Comparative study on time weighted average, chemical characterization & source profiling of PM_{10} aerosols

A Dissertation

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Submitted by
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She was punctual and hard working. We wish her all success in her future endeavors.

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DECLARATION CUM CERTIFICATE

I hereby declare that the project work entitled "**Comparative study on time weighted average, chemical characterization & source profiling of PM_{10} aerosols**" is an authentic record of my own work carried out at "**Eco Laboratories & Consultants Pvt. Ltd., Mohali**" as requirements of one year project internship for the award of degree of M.Tech in **Environmental Sciences & Technology**, Thapar University, Patiala, under the guidance of **Dr. Rai Singh** and **Dr. Anita Rajor**, during Jan 2018 to June 2018.

(Signature of student)

Shivani Gupta

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Date: 04/06/2018

It is certified that the above statement made by the student is correct to the best of our knowledge and belief.

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Shivani Gupta
04/06/2018

Abstract

In most of the countries in the world, ambient air quality has improved considerably from the last few decades. This has been achieved by range of measures that are adopted till yet. However, there is convincing evidence, that current levels of air pollution still pose a considerable risk to the environment and to human health and is considered as one of six harmful pollutants as carcinogenic by USEPA. Basically particulate matter is a widespread air pollutant, consisting of a mixture of solid and liquid particles suspended in the air. Its size and composition is an important factor in determining its sources & effects. Larger particles (dia >2.5µm) which contain iron, silica, potassium, sodium, magnesium and chloride are likely from windblown soil, unpaved roads etc and smaller particles (dia<2.5µm) that contain elemental and organic carbon are likely from combustion sources.

The present research work is based on time weighted average, chemical characterization and source profiling of PM_{10} aerosols in the Industrial area of Mohali and Residential area of Chandigarh during period February 2018 to April 2018. The samples were collected on Whatmann's filter paper using respirable dust sampler in three shifts of 8 hour each. The results shows that sampling of 8 hour for three shifts and taking 16 hour data of any two shifts may be comparable with 24 hour monitoring, leads to resource and time minimization. But this study is conducted on only two locations and may not be applicable to other ones. The mean concentration of PM_{10} is 143µg/m^3 at residential area with maximum average concentration is 187µg/m^3 and minimum average concentration is 102µg/m^3 and 163µg/m^3 at industrial area, with maximum average concentration is 193µg/m^3 and minimum average concentration is 139µg/$m^{3,}$ which is found to be very high as per NAAQS. The chemical characterization of particulate matter includes trace metals (As, Pb, Ni, Cd, Cr, Mn, Zn, Br, Cu etc), Crustal species (Al, Mg, Ca, Fe, Si, Sc) and inorganic ions such as NH_4^+, SO_4^{2-}, NO_3^-, K^+, F^-, Cl^-. The source apportionment study has been carried out using principal component analysis (PCA). The major sources identified crust material (31%), coal/ biomass burning (21%), industrial dust (18%), vehicular emissions (15%) and secondary emissions (7%).

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Abbreviations

NAAQS	National Ambient Air Quality Standards
CPCB	Central Pollution Control Board
NAMP	National Air Monitoring Programme
IARC	International Agency for Research on Cancer
FAAS	Flame Atomic Absorption Spectrophotometer
SPSS	Statistical Package for Social Sciences
PAHs	Polycyclic aromatic hydrocarbons
WHO	World health organization
EPA	Environmental Protection Agency
AQI	Air Quality Index
PCA	Principal Component Analysis
MMR	Mismatch repair mechanism
SEZ	Special Economic Zone
DDW	De ionized distilled water
SOP	Standard operating procedure
HVS	High Volume Sampler
PM	Particulate matter
EF	Enrichment Factor
QC	Quality Control
QA	Quality Assurance
IC	Ion Chromatography
µm	Micron meter
$\mu g/m^3$	Micron gram per meter cube

ng/m^3	Nano gram per meter cube
Na	Sodium
Al	Aluminum
As	Arsenic
Br	Bromine
Ca	Calcium
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
Fe	Iron
Mn	Manganese
Ni	Nickel
Pb	Lead
Rb	Rubidium
S	Sulfur
Sc	Scandium
Si	Silicon
V	Vanadium
Zn	Zinc
Cl^-	Chlorine
F^-	Fluorine
K^+	Potassium
NO	Nitric oxide
NH_3	Ammonia gas

SO_2	Sulfur dioxide
NO_2	Nitrogen Dioxide
NO_X	Oxides of nitrogen
HCL	Hydrochloric acid
NO_3^-	Nitrate
NH_4^+	Ammonium
SO_4^{2-}	Sulfate
HNO_3	Nitric acid
NaCl	Sodium Chloride
$NaNO_3$	Sodium nitrate
H_2SO_4	di hydrogen sulfate
$(NH_4)_2SO_4$	Ammonium Sulfate
NH_4HSO_4	Ammonium bisulfate
NH_4NO_3	Ammonium Nitrate

1 INTRODUCTION

Atmospheric aerosols play an important role in atmospheric pollution and climate change. [Yadav et al., 2014]. The presence of excess amount of aerosols in the atmosphere making it less fit or unfit for life. These aerosols exceeds in number due to rapid industrialization, globalization, growing automobile sector etc leads to degrade the ambient air quality. Further ambient air quality has been getting worse to a considerable extent through over exploitation of natural resources. Though various measures have been adopted but significant progress has not been achieved. The Environmental Kuznets Curve (EKC) hypothesis suggests that there is more resources utilization and more emissions during the initial phase of economic growth but when a country shifts from developing to developed stage, resources utilization becomes stable along with greater protection of environment due to technological advancements and other factors. At present India is in its developing phase and it must move to second stage.[1] But till then, we have to concern about the environmental degradation consequences.

As per the recent report published by World Health Organization (WHO), which summarized 2016 data for 4300 cities, India have 14 cities among the 20 most polluted cities globally. Out of which Delhi comes at sixth place, Kanpur, Faridabad, Varanasi, Gaya and Patna are ranked ahead of it in particulate emissions.[2]

Particulate matter has been related to wide range of health effects. [Dutton et al., 2010, Yang et al., 2012]. Even particulate matter are classified as one of the six harmful pollutant by the United States Environmental Protection Agency (US EPA) [Vaio et al., 2018]

It has been observed that particulate matter are responsible for various human health problems as well as atmospheric processes such as visibility, cloud formation, precipitation, solar radiation and climate change, acidification of rain, clouds and fog [Celis et al., 2014]. Besides these effects, it can also affect our ecosystems, vegetation, and works of art & building materials [Singh et al., 2012].The long-term studies indicate that the adverse health effects are mainly due to particulate matter, especially with aerodynamic diameter less than 10μm as they can be inhaled into respiratory tract and leading to health problem [Yang et al., 2012]. In fact these particles have higher burden of toxics which will be absorbed by human body and can cause various respiratory issues. [Satsangi et al 2011] Due to adverse effects of

[1] http://www.thehindu.com/opinion/op-ed/the-cost-of-pollution/article23732017.ece

[2] http://www.thehindu.com/opinion/editorial/call-to-action/article23752456.ece

particulate matter, they has been identified as the criteria pollutant to indicate air quality. Considering this, it is important to understand the abundance, distribution and potential sources of PM_{10} and its various components so that effects caused by PM can be controlled. [Dubey et al 2014]

The main objective of ambient air quality monitoring is to gauge the deterioration and improvement in the ambient air quality by considering meteorological and other conditional parameters. CPCB has given guidelines for monitoring and analysis of particulate matter in ambient air. Under the provision of Air (Prevention & Control of pollution) Act, 1981 fourth version of National Ambient Air Quality Standards (NAAQS) 2009 are given. In which the permissible limit for PM_{10} is 100µg/m^3 for 24 hour sampling and 60µg/m^3 for 8 hour sampling.

Our study is conducted in Tricity (Chandigarh & Mohali), where we observed and concluded that sampling of 8 hour for three shifts and taking 16 hour data of any two shifts may be comparable with 24 hour monitoring data. However, the present study is an attempt to establish at a location, where there is not much change in the activities during day and night and may not be applicable for other stations. Moreover, source profiling of particulate matter is also performed and the major sources that contribute in particulate matter are Crustal / Natural metals, Vehicular emissions, Industrial emissions and biomass burning.

1.1 Reasons for selection of sampling location

Chandigarh is a city and union territory of India that serves as the capital city of two states Haryana and Punjab. The metropolitan area of Chandigarh-Mohali-Panchkula collectively forms a tri city with a combined population of around 2 million. In 2014, a survey was conducted by Ministry of Urban Development (GOI) and Chandigarh ranked first place among top 10 clean cities of India. But in 2016, the concentration of fine particulate matter in ambient air in Chandigarh was found to be more than Delhi. As per the data generated by Centre pollution Control Board (CPCB), $PM_{2.5}$ level in Chandigarh was 123µg/m^3 while in Delhi it was 118µg/m^3.[3.3] The CPCB standard for $PM_{2.5}$ is 60µg/m^3.

[3] https://www.hindustantimes.com/environment/pm2-5-pollution-level-in-chandigarh-was-higher-than-delhi-in-2016-cpcb/story-Aa6v7dA18OCvccBWTe33SI.html

1.2 Particulate Matter

Particulate matter is a complex mixture of organic and inorganic substances suspended in air as solids and liquids such as dust, pollen, soot, smoke and liquid droplets. These aerosols have variation in size, shape and chemical composition depending on the source, meteorological conditions and geographical location of the area. The emission of particulate occurs due to anthropogenic sources and it consists of very toxic compounds such as PAHs and trace metals in the atmosphere. It is a ubiquitous component of atmosphere that imposes significant health risk to human body. [Satsangi et al., 2011]. The international Agency for Research on Cancer (IARC) has classified particulate matter as carcinogenic. [Vaio et al., 2018] The harmful effect of particulate matter depends on the size of particulate.

Particle size is the key parameter which governs transport and removal of particles in the atmosphere as well as deposition of particles in the respiratory system. The size of particles has different shapes and densities and is measured in terms of aerodynamic diameter. The aerodynamic diameter (da) defined as a spherical particle which has unit density ($1.0 gm/cm^3$). However the term "diameter" does not applicable for non-spherical particles such as a flake of material or a fiber.

USEPA has classified four categories of the particulate matter having different sizes as- (I) Ultra-fine particles (<0.1μm), (II) fine particles (0.1-2.5μm), (III) coarse particles (2.5 to 10μm) and (IV) super coarse particles (10 to 100μm). Various studies on transportation and transformation of particulate matter strongly indicate that it generally found in two distinct modes: the fine (<2.5 μm) mode and the coarse (2.5 - 10.0 μm) mode. According to EPA, particle that can be inhaled into respiratory system causes adverse health effects (Yang et al., 2012, EPA method IO-3.2).

The fine particles (<2.5 μm) differ from coarse particles (2.5 to 10.0 μm) in origin and chemistry. Fine fraction is mainly composed of varying amount of Sulfate, nitrate, ammonium, organic and elemental carbon compounds, water, small amount of soil dust and trace species (Zn, Mn, Fe, V, Ni, Cu, Pb, Cd etc). These aerosols are generally of primary anthropogenic or secondary in origin and tend to be acidic in nature. Their lifetime is ranges from days to weeks. They travel distance ranges from 100s km to >1000s km and they are associated with decreased visibility.

The coarse fraction (>2.5μm) primarily consisting of crust material (oxides of iron, calcium, silicon and aluminum) is generally formed by natural and mechanical processes. [Alam et al., 2014]. Major sources include crushing and grinding, windblown dust, paved and

unpaved roads, agriculture, industry, combustion of fossil fuels, construction and demolition. This size range is typically basic in nature, lifetime being from minutes to hours and the travel distance varies from <1km to 10kms. There are some chemical species that are exists in both fine and coarse fraction like nitrates and chlorides.

1.3 Chemical Characterization of Particulate Matter

The behavior and fate of particulate matter in the atmosphere and within the respiratory system depend upon its physical and chemical properties. Physical characterization of particulate matter includes determination of size, shape, and optical properties, elemental, molecular and isotopic structures while chemical characterization of PM_{10} can help in better understanding its behavior and influence on environment and human body.

Therefore, chemical characterization can be divided into elemental, ionic and carbon analysis. The elemental composition of particulate matter is mainly contributed by crust sources consisting of the elements such as iron, potassium, sodium, aluminum, silicon, calcium, magnesium, manganese and strontium and combustion sources like arsenic, cadmium, chromium, lead, and nickel etc.

Simple ions such as sodium, potassium, calcium and magnesium are best determined by atomic absorption spectrophotometer, whereas polyatomic ions i.e. nitrate, sulfate, phosphate and ammonium along with chloride are best determined by ion chromatography.

1.4 Chemical Composition of Particulate Matter

Atmospheric particles have very diverse chemical composition that varies with particle size both in time and space. Chemical composition of particulate matter has been broadly classified into ions, trace metals and earth crust materials.

1.4.1 Ions

In chemical characterization of particulate matter, generally SO_4^-, $NO_3^-$and NH_4^+ are the dominating species. Out of these, SO_4^- and NO_3^- are originated as a secondary component from the photochemical oxidation of SO_2 and NO_2 present in the atmosphere. The emission sources of SO_2 are mainly combustion of coal and sulfur containing fuels. SO_2 changes to particulate sulfate through gas phase and aqueous-phase transformation pathways. The majority of secondary sulfates are found as a combination of di hydrogen sulfate (H_2SO_4), ammonium sulfate [$(NH_4)_2SO_4$] and ammonium bisulphate (NH_4HSO_4). While nitrate

originated by oxidation of nitrogen dioxide (NO_2) and/or normally present as ammonium nitrate (NH_4NO_3) resulting from neutralization of nitric acid (HNO_3) vapor by ammonia (NH_3), or as sodium nitrate ($NaNO_3$) resulting from chemical reaction of HNO_3 vapor by sodium chloride (NaCl). Nitric oxide (NO) directly emitting into atmosphere is converted to nitrogen dioxide (NO_2), primarily via reaction with ozone. Particulate ammonium (NH_4^+) originates from ammonia gas (NH_3) by gas to particle conversion. It rapidly reacts with acidic species sulfate and nitrate and forms salts of ammonium sulfate [$(NH_4)_2SO_4$] or ammonium nitrate NH_4NO_3 in the atmosphere.

1.4.2 Trace Metals:

Trace metals such as lead (Pb), cadmium (Cd), nickel (Ni), chromium (Cr), zinc (Zn) and manganese (Mn) are used in metallurgical processes, while some occur as impurities or additives in fuels and industrial products causing emissions to the atmosphere.

1.4.3 Mineral (Crust) Material:

Crust material (rock and soil) rich in elements like aluminum, silicon, iron and calcium, magnesium is generally present in coarse dust that arises from born soil, fugitive emission and anthropogenic sources such as quarrying, construction and demolition activities [Alam et al., 2014, Wang et al., 2008].

1.5 Source Apportionment of Particulate Matter

It is very essential to elaborate the emission sources of particulate matter in view of air quality and human health perspectives. Source apportionment is based on the fact that different emission sources of particular location have their characteristic chemical signature or source profile at that site.

Source apportionment of particulate aerosols from urban atmosphere is a complicated issue due to various reasons as (i) numerous source categories anthropogenic, natural and biogenic contributing to primary and secondary components, (ii) inadequate characterization of all emission sources; and (iii) variability in emission pattern and sources due to different shapes, sizes, densities and lifetimes of pollutants, atmospheric chemistry, varying geographical and climatological conditions of the area.

1.6 Health Effects of Particulate Matter

Airborne particulate matter is serious concern to the world as it is linked with wide ranging of health effects. Size, chemical nature and quantity of particulate matter in the atmosphere play a vital role on human health. Small particles which have diameter less than 10 micrometers can cause the more serious problems to human health. They can go deep into human lungs and into bloodstream. The various problems caused by them includes: short term effects (acute) and long term effects (chronic). Short term effects consist: coughing, shortness of breath, tightness of chest, irritation of eyes and long term effects consists: premature death, nonfatal heart attack, irregular heartbeat, aggravated asthma, decreased lung function.[4]

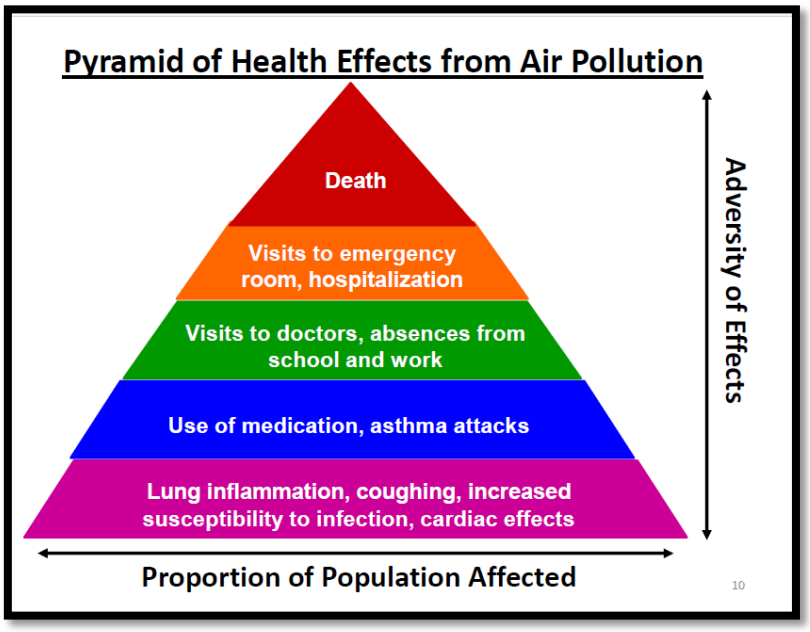


Figure 1.1: Pyramid of health effects from air pollution

Toxic metals in association with particulate aerosols have a significant role in human health. The transition metals such as Cr, Fe, Cu, Ni, Zn, Cd, V and As derived from fossil fuel combustion, vehicular and industrial sources act as catalysts and activate biological processes.

