FINAL TECHNICAL REPORT

ON

POLLUTION LOAD CARRYING CAPACITY AND SOURCE APPORTIONMENT STUDIES IN CPA SILTARA

Submitted to

Chhattisgarh Environmental Conservation Board (CECB), Paryavas Bhavan, North Block, Sector-19, Atal Nagar, Dist- Raipur (C.G.) Pin: 492002

By

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CERTIFICATE

This is to certify that the content of the final technical report entitled "Pollution Load Carrying Capacity and Source Apportionment Studies in CPA Siltara" submitted to Chhattisgarh Environmental Conservation Board (CECB) is based on the field monitoring data collected by IIT Kharagpur team members The data is collected during March 2021 to March, 2023 of Air, Water, Soil and Noise, Biological and Socio-economic component of environment and large scale development activities etc. The data presented in this report are actual typical representation of environmental data and collected only the above duration of periods and few representative data are presented in this report which are significant and may vary with time. This report is submitted to the Chhattisgarh Environmental Conservation Board for their own use and not to be used for any legal purpose for which IIT Kharagpur will not be responsible at any stage.

(Prof. B. C. Meikap)
Principal Investigator
IIT Kharagpur

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CHAPTER-I

INTRODUCTION

1.1 Introduction

The term "pollution" refers to any substance that negatively impacts the environment or organisms that live within the affected environment. Pollution originates from a number of natural and man-made sources, and it occurs in an idea variety of forms, including biological, chemical, particle, and even energy. The adverse consequences of the pollutions are frequently visible, e.g., some rivers are visually filthy, have an unpleasant stench, or appear to have biotic population issues. Based on the environment media, pollutants are categorized into four major types: air, water, land, and noise pollutions. The extent of pollution and load-carrying capacity of a region during various atmospheric and industrial conditions is determined by the assimilative capacity parameter. It is defined as the maximum amount of pollutant load an area can take without exceeding the specified standards. It is the key to the sustainable use of the planet. It is based on the assumption that natural systems can be used but should not be abused. It varies with respect to changing meteorological conditions, types of pollutants, and stack characteristics. To keep the pollution level within the assimilative capacity of the region, a critical study is carried out known as source apportionment study. It is the identification of pollution sources and the quantification of their contribution to pollution levels. This task can be accomplished using three main approaches: emission inventories, source-oriented models, and receptor-oriented models.

In the present study, Siltara industrial cluster in Chhattisgarh State is identified as the research area where pollution is a critical issue. Siltara industrial cluster refers to Siltara industrial areas located about 13 km away from the Raipur city on Raipur-Bilaspur Road located at about 21.22° N and 81.39° E. It is placed in the category of Critically Polluted Area. There are two industrial sites in Siltata, one on the left and another on the right side of the road, named as: Siltara I and Siltara II. Siltara is a Village in Dharsiwa Tehsil in Raipur District of Chhattisgarh State. It has experienced rapid industrial expansion and has emerged as a key business center in central India. Initially 17 sampleing stations have been chosen for air monitoring in the Siltara and the sample code for those station are S01 to S17. Three rivers, namely Mahanadi, Kharun and Seonath are flowing in the Siltara city. Mahanadi is the main river that forms the eastern boundary of the district. The western boundary district runs along the Kharun River which flows towards north joining the Sheonath about 8 km southwest of Simga. A large number of small streams flow through the low-lying areas which are diverted to join the Mahanadi in the east. Siltara has a tropical wet and dry climate, with temperatures being mild all year except March to June, when it can be very hot.

Environment pollution directly co-relates with public health. Despite Chhattisgarh Government has taken various actions like – introduction of improved emission norms for vehicles, reducing sulphur in diesel, phasing out lead from gasoline, introducing CNG consuming public transport systems, banning old commercial vehicles, relocating of industries, prohibiting open combustion, planting trees, etc. Though all these actions seems to be not enough for such mining and related areas in Chhattisgarh like; Siltara, Bhilai. So, further analysis of actions and future needs become even more important in view of revised air quality standards.

Pollutants come from different sources and initially expose in ambient air. Varying air quality and then gradually disperse in water and soil. These pollutants can be measured in the air in the name of Source Apportionment assay (pollutant measurement and study of effects of those pollutants through receptor modelling) in two ways. One is the calculation of emissions from various sources and other is the quantification of percent fraction by different sources to any receptor. There are two widely used modelling techniques – Dispersion modelling and Receptor modelling, for realization of related impacts of different sourced pollutants. Indian Government carried out air quality monitoring programme in different cities or towns in India under National Air Monitoring Programme (NAMP) to provide air quality data, planning the strategies, solution of the situation, implementation of the Air (Prevention and Control of Pollution) Act (1981) and various policy instruments in the country. Central Pollution Control Board (CPCB) stipulated $PM_{2.5}$ standard values for different cities for annual and 24 hr averages are 40 and 60 $\mu g/m^3$.

Air Quality Management (AQM) is the regulation of source emissions in the ambient air in order to achieve specified National Ambient Air Quality Standards (NAAQS). A well-structured Air Quality Management Strategy (AQMS) is an efficient tool which integrates a multiple data sets like; source density, emission intensity, meteorology, geography and receptor information. Over the past few years, several Governmental agencies or administrators, legislators and the general people have shown stark increase in interest in transgressing air quality. Such a response is essential for the management of urban environment and the factors influencing its agglomeration. This forced the Government to bring forward laws for protecting the environment from emission sources. Air Pollution Act, 1988 (Preservation and Control of Pollution), the Motor Vehicles Act, 1988 and Central Motor Vehicle Rules, 1989 are most important implementation among them. Also implementation of NAAQS and emission standards are made to control air pollution in India. However, fast urbanization, lack in effective public transport system and traffic congestion led decline of local ambient air quality, predominantly near traffic intersections, at busy urban centres and around the industrial areas.

Particulate Matter (PM) concentrations in ambient air of different Indian cities are quite high. Various instruments are enforced by Indian Government for Air-Quality Monitoring and Source Apportionment study but those seem to be less adequate. Again, seasonal variation in Indian weather effects on PM values. Some other factors like - population, modern household consumption patterns, improper solid waste management and increase number of vehicles, etc. play important role in aggravating air pollution in India. Presently the air quality and emission regulations are mainly based on the measured mass of fine particulate matters concentrations ($PM_{2.5}$ and PM_{10}). The study of particle concentrations exposure to the receptor is important to elucidate the Airborne Particulate Matter (APM) sources and the mechanisms associated with their formation. APM generated with various sources has different physicochemical characteristics and detrimental health effects. APM is a complex mixture of both organic and inorganic species. Hence, the identification and quantification of emission sources has enormous importance to establish the relation between specific sources to its health outcomes. Without source apportionment it is not possible to control the emissions in an informed way. Emission inventories, source and receptor models are the three main approaches to achieve this goal.

Receptor models represent the statistical evaluation of ambient measurements at different times and locations. Hence, it forms a sub-category of apportionment techniques and apportions the species based on the measured data and the knowledge on the sources compositions. Various techniques have been used for source apportionment of APM. Chemical Mass Balance (CMB) analysis, Enrichment Factor Analysis (FA), Times series analysis (TSA), Multivariate factor analysis (MFA), Species series analysis (SSA) and Multi-linear Engine (ME) analysis are the major techniques have been used for source apportionment of APM. The most subjective and the least quantitative aspect of the entire modelling process is the interpretation of factors predicted by the receptor models. For selection of their source origins, researchers are forced to search vast libraries of APM source composition similar to those in their source factors. Receptor models' never guarantees a single source type. Therefore, identification and quantization of organic molecular markers for source apportionment is turning into a promising field of research in recent years.

Initially, CMB has been proposed for both the identification and quantification of source contributors. This model is robust and relatively easy to apply, based on the mass conservation of individual chemical species or markers viz. Organic compounds, elements and ions. These concentrations and compositions at 'receptor' are expressed in linear sum of products of source profile abundances and their contributions. The proportions must be different for each of the source emissions and changes between source and receptor proportions are negligible or can be approximated. Here, we

are discussing about the Source Apportionment scenario among 15 different sampling stations of Siltara by using CMB Model.

Study Area:

A Central Indian state named Chhattishgarh is heavily forested state, with co-ordinates 21.25º N to 81.60º E. Our study area, Siltara is known as iron and steel area of Chhattishgarh.

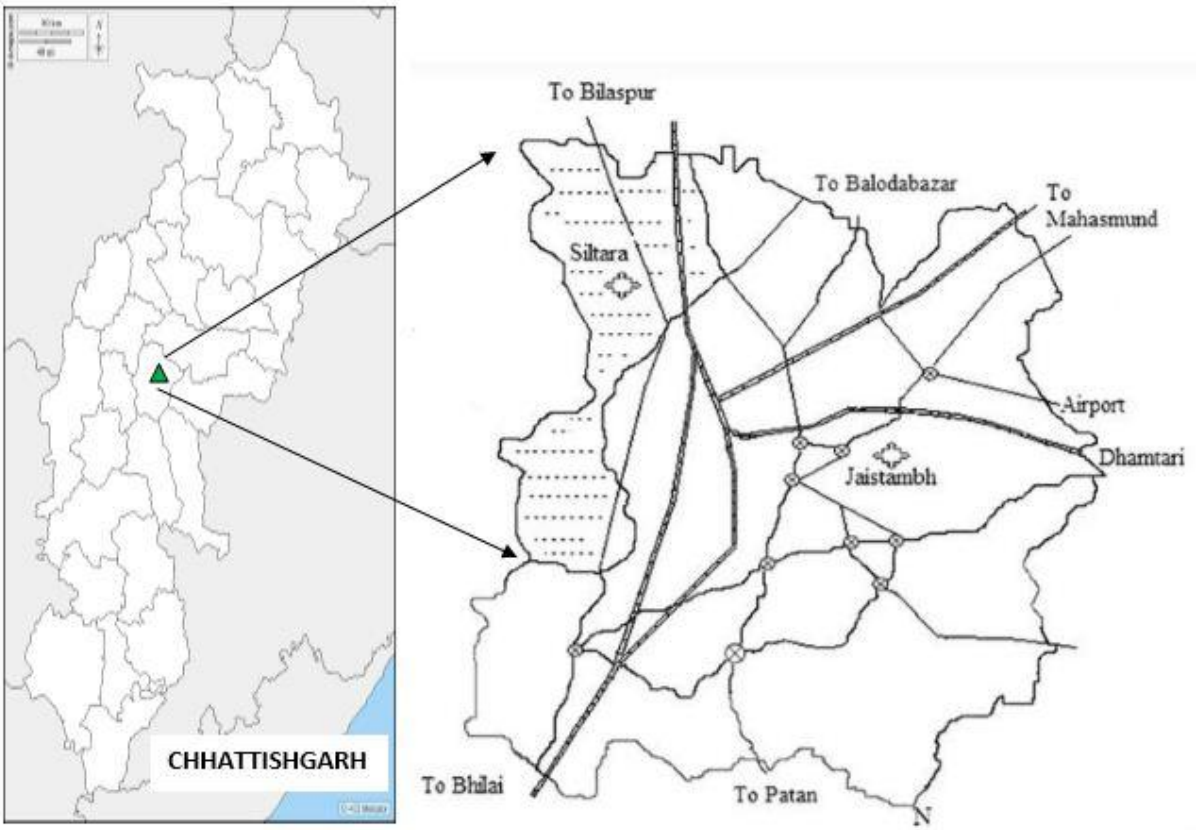


Figure 1.1: Study area of Siltara in Chhattishgarh (*Source: www.Google.com).

1.2 Objectives

The aim of the project is to conduct the carrying capacity including source apportionment studies are carried out for OPA Siltara for a radius of 15 km from the center of the study area.

1.3 Scope of Work

The major components of the study have been assessed of the various activities, estimation of assimilative capacity, and supportive capacity leading to the sustainable development of these regions. The assessment of various activities in the study regions includes:

[1] The identifications of various activities, e.g., industrial, commercial, residential, transport, and construction activities.
[2] The prediction of the impact of these activities on the different receiving environments.
[3] Quantification of the waste generation due these activities in terms of air, water, and solid waste.

The main components of work in estimating assimilative capacity are:

[1] Assessment of present level of pollution due to various activities.
[2] Characterization of receiving environment (air, water and land) for predictive modeling.
[3] Delineation of sources of pollution and quantification of pollution loads.
[4] Validation of predictive models using data on present pollution loads and environmental quality status.
[5] Estimation of future pollution loads and pollution levels in the next ten years.
[6] Assessment of congestion levels based on environmental standards for receptors.
[7] Delineation of environmental management plans to prevent and minimize pollution loads on the environment.

1.4 Work Plan

Detailed work plans for monitoring air, water, land, and noise pollutions are described in the following sections.

1.4.1 Air Pollution

Air pollution is one of the leading causes of damages to human health in the world. Air pollutants are released into the atmosphere from a number of sources that alter the composition of the atmosphere and impact the biotic environment. Sources of air pollution are vehicles, industry, residential, and natural sources. The concentration of air pollutants is determined not only by the amount of pollution emitted by pollution sources, but also by the capacity of the atmosphere to absorb or disperse these emissions. Because of variations in meteorological and topographical conditions, air pollution concentrations change geographically and temporally, leading the air pollution pattern to shift with various places and times. For the prevention, control and abatement of air pollution, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981, which has been further emphasized under the Environment (Protection) Act, 1987. In India, air quality monitoring programs have been

carried out under National Air Quality Monitoring Programme (NAMP). The work plan for air quality monitoring in this project is as follows:

- The emission inventory is the first step toward understanding the sources and their strength. Thus, the inventory of point, line, and area sources have been prepared.
- The number of monitoring stations should be as per IS 5182 (Part 14) 2000 "Method for measurement of Air pollution (Part 14 Guidelines for planning the sampling of Atmosphere)". We have collected air samples from 17 air quality monitoring stations in Siltara.
- 17 air monitoring stations have been installed at different locations such as residential, industrial, commercial and kerbside.
- To capture regular variations of sources as well as the meteorological changes, monitoring have conducted over 60-100 sampling days. The number of sampling days at each site for each season are 20 days. Monitoring of meteorological parameters have been carried out simultaneously at each station or minimum at one location. Additional meteorological data for the study period are obtained from IMD.
- The major information about the character of a city has obtained by studying the location of sources, their level, frequency, and duration of emission.
- The monitoring for the air pollutants have been carried out for all three seasons i.e., summer, post/pre-monsoon and winter, to examine meteorological impacts on seasonal variation of air pollutants.
- The detailed land use map on a GIS platform and an updated GIS-based emission inventory of 2 x 2 sq. km grids for pollutants are prepared.
- A dispersion model is developed and validated against measured data.
- The potential approaches for improving air quality are categorized into two categories: short-term and long-term. Low-cost approaches that provide the most benefit has prioritized.
- Pollution load due to various activities for different pollutants have been quantified.
- The cumulative impact of all air pollutants sources has predicted using a suitable mathematical model. Estimation of the assimilative capacity of the region for different pollutants has been carried out.
- A comprehensive road map has been prepared to reduce the pollution level based on the acquired data and the interpretation of the assimilated information. During the formation of the action plan, the sources in neighbouring districts have also been considered.

All selected sampling stations in Siltara are presented here in Table 1.1 and their geographic location in Topo map is shown in Figure 1.2.

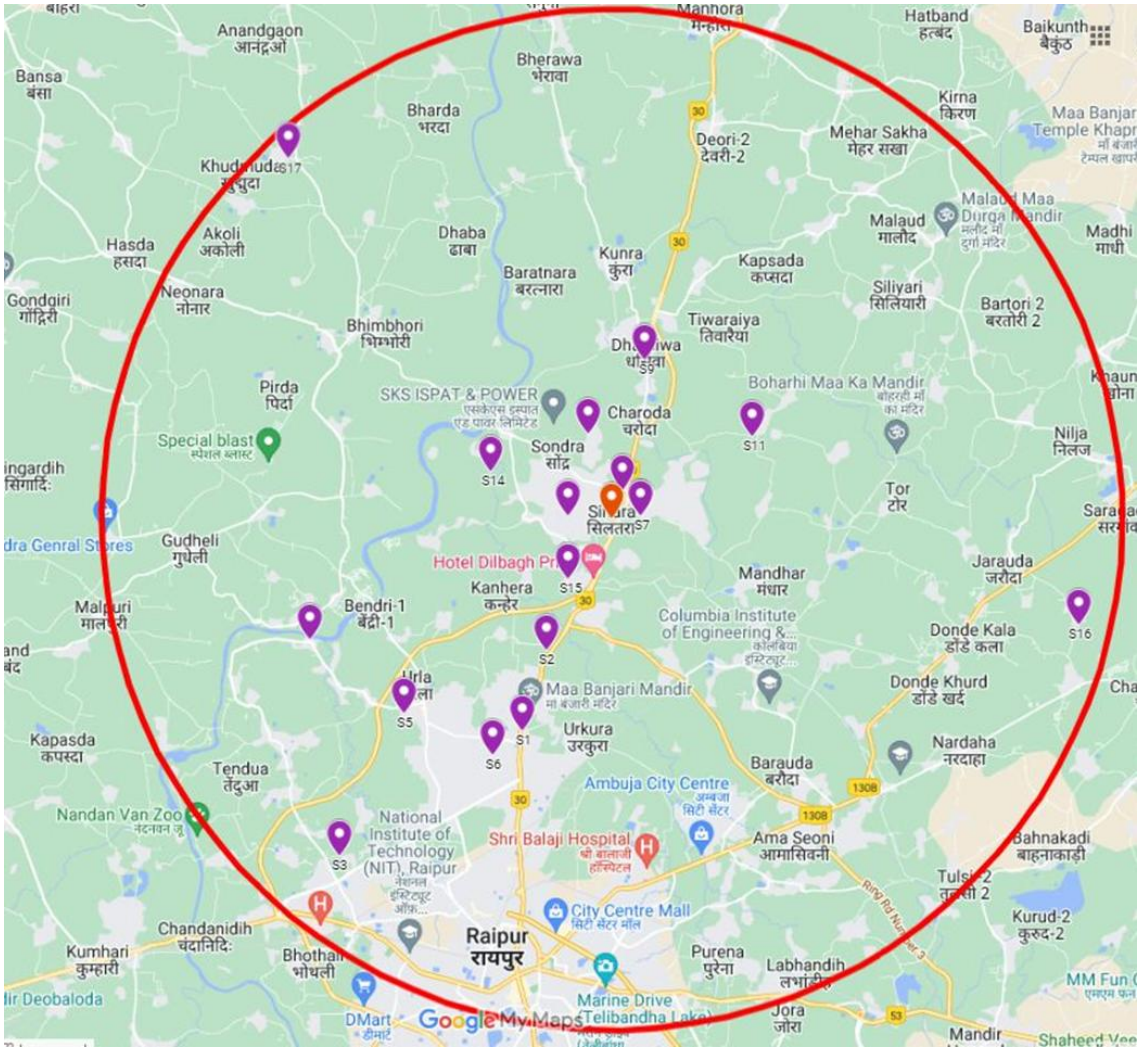


Figure 1.2: Geographical representation of different air sampling stations in Siltara.

Table 1.1: Air Quality Monitoring Stations (17 different places) and type of stations in Siltara are represented in tabular form.

Station Name	Code	Type
Bhanpuri	S01	Industrial
Metal Park	S02	Industrial
Hirapur	S03	Commercial
Kara Panchayat	S04	Mixed
Urla	S05	Industrial
Birgaon	S06	Silent
CIAL- S.D. (Jayaswal Nico Siltara)	S07	Industrial
CSIDC	S08	Industrial
Library (Education lab)	S09	Silent
Mahendra sponge & power Ltd.	S10	Industrial
Mohadi High School	S11	Silent
Nico Jayaswal Industrial Ltd.	S12	Industrial
SKS colony	S13	Industrial
C G Ispat	S14	Industrial
Apollo Pipes	S15	Industrial
Chataud High School	S16	Silent
Shaskiya Madhyamic Vidyalaya Madhaipur	S17	Silent

1.4.2 Water Pollution

Water is the most important but precious resource. In the present situation, the most urgent of the numerous environmental concerns is the quality and quantity of freshwater supplies on the national horizon. The rapid urbanization, industry, and agricultural expansion have a significant influence on the quality and quantity of water in our country. The problem necessitates immediate action by way of drastically enhanced water resources and water quality management systems. For prevention, control, and abatement of water pollution and the maintenance or restoration of the water, Govt. of India has enacted the Water (Prevention and Control of Pollution) Act in 1974. The sampling and analysis of surface and groundwater will be carried out as per the IS 3025 (Part I): 1987 “Methods of sampling and test (Physical and Chemical) for water and wastewater: Part 1 sampling (First Revision)’’ and CPCB guidelines/norms. The work plan for water quality monitoring in the current research is as follows:

- A qualitative and quantitative study on the assessment of water resources have been carried out.

- The water pollutions load due to different existing activities are quantified and characterized.
- The impact of water withdrawal on surface and groundwater sources has measured.
- Assessment of present pollution loads, environmental quality status and predicting the cumulative impacts under different future development scenarios have been carried out.
- On completion of data collection, validation and interpretation of the assimilated information, a detailed road map has been drawn considering all possible measures for water quality improvement.
- Prediction and evaluation of impacts due to wastewater discharges from various activities on receiving water bodies have been carried out.
- Estimation of the assimilative capacity of the water bodies (surface and underground) of the study area/ region for various pollutants vis-à-vis water quality standards has been carried out.
- Delineation of appropriate water environment management plan for the pollution sources has been carried out.
- These management plans have been classified into short and long-term with due priority to low cost measures that give maximum benefits.

1.4.3 Land Pollution

Land pollution is defined as any undesired change in the physical, chemical, or biological qualities of the land that has a negative impact on living biota. The accumulation of solid waste materials on land is the leading cause of the contamination of land. We need secure and reliable waste management to protect human health and the environment. There are four main categories of waste, namely (i) Municipal solid waste, (ii) Industrial waste, (iii) Hazardous waste and (iv) E- waste. Municipal solid waste is non-liquid waste generated by residences, institutions, and small businesses. Industrial waste is the waste generated during the manufacturing of consumer items, mining, agriculture, and the extraction and refining of petroleum. Hazardous waste refers to toxic, chemically reactive, combustible, or corrosive solid waste. It includes everything from paint and household cleaners to medical waste to industrial solvents. E-waste refers to any discarded electrical or electronic equipment. Efforts should be made to decrease solid waste disposal to the land. The following work plans are prepared to monitor the land quality in this investigation:

- The existing land use pattern has been assessed using satellite imagery and field surveys.
- The generation of municipal and industrial solid waste have been quantified.

- The present solid waste disposal procedures and their consequences on the predetermined receiving land environment have been evaluated.
- Soil samples have been collected and analysed for physicochemical features.
- In collaboration with the CECB, the number and placement of monitoring stations have been determined.
- Present pollutant loads and environmental quality, as well as anticipate cumulative consequences under various future growth scenarios are assessed.
- Following the conclusion of data collection, validation, and interpretation of the assimilated data, a complete road plan incorporating all viable steps for improving the land environment have been developed.
- The assimilative capacity of the land environment of the research area for various contaminants in comparison to norms has been estimated.
- Inventory and management plan for municipal, industrial, hazardous and E-waste have been carried out.
- These management plans have been divided into short and long-term categories, with a focus on low-cost, high-benefit measures.

1.4.4 Noise Pollution

Noise pollution is characterized as prolonged exposure to high sound levels that may cause harm to people or other living organisms. The increasing ambient noise levels in public places from various sources, inter-alia, industrial activity, construction activity, firecrackers, sound-producing instruments, loudspeakers, music systems, vehicular horns, and other mechanical devices have deleterious effects on human health and the psychological well-being of the people. Govt. of India has taken measures to monitor and control noise producing and generating sources to maintain the ambient air quality standards in respect of noise under Noise Pollution (Regulation and Control) Rules, 2000. The following work procedures are designed in the current research to monitor noise quality:

- The present noise levels in the research area have been assessed owing to diverse activities, workplaces, residential areas, state/national roads, changing commercial centres, hospitals, schools, and other factors.
- The number and placement of monitoring stations have been determined.
- Prediction and evaluation of impacts due to noise generation by existing and proposed development activities, including transportation has been carried out.

- High-noise-level zones that require mitigating measures have been identified.
- The cumulative effects of all noise pollution sources have been predicted using proper mathematical models.
- These management plans have divided into short and long-term categories, with a focus on low-cost, high-benefit measures.

1.4.5 Detrimental Effects of Particulate Matters [$PM_{2.5}$ and PM_{10}] on Living World

1.4.5.1 Impact of Carbon on Living Ecosystem

Carbonaceous components contribute significant fraction of fine particulate matter ($PM_{2.5}$). Study of organic carbon (OC) and elemental carbon (EC) in $PM_{2.5}$ may lead to better understanding of secondary organic carbon (SOC) formation. Elemental carbon generates predominantly from incomplete combustion process, and it has been used as a tracer for primary organic carbon (POC). Organic carbon includes primary organic carbon, which refers to carbon material emitted in particulate form, and secondary organic carbon, which is formed through atmospheric physical and chemical reactions. Although knowledge about primary organic carbon and secondary organic carbon is important to develop strategies for controlling particulate carbon pollution, quantification has been difficult to accomplish because of the complexity and no available simple analytical method.

Elemental carbon is actually a mixture of graphite like particles and light absorbing organic matters. The surface of EC contains numerous adsorption sites that are capable of enhancing catalytic processes. As the result of its catalytic properties, EC may intervene in some important chemical reactions involving atmospheric sulphur dioxide (SO_2), nitrogen oxides (NO_2), ozone (O_3) and other gaseous species. Carbonaceous species in particles also play an important role in global climate change by affecting radiative forcing. Elemental carbon is currently used as a surrogate for underground mines and fossil fuels like coal, petroleum substances, since it can be accurately measured at low concentrations.

The totals organic carbon is the summation of gaseous organic carbons and particle-phase organic carbon. The large emissions of non-methane organic carbon relative to their relatively modest atmospheric burden imply rapid turnover of these compounds. Atmospheric organics are terminally removed by conversion to carbon monoxide (CO) and carbon dioxide (CO_2), or wet and dry deposition to the surface as aerosols or gases. Organic carbon plays a significant role in natural and anthropogenic emissions, atmospheric reactivity (mainly with OH radicals), and the formation of secondary pollutants, e.g., ozone and secondary organic aerosols. Nascent organic carbon is present mainly in the gas phase, highly reactive in nature, can undergo multi-generation oxidation reactions to form increasingly oxygenated, lower-volatility compounds, some of which will partition into the particle phase to form secondary organic aerosols.

