50
	NO _x	34	39	31	29	25.8	28	28.9	80	40
M/s United Steel Rolling Mills, Amloh Road (Mixed Use Area)	RSPM	-	-	-	226	251.8	216	203.7	60	PM10-60, PM2.5-40
	SO ₂	-	-	-	11	12.8	11.7	9.8	60	50
	NO _x	-	-	-	30	30.1	28	28.9	60	40
M/s Modi Oil & General Mills, Railway Road (Residential-cumcommercial Area)	RSPM	271	252	242	223	249.2	-	-	60	PM10-60, PM2.5-40
	SO ₂	10	14	16	11	12.6	-	-	60	50
	NO _x	33	40	31	30	30.5	-	-	60	40

In addition to the industrial air pollution, the other factors contributing towards the ambient air quality deterioration of Mandi Gobindgarh is lack of proper infrastructure such as roads, green belts, buffer zones, movements of vehicles along the highway etc.

1.6 Monitoring

So far various research works has been done on urban air quality in various cities of India like Bhopal, Tuticorin, Bangalore, Kolkata, Haridwar etc. (*Bansal, 1996; Dayal and Nandini, 2000; Chandrasekar et al., 2002; Gupta et al., 2008; Chauhan et al., 2010*). The monitoring of pollution levels in the atmosphere is of fundamental importance because it measures the extend of existing pollution, effectiveness of air pollution control devices and future efforts required. So, numbers of factors which are considered before starting sampling at study area are as follows (*CPCB, 2003*):

- a) Selection of procedures for sampling and analysis
- b) Sampling locations
- c) Period of sampling, frequency and duration of sampling
- d) Processing of data

1.6.1 Selection of sampling procedure

There are two types of sampling:

- Continuous sampling
- Time averaged in-situ sampling

Continuous sampling is carried out by automatic sensors, optical or electrochemical, and spectroscopic methods which produce continuous records of concentration values. The specific time-averaged concentration data can then be obtained from continuous records. Time-averaged data can also be obtained by sampling for a short time – i.e. by sampling a known volume of air for the required averaging time. Samples are then analyzed by established physical, chemical, and biological methods for the concentration values which are the effective average over the period of sampling.

1.6.2 Sampling locations

Sampling locations are in general governed by factors like objectives, method of sampling and resources available. If the objective is to study health hazards and material damages, then locations should be kept close to the objects where the effects are being studied and should be kept at breathing level in the population centres, hospitals, schools, etc. For background concentration, sampling location should be away from the sources of pollution. It can also be done by gridding the entire area to get statistically recommended values.

During ambient air quality sampling, sampling was done for number of pollutants on selected sites. Sampling site must be carefully selected so that it can represent the areas under study. Concentration of pollutants varies with altitude i.e. results obtained on breathing level ground to that obtained on a taller building differs. Number of sampling stations and their location depend on several factors including the objectives of the programmes, the size of the study area, the proximity of the source of pollution, topographical features, local weather condition and meteorological conditions. A representative number of sampling stations for a given area may be established by means of a preliminary survey, whose objectives should be:

- To gather preliminary information of the study area and principal sources of pollution.
- To review the available climatological and meteorological data.
- To gather data on the concentration of pollutants in areas of severe and slight pollution.

During ambient air sampling, it is necessary to collect information on qualitative and quantitative data on the local sources of air pollution, topography, population distribution, land use pattern etc, depending upon the objectives of the survey or measurement campaign. For example, an area map to locate pollution sources and monitoring locations, sources of pollution situated at far distances, etc. and other relevant data that describe the behaviour of atmosphere for a specific pollutant to be sampled may also be required.

Site selection must consider the location of identified or suspected sensitive receptors and the locations where the highest concentrations of air contaminants are anticipated based on meteorological and modeling information.

1.6.3 Period of sampling, frequency and duration

Period, frequency and duration of sampling should be appropriate to measure the actual existing ambient air quality. It should be such that the measurable quantities are trapped in the sample at the end of the sampling. It is preferable to observe sampling period consistent with the averaging times for which air quality standards of the given pollutants are specified.

1.6.4 Processing of data

1.7 Objectives of the Present Study

The City selected for the study is Mandi Gobindgarh which is a secondary steel industrial area and is a critically polluted area. The objectives of the present study are as follows:

1. Monitoring (sampling and analysis) of air quality,
2. Calculation of Air Quality Index (AQI),
3. Comparison between Indian Air Quality Index (IND-AQI) and USEPA-AQI.

CHAPTER 2

AIR QUALITY INDEX

2.1 Overview

Air quality is defined as a measure of the condition of air relative to the requirements of one or more biotic species or to any human need or purpose. During monitoring the concentration of different air pollutants within study area are evaluated which are further used to calculate Air Quality Index. An air quality index is one of the important tools available for analyzing and representing air quality status uniformly. The Air Quality Index (AQI) can be used as a measure to assess the relative change in the concentrations of groups of pollutants in two situations. The two situations may represent either two time periods or two regions. The relative change may also be with respect to the concentrations of pollutants and respective stipulated standards (*Chelani et al., 2002*). Or we can say, Air quality indices (AQI) are indices/numbers used by government agencies to characterize the quality of the ambient air at a given location and to compare it with other locations. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects. In order to compute the AQI, air pollutant concentration is required from monitoring or from a model. The function used to convert from air pollutant concentration to AQI varies by pollutant, and is different in different countries. Air quality index values are divided into ranges, and each range is assigned a descriptor and a color code.

Voluminous data on Air quality is being generated under various monitoring programs, but interpreting and understanding the vast data become tedious and confusing even to scientific and technical community. As for the general public, unless information is presented in simple and lucid settings, people tend to lose interest and can neither appreciate the problem nor the pollution mitigation efforts.

2.2 Indian Air Quality Index

With the intent that ambient air quality information must reach common people in a easily understandable terms, Central Pollution Control Board (CPCB) has developed an Air Quality

Index (AQI) in collaboration with Indian Institute of Technology (IIT), Kanpur for easy calculation of Air Quality of a particular place/in a day/month/year for simpler way for the public and others. The index has been developed based on the dose-response relationship of various pollutants. The index is named as IND-AQI (Indian Air Quality Index). A minimum number of three pollutant parameters (RSPM, SO₂ and NO₂) are essential to calculate the IND-AQI. Any additional information on other pollutants such as PM 10, PM 2.5, CO and O₃ are included to calculate conclusive and complete value of index.

The developed index is classified in five categories:

- **Good:** The AQI value for a community is between 0 and 100. Air quality is considered satisfactory, and air pollution poses little or no risk.
- **Moderate:** The AQI for a community is between 101 and 200. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.
- **Poor:** When AQI values are between 201 and 300, members of sensitive groups may experience health effects. This means they are likely to be affected at lower levels than the general public. For example, people with lung disease are at greater risk from exposure to ozone, while people with either lung disease or heart disease are at greater risk from exposure to particle pollution. The general public is not likely to be affected when the AQI is in this range.
- **Very Poor:** Everyone may begin to experience health effects when AQI values are between 301 and 400. Members of sensitive groups may experience more serious health effects.
- **Severe:** Values between 401 and 500 trigger a health alert, meaning everyone may experience serious health effects. This would trigger a health warnings of emergency conditions.

A website is developed for display of nation-wide air quality index. As the air quality data become available, online calculation of AQI is carried out and displayed as an Air Quality Meter showing index value (with a pointer) with animation on the screen. The general public can access

the information through Internet and other media agencies like newspaper, Television and Radio (CPCB, 2000). The address of website for air quality index is <http://home.iitk.ac.in/~mukesh> but it is temporary. The information presented at this website is processed from NAAQM data generated by CPCB and covers over 80 cities and 220 locations spread all over the country.

On the map of India, a map for each state exists. From the map of state, one can select a particular city to know about its air quality. The cities where air quality monitoring has been carried out are marked with red spot. On selecting the particular city, a form will appear where a user will have to select a particular location, year, month and date. In month and date options, user can also select "All" options to know the average air quality index of whole year and whole month. After selecting all required data, click the specified button. Then new page and a small window will appear.

One can also compare air quality index (current as well as historical) of different locations within a city or different cities at the same time by opening multiple windows. The above information can also be used by the individual or displayed by the various media to take the information to general public and decision makers (CPCB, 2000).

To calculate the IND-AQI for a given time period, the sub-index values (sub-AQI) for all six air pollutants or three pollutants at the minimum (SO_2 , NO_x and SPM) are first calculated using the adopted sub-index functions (i.e. sub-index vs concentration). Out of all sub-AQIs, the highest value becomes the overall index and reported as IND-AQI. The pollutant for which the sub-AQI is the highest, becomes the responsible pollutant, and indicated alongside the IND-AQI value. SO_2/NO_2 ratio can also be calculated to know the impact of traffic density on to the calculated AQI.

2.3 Different Methods Used to Calculate AQI

A number of methods are used to calculate AQI in different countries. Some of the common methods are listed below:

2.3.1 IND-AQI

Calculation for INDAQI includes first calculation for sub-indices, which can be made by using following equation (*Chattopadhyay et al., 2010*):

$$q = 100 (V/V_s)$$

Where,

q = Quality Rating

V = observed values of the parameter and

V_s = standard value recommended for the parameter

If 'n' numbers of parameters are considered, the Geometric Mean of these "n" numbers of Quality Rating is found out and this is considered as Air Quality Index (AQI).

$$g = \text{anti log } \{(\log a + \log b + \dots \log x)/n\};$$

Where

g = geometric mean;

a, b, c, d, x = different values of air quality rating; and

n = number of values of air quality rating,

log = logarithm.

Description	AQI	Colour Coding
Good	0-100	Green
Moderate	101-200	Yellow
Poor	201-300	Orange
Very poor	301-400	Red

Fig 2.1: Colour coding for AQI ranges (*Gufran, 2010*)

2.3.2 USEPA-AQI

USEPA AQI can be calculated from the values of concentration of different pollutants using following equation (*Upadhyaya and Dashore, 2006; Bishoi et al., 2009; Gufran, 2010*).

$$I = (I_{\text{high}} - I_{\text{low}}) * (C - C_{\text{low}}) / (C_{\text{high}} - C_{\text{low}}) + I_{\text{low}}$$

where:

I = the (Air Quality) index,

C = the pollutant concentration,

C_{low}= the concentration breakpoint that is ≤ C,

C_{high}= the concentration breakpoint that is ≥ C,

I_{low}= the index breakpoint corresponding to C_{low},

I_{high}= the index breakpoint corresponding to C_{high}

Table 2.1: Air Quality Index for different Pollutants as proposed earlier for India (*Gufran, 2010*)

Index	Category	SO ₂ (24 hr avg) (µg/m ³)	NO ₂ (24-hr avg) (µg/m ³)	SPM (24-hr avg) (µg/m ³)	CO (8-hr avg) (mg/m ³)	O ₃ (8-hr avg.) (µg/m ³)	PM ₁₀ (24-hr avg) (µg/m ³)
00-100	Good	0-80	0-80	0-200	0-2	0-157	0-100
101-200	Moderate	81-367	81-180	201-260	2.1-12	158-196	101-150
201-300	Poor	368-786	181-564	261-400	12.1-17	197-235	151-350
301-400	Very poor	787-1572	565-1272	401-800	17.1-35	236-784 (1-hr avg)	351-420
401-500	Severe	>1572	>1272	>800	>35	>784 (1-hr avg)	>420

2.3.3 Average Method

There is one more method to calculate Air quality index which represents air quality by using equation (4) (*Chauhan et al., 2010; Kumar et al., 2011*):

$$AQI = 1/4[PM_{10}/sPM_{10} + PM_{2.5}/sPM_{2.5} + SO_2/sSO_2 + NO_2/sNO_2] \times 100 \dots\dots (4)$$

Where

sPM_{10} , $sPM_{2.5}$, sSO_2 and sNO_2 represent the ambient air quality standards as prescribed by the CPCB, for PM_{10} , $PM_{2.5}$, Sulphur Dioxide and Nitrogen Oxides respectively.

PM_{10} , $PM_{2.5}$, SO_2 and NO_2 represent the actual values of the pollutants obtained on sampling.

2.4 AQI Limitations

An AQI is seen as a communication tool (*Stieb et al., 2005; Giles et al., 2011*), but the effective communication of air quality information still needs improvement (*Shooter and Brimblecombe, 2005*) and monitoring networks may be ill equipped to provide the appropriate information. Once generated an air quality index can:

- (1) Help link air quality and health effects by being used to inform the general public of air quality and possible remedial actions.
- (2) Simplify and condense air quality data hence it can also be a convenient means of providing an information overview for development of policy and regulation, optimize resources allocation and assess compliance with standards.

However, AQIs may not accurately reflect our current understanding of the adverse health effects of ambient air pollution. It typically fails to recognize low level exposure and additive contribution of multiple pollutants (*Stieb et al., 2005*). Although AQIs can be used at a research level, the original quality-assured data is often more appropriate that's why main rational for AQIs remains as a tool to provide air quality information to the public. When available on the internet, they can display current information and background material on air quality.

CHAPTER 3

REVIEW OF LITERATURE

Different air pollutant released from different industries is posing a great threat not only to health of mankind but also to the landmass fertility as well as natural flora and fauna. So regular monitoring is needed, involving selection of correct sampling site so that representative sampling can be done and analyzing those samples so that correct data can be collected. This voluminous data is represented in simple terms as Air Quality Index of that area. So this review addresses the various studies made to study AQI of different cities considering different pollutants and different methodology. This review also addresses the different limitation within the calculation of AQI.

Ambient air quality was studied in Madurai City of South India by *Meenakshi and Mahadevan*, 1991 and at Bhopal city by *Bansal*, 1996. For Madurai City, sampling was done at 6 sites for SPM, SO₂, NO_x and result shows that the SPM concentration varied from 200 to 500 µg/m³, NO_x from 50 to 170 µg/m³ and SO₂ from 10 to 25 µg/m³ whereas for Bhopal city study was done for the period of 1992-94. Only NO_x concentration was studied in Commercial, Industrial and Residential Areas and maximum values recorded were 96.4 µg/m³, 66.3 µg/m³, 53.5 µg/m³ respectively and the monthly average values obtained were well below the prescribed standards.

Sarangi and Mishra, 1997; *Joshi and Mishra*, 1998 studied the Ambient Air Quality of Jyotivihar, Orissa during December 1994 to November 1995 and of Indore, Madhya Pradesh during 1991 to 1995 respectively. Air pollutant likes SPM, SO₂ and NO_x were reported for the both the studies. The minimum and maximum values were 82.995 µg/m³ and 182.7 µg/m³ for SPM, 4.62 µg/m³ and 25.74 µg/m³ for SO₂ and 4.39 µg/m³ and 16.89 µg/m³ for NO_x for Jyotivihar whereas concentration of SO₂ and NO_x were found under limits and SPM exceeding the prescribed standards for Commercial and Residential Areas.