[4] https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm

1.7 Present Study

The present study describes the time weighted average of PM_{10} in which 24 hour sampling is compared with 8 hour sampling for three shifts, taking any two shifts at a time. It also consists of characterization of particulate matter that includes crustal elements (Na, Mg, Al, Si, Ca, Sc, Fe), trace metals (As, Pb, Ni, Zn, Cd, Cr, Mn, Br, Cu) & ions (NH_4^+, NO_3^-, SO_4^+, K^+, Cl^-, F^-) and source profiling of particulate matter by taking two locations : Industrial area(Sector 74, Mohali) and Residential area (Sector 34, Chandigarh).

1.8 Objectives of the Study

The specific objectives of the study are as follows:

- Reduction in sampling span by comparison of time weighted average of different sampling slots.
- Characterization of Chemical Species bound/ in relation to $PM_{10.}$
- Source Profiling of PM_{10} based on their chemical markers/indicators.
- Resource minimization & Cost effective sampling by reducing sampling duration

2 REVIEW OF LITERATURE

2.1 Introduction

Nowadays, ambient air pollution is becoming a challenge for the developing countries which try to achieve rapid economic development without concerning about environment. With the rapid increase in urbanization, industrialization, vehicular emission, ozone depletion, deforestation, waste burning pollution has increased beyond the carrying capacity of environment. [Alam et al., 2015] Due to which it adversely affects our economy as well as health. Therefore environment protection becomes an important issue throughout the world. [Araujo et al., 2014]

Particulate matter or particulate pollution is a mixture of liquid droplets and solid particles present in the natural atmosphere with wide range of size & composition. [Araujo et al., 2014 satsangi et al., 2011]. It plays a significant role in changing the climate globally as well as regionally. [Alam et al., 2015]. Particulate matter are ubiquitous components of the atmosphere, that impose adverse effect on human health, non living structure etc. [Dubey et a., 2014]. United States Environmental protection Agency (U.S. EPA) has classified the particulate matter as one of the six harmful pollutants to public health and the environment. [Vaio et al., 2018].

According to the survey in 2014 by World Health Organization (WHO), Out of top 100 cities that have worst PM_{10} pollution, India stood at 37^{th} rank and Indian cities Delhi, Raipur, Gwalior, and Lucknow are listed in the top 10. A similar study by WHO was performed in 2011, in which 27 Indian cities come under the top 100. More than 100 cities under the national ambient monitoring program exceed the WHO guideline for PM_{10}[Guttikanda et al., 2014].

Source: Salvador et al 2012

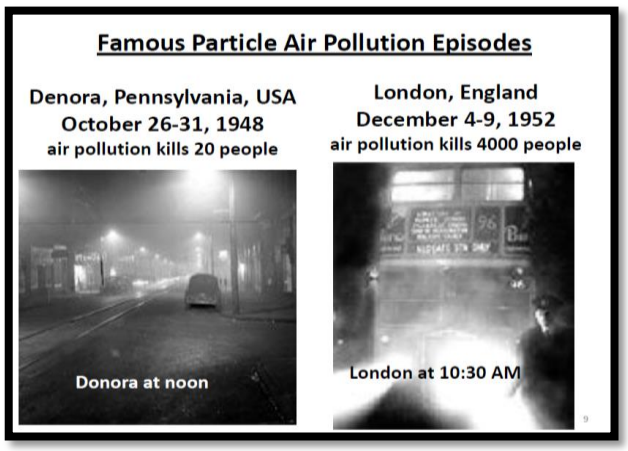
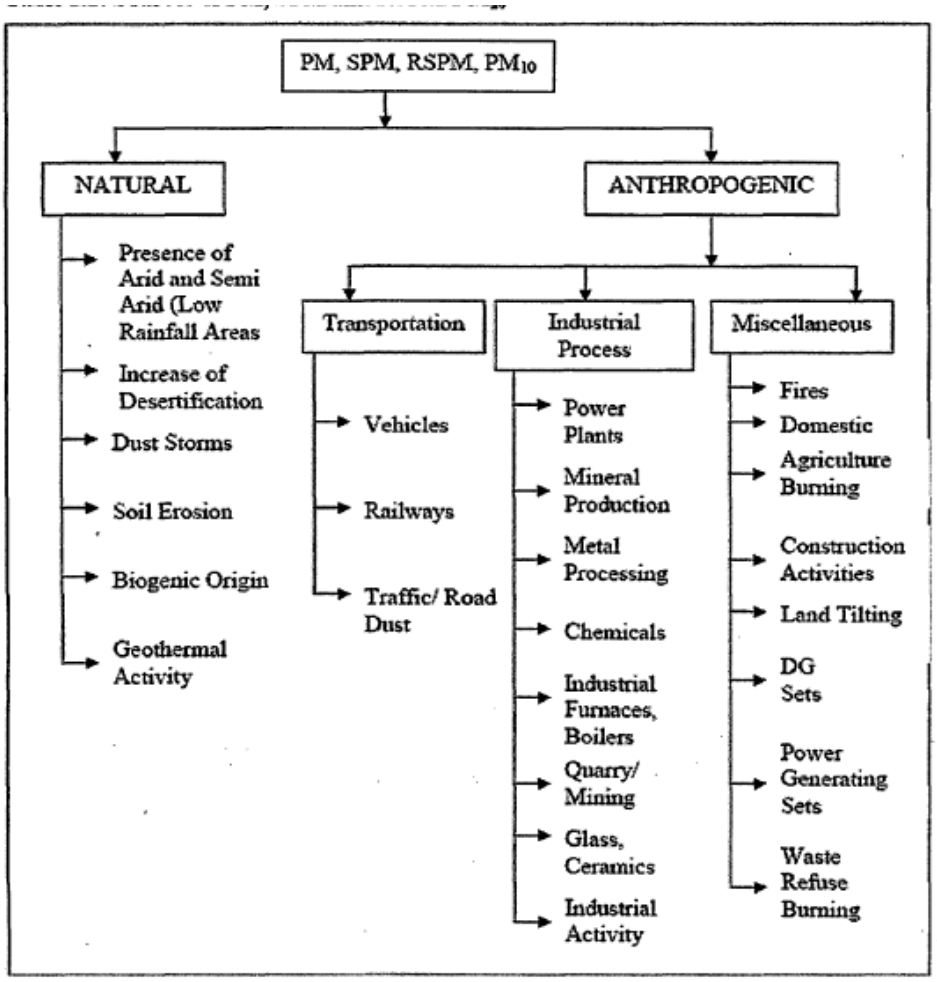


Figure 2.1: Air pollution incidence in history

2.2 Origin of Particulate Matter

Particulate matter is originated from variety of sources. The main sources include the anthropogenic and natural sources based on the particle size distribution. [Alam et al.,2015] The natural sources includes volcanic eruption, forest fire, soil, dust etc while anthropogenic sources consists of industrial emission, vehicular emissions, coal combustion, cooking, construction activities etc. [Arjauo et al.,2014]. These emissions are considered as primary emission sources while chemical reactions in the atmosphere come under secondary sources. [EPA 2012]. Table 2.1 shows the different sources of particulate matter [Peavy et al., 1985]

Table 2.1: Sources of PM, SPM, RSPM, PM_{10}



2.3 Size range of Particulate Matter

Aerosol particles have different shape, size, chemical composition and optical properties. They are generally found in fine and coarse size particles. The size range for fine particulates is lesser than 2.5µm in diameter while coarse particulate matter lies between 2.5 to 10 µm.

Fine particles are primarily originated from combustion process in the atmosphere. On the other hand coarse particles are originated from mechanical processes that include tire wear, windblown soil, dust brake lining abrasion etc. [Pakbin et al.,2017]. Table 2.2 shows the description of particle size with example: [Source: Peavy et al., 1985]

Table 2.2: Description of particle size with example

Description	Examples
Very Small (0.01 to 5µm)	Paint pigments, tobacco, smoke, sea salt particles
Larger (5 to 100 µm)	Cement dust, soil dust, pulverized coal
Liquid (Mist) (5 to 10,000 µm)	Fog, smog, mist, raindrop
Biological origin (0.001 to 01 µm)	Viruses, bacteria, pollen, spores
Chemical formation (0.001 to 100 µm)	SO_2 to H_2SO_4, Haze

Particulate matter (PM_{10} & $PM_{2.5}$) consists of inhalable particles, when breathed in can lodge in our lungs and cause lung damage and respiratory problems. The effect of exposure to particulate matter is both the short term (hours, days) and long term (months, years). [EPA 'health effects of PM' 2013]. Chemical compounds of particulate matter such as heavy metals, ions, organic and others are also comes under fine size distribution. Figure 2.2 shows the size and distribution of particulate matter.

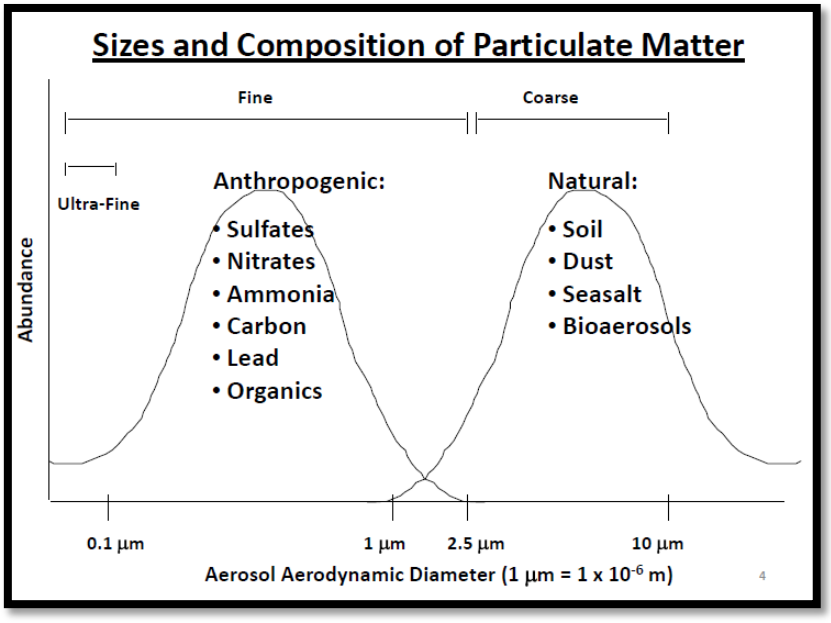


Figure 2.2: Size and Composition of Particulate Matter

2.4 Ambient Air Quality Standards for Particulate Matter

In India, Centre Pollution Control Board (CPCB) has notified the fourth version of National Ambient Air Quality Standards (NAAQS) in 2009 for monitoring and analysis of ambient air. This national standard aims to provide uniform air quality for all, irrespective of land use pattern, across the country [CPCB 2012]. In USA, EPA has also set standards under clean air act for six pollutants that are considered harmful to public health and the environment (the other pollutants except particulate matter are sulfur dioxide, nitrogen oxides, ozone, carbon monoxide, and lead) and known as criteria pollutants.[5] Table 2.3 shows the NAAQS for CPCB & US EPA. Table 2.4 shows the Air quality index for particulate matter by CPCB.

Table 2.3 Ambient Air Quality Standards By CPCB & EPA[6]

Standards by CPCB				**Standards by US EPA**	
		Concentration in ambient air			
Pollutants	**Time weighted average**	**Industrial, Residential, Rural and other areas**	**Ecologically sensitive areas(Notified by Central Government)**	**Average time**	**Level**
PM10	24 hour	100 µg/m^3	100 µg/m^3	24 hour	150 µg/m^3
	Annual	60 µg/m^3	60 µg/m^3	Annual	Not specified
PM2.5	24 hour	60 µg/m^3	60 µg/m^3	24 hour	35 µg/m^3
	Annual	40 µg/m^3	40 µg/m^3	Annual	12.0µg/m^3 (Primary) 15.0µg/m^3(Secondary)

[5] https://www.epa.gov/naaqs/particulate-matter-pm-air-quality-standards

[6] https://www3.epa.gov/ttn/naaqs/standards/pm/data/201612-final-integrated-review-plan.pdf

2.5 Air Quality Index (AQI)

In India, the National Air Quality Index (AQI) was launched in New Delhi on 17 September 2014 under the Swachh Bharat Abhiyan. The Central Pollution Control Board along with State Pollution Control Boards has been operating National Air Monitoring Program (NAMP) covering 240 cities of the country having more than 342 monitoring stations. There are six AQI categories, namely Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe. Table 2.4 shows the index given by CPCB in India and Table 2.5 shows the index proposed by US EPA.[7]

Table 2.4: Air quality Index proposed by CPCB

S.No.	AQI Category(Range)	PM_{10} (24hr)
1	Good (0–50)	0–50
2	Satisfactory(51–100)	51–100
3	Moderately polluted (101–200)	101–250
4	Poor (201–300)	251–350
5	Very poor (301–400)	351–430
6	Severe (401–500)	430+

[7] https://en.wikipedia.org/wiki/Air_quality_index#cite_note-sepa.gov.cn-17

Table 2.5: Air Quality Index (AQI) by US EPA

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

2.6 Time weighted average for monitoring of Particulate Matter

Central Pollution Control Board (CPCB) & United States Environmental Protection Agency (US EPA) has notified in the National Ambient Air Quality Standards (NAAQS) that sampling duration for particulate matter (PM_{10}) should be either 8 hour or 24 hour [CPCB Manual 2012] Conventionally, it is done in three shifts of 8 hour interval each for 24 hour. However there is large possibility of losing the data due to technical reasons. Moreover in 24 hour sampling, there is more resource utilization like usage of High volume sampler/ Respirable dust sampler, electricity, man power etc which ultimately leads to the economically inefficient sampling. The present study had the opportunity to examine the observed values and come to conclusion that even 16 hour data of any two shifts may be comparable with 24hour monitoring data without affecting the trend. The aim of the study is to reduce the sampling span by comparison of time weighted average of different slots, along with resource minimization and make the sampling cost effective. Although this study is performed only at two locations and it may not be applicable to other locations, thus it is recommended to obtain more authentic data with wider scope of research.

2.7 Chemical Characterization of Particulate Matter

Particulate matter (PM) is composed of inert carbonaceous cores with multiple layers of various adsorbed molecules, including metals, organic pollutants, acid salts, ions and biological elements [Araujo et al., 2014]. Many researchers prove that toxic compounds such as PAHs, heavy metals, ions in the particulate matter are carcinogenic in nature [Vaio et al., 2018].

2.7.1 Heavy Metals

The heavy metals analyzed in the present study are Pb, As, Ni, Cu, Cr, Mn, Zn, V, Cd, Br.

- Lead (Pb) is present in the earth crust. It is used in glass panels and gaskets in computer monitors. It is responsible for causing pathological effects in the nervous and vascular system. It is also responsible for the synthesis of heme and porphyrin. Arsenic (As) is responsible for causing disorders in cardio vascular, hematopoietic, respiratory, immune, nervous, reproductive and development system [Vaio et al., 2018]. Nickel (Ni) produces dermatitis and disorders in the respiratory system.
- Zinc is component of earth's crust. It maintains copper in the human body, and is necessary for male reproductive activity. Its deficiency causes anemia and retardation of growth and development. [Duruibe et al., 2007].
- Cadmium (Cd) is a byproduct of zinc refining and involves respiratory inflammation. It accumulates in the human body, generally in kidneys. [Vaio et al., 2018].
- Calcium (Ca) is important for human bones and teeth in mammals. It is vital for human metabolism. Magnesium is an important electrolytic constituent of the blood, present in the blood plasma and body fluids, interstitial and cell fluids [Duruibe et al., 2007].
- Antimony is found naturally in environment and is responsible for causing inflammation of lungs, chronic bronchitis and other respiratory effects, [Geiger et al., 2010]. Chromium VI can cause damage to DNA and is extremely toxic in the environment. It can have both natural & anthropogenic origin. [Rodriguez et al., 2017].