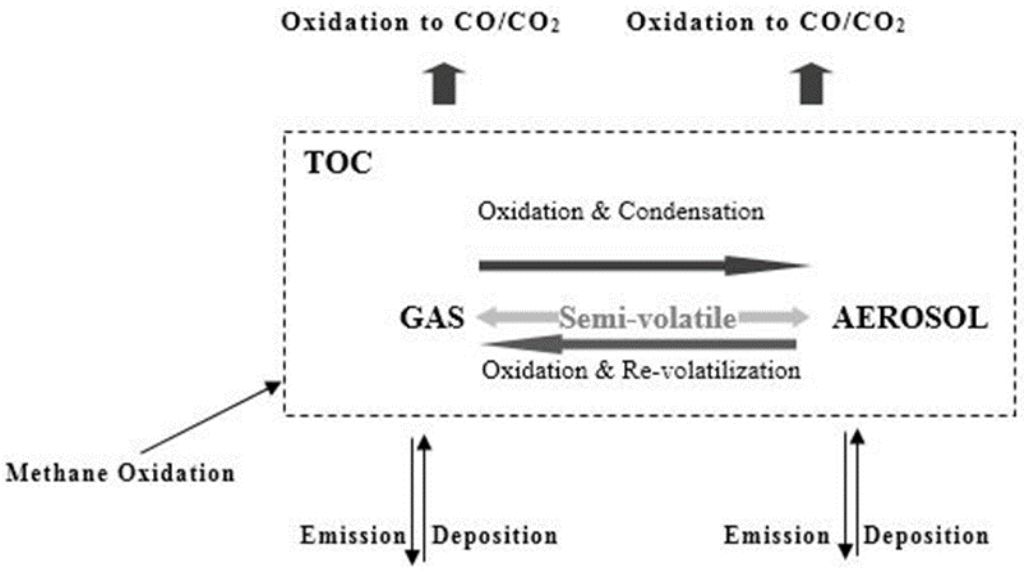


Figure 1.3: Framework for conversion of total organic carbon (TOC) into carbon monoxide (CO) and carbon dioxide (CO_2).

Carbon dioxide (CO_2) is dominated form of the inorganic carbon and methane is the dominated form of organic carbon in the troposphere. Methane is an important greenhouse gas and has a lifetime about 10 years. Organic carbon in the atmosphere, excluding methane, has a much smaller reservoir. However, they can play as a climate forcing agent. Recent studies suggest that organic carbon may undergo chemically mediated phase changes under ambient conditions (Figure 1.3). Higher is the organic carbon burden in the atmosphere higher is the carbon dioxide concentration in the ambient air reveals harmful near living ecosystems. The primary concern with carbon dioxide pollution is it exacerbates the greenhouse effect. By increasing temperature and humidity, carbon dioxide emissions increase the formation of smog (photo-chemical smog), which has adverse effects on human

respiratory health. As the average global temperature rises due greenhouse effect, the polar ice melts. This raises the overall sea level and can cause flooding in coastal areas. Global temperature change helps in the formation of major weather events like, hurricanes, storms. The changing sea temperature also impacts aquatic life and fish populations migrate to colder regions for better natural life, which disturbs local fishermen's economy.

Total carbon (TC), is the sum of all organic carbon (OC) and inorganic or elemental carbon (IC/EC) fractions, are measured by TOR/TOT method after the acid leaching as described in the method section 2.2.11. In aerosol studies, the TOR method has originally been designed for an ambient environmental OC/EC measurement, whereas the TOT method measures mainly sources samples with small influence from ambient solid particles. Atmospheric fine particle matter's ($PM_{2.5}$) carbonaceous fractions are used in air quality, dispersion, climate models that forecast regional and global weather patterns. Analytical technique involves collecting aerosol deposits on quartz-fibre filters and subjecting a filter punch to a two-phase heating process. Volatile and semi-volatile OC evolves by thermal desorption in the He phase and EC evolves following oxidation in the He-Ox phase of analysis.

Carbon evolves at each phase passes over a catalyst bed where it is oxidized to CO_2, then converted to CH_4 and detected by a flame ionization detector (FID). A major drawback of this analysis is during the He phase, certain carbon compounds (presumably OC) pyrolyzed or "char" to form an EC-like material. Both the charred OC and native EC oxidize simultaneously either during the He phase or He-Ox phase analysis. Charred OC and native EC are assumed to possess similar chemical and optical properties. They are differentiated by continuous monitoring the formation and evolution of charred OC throughout the filter media via transmittance (TOT) or reflectance (TOR) using an optical laser (λ = 680 nm). Without this optical correction, charred OC values are measured as EC, thus rendering higher EC values.

1.4.5.2 Volatile Organic Carbons (VOCs)

The presence of volatile organic compounds (VOCs) on the earth can be dated back to the distinct beginnings of life when the appearance of plants and microorganisms led to the conversion of gases (produced by geochemical processes) into organic molecules. Since that time, VOCs have taken part in the carbon cycle by regulating the content of organic compounds in air, soil and water reservoirs. Before humans have entered into the picture, natural cleansing action was able to control the quality and quantity of VOCs in air by dispersion, chemical conversion and deposition processes. Through the complex physical and biogeochemical equilibrium establishment in the biosphere, VOCs become part

of the transmission belt converting carbon dioxide into the organic material and back to inorganic carbon.

The atmosphere contains a variety of organic carbons, including volatile organic compounds (VOCs) such as hydrocarbons, alcohols, carbonyl, aromatics, ethers, etc. as well as low-volatile compounds and aerosols. Many VOCs are reactive and affect the atmospheric oxidative capacity, while organic aerosols are important for air quality, human respiratory health and cloud formation. Volatile organic carbons (VOCs) are mainly four compounds: benzene, ethyl-benzene, xylene and toluene. Gaseous pollutants include ozone (O_3), nitrogen oxides (NOx), carbon monoxide (CO), sulfer dioxide (SO_2), volatile organic compounds and various toxic air pollutants. Ozone generates in ambient air as a result of a chemical reaction between nitrogen oxides and volatile organic compounds in the presence of sunlight ($h\lambda$, where $\lambda \leq 410$ nm):

$$VOC + NO + h\lambda \longrightarrow NO_2 + O_3$$

This reaction also produces many secondary species that from “photochemical smog” provided the first compelling evidence that volatile organic molecules are also able to act as precursors of secondary pollution. High concentration of VOCs may effects on human health. Health effects may include: eye, nose and throat irritation; headaches, loss of coordination and nausea. VOCs may damage to liver, kidney, central nervous system and other adverse effects. CPCB, India prescribes the limit of benzene in ambient air is 5 $\mu g/m^3$. The district Siltara experiences Sub-tropical climate characterized by extreme cold in the winter and extreme hot in summer. The normal annual rainfall for the district is 1506.7 mm with 50-65 rainy days. The annual temperature varies from 10 ºC in winter to 46 ºC in summer. The relative humidity varies from 82% in rainy season to 35-40 % during winter. It is now clear that the widespread use of fossil fuels for energy production and the increased demand for new chemical products to make life more comfortable would unavoidably be associated with a drastic change in the quality of the atmosphere; thus efforts are made to keep VOC emission under control.

The appearance of humans has gradually changed the natural balance. The amount of waste material released by man-made activities has increased to such a point that inevitable side-effects are now felt. The numerous accidents that are occurred revealed the lack of knowledge on the fundamental processes responsible for the dispersion and deposition of gases and aerosols, and the factors influencing meteorology. A group of scientists has been charged with studying the meteorology of the low troposphere and dispersion of gas and aerosols in air. Global estimates indicate that approximately 235 metric tons per year of VOCs are released into the atmosphere by man-made sources. An

additional input of approximately 153 million tons per year of methane comes from man-controlled emissions.

The uncertainty concerning global estimates illustrates well the intrinsic difficulties associated with the evaluation of VOC emission. Modelling studies performed in different scenarios provide emission data and facilitate selection of the best control or abatement strategies for local, religion or global scales. The ideal situation would be real-time knowledge of the amount of each organic component released in a given parcel of air by any existing source. In practice this is virtually impossible because of: (1) The number and type of sources emitting VOCs; (2) The large differences in chemical composition of VOCs; and (3) The possibility that changes in emission occur in space and time. To give an idea of the difficulties have encountered in evaluating VOC emission, it should be recalled that more than 200 different organic compounds can be present in some sources, and their identification and accurate quantification is not even for dedicated laboratories with sophisticated analytical techniques and skilled personnel. Consequently, continuous and accurate knowledge of the amount of each component present in VOC emission sources applies only a limited number of existing sources. For this reason, continuous and semi-continuous instrumentation for evaluating the total or non-methane VOC content in air and emission sources has been developed and used in last two decades (see section 2.2.7).

There are several reasons justifying the monitoring of VOCs in the atmosphere, each of which basically responds to the following needs: (1) assessment of the exposure of the population and other vulnerable receptors to potentially toxic compounds released by emission sources or formed in the atmosphere, (2) creation of data bases to permit the analysis of long-term trends in air pollution or for other research purposes. However, in both cases, the techniques adopted are similar to those used in emission sources, a higher degree of sensitivity, and hence sophistication, is necessary for accurate determination of individual VOCs at the levels existing in air (ppb-ppt). Since the number and type of human diseases associated with VOC emission depend both on the levels of pollution existing in air and on the number of individuals exposed, monitoring networks devote to risk assessment are mainly designed to cover densely populated areas experiencing severe pollution.

1.4.5.3 Effect of Polycyclic Aromatic or Aliphatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs), a class of compounds that consist of two or more fused aromatic rings, are well known class of carcinogens found in the atmosphere, and they have been intensively studied over the past few years. PAHs are a group of organic chemicals characterized by

chemical stability, low volatility, and low solubility in water. PAHs belong to the group of persistent organic pollutants (POPs). These are organic contaminants that are resistant in spontaneous or natural degradation. Some of them are susceptible to dispersion on a global scale because in addition to having environmental persistence, they are “semi-volatile”, i.e. under environmental conditions they move between the atmosphere and the Earth’s surface in repeated, temperature driven cycles of deposition and volatilisation. POPs are truly multimedia contaminants which occur in all parts of the environment: atmosphere, inland, sea waters, sediments, soils and vegetation. They are mainly of anthropogenic origin and have no significant natural sources.

PAHs are formed during the incomplete combustion of organic substances, are widespread in the environment, and typically occur in mixtures. Their production is favoured by an oxygen deficient flame, temperatures in the range of 650 – 900 ºC and fuels which are not highly oxidised. Natural sources of pyrogenic PAH such as volcanic activity and forest fires do not significantly contribute to overall PAH-emission. Anthropogenic sources can be divided into two categories: the combustion materials for energy supply (e.g., coal, oil, gas, wood, etc.) and combustion for waste minimization (e.g., waste incineration). The first category includes stationary sources like industry (mainly coke and carbon production, petroleum processing, aluminium sintering, etc.), residential heating (furnaces, fireplaces and stoves, gas and oil burners), power and heat generation (coal, oil, wood and peat power plants) and mobile sources like cars, lorries, trains, airplanes and sea traffic (gasoline and diesel engines). The second category cover: incineration of municipal and industrial wastes. Other miscellaneous sources contain unregulated fires such as agricultural burning, recreational fires, crematoria, etc., cigarette smoking as well as volatilization from soils, vegetation and other surfaces.

Gaseous and particle-bound PAHs can be transported or travelled over long distances before deposition, and may accumulate in vegetation. This may indirectly cause human exposure to PAHs through respiration, food consumption, and thus may pose a human health threat. Health damage associated with PAHs exposure has been evaluated repeatedly by different health and environmental protection agencies, such as the International Agency for Research on Cancer (IARC), the Environmental Protection Agency (EPA), the National Toxicology Program (NTP), and the Agency for Toxic Substances and Disease Registry (ATSDR). The main sources of human exposure to PAHS are occupation, passive and active smoking, food and water, and water pollution. The total intake of carcinogenic PAHs in the general population has been estimated to be 3 µg/day. One of the most abundant PAH compounds is benzo(a)pyrene [B(a)P] which vary widely in different industrial activities, ranging from 0.1 to 48000 ng/m^3. Levels in water may range from 0 to 13 µg/L B(a)P. Aerosols

associated with transportation, coal combustion and wood burning have higher benzo(a)pyrene concentrations. In contrast, oil combustion is not a major source of PAHs. PAHs are adsorbed onto many types of solid aerosols, including black carbon and road dust, and when they reach the lungs, PAHs can be activated; showing cytotoxic effects and generating DNA adducts. Pollution of air by PAHs is mainly due to the incomplete combustion of wood or fuel used for residential heating and industrial or motor vehicle exhaust.

PAHs entering the atmosphere derived from the combustion and from volatilization. They are present in the ambient air as vapours or adsorbed into airborne particulate matter. Gas to particle partition of PAHs depends on the molecular weight of the compounds, temperature, humidity and precipitation. In general, low-volatile PAHs with > 5 rings, characterized by relatively high temperature of condensation, are adsorbed on the airborne particles. They are classified in the low mobility category of POPs subjected to rapid deposition and retention close to the source. The lower-molecular weight compounds with 2-3 rings, exhibiting low temperatures of condensation, are more abundant in the gas phase. These hydrocarbons (included in the high or moderately high mobility categories), undergo world-wide atmospheric dispersion and preferentially accumulate in polar latitudes. Semi-volatile 4-ring PAHs (like pyrene or phenanthrene) can be found in both phases and their gas to particle partition coefficients are most susceptible to the influence of environmental factors. With high summer temperatures (or in the tropical regions), the concentrations of PAHs in the gas phase increase whereas during winters (or in Arctic regions) particulate phase PAHs dominate. The adsorption of PAHs onto particle phases may be affected not only by temperature but also by humidity as well: it has been found that the gas to particle PAH ratio decreases with increasing humidity. The range of PAH adsorption on the atmospheric sorbents depends also on the quantity of the suspended particulates and their nature (soot, dust, fly-ash, pyrogenic metal oxides, pollens, etc., of different particle size).

PAHs present in the atmosphere are subject to complex physic-chemical reactions and transformations in the atmosphere; dry and wet deposition, photochemical transformations and reactions with other pollutants. The physical mechanism of PAHs loss from the atmosphere is deposition. PAH associated with particulates are subject to gravitational settling and scavenging by precipitation / water vapour with efficiency related to the depository surface type. In absence of light some PAHs may react with molecular oxygen but these reactions appear to be very slow and to represent an insignificant degradation pathway. PAHs have been found to react with atmospheric ozone, with NOx (to produce nitro-PAHs which are potentially more mutagenic and carcinogenic than PAH precursors), with SOx and OH radicals. The persistence of PAHs in the air is strongly influenced

by sunlight, humidity, temperature and precipitation. The half-lives of atmospheric PAHs may vary from hours (sunlight, moderate temperatures and humidity) to days or even weeks (low intensity sunlight, low temperature and low humidity).

1.4.5.4 Presence of Heavy Metals in Particulate Matters

Sources of heavy metals in the ambient air may include industrial production (chemical industry, oil refineries, petrochemical plants, pesticide production, etc.), mining, untreated sewage sludge, and heavy traffic as well as combustion by-products from coal-burning power stations. So chance of emission of heavy metals in ambient air or biosphere is also high. Thus particulate matters with different size are easily coming in open air and local peoples are subjected to it. Control of heavy metals in the mining sector is very difficult but in industrial or ore processing centre it is mandatory. Industries are seriously installing different filters and checking their efficiency in regular basis.

1.4.6 Ambient Air Quality Sampling Schedule

Sampling of ambient PM_{10}, $PM_{2.5}$, SO_2, NO_2, Ammonia and Ozone was carried out with various samplers as per the guidelines of Central Pollution Control Board. PTFE and quartz filters were used. A 6-digit microbalance was used for initial and final gravimetric estimation of the filters. We initially started with 18 site location i.e. R01 to R18 but due to lack of electricity and other reason we have to discard two stations which are R01 and R14. 30 samples each were collected for SO_2, NO_2, NH_3 and, O_3. 40 samples each were collected for PM_{10} and $PM_{2.5}$ for 3 season (winter, summer and pre/post monsoon).

1.4.6.1 Ambient Air Quality: Pre/Post Monsoon

Ambient air quality was monitored at 15 stations in pre/post monsoon season in 2021 and 2022. Air sampling for post monsoon season was collected in October and November months of 2021 and 2022. Pre monsoon sample collected from 15th May to June.

1.4.6.2 Ambient Air Quality: Winter

Ambient air quality was monitored at 15 stations in winter 2021and 2022. Air sampling for winter season was started from December 2021 to February 2022 for another year sample collected from December 2022 to February 2023. (Winter stayed till last February so we took data for two extra month that is January and February).

1.4.6.3 Ambient Air Quality: Summer

Ambient air quality was monitored at 15 stations in summer 2022. Air sampling for summer season was started from 1st Mar 2022 (at least 30 days monitoring with 24 hours frequency, three sites at a time), continued till second week of May and completed before onset of pre monsoon.

CHAPTER-II

AIR ENVIRONMENT

2.1 Introduction

Monitoring air quality is important because polluted air can be bad for our health and the health of the environment. Air quality is measured with the Air Quality Index, or AQI. However, instead of showing changes in the temperature, the AQI is a way of showing changes in the amount of pollution in the air. The monitoring of air pollution is necessary for the health and safety of our society, as knowledge of air pollution levels is required to safeguard people from the harmful effects of air pollution. Accurate measurements of air pollution levels must be taken in order to take informed steps in combating air pollution.

Emission inventory was prepared for the city of Siltara (by identifying sector-wise major and minor sources of PM_{10} and $PM_{2.5}$, their respective activity data i.e. fuel type, fuel usage rate, total fuel usage, human population and number of entities like hotels and restaurants, households, crematoria, ironing vendors, vehicles (with types, vintage, numbers, mileage etc.). The emission inventory exercise aimed to prepare sector-wise PM_{10} and $PM_{2.5}$ based on best available activity database at the time of finalization of study results. It must be noted that emission estimates are as good as the quality of activity data and hence availability of proper activity data will determine the quality of emission estimates. Best efforts have been made to collect most relevant and realistic activity data from various sectors but collected data may not have been equally robust for all sectors or cities due to incomplete database, absence of proper database specifically needed for this type of study, absence of database in a particular region or on a specific aspect and below par willingness of general public, vendors, users and local bodies to spare time to take interviews or share data. Therefore, there may be low to moderate uncertainty in emission estimates. Also, such emission estimates might not remain relevant for several years as activity data is known to change fairly quickly.

2.2 Materials and Methods

2.2.1 Determination of Particulate Matter (PM_{10}) in Ambient Air

Method: Gravimetric Method (IS 5182 Part 23 Method of Measurement of Air Pollution: Respirable Suspended Particulate Matter (PM_{10}) cyclonic flow technique)

2.2.1.1 Principle

Air particles which have in diameter beneath cut-point of conduit are gathered using filter media. Particle weight is enumerated measuring contrast of avoirdupois of filter paper before and after

sampling. The concentration of PM_{10} is deliberated from division of the avoirdupois achieved in filter by air volume.

2.2.1.2 Sampling

Sampler: Pictorial view of Respiratory Dust Sampler (RDS) is shown in Figure 2.1.

Filter Media: Glass fibre filter (25.4 cm × 20.3 cm).

Figure 2.1: Respiratory dust sampler.

2.2.1.3 Working Method

The filter paper is placed in desiccators for 24 hrs to remove moisture and Initial weight is taken before placing it in the jacket. Then faceplate wing nuts are loosened for confiscation of faceplate. Filter is taken out of integument to place on the sustain display. The plate is placed at its slot and the wing screws are tightened to secure the rubber washer against the filter brim. Now RDS instrument is connected to electric supply to run. Immediately initial time and flow rate is measured and noted. After specific time of running [generally 8 hrs] again final time and flow rate is measured from the time meter and flow rate meter and immediately the system is stopped. Now the filter paper as shown in Figure 2.2 is taken out and placed in desiccators to remove moisture and then final weight is taken.

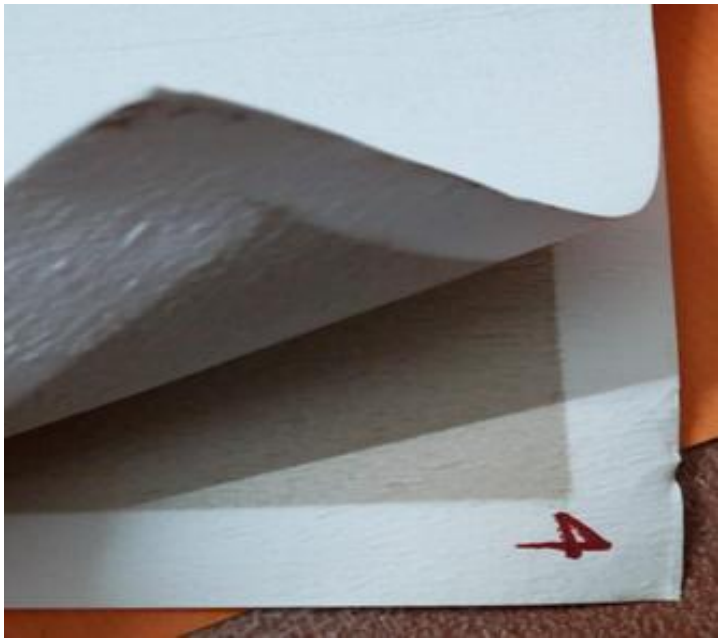


Figure 2.2: Photograph of filter paper of size 25.4 cm × 20.3 cm.

2.1.1.4 Analysis

$$\text{Total Volume of air (V)} = \left[\text{Avg. Flow Rate } \left(\frac{\text{m}^3}{\text{Min}}\right) \times \text{ Time (min)}\right] \text{m}^3 \quad (2.1)$$

$$\text{Avg. Flow Rate} = [\text{Initial flow } + \text{ Final flow}]/2 \quad (2.2)$$

$$\text{C } PM_{10} \text{ (µg/m}^3\text{)} = (W_f - W_i) \text{ x } 106 \text{ / V} \quad (2.3)$$

Where,

CPM_{10} = Concentration of PM_{10}, µg/m^3

W_f = Initial weight of filter in g

W_i = Initial weight of filter in g

10^6 = Conversion of g to µg

V = Volume of air sampled, m^3

2.2.2 Determination of Particulate Matter ($PM_{2.5}$) in Ambient Air

Method: Gravimetric Method

2.2.2.1 Principle

Air particles which have in diameter beneath cut-point of conduit are gathered using filter media. Particle weight is enumerated measuring contrast of avoirdupois of filter paper before and after sampling. Then concentration in ambient air [µg/m^3] is worked out by dividing total mass exceeded by exact volume of air sampled.

2.2.2.2 Sampling

Sampler: Pictorial view of Fine Particulate Sampler (FPS) is shown in Figure 2.3.

Filter Media:

- 47 mm Filter: Teflon membrane
- 46.2 mm effective diameter
- A polypropylene support ring or filters

Figure 2.3: Fine particulate sampler.

2.2.2.3 Working Method

The filter paper is placed in desiccators for 24 hrs to remove moisture and initial weight is taken before placing it in the filter cassette carrier. Then the filter is taken from its protective filter cassette carrier and fixed in slot under WINS impact or. After that the system clock is checked and the memory card is placed in its slot and it is made sure that all automated data to be stored in it. Digital screen shows the data for sampling system which is set as per requirement. When sampling is run, auto diagnosis for all parameters gets finished and the sampler switches sampling mode by own. After specific time of running [generally 8/24 hrs] the system is stopped and the filter is taken out and placed in desiccators to remove moisture and then final weight is taken. All the data except filter paper weight is found from the memory card.

2.2.2.4 Analysis

$$C\ PM_{2.5}\ (\mu g/m^3) = (W_f - W_i)\ x\ 106\ /\ V \qquad (2.4)$$

Where,

C $PM_{2.5}$ = Concentration of $PM_{2.5}$, $\mu g/m^3$

W_f = Initial weight of filter in g

W_i = Initial weight of filter in g

10^6 = Conversion of g to µg

V = Volume of air sampled, m^3

2.2.3 Determination of Sulfur Dioxide (SO_2) Concentration in Air

Method: Modified West and Geake Method (IS 5182 Part 2 Method of Measurement of Air Pollution: Sulphur dioxide)

2.2.3.1 Principle

A. When air is passed through solution of tetrachloro mercurate (TCM) of potassium sulphur dioxide absorbed in it to from a dichloro sulphitomercurate complex.

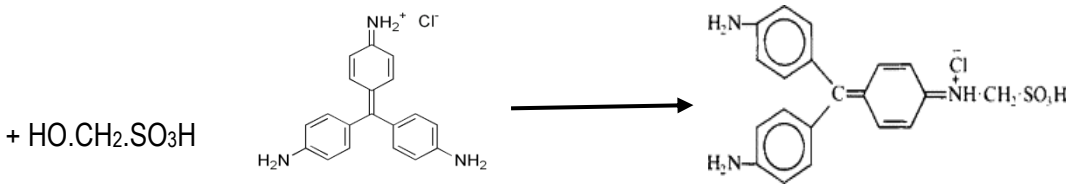
$$HgCl_4^{--} + SO_2 + H_2O \quad \rightarrow \quad HgCl_2.SO_3^{--} + 2Cl^- + 2H^+$$

This complex is stable against strong oxidants like O_3, NO_X. Hence the absorbing solution can be stored for a limited time till analysis.

B. The solution reacts with formaldehyde producing the fiercely colored Hydroxymethyl sulphonic acid.

$$HgCl_2.SO_3^{--} + HCHO + 2H^+ \rightarrow HO.CH_2.SO_3H + HgCl_2$$

C. Pararosaniline hydrochloride is colourless in strong acidic medium. Hydroxymethylsulphonic acid reacts with it to give purple colored pararosaniline methyl sulphonic acid.



D. The absorbance is measured using a spectrophotometer at 560 nm.

2.2.3.2 Calibration

For calibration we used various concentrations of sulphite solution as standard.