Gupta et al., 1998; *Ravichandran et al.*, 1998 studied Ambient Air Quality of Paonta Sahib (H.P) during 1994 – 96 and Tiruchirapalli at four sampling stations respectively. Monthly average values obtained for SPM and NO_x in Paonta Sahib were well below the prescribed standards in

Industrial Area but for Tiruchirapalli, SPM levels exceeds at two sampling stations (Bishop Harber College and Thillai Nagar) where as the SO₂ and NO_x level exceeds in Thillai Nagar sampling station.

Kali et al., 1998 studied scenario of active mine fires in the Jharia coalfield and their impact on the environment was alarming. The study outlines the air pollution and societal problems of a fire in the IX/X seam of Sudamdih in Jharia coalfield. It was found that fire and mining activities have contributed significantly to air pollution in the surrounding area. The concentrations of suspended particulate matter (SPM), respirable particulate matter (PM10), sulphur dioxide (SO₂), and oxides of nitrogen (NO_x) were found to be more than the permissible levels. In winter months specially, these concentrations were much higher than the permissible limits for industrial and mixed-use areas. The air quality index (AQI) of the study area was found to be 117.04, which indicated that the area was heavily polluted. The human response survey around the study area showed that most of the subjects were inconvenienced and stressed due to higher temperatures, high concentrations of dust and other gaseous pollutants, reduction in visibility, health impacts, degrading vegetation, etc.

Alam et al., 1999 studied the ambient air quality at road side in Dhaka City and estimated the Air Quality Index (AQI) at various locations of the city of which seventy percent were severely polluted and rest of the location were highly polluted. This environmental condition had very serious implications on the health of the inhabitants of the city, particularly the commuters, causing eye and skin irritation, headache, breathing problems etc.

Meenambai and Akil, 2000 evaluated the Ambient Air Quality of Coimbatore City at ten important junctions and found that the level of SPM exceeds the ambient air quality standard of CPCB and SO₂ and NO_x were well within the limits. This high SPM concentration may be due to Traffic congestion, increased human activities and high rise buildings, existing parallel to each other. The remedial measures suggested includes banning old technology vehicles, upgrading 2 stroke engines to 4 stroke engines, use of catalytic converters, planting more trees along the road sides and proper Traffic regulation.

Dayal and Nandini, 2000 studied the Ambient Air Quality for 10 congested areas in Bangalore City. Results indicate out that the SPM values in six out of 10 congested areas were above the limit, while Oxides of Nitrogen (NO_x) and SO₂ were within the prescribed limit in all the areas. Air Quality Index (AQI) for all places were calculated and it was observed that in 1 out of the 10 places, the air was clean, in 4, it could be classified as light air pollution and the remaining 5 places, was moderately polluted.

Mandal, 2000 monitors Ambient Air Quality in respect to SPM, NO_x, SO₂ and CO over various parts of Calcutta. Comparison of air quality was also done between urbanized areas of the western part of Calcutta to areas which is highly urbanized, closed to the Howrah Industrial Sector. Greater concentration of pollutants in area close to Howrah was found which may be due to high density of population.

Index of pollution was developed based on the epidemiological dose-response function associated with each pollutant and the welfare losses due to exposure to pollution. The probability of damage was translated into welfare losses, which provides the common metric required for aggregation. An Air Pollution Index (API) was computed using 1997 data for the criteria pollutants under the Clean Air Act (CAA). The results were then compared with the EPA's Pollutant Standards Index (PSI). Two significant differences emerge: unlike the PSI, the API facilitates a detailed ranking of regions by air quality and API values may contradict PSI results. Some regions with PSI values of 100–200 were considered less polluted under the proposed methodology than those with PSI values between 50 and 100(*Khanna, 2000*).

Cogliari, 2001 studied daily index highly correlated with meteorological variables and the index capable of identifying those variables that significantly affect the air pollution. The index was connected with attention levels of NO₂, CO and O₃ concentrations. The relation of index with some meteorological variables was analysed by the linear multiple partial correlation statistical method. During the January–March period the correlation coefficient reaches 0.85 at Milan. The deterministic methods of forecasting air pollution concentrations showed very high evaluation errors and were applied on limited areas around the observation stations, as opposed to the whole urban areas.

Liu, 002 study a newly-modified Air Quality Index (AQI) as USEPA had included sub-indices of 8-hour average O₃ concentration and 24-hour average PM_{2.5} level into it. Study was done at 4 locations in Taiwan, i.e. at KuTin, ChungMing, FonSam and LinYuan for a period of 30 month from July 1997 to December 1999. Calculations for air-quality shows that the updated AQI system was associated with two to three times higher occurring frequency of days with AQI larger than 100 than that of the widely used Pollution Standard Index (PSI) larger than 100. On these unhealthy days, more than 50% was dominated by PM_{2.5} sub-index, followed by 8-hour average O₃ sub-indices. It was found that PM_{2.5} tends to occupy more than 50% of the PM₁₀ level. Result indicates that the importance of fine particles in urban smog had been magnified in the AQI system. With a new category between 101-150, AQI does pose as a better descriptor than PSI to warn of an unhealthy environment for the sensitive group.

Senthilnathan and Rajan, 2002 studied the suspended particulate matter (SPM) concentration at five sampling stations in Chennai City, during the year 2000. Result shows that monthly average SPM concentration was above National Ambient Air Quality Standard values.

Chelani et al., 2002 presents an approach to assess and represent air quality status through an Air quality Index (AQI), in major metropolitan cities, where different types of activities, viz. industrial, commercial and residential were in progress, on a short and a long term basis. To make the index more informative, air quality status was classified into five different categories, viz. Clean, Moderate, Poor, Bad and Dangerous. Long term air quality indices were then calculated for four metropolitan cities and one city, which was fast developing each representing the different climatological features in India viz. Mumbai, Delhi, Calcutta, Chennai and Nagpur. The air quality index was calculated according to national standards stipulated for different pollutants and zones.

Chandrasekar et al., 2002 monitored the air quality parameter (SPM, SO₂, and NO_x) at the three different locations in and around Tuticorin City at weakly intervals for a year. The Air Quality Index varies from maximum 27.9 (fairly clean) to 9.00 (clean). The concentration of SO₂ and NO_x were high during winter, where as SPM level was high in the Commercial cum – Residential Area during summer.

Sharma et al., 2003 interpret air quality data using air quality index of Kanpur city for simplified public information and data interpretation. A maximum operator concept was used to determine the overall AQI; maximum value of sub-indices (of each pollutant) was taken as overall AQI. Results shows that air quality become severe from very poor condition in winters and during early summer months. Overall 95% of the time, sub-index values correspond to SPM levels were responsible for overall AQI.

Goyal and Sidhartha, 2003 studied the ambient air quality of Delhi from the point of view of replacing diesel by Compressed Natural Gas (CNG) in transportation in Delhi. A relative comparison of ambient air concentration of pollutants, e.g. carbon monoxide (CO), sulphur dioxide (SO₂), suspended particulate matter (SPM) and oxides of nitrogen (NO_x), emitted from transport sector, during the years 1995–2000 (without CNG) and the year 2001 (with CNG) was made in order to assess the impact of CNG vehicles on ambient air quality in Delhi. It was found that concentration contributions of pollutants were reduced considerably. The annual average concentration of SPM came down to 347 from 405 µg/m³, which was still beyond the permissible limits. The concentration of annual averages of CO, SO₂ and NO_x decreased to 4197 from 4681 µg/m³, 14 from 18 µg/m³ and 34 from 36 µg/m³, respectively, and were well within the permissible limits. An analysis of SO₂/NO_x and CO/NO_x concentrations, whose correlation coefficient r^2 has the values 0.7613 and 0.7903, respectively, indicates that point sources are contributing to SO₂ and mobile sources are contributing to NO_x concentrations.

Cheng et al., 2004 discusses a more effective way of determining a suitable concentration level of pollutants in Taiwan. By combining the original PSI with an entropy function, they develop a revised air quality index (RAQI). As the Environmental Protection Administration of Taiwan had provided air quality service by reporting the pollutant standard index (PSI) since 1997, which compares concentrations of the five main pollutants (PM₁₀, O₃, SO₂, CO, NO₂). For each pollutant, a sub-index was calculated from a segmented linear function that transforms ambient concentrations onto a scale extending from 0 to 500. The standard index was based on the highest sub-index. Some confusion was faced because of different standard pollution concentration level among various countries which was rectified by RAQI. It considers the

association of the five pollutants, and had the comparative index function. According to tentative results, RAQI should be representative, supplying the public with a better indicator of air quality.

Longhurst, 2005 presented a case study of the creation and criticism of an air pollution index in Pittsburgh, Pennsylvania, long known for its industrial production and the resulting pollution. County engineers created a daily air pollution index to summarize the information from the network, leading to public debates over the intent, meaning and representation of air quality data. This case study serves to illustrate the inherent complexity of creating accessible, understandable and uniformly acceptable indices of environmental quality. It also emphasizes the importance of understanding the social and political context in which data is collected, organized and interpreted.

Shooter and Brimblecombe, 2005 raises some issues that should be considered during design of AQI model like Averaging times, Siting issues, Single pollutant indices, number of pollutants to report and based on sound understanding of public health. Other characteristics such as consistency, simplicity, versatility and flexibility are also important.

Ravindra et al., 2006 study the concentrations of various criteria air pollutants (SPM, PM10, CO, SO₂ and NO_x) and organic pollutants such as benzene, toluene, xylene (BTX) and polycyclic aromatic hydrocarbons (PAHs) before and after the implementation of CNG. Public transport in Delhi was amended by the Supreme Court of India to use Compressed Natural Gas (CNG) instead of diesel or petrol. After the implementation of CNG since April 2001, Delhi had the highest fraction of CNG-run public vehicles in the world and most of them were introduced within 20 months. A decreasing trend was found for PAHs, SO₂ and CO concentrations, while the NO_x level was increased in comparison to those before the implementation of CNG. Further, SPM, PM10, and BTX concentrations showed no significant change after the implementation of CNG. However, the BTX concentration demonstrated a clear relation with the benzene content of gasoline. In addition to the impact of the introduction of CNG the daily variation in PAHs levels was also studied and the PAHs concentrations were observed to be relatively high between 10 pm to 6 am, which gives a proof of a relation with the limited day entry and movement of heavy vehicles in Delhi.

Ziauddin and Siddiqui, 2006 had collected data at 15 monitoring stations with respect to SPM, RSPM, SO₂, NO_x where sampling is carried out for the measurement of AQI. Five stations showed critical condition of air quality with AQI value above 100. Seven sites showed AQI value between 76 & 100, representing heavy air pollution. Two sites showed moderate air pollution and one site showed light air pollution.

Cheng et al., 2007 discussed the optimal method of assessing air quality using the latest developed Revised AQI (RAQI), a system that serves as an alternative to the PSI and AQI systems. The feasibility, effectiveness, and the differences between RAQI, AQI, and PSI in their applications to several air pollution conditions were also studied in this research. Results showed that southern Taiwan's suspended particulates had significantly greater impact on PM_{2.5}/PM₁₀ ratios than in central and northern metropolitan areas, and that the ratios were higher in Taiwan as a whole compared to many other countries. It was also found that the RAQI shows more significant results compared to the PSI and AQI as it had a wider coverage of the range of pollutant concentration levels.

Krykillis et al., 2007 tried to develop an aggregate Air Quality Index (AQI) based on the combined effects of five criteria pollutants (CO, SO₂, NO₂, O₃ and PM₁₀) taking into account the European standards. Hourly data of air pollutants from 4 monitoring stations, available during 1983–1999, were analysed for the development of the proposed index. Then a comparison was made with a modified version of Environmental Protection Agency/USA (USEPA) maximum value AQI model adjusted for European conditions. The proposed aggregate model was more estimates more effective in measuring the exposure of citizens comparing with the modified USEPA maximum value model, because it takes the impact of all the pollutants measured.

Air Quality Indices based on the US Environmental Protection Agency procedure to assess the status of ambient air quality near busy traffic intersections in Bangalore, India. Pollutant concentrations for the specified period (1997-2005) at three air quality monitoring stations was used for the development of AQIs. The results indicate that 91% of the study period AQI values (SPM concentration) were in the category of “good” and “moderate,” 7% “poor” and the

remaining 2% “very poor” and “severe.” Yearly AQI values of RSPM and SPM were shared a decreasing trend with more occurrences of “good” and “moderate” values (*Nagendra et al., 2007*).

Sengupta et al., 2008 study the comparison between Ambient Air Quality Management Practices in India (Hyderabad) and USA (Philadelphia and Pittsburgh). City of Hyderabad, India being an international information technology hub, had almost doubled its population from 3.6 million in 2001 to 7 million in 2004 (Census Bureau of India) and had added 700,000 vehicles of all kinds on its roads thereby increasing the air pollution (PM10, PM2.5, NO_x, SO_x etc.) load by 21% from the 1998 levels (Andhra Pradesh Pollution Control Board; APPCB, 2006). The detrimental health impacts of such unsustainable growth are already being felt, with a close to 36% of the population from certain prominent city locations reporting different forms of respiratory disorder. Same had happened in western cities i.e. USA in 1990’s.

Senthilnathan, 2008 determined the background concentration of the pollutants within the air of Chennai city, like SO_x, NO_x, SPM, RSPM. Study was done at two sites named Anna Nagar and Kilpauk. It was observed that pollutants concentration increases rapidly there due to increase in urbanization, industrialization and vehicular emission. Annual mean values of particular matter exceed NAAQS values by a large amount whereas gaseous pollutant concentrations were well below the recommended values. Several issues and remedies related to probable sources of SPM concentration were also discussed.

Elshout et al., 2008 made a review of existing websites used for knowing air quality indices. In these websites air quality was being presented as an index ranging from good to bad. The index was part of a project to develop a website dedicated to comparing air quality in European cities. The common air quality index (CAQI) was not aimed at replacing existing local indices. The CAQI was a set of two indices: one for roadside monitoring sites and one for average city background conditions. Differentiating between roadside and general city conditions was a first step in assuring consistence in the parameters that were being compared.

Gupta et al., 2008 study air quality in an urban region of Kolkata, consisting of residential, commercial and industrial sites having high population density and pollution. Concentrations of ambient SO₂ (sulfur dioxide), NO₂, (nitrogen dioxide), NH₃ (ammonia) and PM₁₀ were measured once in a week for 24 h at selected residential and industrial sites and 8 h at a commercial site. The meteorological parameters (wind speed, wind direction, rainfall, temperature and relative humidity) were collected simultaneously from the Indian Meteorological Department, Kolkata. Winter concentrations of ambient SO₂, NO₂, NH₃ and PM₁₀ were observed to be higher irrespective of the monitoring sites and duration of sampling, suggesting longer residence times of these pollutants in the atmosphere during winter due to stagnant conditions and low mixing heights. The SO₂/NO₂ ratios at the residential, commercial and industrial sites were found to be 0.38, 0.42 and 0.43, respectively. These low SO₂/NO₂ ratios were indicative of major emissions from mobile sources within the city.