2.7.2 Ionic compounds

Ammonium, Nitrate and Sulfate are the secondary compounds that are formed by the atmospheric reactions of SO_2, NO_X and NH_3. Particulate ammonium (NH_4^+) originates from ammonia gas (NH_3) by gas to particle conversion. Ammonia comes from use of nitrogen fertilizers, oceans and biomass burning [Tiwari et al., 2008]. Ammonium rapidly reacts with acidic species sulfate and nitrate and forms salts of ammonium sulfate [$(NH_4)_2SO_4$] or ammonium nitrate NH_4NO_3 in the atmosphere. Nitrate can be distributed in fine particulate mode when it is formed through the reaction of nitrogen oxide, precursors of particulate nitrate and ammonia gas. Ammonium sulfate, ammonium bisulphate and ammonium nitrate are the most likely sulfate and nitrate compounds found in the atmosphere [Singh et al., 2012]

2.8 Source Apportionment

In the present study, source apportionment is performed by using PCA (principal Component Analysis). It is a technique of factor analysis by reducing dimensions of larger set of data into its components. This method transforms the multivariate data sets into smaller set of independent components. [kalaiarasan et al., 2017].

In year 2009, a research was conducted in Agra in which seasonal variation in mass concentration of particulate matter and its ionic composition presented. The study concluded that concentration of particulate matter and its ions were influenced by the meteorological parameters. Also it concluded that Ca, K^+, Mg^{2+}, SO_4^{2-} were the sources of anthropogenic or natural emission that includes soil, sea salt etc. K+ was identified as a source of biomass burning. [Singh et al., 2009].

Similar study was conducted in 2012 at Agra, where source apportionment was performed using PCA. The study concluded that Na, Mg, Al, Ca, Si, Sc and Fe were originated as crust material. Zn, Mn, S and V were identified as sources of vehicular emissions. Cr, Ni, Cu and Cd contributed from industrial emissions. K^+, Cl^-, F^-, As and Pb were makers of biomass burning. SO_4^{2-}, NH_4^+, NO_3^- were represented the secondary pollutants that generated from chemical transformation occur in the atmosphere [Singh et al., 2012]

In 2011, research on measurement of particulate aerosols was conducted in Agra. The results of the study shown that residential area is under the influence of long range transport of particulate matter along with crustal and biomass burning in the area. While in industrial area soil, traffic and secondary pollutants were identified as major contributors [Satsangi et al., 2011].

In year 2013, study was conducted in Delhi for the purpose of source apportionment of PM_{10}. The major analyzed elements were Na, Mg, Al, Ca, Mg, Si, P, S, K, Ca, V, Cr, Mn, Fe, Cu, Zn, Pb, As, Ni, Br, Sr, Ba, Cd, Sn and Sb and ions Cl^-, NO_3^-, SO_4^{2-}, Na^+, NH_4^+, K^+. The sources of Particulate matter found were crust materials, vehicular emissions and secondary aerosols. In source apportionment Pb, Cu, Zn, Ni and V were identified as the sources of vehicular emissions; Si, Fe, Al, Ca and Mg were identified as the markers of crust material. NH_4^+, NO_3^- represented the secondary pollutants that were formed due to chemical transformations in the atmosphere [Tiwari et al., 2013].

In 2014, Chemical Characterization and source apportionment study on PM_{10} was conducted in Lahore. In the study carbonaceous species, crustal and trace elements were analyzed in the collected sample of particulate matter. Sources were identified using PMF model in which Cu, Cr, Cd, Fe, Mn, & Ni were identified as sources of industrial dust. Fe and Cd might be emitted from abrasion, incineration, combustion of fuel and lubricants; As, Pb, Cd, S & Fe were identified as the sources of vehicular emissions. The use of biomass as fuel had increased the concentration of S, & Pb; Zn, Al, Ca, Mg attributed to biomass fuel that include firewood, coal, wood burning, combustion of agriculture residue, emission from brick furnaces. Also Pb, Ca, Al & Ba were identified as sources of soil and road side dust. [Alam et al., 2014]

In 2015, study on characterization of PM_{10} sources in the central Mediterranean sea concluded the five factors using PMF. In which Na^+, Cl^-, Mg, K^+, and Br were identified as sources of sea salt, Al, Si, Mn, Fe, Ca, K, Mg were identified as crustal elements. While NH_4^+, SO_4^-, NO_3^- were attributed to secondary elements, indicated the presence of $(NH_4)HSO_4$ and $(NH_4)_2SO_4$ compounds. [Calzolai et al., 2015].

In the same year, research was conducted in Peshawar, Pakistan, where sources of particulate emissions were identified as re suspension of road/soil, vehicular emissions, small industries emissions, kiln emissions & household combustion. Al, Mg, Ca, Cr, Fe, Ni Mg, Pb, Sr, Ti, Zn, were identified a sources of small industrial emissions. Ca, Fe, S, Sr, Pb, Ti, Zn, Ni were emitted due to household combustion that include biomass burning for cooking and heating purposes. Vehicular emission was characterized by Mn, Pb, Sr, and Zn; Al, Mg, Ca, Cr, Fe, Pb, Ni, S, Zn were identified as markers of kiln emissions. Re-suspended road/soil dust includes very high concentrations of Al, Mg, Ca, Fe, Mn, Sr, and Zn [Alam et al., 2015].

A research was conducted over mid Brahmaputra valley in 2016 , in which various metallic analysis was performed that includes Mg, Ca, K, Cr, Fe, Mn, Co, Ni, Cu, Cd, and Pb. The sources of PM_{10} indicated by the study were biomass burning, crustal dust, soil & fossil fuel

using Enrichment Factor (EFs). EF > 10 indicated the anthropogenic activities while its less than 7 indicated crustal elements. Ca, Mg, Mn, and Co indicated to have a source of crustal origin. EF value close to one for K, Ca, Mn, and Fe, and the EF was quite high in case of Pb [Deka et al., 2016].

In the year 2018, heavy metal analysis was performed in PM_{10} at Italy. The mass concentration of various metals like Al, Pb, As, Ni, Cd, Cu, Cr, Co, Fe, Mn, V, and Zn was determined at industrial and residential area. The source apportionment study was performed using PCA in which four sources are identified. First factor includes the Cr, Ni & V with variance of 21%, indicates the oil combustion. Similarly Cd, CO, Zn comes under industrial emission with variance of 12.54 %. Al, Fe and Pb were identified as crustal origin and As was identified as source of vehicular emission [Vaio et al., 2018]

3 MATHEDOLOGY

This chapter has been broadly divided into following sections: Description of sampling site (Industrial & Residential), Sampling of Respirable Suspended Particulate Matter (PM_{10}), Gravimetric Analysis of PM_{10}, Chemical Analysis of PM_{10} (Elemental Analysis and Ionic Analysis), Quality Assurance (QA) & Quality Control (QC) and Source Apportionment of PM_{10}.

3.1 Description of sampling site

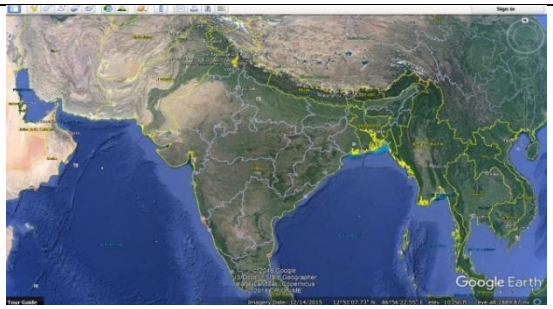
3.1.1 Sampling Site 1: Residential area (Sector 34), Chandigarh

Chandigarh is a city and union territory of India that serves as the capital city of two states Haryana and Punjab. It is located near the foothills of shivalik range of Himalayas in the northeast India. The Co-ordinates of the city are 30.74º N 76.79º E with an average elevation of 321 m. The total area of the city is 114km^2. According to census 2011, Chandigarh had population of 1,055,450. This area has a humid subtropical climate with season rhythm: very hot, summers, mild winters with great variation in temperature. The area receives winter rains from western disturbances originating from Mediterranean Sea. The surrounding cities of Chandigarh are: Mohali, Zirakhpur & Roopnagar in Punjab while Panchkula & Ambala in Haryana.

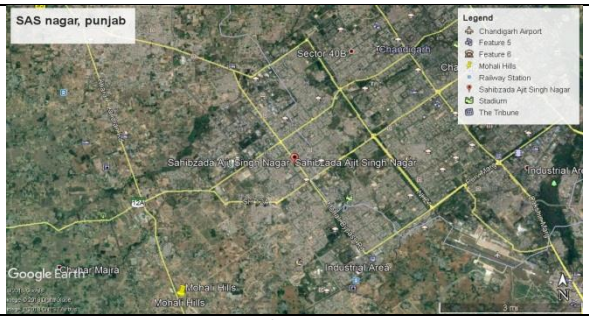
There are around 15 large or medium scale units while 2100 are small scale industries. The major industries are transport equipment, food products, electrical goods metal products, machine tools, and pharmaceutical, leather & plastic goods.

According to Registering and Licensing Authority (RLA), Chandigarh had set a new record of 11.7 lakh vehicle registration in 2014. RLA informed that on an average 200 new vehicles are registered daily with annual average of 45000 vehicles that contributes the maximum vehicular pollution in the region. [8]

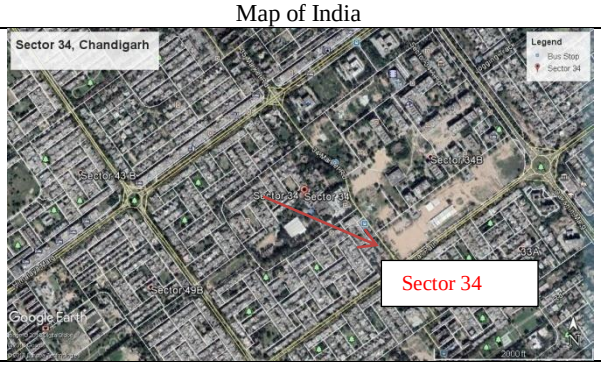
[8] http://indianexpress.com/article/cities/chandigarh/chandigarhs-vehicle-population-creates-new-record-at-11-7-lakh/



Map of India



Location map of SAS Nagar(Mohali)



Location map of Sector 34, Chandigarh

View of sampling location

Figure 3.1: Images of sampling location at Sector 34c, Chandigarh

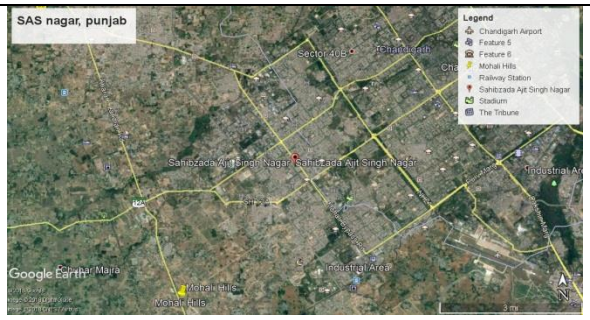
3.1.2 Sampling site 2: Industrial area (Sector 74), Mohali

Mohali is also known as Sahibzada Ajit Singh Nagar (SAS) or Ajitgarh. It is lying to the southwest of Union Territory Chandigarh. Mohali and Chandigarh are contiguous areas with only the boundary between Punjab and Chandigarh dividing this area. The co-ordinates of the city are 30.7046° N, 76.7179° E with elevation 312 m above sea level. It has a population of 176,170 in 2011, making it 10th biggest city of Punjab. The city has a sub-tropical climate with season variations: hot summers, slightly cold winters, unreliable rainfall. The temp in summers generally lies between 30 and 40ºc with maximum range of 47ºc. While in winters maximum temperature lies between 7 to 15ºc and minimum temperature goes down 1 and 5ºc.

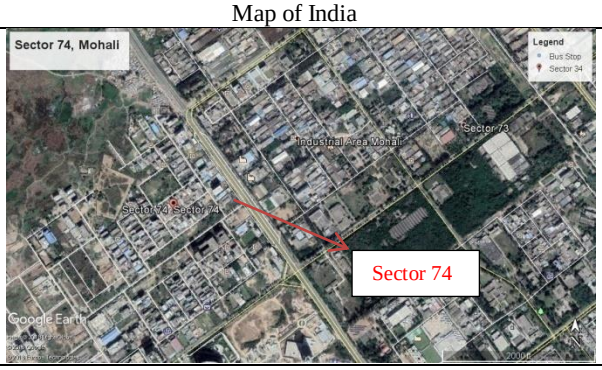
There are many state level companies situated in this Sector 74, known as industrial area. The major companies are: Punjab Communications Limited, Telecom Service Providers like Tata Communications and Vodafone and the Godrej Group. Global tech giants are: Quark and Philips. Quark City is a 51-acre (210,000 m^2), multi-use development city that includes a Special Economic Zone (SEZ). The city includes a residential complex comprising 30% of the 'city'; another 10% consume by entertainment, shopping, medical, and educational district. It is expected to generate 25,000 direct, and 100,000 indirect jobs.

The metropolitan area of Chandigarh-Mohali-Panchkula collectively forms a tri city with a combined population of around 2 million. The images are given as shown:

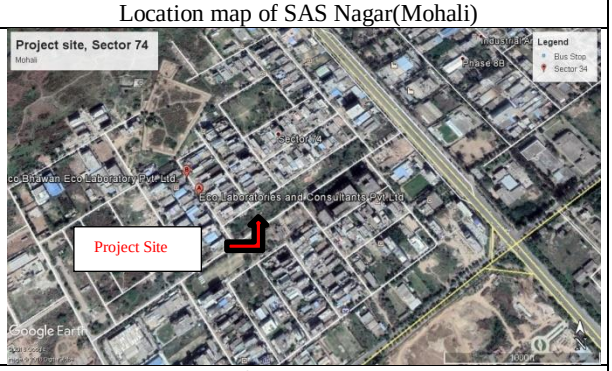
Map of India



Location map of SAS Nagar(Mohali)



Location map of Sector 74, Mohali



View of sampling location

Figure 3.2: Images of sampling location at Sector 74, Mohali

3.2 Monitoring of Particulate Matter (PM_{10})

PM_{10} samples were collected as per guidelines prescribed in 'Guidelines for the Measurement of Ambient Air Pollutants- Volume I' by Centre Pollution Control Board (CPCB) for sampling and analysis of particulate matter by gravimetric method. The sampling period was 1, February 2018 to 14, April 2018 using Respirable Dust Sampler (Model: AAS 217NL Eco tech Instruments Pvt. Ltd). The high volume sampler coupled with size-selective (cyclone) inlet for PM_{10} is considered a reliable instrument for measuring the net weight particulate matter in ambient air (USEPA—Method IO-2.1 1999). Each PM_{10} sample was collected on EPM 8 X 10" Whatman quartz micro-fiber filters having Cat no. – 1882866. Sampling was carried out in 8 hours interval from 0600 to 1400 hours, 1400 to 2200 hours and 2200 to 0600 hours for 24 hours as per standard method of USEPA & CPCB (USEPA—Method IO-2.1 1999). Monitoring was done for 21 days and a total of 63 air samples (three samples per day) were drawn from each site. The flow rate of sampler was checked hourly through manometer and is calibrated by the Eco tech Instruments pvt Ltd.

Exposed filter papers along with field blanks were placed in properly labeled bags and transported to the analytical laboratory for analysis. Filter paper were conditioned in desiccators containing silica gel for 24 hours before and after sampling in a room of constant

relative humidity, temperature and gravimetrically tarred (USEPA—Method IO-3.1 1999). The sampling was done on Industrial &residential roof tops at both sites at a vertical height of 10 meters from the ground level as per the Bureau of Indian Standards and USEPA (ISI, 1986 and USEPA, 1998).

3.2.1 Instruments required for sampling

The following are the main instruments that are required in sampling of particulate matter:

- **Analytical balance**

  In this study, five point check analytical balance is used. It is making of Denver Instruments Ltd and calibrated by Eco tech instruments Pvt ltd.