2.2.3.3 Preparation of Reagents

1) **Stock Iodine Solution (0.1N)**

   0.635 gm Iodine + 2 gm potassium Iodide is dissolved in distilled water with constant stir until dissolved before poring distilled water to make the volume 50 ml.

   Working Iodine Solution (0.01N)

   25 ml Iodine stock is watered down to 250 ml with distilled water.

2) **Starch Indicator**

   0.5 gm soluble starch and 0.005 gm Mercuric iodide is taken in water to make a paste. Now that is adulterated to 250 ml by distilled water and continuously boiled until clear solution appears.

3) **Primary Standard Potassium Iodate Solution:**

   0.75 gm Potassium iodate is dissolved and distilled water is poured to 250 ml.

4) **Stock Sodium Thiosulphate Solution (0.1N)**:

   6.25 gm Sodium thiosulphate and 0.025 gm Sodium carbonate is disintegrated in 250 ml distilled water.

5) Stock Sulphite Solution:

0.30 gm. Sodium meta-bisulphite is disintegrated in 500 ml distilled water

6) Absorbing Reagent: [0.04 M Potassium Tetrachloro mercurate (TCM)]

a. Mercuric chloride 10.86 gm.
b. EDTA 0.066 gm.
c. Potassium chloride 6.0 gm.

Or Sodium chloride 4.68 gm. are dissolved in water and volume is made to the mark in a 1 litre volumetric flask.

7) Sulphamic Acid (0.6%)

0.3 gm. Sulphamic acid is deliquesced in 50 ml distilled water.

8) Formaldehyde (0.2%)

0.5 ml HCHO (36-38%) is diluted to 100 ml using distilled water.

9) Purified Pararosaniline Stock Solution (0.2% Nominal)

0.5 gm. Pararosaniline (PRA) is solvated in 100 ml distilled water and kept for 48 hours before use.

10) Pararosaniline Working Solution

10 ml stock Pararosaniline is taken in a 250 ml volumetric. 15 ml conc. HCL is added and adulterated to 250 ml using distilled water.

2.2.3.4 Working Method

I) Standardization of Sodium Thiosulphate

50 ml of Potassium iodate solution is taken in 250 ml in iodine-flask. Then 2 gm Potassium Iodide and 10 ml of (1:10) HCl is added to it. After that flask is locked by stopper and allow reacting for 5.0 min. It titrated with stock sodium thiosulphate solution until a pale-yellow colour arrives. Then few drops of starch indicator is added which will give blue colour. Again it is titrated until disappearance of colour.

$$\text{Stock Thiosulphate Solution Concentration} = \frac{w \times 1000 \times 0.1}{v \times 35.67} = \frac{1.97 \times 1000 \times 0.1}{44.2 \times 35.67} = 0.1249 \text{ N}$$

Where,

W = Weight of Potassium Iodate, gm = 1.97 gm

V = Volume of Sodium thiosulphate solution consumed (ml) = 44.2 ml

35.37 = Equivalent wt. of Potassium iodate.

N = Normality of Sodium thiosulphate.

II) Working Sodium thiosulphate Solution (0.01N)

$$N_1V_1 = N_2V_2 \rightarrow V_1 = N_2V_2/N_1 = 0.01 \times 500/0.1249 = 40.032 \text{ ml}$$

Where,

N_1 = Normality stock Sodium thiosulphate Solution = 0.1249N

V_1 = Volume of stock Sodium thiosulphate solution

N_2 = Normality of working Sodium thiosulphate (0.01N)

V_2 = Required volume of working Sodium thiosulphate solution = 500 ml

40 ml stock Thiosulphate taken and thinned to 500 ml using distilled water.

Strength of sulphite is determined by the following steps provided in Table 2.1.

Table 2.1: Determination of sulphite strength

Iodine Flask (250 ml) – A (Blank)	**Iodine Flask (250 ml) – B (Sample)**
Pipette out 50 ml 0.01 N Iodine solution	
25 ml distilled water is put in to it	25 ml Stock Sulphite is put in to it
Flask is stoppered and allowed to react for 5 min.	
Each flask is titrated with working sodium thiosulphate solution (0.01N) till pale yellow color appears	
Few drops of starch is added to get blue color and titrated till color disappears	

Blank iodine flask (V_A) = 40.7 ml

Sample iodine flask (V_B) =12.4 ml

III) Strength of Stock Sulphite Solution

$$C = (V_A\text{-}V_B) \times N \times K/V = (40.7\text{-}12.4) \times 0.01 \times 32000/25 = 362.24 \text{ µg/ml}$$

Where,

C = Concentration of SO_2 (µg/ml)

V_A = Sodium thiosulphate (0.01N) volume needed for Blank (ml)

V_B = Sodium thiosulphate (0.01 N) required for sample (ml)

N = Strength of Sodium thiosulphate solution

K = 32000 Miliequivalent wt. of SO_2/µg

V = Sulphite volume (25 ml)

IV) Working Sulphite Solution

2 ml of stock Sulphite solution is taken and volume is made up to 100 ml with (TCM 0.04 M) Absorbing Reagent.

Strength of Working Sulphite solution: 362.24 x 2/100 = 7.2448 µg/ml

1 ml of this solution = 7.25 µg SO_2/ml

V) Calibration Curve

The preparation steps and absorbance at various concentrations is given in Table 2.2 and 2.3 respectively. Calibration curve and pictorial view of sample prepared for SO_2 is presented in Figure 2.4 and 2.5 respectively.

Table 2.2: Data for SO_2 calibration curve

Volumetric Flask 25 ml	**Blank**	**1**	**2**	**3**	**4**	**5**
Working Sulphite (ml)	0	0.5	1.0	1.5	2.0	3.0
Absorbing Reagents TCM 0.4M (ml)	10	9.5	9	8.5	8	7
Sulphamic acid (ml)	1	1	1	1	1	1
	It is allowed to react to devastate the nitrite coming out from NOx					
Formaldehyde 0.2% (ml)	2	2	2	2	2	2
Working PRA (ml)	2	2	2	2	2	2
	Volume is taken to 25 ml with distilled water and mixed well					

Table 2.3: Absorbance measurement at 560 nm

SO_2 in 25 ml (µg)	0	3.625	7.250	10.875	14.500	21.750
Absorbance	0.0	0.057	0.110	0.167	0.212	0.298

For Figure 2.4: Tangent = 0.0143 and Calibration Factor = 0.0143^{-1} = 69.93

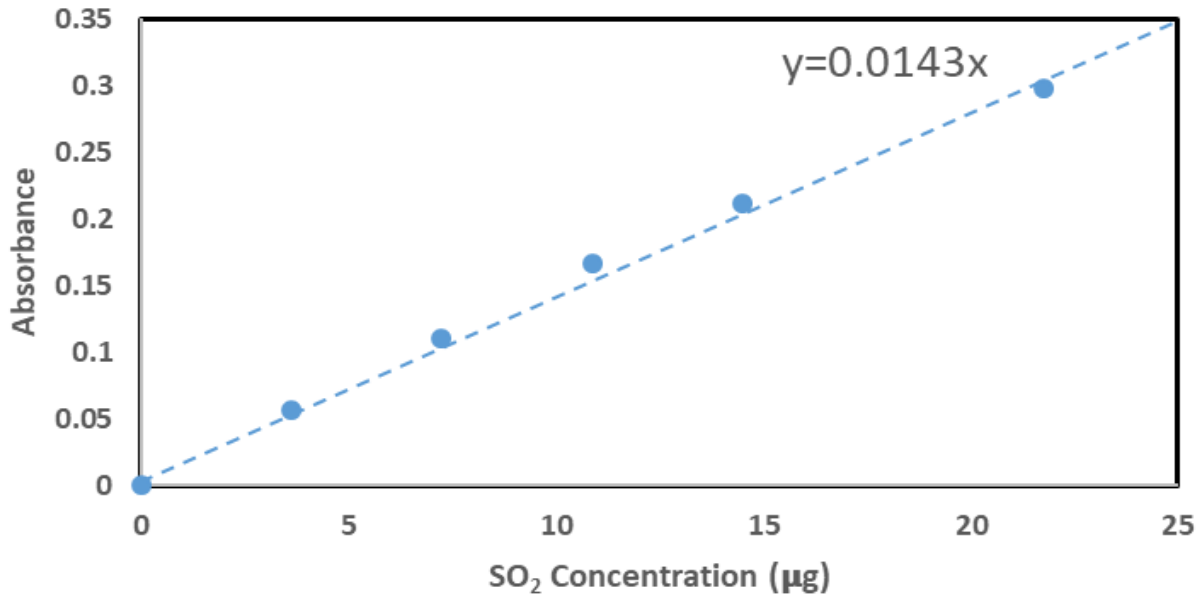


Figure 2.4: Calibration curve of SO_2.

Figure 2.5: Samples of SO_2.

VI) Sampling

Absorbing Reagent**:** [0.04 M Potassium Tetrachloro Mercurate (TCM)]

10.86 gm of Mercuric chloride, 0.066 gm of EDTA

10.86 gm of Potassium chloride, 6.0 gm of sodium chloride are dissolved in water and volume is made to the mark in a 1 litre volumetric flask.

VII) Procedure

30 ml absorbing solution is taken in Impinger as shown in Figure 2.6.and flow rate 1 LPM for 4 hrs. At end solution is measured (if less then filled up to 30 ml with distilled water) and stored in storage bottle.

Total Volume of air = [Avg. Flow Rate (lpm) × Time (min)] L

Flow Rate = Initial Flow (lpm) + Final flow (lpm)/2

Figure 2.6: Photograph of Impinger used for gas samples collection.

VIII) Analysis

These are the following necessary reagents utilized for analysis of SO_2.

Preparation of Solutions:

1. **Sulphamic Acid (0.6%)**
    a. 0.3 gm. Sulphamic acid is dissolved in 50 ml distilled water.
    b. Prepared freshly

2. **Formaldehyde (0.2%)**
    a. 0.5 ml HCHO (36-38%) is diluted to 100 ml using distilled water.
    b. Prepared freshly

3. **Purified Pararosaniline Stock Solution (0.2% Nominal)**

    0.5 gm Pararosaniline (PRA) is solvated in 100 ml distilled water and kept for 48 hours before use.

    Pararosaniline Working Solution

    10 ml stock Pararosaniline is taken in a 250 ml volumetric. 15 ml conc. HCL is added and adulterated to 250 ml using distilled water.

IX) Working Method

10 ml of sample is taken in a 25 ml volumetric flux. Then 1 ml 0.6% Sulphamic acid solution is added to it and mixed well. After 10 minutes 2 ml 0.2% formaldehyde and 2 ml pararosaniline solution are added and mixed well before aquating up to 25 ml using distilled water. Similarly blank is prepared using 10 ml absorbing solution. After 20 minutes absorbance of sample is measured as well as blank using distilled water at optical reference and 560 nm (generally, absorbance is set 0 by blank).

X) Calculation

$$C_{SO_2}\ (\mu g/m^3) = (A_s - A_b) \times CF \times V_s/(V_a \times V_t) \qquad (2.5)$$

Where,

C_{SO_2} = Amount of Sulphur dioxide in air, $\mu g/m^3$
A_s = A for sample
A_b = A for reagent blank
CF = Calibration factor = 69.93
V_a = Air sample volume, m^3= [L/1000]
V_s = Sampling volume= 30 ml
V_t = Sample taken for analysis = 10 ml

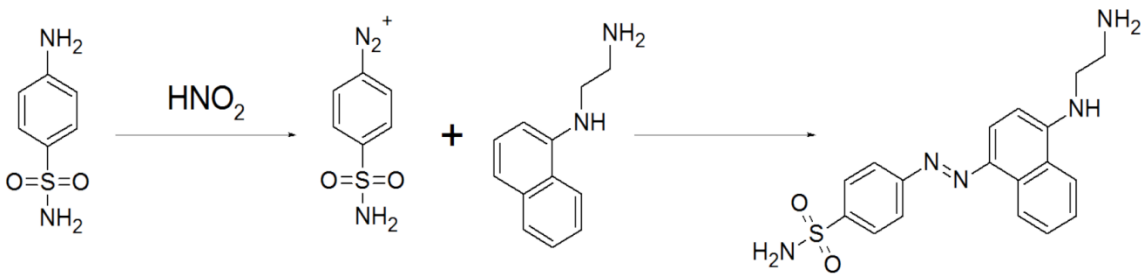
2.2.4 Determination of Nitrogen Dioxide (NO_2) Concentration in Air

Method: Modified Jacob and Hochheiser Method (IS 5182 Part 6 Methods for Measurement of Air Pollution: Oxides of nitrogen)

2.2.4.1 Principle

When air passes through solution of Sodium arsenite and NaOH, NO_x in the air is converted to nitrite. The NO_2^- is converted to nitrous acid when acidified with phosphoric acid.

A. Nitrous acid while reacted with NEDA in presence of Sulphanilamide produces a purple azo dye.



B. The absorbance of azo-dye is taken at 540 nm.

2.2.4.2 Calibration

For calibration we used various concentrations of nitrite solution as standard.

2.1.4.3 Preparation of Reagents

The following reagents are used for analysis.

A. Stock Sodium Nitrite Solution (1000 µg NO_2/ml)

0.75 gm Sodium nitrite is deliquesced in distilled water and maculated to 500 ml by distilled water. It can be used for six weeks, if kept in refrigerator

B. Working Sodium Nitrite Standard Solution

- **Solution A (10.0 µg NO_2/ml):** 1 ml stock Nitrite is watered to 100 ml by distilled water.
- **Solution B (1.0 µg NO_2/ml):** 25 ml Solution A is diluted to 250 ml with absorbing Solution. It is prepared freshly.

C. Hydrogen Peroxide Solution

0.4 ml of Hydrogen peroxide is adulterated to 500 ml by distilled water. It can be stored for 4 weeks while refrigerated and guarded from light.

D. Sulphanilamide Solution

10 gm Sulphanilamide is deliquesced in distilled water. 25 ml 85% Phosphoric acid is added and diluted to 500 ml. This is stable for 4 weeks, while refrigerated.

E. NEDA Solution

0.25 g NEDA is deliquesced in 250 ml distilled water. It can be used for one month, if refrigerated in dark.

2.2.4.4 Calibration Curve

The preparation steps and absorbance at various concentrations is given in Table 2.4 and 2. 5 respectively. Calibration curve and pictorial view of sample prepared for NO_2 is presented in Figure 2.7 and 2.8 respectively.

Table 2.4: NO_2 calibration data

Volumetric Flask 50 ml	**Blank**	**1**	**2**	**3**	**4**	**5**
Working Nitrite (ml)	0	2	4	6	8	10
Absorbing Reagents (ml)	10	8	6	4	2	0
hydrogen peroxide (ml)	1	1	1	1	1	1
Sulphanilamide (ml)	10	10	10	10	10	10
NEDA (ml)	1.4	1.4	1.4	1.4	1.4	1.4
	Volume filled to 50 ml by distilled water and mixed well					

Table 2.5: Absorbance measurement at 540 nm

NO_2 in 50 ml (µg)	0	2	4	6	8	10
Absorbance	0.0	0.038	0.075	0.115	0.152	0.190

For Figure 2.7: Tangent = 0.019 and Calibration Factor = 0.019^{-1} = 52.63

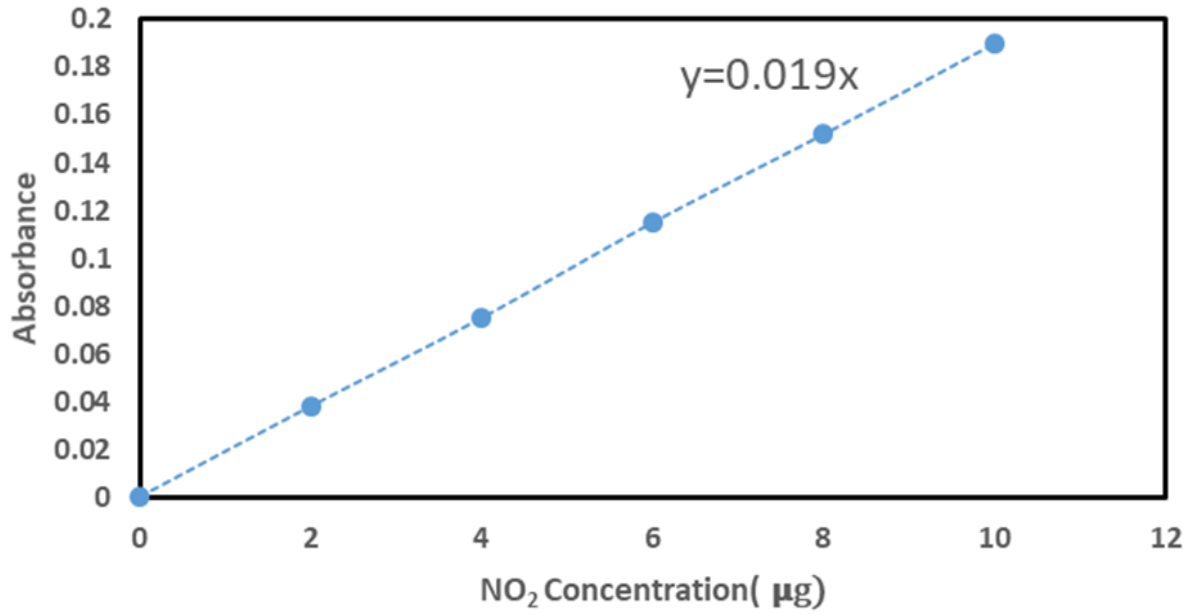


Figure 2.7: Calibration curve of NO_2.

Figure 2.8: Sample of NO_2 for calibration.

2.2.4.5 Sampling

Absorbing solution required for sampling of Nitrogen Dioxide is

a. Sodium hydroxide 4.0 g
b. Sodium arsenite 1.0 g

Are deliquesced in water and aquated to 1 liter using distilled water.

2.2.4.6 Procedure

30 ml absorbing solution is taken in Impinger at flow rate 1 LPM for 4 hrs. At the end solution is measured (if less then filled up to 30 ml with distilled water) and stored in storage bottle.

Total Volume of air = [Avg. Flow Rate (lpm) × Time (min)] L (2.6)

Flow Rate = Initial Flow (lpm) + Final flow (lpm)/2 (2.7)

2.2.4.7 Analysis

The following reagents are used for analysis.

1. **Hydrogen Peroxide Solution**
   0.4 ml Hydrogen peroxide is watered to 500 ml by distilled water. It is used for 4 weeks while refrigerated and covered from light.

2. **Sulphanilamide Solution**
   10 gm of Sulphanilamide is dissolved in distilled water. 25 ml of 85% Phosphoric acid is added and diluted to 500 ml. It can be used for 4 weeks, while refrigerated.

3. **NEDA Solution**
   0.25 gm NEDA is deliquesced in 250 ml distilled water. It can be used for 4 weeks while refrigerated and protected from light.

2.2.4.8 Method in Brief

10 ml sample is taken in 50 ml volumetric flux and 1 ml hydrogen peroxide is added to it. Then 10 ml sulphanilamide solution is added followed by 1.4 ml NEDA solution with thoroughly mixing before filling to 50 ml using distilled water. Similarly a 'Blank' is prepared by using 10 ml absorbing solution. After 10 minutes absorbance of sample is measured as well as of blank as optical reference at 540 nm.

2.1.4.9 Calculation

$$C_{NO_2}(\mu g/m^3) = (A_s - A_b) \times CF \times V_s / (V_a \times V_t \times 0.82) \quad (2.8)$$

Where,

C_{NO_2} = Amount of NO_2, µg/m^3

A_s = Absorbance for sample

A_b = Absorbance for reagent blank

CF = Calibration factor = 52.63

V_a = Air sample volume, m^3 = [L/1000]

V_s = Sampling volume = 30 ml

V_t = Sample taken in analysis = 10 ml

0.82 = Sampling efficiency

2.2.5 Determination of Ammonia (NH_3) Concentration in Air (Indophenols Method)

2.2.5.1 Principle

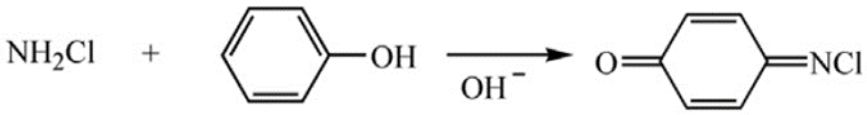
A. When air passes through dilute solution of H_2SO_4, the NH_3 in the air is converted to ammonium sulphate

$$NH_3 + H_2SO_4 + H_3O^+ \rightarrow (NH_4)_2SO_4$$

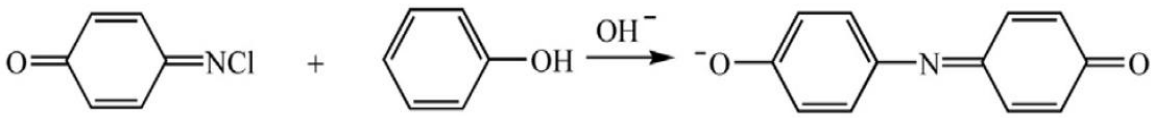
B. The ammonium ion reacts with hypochlorite ion to produce monochloroamine

$$NH_4^+ + ClO^- \rightarrow NH_2Cl + H_2O$$

C. Monochloroamine in presence of hydroxide base reacts with phenol and gives quinone chloramine.



D. Quinone chloramine reacts with another phenol in basic solution which results to blue colored indophenol.



2.2.5.2 Calibration

For calibration we used various concentrations of ammonium ion solution as standard.

2.2.5.3 Preparation of Reagents

A. Sodium nitroprusside

5 gm Sodium nitroprusside is disintegrated in 250 ml distilled water.

B. 6.75 M Sodium hydroxide

135 gm NaOH is deliquesced in distilled water and volume is made upto 500 ml. It is stored in polyethylene bottle.

C. Sodium hypochlorite solution (0.1N)

37 ml of 10% Sodium hypochlorite is deliquesced in distilled water and volume is made to 100 ml using distilled water.

D. Buffer Solution

25 gm of Sodium phosphate ($Na_3PO_4.12H_2O$) and 37 ml 6.75 M NaOH is dissolved in 500 ml of distilled water

E. Working Phenol Solution

1. Phenol 45% v/v: 45 ml is diluted to 100 ml using methanol.
2. 20 ml of 45% Phenol is mixed with 1 ml of 2% Sodium nitroprusside and adulterated to 100 ml using distilled water

F. Working hypochlorite solution

30 ml of N/10 Sodium hypochlorite and 30 ml of 6.75 M Sodium hydroxide is mixed and adulterated to100 ml using distilled water.

G. Absorbing Solution [0.1N Sulphuric Acid]

3 ml of 18 M H_2SO_4 is adulterated to 1000 ml using distilled water.

H. Stock Ammonia Solution (1000 µg NH_3 /ml)

Dissolve 3.18 gm of Ammonium Chloride and make up to 1000 ml with distilled water. Add few drops of Chloroform ($CHCl_3$) for better preservation. This solution can be utilized for two months, if refrigerated and covered from light.

I. **Working Ammonia (10.0µg NH_3/ml)**

10 ml of stock Ammonia Solution is adulterated to 1000 ml using absorbing Solution. It is prepared fresh.

2.2.5.4 Calibration Curve

The preparation steps and absorbance at various concentrations is given in Table 2.6 and 2.7, respectively. Calibration curve and pictorial view of samples prepared for NH_3 is presented in Figure 2.9 and 2.10, respectively.

Table 2.6: NH_3 calibration data

Volumetric Flask 25 ml	**Blank**	**1**	**2**	**3**	**4**	**5**
Working Ammonia (ml)	0	0.25	0.50	1.0	1.5	2.0
Absorbing Reagents (ml)	10	9.75	9.50	9.0	8.5	8.0
Buffer (ml)	2	2	2	2	2	2
Working Phenol (ml)	5	5	5	5	5	5
	5.0 ml Distilled Water is added to each and mixed					
Working Hypochlorite (ml)	2.5	2.5	2.5	2.5	2.5	2.5
	Volume is increased to 25 ml using distilled water and mixed well					

Table 2.7: Absorbance measurement at 630 nm

NH_3 in 25 ml (µg)	0	2.5	5.0	10	15	20
Absorbance	0	0.111	0.223	0.447	0.657	0.895

Figure 2.9: Tangent = 0.0445, Calibration Factor = 0.0445^{-1} = 22.47

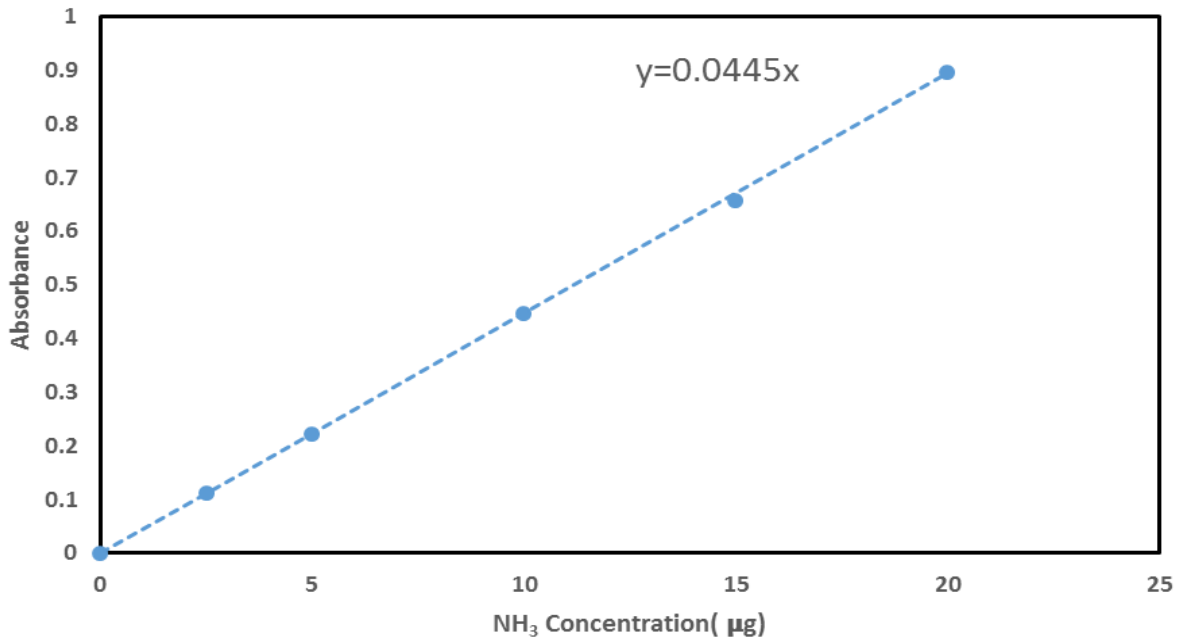


Figure 2.9: Calibration curve of NH_3.