Gurjar et al., 2008 evaluated and rank megacities in terms of their trace gas and particle emissions and ambient air quality. Several concepts and indicators exist to measure and rank urban areas in terms of their socio-economic, infrastructural, and environment-related parameters. Besides ranking the megacities according to their surface area and population density, evaluation on the basis of carbon monoxide (CO) emissions per capita, per year, and per unit surface area was employed. Further, ranking the megacities according to ambient atmospheric concentrations of criteria pollutants, notably total suspended particles (TSP), sulfur dioxide (SO₂), and nitrogen dioxide (NO₂) was done. A multi-pollutant index (MPI) was proposed considering the combined level of the three criteria pollutants (i.e., TSP, SO₂, and NO₂) in view of the World Health Organization (WHO) Guidelines for Air Quality. Of 18 megacities considered here 5 classify as having “fair” air quality, and 13 as “poor”.

Biswanath et al., 2009 made an attempt to calculate the Air Quality Index based on Factor Analysis (NAQI) which incorporated the deficiencies of USEPA method. The daily, monthly and seasonal air quality indexes were calculated by using both these methods. Although the index proposed by USEPA gives an overall assessment of air quality but it does not include the combined effects (or synergistic effects) of the major air pollutants. It was observed that a

significant difference exists between NAQI and EPAQI. However, NAQI followed the trends of EPAQI when plotted against time.

Spatial and temporal variations in concentrations of CO, NO, NO₂, SO₂, and PM₁₀ were studied at traffic-impacted and residential stations in Ankara for 1999 and 2000. Air quality in residential areas was found to be influenced by traffic activities in the city. Pollutant ratios were proven to be reliable tracers to differentiate between different sources. Air pollution index (API) of the whole city was calculated to evaluate the level of air quality in Ankara. Multiple linear regression models were developed for forecasting API in Ankara. The correlation coefficients were found to be 0.79 and 0.63 for different time periods (*Genc et al., 2009*).

Croft and Melendez, 2009 examined Daily Air Quality Index (AQI) for the months of April through July of 2004 in the northern Mid-Atlantic region. Data were stratified by county for Delaware, Maryland, New Jersey, New York, and Pennsylvania and included maxima, minima, and mean AQI values for each day. Summary information for each of the 45 counties revealed both a similarity of behaviors, such as variations in maxima and minima, as well as a dichotomy and divergence of values based on their positions relative to obvious sources and sinks in the area, such as urban versus rural locations. Data were also separated according to the prevailing weather regimes and flows (upper air and surface) to determine any apparent dependencies on specific weather features.

Bahauddin and Uddin, 2010 investigate the level of particulate matter to determine its adverse impact on health of roadside population of Dhaka city. Maximum concentration of PM_{2.5} and PM₁₀ of Dhaka city were reported to be 405 µg/m³ and 543 µg/m³ respectively during 2002-07. The city's average particulate matter level was about 2 times higher than the Bangladeshi standard of 200 µg/m³ in residential areas and 10 times higher than the WHO guidelines of 120 µg/m³ (24 hours) in commercial areas. It was observed that 98.83% roadside population was affected by high particulate matter concentration causing asthma, allergy, coughing, breathing difficulties, headache and itching. Among these, major incidences were of eye problem i.e. about 52.05%. The percentages of other recognized health problems like cough, breathing difficulties and allergy were 40.94%, 23.39%, and 18.71% respectively.

Buchholz et al., 2010 had calculated an impact related daily air quality index (DAQx), for 15 air quality monitoring stations (traffic, background, and industry) in Belgium, France, Germany and Luxembourg, was compared to mesoscale atmospheric patterns between 2001 and 2007. DAQx values indicate sufficient to poor air quality in the urban area of Brussels and at urban traffic stations, as well as satisfactory air quality at the background stations. The air quality index refers to more than 90% to the presence of high PM₁₀, O₃ and NO₂ concentrations. SO₂ and CO play only a minor role. A trend analysis of weather regimes from 1978 to 2007 shows significant positive trends for weather classes associated with lower PM₁₀ concentrations.

Upadhyaya and Dashore, 2010 applied a real time Fuzzy Logic System with Simulink to calculate AQI instead of Conventional method that uses Linear Interpolation for calculating Indian Air Quality Index (IND-AQI). This proposed methodology showed gives satisfactory result and it was efficient to work under continuous working mode.

Sharma et al., 2010 try to establish two mathematical models, first one was meteorology-based air quality level predictions in which pollutant concentration was predicted on basis of wind speed and temperature and second for meteorology forecasting (to forecast wind speed and temperature) had been developed (based on four year data) using neural network to forecast AQI for next three days. The AQI forecasting model was concluded as being satisfactory and useful for dissemination of information to general public.

Shukla et al., 2010 deals with the measurement of air quality by observing the concentration of pollutants in the atmosphere namely suspended particulate matter, NO_x and SO₂ at five different selected locations in Lucknow city. The locations for the study were chosen on the basis of land use pattern. According to air quality scale, the air quality status was measured at each location and zone. From the study it was found that the residential zone had highest air quality index in comparison to other zones. It was observed that the value of SPM was much higher than standard value while the value of SO₂ was much lower to the standard value. Value of NO_x was also found higher than the standard value. The average air quality index of heavy traffic zone, commercial zone and residential zone were 119.5, 188.2 and 188.2 respectively.

Another study proposed an index that measures deterioration in ambient Air Quality, on an arbitrary scale that ranges between 0 and -10, on more realistic terms than comparing with National Ambient Air Quality Standards, which was then applied to the ambient air monitoring data collected from some areas of Korba Coalfields in India. An index value of '0' represents most desirable air quality having no depreciation from the best possible air quality with respect to the pollutants under consideration while an index value of -10 represents maximum depreciation or worst air quality. The proposed Air Quality Depreciation Index (AQDI) had shown that the index allows for more realistic air quality assessment as compared to interpretive evaluations that revolve around comparing observed concentrations to national ambient air quality standards. The Air Quality Depreciation index could be an invaluable tool to map periodic deterioration in air quality with respect to its potential for environmental damages. Since the air quality depreciation index was neither geographically specific nor constrained for the type or number of pollutants, it could be easily used for different situations and applications (Singh, 2010).

Chauhan et al., 2010 study effect of industrialization, urbanization and automobile emission on ambient air quality in Haridwar and Dehradun City. For this, differences in air pollutants concentrations and air quality index (AQI) at urban, industrial, commercial and agricultural areas of Uttarakhand for March 2007 to February 2008 were examined. Meteorological parameters such as temperature, relative humidity, wind speed and rainfall were also recorded simultaneously during the sampling period. It was observed that the concentrations of the pollutants were high in winter when compared to summer or the monsoon seasons. It was observed that the SPM and PM10 levels at all selected sites (excluding Roshnabad) exceeds the prescribed limits as stipulated by Central Pollution Control Board (CPCB) New Delhi, India. Apart from this the SO₂ and NO_x levels in residential, industrial and commercial areas remain under prescribed limits of CPCB.

Air Quality Index (AQI) was computed for ten air quality sampling stations within the radius 10 kms from the core zone for describing air pollution in Choudwar Area. SPM levels were in permissible limits specified by Central Pollution Control Board (CPCB). However SPM was found to be higher in most of the locations in premonsoon and postmonsoon seasons in both the

urban and the rural areas. The areas nearer to the vicinity of the industries were moderately air polluted as per the AQI values i.e. 51 to 75. The moderate AQI values may be attributed to ecofriendly control measures taken such as green plantation and sprinkling of water despite the continuous production of ferroalloys and generation of thermal power round the year (*Pradeepta et al., 2010*).

Jha et al., 2010 study the seasonal variation of SPM, SO_x and NO_x at different five selected sites (CFRI Campus, Jharia coalfields-North Tisra, GT Road, Indian School of Mines, Sindri). Meteorological parameters were also collected. Annual average concentration of SPM varied from site to site. SO_x and NO_x also shows seasonal variations and their presence varied from site to site.

Chattopadhyay et al., 2010 investigated the seasonal variation of ambient air quality status of Burdwan town using GIS approach. Concentration of SO₂, NO₂ and RSPM were measured once a week for 24 hour in both premonsoon and postmonsoon season. Statistical analysis showed the significant monsoonal effect on mean difference of RSPM, SO₂ and NO₂ concentration. Postmonsoon concentration of ambient SO₂ and NO₂ were observed to be higher than premonsoon, suggesting longer residence times of these pollutants in the atmosphere due to stagnant conditions and low mixing height. On the basis of Air Quality Index (AQI), a GIS based air pollution surface model was generated in both the seasons by means of Inverse Distance Interpolation (IDINT) technique. From the output of surface model, it was found that in comparison to premonsoon there was a significant increase of clean and fairly clean area and decrease of moderately polluted area of the town during postmonsoon.

Banerjee and Srivastava, 2010 continuously monitored the ambient air quality to assess the extent of impacts due to rapid industrialization and commercial activities at the Integrated Industrial Estate-Pantnagar (IIE-Pantnagar), from June 2007 to May 2008. The measured 24-h average criteria pollutants, namely, sulfur dioxide (SO₂), oxides of nitrogen (NO₂), respirable suspended particulate matter (RPM) and suspended particulate matter (SPM) were used for the development of the air quality index (AQI). Among the monitored air quality variables, SPM revealed as the major pollutant followed by RPM with annual average concentrations of 281.8

and $137.6 \mu\text{g}/\text{m}^3$, respectively. However, the average concentrations of gaseous pollutants (SO_2 and NO_2) were 21.1 and $21.7 \mu\text{g}/\text{m}^3$ respectively, which were lower than the prescribed national standards. The computed AQI reveals a gradual increasing trend with a range of 48.02–79.25, signifying the prevalence of moderate to heavy pollution levels.

Kumar and Goyal, 2011 study with main objective of forecasting short-term daily AQI through previous day's AQI and meteorological variables using principal component regression (PCR) technique. Study was made for AQI estimation for four different seasons namely summer, monsoon, post monsoon and winter, for the period of seven years from 2000–2006 at ITO (a busiest traffic intersection) for criteria pollutants such as respirable suspended particulate matter (RSPM), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and suspended particulate matter (SPM) using a method of US Environmental Protection Agency (USEPA), in which sub-index and breakpoint pollutant concentration depends on Indian National Ambient Air Quality Standard (NAAQS). The values of normalized mean square error (NMSE) were found to be 0.0058, 0.0082, 0.0241 and 0.0418 for winter, summer, post monsoon and monsoon respectively.

Kumar et al., 2011 made an attempt to express the ambient air quality of Jaipur city in the form of Air Quality Index (AQI). The data on air pollutants was collected from twelve sites in residential, industrial and commercial areas of the city. The survey was carried out to evaluate Suspended Particulate Matter (SPM), Respirable Suspended Particulate Matter (RSPM), Sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) by sampling for a period of 24 hours in winter season of the year, 2009-2010. Air Quality Index was calculated and results showed that the concentration of suspended particulate matter exceeded the permissible standards stipulated by Central Pollution Control Board (CPCB) in highly commercial or industrial zones excluding residential area of Tilak Nagar. Apart from this, the SO_2 and NO_x levels in residential, industrial and commercial areas remain under prescribed limits of CPCB. One site showed AQI values above 100, representing severe air pollution, five sites showed AQI values between 76 to 100, representing heavy air pollution.

Prakash and Bassin, 2011 analyse the quality of ambient air in Delhi city by employing air quality index (AQI) by measuring Suspended particulate matter (SPM), Respirable suspended particulate matter (RSPM), Sulphur Dioxide (SO₂) and Nitrogen Dioxide (NO₂) for the year 2009 at three different locations in Delhi city (industrial at Mayapuri, commercial at Town Hall and residential at Sarojini Nagar) according to Indian Air quality Index (IND-AQI). The results reveals that Suspended particulate matter (SPM) was mainly responsible for high AQI values in all sites of Delhi which falls under the category of 'Very Poor'. This could be due to rapid increase in urban population, growth of vehicular population, frequent dust storms, infrastructure development like construction of flyovers, metro rail services etc. Measures being taken by the Delhi government to improve the quality of air, includes use of clean fuel CNG by vehicles, closure of industrial units, phasing out older vehicles and encouraging people to use public transport means like metro rails and high capacity buses.

From this literature, we got to know different methodologies to calculate AQI. Large amount of studies were done by different scientists to measure concentrations of different pollutants at their respective studied areas. Results of such studies helped us to know different methods to observe pollutants and to observe parameters which are important for site selection to do air sampling.

CHAPTER 4

MATERIALS AND METHODS

In this chapter, materials and methods used in this study are described in details, including the chemicals, glassware, instrument and procedures used for sampling site selection, sampling of air, analysis of pollutant concentration and calculation of air quality index.

4.1 Chemicals

- Barium chloride solution
- Sodium Hydroxide
- Sodium Arsenite
- Absorbing solution: Dissolve 4.0 g of sodium hydroxide in distilled water and make up the volume to 1,000 ml.
- Sulphanilamide Solution: Dissolve 20 g of sulphanilamide in 700 ml of distilled water. Add 50 ml of 85% phosphoric acid, mix and make the volume to 1000 ml. This solution is stable for one month, if refrigerated.
- N-(1-Naphthyl)-ethylenediamine Di-hydrochloride (NEDA) Solution: Dissolve 0.5 g of NEDA in 500 ml of distilled water. This solution is stable for one month, if refrigerated and protected from light. (1% aqueous solution should have only one absorption peak at 320 nm over the range of 260-400 nm. NEDA showing more than one absorption peak over this range is impure and should not be used.)
- Hydrogen Peroxide Solution: Dilute 0.2 ml of 30% hydrogen peroxide to 250 ml with distilled water. This solution may be used for one month, if, refrigerated and protected from light.
- Phosphoric Acid: 85%
- Sodium nitrite: Assay of 97% NaNO_2 or greater
- Sodium nitrite stock solution (1000 $\mu\text{g NO}_2/\text{ml}$) Dissolve desiccated NaNO_2 1.5g (assay 100%) or 1.5/assay % (for assay less than 100%) in 1000 ml of distilled water.
- Sodium nitrite solution (10 $\mu\text{g NO}_2/\text{ml}$.)