- **Top Loading Calibrator**

  This is used for internal calibrating the Respirable/ high volume sampler. The calibration certificate is attached as Annexure:

- **Respirable / High volume dust sampler**

Figure 3.3: Respirable dust sampler

3.2.2 Procedure of sampling

Ambient air with suspended particulates enters the respirable dust sampler through inlet pipe. As air enters the cyclone, coarse non-respirable dust is separated from the air by centrifugal forces acting on the solid particles. Intially it separates coarser particles which have size larger than 10µm from the air stream before filtering it on the Whatman's quartz

micro fibre filter paper. These coarser particles fall through the cyclone and get collected in the dust cup fitted at its bottom. The air stream deposited to the quartz micro fibre filter paper carries the fine dust forming the respirable fraction (PM_{10}) of total suspended particulate matter [karar et al., 2007]. The images of sampling are shown as below:

Location of Respirable dust sampler

Sampling under supervision of Dr. Rai Singh

Unexposed Filter paper before sampling

Exposed Filter paper after sampling

Figure 3.4: Images of PM_{10} sampling at Industrial area, sector 74, Mohali

3.3 Analysis of Particulate Matter

3.3.1 Gravimetric Analysis of PM_{10}

In gravimetric analysis, the net mass of particulate matter is determined by weighing the filter papers before and after sampling with a balance in a temperature (15 to 30°C) and relative humidity (20 to 45%) controlled environment. A total of 63 filter samples from each site were weighed by pre-calibrated electronic balance of 5µg precision. The net mass of PM_{10} is determined by the weight difference of filter papers before and after sampling. The net mass concentrations of PM_{10} are calculated by dividing the weight gain of filter by the volume of air sampled as per standard method of CPCB Manual Vol-1(2012-13) & USEPA (USEPA—Method IO-3.1 1999).

Calculations for the Mass Concentration of PM_{10}

a) Volume of Air Sampled:

$$V\ (m^3) = QT$$

Where:

V = Volume of air sampled in cubic meter (m^3)

Q = Average flow rate in cubic meter per min (m^3/min)

T = Total sampling time in minute (min)

b) Mass Concentration of PM_{10}

$$PM_{10}\ (\mu g/m^3) = \frac{(W_f - W_i) \times 10^6}{V}$$

Where:

PM_{10} = Mass concentration in micrograms per cubic meter ($\mu g/m^3$)

W_i = Initial weight of filter paper in grams (g)

W_f = Final weight of filter paper in grams (g)

V = Volume of air sampled in cubic meter (m^3)

10^6 = conversion of grams (g) to micrograms (µg)

The obtained mass concentrations of particulate matter are expressed in terms of particle numbers by weight in per cubic meter of air. Field and laboratory blank filters were also used to ensure accuracy of weights. Mass readings for duplicate weighing were within 2µg which represent a valid weighing. The accuracy of microbalance (scale and reading) was checked regularly with standard weights.

3.3.2 Chemical Analysis of PM_{10}

To measure the chemical species of PM_{10}, the weighted filters were divided into two equal pieces using a cutter. The selection and sample preparation including extraction and acid digestion of filters analysis for chemical analysis were carried out based on USEPA method [USEPA—Method IO-3.1]. Chemical composition of particulate matter was determined by dividing the sample into water soluble and insoluble fractions. Water-soluble components were extracted in de-ionized water by ultra-sonication and analyzed for inorganic ions by ion chromatograph (IC). The insoluble elements were determined by ICP-AAS after acid digestion of samples. Chemical analysis can be broken into the elemental and ionic analysis.

Elemental Analysis

3.3.2.1 Instrument/Equipment required for analysis

- Hot plate
- Digestion chamber
- Glassware
- FAAS (Flame atomic absorption spectrophotometer) or GFFAS (Graphite Furnace Atomic Absorption Spectrophotometer)
- Hollow cathode or electrode less discharge lamp.(For each element to be determined)
- Acetylene gas and regulator
- Nitrous oxide gas and regulator
- Air supply

3.3.2.2 Reagents

- Filter Paper: EPM 2000 or equivalent, 20.3 X 25.4 cm (8 X 10 inchs)
- Concentrated Hydrochloric Acid (HCl) (AR grade)
- Concentrated Nitric Acid (HNO_3) (AR grade)
- De-ionized distilled water

3.3.2.3 Standard stock solutions

- Aluminum solution, stock (1 mL = 1000 µg of Al)
- Arsenic solution, stock (1 mL = 1000 µg of As)
- Bromine solution, stock (1 mL = 1000 µg of Br)
- Cadmium solution, stock (1 mL = 1000 µg of Cd)

- Calcium solution, stock (1 mL = 1000 µg of Ca)
- Chromium solution, stock (1 mL = 1000 µg of Cr)
- Copper solution, stock (1 mL = 1000 µg of Cu)
- Iron solution, stock (1 mL = 1000 µg of Fe)
- Lead solution, stock (1 mL = 1000 µg of Pb)
- Magnesium solution, stock (1 mL = 1000 µg of Mg)
- Manganese solution, stock (1 mL = 1000 µg of Mn)
- Nickel solution, stock (1 mL = 1000 µg of Ni)
- Rubidium solution, stock (1 mL = 1000 µg of Rb)
- Scandium solution, stock (1 mL = 1000 µg of Sc)
- Silicon solution, stock (1 mL = 1000 µg Si)
- Sodium solution, stock (1 mL = 1000 µg of Na)
- Sulphur solution, stock (1 mL = 1000 µg of S)
- Vanadium solution, stock (1 mL = 1000 µg of V)
- Zinc solution, stock (1 mL = 1000 µg of Zn)

3.3.2.4 Sample Extraction (Hot Plate)

Cut the half filter paper into small stripes using stainless steel scissor and put it into a beaker. Cover the filter paper with the extraction solution. The extraction solution is made of 3% HNO_3 & 8% HCl. Now place the beaker on hot plate in digestion chamber for 30 min. Do not allow the sample to dry completely. Then remove the beaker from the hot plate and keep it for some time to cool it down. Wash the walls of beaker with distilled water and add approximately 10 ml distilled water and keep it for 30 min. After 30 min, filter the solution using whatmann filter paper no.41 into 100 ml volumetric flask. Rinse the beaker and any remaining solid material with distilled water and add the rinses to the flask. Dilute to the 100 ml mark with Distilled water and shake. The filtered sample is now ready for analysis.

Reagent blank was also prepared by using unexposed filter paper following the same procedure. These digested samples were analyzed for elemental composition of PM_{10} by atomic absorption spectroscopy (ICP-AAS). Figure 3.3 shows the digestion of filter paper for heavy metal analysis.

Digestion of Filter paper

Filtration

Analysis

Figure 3.5: Images of Digestion and filtration of filter paper

3.3.2.5 Sample analysis

Atomic Emission Spectroscopy (ICP-AAS)

AAS technique is working on the principal of energy changes in the atomic state of analyte. The elements which are analyzed is aspirated through nebulizer into a flame furnace and atomized. The atoms in the ground level will absorb energy, become excited and reaches to higher energy level. Light emission from the excited atoms in the analyte is converted to electrical signals employing a photomultiplier within the spectrophotometer and the intensity of the electrical signal produced is compared to the measured intensity of signals generated using elemental standards. The mass concentrations of metal elements are calculated as per standard method of USEPA (USEPA, 1999).

Emission of light at characteristic wavelength by each element is used for the identification and the intensity of light is used for the quantification of elements. Figure 3.4 shows the illustrative figures of AAS (Agilent technologies). Sample Graph of AAS is attached as **Annexure 1.**

Figure 3.6: Atomic Absorption Spectrophotometer

Calibration

Calibration is done through preparing standard graphs from stock solution. Select at least three standards. Aspirate the standards into the flame and record the absorbance. Only those Standards are prepared for the metals which are to be analyzed.

Calculations for the Mass Concentration of Metals in PM_{10}

a) Volume of Air Sampled:

$V\ (m^3) = QT$

Where:

V = Volume of air sampled in cubic meter (m^3)

Q = Average flow rate in cubic meter per min (m^3/min)

T = Total sampling time in minute (min)

b) Metal Concentration of Metals:

$$C\ (\mu g/m^3) = \frac{(Ms-Mb)* Vs* Fa}{V\ (m^3)* Ft}$$

Where:

C = Concentration (µg metal/m^3)

Ms = Metal concentration of sample (µg/ml)

Fa= Exposed area of Filter Paper (cm^2)

Ft = Exposed area of Filter Paper used in digestion (cm^2)

Mb = Metal Concentration of blank filter paper (µg/ml)

Vs = Total volume of extraction (ml)

V = Volume of air sampled through filter paper (m^3)

Ionic Analysis

3.3.2.6 Equipment/Instrument for ionic analysis

- IC
- Glassware

3.3.2.7 Reagents/Chemicals

All the chemicals used were analytical reagent grade and the reagents were made using de-ionized distilled water are as follows:

- De-ionized water: Type I reagent grade
- Sodium and potassium salts, ACS reagent grade, for preparing anion standards (VWR)

3.3.2.8 Standards

- Fluoride standard 1000 mg/L, 100 mL
- Chloride standard 1000 mg/L, 100 mL
- Sulphate standard 1000 mg/L, 100 mL
- Nitrate standard 1000 mg/L, 100 mL

3.3.2.9 Sample Preparation

For ion analysis, a known portion of each sampled filter was extracted in 25 ml distilled water (DW) by ultra sonication and filtered through a filter (Whatman No. 42) into pre-cleaned polypropylene bottles to remove suspended particulate matter prior to analysis. Blank samples were also prepared from the unexposed filter papers in the same procedure. The resulting extracts were analyzed for inorganic ions using Ion Chromatograph.

Calculations for the Mass Concentration of Ions in PM_{10}

a) Volume of Air Sampled:

$V\ (m^3) = QT$

Where:

V = Volume of air sampled in cubic meter (m^3)

Q = Average flow rate in cubic meter per min (m^3/min)

T = Total sampling time in minute (min)

b) Mass Concentration of Ions:

$$C\ (\mu g/m^3) = \frac{(I_s - I_b) * V_s * F_T}{F_{Ex} * V\ (m^3)}$$

Where:

C = Concentration (µg ion/m^3)

I_s = ion concentration determined by the instrument (µg ion/ml)

F_T = Total area of Exposed filter paper (cm^2)

F_{Ex} = Area of filter paper used in extraction (cm^2)

I_b = Concentration of blank filter paper (µg)

V = Volume of air sampled through filter paper (m^3)

V_s = Volume of extraction (ml)

3.4 Quality Assurance (QA) & Quality Control (QC)

To maintain the accuracy and precision, intensive quality control program was implemented during sampling and analysis throughput the study period. The following quality assurance procedures were taken into the study -

- Maintenance and service of the sampling and analysis equipments was done at frequent intervals.
- As per standard operating procedure (SOP) regular check-up water level in manometer and cleaning of cyclone and dust cup before sampling.
- Representative sampling with proper labeling (e.g. F/P numbering, sampling location, date, time and environmental conditions) was ensured.
- Routine calibration of the pump of high volume sampler to ensure the accurate flow rate.
- Filter handling in sampling and analysis was done with non-serrated clean forceps to avoid finger moisture and salt contamination.
- Sampler flow was monitored at hourly basis during 8 hours sampling.
- Filters, glass wares, chemical reagents and solvents were used of a standard quality.
- All the glass wares washed with acid (Chromic acid) and dried on oven before use

- Pre and post filter conditioning in desiccators for 24 hours at controlled laboratory conditions such as temperature (25ºC±5ºC) and relative humidity (35%±5%).
- Exposed filters papers were kept in sealed plastic bags in refrigerator until the analysis was done.
- The obtained gravimetric mass and chemical composition data were corrected with blank values.

3.5 Statistical Analysis

3.5.1 Basic Statistic

A basic statistical analysis was carried out for both sites for PM_{10} and Chemical species of PM_{10}. The basic statistics include minimum, maximum, mean, standard deviation of each variable. Basic Statistic was conducted using the Statistical Package for Social Sciences (SPSS Version 20) and Excel 2010.

3.5.2 Pearson Correlation Coefficient

Pearson correlation coefficient analysis was performed for calculating the average of two shift data (16 hour) and three shift data (24 hour) of particulate pollutants of PM_{10} to investigate the relationships between them. It was conducted using the Statistical Package for Social Sciences (SPSS Version 20).

3.5.3 Factor Analysis for Source Apportionment

Factor analysis, a statistical technique that reduces the number of dimensions, form sets of multivariate data in some linear combinations of variables called principal component. This technique identifies the emission sources using varimax rotated factor matrix method. Eigenvalue >1 is necessary for factor selection. Results of PCA can be plotted to interpret the correlations among variables [Vaio et al., 2018]. In this study Factor analysis was conducted using PCA technique of Statistical Package for Social Sciences (SPSS Version 20).

4 RESULTS AND DISCUSSION

4.1 Mass Concentrations of Respirable Suspended Particulate Matter (PM_{10})

For the present study, particulate matter (PM_{10}) samples are collected from sector 74, Industrial area and sector 34, residential area from February 2018 to April 2018. The sampling is done for 24 hours in 8 hours intervals from 0600 to 1400 hours, 1400 to 2200 hours and 2200 to 0600 hours with a sampling duration of twice a week (21 days). Total of 63 PM_{10} samples (three samples per day) are collected at each site. The mass concentration of PM_{10} during the study period ranges from 147 $\mu g/m^3$ to 195 $\mu g/m^3$ at industrial area and 129 $\mu g/m^3$ to 172 $\mu g/m^3$ at residential area. The Shift wise mass concentration of PM_{10} at both the locations is shown in the Table 4.1 & 4.2

Table 4.1 Shift wise mass concentration of PM_{10} in $\mu g/m^3$ at residential Area, Mohali

Residential Area										
Date	**Shift I(6am-2pm)**	**Shift II(2pm-10pm)**	**Shift III(10pm-6am)**	**Average (I,II & III)**	**Avg (I,II)**	**Avg (I,III)**	**Avg (II,III)**	**Minimum**	**Maximum**	**S.D**
2/1/2018	143	172	129	148	157	136	150	129	172	26.3
2/5/2018	142	166	125	144	154	134	146	125	166	24.4
2/8/2018	138	163	120	170	161	172	176	158	187	29.1
2/12/2018	152	144	130	140	151	129	142	120	163	20.3
2/15/2018	121	140	106	142	148	141	137	130	152	19.1
2/19/2018	136	154	113	122	130	114	123	106	140	21.0
2/22/2018	174	148	160	160	155	160	167	148	172	28.6
2/26/2018	148	162	172	161	161	167	154	148	174	28.3
3/1/2018	156	163	177	134	145	125	133	113	154	30.0
3/5/2018	169	158	109	165	159	167	170	156	177	33.0
3/8/2018	150	143	110	145	163	139	133	109	169	23.1
3/12/2018	174	172	128	158	173	151	150	128	174	31.7
3/15/2018	133	149	113	131	141	123	131	113	149	19.0
3/19/2018	125	140	155	140	132	140	148	125	155	20.8
3/23/2018	124	154	118	132	139	121	136	118	154	19.7
3/26/2018	148	165	174	162	156	161	169	148	174	29.4
3/29/2018	128	143	114	134	147	130	126	110	150	16.9
4/3/2018	127	145	108	128	136	121	128	114	143	18.0
4/6/2018	152	140	102	127	136	117	126	108	145	23.0
4/10/2018	127	155	108	131	146	127	121	102	152	21.5
4/14/2018	158	165	187	130	141	118	132	108	155	33.6

The average mass concentration of PM_{10} at residential area is 148 $\mu g/m^3$, 144 $\mu g/m^3$, 170 $\mu g/m^3$, 140 $\mu g/m^3$, 142 $\mu g/m^3$, 122 $\mu g/m^3$, 160 $\mu g/m^3$, 161 $\mu g/m^3$, 134 $\mu g/m^3$, 165$\mu g/m^3$, 145

µg/m^3, 158 µg/m^3 ,131 µg/m^3, 140 µg/m^3, 132 µg/m^3, 162 µg/m^3, 134 µg/m^3, 128 µg/m^3, 127 µg/m^3, 131 µg/m^3, 130 µg/m^3. The average concentration of 24 hour data is 143µg/m^3 with maximum average concentration is 187µg/m^3 and minimum average concentration is 102µg/m^{3}as shown in table 4.1. The high mass concentration of PM_{10} at residential area is due to heavy traffic flow on the road which emits small particles [Satsangi et al., 2011]. Also DG sets and indoor fuel combustion in the kitchen is also a possible reason for high concentration of particulate matter [Guttikanda et al., 2014].