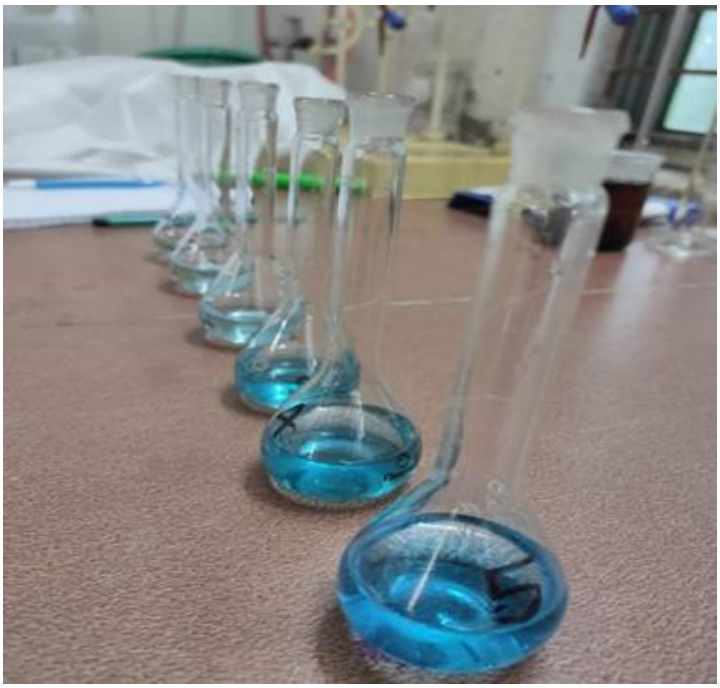


Figure 2.10: Sample of NH_3 for calibration.

2.1.5.5 Sampling

Preparation of absorbing solution [0.1 N Sulphuric acid] used for sampling 3 ml of 18 M Sulphuric acid is adulterated to 1000 ml using distilled water.

2.1.5.6 Procedure

30 ml absorbing solution is taken in impinger at flow rate 2 LPM for 1 hrs. At the end solution is measured (if less then filled up to 30 ml with distilled water) and stored in storage bottle and analysed as soon as possible.

Total Volume of air = [Avg. flow rate (lpm) × Time (min)] L (2.9)

Flow Rate = Initial flow (lpm) + Final flow (lpm)/2 (2.10)

2.2.5.7 Analysis

1. **Sodium Nitroprusside**
    a. 5 gm Sodium nitroprusside is deliquesced in 250 ml distilled water.

2. **6.75 M Sodium Hydroxide**
    a. 135 gm NaOH is deliquesced in distilled water and volume is filled to 500 ml. It is stored in polyethylene bottle.

3. **Sodium Hypochlorite Solution (0.1N)**
    a. 37 ml of 10% Sodium is deliquesced in distilled water and volume is filled to 100 ml with distilled water.

4. **Buffer Solution**
    a. 25 gm of Sodium phosphate ($Na_3PO_4.12H_2O$) and 37 ml 6.75 M NaOH is dissolved in 500 ml distilled water

5. **Working Phenol Solution**
    i. Phenol 45% v/v: 45 ml is diluted to 100 ml using methanol.
    ii. 20 ml of 45% Phenol is mixed with 1 ml of 2% Sodium nitroprusside and adulterated to 100 ml using distilled water.

6. **Working Hypochlorite Solution:** 30 ml of N/10 Sodium hypochlorite and 30 ml of 6.75 M Sodium hydroxide is mixed and adulterated to 100 ml using distilled water.

2.2.5.8 Working Method

10 ml sample is taken in a 25 ml volumetric flux and maintained at 25°C. Then 2 ml buffer solution and 5 ml working phenol is added to it. Approximately 5 ml distilled water is added and thoroughly mixed. Then 2.5 ml of working hypochlorite solution is added with rapid mixing before aquating to 25 ml using

distilled water. Similarly blank is prepared using 10 ml absorbing solution. After 30 minutes absorbance of sample as well as blank is measured as optical reference at 630 nm.

2.2.5.9 Calculation

$$C_{NH_3}\ (\mu g/m^3) = (A_s - A_b) \times CF \times V_s / (V_a \times V_t) \qquad (2.11)$$

Where,

C_{NH_3} = Amount of Ammonia in Air µg/m^3

A_s = Absorbance for sample

A_b = Absorbance for reagent blank

CF = Calibration factor = 22.47

V_a = Air sample volume, m^3 = [L/1000]

V_s = Sampling volume = 30 ml

V_t = Sample taken for analysis = 10 ml

2.2.6 Determination of Ozone (O_3) Concentration in Air

Method: Chemical method

2.1.6.1 Principle

A. Ozone reacts with solution of KI buffering at pH 6.8 for production of Iodine.

$$O_3 + 3KI + H_2O \rightarrow KI_3 + 2KOH + O_2$$

B. The iodine is measured by spectrophotometer by taking the absorption of tri-iodide at 352 nm.

2.2.6.2 Calibration

For calibration we used various concentrations of Iodine solution as standard. Calibration curve for O_3 is presented in Figure 2.11.

2.2.6.3 Preparation of Reagents

A. Stock Iodine Solution (0.025 M I_2 or 0.05 N):

1.588 gm re-sublimed Iodine and 8 gm Potassium Iodide is deliquesced in 250 ml distilled water. It is kept at room temperature one day before use. It is standardized before use against 0.05 N Sodium thiosulphate.

B. Standard Iodine Solution (0.002 N I_2)

2 ml Stock Iodine Solution (0.05N) is diluted to 50 ml by Absorbing Reagent.

C. Working Iodine Solution (1µl O_3 /ml)

5.11 ml Standard Iodine Solution (0.002N) is diluted to 100 ml by Absorbing Reagent before use.

D. Absorbing Medium (1% KI in 0.1 m Phosphate Buffer)

KH_2PO_4	13.6 g
Na_2HPO_4	14.2 g
Or $Na_2HPO_4.12\ H_2O$	35.8 g
KI	10.0 g

Are dissolved in distilled water in sequence in volume is watered to 1000 ml.

2.1.6.4 Calibration Curve

The preparation steps and absorbance at various concentrations is given in Table 2.8 and 2.9 respectively. Calibration curve of samples prepared for O_3 is presented in Figure 2.11.

Table 2.8: O_3 calibration data

Volumetric Flask 10 ml	**Blank**	**1**	**2**	**3**	**4**	**5**
Working Iodine (ml)	0	1	2	4	6	8
Absorbing Reagents (ml)	10	9	8	6	4	2

Table 2.9: Absorbance measurement at 352 nm

O_3 in 25 ml (µl)	0	1	2	4	6	8
Absorbance	0	0.057	0.114	0.224	0.343	0.458

For Figure 2.11: Tangent = 0.057 and Calibration Factor = 0.057^{-1} = 17.54

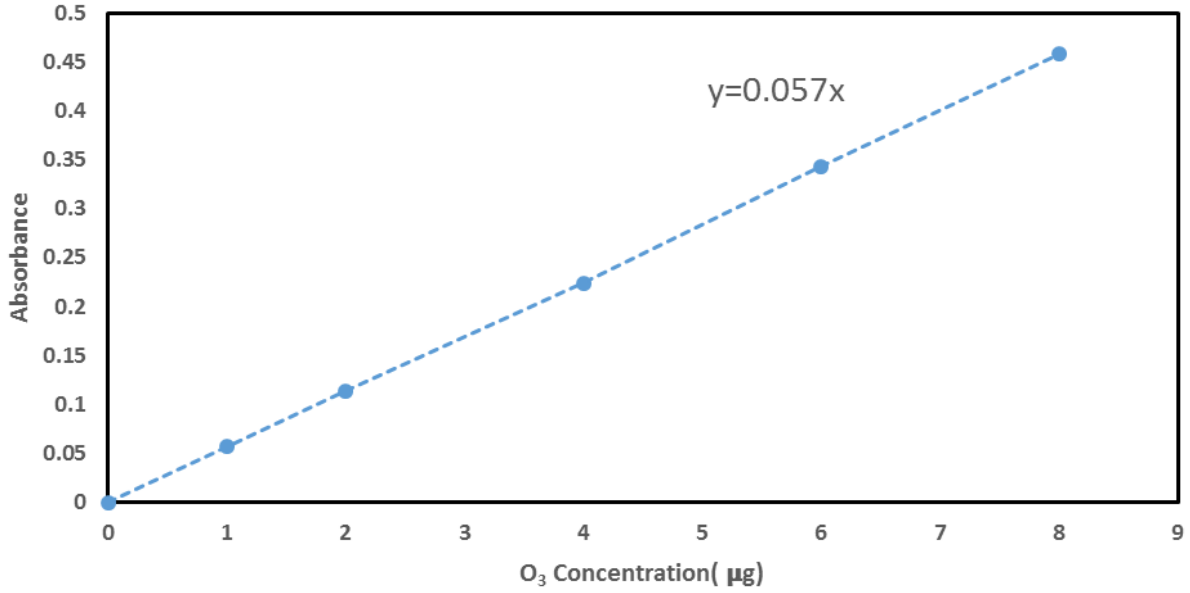


Figure 2.11: Calibration curve of O_3

2.2.6.5 Sampling

Absorbing Medium (1% KI in 0.1 m Phosphate Buffer)

KH_2PO_4	13.6 g
Na_2HPO_4	14.2 g
Or $Na_2HPO_4.12\ H_2O$	35.8 g
KI	10.0 g

Are dissolved in distilled water in sequence in volume is watered to 1000 ml.

2.2.6.6. Procedure

10 ml absorbing solution is taken in Impinger at flow rate 1 LPM for 1 hrs and at the end solution is measured (if less then filled up to 10 ml with distilled water) and stored in storage bottle and analysed as soon as possible.

Total Volume of Air = [Avg. Flow Rate (lpm) × Time (min)] L

Flow Rate = Initial flow (lpm) + Final flow (lpm)/2

2.2.6.7 Analysis

In between 30 to 60 minutes completing sampling, absorbance of blank and sample is measured using distilled water at optical reference 352 nm.

2.1.6.8 Calculation

$$C_{O_3}\ (\mu g/m^3) = (A_s - A_b)\ x\ CF\ x\ 1.962\ x\ V_s\ /\ (V_a\ x\ V_t) \qquad (2.12)$$

Where,

C_{O_3} = Amount of Ozone in Air µg/m^3

A_s = Absorbance for sample

A_b = Absorbance for reagent blank

CF = Calibration factor = 17.54

V_a = Air sample volume, m^3 = [L/1000]

V_s = Sampling volume = 30 ml

V_t = Sample taken for analysis = 10 ml

1.962 = Conversion factor, µl to µg

2.2.7 Measurement of Benzene, Toluene, Ethyl benzene and Xylene (BTEX) in Ambient Air Sample

Method: IS 5182 (Part 11): 2006 method 1 (Active sampling using activated charcoal tubes, desorbed by Carbon disulphide)

2.2.7.1 Working Method

The charcoal tubes are available in different sizes and contain varying amount of activated charcoal. The ambient air is sucked through the tube using a low flow sampler used for collection of BTX sample in a way that results in an enrichment of the relevant substances in the activated charcoal. Desorption of the adsorbed benzene is done using carbon disulphide (CS_2). The substances desorbed in the CS_2 are analysed by capillary gas chromatography (GC). Any suitable gas chromatography with flame ionization detector (FID) with fused silica capillary column (Capillary 624 column) used for analysis, while quantification is performed using the internal/external standard.

2.1.7.2 Sampling

APM 802 VOC Sampler as shown in Figure 2.12 is used for monitoring volatile organic compounds present in the ambient air. It is a battery operated instrument. After an overnight charge the system will operate for a full 8 hour shift allowing comparison with TLV limits for toxic organics present in indoor environments. An adsorption tube (Figure 2.13) is connected at the suction port to trap VOCs present in ambient air. VOCs are collected from ambient air by adsorption on a suitable collection matrix such as activated charcoal (coconut shell, Chromosorb 106) and desorbed for analysis via GC. The APM 802 uses a digital flow-meter to accurately measure low flow rates in the range of 20 to 100 ml/min. Very low flow rates coupled with its feature of collecting a composite sample allows the user to collect a representative sample over several hours without fear of sample loss due to saturation or breakthrough in the adsorbing column.

Figure 2.12: VOC sampler.

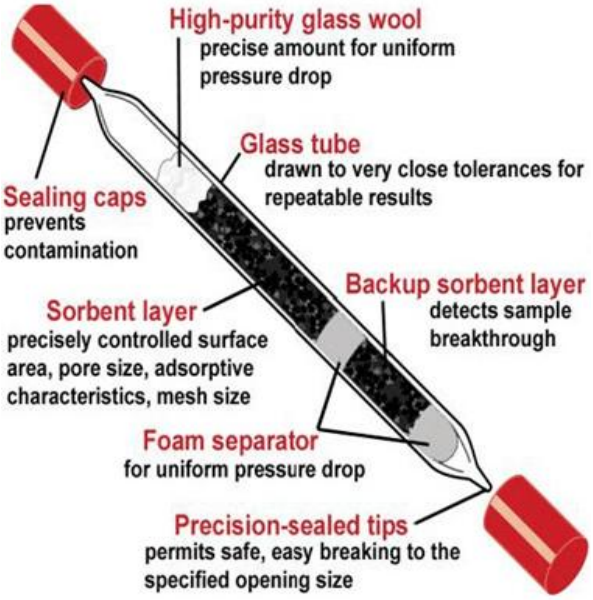


Figure 2.13: Adsorption tube used in VOC sampler.

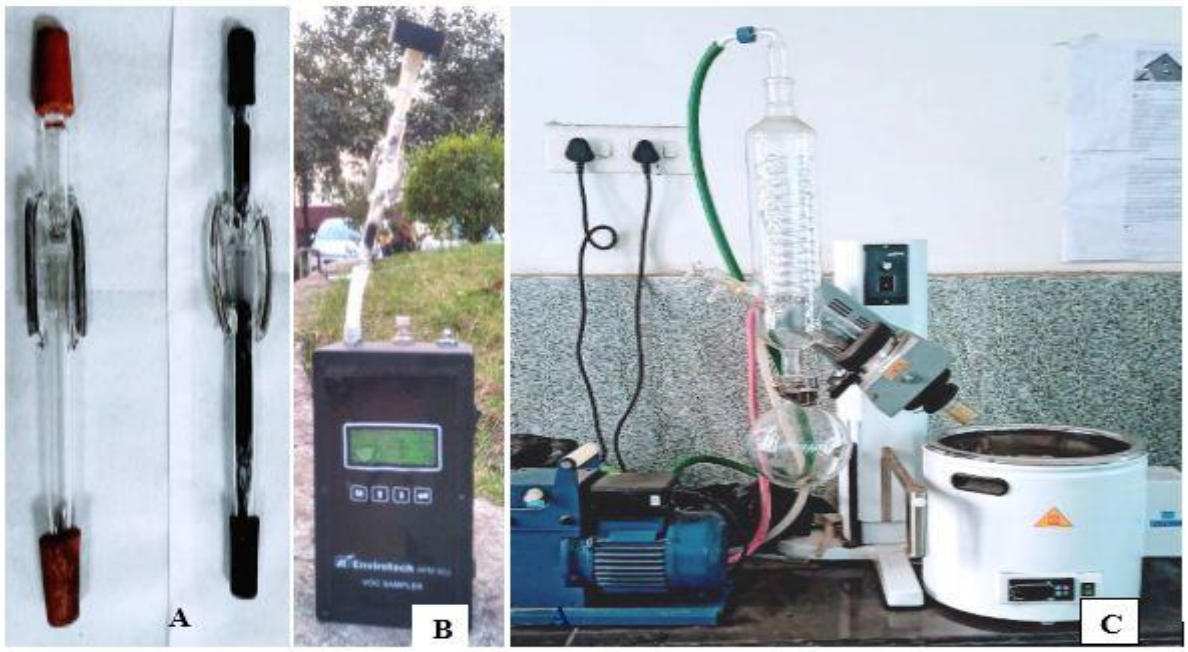


Figure 2.14: [A] Charcoal tube or VOCs sampling tube. Both empty [L.H.S.] and activated charcoal filled [R.H.S.] tubes are shown side by side; [B] VOC sampler and [C] Rotary vacuum evaporator to concentrate the VOC extract in CS_2 solution.

2.2.7.3 Calibration of GC

A mix stock standard solution of benzene, toluene and xylene each was prepared gravimetrically (50 µg/µl) using a micro syringe in the eluting solvent CS_2. Further diluted solutions of concentration range of 10, 1.0, and 0.10 µg/µl with CS_2 were prepared from stock standard in a clean vial (1 ml final volume). Injected immediately 1µl standard solution into the injector of GC directly and plot the curve between the concentration and response (peak area).

2.2.7.4 Sample Analysis

Amount of VOCs absorbed in tube can be converted into mg/m³, by using the formula = (S × t) x 10^6
Where, *S* = sampling rate, in ml/min and *t* = sampling time, in min.

$$\text{Concentration (µg/m}^3\text{) (at ambient condition)} = \frac{C \times V_1 \times 10}{V_2} \times V_3 \qquad (2.13)$$

Where, *C* = amount of compound found injection sample volume from standard curve, in µg/ml; V_1 = total volume of the sample extracted in ml; V_2 = volume of sample extract injected into GC, in µl; and V_3 = volume of air sucked through the tube, in m^3.

2.2.8 Measurement of Benzo(a)Pyrene [BaP] and other Polycyclic Aromatic Hydrocarbons [PAHs] in Ambient Air

Method: BIS method IS 5182 (Part 12): 2004 and USEPA method TO-13 (Solvent Extraction and Gas Chromatography Analysis).

2.2.8.1 Working Method

This method is designed to collect particulate phase PAHs in ambient air and fugitive emissions using capillary gas chromatograph (GC) fitted with flame ionization (FID) detector. Whatman Glass Fibre Filter Paper (EPM – 2000) is exposed with PM_{10} – High Volume Sampler (1.2 m^3/min) for 24 hours (i.e. 3 shifts of 8 hour). Trapped PAHs are extracted in Toluene using ultrasonic bath for about 30 minutes. Extracted samples are filtered (Whatman filter paper no. 41), concentrated (by using Rotary vacuum evaporator), cleaned – up through silica gel (60-80 mesh) column (200-250 mm × 10 mm) and analysed in GC against all standards.

2.2.8.2 Calibration of GC

A PAHs mix Stock Standard solution of 16 compounds including B(a)P (1000 ng/µl) has been prepared in Toluene. Then Working Standard solutions of concentrations 1, 10, 20, 30, 40, 50 ng/µl have also been prepared from Stock Standard solution in Toluene. 1µl of each Working Standard solutions are injected into GC directly and plot the curve between the concentration and peak area. Gas Chromatography fitted with capillary column and FID detector are used for PAH measurement in ambient air is shown in Figure 2.15.

2.2.8.3 Sample Analysis

1 µl of sample was injected into GC and found concentration from standard plot was calculated as follows:

$$\text{Total Sample volume: } V = Q \times T \tag{2.14}$$

Where; Q = Average flow rate of sampling, in m^3/min; T = Sampling time, in min.

$$\text{Concentration of analyte (identified PAH): } C\ (ng/m^3) = (C_s \times V_e) / (V_i \times V_s) \tag{2.15}$$

Where; C_s = Concentration B(a)P or any PAH compound in the extract, V_e = Final volume of extract, V_i = Injected volume and V_s = Volume of air sample, in m^3.

Figure 2.15: Gas Chromatography fitted with capillary column and FID detector used for PAH measurement in ambient air.

2.2.9 Measurement of Heavy Metals in Ambient Air Sample (Atomic Absorption Spectrophotometer and Inductively Coupled Plasma – Mass Spectrometry Methods)

Methods:

1. IS 5182 (Part 23) (Method of Measurement of Air Pollution: PM_{10} cyclonic flow technique),
2. Method IO-2.1 (Sampling of Ambient Air for SPM and PM10 using High Volume (HV) Sampler),
3. Method 501 (Air Sampling and Analysis, 3rd Ed. Lewis Pub. Inc.), and
4. Standard Method- American Public Health Association (APHA), 20th Ed. 1998.

2.2.9.1 Working Method

The method is based on active sampling using PM_{10} High Volume Sampler. A part (1" × 8") of exposed Glass Fiber Filter Paper (EPM – 2000; Sized: 8" × 10") was covered with the extraction solution (3% HNO_3 and 8% HCl) and extraction was carried out by Hot-plate procedure for 30 min. After cooling down, extracted solution was filtered and transferred into a 100 mL volumetric flask. Make the volume with deionized water and shake. This solution was analysed by Atomic Absorption Spectrophotometer

(AAS) and Inductively Coupled Plasma–Mass Spectrophotometer (ICP-MS). Atomic Absorption Spectrophotometer used in measuring heavy metals in ambient air sample is shown in Figure 2.16.

2.2.9.2 Calibration of AAS and ICP-MS

A standard of mixture of different heavy metals was serially diluted to different concentrations in µg/ml. The calibration graph was prepared by plotting absorbance vs. concentrations.

Figure 2.16: Atomic absorption spectrophotometer used in measuring heavy metals in ambient air sample.

2.2.9.3 Calculation

Sample air volume was calculated by using the following formula:

$$V = Q \times t \quad (2.16)$$

Where, V = volume of air in m^3; Q = average sampling rate in m^3/min; t = time in min.

Then metal concentrations were calculated as:

$$C = (M_s - M_b) \times V_s \times F_a/V \times F_t \quad (2.17)$$

Where, C = concentration, µg metal/m^3; M_s = metal concentration in µg/mL; M_b = blank concentration in µg/mL; V_s = total volume of extraction in mL; F_a = total area of exposed filter in cm^2; V = Volume of air samples in m^3 and F_t = area of filter taken for digestion in cm^2.

2.2.10 Measurement of Polyatomic Ions in Ambient Air (Water Extraction and Ion Chromatography Method)

2.2.10.1 Method in Brief

Water soluble ionic species are best analysed by AAS or ICP-MS but poly-atomic ions like, sulphate, nitrate, ammonium and phosphates are typically quantified by ion chromatography (IC). $PM_{2.5}$ Teflon filter papers are refluxed with deionized water for 30 min and filtered. Filter extract is ready for IC analysis.

2.2.10.2 Calibration of IC

A standard of mixture of different ions was serially diluted to different concentrations in µg/ml. The calibration graph was prepared by plotting absorbance vs. concentrations. The Ion-Chromatography instrument used for measuring Poly-atomic ions is shown in Figure 2.17.

Figure 2.17: Ion–chromatography for poly-atomic ions measurement.

2.2.11 Measurement of OC, EC, TC and CC in Ambient Air Sample by TOR/TOT Method

The separation between organic carbons (OC) and elemental carbons (EC) as well as the correction for the pyrolyzed carbons (Pyrol-C) is carried out by both the Thermal-Optical Reflectance (TOR) and Thermal-Optical Transmittance (TOT) methods. A 0.6 cm^2 sized PM_{10} quartz-filter paper sample is placed inside the quartz oven. The oven is then purged with pure helium gas (He) to remove air and a

simultaneous stepped temperature increases to 580 ºC to desorb the organic and carbonate carbons. After initial cooling down, an oxidizing carrier gas (He with 10% O_2) is passed at 500 ºC. In this stage, the EC (elemental carbon) and Pyrol-C (pyrolyzed organic carbon) are oxidized. All types of carbons are then oxidized to CO_2 in a manganese dioxide (MnO_2) oxidizing oven immediately downstream from the desorption oven. Finally, the produced CO_2 is then reduced to CH_4 in a methanator oven and is analyzed by a flame ionization detector (FID).

FID calibration is carried out by using a set of external sucrose in deionised water (200, 100, 40, 20, 10 and 2 µg-C/10 µL) and internal 5% methane in helium standards. The concentrations (C_{air}) of each type of carbon in the ambient air are calculated by dividing the mass loading (m, in µg C) of each type of carbon on a quartz filter by the volume (V_{air}) of air sampled (in m^3). The blank correction value (B) is subtracted from the mass loading for the blank corrected samples. 'B' is zero for uncorrected values.

$$C_{air} = \frac{m-B}{V_{air}} \tag{2.18}$$

2.2.12 Principles of Operation of Stack Monitor

The image of Vayubodhan Stack Sampler VSS1 is shown in Figure 2.18. Flue gases enter the system through the nozzle at the tip of the sampling probe, pass through the filter thimble, where particulate matter (PM) is removed and reach the sampling train/condenser assembly in the cold box section of the instrument panel. Here the gas stream is split into two sections. One section passes at low flow rate (0.5 - 3 LPM) through a train of impingers loaded with suitable reagents to absorb gaseous pollutants, relevant to the emission source while the remaining gas stream bubbles through a distilled water impinger followed by silica gel. On passing through the cold box section, the flue gases cool down, releasing any moisture or condensable present and are scrubbed for corrosive or toxicant fractions. Relatively clean gases then pass through the flow meter and dry gas meter so that the volume of flue gas sampled is measured and are subsequently exhausted into the atmosphere through the vacuum pump. Provision has been made to accurately measure the pressure drop across the thimble and sampling train assembly using a vacuum gauge. Similarly the temperature of the gas stream near the flow meter inlet can be measured by a pyrometer. Hence the flue gas sample volume can be normalized as per gas laws. Change in weight of the filter is used to determine the quantity of dust contained in the flue gas sample while a product of the sampling rate and time is used to measure the sample volume.

The basic properties of various gaseous pollutants are used to absorb them in suitable chemical reagents. A filtered sample of flue gas is bubbled through an impinger train at a metered flow rate. The impingers are filled with appropriate reagents that would absorb the gases of interest from the process being monitored. The system allows two gases to be sampled simultaneously. While the volume of gas sampled is determined from the knowledge of the sampling time and flow rate, concentration of individual pollutants must be determined through an analysis of the absorbers. Since particles in motion have inertia, if the PM concentration in the sample drawn from the stack is to truly represent the PM concentration in the stack, Isokinetic conditions must be maintained at the tip of the sampling probe. Apparently non-isokinetic conditions tend to cause a separation of particles and gas molecules so that both the concentration and size distribution are altered by non-isokinetic sampling. Obviously heavier/larger particles are more likely to be affected with lighter/finer particles behaving almost like gas molecules. A standard S-type pilot tube is used to sense the draft velocity in the stack and the differential pressure produced is measured on a digital manometer. A thermocouple and Digital pyrometer have been provided to measure the stack gas temperature.