- Sodium nitrite working solution ($1 \mu\text{g NO}_2/\text{ml}$) (Dilute with absorbing reagent, prepare fresh daily)

4.2 Instruments Used

4.2.1 High Volume Sampler with gaseous attachment



Fig 4.1: High Volume Sampler APM 415

High Volume Samplers are the basic instruments used to monitor ambient air quality. In this study, Envirotech APM 415 with its attachment for gaseous pollutant monitoring APM 411 was used. In these samplers, air-borne suspended particulates (SPM) are measured by passing air at a high flow-rate of 1.1 to 1.7 cubic meters per minute through a high efficiency filter paper (Whatman 934-AH Glass Microfiber Filters) which retains the particles. The instrument measures the volume of air sampled, while the amount of particulates collected is determined by measuring the change in weight of the filter paper as a consequence of the sampling. In High Volume Sampler provisions have been made for simultaneous sampling of gaseous pollutants. Gaseous attachment contains three impinger bottles of 35 ml capacity for simultaneous absorption of different gaseous pollutants. Here the air is passed through suitable reagents that would absorb specific

gases where gaseous pollutants like SO₂, NO_x etc. are analyzed subsequently by simple wet chemistry method to determine the concentration of specific pollutant. The gaseous sampling requires only a few LPM (1-3 LPM) of air flow. This absorbing solution is placed within the impinger bottles placed in between ice cubes or cold water, for complete absorption of sparsely soluble gases. These absorbing solutions can then be taken directly to the laboratory for analysis.

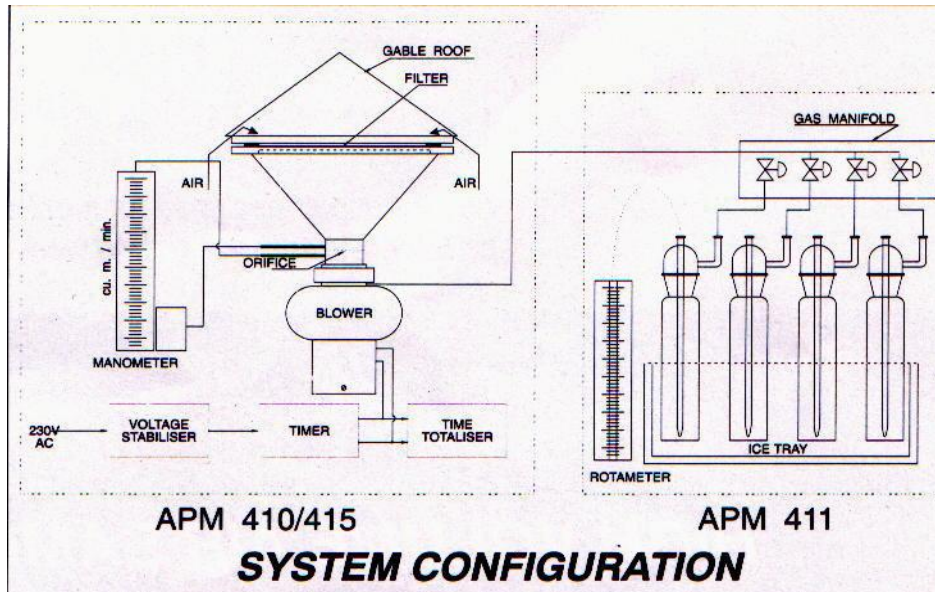


Fig 4.2: System Configuration of gaseous extension with the HVS

4.2.2 PM 2.5/10 sampler

PM 2.5/10 Sampler i.e. Ambient Fine Dust Sampler, Model no. IPM-FDS-2.5 μ /10 μ of INSTRUMEX is an advanced sampler conforms to the USEPA and CPCB norms. This sampler uses a set of Impactors standardized by USEPA to separate coarse particulates from the air stream. For sampling of PM 2.5, particles with aerodynamic diameter larger than 10 microns are trapped by using the opposed jet impaction over a filter paper of specified Whatman number 7582-004 37mm diameter supported on surface by silicon oil and those having a diameter between 2.5 and 10 Microns are trapped over PTFE filters using the WINS Impactor. But for sampling of PM 10, WINS Impactor unit is replaced by PM 10 impactor assembly. Finally air stream leaving the WINS Impactor consists of only fine particulates with an aerodynamic diameter smaller than 2.5 microns. The flow

is controlled by microprocessor based flow controller for maintaining the flow rate constant at 16.67 LPM. This instrument also has two other sensors for the temperature and pressure. All the parameters like sampling period, flow rate etc. were set in control module. The instrument samples for a specific period.



Fig 4.3: PM 2.5/10 Sampler

4.2.3 Weather Monitoring Station (WMS)

The weather monitoring station used in this study was Watch Dog of Spectrum Series 2000 which has been used for weather monitoring which uses different sensors to monitor seven parameters including wind speed, wind direction, temperature, relative humidity, dew point, pressure and solar radiations. Weather monitoring station must be installed at site where there is no obstruction in path of wind so that correct data can be collected. It consist of lightweight three cup type anemometer for measuring wind speed ranging from 0 to 150 mph and wind vane for the determination of wind direction. Interval for the data collection can be chosen between 1 to 60 minutes. Data logger allows storage of data for 6 months at a time and the stored data can be transferred to computer using data cable.



Fig 4.4: Weather monitoring station

4.2.4 UV-VIS Spectrophotometer

The spectrum was taken with UV-VIS Spectrophotometer (Hitachi V-500 UV/VIS (Japan) double-beam spectrophotometer). The degradation studies were conducted by measuring absorbance in UV-VIS spectrophotometer, having a wavelength range from 190-1100nm using a 1 cm glass cell. All the experiments reported were carried out in a 4 ml glass cuvette. The scan speed is 200 nm/min with a step of 1.0 nm. Wavelength resolution is 0.1 nm. Spectrophotometer is having both Tungsten and Deuterium lamp at operating temperature of 0-40°C.

4.3 Software Used

4.3.1 SpecWare 6

SpecWare 6 is a company provided weather monitoring station compatible software to download data stored in the instrument. The software may be used to look at current

weather condition, make a new station and readout wind data. It stores data to disk in monthly files. SpecWare can also be used to present data in both graphical and tabular form in .txt format.

4.3.2 Wind Rose PRO

It is a windows application for analyzing and plotting directional variables starting from raw data or from their frequencies and creating wind roses. A wind rose is a chart which gives a view of how wind speed and wind direction are distributed at a particular location over a specific period of time. It is a very useful representation because a large quantity of data can be summarized in a single plot. In this length of arm represents the frequency of a specific wind direction and its position on polar coordinate represent wind direction. The number of arms can be decided by user, 4, 8, 16 and maximum of 360 (George et al. 2008). It imports data in many formats, analyzes them and creates different types of charts. The results can be exported in Microsoft excel format, and charts are automatically created within excel. Wind roses can be saved in raster format (BMP, JPG and PNG), and exported as DXF, shape files (SHP) or KML for Google Earth.

4.4 Methodology

The study was carried out in three steps which are:

- Selection of sampling site
- Air sampling and analysis
- Calculation of Air Quality Index (AQI)

4.4.1 Selection of sampling site

In first step, sampling sites were selected on the basis of wind data, population density, topography, impact area, industrial clusters and other local parameters of study area. With the help of Google map we identified different population clusters or zones with maximum population density and industrial clusters were identified. Moreover residential areas near to an industrial zone were given more preference as they get mostly affected from industrial pollution. The wind data collected for the period October 2010 to September 2011 was used

to calculate impact area and to develop impact area diagrams which were used in selecting site for sampling.

Monthly, quarterly and half yearly wind roses were constructed from the wind data i.e. its speed and direction, collected for the period of 18 months i.e. October 2010 to March 2012 by using weather monitoring station. The site for installation of weather monitoring station should be an open area with no obstruction to ensure accurate measurement of wind speed and direction. So for this study, the site selected was DBTES, Thapar University (30°35'39"N, 76°37'07"E), Patiala.

In diagrammatic representation of wind rose, each concentric circle represents a different frequency, emanating from zero at the center to increasing frequencies at the outer circles. Using a polar coordinate system of gridding, the frequency of winds over a long time period were plotted by wind direction, with color bands showing wind ranges. In order to plot wind rose diagram, seven different wind speed ranges were taken into consideration. The direction of the wind rose with the longest spoke shows the wind direction with maximum frequency. Calm period was taken for speed range <1kph and it was included at the centre of the diagram. Wind rose diagram were plotted using Wind Rose Pro setup from Enviroware.

After plotting wind roses, impact area diagram were constructed using methodology given in *George et al., 2009*. Impact area diagrams were drawn by superimposing all the sector area over one center having arc radius equal to the average wind speed (*George et al., 2008*). Impact area diagrams are helpful in obtaining the idea about most affected wind direction from the source. Wind data were then grouped into different category of wind speed, and for each wind speed category, the average distance traveled by the pollutant per unit time from the source can be represented by the mean wind speed (V_j) of that category. For example, wind speed category can be taken from 1 to 3, 3 to 5, 5 to 7 and 7 to 9 kmh^{-1} etc. For calculating standard deviation, wind speeds more than 1 kmh^{-1} were taken into consideration excluding calm wind conditions. Impact area under different wind speed categories were summed up to obtain the total impact area (*George et al., 2009*). Since

different wind speed groups may indicate different direction of impact area, its linear summation was weighted by persistence of impact area, thereby yielding dilution potential.

The standard deviation (σ_θ) of the wind direction is estimated from Yamartino method (Yamartino, 1984; Isikwue et al., 2010).

$$s_a = n^{-1} \sum_{i=1}^{i=n} \sin \Theta_i \dots\dots\dots(1)$$

$$c_a = n^{-1} \sum_{i=1}^{i=n} \cos \Theta_i \dots\dots\dots(2)$$

First of all, average of sine and cosine of wind direction angle was calculated using equation 1 and 2 for each specific wind speed class. Then these average values were used to calculate average wind direction for that specific wind speed class (Farrugia and Micallef, 2006).

Average wind direction was calculated using the four-quadrant arctan(x,y) function as mentioned in equation 3. Values of c_a and s_a were taken without any positive and negative sign (Gaile and Burt, 1980).

$$\Theta = \tan^{-1}(s_a/c_a) \dots\dots\dots(3)$$

But values obtained from above equation needs correction as sign of c_a and s_a are neglected in above formula. So to calculate final average wind directions following condition was used.

- $\Theta =$ If $s_a < 0$ & $c_a < 0$ then $180 + \Theta$**
- If $s_a > 0$ & $c_a < 0$ then $180 - \Theta$**
- If $s_a > 0$ & $c_a > 0$ then Θ**
- If $s_a < 0$ & $c_a > 0$ then $360 - \Theta$**

Consider an example that if value obtained for Θ is 60° from equation 3, with value of c_a with negative and s_a with positive sign, means final value of Θ will lie in 2nd quadrant. This is due to the fact that in 2nd quadrant, sine function has positive value and cosine function has

negative value. Then the final value taken for Θ is 120° i.e. by applying 2nd condition by which $180^\circ - 60^\circ = 120^\circ$ is the final value for Θ .

For the calculation of standard deviation, first \mathcal{E} is calculated using values of s_a and c_a using following equation. This value of \mathcal{E} is then used to estimate the value of standard deviation which can be obtained by using equation 4.

$$\sigma_\Theta = [\sin^{-1}(\mathcal{E})] [1 + \{(2/\sqrt{3}) - 1\} \mathcal{E}^3] \dots \dots \dots (4)$$

Where,

$$\mathcal{E} = [1 - (s_a^2 + c_a^2)]^{1/2}$$

Mean wind speed was calculated by just taking average of all the value of wind speed obtained with in a specific wind speed class. Impact area can be calculated by using equation 5 (George et al., 2009).

$$a_j = \sigma_\Theta / 2 [V_j^2 * n_j / (N - N_{\text{calm}})] \dots \dots \dots (5)$$

Where,

- σ_Θ = angular standard deviation of the specific group;
- V_j^2 = mean wind speed for the specific group;
- n_j = number of wind data in specific wind speed category;
- N_{calm} = number of wind data in calm period range (<1kph) and
- N = total number of wind data.

Values for standard deviation, mean wind direction calculated earlier were used to calculate impact area.

The total industrial hub of Mandi Gobindgarh has been sub divided into six industrial clusters (PPCB, 2010). As these clusters consist of mainly rolling mills, Induction furnaces, refractories etc., so sampling is done in these areas so that all types of industries get covered. On the basis of wind roses, impact area diagrams, 6 industrial clusters and local data collected related to study area, 10 sampling sites were selected so that representative

sampling can be done. Out of 11 sampling sites selected, 7 are within industrial areas and 2 are in residential area, 1 each in commercial and agricultural area. Duration for sampling for each pollutant is 24hr, twice a week at a particular site. So total of 11 sites were covered within 11 weeks starting within month of March 2012 to May 2012.

4.4.2 Air sampling and analysis

The second step involves the air sampling for four pollutants which are PM 10, PM 2.5, SO₂, NO₂ (*Chauhan et al., 2010; Kumar et al., 2011*) at all the selected sites so that the concentration at these points can be known. All the instruments required for sampling were taken to the first sampling site. Sampling at a particular site was done twice a week. All the instruments were shifted to the next site and the procedure was repeated again. Different precautions and procedures used for sampling of 4 parameters are as follows:

PM 2.5 analysis:

PM 2.5/10um or Fine dust sampler with WINS impactor assembly was used to find out the concentration of suspended particulate of size between 2.5um to 10um. Different steps followed during sampling are:

1. Install the tripod stand and place the instrument case over it by making sure that exhaust pipe at right rear of the instrument is not stuck between the frame of the stand and the instrument body.
2. The instrument case houses the WINS impactor and the filter holder along with the vacuum pump and control module. Mount the WINS impactor on filter holder cover.
3. Open WINS impactor assembly, place a fresh 37 mm diameter filter in the well and pour 1 ml of silicon oil over filter paper using a dropper.
4. Open the filter holder that follows the WINS impactor having a filter cassette with metal wire mesh inside it. Place preconditioned and pre weighed PTFE 46.2 mm filter paper on it and snap it into filter cassette. Tight the entire assembly.
5. Now set different parameter like flow rate and sampling period in control module and sampling starts.

Calculation of the volume of air sampled can be done using equation:

$$V = (F_1 + F_2) * T / 2$$

Where,

V = volume of air sampled in m³

F₁ = measured flow rate before sampling

F₂ = measured flow rate after sampling

T = time of sampling

PM 2.5 concentration is calculated by:

$$PM\ 2.5 = (W_f - W_i) * 1000 / V_a$$

Where,

PM 2.5 = Total mass concentration of PM 2.5 collected during the sampling period, ug/m³

W_f, W_i = Final and Initial mass of PTFE filter paper, mg

V_a = Total air volume sampled, m³

PM 10 analysis:

PM 2.5/10um or Fine dust sampler with PM 10 impactor assembly is used to find out concentration of suspended particulate of diameter higher than 10um within the air. For this WINS impactor assembly is removed and only one 47mm diameter filter paper is used. Following are the steps followed during air sampling for PM 10:

1. Install the tripod stand and place the instrument over it by making sure that exhaust pipe at right rear of the instrument is not stuck between the frame of the stand and the instrument body.
2. PM 10 impactor assembly was placed in place of WINS impactor assembly and all the joints are tightened each joint tightly.
3. Open the filter holder and place preconditioned and pre-weighed 47 mm diameter glass fiber filter paper on metal wire mesh present in filter cassette. Cover the filter holder and tighten the entire assembly.
4. Now set different parameter like flow rate and sampling period in control module and sampling starts.