Table 4.2 Shift wise mass concentration of PM_{10} in µg/m^3 at industrial Area, Mohali

Industrial Area										
Date	**Shift I(6am-2pm)**	**Shift II(2pm-10pm)**	**Shift III(10pm-6am)**	**Average (I,II & III)**	**Avg (I,II)**	**Avg (I,III)**	**Avg (II,III)**	**Minimum**	**Maximum**	**S.D**
2/1/2018	162	195	147	168	179	155	171	147	195	20.0
2/5/2018	159	186	141	162	173	150	164	141	186	18.5
2/8/2018	179	188	212	193	184	196	200	179	212	13.9
2/12/2018	152	179	132	154	166	142	156	132	179	19.3
2/15/2018	173	164	148	162	169	161	156	148	173	10.3
2/19/2018	137	159	121	139	148	129	140	121	159	15.6
2/22/2018	168	184	195	182	176	182	190	168	195	11.1
2/26/2018	193	164	178	178	179	186	171	164	193	11.8
3/1/2018	155	175	128	153	165	142	152	128	175	19.3
3/5/2018	173	181	197	184	177	185	189	173	197	10.0
3/8/2018	188	175	121	161	182	155	148	121	188	29.0
3/12/2018	183	181	135	166	182	159	158	135	183	22.2
3/15/2018	148	165	125	146	157	137	145	125	165	16.4
3/19/2018	152	171	189	171	162	171	180	152	189	15.1
3/23/2018	142	177	136	152	160	139	157	136	177	18.1
3/26/2018	168	187	198	184	178	183	193	168	198	12.4
3/29/2018	177	168	129	158	173	153	149	129	177	20.8
4/3/2018	146	162	130	146	154	138	146	130	162	13.1
4/6/2018	151	173	128	151	162	140	151	128	173	18.4
4/10/2018	179	165	120	155	172	150	143	120	179	25.2
4/14/2018	155	189	132	159	172	144	161	132	189	23.4

The average mass concentration of PM_{10} at industrial area is 168 µg/m^3, 162 µg/m^3, 193 µg/m^3 , 154 µg/m^3, 162 µg/m^3, 139 µg/m^3, 182 µg/m^3, 178 µg/m^3, 153 µg/m^3, 184µg/m^3, 161 µg/m^3, 166 µg/m^3 ,146 µg/m^3, 171 µg/m^3, 152 µg/m^3, 184 µg/m^3, 158 µg/m^3, 146 µg/m^3, 151 µg/m^3, 155 µg/m^3, 159 µg/m^3. The average concentration of 24 hour data is 163µg/m^3 with maximum average concentration is 193µg/m^3 and minimum average concentration is 139µg/m^{3}as shown in table 4.2. The possible sources for the higher concentration of PM_{10} at

industrial area are emissions from the industrial activities, oil combustion, dust from construction activities etc. Hence, it is found that the average concentration of 24hour data at both the locations exceed the National Ambient Air Quality Standards (NAAQS) which 100 $\mu g/m^3$ as shown in figure 4.1.

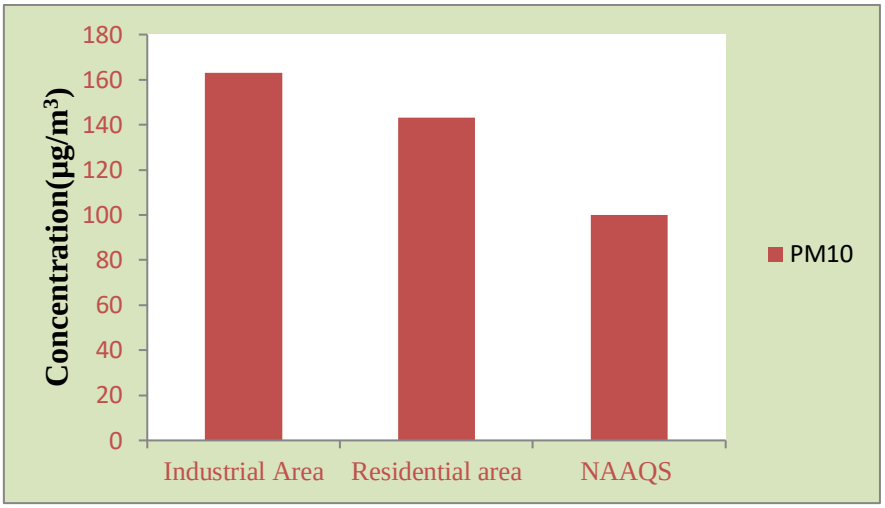


Figure 4.1: Comparison of concentration at residential, industrial & NAAQS

Moreover, in the present study, we observed that during three shift sampling, PM_{10} concentration is generally lower in the III shift (10pm-6am) as compared to other two for both the locations. This is may be due to the fact that in the night time, the vehicular emissions are very less and also there is decrease in the industrial activities. Where as in the II shift (2pm-10pm), the particulate concentration is much higher than other two .The comparison between three shifts on both the locations is shown in the graphs given below:

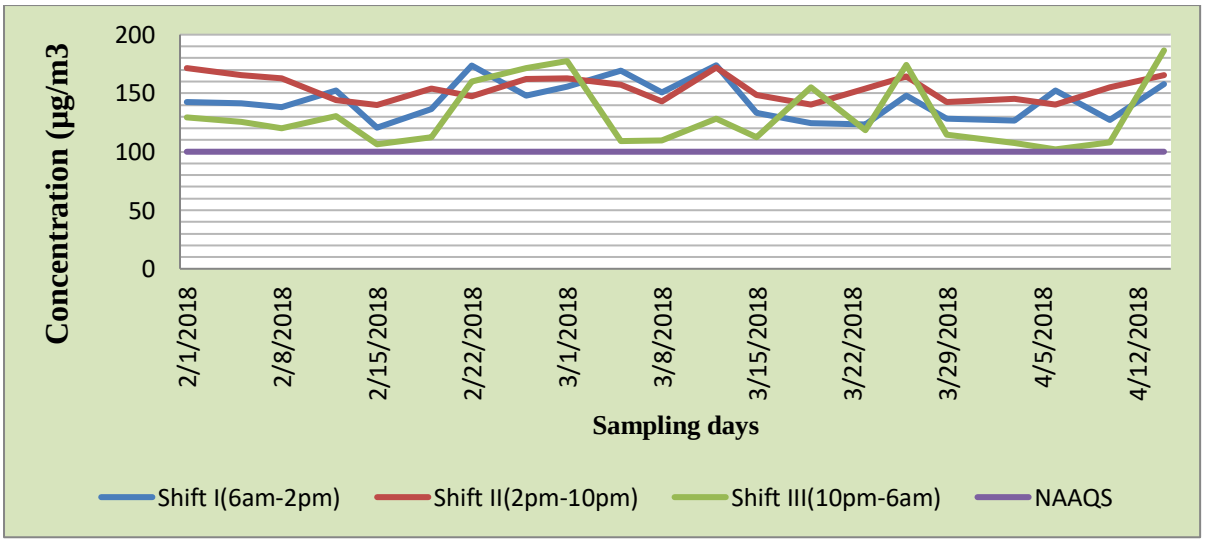


Figure 4.2 : Comparison of mass concentration of PM_{10} of three shift data at residential area

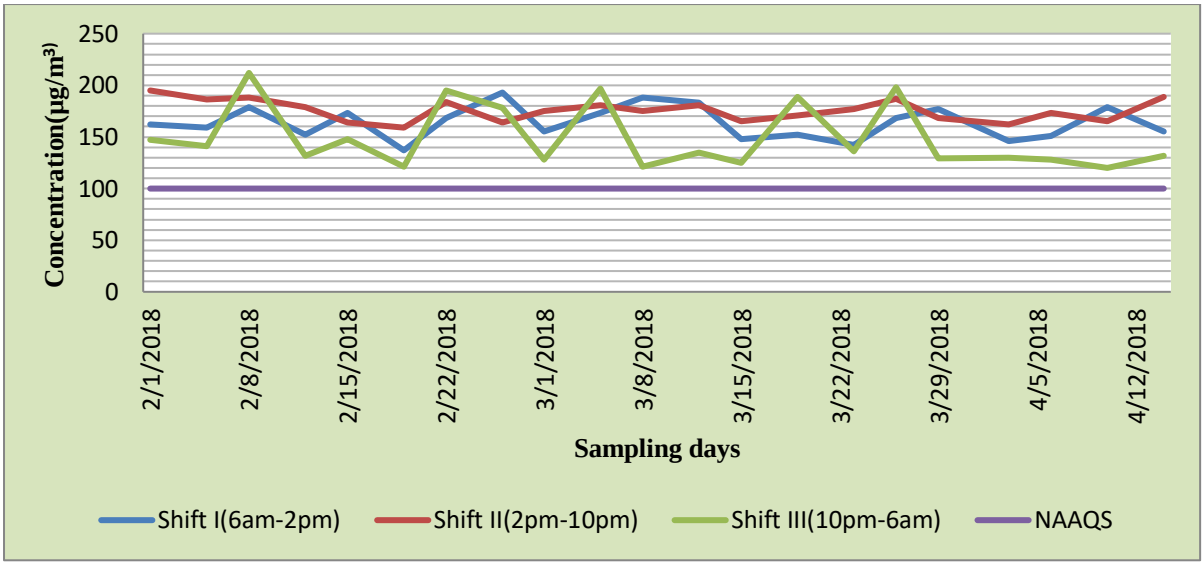


Figure 4.3: Comparison of mass concentration of PM_{10} of three shift data at industrial area

4.2 Correlation of 24 hour (Three shifts) PM_{10} data with 16 hour (two shifts) data

In the present study, PM_{10} monitoring is undertaken for 24 hours twice a week. The Table 4.1 & 4.2 shows the average of 24 hour (three shifts) data and 16 hour (two shifts) data. As per NAAQS given by CPCB (Central Pollution Control Board) the sampling duration for PM_{10} is 8 hour as well as 24 hours for a representative sample in which sampling is done in three shifts of 8 hour each. In our study, we conclude that 16 hour data of any two shifts may be comparable to 24 hour data under same metrological conditions [Saha et al., 2012]. However, the present study is performed only at two locations and it may not be applicable for other stations. Moreover it is difficult to generate 100% data with accuracy so some statistical formulas are taking into account for assessment of overall results. The correlations are calculating using Pearson correlation coefficient by SPSS as shown in figure 4.4. The correlation found between average of shift (I, II, III) and shift (I, II) is 0.82, shift (I, II, III) and shift (I, III) is 0.97 & shift (I, II, III) and shift (II, III) is 0.93 at residential area. Similarly correlation between shift (I, II, III) and shift (I, II) is 0.80, shift (I, II, III) and shift (I, III) is 0.97 & shift (I, II, III) and shift (II, III) is 0.94 at industrial area.

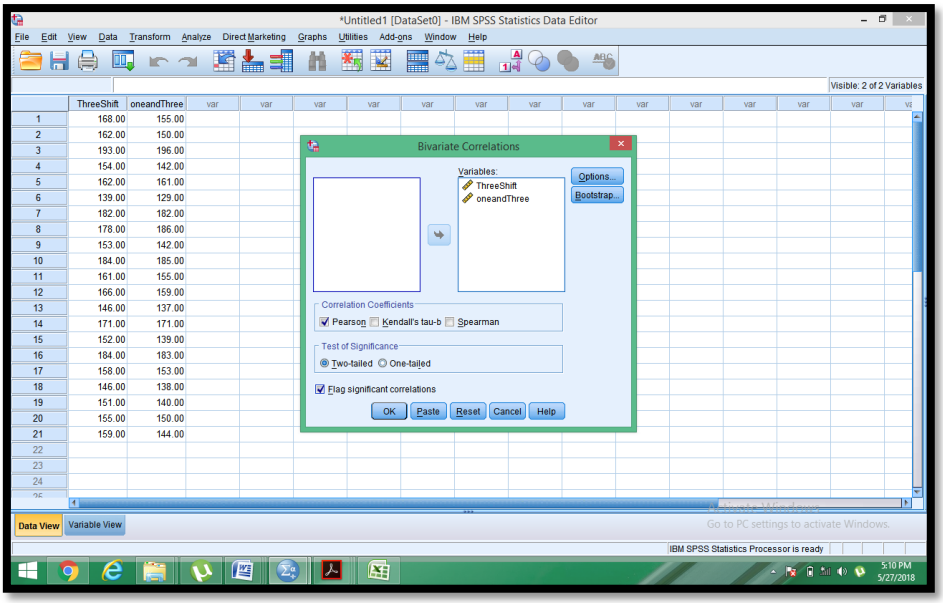


Figure 4.4: Correlation between Shift (I, II & III) and Shift (II, III) using SPSS

Table 4.3: Pearson Correlations between shift (I,II, III) & shift (I, II) for residential area.

		Three	Two
Three	Pearson Correlation	1	.820**
	Sig. (2-tailed)		.000
	N	21	21
Two	Pearson Correlation	.820**	1
	Sig. (2-tailed)	.000	
	N	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.4: Pearson Correlations between shift (I,II, III) & shift (II, III) for residential area.

		Three	Two
Three	Pearson Correlation	1	.938**
	Sig. (2-tailed)		.000
	N	21	21
Two	Pearson Correlation	.938**	1
	Sig. (2-tailed)	.000	
	N	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.5: Pearson Correlations between shift (I,II, III) & shift (I, III) for residential area

		Three	Two
Three	Pearson Correlation	1	.976**
	Sig. (2-tailed)		.000
	N	21	21
Two	Pearson Correlation	.976**	1
	Sig. (2-tailed)	.000	
	N	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.6: Pearson Correlations between shift (I,II, III) & shift (I, II) for industrial area

		Three	Two
Three	Pearson Correlation	1	.810**
	Sig. (2-tailed)		.000
	N	21	21
Two	Pearson Correlation	.810**	1
	Sig. (2-tailed)	.000	
	N	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.7: Pearson Correlations between shift(I,II, III) & shift(II, III) for industrial area

		Three	Two
Three	Pearson Correlation	1	.975**
	Sig. (2-tailed)		.000
	N	21	21
Two	Pearson Correlation	.975**	1
	Sig. (2-tailed)	.000	
	N	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.8: Pearson Correlations between shift (I,II, III) & shift (I, III) for industrial area

		Three	Two
Three	Pearson Correlation	1	.939**
	Sig. (2-tailed)		.000
	N	21	21
Two	Pearson Correlation	.939**	1
	Sig. (2-tailed)	.000	
	N	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

This is further verified statistically by correlating the different slots of two shifts (I, II; I, III & II, III) averages with three shifts average, which are noted to be 0.83, 0.98 & 0.94 for residential area & 0.80, 0.98 & 0.94 for industrial area. The figures have shown the statically correlated data for both the locations. Figure 4.5, 4.6, 4.7 shows the correlation for residential area while 4.8, 4.9 & 4.10 shows the correlation for industrial area

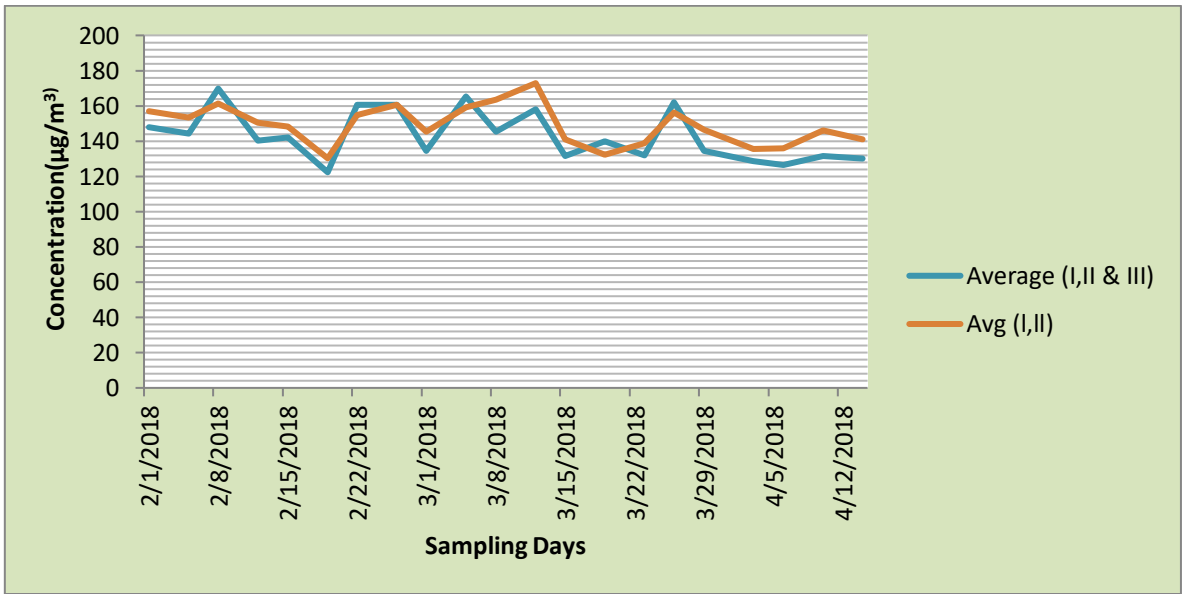


Figure 4.5: Correlation between three shift (I, II, III) and two shift (I, II) data for residential area