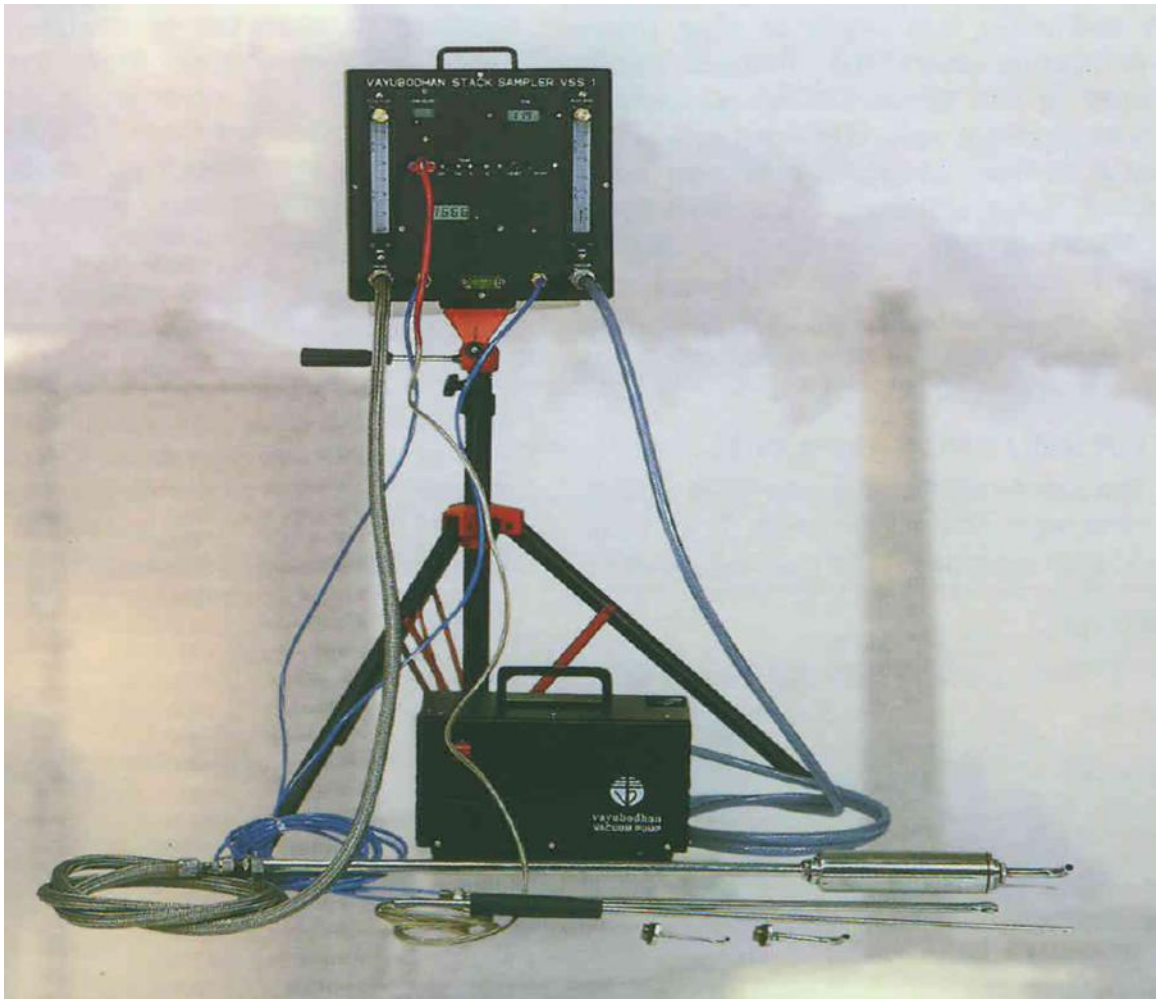


Figure 2.18: Vayubodhan stack sampler.

The stack gas velocity can be determined by using the Equation (2.19). It gives the relation that can be used to determine the stack gas velocity (V) in meter per second. '**S**' type pilot tube along with a digital manometer to measure the velocity of air - stream inside the chimney or duct. The pilot tube inserted into a stack develops a differential pressure proportional to the kinetic head of the smoke-stream. This pressure is measured by the Digital manometer in Water-Gauge (WG) units. The air velocity can be calculated from the relation.

$$V = K\sqrt{(2GHD_m/D_s)} \qquad (2.19)$$

Where, V is the air - velocity in m/sec, K is a pitot calibration constant (tube no: V-872 and k= 0.828), G is gravitational acceleration equal to 9.81 m/sec, H is the height of manometer fluid displacement in meter, D_m is 1000 Kg/m^3 for H_2O, and D_s is the stack - gas density in kg/m^3 (Standard 760 mm of Hg).

The stack gas density is a function of the molecular weight of gases comprising the flue gas, the static pressure inside the duct/chimney and the temperature of flue gas. To be scientifically exact partial fractions of major constituents of the flue gas must be determined to estimate the molecular weight of the flue gas. Similarly the static pressure and stack gas temperature need to be measured before the velocity of smoke stream inside the stack can be determined. However, in most situations the molecular weight of stack gas is practically the same as that of air while the static pressure is close to atmospheric pressure. Hence stack gas density can be approximated by Equation (2.20) without significant errors.

$$\mathrm{Ds} = \frac{\mathrm{Da.Ta}}{\mathrm{Ts}} \qquad (2.20)$$

Where, D_a is the density of atmospheric air at a known temperature T_a and T_s is the temperature of stack gas. Both T_a and T_s are in degrees Kelvin.

D_a = 1.25 kg/m^3, at (273+25) K and Ds = 1.25 x 298/T_s.

Substituting in Equation (2.1) we have:

$$\mathrm{V} = \mathrm{K}\sqrt{\frac{(2 \text{ x } 9.81 \text{ x } 1000 \text{ x H x } \mathrm{T_s})}{(1.25 \text{ x } 298)}}$$

$$= K\sqrt{(0.0527 \text{ x } 1000 \text{ x H x } \mathrm{T_s})}$$

Taking 'h' in millimeters.

$$V = C\sqrt{(\mathrm{h \text{ x } T_s})} \qquad (2.21)$$

Where, $\mathrm{C} = 0.22956 \text{ x K}$

A set of graphs are available where Equation (2.5) has been plotted for various stack temperatures. These can be used for a quick determination of velocity in the field.

Hence, formula for velocity of this kit $= 0.1900\sqrt{(\mathrm{h \text{ x } T_s})}$

Aerodynamic drag along the stack wall, damper vanes, right angle bends, and side entry ducts etc. cause the flow rate across the cross-section of the duct/chimney to vary. Hence air velocity

measurements must be averaged out by determining the velocity at different points across the cross-section.

The velocity measured is used to calculate the Isokinetic sampling rate for a nozzle at known temperature. A set of three nozzles with different diameter is provided. The rate of sampling which would achieve isokinetic conditions for a nozzle of cross sectional area 'A_n' is given by:

$$Qs = V \times A_n \times 60 \times 1000 \quad (2.22)$$

Where, Q_s is the rate of sampling from the stack in LPM; V is stack gas velocity in m/sec and A_n is area of nozzle in m^2.

However, stack gases cool down as they pass through the sampling train and the rate of flow indicated by the flowmeter must correspondingly be corrected as per gas laws. Therefore,

$$Q's = (25 + 273)\frac{Qs}{Ts} \quad (2.23)$$

Where, Q's = Sampling rate indicated by flow meter in LPM after normalization.

In fact there could also be a pressure drop across the sampling train so that for an exact measurement of flow rate, correction for both pressure and temperature must be made. Vayubodhan has designed its sampling train for minimal pressure loss requiring no pressure correction. However, the VSS1 system provides a vacuum gauge and a pyrometer to measure the pressure and temperature of sampled flue gas at the point of flow measurement so that appropriate corrections can be applied by using relation (2.24).

$$Qm = Q's \times \frac{(P'm - Pm)}{Patm} \times \frac{273 + 25}{T'a} \quad (2.24)$$

Where;

Q_m = Actual flow rate in LPM

Q'_s = Sampling rate from stack

P_{atm} = Standard pressure (760 mm of Hg)

P_m = Average mean pressure at the metering point.

P'_m = Barometric pressure at the metering point.

T_s = Stack gas temperature (K)

T'_a = Temperature at metering point (K)

Note: The pressure unit must be consistent.

Since the flow meter of stack gases varies across the cross-section of the duct/chimney, the particulate concentration too is likely to vary and must be sampled at different traverse points with corresponding change in sampling rate to maintain isokinetic conditions. Besides the standard equipment which is supplied to all the customers, some optional accessories have also been developed for special application requirements.

2.2.13 Real Time Air Monitoring

To measure the real time air pollutant in different location within Siltara we have used the device called Aeroqual (500 series). The Series 500 Portable Air Quality Monitor enables accurate real-time surveying of common outdoor pollutants, in an ultra-portable device. Compatible with swappable sensor heads measuring up to 16 different pollutants (sensor heads available separately.) Suitable for use on a range of projects, including wide area air quality surveys, personal exposure monitoring, and short-term fixed monitoring. Using this device we have measured different pollutants which are shown in Figure 2.19.

Methodology:

First turn on the device and then let it stable for few minutes after that choose the pollutant you want to measure and then choose the unit in which you want the data after that it will display the data on screen this data you can write down manually or you can also download it, later using USB device transfer of the data can be done whenever required.

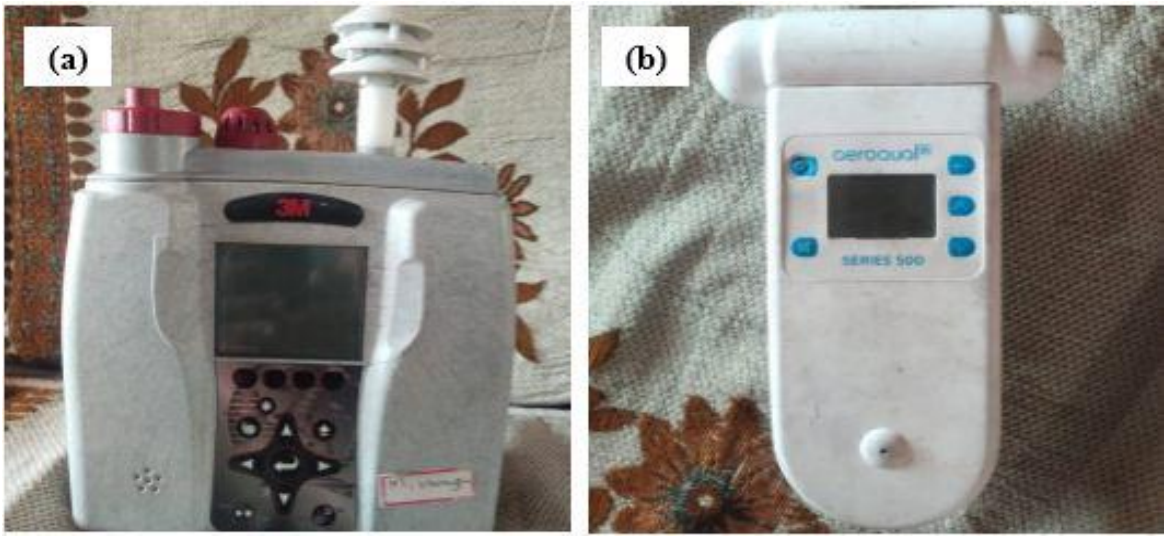


Figure 2.19: Real time air monitoring devices (a) 3M Instrument (b) Aeroqual series 500.

2.2.14 Molecular Markers

According to CPCB, India our targeted physical and chemical components (groups) for the characterization of particulate matters are shown in tabular form as below:

Table 2.10: Chemical compounds considered as toxic compounds for human-health and the way of their quantification.

Components	Sample	Instrument(s)/ Method used
Elements: Na, Mg, Al, Si, P, S, Cl, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Y, Zr, Mo, Pd, Ag, Cr, Cd, In, Sn, Sb, Ba, La, Hg, Ti, and Pb	$PM_{2.5}$ (Teflon filter paper), Water and Soil	ED-XRF, GT-AAS, ICP-MS
Ions: F^-, Cl^-, Br^-, NO_2^-, NO_3^-, SO_4^-, K^+, NH_4^+ and Na^+	$PM_{2.5}$ (Teflon filter paper)	Ion Chromatography with conductivity detector
Carbon (Organic carbon [OC], Elemental carbon [EC] and Carbonate carbon [CC])	PM_{10} (Quartz filter paper)	Thermo-Optical Reflectance (TOR) / Thermo-Optical Transmittance (TOT) method
Alkanes: n- Hentriacontane ($C_{31}H_{64}$), n- Tritriacontane ($C_{33}H_{68}$), n- Pentatriacontane ($C_{35}H_{72}$)	PM_{10} (Quartz filter paper)	Gas Chromatography fitted with a capillary column and FID detector.
Hopans: 22,29,30 – Trisnorneohopane, 17α(H), 21β(H)-29 Norhopane, 17α(H), 21β(H) norhopane	PM_{10} (Quartz filter paper)	Gas Chromatography fitted with a capillary column and FID detector.
Alkanoic acids: Hexadecanamide ($C_{16}H_{33}NO$), Octadecanamide ($C_{18}H_{37}NO$)	PM_{10} (Quartz filter paper)	Gas Chromatography fitted with a capillary column and FID detector.
PAHs: Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo(e)pyrene, Indeno [1,2,3-cd] fluoranthene, Indeno [1,2,3-cd] pyrene, Phenylenepyerene, Picene, Coronene	PM_{10} (Quartz filter paper)	Gas Chromatography fitted with a capillary column and FID detector.
Others: Stigmasterol ($C_{29}H_{48}O$), Levoglucosane ($C_6H_{10}O_5$)	PM_{10} (Quartz filter paper)	Gas Chromatography fitted with a capillary column and FID detector.
Gas: H_2S, CO, HCHO, CO_2	Real time monitoring via device	Aeroqual (500 series) 3M

2.2.15 Air Quality Management Plan

A comprehensive air quality management plan usually has three basic requirements i.e., ambient air quality monitoring, development of emission inventory and source apportionment analysis. In this study, guideline document of CPCB on air quality monitoring, emission inventory and source apportionment study in Indian cities is referred for the purpose (CPCB, 2011). All followed methodologies were given below:

- Sampling of PM_{10} and $PM_{2.5}$ on selected filter papers (made of PTFE / Quartz) by using specific samplers, RDS and others at 17 sampling sites in Siltara. Details of site selection have been given in study area section.
- Sampling (for 24 hrs.) for at least 20 days in each season.
- Calculation of PM emission load for different sampling stations based on primary surveys.
- Analyses of collected samples in PM sampling filter papers (PTFE / Quartz) were undertaken in the following methods described in CPCB methods, 2011.

2.2.16 Air Quality Modelling

Based on measured inputs, air quality modelling simulates how air contaminants react and disperse in the atmosphere to affect quality of ambient air. These models characterize primary contaminants that are emitted directly into the environment as well as, in some circumstances, secondary contaminants depend on inputs from source information such as stack height, emission rates, stack diameter, etc., and meteorological data. Consequently, analysing the effects of various emission sources is crucial using practical air quality prediction algorithms to quantify the consequences of emission sources on quality of ambient air and human health.

Additionally, a crucial component of quality of air management techniques is the prediction of contaminants concentrations using regulatory air quality models, the regulatory model's validation for which it was initially built is crucial before adoption. Before being used to predict and forecast pollutant load, because model performance changes for various scenarios for sources and weather conditions, a model needs to be assessed for the unique features of the surrounding area. For this purpose, different dispersion models are used for other points, lines, areas, and volume sources.

2.2.16.1 Dispersion Modelling

A set of mathematical equations called dispersion modelling is used to mimic the emission and dispersion of air contaminants within the environment. Another way to put it is that it is a mathematical simulation of the physics and chemistry underlying the dispersion, transformation and movement of contaminants in the environment. They are scientific means of predicting ground-level concentrations from any point, line, area, or volume source over a period and location. Urban pollution is caused by the constant expansion of industries and vehicle traffic, creating a need for thorough monitoring quality of air through modelling. Monitoring or measuring pollutant concentration is not always feasible at different sites in a specific area because of the high cost, time constraints, and experimental challenges involved.

2.2.16.2 Gaussian Plume Dispersion Model

Gaussian Plume models have the benefit of responding almost immediately. The computational cost the model is primarily made up of meteorological data pre-processing and the parameterization of turbulence, and calculation is entirely depended on solving a single formula for each receptor site. Depending on how sophisticated these sub-modules are, the runtime model lowers significantly, enabling its use in nearly real-time decision support software. Gaussian models have become a remarkably effective device for controlling quality of air during the recent decades, particularly at the beginning when computers with high-performance were all out of reach for governments and organizations devoted to environment safety because of high expense. Model's prompt responses primarily rely on several assumptions, making them only helpful in certain situations. Schematic diagram of Plume Dispersion is shown in Figure 2.20.

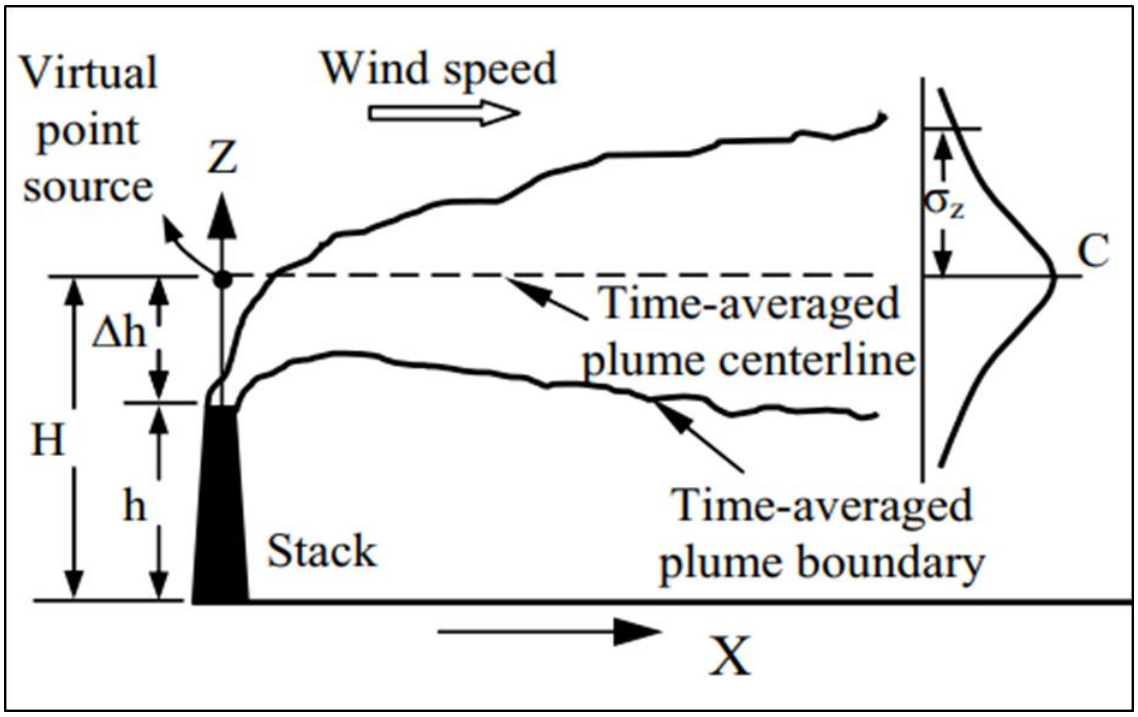


Figure 2.20: Schematic diagram of plume dispersion.

2.2.16.3 Derivation of Gaussian Plume Dispersion Model

The important crucial assumptions include the following:

1. The source has a steady emission rate. i.e., the amount of time the pollutant requires to travel to the receptor is neglected.
2. Plumes are spread only by molecular diffusion.
3. The level of dispersion (diffusion) in the downwind direction is negligible;
4. Over the space modelled, there is homogeneity in the horizontal meteorological conditions.
5. The wind's velocity is constant.
6. The direction of the wind is constant.
7. Temperature remains constant.
8. There is a fixed mixing height.
9. Neither a horizontal nor vertical wind shear.
10. Non-reactive gases or aerosols make up the contaminants.
11. No deposition or surface reaction occurs as a result of the plume's reflection at the surface.
12. Gaussian distributions are used to explain the crosswind and vertical dispersion.

Consider the mass transport within a small volume for derivation of an equation describing the distribution of mass within the plume. The average horizontal wind affects mass transport in the X-

direction. The turbulent motions affect the Y and Z-directional mass transport. On solving the differential equation obtained after applying the mass balance, gives the concentration correlation shown in Equation 2.25.

$$C(x, y, z) = \frac{Q}{2\pi U \sigma_y \sigma_z} \cdot e^{\left[-\left(\frac{y2}{2\sigma_z^2}\right)\right]} \cdot \left\{ e^{\left[-\left(\frac{(z-H)2}{2\sigma_z^2}\right)\right]} + e^{\left[-\left(\frac{(z+H)2}{2\sigma_z^2}\right)\right]} \right\} \quad (2.25)$$

Where;

C (x, y, z) = mean concentration of diffusing substance at a point (x, y, z) [kg/m^3]

x = downwind distance [m]

y = crosswind distance [m]

z = vertical distance above ground [m]

Q = contaminant emission rate [kg/m^3/s]

σ_x = lateral dispersion coefficient function [m]

σ_y = vertical dispersion coefficient function [m]

U = mean wind velocity in downwind direction [m/s]

H = effective stack height [m]

Concentration at ground level (z = 0)

$$C1(x, y, 0) = \frac{Q}{\pi U \sigma_y \sigma_z} \cdot e^{\left[-\left(\frac{y2}{2\sigma_z^2}\right)\right]} \cdot \left\{ e^{\left[-\left(\frac{(H)2}{2\sigma_z^2}\right)\right]} \right\} \quad (2.26)$$

Concentration at ground level (z = 0) on center-line (y = 0)

$$C(x, 0, 0) = \frac{Q}{\pi U \sigma_y \sigma_z} \cdot \left\{ e^{\left[-\left(\frac{H2}{2\sigma_z^2}\right)\right]} \right\} \quad (2.27)$$

Source at ground level (h = 0)

$$C(x, 0, 0) = \frac{Q}{\pi U \sigma_y \sigma_z} \quad (2.28)$$

Maximum concentration: For a given x, the maximum concentration is at the plume centerline and decrease along centerline at a rate dependent on σ_y, σ_z.

Maximum ground level centerline concentration from elevated sources

$$C(x, 0, 0) = \frac{2Q\sigma_z}{\pi U e H^2 \sigma_y} \quad \text{at} \quad \sigma_z = \frac{H}{\sqrt{2}} \quad (2.29)$$

2.2.16.4 Software for Air Dispersion Modelling

Different software for air dispersion modelling:

A) Model Selection

ISC 3

AERMOD – most recent version for Dispersion modelling

SEC3 – Specify reasons for use

B) Dispersion Coefficient

Urban

Rural

Urban or Rural conditions can be determined through the use of an Area Land Use or Population Density analysis.

C) Coordinate System

UTM Coordinates

Local Coordinates

Other

AERMOD requires UTM coordinates be used to define all model objects. Use of an alternative coordinate system requires pre-consultation with the regulatory agency. AERMOD is a steady-state dispersion model because the meteorological conditions are assumed to be consistent during the modelling period of 1-h and horizontally homogenous. However, it accounts for vertical variations of meteorological parameters in the planetary boundary layer. AERMOD can handle multiple point, area and volume sources. It does not differentiate between different pollution types, but algorithms for dry and wet deposition are incorporated. AERMOD uses a large amount of meteorological information, including the surface friction velocity, Deardorff convective velocity, vertical potential temperature gradient, height of the convectively generated boundary layer, height of the mechanically generated boundary layer L, surface roughness length (z_0), wind speed, wind direction, temperature, and the measurement heights of wind and temperature.

2.2.16.5 AERMOD - Air Dispersion Model

In this dispersion model, AERMOD utilizes both a Gaussian and a bi-Gaussian method (USEPA, 2002). A standard Gaussian model is not AERMOD. It operates several algorithms depending on the prominent meteorological features of the region where the predictions are to be produced. AERMOD

produces ambient air pollution concentrations on a daily, monthly, and annual basis. The model can handle a variety of contaminants in both urban and rural environments, as well as on level and difficult terrain.

The software consists of 3 components extensively:

1. AERMOD-(AERMIC-Dispersion-Model),
2. AERMAP- (AERMOD-Terrain Pre-processor)
3. AERMET- (AERMOD-Meteorological-Pre-processor)

2.2.16.6 Procedure for Dispersion Modelling

A. AERMET View: Pre-processing of meteorological data

Pre-processor AERMET View transforms unprocessed meteorological data into the format needed by AERMOD (version 10.2.1). Chhattisgarh Environment Conservation Board (CECB) provided the raw meteorological data from January 2022 to December 2022. AERMET View imports a datasheet providing meteorological parameters for one hour on average for the given period, including temperature, cloud coverage, velocity of wind, relative humidity, direction of wind. This file is converted to Samson format, and the software generates surface properties for an area with deciduous forests/cultivated region, including albedo, the Bowen ratio, and surface roughness. The upper air estimator of AERMET (for UTC +5 Islamabad time zone) generates upper air data by using input meteorological characteristics, including temperature, humidity, wind, and cloud cover. These characteristics help determine sensible heat flux, which is then utilized to calculate the shear stress caused by wind speed and turbulence. Surface shear stress is used to compute the night time boundary layer, whereas sensible heat flux is used to calculate the mixing height. Two output files surface meteorological file (*.sfc format file) and profile meteorological file (*.pfl format file) are generated once the AERMET model has been assembled.