Calculation of the volume of air sampled

$$V = (F_1 + F_2) * T / 2$$

Where,

V = volume of air sampled in m³

F₁ = measured flow rate before sampling

F₂ = measured flow rate after sampling

T = time of sampling

PM 10 concentration is calculated by

$$PM\ 10 = (W_f - W_i) * 1000 / V_a$$

Where,

PM10 = Mass concentration of PM 10 collected during the sampling period, ug/m³

W_f, W_i = Final and Initial mass of glass fibre filter paper, mg

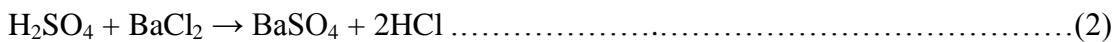
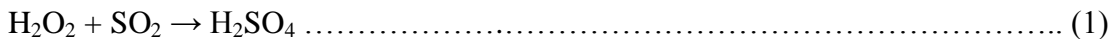
V_a = Total air volume sampled, m³

Precaution taken during handling of filters:

- Minimize the exposure of the filters to open air by keeping them covered inside the filter carriers provided with the instrument.
- Since filter papers are fine and fragile materials, so handle with care.
- Filters are inspected against the light source for pinholes and loose contamination before use.

SO₂ analysis

SO₂ is gravimetrically estimated by adding barium chloride in slight excess in absorbing solution. H₂O₂ is used as an absorbing solution which gets converted to sulphuric acid during sampling (Eq. (1)).



When barium chloride reacts with sulphuric acid (Eq. (2)), it leads to the formation of barium sulphate which is estimated gravimetrically. With stoichiometric calculation, we estimate sulphur dioxide concentration in ambient air. Steps followed for SO₂ analysis:

- Install high volume sampler with its gaseous extension having impinger bottles filled with 30 ml of absorbing solution. Set flow rate of air flow in between 0.2 to 1 LPM.
- After sampling for 24 hrs, add BaCl₂ in excess to absorbing solution while slightly heating, as to precipitate SO₄²⁻ as BaSO₄.
- Once the reaction is completed, the precipitates formed are filtered on a pre-conditioned and pre-weighed Whatman filter paper. After filtration, the precipitates are dried in an oven and final weight of filter paper is recorded.
- Difference of the final weight and initial weight of the filter paper gives the amount of precipitates formed. With the help of stoichiometric calculations, calculate the concentration of SO₂ in the ambient atmosphere.

SO₂ concentration can be calculated by

$$\text{SO}_2 = (\text{Mol. wt. of SO}_2 * W * 10^6) / (\text{Mol. wt of BaSO}_4 * V_a)$$

Where,

SO₂ = Concentration of SO₂, ug/m³

V_a = Total air volume sampled, m³

W = weight of BaSO₄ formed i.e. difference between filter paper before and after filtration, g

NO₂ analysis

Ambient nitrogen dioxide (NO₂) is collected by bubbling air through a solution of sodium hydroxide. The concentration of nitrite ion (NO₂) produced during sampling is determined colorimetrically by reacting the nitrite ion with phosphoric acid, sulfanilamide, and N-(1-naphthyl)-ethylenediamine di-hydrochloride (NEDA) and measuring the absorbance of the highly coloured azo-dye at 540 nm. Steps taken during NO₂ sampling are as follows:

Preparation of Standards

1. Pipette 2, 4, 5, 6 ml of working standard solution in to 50 ml volumetric flask and fill to 20 ml mark with absorbing solution.
2. A reagent blank with 10 ml absorbing solution is also prepared.
3. Pipette in 1 ml of hydrogen peroxide solution, 10 ml of sulphanilamide solution and 1.4 ml of NEDA solution, with thorough mixing after the addition of each reagent and make up to 50 ml with distilled water.
4. Read the absorbance of each standard and reagent blank against distilled water reference after 10 minute color development interval.
5. Standard curve is plotted having absorbance on Y axis versus concentration at X axis.

Sample Analysis

1. Prepare absorbing reagent (a solution of sodium hydroxide and arsenite) by dissolving 4g of sodium hydroxide and 1g of sodium arsenite in 1lit of distilled water. A drop of H_2O_2 is added to remove interference of SO_2 .
2. Place 30 ml of absorbing solution in an impinger bottle and are sampled for 24 hrs using HVS at the flow rate of 0.2 to 1 L/min.
3. After sampling measure the volume of sample and transfer to a sample storage bottle.
4. Replace any water lost by evaporation during sampling by adding distilled water up to the calibration mark on the absorber, mix thoroughly.
5. Pipette out 10 ml of the collected sample into a 50 ml volumetric flask.
6. Pipette in 1 ml of hydrogen peroxide solution, 10 ml of sulphanilamide solution and 1.4 ml of NEDA solution, with thorough mixing after the addition of each reagent and make up to 50 ml with distilled water.
7. Prepare a blank in the same manner using 10 ml of unexposed absorbing reagent.
8. After a 10 min colour development interval, measure and record the absorbance of samples and reagent blank at 540 nm using distilled water as the optical reference.

Values of NO₂ concentration can be taken from the standard curve plotted between concentration and absorbance and then divided by the volume of air sampled.

4.4.3 Calculation of AQI

In last step, Air quality index was calculated using methodology provided by CPCB and USEPA both. For IND-AQI, sub-index values (sub-AQI) for all four air pollutants (PM 10, SO₂, NO_x and PM 2.5) were first calculated using the adopted sub-index functions. Out of all sub-AQIs, the highest value becomes the overall index and reported as IND-AQI. The pollutant for which the sub-AQI is the highest, becomes the responsible pollutant, and indicated alongside the IND-AQI value.

Sub-indices can be calculated using following equation (*Chattopadhyay et al., 2010*):

$$q = 100 (V/V_s)$$

Where,

q = Quality Rating

V = Observed values of the parameter and

V_s = Standard value recommended for the parameter

$$g = \text{anti log } \{(\log a + \log b + \dots \dots \dots \log x)/n\};$$

Where,

g = Geometric mean;

a, b, c, d, x = Different values of air quality rating; and

n = Number of values of air quality rating,

Air Quality Index according to USEPA is calculated (*Upadhyaya and Dashore, 2006; Bishoi et al., 2009; Gufran, 2010*) by using following equation:

$$I = [(I_{\text{high}} - I_{\text{low}}) * (C - C_{\text{low}}) / (C_{\text{high}} - C_{\text{low}})] + I_{\text{low}}$$

Where:

I = Air Quality Index,

C = the pollutant concentration,

C_{low} = the concentration breakpoint that is ≤ C,

C_{high} = the concentration breakpoint that is $\geq C$,

I_{low} = the index breakpoint corresponding to C_{low} ,

I_{high} = the index breakpoint corresponding to C_{high}

S.No	Index	Category	SO ₂ (24 hr avg) ($\mu\text{gm}/\text{m}_3$)	NO ₂ (1-hr avg) ($\mu\text{gm}/\text{m}_3$)	SPM (24-hr avg.) ($\mu\text{gm}/\text{m}_3$)	CO (1-hr avg.) ($\mu\text{gm}/\text{m}_3$)	CO (8-hr avg) ($\mu\text{gm}/\text{m}_3$)	O ₃ (1-hr avg.) ($\mu\text{gm}/\text{m}_3$)	NH ₃ (24-hr avg.) ($\mu\text{gm}/\text{m}_3$)	PM _{2.5} (24-hr avg.) ($\mu\text{gm}/\text{m}_3$)	Pb (24-hr avg.) ($\mu\text{gm}/\text{m}_3$)	PM ₁₀ (24-hr avg.) ($\mu\text{gm}/\text{m}_3$)
1.	0-100	Good	0-80	0-80	0-200	0-4	0-2	0-180	0-60	0-400	0-1	0-100
2.	101-200	Moderate	81-367	81-180	201-260	4.1-25	2.1-12	180-225	61-90	400-550	1-1.5	101-150
3.	201-300	Poor	368-786	181-564	261-400	25.1-35	12.1-17	225-300	91-210	550-700	1.5-2.25	151-350
4.	301-400	Very poor	787-1572	565-1272	401-800	35.1-75	17.1-35	301-800	211-250	700-900	2.25-3.25	351-420
5.	401-500	Severe	>1572	>1272	>800	>75	>35	>800	>250	>900	>3.25	>420

Fig 4.5: Air Quality Index for different Pollutants with their concentrations for India

CHAPTER 5

RESULTS & DISCUSSION

This chapter presents the wind roses, impact area diagram and concentration of different pollutants such as PM 10, PM 2.5, SO₂ and NO₂ at different selected sites. As it has been discussed in methodology that first step for calculating Air Quality Index, was to decide sampling sites on the basis of wind roses, impact area diagrams, local data and topography. So firstly impact area and impact area diagrams were plotted for period of October 2010 to September 2011. Wind data was collected at mentioned site at an interval of 1 hr for the study period of twelve months. Wind impact area diagram have been plotted and are presented in Fig. 5.1. However, if the center of wind impact area diagram is superimposed over a ground level pollution source, the downwind distance up to which pollution can travel can be gauged and accordingly the sampling location can be fixed. Wind speeds were grouped into seven categories and standard deviations of the wind direction and impact area were determined. These calculated values of standard deviation and impact area are given in Table 5.1. From these impact area diagrams, it was noticed that maximum affected direction by air pollution is towards North-West and East of study area. In most of the study period, impact area calculated was near to 14m² which is very less and represents concentrated pollutant concentration within small area. In Mandi Gobindgarh maximum industrial clusters are situated next to residential area so sites are chosen such which covers extremely affecting area.

Conventional wind roses were plotted for the period of 18 months i.e. from October 2010 to March 2012 by taking wind speed <1kph as calm period. The conventional wind rose diagram can only depict wind frequencies from different directions at a location but it does not give a pictorial view of the downwind distance up to which wind can cause pollutant to travel. Through them the predominant wind direction can be determined and wind speed during different seasons can be known.

The concentration of pollutant was used to estimate Air Quality Index (AQI) of the different site and further IND-AQI values were compared with AQI calculated using USEPA methodology.

5.1 Selecton of sampling sites

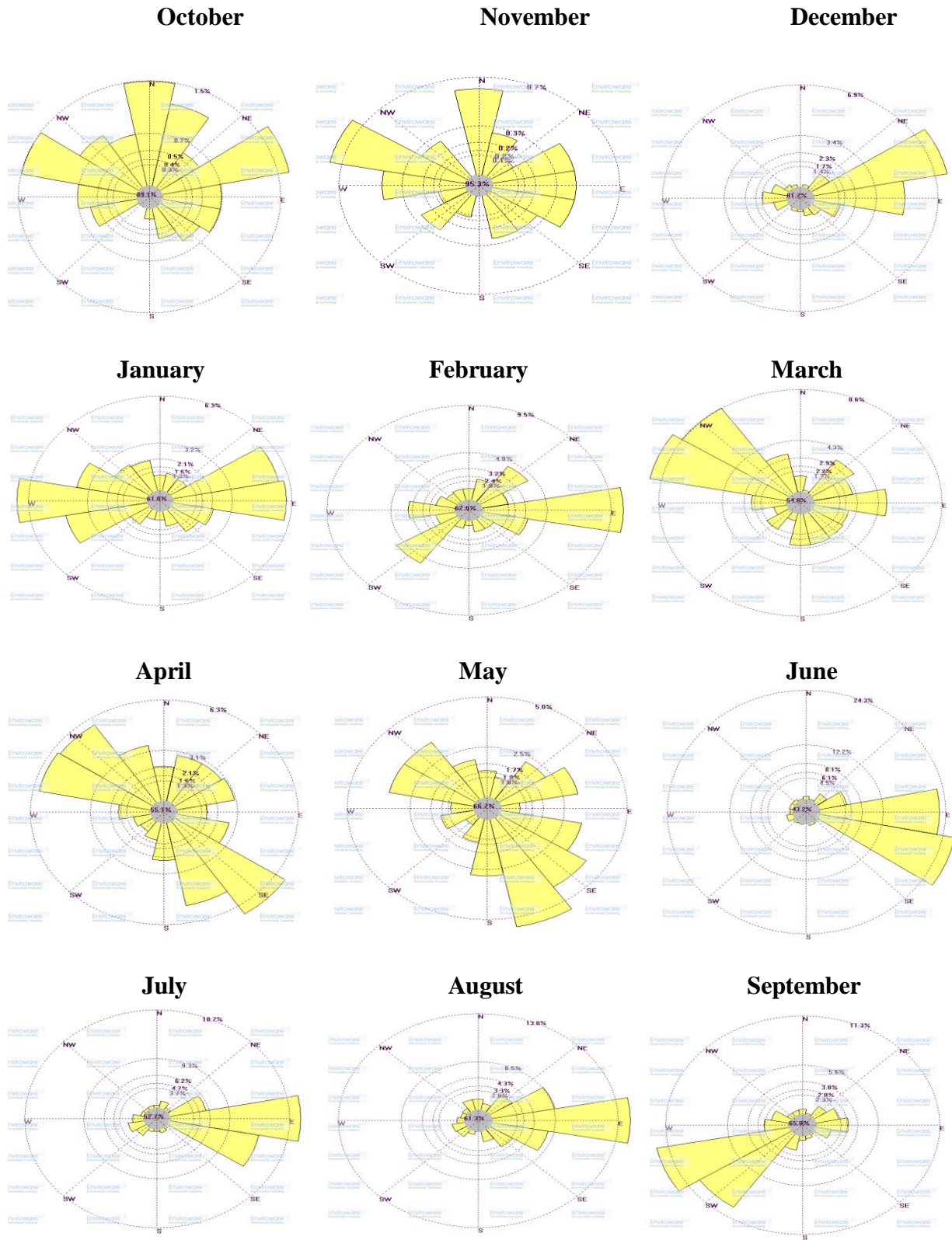


Fig 5.1: Impact area diagrams

Table 5.1: Calculated values for Standard Deviation and Impact Area.