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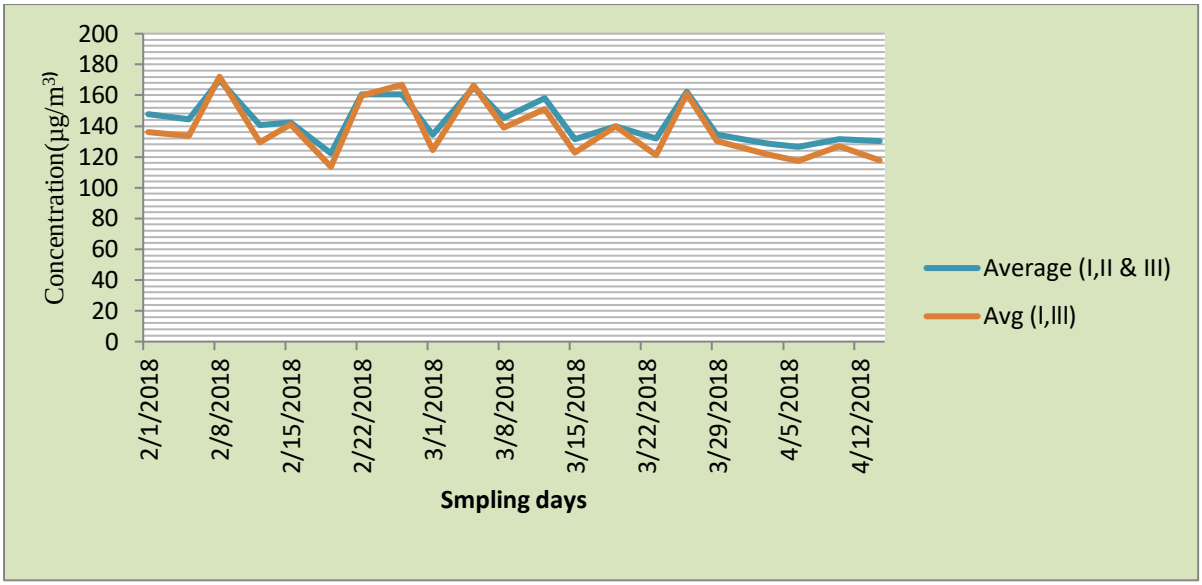


Figure 4.6: Correlation between three shift (I, II, III) and two shift (I, III) data for residential area

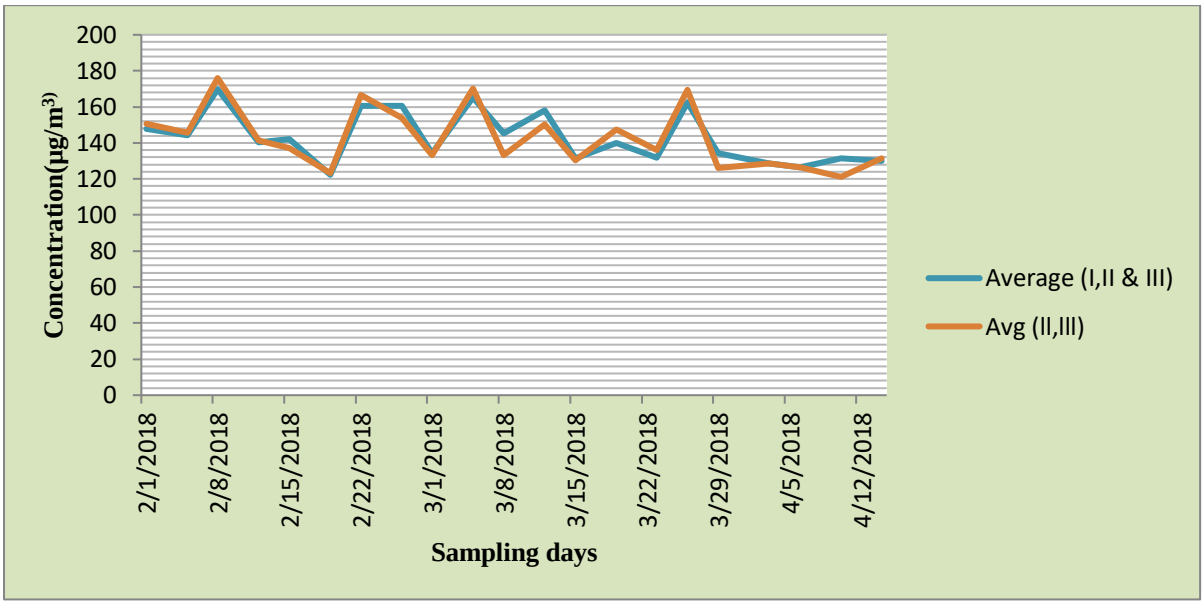


Figure 4.7: Correlation between three shift (I, II, III) and two shift (II, III) data for residential area

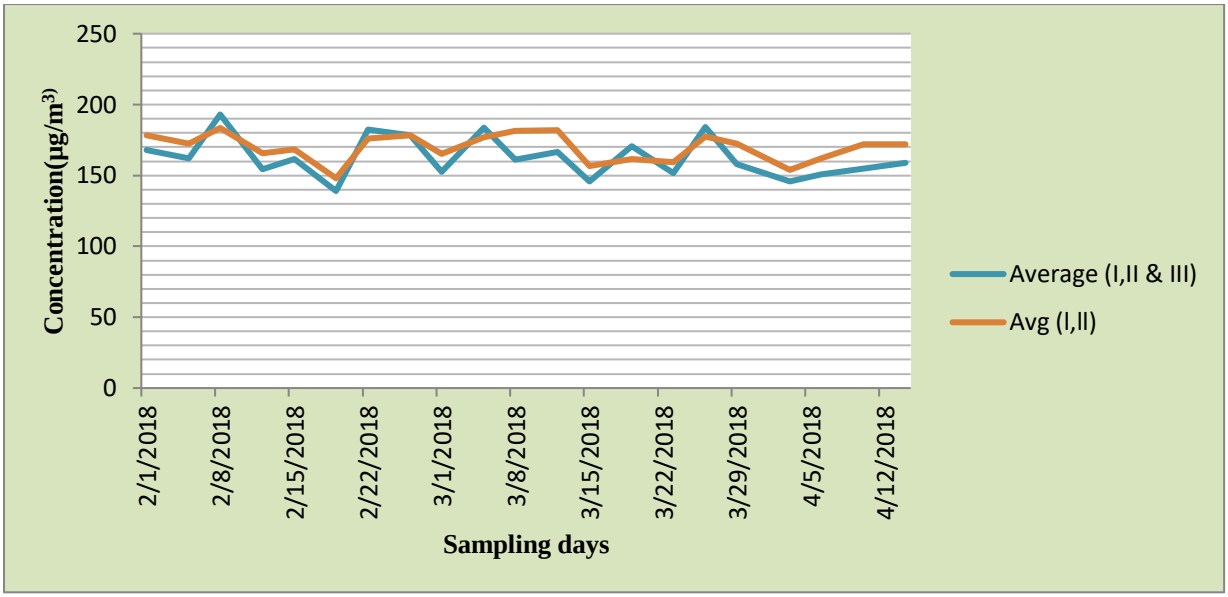


Figure 4.8: Correlation between three shift (I, II, III) and two shift (I, II) data for industrial area

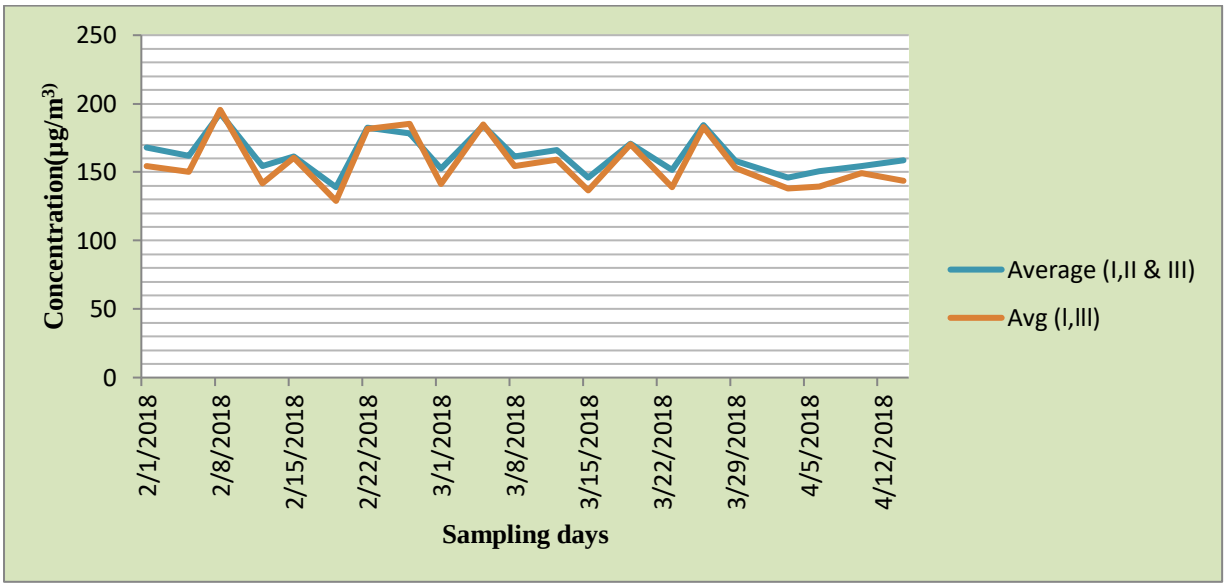


Figure 4.9: Correlation between three shift (I, II, III) and two shift (I, III) data for industrial area

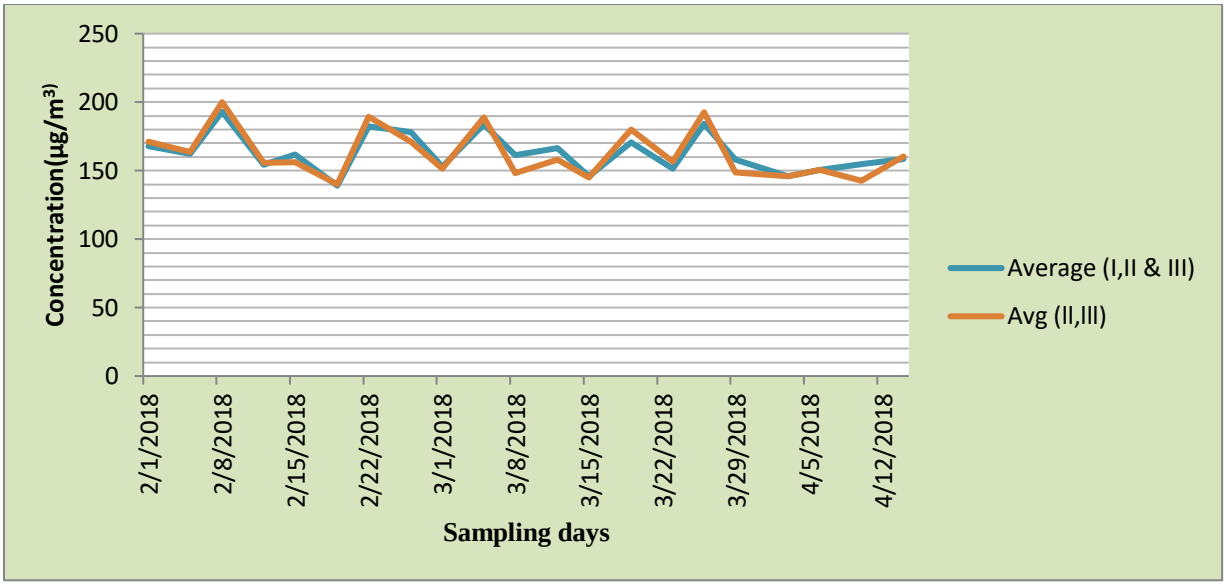


Figure 4.10: Correlation between three shift (I, II, III) and two shift (II, III) data for industrial area

The overlapping in the average values of three shifts and different slots of two shifts clearly depicts & proves that monitoring of two shift data instead of three shifts can be taken in to account. Thus on the basis of present study, it can be suggested that considering the above locations, monitoring only during daytime will be enough for generating the required data. The sample size for the present study is small, therefore there is need to further establish the above findings for more authentic study.

4.3 Mass Concentrations of PM_{10} Chemical Species

In the chemical characterization of PM_{10} various elements such as sodium (Na), magnesium (Mg), , calcium (Ca), aluminum (Al), silicon (Si), sulfur (S), scandium (Sc), vanadium (V), manganese (Mn), chromium (Cr), iron (Fe), copper (Cu), zinc (Zn), lead (Pb), arsenic (As), nickel (Ni), bromine (Br), rubidium (Rb), cadmium (Cd), barium (Ba) are analyzed by Atomic Absorption Spectroscopy (AAS) and inorganic ions such as ammonium (NH_4^+), potassium (K^+), sulfate (SO_4^{2-}), nitrate (NO_3^-), fluoride (F^-) and chloride (Cl^-) by Ion Chromatograph (IC). Out of total samples collected from the both the location, only 50% samples were analyzed for chemical analysis due to time constraint. The mass concentrations of these species in tricity (Industrial & residential) are given in Table 4.9. from the figure 4.11 , we observed that sodium (Na), magnesium (mg), aluminum (Al), calcium (Ca), silicon (Si), sulfur (S) were the major elements present in the atmosphere. This is may be due to the fact that these elements were comes under crust material or generated due to soil erosion, unpaved roads, construction activities etc, [Alam et al., 2015] . Sulfur and zinc (Zn) is the

major contributor in vehicular emissions. Vanadium (V), manganese (Mn) is almost negligible as compared to other metals.

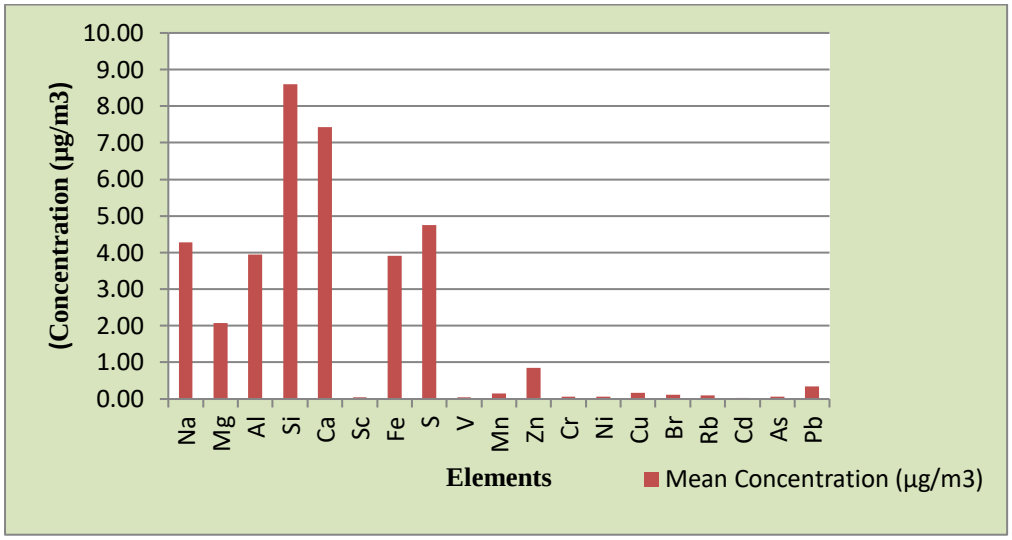


Figure 4.11: Mean concentration of various elements

Among the ions, Nitrate (NO_3^-), (NH_4^+), SO_4^{2-} was the dominant species as shown in figure 4.12. These species were known as secondary compounds that form due to the transformations in the atmosphere by their precursor gases (SO_2, NO_2, and NH_3) and indicates the presence of compounds $(NH_4)HSO_4$, $(NH_4)_2SO_4$ [Calzolai et al., 2015]. The mean concentration of NO_3^- , SO_4^{2-} , NH_4^+ was 10.76, 9.99 & 6.93µg/m^3. SO_4^{2-} originated from the photochemical reaction of sulfur dioxide that emitted from coal and sulfur combustion in industries [Singh et al., 2012]. The emissions of these species indicate the usage of fossil fuel & biomass burning.