B. AERMAP: Terrain pre-processing

Irregular elevations are a part of complex terrain modelling. Therefore, pre-processing is carried out for terrain that is raised and flat. Shuttle Radar Topography Mission (SRTM), National Elevation Dataset (NED) and Digital Elevation Model (DEM) are just a few of the convenient terrain data sources offered by Web GIS. Terrain data used for the present modelling process is obtained from SRTM 30. The Source output file and the receptor output

file, which are utilized as input for the Source and Receptor pathways, respectively, are provided by AERMAP in a similar way to that of AERMET. As a result, a correlation between plume rise and terrain characteristics is created. After running AERMAP, the topographic map is obtained and superimposed on the model's base map.

C. Compiling AERMOD

The following dispersion modelling procedure is used for the Siltara location after pre-processing data from AERMET and AERMAP:

a. Tile maps from the Lakes satellite have been used to import the map of the study region.
b. The base map imported from the Lakes satellite covers a specific region in the present modelling.
c. Control paths are chosen for non-default regulatory alternatives without gas deposition, exponential decay, or growing downwash. Pollutant has been chosen for the modelling with time weighted average utilized to calculate the concentration of pollutant.
d. Point source is located in the given area by using function in the left bar of AERMOD interface.
e. Also, modelling is only carried out using consistent polar grid receptors covering the full map region. The AERMAP receptor output file is used to import the receptor elevations.
f. Finally, AERMET results are imported into the meteorological system. Options for default wind speed are selected.
g. Following the input of all the data, AERMOD is constructed.

The flowchart below (Figure 2.21) shows the methods used for dispersion modelling and monitoring in this study.

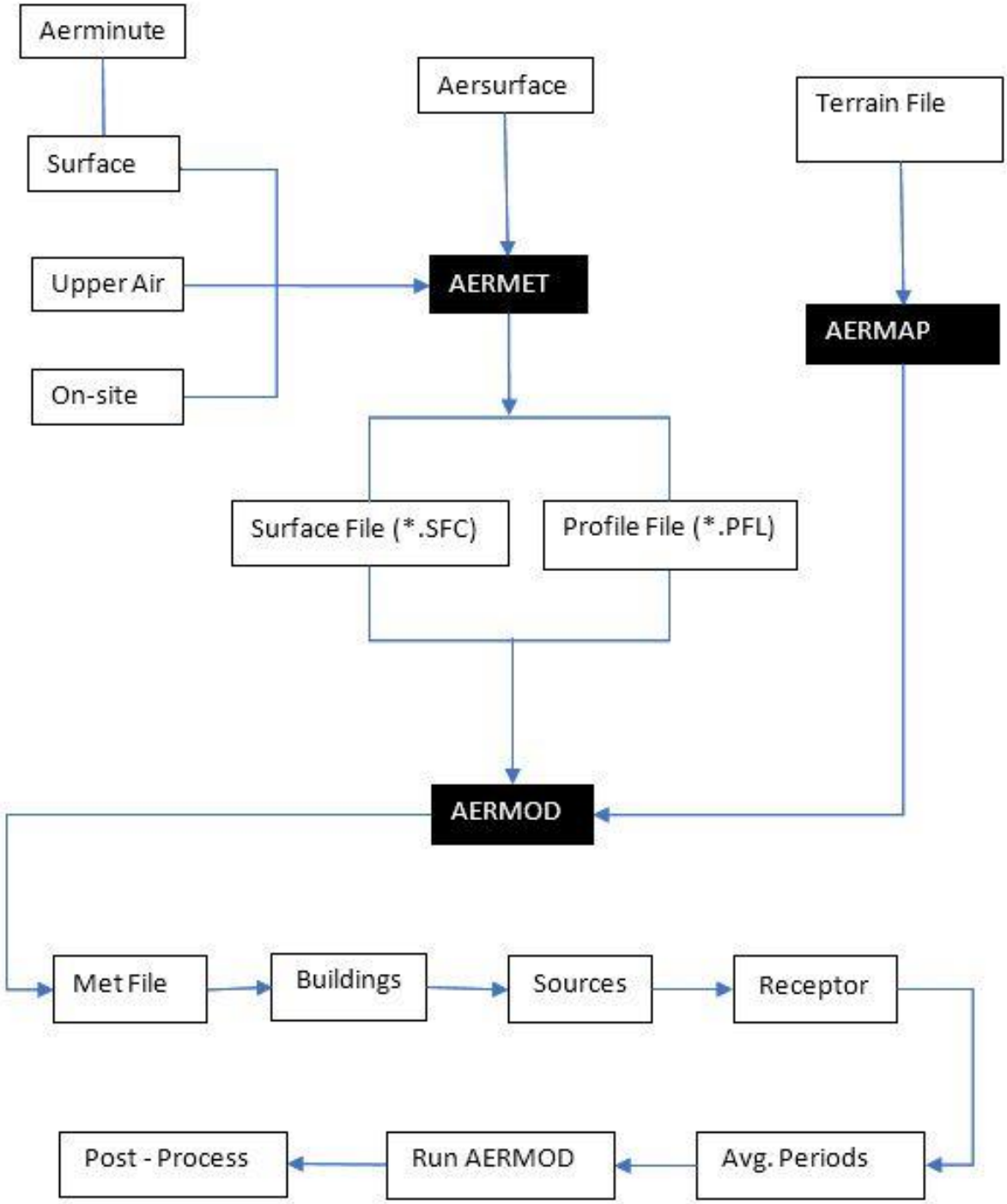


Figure 2.21: Flowchart for input parameters for AERMOD.

2.2.17 Receptor Modelling and Source Apportionment Analysis

The principle of receptor models is the mass conservation can be assumed and a mass balance analysis can be used to identify and apportion sources of airborne particulate matter in the atmosphere. Receptor models use monitored pollutant concentration and some information about the chemical composition of air quality profile of study area. These models are retrospective; they can only assess the impacts of monitored air pollution. This model is robust and relatively easy to apply and based on the mass conservation of individual chemical species or markers viz. organic compounds, elements and ions. These concentrations and compositions at 'receptor' are expressed in linear sum of products of source profile abundances and their contributions. The proportions must be different for each of the source emissions and changes between source and receptor proportions are negligible or can be approximated. Presently, for mass balance analysis and source identification at receptors, a U.S. E.P.A-CMB version 8.2 Model is used globally. The measured data is apportioned to source profiles using effective variance least squares algorithm. A mass balance equation is there to account for all 'm' chemical species in the 'n' samples as contributions from 'p' independent sources:

$$C_i = \sum_j m_j X_{ij} a_{ij} \quad i = 1, 2, \ldots I \tag{2.42}$$

Where; 'C_i' is the concentration of the 'i^{th}' - species measured at a receptor site, 'X_{ij}' is the 'i^{th}'- elemental concentration measured in the 'j^{th}'- sample. 'a_{ij}' is the adjustment parameter for any gain or loss of species 'i' between the source and receptor.

The term is assumed to be unity for most of the chemical species. (EPA Website: https://www3.epa.gov/scram001/receptor_cmb.htm).

There are some assumptions for CMB model:

a) Compositions of source emissions are constant over the period of ambient and source sampling,
b) Chemical species do not react with each other (i.e., they add linearly),
c) All sources with a potential for contributing to the receptor have been identified and have had their emissions characterized,
d) The number of sources or source categories is less than or equal to the number of species,
e) The source profiles are linearly independent of each other, and
f) Measurement uncertainties are random, uncorrelated, and normally distributed.

Following approach has been used for CMB modelling:

a) Identification of the contributing sources to the monitoring sites.
b) Selection of chemical species to be included in the calculation. Following species are analysed from the PM_{10} and $PM_{2.5}$ samples collected at respective sites in the summer and winter seasons.
    1. Carbon fractions based on temperature (Organic Carbon and Elemental Carbon) using Thermal Optical Reflectance (TOR) Carbon Analyser,
    2. Ions (Anions – fluoride, chloride, bromide, sulphate, nitrate and Cations – sodium, ammonium, potassium) using Ion-chromatography.
    3. Elements (Cu, Fe, Ni, Zn, Cd, Pb and As) using Atomic Absorption Spectrophotometer (AAS) and Inductively Coupled Plasma – Mass Spectrophotometer (ICP-MS).
    4. A few study-specific analyses like the presence of heavy metals in both the soil as well as water has been carried out by using X-ray Fluorescence Spectrometer and Atomic Absorption Spectrophotometer (AAS) or Inductively Coupled Plasma – Mass Spectrophotometer (ICP-MS), respectively.
c) Estimation of both the ambient concentrations and uncertainty of selected chemical species from the particulate matter has been collected at respective sites.
d) Solution of the chemical mass balance equations has obtained through CMB-8.2 receptor model by using the chemical composition results of 24 hr daily samples collected at all sites and sources profiles of applicable sources at respective sites as an input.
e) Contributing sources has been identified by averaging the contribution from sources observed based on daily samples across the monitoring period.

Different air pollutants, which are described above, are quantified and arranged in a tabular form for CMB modelling. 17 sampling stations of Siltara are categorized as Residential, Commercial, Industrial, Traffic, Agricultural, Mixed and Silent. The sources which have been taken for this analysis are: (i) Waste Burning (uncontrolled), (ii) Industrial Emissions, (iii) Road Dust, (iv) Construction, (v) Domestic Fuels Combustion, (vi) Power Plant, (vii) Crematoria (viii) Bric Kilns and (ix) Transports Emissions. In below a flow diagram (Figure 2.22) has been drawn for clear understating of sampling stations categories and different sources of pollutants are found there in:

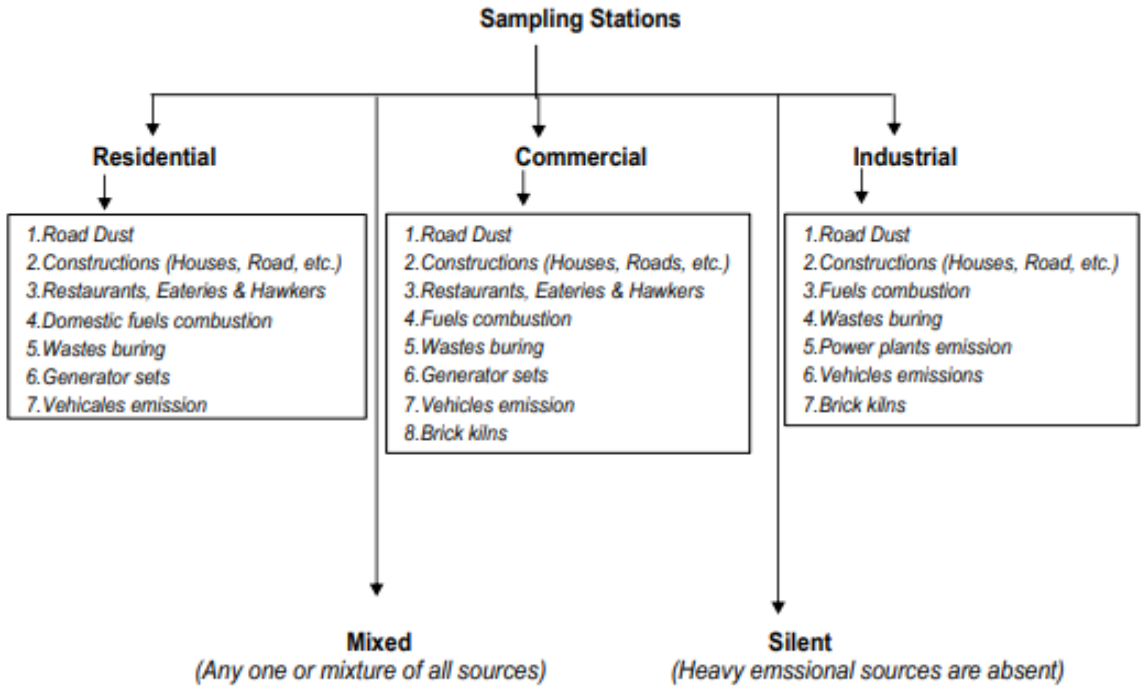


Figure 2.22: Types of different sampling stations and different sources of pollution may present there.

Performance of CMB analysis usually evaluated by six parameters: (i) T statistics (ratio of source contribution to standard error and this value should be > 2.0); (ii) R^2 (fraction of variance between measured and species concentrations should be between o to 1; (iii) correlation coefficient (> 0.6); (iv) χ^2 (weighed sum of squares of differences between estimated and measured fitting markers and should be < 4); (v) % mass (predicted / measured mass concentration percent value and it should be between (60 – 120%) and (vi) R/U ratio (ratio of residual to uncertainty and should be < 2).

2.3. Results and Discussion

2.3.1 Assembling of Air Quality Monitoring Stations for Measurement of Air Pollution

Following 17 sampling stations has been identified in Siltara industrial cluster for air sampling.

Table 2.11: Air sampling stations at Siltara

Location ID	Location Name	Latitude (°N) and Longitude (°E)	Zone	Station View
S01	Bhanpuri	21.307851, 81.636708	Industrial	
S02	Metal Park	21.329439, 81.643406	Industrial	

S03	Hirapur	21.275095, 81.58474	Commercial	
S04	Kara Panchayat	21.33213423, 81.57644771	Mixed	
S05	Urla	21.312755, 81.602945	Industrial	

S06	Birgaon	21.301593, 81.62837	Silent	
S07	CIAL- S.D. (Jayaswal Nico Siltara)	21.364876, 81.67029	Industrial	
S08	CSIDC	21.37149443, 81.66505157	Industrial	

S09	Library (Education lab)	21.406065, 81.671389	Silent	
S10	Mahendra Sponge & Power Ltd.	21.364942, 81.649672	Industrial	
S11	Mohadi High School	21.386073, 81.70198	Silent	

S12	Nico Jayaswal Industrial Ltd.	21.364828, 81.670312	Industrial	
S13	SKS colony	21.386583, 81.655517	Industrial	
S14	C G ISPAT	21.376821, 81.627804	Industrial	

S15	APOLLO PIPES	21.34807649 81.64975941	Industrial	
S16	Chataud High School	21.33602768 81.79454225	Silent	
S17	Shaskiya Madhyamic Vidyalaya Madhaipur	21.45943463 81.57029993	Silent	

2.3.2 Ambient Air Monitoring Stations Details

Table 2.12: Observed sources near sampling site.

Location ID	Location Name	Coordinates	Station Classification	Observed Sources
S01	Bhanpuri	21.307851° N 81.636708° E	Industrial	Restaurant, Loha pvt Ltd., Petrol Pumps, Lathe works, Hotel
S02	Metal park	21.329439° N 81.643406° E	Industrial	Sarna Petrol Pump, Bharat petroleum, Hotel, Main Road
S03	Hirapur	21.275095° N 81.58474° E	Commercial	Plywood and Steel Industry, Mettalic work
S04	Kara Panchayat	21.33213423° N 81.57644771° E	Mixed	Shopping mall, Recidential area, Local shops
S05	Urla	21.312755° N 81.602945° E	Industrial	Restaurant, Srinivas Ferro Alloy
S06	Birgaon	21.301593° N 81.62837° E	Silent	School, Offices, Restaurant
S07	Jayaswal Nico Siltara	21.25744283° N 81.5772757° E	Industrial	Ispat Power Plant, Mineral factory, Hotel, Restaurant, Purnima Ispat, Simron Carbon And Chemical, Oxygen Power Plant, Apollo Pipes
S08	CSIDC	21.23767177° N 81.63747553° E	Industrial	Bajaj Steel, Restorants, Mahaluxmi Industry, Ador Welding, Petrol Pump, Godawari Power Plant, Wire Industry, Jaiswal Neco Industry. Electronics
S09	Library (Education lab)	21.23566682° N 81.59940184° E	Silent	Computer Service, School, Petrol Pump, Furniture shop
S10	Mahendra Sponge & Power Ltd.	21.260606° N 81.655514° E	Industrial	Many industries, National highway within 500 m
S11	Mohadi high School	21.27922° N 81.637126° E	Silent	School, Commercial activity Market within 500m, Hospital construction site nearby, Petrol pump near 1km
S12	Nico Jayaswal Industrial Ltd.	21.216184° N 81.631004° E	Industral	Industries, Main road within 400m, Water filter plant, Residential area

S13	SKS Colony	21.26656833° N 81.59484166° E	Industrial	Industries, Commercial activity roadside food stall present within 500m, Police station, Hostels, Pond nearby
S14	CG Ispat	21.28485769° N 81.60492616° E	Industrial	Industries, Market shops
S15	Apollo Pipes	21.15474378° N 81.55273462° E	Industrial	Industries, 1-2 kirana store present near by temple
S16	Chataud High School	21.16882848° N 81.72500002° E	Silent	School, Traffic area Main road in 100m, Offices, Nearby highway
S17	Shaskiya M M Vidyalaya (Khudmud)	21.24967416° N 81.49626955° E	Silent	School, Shops, Highway within 2 km

2.3.3 Graphical Representation Ambient Air Monitoring Data

2.3.3.1 PM_{10} Variation in Different Season

Air sample collected from 17 stations and the highest PM level were found in S08, S10, S13, and S16 as the main reason could be the nearby industries and transport sources. In pre/post monsoon season the temperature is low and for the post monsoon season as monsoon season has already passed so most of the pollutants has already wiped out so atmosphere is little bit clear than the summer season but still we have got some values in station that mainly because of traffic in nearby area and the industries or ongoing construction taking place nearby these areas. Winter season has the most pollutant and the main reason is in winter people burn more coal, wood other material so generation of pollutant matter in air is more. The concentration of PM_{10} in winter, summer and pre/post-monsoon seasons is shown in Figure 2.23 to 2.25

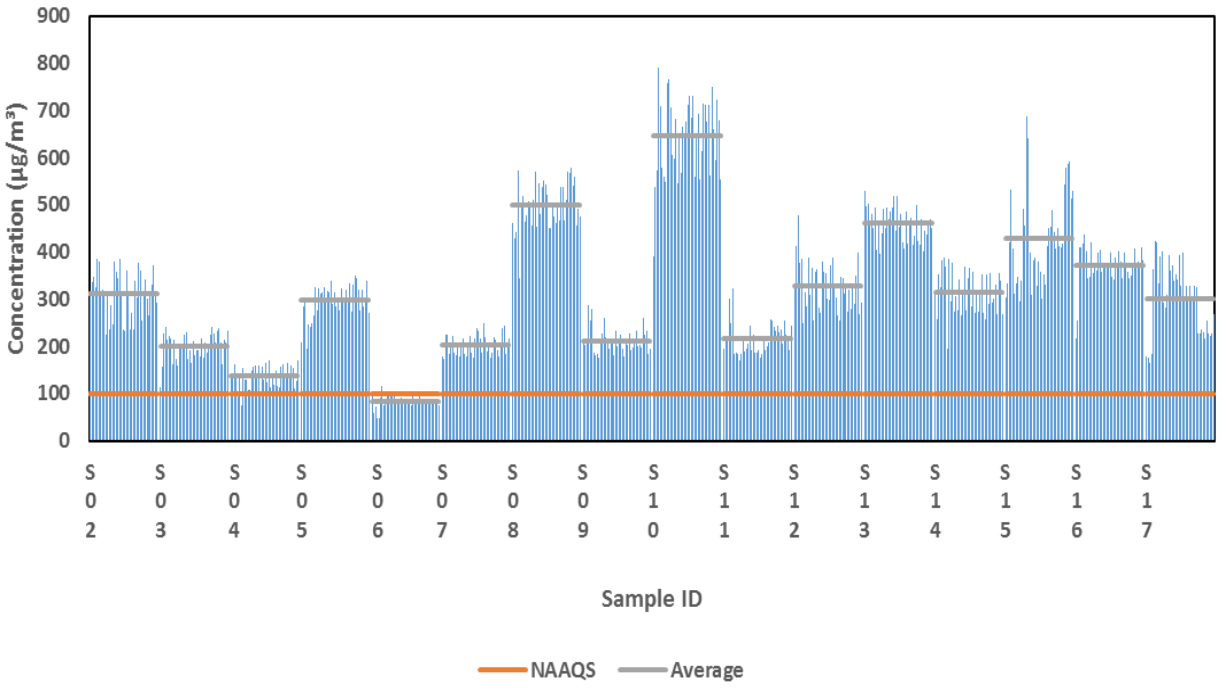


Figure 2.23: Concentration of PM_{10} in winter season.

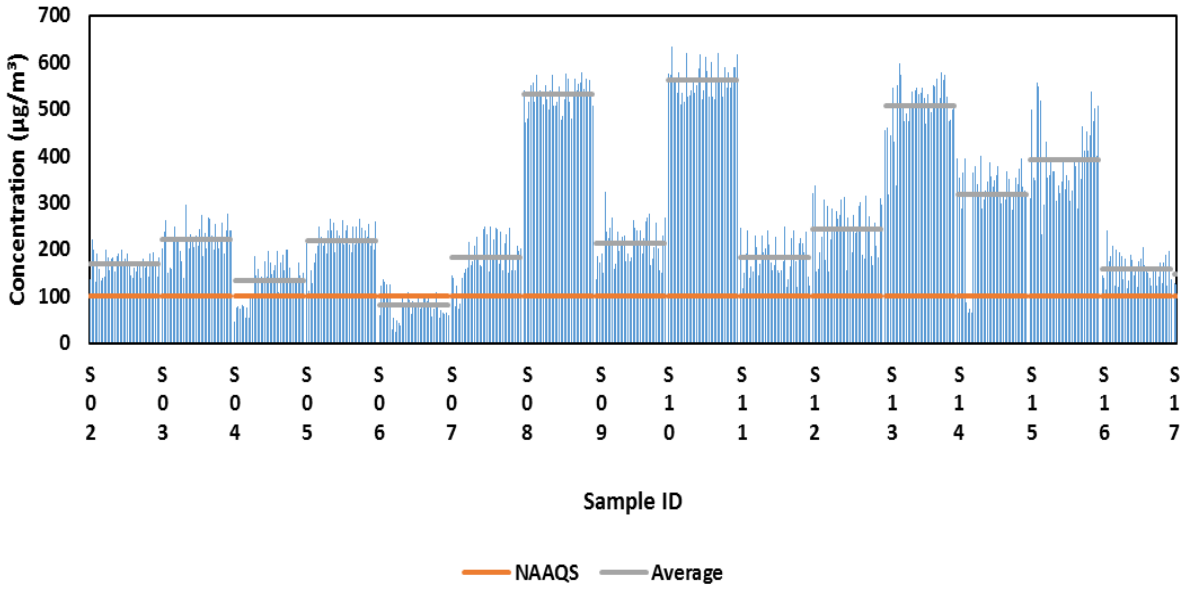


Figure 2.24: Concentration of PM_{10} in summer season.

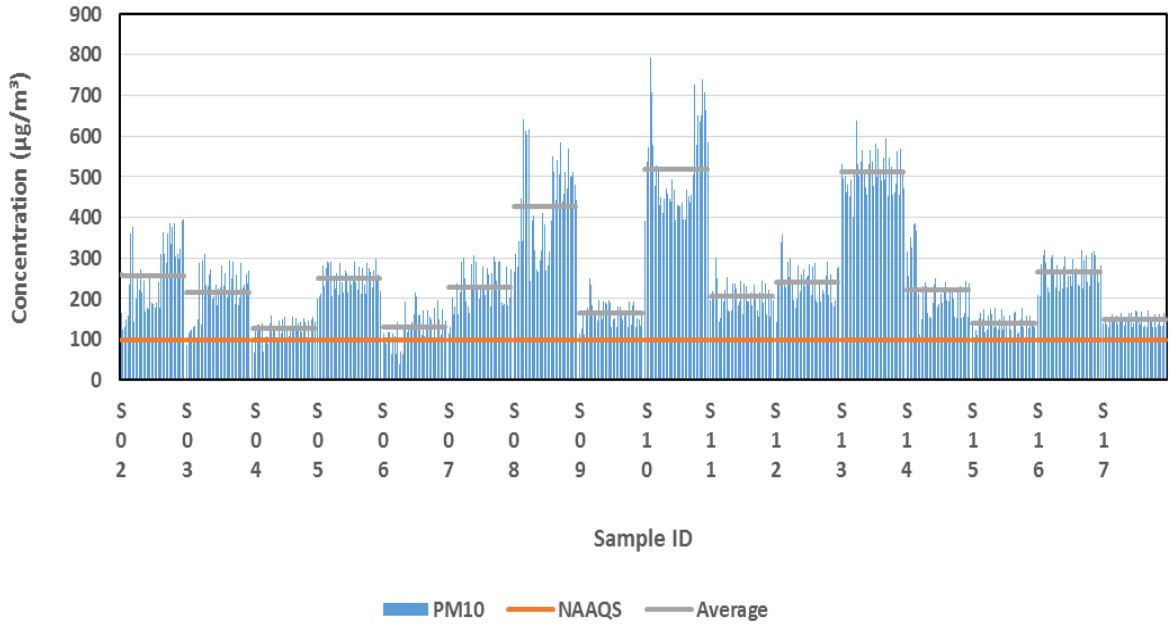


Figure 2.25: Concentration of PM_{10} in pre/post-monsoon season.

2.3.3.2. $PM_{2.5}$ Variation in Different Season

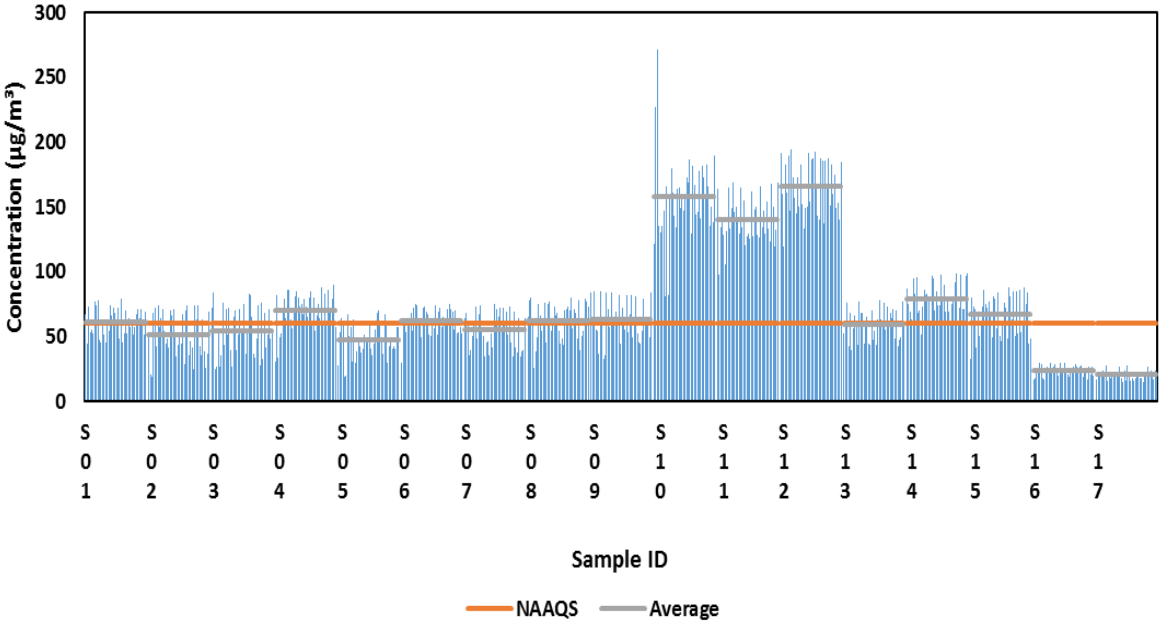


Figure 2.26: Concentration of $PM_{2.5}$ in winter season.