S/n	Wind speed class	Data wind class	S _a	C _a	Mean wind direction	Standard Deviation	Wind specific impact area(m ²)
October 2010							
1	1-3	5.91	-0.024	0.355	356	77.87	4.28
2	3-5	4.3	0.200	0.294	34.4	77.87	14.7
3	5-7	.13	0.643	0.766	40	0	0
4	7-9	.4	0.177	0.414	23.1	70.13	6.48
5	9-11	0	-	-	-	-	-
6	11-13	.13	-0.682	0.731	317	0	0
7	13-15	0	-	-	-	-	-
November 2010							
1	1-3	2.64	0.190	0.169	311.8	85.75	4.65
2	3-5	0.55	0.662	0.069	84	51.3	2.41
3	5-7	0.84	0.263	0.167	57.6	81.33	22.87
4	7-9	0.14	-0.766	-0.643	230	0	0
5	9-11	0.55	0.053	0.080	33.4	97.32	41.1
6	11-13	0	-	-	-	-	-
7	13-15	0	-	-	-	-	-
December 2010							
1	1-3	9.54	0.619	0.134	77.8	54.35	2.834
2	3-5	7.25	0.561	0.170	73.1	58.42	11.44
3	5-7	1.07	0.394	-0.018	92.6	74.76	7.02
4	7-9	0.40	0.829	-0.506	121.4	13.726	0.75
5	9-11	0	-	-	-	-	-
6	11-13	0	-	-	-	-	-
7	13-15	0	-	-	-	-	-
January 2011							
1	1-3	22.44	0.008	0.105	4.7	96.44	5.66
2	3-5	13.57	-0.090	0.0433	295.6	97.11	16.96
3	5-7	1.34	-0.336	0.069	281.6	78.83	4.43
4	7-9	.4	0.309	0.100	72	80.3	2.12
5	9-11	.13	-0.927	-0.374	248	0	0
6	11-13	.27	-0.827	-0.394	244.5	23.68	0.93
7	13-15	0	-	-	-	-	-
February 2011							
1	1-3	14.88	0.141	0.049	70.8	93.24	3.72
2	3-5	17.56	0.279	-0.057	101.6	83.3	21.17
3	5-7	2.82	0.682	-0.241	109.5	45.84	5.56

4	7-9	1.04	0.108	0.117	42.6	92.76	6.48
5	9-11	.59	0.098	-0.357	164.5	76.56	4.40
6	11-13	.29	0.170	-0.421	158	69.89	3.14
7	13-15	0	-	-	-	-	-
March 2011							
1	1-3	14.92	-0.054	0.227	346.6	87.32	2.88
2	3-5	19.89	-0.205	0.217	316.6	82.3	21.30
3	5-7	5.91	-0.174	0.030	280	91.49	19.14
4	7-9	2.69	0.130	-0.229	150.4	84.91	12.62
5	9-11	.8	-0.106	-0.073	235.2	95.02	6.10
6	11-13	.94	0.375	-0.538	145.1	52.22	5.32
7	13-15	0	-	-	-	-	-
April 2011							
1	1-3	20.69	-0.038	0.142	345	93.69	4.31
2	3-5	17.08	0.062	0.029	64.37	99.24	3.77
3	5-7	4.3	0.258	-0.103	111.43	83.83	12.85
4	7-9	.69	0.279	-0.290	136.14	74.08	2.86
5	9-11	.97	0.503	-0.194	111.05	62.61	4.88
6	11-13	.83	0.283	0.032	83.56	83.41	8.32
7	13-15	.27	0.877	-0.310	109.5	21.66	1.08
May 2011							
1	1-3	13.03	0.165	-0.037	102.634	92.09	3.60
2	3-5	13.17	0.032	-0.041	142.5	100.4	21.63
3	5-7	2.55	0.042	-0.138	163.1	93.93	11.50
4	7-9	1.74	0.217	-0.420	152.7	68.31	8.94
5	9-11	1.47	0.357	-0.405	138.6	62.55	9.97
6	11-13	1.34	0.472	-0.529	138.3	47.22	10.13
7	13-15	0	-	-	-	-	-
June 2011							
1	1-3	19.72	0.797	-0.074	95.3	38.02	1.32
2	3-5	23.61	0.869	-0.114	97.5	29.14	6.90
3	5-7	5.97	0.928	-0.1876	101.4	18.75	3.15
4	7-9	3.75	0.857	-0.034	92.4	31.55	5.20
5	9-11	1.38	0.872	-0.065	94.3	29.52	2.60
6	11-13	2.22	0.54	0.004	89.6	62.58	13.30
7	13-15	.002	0.9975	-0.069	94	-	-

July 2011							
1	1-3	19.75	0.647	-0.102	99	52.29	2.18
2	3-5	22.98	0.638	-0.076	96.81	53.47	14.70
3	5-7	3.22	0.721	0.022	88.2	46.03	5.01
4	7-9	1.2	0.869	-0.018	91.19	30.19	1.93
5	9-11	0	-	-	-	-	-
6	11-13	0.13	-0.899	0.438	296	0	0
7	13-15	0	-	-	-	-	-
August 2011							
1	1-3	15.72	0.5674	-0.029	92.95	60.16	2.44
2	3-5	18.01	0.6476	0.0513	85.47	52.82	14.35
3	5-7	3.36	0.7562	0.2148	74.14	39.56	5.49
4	7-9	1.2	0.89	-0.226	104.24	23.35	1.82
5	9-11	.27	0.743	0.57	52.5	20.62	0.51
6	11-13	.13	0.9925	-0.1218	97	0	0
7	13-15	0	-	-	-	-	-
September 2011							
1	1-3	16.52	-0.250	-0.213	229.53	80.07	3.77
2	3-5	15.14	-0.557	-0.314	240.55	53.8	13.84
3	5-7	3.05	-0.719	-0.478	236.36	30.96	4.32
4	7-9	.27	-0.889	-0.415	245	10.96	0.21
5	9-11	0	-	-	-	-	-
6	11-13	0	-	-	-	-	-
7	13-15	0	-	-	-	-	-

As it can be observed from Fig 5.3, 5.4 that during first 12 months of study period, predominant wind was western wind i.e. winds blowing from west to east direction and from Fig 5.5, 5.6 that during period of October 2011 to March 2012 predominant wind direction was South-East i.e. blowing from South-East to North-West. Over whole study period two predominant wind directions came across are South-East and West. As maximum industrial clusters are located such that pollutants released affect local population for maximum period.

Punjab Pollution Control Board had also identified 6 most polluted industrial clusters within study area. Population density was observed with the help of Google Earth providing mainly 2 areas where population density was maximum. Air Quality within city is also affected by presence of heavy traffic on GT road, considering this; sampling sites were chosen such that impact of GT road on results will be least. On the basis of all these wind roses, impact area diagrams, impact area calculated and industrial clusters identified, 7 industrial sampling sites

were selected. 2 residential sites were also selected on basis of population density, wind roses and impact area diagrams. These sites are selected such that the population which gets mostly affected were got covered. One site was selected as agricultural site, 35km far from study area and one commercial site was also selected.

Table 5.2: Sampling sites selected

Site code	Description of the site	Sampling Site	Type of sources based on land use
S1	Industrial Sampling Sites	Talwara Road	Rolling mills, Refractories
S2		Near RIMT	Rolling Mills
S3		Prem Nagar	Induction Furnaces, Rolling Mills, Refractories
S4		Guru ki Nagri	Induction Furnaces, Rolling Mills
S5		GT road, Khanna Side	Induction Furnaces, Rolling Mills, NH-1
S6		Focal point	Induction Furnaces, Rolling Mills, NH-1
S7		Near Village Kumbh, Amlah road	Induction Furnaces, Rolling Mills, Refractories
S8	Residential	Motia Khan	Induction Furnaces, Rolling Mills,
S9	Sampling Sites	Shastri nagar	Induction Furnaces, Rolling Mills,
S10	Commercial site	Near Bus Stand	Induction Furnaces, Rolling Mills,
S11	Agricultural site	Kharorha	-----