Table 4.9: Average mass concentration of elements

Elements	Mean Concentration (µg/m3)	Sd	Max	Min
Na	4.28	1.99	10.45	1.11
Mg	2.07	1.04	4.25	0.47
Al	3.96	1.56	8.00	1.05
Si	8.60	3.17	16.87	3.06
Ca	7.44	2.44	13.59	2.57
Sc	0.05	0.02	0.12	0.00
Fe	3.92	1.81	8.52	0.66
S	4.76	2.58	11.57	1.29
V	0.04	0.02	0.11	0.00
Mn	0.16	0.12	0.45	0.02
Zn	0.85	0.79	2.71	0.06
Cr	0.07	0.04	0.17	0.00

Ni	0.06	0.05	0.20	0.00
Cu	0.17	0.09	0.42	0.04
Br	0.12	0.09	0.36	0.00
Rb	0.09	0.04	0.18	0.00
Cd	0.03	0.01	0.05	0.00
K+	5.64	3.12	12.46	1.20
Cl-	4.06	3.08	10.24	0.18
F-	0.91	0.58	2.15	0.08
As	0.07	0.04	0.15	0.00
Pb	0.35	0.21	0.79	0.00
NH4+	6.93	3.79	16.23	1.96
NO3-	10.76	3.29	20.94	4.45
SO42-	9.99	4.14	22.57	5.42

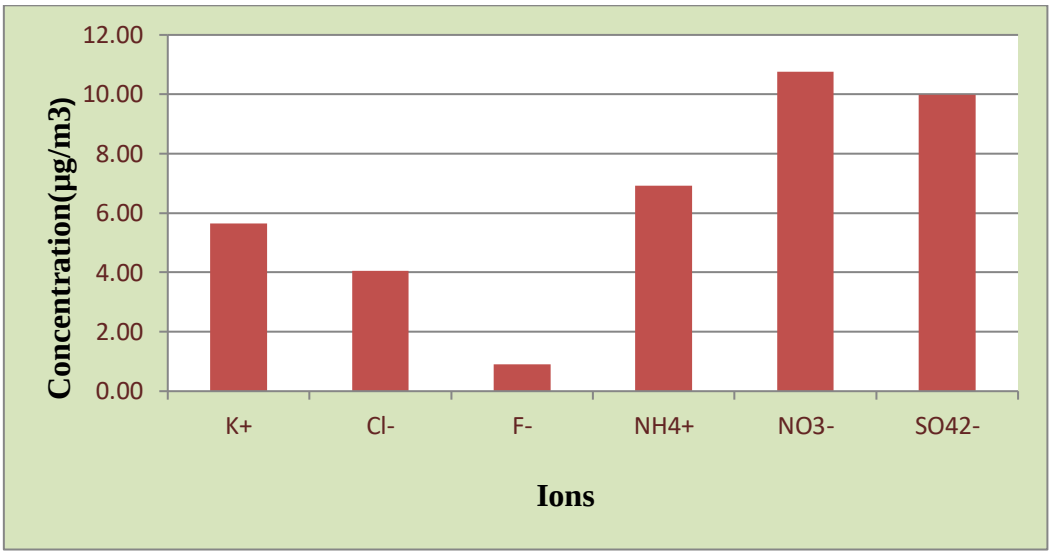


Figure 4.12: Mean concentration of Ions

4.4 Effect of meteorological factors

Dispersion of pollutants in the atmosphere is greatly affected by meteorological factors viz. temperature, relative humidity, wind speed, wind direction, atmospheric stability and precipitations. To understand the influence of meteorology on the degree of particulate pollution, meteorological factors such as wind speed, wind direction, temperature, relative humidity, precipitation were recorded through an automatic weather monitoring station which is installed at roof top of Eco laboratories & consultants Pvt. Ltd, Mohali. The instrument stores the data that can be download later in the computer using software. The data were collected over the period January 2018- April 2018.

Using the meteorological data, windrose diagram was made to know the distribution of direction and speed of wind. The average wind speed in the tricity was found to be 2.34 m/s.

From the windrose as shown in figure 4.9, we observed that 3 to 6 % of the wind was blow from North West direction with the average speed of 2 m/s while 12.4 % of the wind was blow from North West direction with the speed of 2 to 3 m/s. Therefore, we concluded that the wind during the study period was blow from the North West direction with speed of 2.34 m/s.

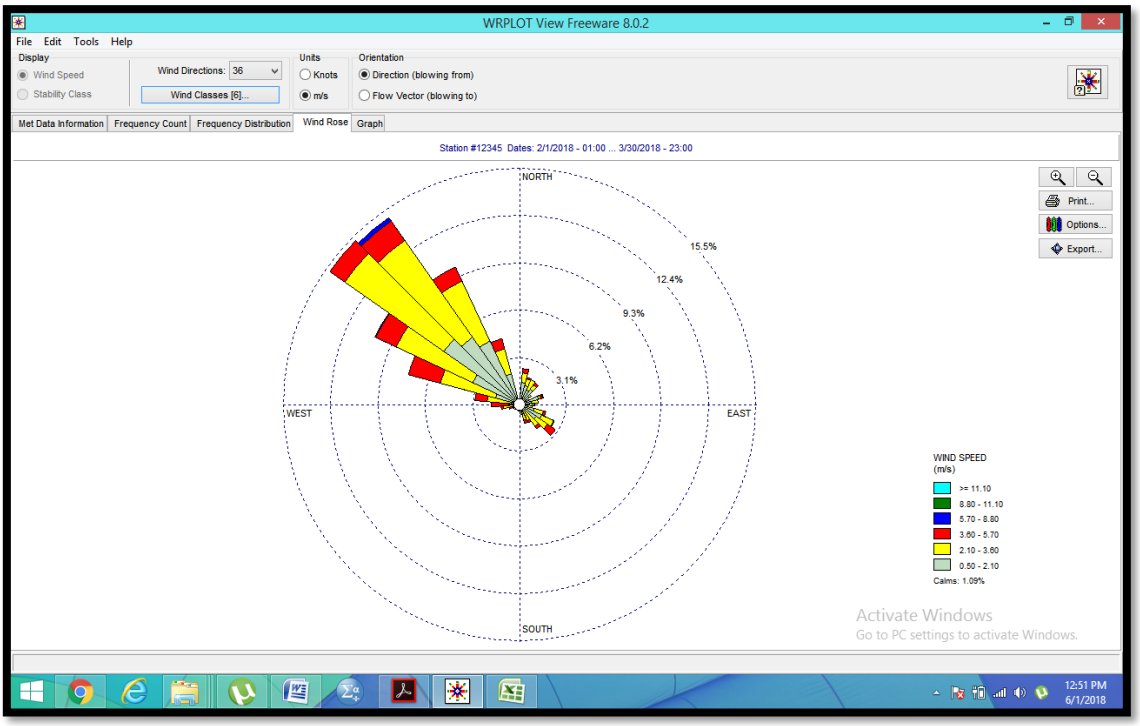


Figure 4.13: Wind rose diagram of tricity

Figure 4.10 indicates the frequency distribution of wind class. In which there are 7 wind classes with wind speed < 0.5 m/s, 0.5- 2.1m/s, 2.1 – 3.6 m/s, 3.6 – 5.70 m/s, 5.70 – 8.80 m/s, 8.80 – 11.10 m/s, > 11.10 m/s.

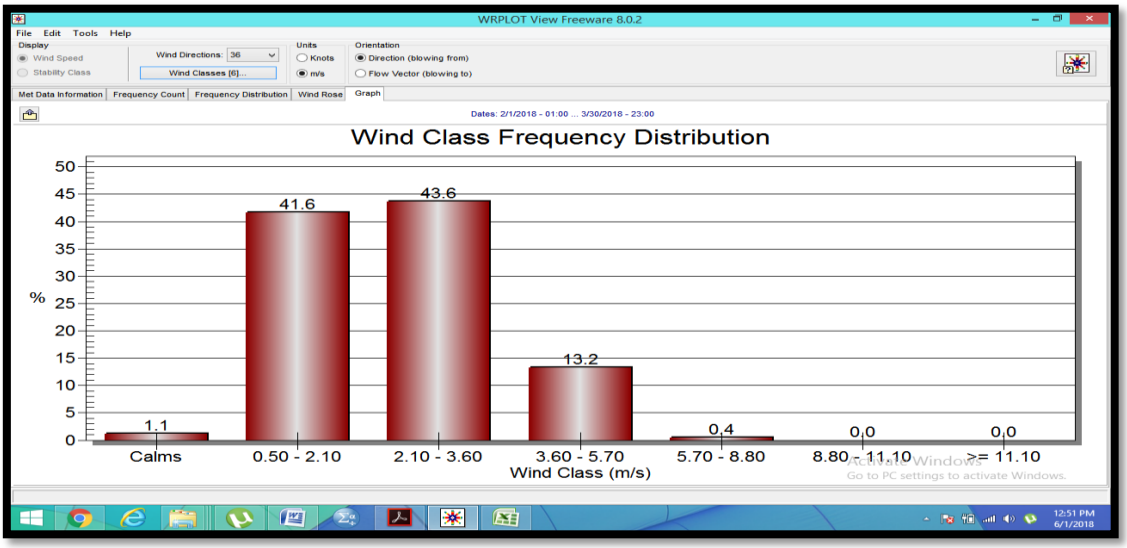


Figure 4.14: Frequency distribution of wind classes

We observed that winds with wind speed less than 0.5 m/s are considered as calm winds. In the present study, most of the winds fall in the range of 0.5 – 3.60 m/s with 43% lies in the range of 2.10 to 3.60 m/s & 41.6 % of the winds lies in the range of 0.5 to 2.10 m/s.

The average temperature observed during the study period was 41.91 °c. This will results stronger winds which flush out particulate pollutants from local sources [Singh et al., 2012] but higher temperature and winds cause air convections which bring more pollution load of soil dust particles into the city by trans-boundary migrations and long range dust transportation from regional as well as remote dry and dessert areas. On the other hand, lowest temperature and wind speed leads to stagnant or static atmosphere which favor accumulation by limiting dilutions and dispersions and enhance longer residence time of particulate aerosols in the atmosphere. Figure 4.15 and Figure 4.16 shows the variation of particulate matter with wind speed at both the locations.

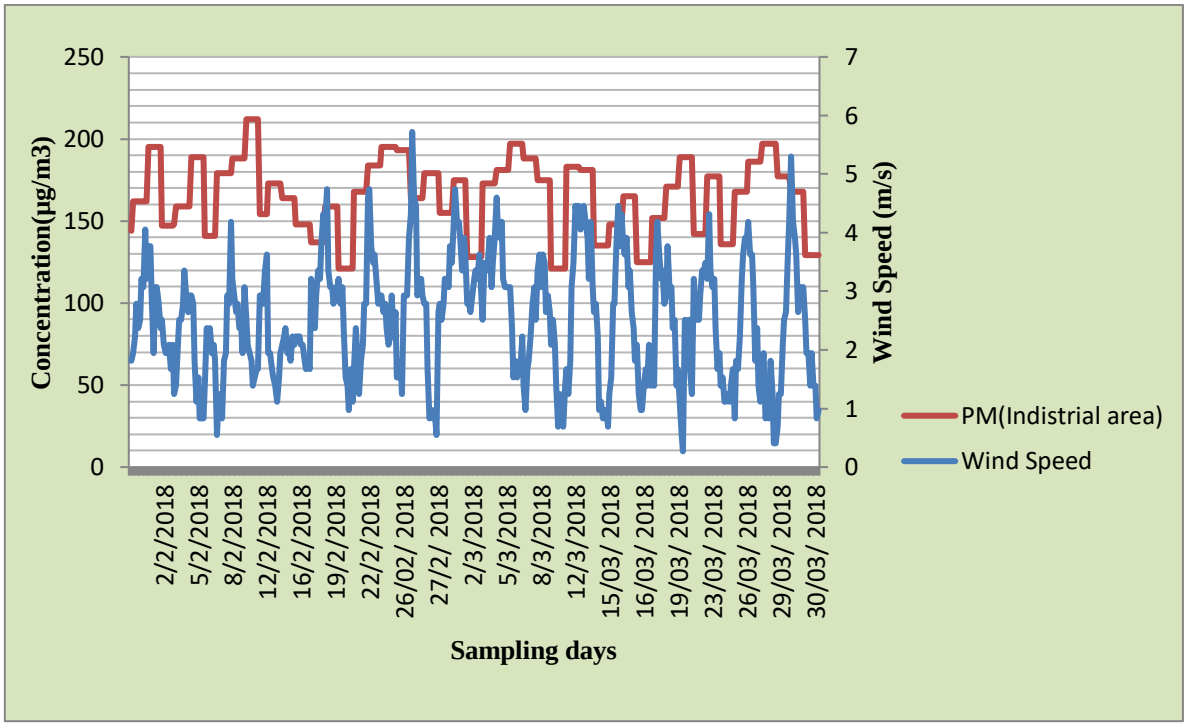


Figure 4.15: Variation in mass concentration of particulate matter with wind speed at industrial area

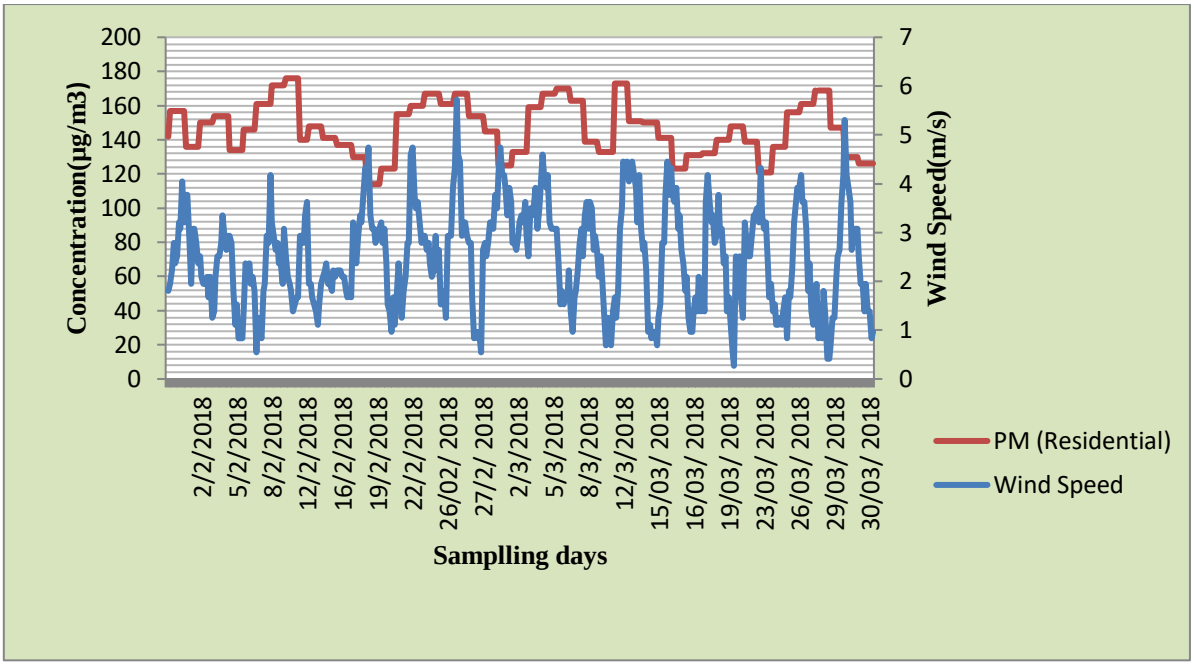


Figure 4.16: Variation in mass concentration of particulate matter due to wind speed at residential area

4.5 Source apportionment of Particulate matter

Principle Components Analysis (PCA) or Factor Analysis (FA) is performed to 24 hours average elemental and ionic data set of PM_{10} at both sites to identify the possible sources of particulate aerosols in Tricity. Among the factors extracted by SPSS, five factors are selected on the basis of each factor associates with eigen-values >1 [Satsangi et al., 2011] and total percentage variance explained by all factors is more than 91%. Five factors explained by PCA denoted five common sources - crust material, coal and biomass burning, industrial emission, vehicular emission, and secondary aerosols as shown in figure 4.17

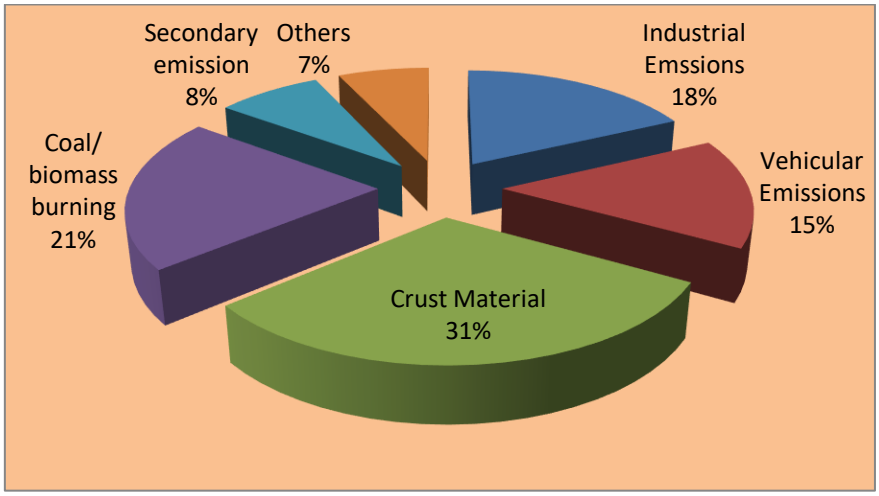


Figure 4.17: Source apportionment of particulate matter

Table 4.10: Component Matrix[a]

	Component				
	1	2	3	4	5
Na	.922	.080	.309	-.064	-.103
Mg	.921	.097	.330	-.111	-.107
Al	.922	.086	.325	-.112	-.106
Si	.927	.080	.329	-.091	-.079
Ca	.903	.058	.328	-.038	-.032
Sc	.800	.066	.288	-.119	-.100
Fe	.919	.069	.321	-.115	-.118
S	-.041	.448	.297	.835	.024
V	-.039	.442	.277	.839	.026
Mn	-.052	.431	.306	.825	.004
Zn	.013	.437	.283	.833	.047
Cr	.116	-.662	.051	-.019	.277
Ni	-.496	-.567	.531	.069	.246
Cu	-.243	-.584	.680	.037	.196
Br	-.234	-.628	.624	.126	.285
Rb	.063	-.618	.537	.030	.186
Cd	-.013	-.646	.710	.026	.197
K	-.270	.657	.519	-.437	.113
Cl	-.314	.705	.447	-.425	.119
F	-.405	.647	.470	-.398	.158
As	-.643	.492	.346	-.260	.256
Pb	-.290	.678	.465	-.437	.127
NH4	.487	.185	-.391	.045	.739
NO3	.524	.198	-.399	.014	.704
SO42	.531	.160	-.392	.040	.722

Extraction Method: Principal Component Analysis.

a. 5 components extracted.