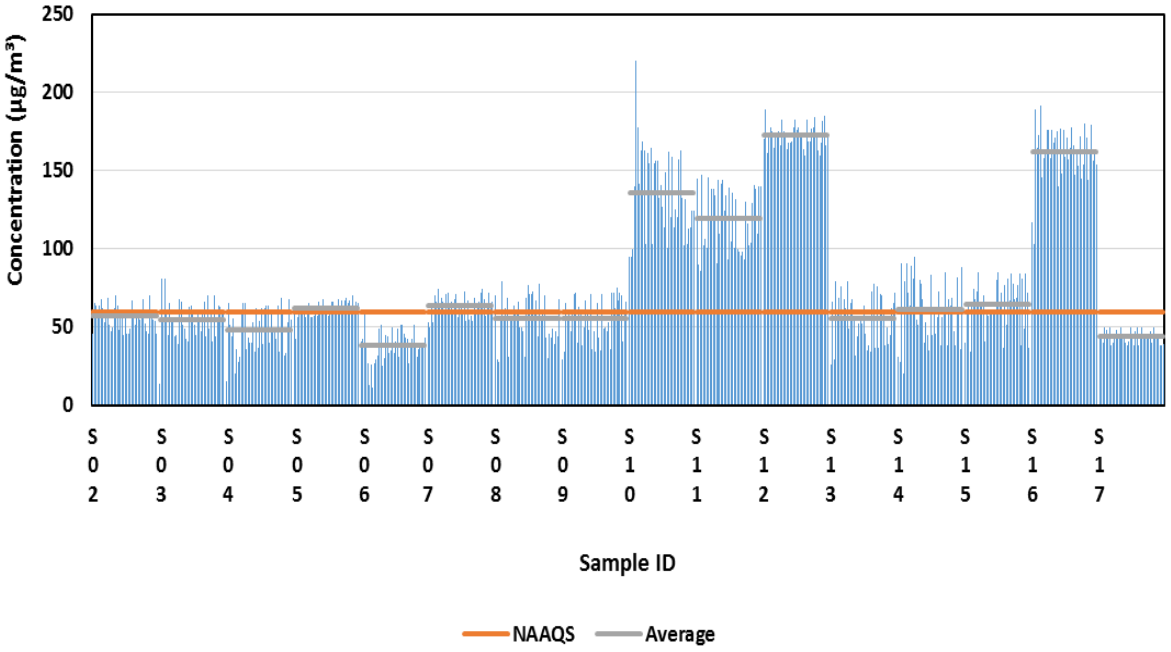


Figure 2.27: Concentration of $PM_{2.5}$ in summer season.

Air sample collected from 17 stations and in the summer season highest $PM_{2.5}$ level were found in S10, S12 and S16 as it is very heavily traffic area and there nearby locations constructions are also going on. In post monsoon season the temperature is low and monsoon season has already passed so most of the pollutants has already wiped out so atmosphere is little bit clear than the summer season but still we have got some values in station that mainly because of traffic in nearby area and the industries or ongoing construction taking place nearby these areas. In winter season has the most pollutant and the reason is simple in winter people burn more coal, wood other material so generation of pollutant matter in air is more. The concentration of $PM_{2.5}$ in winter, summer and pre/post-monsoon seasons is shown in Figure 2.26 to 2.28.

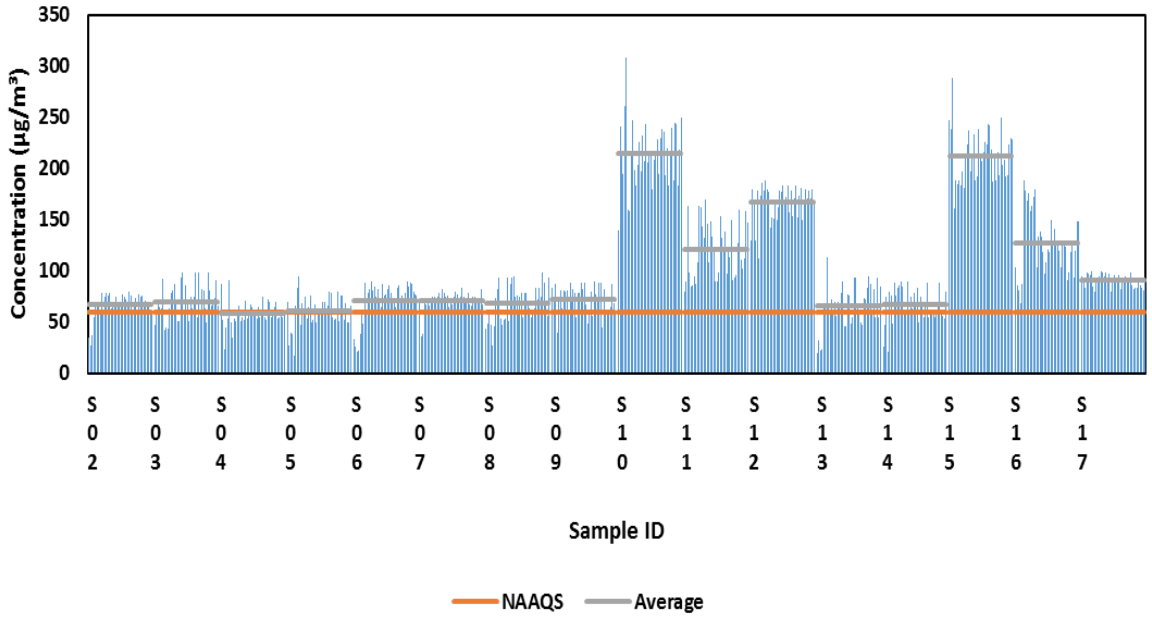


Figure 2.28: Concentration of $PM_{2.5}$ in pre/post monsoon season.

2.3.3.3 SO_2 Variation in Different Season

Air sample collected from different season in Siltara for SO_2 as shown in Figure 2.29 to 2.31 .as we can see all SO_2 values are within the limit that is 80 µg/m³ but station shows the high value of SO_2 which are K06 and K13 that is mainly because of wood industry and other industries. As we know the main reason for SO_2 high concentration is due to the burning of fossil fuel and also other industrial facilities. High concentration of SO_2 in air can cause a lot of problem to our skin like irritation and rashes and also it is very dangerous for our respiratory system. In the monsoon season we know that most of the dirt wiped out but in post monsoon season still we can see the value of SO_2 which again

are in limit but the same station are showing highest peak and the reason are due to industries nearby or by ongoing construction taking at that moment. In winter it contribute more SO_2 generation as we know it has lowest temperature so people burn many more wood or coal and more tea stall and food stall use often use these coal for selling their food item .so more the burning of these fossil fuels more generation of SO_2 in figure also we can see the highest values are found in winter season as compare to the others.

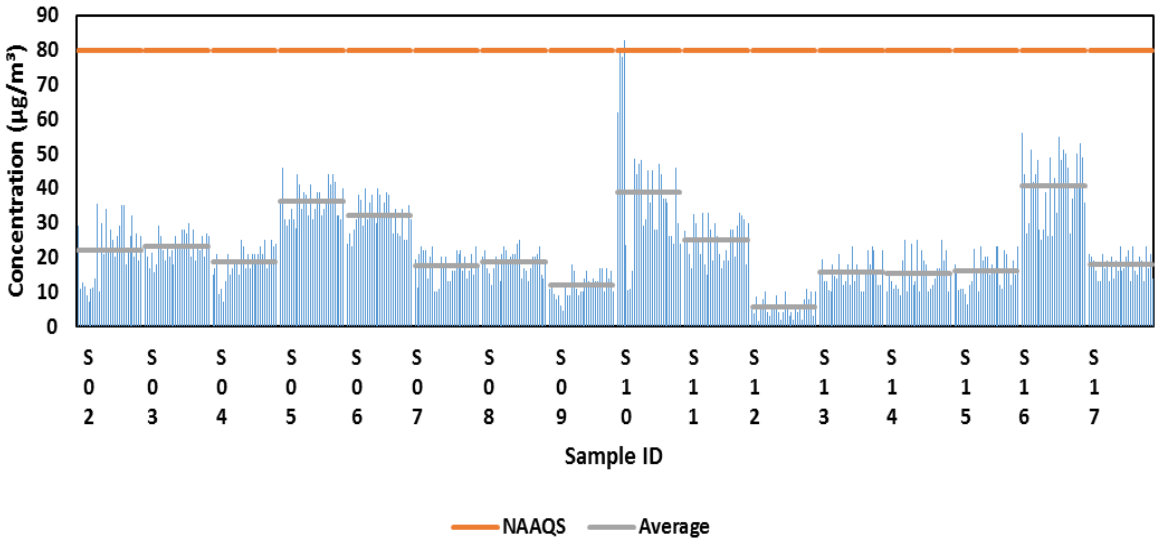


Figure 2.29: Concentration of SO_2 in winter season.

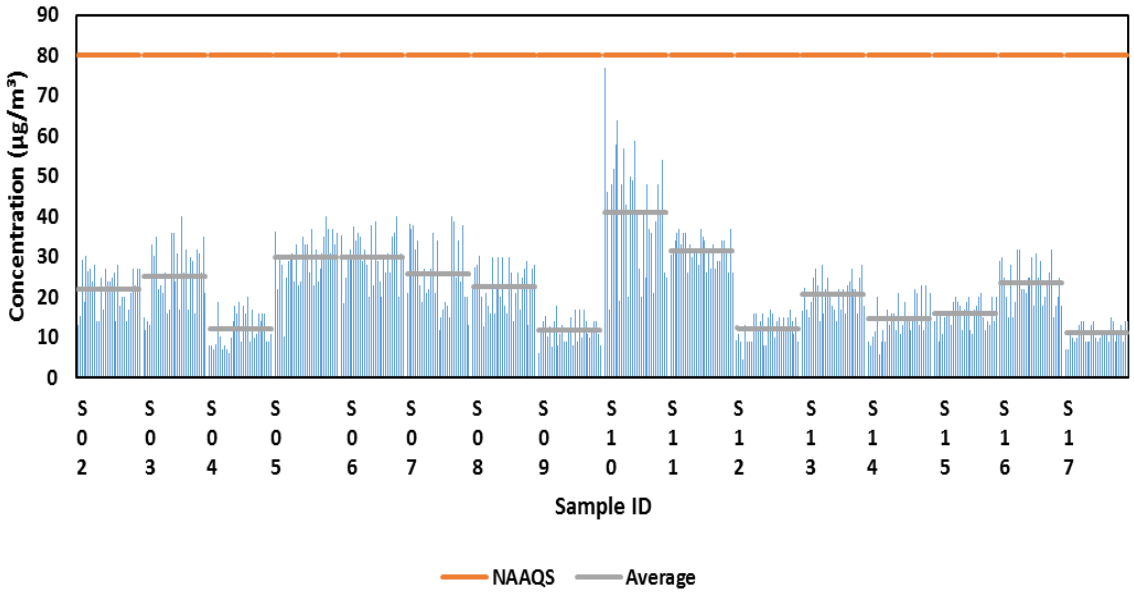


Figure 2.30: Concentration of SO_2 in summer season.

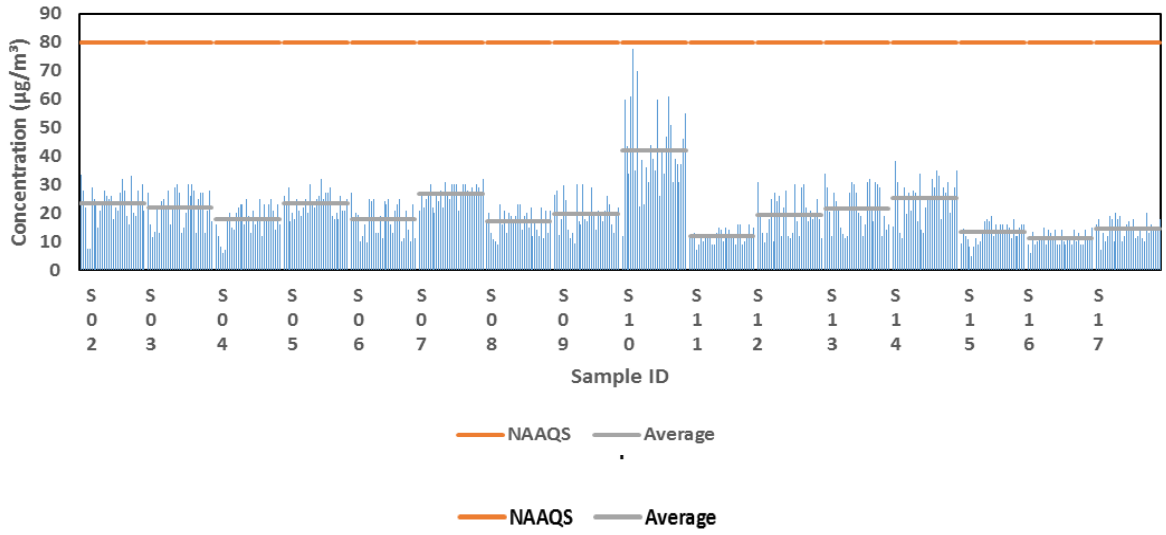


Figure 2.31: Concentration of SO_2 in pre/post-monsoon season.

2.3.3.4 NO_2 Variation in Different Season

Air sample collected from 17 stations as and from Figure 2.32 to 2.34 we can see that all the values are within limit that is 80 µg/m³. However, high concentrations have been found in S10 and S13 air quality monitoring stations. The main reason could be the nearby industry such as lloy industry, metal, steel and other industries as the main cause of NO_2 in air is because of vehicle power plant and industrial emission etc. The high value of NO_2 can cause asthma and respiratory problem. The high value of NO_2 in post monsoon were found in S07, S08, and S13 the main cause could be is more traffic in those station and also industries and ongoing construction contributed an increase of NO_2 concentration. The highest concentration in winter were found in S10 and also the causes could be industrial emission more traffic and all the stations have high value in winter as compare to the winter mainly because of more combustion of wood and coal are taking place .

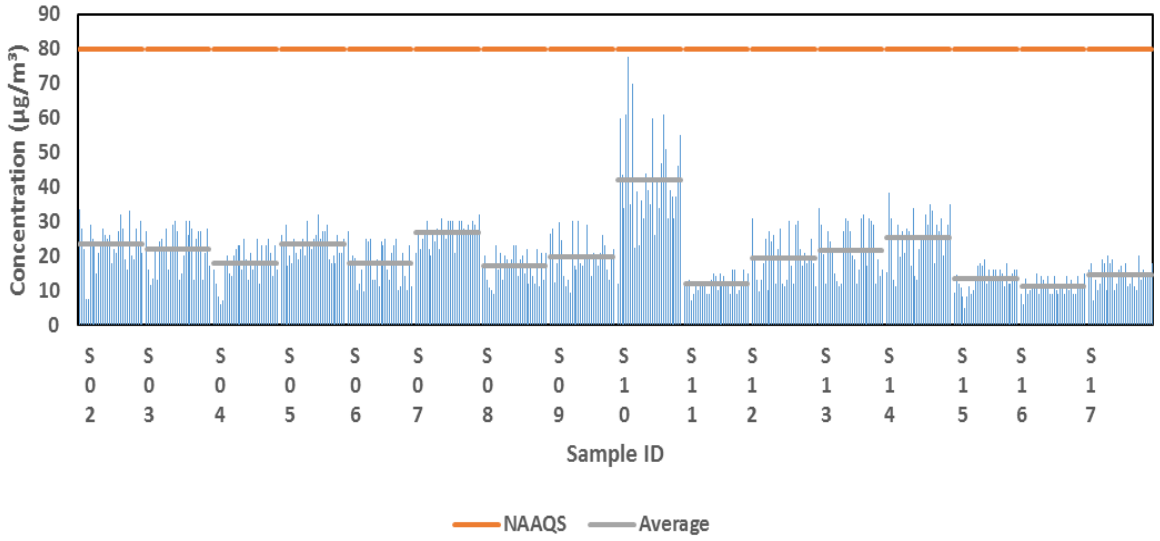


Figure 2.32: Concentration of NO_2 in winter season.

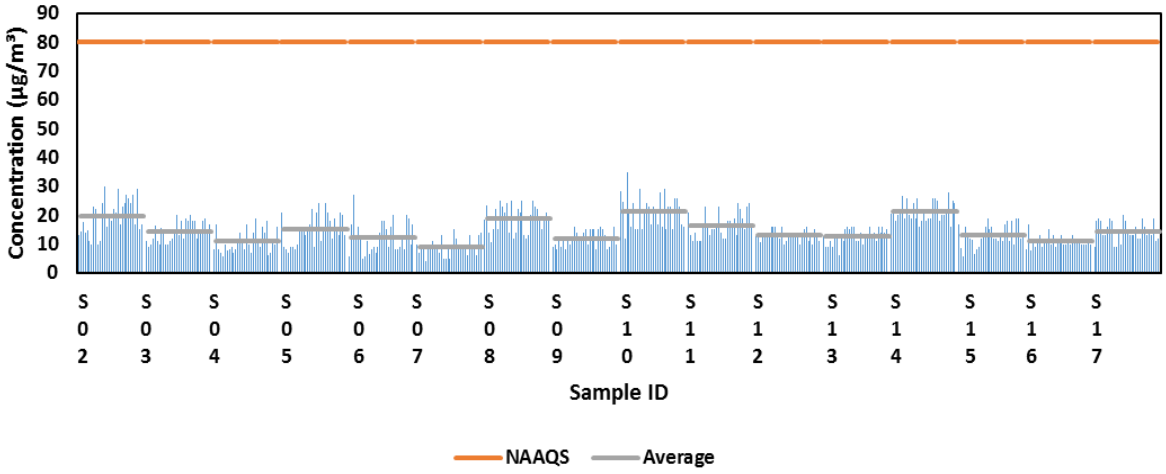


Figure 2.33: Concentration of NO_2 in summer season.

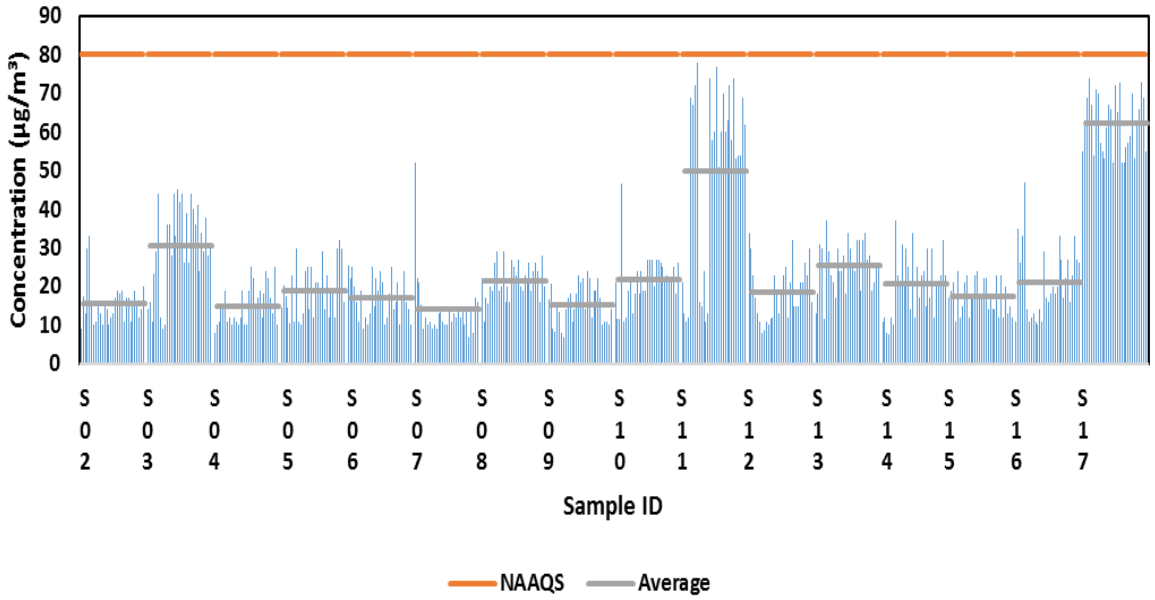


Figure 2.34: Concentration of NO_2 in pre/post monsoon season.

2.3.3.5 NH_3 Variation in Different Season

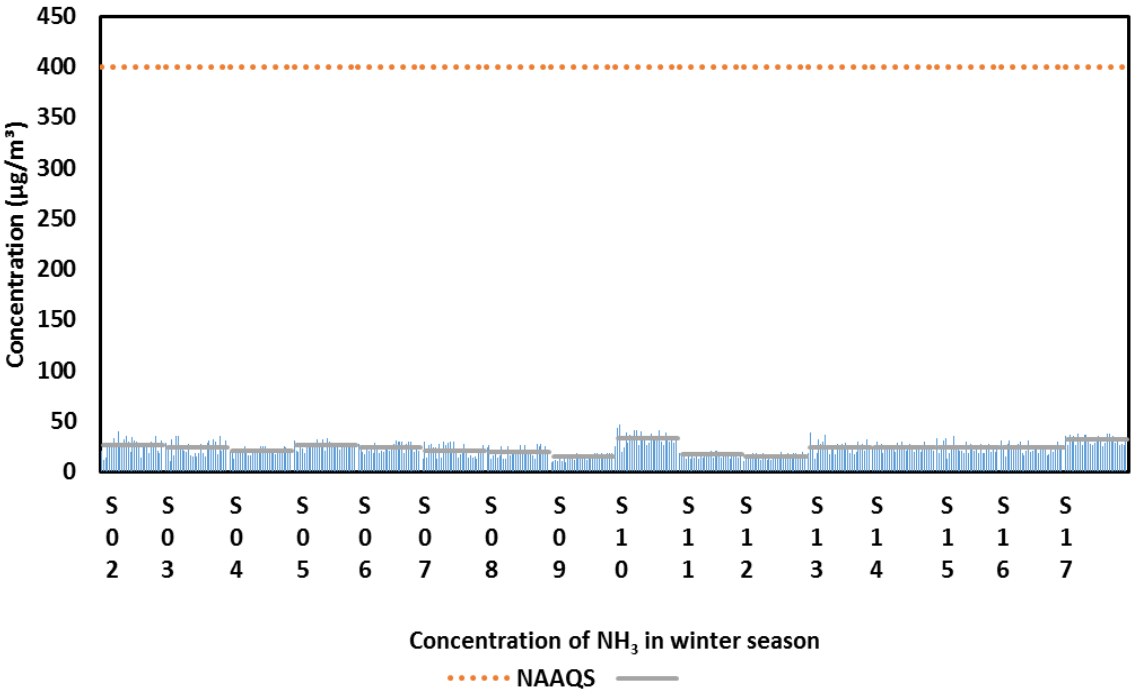


Figure 2.35: Concentration of NH_3 in winter season.

Air sample collected from 17 stations and as we can see Figure 2.35 to 2.37 highest concentration were found in S15, S13, and S05 and it is mainly because of Steel and power industry nearby and also some other activities as the main reason for generation of ammonia in air due to decomposition of organic matter and as a byproduct of agriculture and industry. High concentration of ammonia can cause burning of nose throat and it is also effect the respiratory system. In pre/post monsoon season the highest concentration were found in S02 and S03 is mainly because of nearby sources that is nearby site of industries and as it produces byproducts which result in generation of ammonia. The highest concentration of ammonia in winter were found in S10 and rest of the station has low value as compare to these stations and the reason could be the nearby restaurant and industries as it result in generation of ammonia.

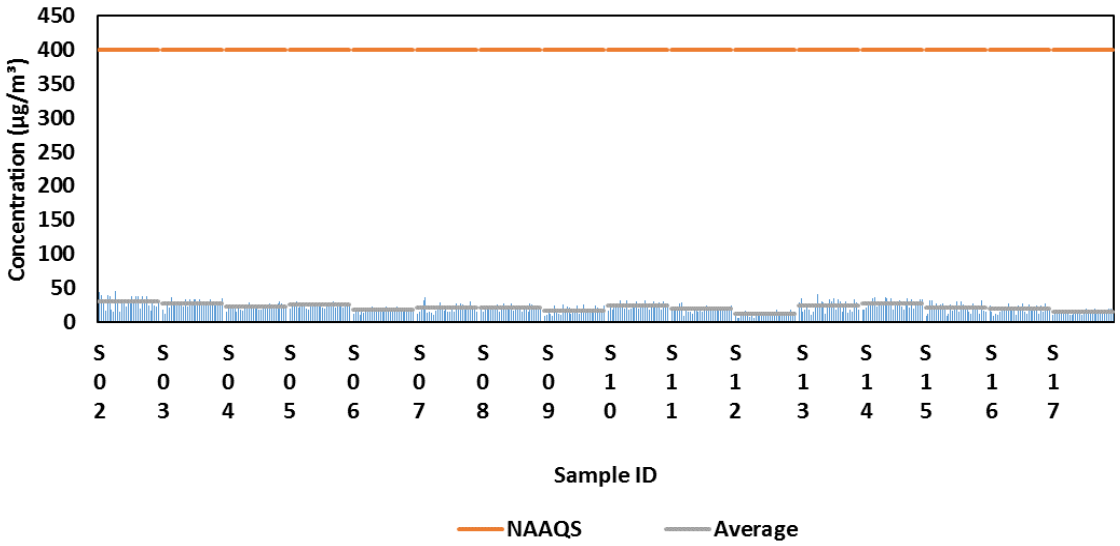


Figure 2.36: Concentration of NH_3 in summer season.