Fig 5.2: Sampling sites selected for monitoring

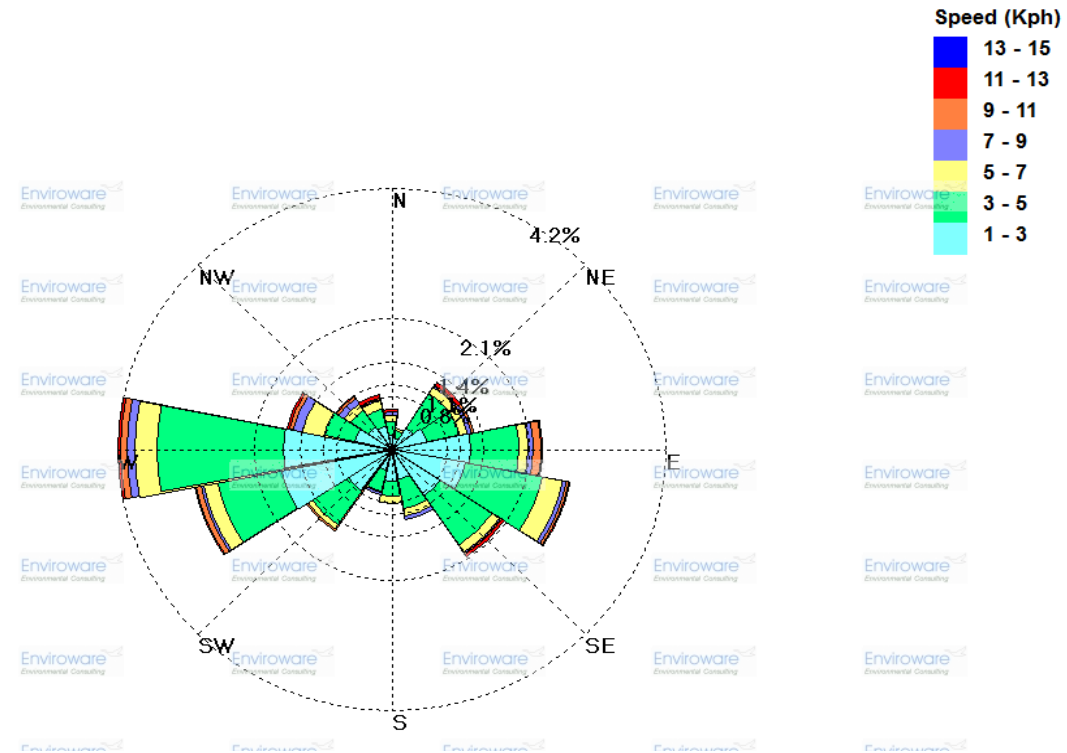


Fig 5.3: Wind rose for period October 2010 to March 11

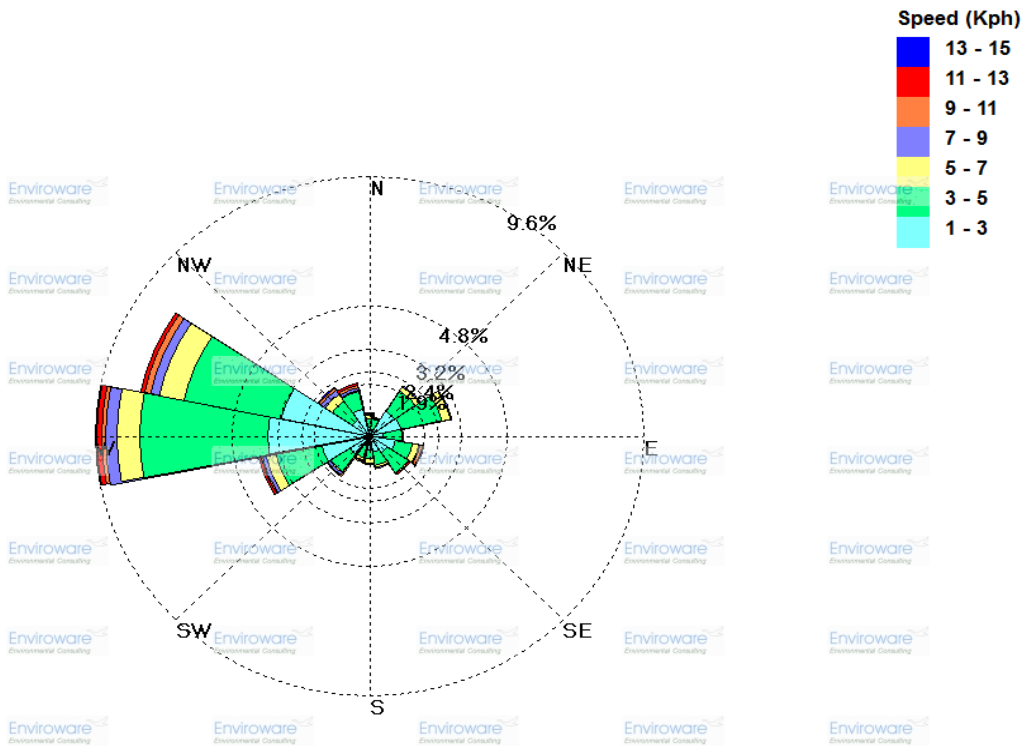


Fig 5.4: Wind rose for period April 2011 to September 2011

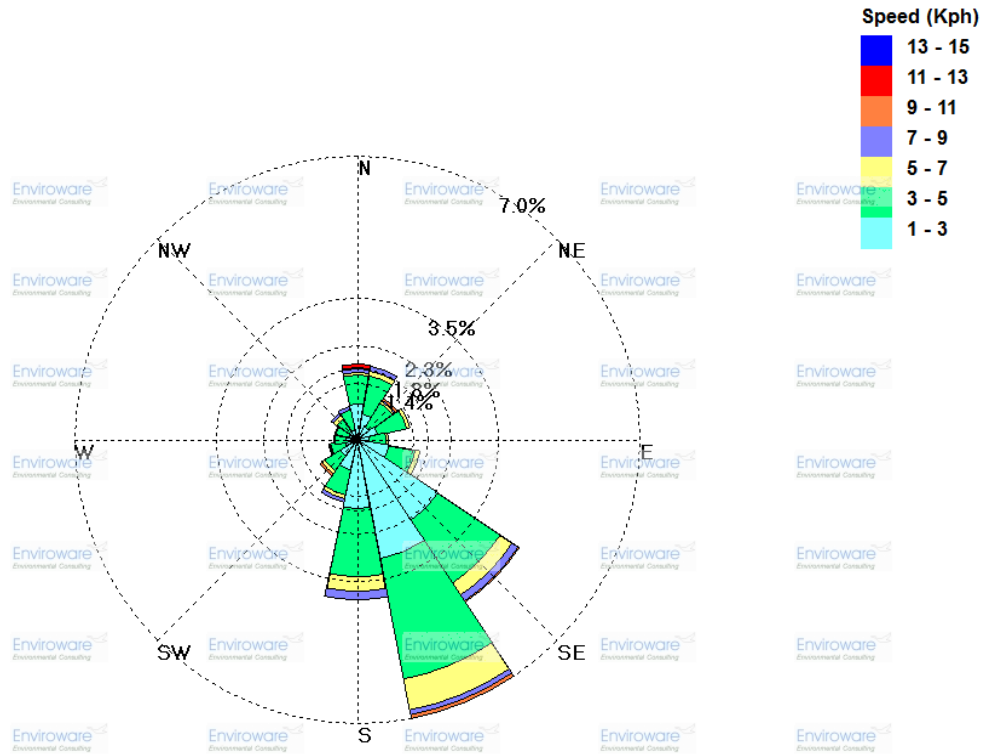


Fig 5.5: Wind rose for period October 2011 to March 2012

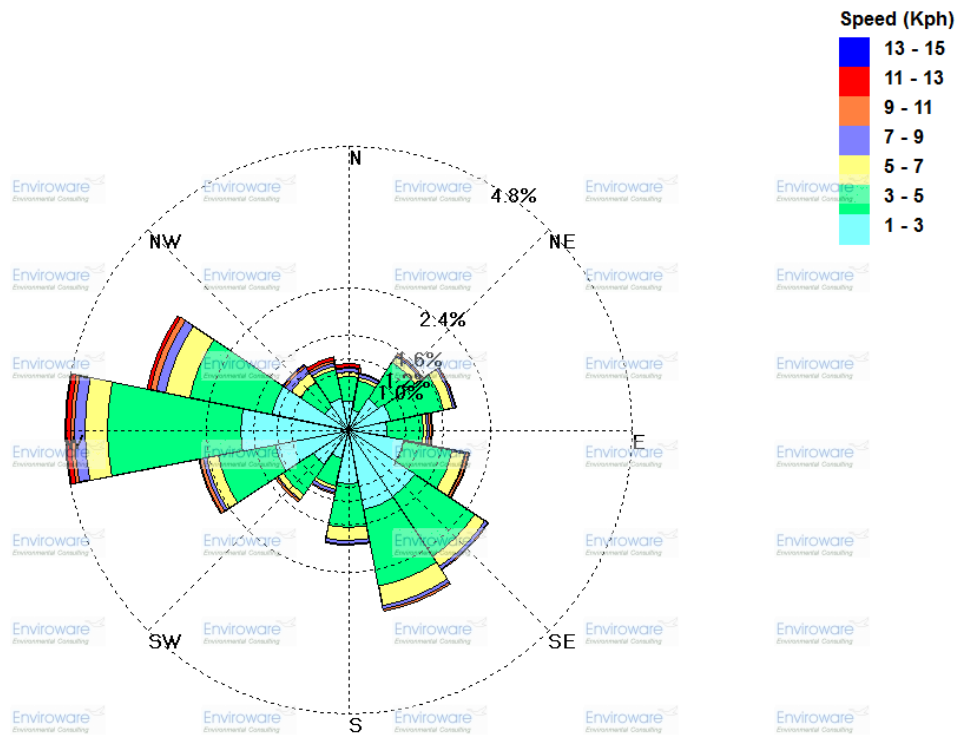


Fig 5.6: Wind rose for period October 2010 to March 2012

5.2 Measurement of Pollutants concentration

After selection of sampling site, monitoring of 4 pollutants i.e. PM 10, PM 2.5, SO₂ & NO₂ was done. Concentrations of different pollutants at different sampling sites were listed in table 5.3.

Table 5.3: Concentrations of pollutant at different sampling sites

Site Code	Sampling Site	Type of Site	Concentrations (ug/m ³)			
			PM10	PM2.5	SO ₂	NO ₂
S1	Talwara Road	Industrial sites	294.85	88.23	48.21	23.37
S2	Near RIMT		170.4	90.56	35.45	20.29
S3	Prem Nagar		283.35	98.8	42.38	27.54
S4	Guru ki Nagri		224.87	82.64	37	23.51
S5	GT road, Khanna Side		294.9	110.77	46.21	25.47
S6	Focal point		285.97	109.5	51.63	30.4
S7	Near Village Kumbh, Amloh road		342.59	85.42	43.65	24.49
S8	Motia Khan	Residential sites	183.58	77.07	29.81	16.2
S9	Shastri nagar		174.38	81.11	32.89	17.97
S10	Near Bus Stand	Commercial sites	192.27	121.48	32.55	18.51
S11	Kharorha	Agricultural site	94.32	45.29	12.37	10.05

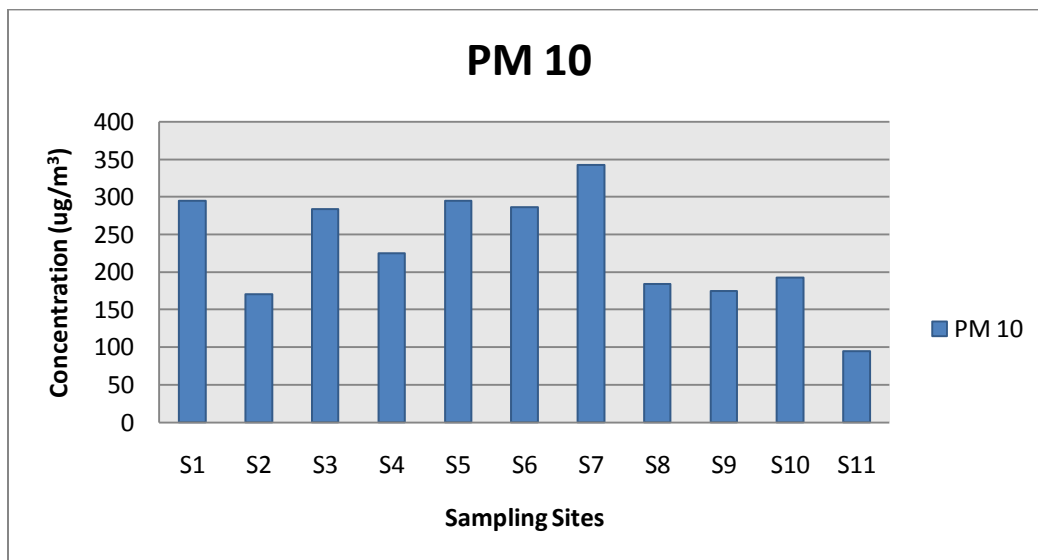


Fig 5.7: Concentrations of PM 10 at all sampling sites

Concentrations of each pollutant were plotted against different sites selected so that comparison can be made. From Table 5.3 and Fig 5.7, it can be seen that highest PM 10 concentration among industrial sites was 342.59 $\mu\text{g}/\text{m}^3$ at site near Village Kumbh on Amloh road and least was 170.4 $\mu\text{g}/\text{m}^3$ at site near RIMT. Among residential sites, concentrations of PM 10 were nearly same. Concentrations of pollutant at agricultural sites were well below the standard values. 24 hr Average Concentration observed at all industrial, commercial and residential sites were much above the standards concentrations of PM 10 established by CPCB.

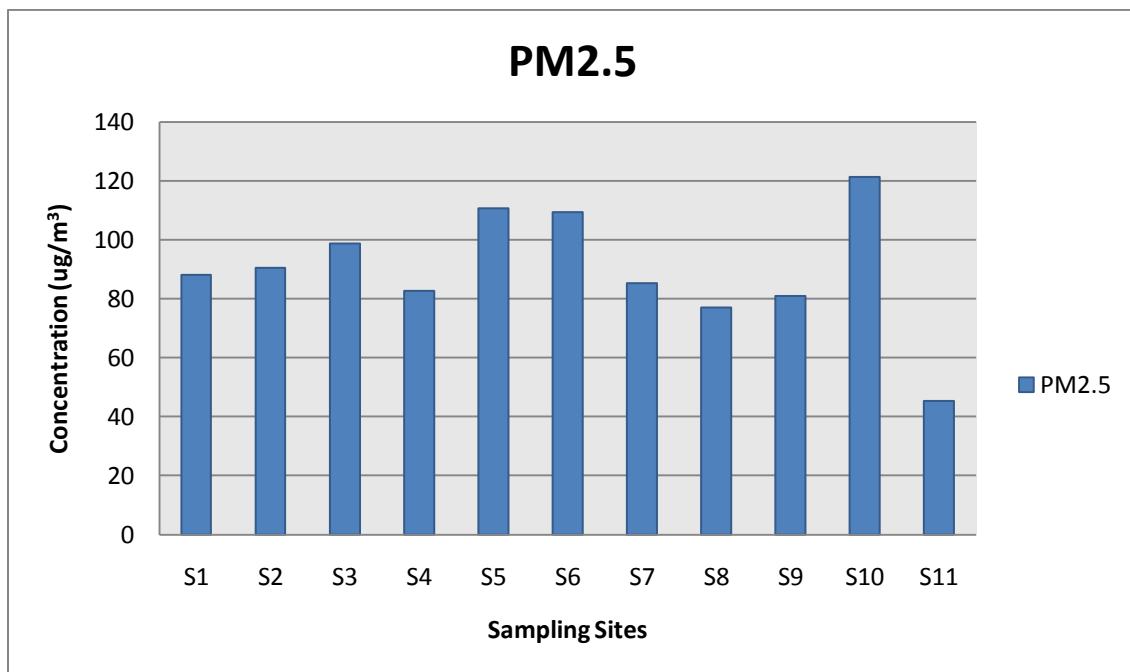


Fig 5.8: Concentrations of PM 2.5 at all sampling sites

From Fig 5.8, it can be seen that maximum concentration of PM 2.5 was 110.77 $\mu\text{g}/\text{m}^3$ at site on national highway towards Khanna side among industrial sites which may be due to both industrial activity and due to heavy vehicular traffic on highway. Least concentration was 82.64 $\mu\text{g}/\text{m}^3$ at site within Guru ki Nagri. Among residential sites, a very high concentration of PM 2.5 of 121.48 $\mu\text{g}/\text{m}^3$ was observed at site near bus stand which may be due to high activity of heavy vehicles. Concentration of PM 2.5 obtained at agricultural site was 45.3 $\mu\text{g}/\text{m}^3$.

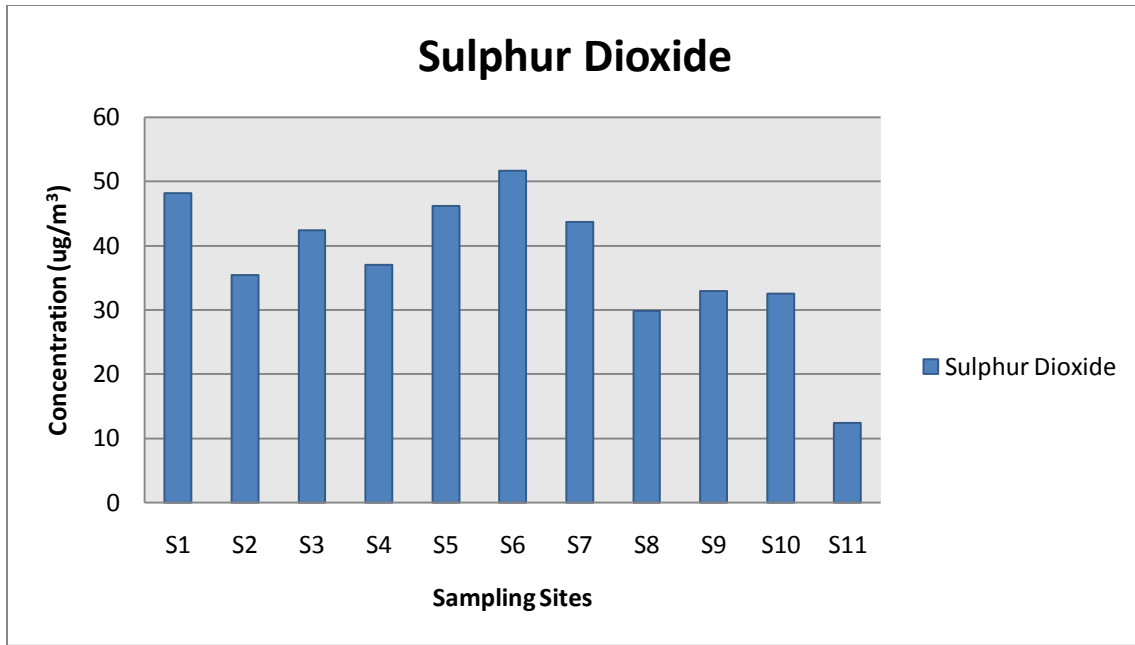


Fig 5.9: Concentrations of SO₂ at all sampling sites

Among industrial sites, concentration of 51.63 ug/m³ was observed as highest concentration of SO₂ at Focal Point and least concentration observed was 35.45 ug/m³ at site near RIMT. Within residential and commercial sites, SO₂ concentration found was near to 30 ug/m³ as depicted in Fig 5.9. Standard value provided by CPCB is 80ug/m³ so all values coming at different sites is less.

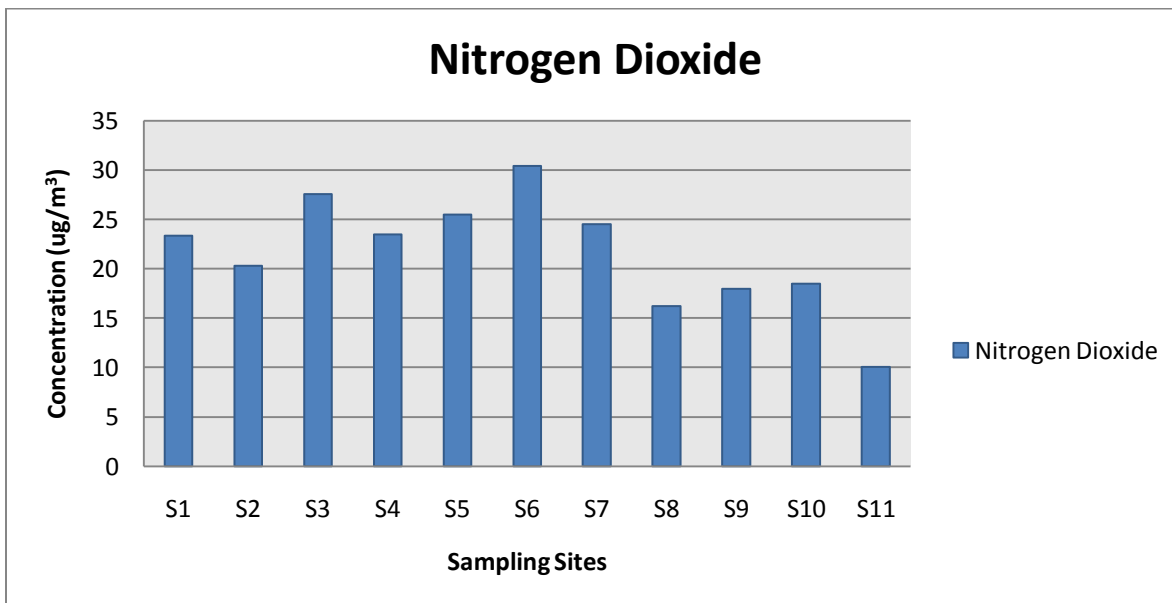


Fig 5.10: Concentrations of NO₂ at all sampling sites

Fig 5.10 shows that the concentration of NO₂ was highest at Focal Point i.e. of 30.41ug/m³ and maximum sites have concentration near to 23 ug/m³. Among non-industrial sites, concentration of NO₂ was highest at site near bus stand. These values are less than standard values provided by CPCB.