FACTOR 1

The first factor is heavily loaded with sodium (Na), magnesium (Mg), aluminum (Al), silicon (Si), calcium (Ca), scandium (Sc) and iron (Fe). These metal elements typically associate with crust material which come from windblown dust, re-suspended dust, dust from paved and unpaved roads, trans-boundary migrations, undisturbed soil, agricultural and construction activities [Singh et al., 2012; Tiwari et al., 2013; calzolai et al., 2015; Deka et al., 2016; Vaio et al., 2018].

FACTOR 2

The second factor shows high loadings of potassium (K^+), chloride (Cl^-), fluoride (F^-), arsenic (As) and lead (Pb) with a total variance of 21% are the indicators Fossil fuels and biomass burning for cooking [Singh et al., 2009; Singh et al., 2012; Alam et al., 2014] . Some studies indicates that K+, Cl- are the sources of sea salt [Calzolai et al., 2015]

FACTOR 3

The third factor with 17% show high loadings of Bromine (Br), nickel (Ni), copper (Cu), cadmium (Cd) and rubidium (Rb). These metals typically associate with industrial emissions that include metallurgical processes and produce the largest emissions of Cu, Ni, Cd, Cr [Alam et al., 2014; Vaio et al., 2018] This factor strongly associates with industrial sources.

FACTOR 4

The fourth factor shows the high loading for sulfur (S), vanadium (V), manganese (Mn), zinc (Zn) with a variance of 14%. These metal elements typically associate with automobile emissions which include combustion products from fuel and oil, road construction materials, road dust and wear products from tires, brake linings and bearings are in agreement with Singh et al., 2012 Zn is attributed to biomass fuel burning that includes firewood, coal burning and emission from brick kiln furnaces [Alam et al., 2014; Alam et al., 2015]

FACTOR 5

The fifth factor shows high loadings of nitrate (NO_3^-), sulfate (SO_4^{2-})and ammonium (NH_4^+) with a variance of 8% . SO_4^{2-}, NO_3^- and NH_4^+ are collectively known as secondary aerosols which formed by gas to particle conversion from their precursor gases SO_2, NO_X and NH_3, respectively in the atmosphere [Calzolai et al., 2015; Tiwari et al., 2013; Singh et al., 2012].

5 CONCLUSION

This study review summarizes the importance of particulate matter in the atmosphere because of their strong influence on human beings. Increase in urbanization, industrialization, automobile sector and population bloom increases the concentration of particulate matter in a very large manner and makes the problem of deterioration in air quality more severe. Today most of the Indian cities are highly polluted with particulate concentrations well above the recommended limits of WHO, US EPA and NAAQ standards in India. Tricity is also not far from this issue.

Combustion of fossil fuels to meet growing energy demand for alarming population and vehicular growth, expansion in urbanization and industrialization sector, combustion of conventional fuels such as coal, coke, kerosene, firewood, biomass materials, agro residues and cow dung cakes not only at nearby slum areas but also at commercial centers especially in roadside hotels, unreliable electricity supply, tremendous use of diesel generators, bad conditions and overloading of vehicles, poor condition and encroachment of roads, congested streets, mismanagement of traffic and frequent traffic jams result in the significant rise of particulate pollution in Tricity. Respirable suspended particulate matter (PM_{10} -the particles <10μm in aerodynamic diameter) is collected from Industrial area, Mohali and Residential area, Chandigarh during February 2018 to March 2018. Sampling is carried out for 24 hours in 8 hours interval uniformly for 21 days. Each PM_{10} sample collected on 20.3cmx25.4cm Whatman's quartz micro fiber filter using Respirable Dust Sampler at a flow rate of $1m^3$/min is analyzed gravimetrically for mass concentrations which showed the range between $147\mu g/m^3$ to $195\ \mu g/m^3$ at industrial area and $129\ \mu g/m^3$ to $172\ \mu g/m^3$ at residential area and chemically for metallic elements such as sodium (Na), magnesium (Mg), aluminum (Al), calcium (Ca) silicon (Si), sulfur (S), scandium (Sc), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), lead (Pb), arsenic (As), nickel (Ni), bromine (Br), rubidium (Rb), cadmium (Cd), and barium (Ba) by Atomic Absorption Spectroscopy (ICP-AAS, Model: Agilent) and ions such as ammonium (NH_4^+), sulfate (SO_4^{2-}), nitrate (NO_3^-), potassium (K^+), fluoride (F^-) and chloride (Cl^-) by Ion Chromatograph. 24 hours average mass concentrations of PM_{10} are considerably higher than 24 hours average NAAQ standard of $100\mu g/m^3$. The higher mass concentrations of PM_{10} can be attributed to the local and regional factors such as increased fossil fuels combustion to meet growing energy demand associated with alarming population and vehicles growth rate, expansion in urban and industrial sector, re-suspension and windblown soil dust and trans-boundary

migrations. Additionally, the meteorological factors such as ambient temperature, wind speed, relative humidity and precipitation, ultraviolet radiations from sunlight, intensity and duration of light may also influence PM_{10} in the atmosphere.

Considerably higher mass levels of respirable suspended particulate matter (PM_{10}) than standard limits results in deteriorating air quality of Tricity and suggests the urgent need for systematic and effective control of atmospheric particles from anthropogenic sources to safeguard the human population, flora and fauna as well as social assets like sites in the world heritage city.

Correlation of 16 hour data with 24 hour data suggests that it sampling span can be reduced. As our findings show that 16 hour data of any two shifts of 8 hour each can be comparable to 24 hour data and therefore sampling duration of particulate matter can be reduces to 16 hour.

The results of the present study can be utilized to evaluate existing and devise more efficient emission reduction strategies and to develop the general guidelines for particulate matter. The study can help the society by providing foundation for making decisions on air quality issues. Two months data about mass levels, composition and sources of PM_{10} from urban region of Chandigarh & Punjab (Mohali) can be basis to manage human health and environmental impacts of anthropogenic activities.

Present study suggests the need for continuous and long term systematical monitoring of airborne particles along with prevailing meteorological conditions in urban as well as back ground areas. A comprehensive time weighted average, chemical characterization and pollutant specific source apportionment of PM_{10} is required for better understanding the emission sources and to draw suitable policy to prevent and control of air pollution in the city.

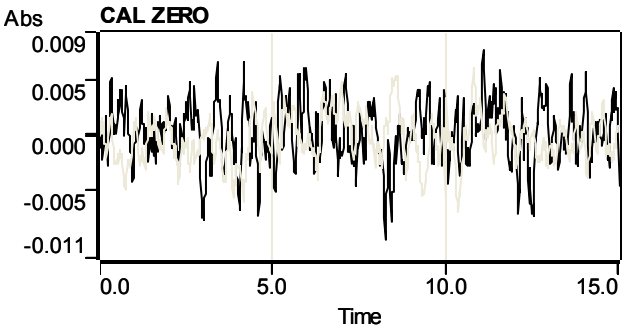
Analyst
Date Started 10:32 AM 3/5/2018
Worksheet lead 050318
Comment
Methods Pb
Computer name COM3-NEHA
Serial Number:

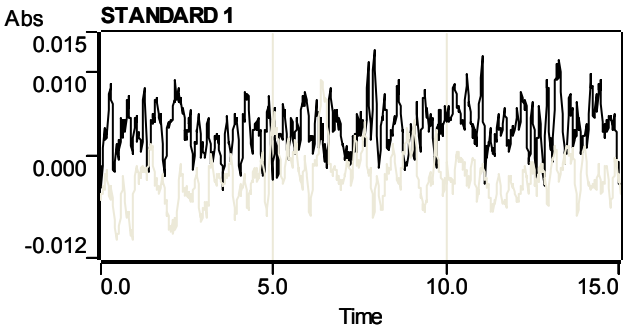
Nominal Weight = 1.0000 Nominal Volume = 1.0000

Method: Pb (Flame)

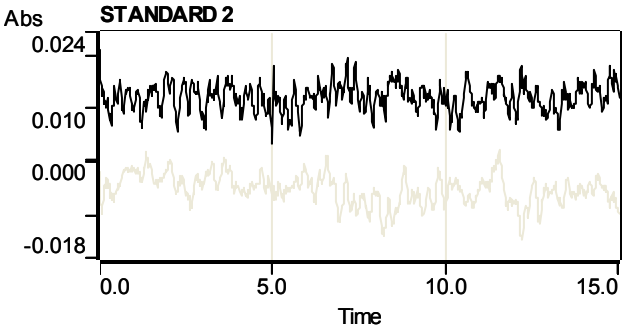
Element - Matrix:	Pb -
Instrument Type:	Flame
Conc. Units:	mg/L
Instrument Mode:	Absorbance
Sampling Mode:	Manual
Calibration Mode:	Concentration
Measurement Mode:	Integrate
Replicates Standard:	3
Replicates Sample:	3
Expansion Factor:	1.0
Minimum Reading:	Disabled
Smoothing:	7 point
Conc. Dec. Places:	2
Wavelength:	217.0 nm
Slit Width:	1.0 nm
Gain:	78 %
Lamp Current:	10.0 mA
Lamp Position:	3
Background Correction:	BC On
STANDARD 1:	0.10 mg/L
STANDARD 2:	0.50 mg/L
STANDARD 3:	1.00 mg/L
Reslope Rate:	50
Reslope Standard No.:	2
Reslope Lower Limit:	75.0 %
Reslope Upper Limit:	125.0 %
Recalibration Rate:	100
Calibration Algorithm:	New Rational
Cal. Lower Limit:	20.0 %
Cal. Upper Limit:	150.0 %
SIPS:	Off
Measurement Time:	5.0 s
Pre-Read Delay:	10 s
Flame Type:	Air/Acetylene
Air Flow:	13.50 L/min
Acetylene Flow:	2.00 L/min
Burner Height:	0.0 mm

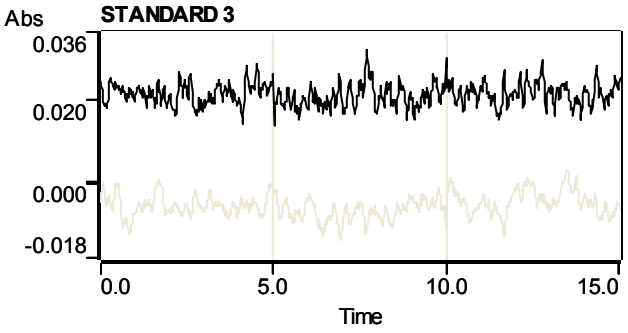
Sample ID	Conc mg/L	%RSD	SD	Mean Abs	BG Abs	Weight	Volume
CAL ZERO	0.00	>100	0.0001	0.0001	-0.0004	1.0000	1.0000
	Readings						
	-0.0001	0.0001	0.0002	3/5/2018	10:47:40 AM		
STANDARD 1	0.10	19.1	0.0006	0.0032	-0.0022	1.0000	1.0000
	Readings						
	0.0027	0.0030	0.0038	3/5/2018	10:48:50 AM		





STANDARD 2	0.50	1.8	0.0002	0.0118	-0.0050	1.0000	1.0000
	Readings						
	0.0116	0.0120	0.0118	3/5/2018	10:50:08 AM		
STANDARD 3	1.00	2.2	0.0005	0.0209	-0.0053	1.0000	1.0000
	Readings						
	0.0212	0.0204	0.0212	3/5/2018	10:50:54 AM		

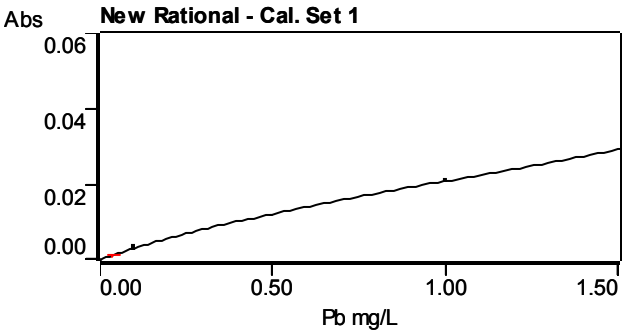




Curve Fit = New Rational
Characteristic Conc = 0.15 mg/L
r = 0.9992
Calculated Conc = 0.00 0.11 0.48 1.01
Residuals = 0.00 -0.01 0.02 -0.01

Conc = A

(14.18709 x A x A - 0.87355 x A + 0.03274)



Sample ID	Conc mg/L	%RSD	SD	Mean Abs	BG Abs	Weight	Volume
Sample 001	0.04	33.5	0.0004	0.0013	-0.0064	1.0000	1.0000
	Readings						
	0.0017	0.0015	0.0008	3/5/2018	10:52:02 AM		
Sample 002	0.11	5.6	0.0002	0.0034	-0.0070	1.0000	1.0000
	Readings						
	0.0035	0.0035	0.0032	3/5/2018	10:53:08 AM		
Sample 003	0.60	3.2	0.0004	0.0139	-0.0050	1.0000	1.0000
	Readings						
	0.0139	0.0144	0.0135	3/5/2018	10:54:24 AM		
Sample 004	0.05	33.8	0.0006	0.0017	-0.0084	1.0000	1.0000
	Readings						
	0.0011	0.0023	0.0017	3/5/2018	10:55:46 AM		
Sample 005	0.49	1.4	0.0002	0.0118	-0.0082	1.0000	1.0000
	Readings						
	0.0120	0.0119	0.0116	3/5/2018	10:56:58 AM		

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7 OTHER WORK ASSIGNED DURING ONE YEAR INTERNSHIP

7.1 Water Usage Matrix of Multistory Building of Housing Complex & Retrofitting for Water Conservation Measures

This research aims to explore the relation between water consumption, its conservation, water use behavior and attitude in residents of a residential township. On the concern of Hon"ble Chairman, PPCB **Sh. Kahan Singh Pannu**, IAS and NGO, Environment Matters, a study was conducted on the water usage in the residential areas of JLPL Housing Group in Sector 90-91, Mohali during September-November 2017. The main objective of the audit is to carry out a study on water usage and consideration of the social strata of the family vis-à-vis secondary data supplied by the local authority. Further it was help us to explore the relation between water consumption and water use behavior and attitudes, and devices applied in households of JLPL Housing Projects in Mohali Sector 90-91. The main areas covered in this audit were:-

- ✓ Water Usage Habits.
- ✓ Dual Plumbing in various Residential Flats.
- ✓ Impact of RO System and determine the waste water generated.
- ✓ Conservation of water by Installation of Male Urinals in the washrooms of flats/apartments.

7.2 Study on Mechanical Composter and Waste Management Rules, 2016

A study on the mechanical composter was performed which was designed and manufactured in 'Eco Paryavaran and Engineers Pvt. Ltd'. In the study major benefits of decentralized composting, its technology and need in the future were analyzed. Also other technologies for waste management and major amendments in the Solid Waste management Rules, 2000 were studied during June- August, 2017. Besides, participated in conference on Waste Management Rules, 2016 conducted by Ministry of Environment and Forests (MoEF) in collaboration with CII.

7.3 Publication

Worked as a Co-author on research paper 'PAHs characterization in tricity' under the guidance of Dr. Amit Dhir , Dr. Anita Rajor, Dr. Rai Singh and Mr. Sandeep Garg.

7.4 Conference/ Training/ Workshop/ Certifications

- Certification on 'Air Pollution Monitoring & Air Quality Modeling 'By QCI (Quality Council of India).
- Participated in 'Capacity building Programme of ULBs and stakeholders on Waste Management Rules, 2016', conducted by MoEF in collaboration with CII in Chandigarh
- Attending conference on 'Convention on Green growth and Future jobs' by CII in Chandigarh.
- Participated in Audit conducted by 'National Accreditation Board for Education & Training (NABET) on 14-16th December, 2017.
- Participated in Audit conducted by "National Accreditation Board of Laboratories (NABL)' on 21-22nd April, 2018.
- Training on ISO/IEC 17025: 2005 by Eco Laboratories & Consultants Pvt. Ltd.