5.3 Calculation of AQI

Finally two types of Air quality index were calculated i.e. IND-AQI and USEPA-AQI using concentration of all pollutants at different sites.

Table 5.4: AQI values obtained at different sampling sites

Site Code	Sampling Site	AQI values due to each pollutants				IND-AQI	Pollutant responsible for AQI
		PM 10	PM 2.5	SO ₂	NO ₂		
S1	Talwara Road	294.85	147.05	60.26	29.21	294.85	PM 10
S2	Near RIMT	170.4	150.93	44.31	25.36	170.4	PM 10
S3	Prem Nagar	283.35	164.65	52.97	34.42	283.35	PM 10
S4	Guru ki Nagri	224.87	137.73	46.24	29.38	224.87	PM 10
S5	GT road, Khanna Side	294.9	184.61	57.76	31.38	294.9	PM 10
S6	Focal point	285.97	182.48	64.53	38	285.97	PM 10
S7	Near Village Kumbh, Amloh road	342.59	142.36	54.56	30.61	342.59	PM 10
S8	Motia Khan	183.58	128.45	37.26	20.25	183.58	PM 10
S9	Shastri nagar	174.38	135.18	41.11	22.46	174.38	PM 10
S10	Near Bus Stand	192.27	202.46	40.68	23.13	202.46	PM 2.5
S11		94.32	75.48	15.46	12.56	94.32	PM 10

Calculations were done to calculate IND-AQI as mentioned in previous chapter. Values obtained for AQI for all the industrial and residential sites are mentioned in Table 5.4. Pollutants responsible are also listed.

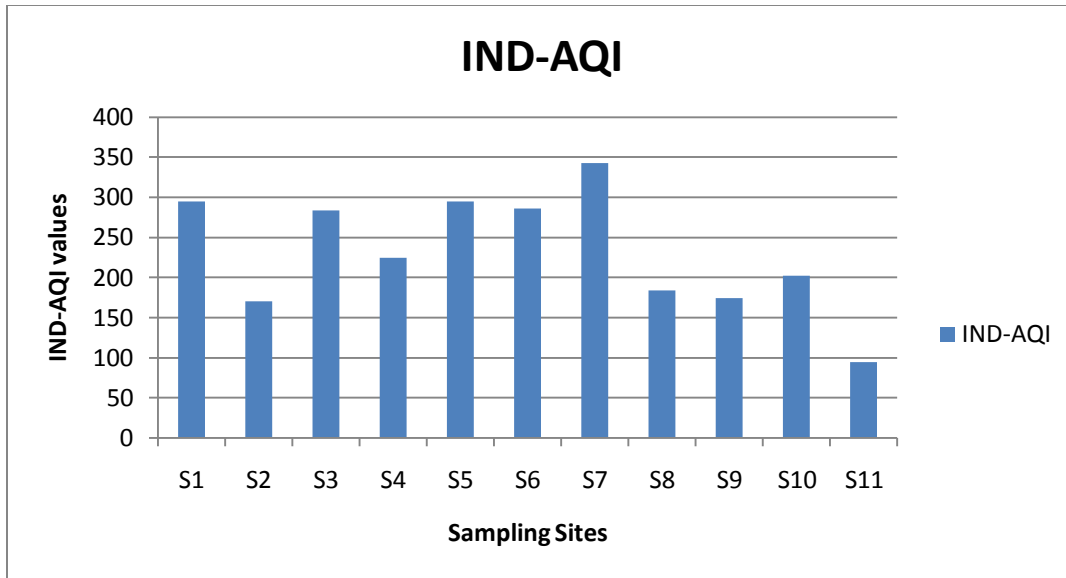


Fig 5.11: IND-AQI values calculated at different sampling sites

Results shows that industrial site near Village Kumbh on Amloh road was with highest Air Quality Index of 342.59 which comes under Very Poor category where everyone may begin to experience health effects and members of sensitive groups may experience more serious health effects (Fig 5.11). 5 sites i.e. site at RIMT Talwara road, Guru ki Nagri, National Highway towards Khanna, Focal Point and Prem Nagar have values of AQI around between 200-300, which comes under category of Poor. Only site near to RIMT comes under Moderate category.

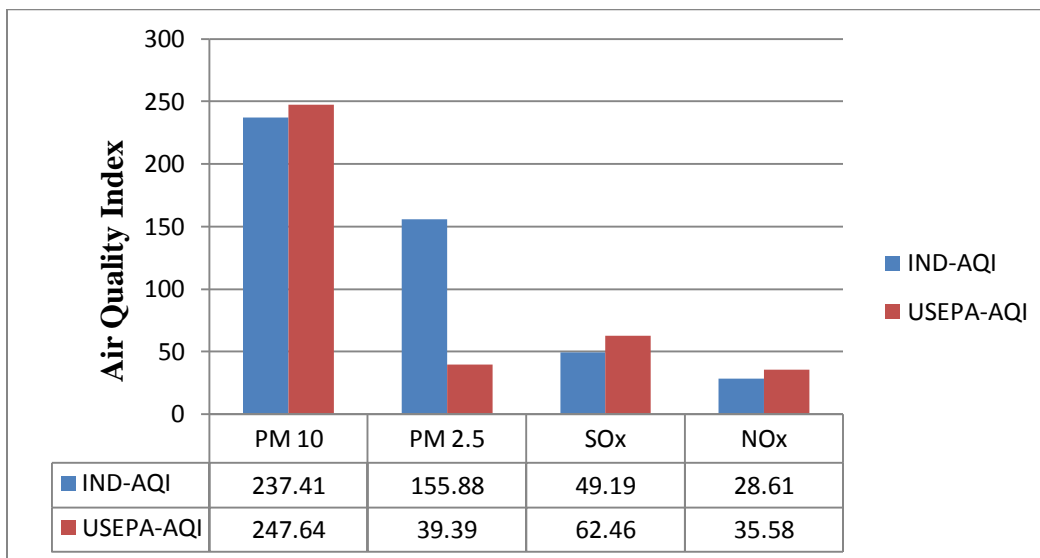


Fig 5.12: Values of AQI obtained using IND-AQI & USEPA-AQI methodology

Values obtained of AQI's for whole study area, after calculations by both methods are listed in Fig 5.12. Values obtained by method of IND-AQI are less than that of USEPA-AQI except for PM 2.5. IND-AQI of Mandi Gobindgarh was observed to be 237.41 and pollutant responsible for this was PM 10. According to USEPA-AQI, pollutant responsible for AQI was PM 10 with AQI value of 247.64.

Table 5.5: SO₂/NO₂ ratio for different sites

Site Code	Sampling Site	SO ₂	NO ₂	SO ₂ /NO ₂
S1	Talwara Road	48.21	23.37	2.06
S2	Near RIMT	35.45	20.29	1.75
S3	Prem Nagar	42.38	27.54	1.54
S4	Guru ki Nagri	37	23.51	1.57
S5	GT road, Khanna Side	46.21	25.47	1.81
S6	Focal point	51.63	30.4	1.70
S7	Near Village Kumbh, Amloh road	43.65	24.49	1.78
S8	Motia Khan	29.81	16.2	1.84
S9	Shastri nagar	32.89	17.97	1.83
S10	Near Bus Stand	32.55	18.51	1.76
S11	Kharorha	12.37	10.05	1.23

SO₂/NO₂ was also calculated to see the effect of vehicular movement on NH-1 which comes to be near to 1.8 at all selected sites. Results show that the impacts of moving source were marginally very less in comparison to the industrial sources to the calculated value of AQI. Site at Talwara road has least impact of moving vehicles on the air quality in comparison to that of due to industries situated there. Whereas, impact of pollution due to mobile vehicle when compared to industrial sources was more at agricultural site selected.

CHAPTER 6

CONCLUSION

Study for Air Quality Index for an industrial estate- 'Mandi Gobindgarh' was done so that air pollution levels can be known which affecting health of local people is. In first step sampling sites were selected on the basis of Wind roses, Impact Area Diagrams, Impact Area, population density, industrial clusters etc. From wind data collected over a period of 18 month (Oct 10 to March12), wind roses were plotted, impact area and impact area diagram were done for wind data of 1 year (Oct10 to Sept 11). It was evaluated from these diagrams that two predominant wind directions was South-East and West, i.e. blowing from South-East to North-West and from west to East respectively. Impact area calculated comes around to 14 m² for maximum month showing that pollutants remains concentrated within small area i.e. dilution potential was very poor. On the basis of above data along with data related to population density and 6 industrial clusters identified by PPCB were used in deciding sampling sites. So total 11 sites were selected out of which, 7 were industrial, 2 residential, 1 commercial and 1 as agricultural site.

Sampling was done twice a week at a particular site for PM 10, PM 2.5, SO₂ and NO₂ for duration of 24 hr. Concentration obtained of PM 10 and PM 2.5 at all sites are above standards levels laid down by CPCB. Some industrial sites at RIMT, Talwara road, GT road, Focal Point, Amloh Road have concentration of PM 10 above 250 ug/m³ whereas all residential area have concentration of 180 ug/m³. SO₂ and NO₂ concentration at all sites are within standard limits.

IND-AQI values are calculated for each site to check different levels of pollution among different sampling sites within study area. Highest AQI value is found to be 342.59 at site near village Kumbh, Amloh road which comes under poor category which may have detrimental effects on human health and members of sensitive groups may experience more serious health effects.

Values of AQI calculated for Mandi Gobindgarh with two different methodologies i.e. IND-AQI and USEPA-AQI were compared. Values of SO₂/NO₂ were also calculated to see the impact of mobile sources on ambient air quality. All values obtained are around 1.8 means concentration of

SO₂ is much higher than that of NO₂ so it can be concluded that effect of vehicular motion is marginally less when compared to pollution due to industries.

CHAPTER 7

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ANNEXURE – I

National Ambient Air Quality Standards, prevailing in 2007

Pollutants	Time weighted average	Concentration in ambient air			Method of measurement
		Industrial areas	Residential, rural & other areas	Sensitive areas	
Sulphur Dioxide (SO ₂)	Annual Average	80 (g/m ³)	60 (g/m ³)	15 (g/m ³)	Improved West and Geake Method
	24 hours	120 (g/m ³)	80 (g/m ³)	30 (g/m ³)	Ultraviolet Fluorescence
Oxides of Nitrogen as NO ₂	Annual Average	80 (g/m ³)	60 (g/m ³)	15 (g/m ³)	Jacob & Hochheiser modified (Na-Arsenite) method Gas Phase
	24 hours	120 (g/m ³)	80 (g/m ³)	30 (g/m ³)	Chemiluminescence
Suspended Particulate Matter (SPM)	Annual Average	360 (g/m ³)	140 (g/m ³)	70 (g/m ³)	High volume sampling (average flow rate not less than 1.1 m ³ /min)
	24hours	500 (g/m ³)	200 (g/m ³)	100 (g/m ³)	
Respirable Particulate Matter(Size less than 10 microns)	Annual Average	120 (g/m ³)	60 (g/m ³)	50 (g/m ³)	Respirable Particulate Matter Sampler
	24 hours	150 (g/m ³)	100 (g/m ³)	75 (g/m ³)	
Lead (Pb)	Annual Average	1.0 (g/m ³)	0.75 (g/m ³)	0.50 □g/m ³	ASS method after sampling using EPM 2000 or equivalent filter paper
	24 hours	1.5 (g/m ³)	1.0 (g/m ³)	0.75 (g/m ³)	
Ammonia	Annual Average	0.1 (mg/m ³)	0.1 (mg/m ³)	0.1(mg/m ³)	
	24 hours	0.4 (mg/m ³)	0.4 (mg/m ³)	0.4 (mg/m ³)	
Carbon Monoxide (CO)	8 hours	5.0 (mg/m ³)	2.0 (mg/m ³)	1.0(g/m ³)	Non Dispersive Infrared (NDR) Spectroscopy
	1 hour	10.0(mg/m ³)	4.0 (mg/m ³)	2.0 (g/m ³)	

* Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.

** 24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.

ANNEXURE – II

Revised National Ambient Air Quality Standards (2009-2010)

S.No.	Pollutant	Time Weighted Average	Concentration in Ambient Air		
			Industrial, Residential, Rural and Other Area	Ecologically Sensitive Area (notified by Central Govt.)	Methods of Measurement
(1)	(2)	(3)	(4)	(5)	(6)
1	Sulphur Dioxide (SO ₂), =g/m ³	Annual 24 hours	50 80	20 80	- Improved West and Gaeke - Ultraviolet fluorescence
2	Nitrogen Dioxide (NO ₂), =g/m ³	Annual 24 hours	40 80	30 80	- Modified Jacob & Hochheiser (Na-Arsenite) - Chemiluminescence
3	Particulate Matter (size less than 10= μ m) or PM ₁₀ =g/m ³	Annual 24 hours	60 100	60 100	- Gravimetric - TOEM - Beta attenuation
4	Particulate Matter (size less than 2.5= μ m) or PM _{2.5} =g/m ³	Annual 24 hours	40 60	40 60	- Gravimetric - TOEM - Beta attenuation
5	Ozone (O ₃) =g/m ³	8 hours 1 hour	100 180	100 180	- UV photometric - Chemiluminescence - Chemical Method
6	Lead (Pb) =g/m ³	Annual 24 hours	0.50 1.0	0.50 1.0	- AAS /ICP method after sampling on EPM 2000 or equivalent filter paper - ED-XRF using Teflon filter
7	Carbon Monoxide (CO) mg/m ³	8 hours 1 hour	02 04	02 04	- Non Dispersive Infra Red (NDIR) spectroscopy
8	Ammonia (NH ₃) =g/m ³	Annual 24 hours	100 400	100 400	- Chemiluminescence - Indophenol blue Method
9	Benzene (C ₆ H ₆) =g/m ³	Annual	05	05	- Gas chromatography based continuous analyzer - Adsorption and Desorption followed by GC analysis

(1)	(2)	(3)	(4)	(5)	(6)
10	Benzo(a)Pyrene (BaP)- particulate phase only, ng/m ³	Annual	01	01	- Solvent extraction followed by HPLC/GC analysis
11	Arsenic (As), ng/m ³	Annual	06	06	- AAS /ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel (Ni), ng/m ³	Annual	20	20	- AAS /ICP method after sampling on EPM 2000 or equivalent filter paper

* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 08 hourly or 01 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Note:- Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigation.

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