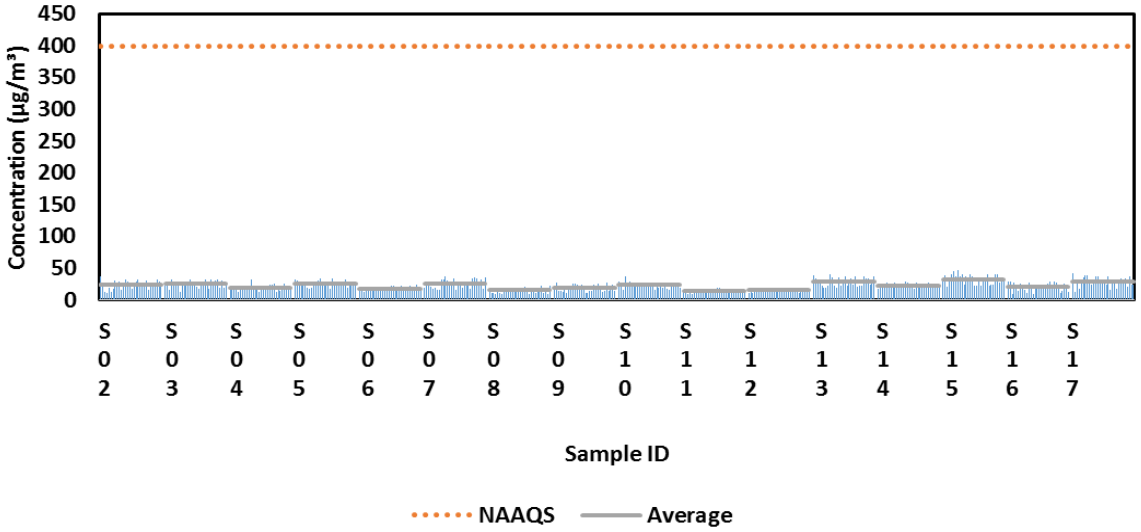


Figure 2.37: Concentration of NH_3 in pre/post monsoon season.

2.3.3.6 O_3 Variation in Different Season

Air sample collected from 17 stations in Siltara in which some shows high concentration of ozone which are S14 and S15 and the main reason could be nearby industries and the heavy traffic in those areas as the generation of ozone is mainly because of car, power plant, refineries, chemical plant. High concentration of ozone can cause irritation in eyes, respiratory and heart problem. And also shortness of breath, chest pain, wheezing. In pre/post monsoon air sample collected from 17 stations as the other two stations are stopped at that time. The values in post monsoon season are less as compare to the summer season that is due the rain has already wiped out the pollutant and the temperature is also low .the highest concentration were found in S08 and S05 the reason could be the traffic and nearby industrial areas. High concentration of ozone in winter were found in S04, S05, and S16 and the reason could be heavy traffic more traffic and all the values are high in winter as compare to the other season which is because of more combustion of wood and furniture , coal in this season as the temperature is lowest in this season.

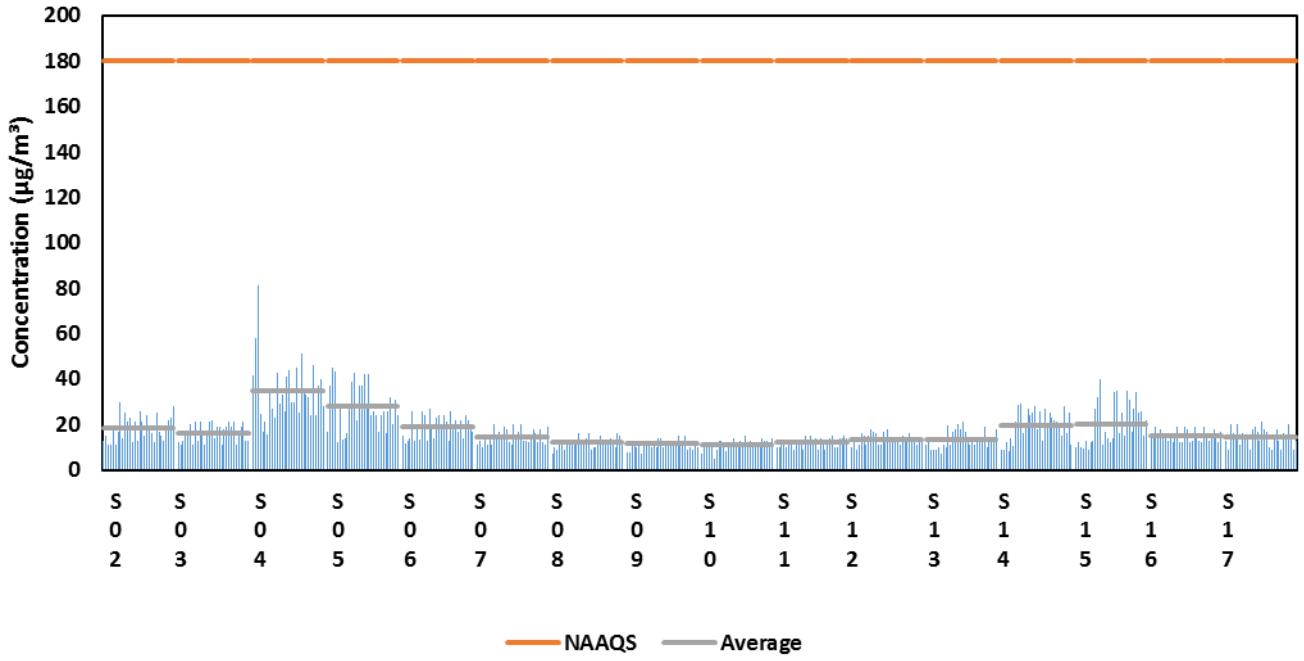


Figure 2.38: Concentration of O_3 in winter season.

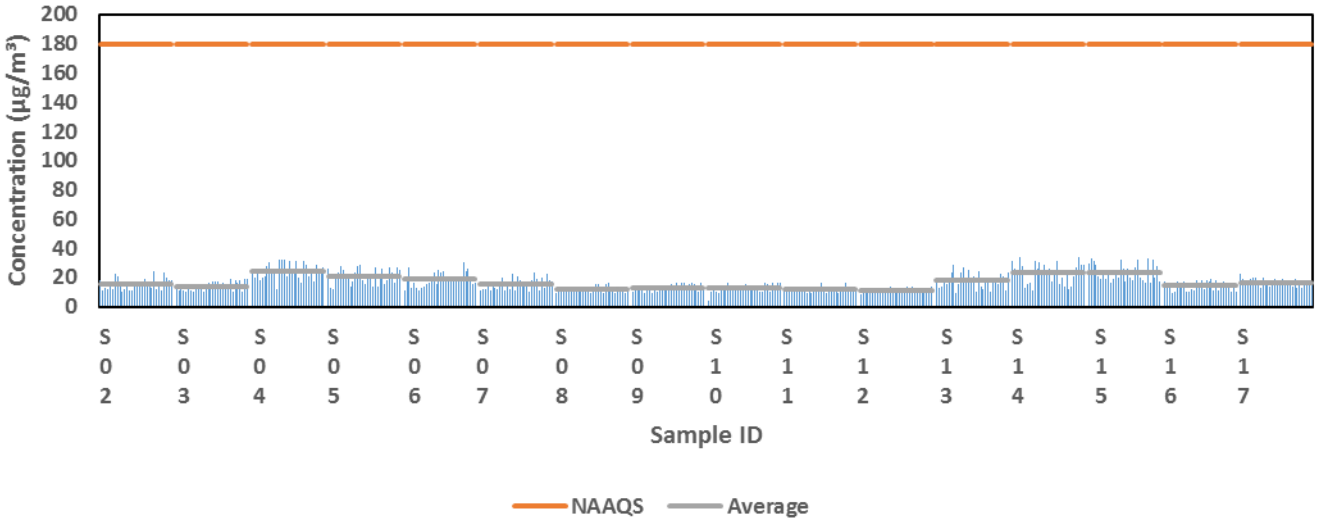


Figure 2.39: Concentration of O_3 in summer season.

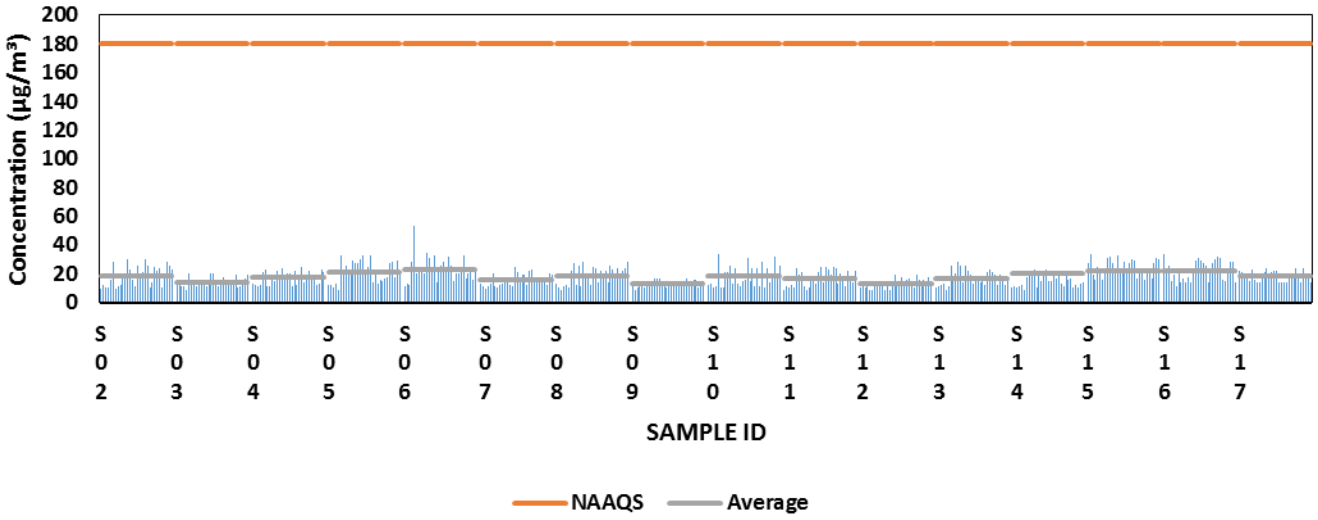


Figure 2.40: Concentration of O_3 in pre/post monsoon season.

2.3.4 Carrying Capacity for PM_{10} and $PM_{2.5}$

Carrying Capacity of the ambient air environment may be defined as "the maximum emission load (PM_{10}), which an area can sustain at maximum rate of operation of any air polluting activity/activities". Further, estimation of the carrying capacity of any area involves estimation of three components -. i) Existing Pollution Load, ii) Total Assimilative Capacity and iii) Supportive Carrying Capacity. The month-wise air volume of each area for dispersion of pollutants, was calculated by multiplying the area (km^2) with average atmospheric mixing heights/depths as obtained from Indian Meteorological Department (IMD), for the months of October, 2021 – June, 2022.

The Pollution load at which the maximum permissible concentration is reached is considered as the assimilative capacity. The maximum permissible concentration of PM_{10} as per National Ambient Air Quality Standard (NAAQS) of PM_{10} (24-hour average) is 100 µg/m^3 and this was used for estimating the **Total Assimilative Capacity**, by multiplying with the volume of air available for dispersion in each grid. The difference between the maximum permissible concentration/load of PM_{10} i.e. Total Assimilative Capacity and the existing average PM_{10} concentration/ load i.e. Existing Pollution Load gives an indication of the **Supportive Carrying Capacity** of an area available for sustaining the operation of additional air polluting activities. The positive values shows the capacity to accommodate additional pollution load and the negative values indicate that the pollution load is in excess of the

assimilative capacity of the area i.e. no additional pollution load can be accommodated and measures are required to bring the pollution load within the assimilative capacity.

1) Estimation of Total Existing Load for PM_{10}

Total area of Raipur district: a $(km)^2$

Average Atmospheric Mixing Height during a particular month: b (km)

Total Volume of Air in Raipur district during a particular month: a x b = c $(km)^3$

Average PM_{10} concentration of Ambient Air in Raipur district for a particular month = d (kg/km^3)

Therefore, Total estimated load of particulate matter (PM_{10}) in ambient air of Raipur district during a particular month (x): c x d = e (kg)

There is continuous/manual ambient air quality monitoring station operational in Siltara district. So, the ambient air quality data has been taken from Siltara city, where manual ambient air quality monitoring stations are being operated by us. Average of both the manual monitoring stations has been taken for calculating total PM_{10} load in the different months of year 2021 at Siltara and as per the CPCB guideline we have excluded the monsoon month (July, Aug., Sep.). Estimated total existing PM_{10} Load in Siltara during different months of year 2021 and 2023 is given at Table 2.13.

Table 2.13: Estimated load (PM_{10}) in Siltara.

Sl. No.	Month	Estimated load (PM_{10}) (kg)
1	October 2021	247061.7
2	November 2021	341307.4
3	December 2021	447258.6
4	January 2022	366404.4
5	February 2022	327021.7
6	March 2022	334747.0
7	April 2022	214885.4
8	May 2022	320421.1
9	June 2022	258085.2
10	October 2022	364500.1
11	November 2022	340747.5
12	December 2022	498703.9
13	January 2023	364601.9

[Area of Siltara adopted from https://Siltara.gov.in, Average Mixing height monthly data (year-2021, 2022) adopted from Continuous air quality station]

2) Estimation of Assimilative Carrying Capacity with respect to PM_{10}

Total volume of air in Siltara during a particular month in km^3, c

Particulate Matter (PM_{10}) required to keep Ambient Air Quality at Satisfactory Level/Prescribed NAAQ Standard: 100 µg/m³ i.e. 100 Kg /km^3 (Ref: Air Quality Index/NAAQ Std.)

Therefore, Assimilative Capacity with respect to PM_{10} in ambient air of Siltara during a particular month (y): C X 100 = y kg

Calculated assimilative carrying capacity in the different months of year 2021, 2022 at Siltara is given at Table 2.14.

Table 2.14: Assimilative carrying capacity in Siltara.

S. No.	Month	Assimilative Carrying Capacity (kg)
1	October 2021	120166.2
2	November 2021	127234.8
3	December 2021	141372.0
4	January 2022	106029.0
5	February 2022	113097.6
6	March 2022	120166.2
7	April 2022	141372.0
8	May 2022	134303.4
9	June 2022	106029.0
10	October 22	120166.2
11	November 22	127234.8
12	December 22	141372.0
13	January 23	106029.0

3) Estimation of Supportive Carrying Capacity of Siltara with respect to PM_{10}

Month wise supportive carrying capacity of Siltara, as determined by using the above is summarized in Table 2.15.

Supportive Carrying Capacity (z) = Assimilative Carrying Capacity (y) − Total Estimated Load (x)

Table 2.15: Supportive carrying capacity in Siltara.

Sl. No.	Month	Supportive Carrying Capacity
1	October 2021	-126895.51
2	November 2021	-214072.55
3	December 2021	-305886.61
4	January 2022	-260375.42
5	February 2022	-213924.11
6	March 2022	-214580.78
7	April 2022	-73513.44
8	May 2022	-186117.65
9	June 2022	-152056.19
10	October 2022	-244333.93
11	November 2022	-213512.72
12	December 2022	-357331.87
13	January 2023	-258572.92

Table 2.16: Carrying capacity assessment of Siltara with respect to PM_{10}.

Sl. No.	Month & Year	Area (km^2)	Mixing height, (m)	Mixing height, (km)	Avg. PM_{10} Conc. ($\mu g/m^3$)	Volume of Ambient Air, (km^3)	Assimilative Capacity, (kg)	Existing PM_{10} Load, (kg)	Supportive Capacity, (kg)
1	Oct-21	706.86	1700	1.7	205.60	20.14	120166.2	247061.71	-126895.51
2	Nov-21	706.86	1800	1.8	268.25	21.33	127234.8	341307.35	-214072.55
3	Dec-21	706.86	2000	2.0	316.37	23.70	141372.0	447258.60	-305886.6
4	Jan-22	706.86	1500	1.5	345.57	17.77	106029.0	366404.42	-260375.42
5	Feb-22	706.86	1600	1.6	289.15	18.96	113097.6	327021.71	-213924.11
6	Mar-22	706.86	1700	1.7	278.57	20.14	120166.2	334746.98	-214580.78
7	Apr-22	706.86	2000	2.0	152.00	23.70	141372.0	214885.44	-73513.44
8	May-22	706.86	1900	1.9	238.58	22.51	134303.4	320421.05	-186117.65
9	Jun-22	706.86	1500	1.5	243.41	17.77	106029.0	258085.19	-152056.19
10	Oct-22	706.86	1700	1.7	303.33	20.145	120166.2	364500.13	-244333.93
11	Nov-22	706.86	1800	1.8	267.81	21.33	127234.8	340747.52	-213512.72
12	Dec-22	706.86	2000	2.0	352.76	23.70	141372.0	498703.87	-357331.87
13	Jan-23	706.86	1500	1.5	343.87	17.77	106029.0	364601.92	-258572.92

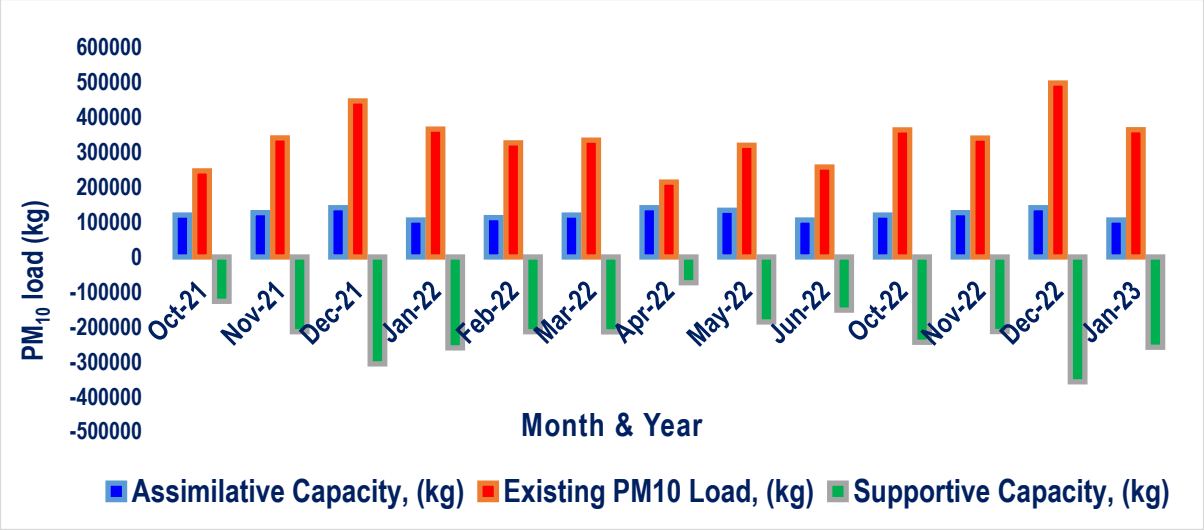


Figure 2.41: Month wise load capacity of PM_{10}.

The final outcome of the assessment with regard to the range of Supportive Carrying Capacity of the ambient air environment in Siltara, is summarized in the Table 4.6. The negative values indicate that there is no supportive carrying capacity and the pollution load in terms of PM_{10}, is exceeding the Assimilative Carrying Capacity. Similar calculation was done for $PM_{2.5}$ load which is shown in Table 2.17 below:

Table 2.17: Carrying capacity assessment of Siltara with respect to $PM_{2.5}$.

Sr. No.	Month & Year	Area (km^2)	Mixing height, (m)	Mixing height, (km)	Avg. $PM_{2.5}$ Conc. ($\mu g/m^3$)	Volume of Ambient Air, (km^3)	Assimilative Capacity, (kg)	Existing $PM_{2.5}$ Load (kg)	Supportive Capacity, (kg)
1	Oct-21	706.86	1700	1.7	58	20.14	72099.72	69696.40	2403.324
2	Nov-21	706.86	1800	1.8	77	21.33	76340.88	97970.80	-21629.9
3	Dec-21	706.86	2000	2.0	53	23.70	84823.20	74927.16	9896.04
4	Jan-22	706.86	1500	1.5	53	17.77	63617.40	56195.37	7422.03
5	Feb-22	706.86	1600	1.6	50	18.96	67858.56	56548.80	11309.76
6	Mar-22	706.86	1700	1.7	67	20.14	72099.72	80511.35	-8411.63
7	Apr-22	706.86	2000	2.0	68	23.70	84823.20	96132.96	-11309.8
8	May-22	706.86	1900	1.9	89	22.51	80582.04	119530.0	-38948.0
9	Jun-22	706.86	1500	1.5	122	17.77	63617.40	129355.4	-65738.0
10	Oct-22	706.86	1700	1.7	303	20.14	72099.72	364500.1	-292400
11	Nov-22	706.86	1800	1.8	267	21.33	76340.88	340747.5	-264407
12	Dec-22	706.86	2000	2.0	352	23.70	72099.72	69696.40	2403.324
13	Jan-23	706.86	1500	1.5	343	17.77	76340.88	97970.80	-21629.9

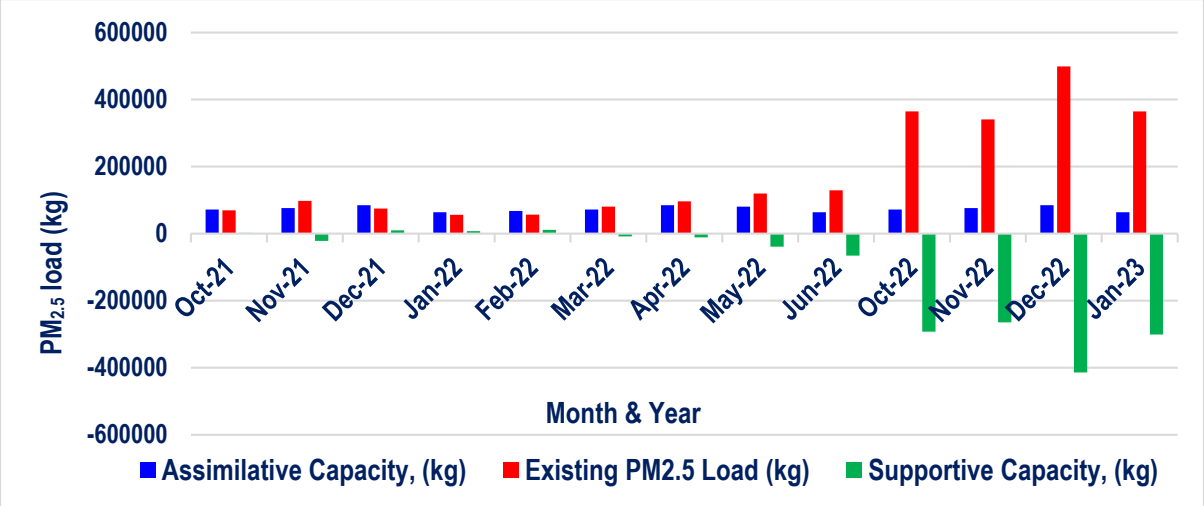


Figure 2.42: Month wise load capacity of $PM_{2.5}$.

The final outcome of the assessment with regard to the range of Supportive Carrying Capacity of the ambient air environment in Siltara, is summarized in the Table 2.17. The negative values indicate that there is no supportive carrying capacity and the pollution load in terms of $PM_{2.5}$, is exceeding the Assimilative Carrying Capacity.

2.3.5 Statistical Analysis

The statistical analysis for the data collected of all the three seasons for PM_{10}, $PM_{2.5}$, SO_2, NO_2, NH_3 and O_3 is shown in Table 2.18 to 2.20.

Table 2.18: Statistical analysis of $PM_{2.5}$ and PM_{10} for three seasons in Siltara during study period.

Siltara	$PM_{2.5}$			PM_{10}		
	Pre and post monsoon	Summer	Winter	Pre and post monsoon	Summer	Winter
Max	308	220	271	792	635	792
Min	17	11	15	38	25	47
Average	100	78	73	254	267	314
STDV	55	44	43	135	154	148
mean	100.33	78.13	73.17	253.60	266.78	314
CV	0.55	0.57	0.59	0.53	0.58	0.47

Table 2.19: Statistical analysis of SO_2 and NO_2 for three seasons in Siltara during study period.

Siltara	SO_2			NO_2		
	Pre and post monsoon	Summer	Winter	Pre and post monsoon	Summer	Winter
Max	119	76.80	83	78	34.89	78
Min	10	4.43	2	7	3.87	5
Average	36	22	22	24	15	20
STDV	24	10	12	16	5	9
mean	36.47	21.97	22	24.07	14.74	20
CV	0.67	0.48	0.53	0.65	0.36	0.46

Table 2.20: Statistical analysis of NH_3 and O_3 for three seasons in Siltara during study period.

Siltara	NH_3			O_3		
	Pre and post monsoon	Summer	Winter	Pre and post monsoon	Summer	Winter
Max	46	46.84	46.31	53	34.09	81.11
Min	7	10	9	8	4	5
Average	21.82	22.84	23.18	17.99	16.54	17.15
STDV	7.13	7.42	6.89	6.44	5.93	8.47
mean	21.82	22.84	23.18	17.99	16.54	17.15
CV	0.32	0.32	0.29	0.35	0.35	0.49

2.3.6 Carbon impact on environment in Siltara

Siltara is an industrial zone and plays significant role on Indian economy. We have selected 17 air quality monitoring stations within the geographical circumstances of Siltara. All those stations are situated within human dwelling areas so that, we can properly study the effects of coal as well as fuel burning, improper agricultural activities, industrial and traffic hazardous on Siltara's population. All these 17 air quality monitoring stations are individually categorized in silent, mixed, agricultural, commercial, and mixed as well as industrial (Table 1.1).

Particulate matters in the air samples ($PM_{2.5}$) have been carefully collected in routine wise time intervals. Filter papers are then collected carefully, preserved and analyzed according to CPCB predicted protocols (TOR / TOT method, see Section 2.2.11). We have found OC values ranges from 0.35 µg/m³ to 0.61 µg/m³ among all air quality monitoring stations. Similarly, we have found TC values

ranging from 0.71 µg/m³ to 1.39 µg/m³ among all air quality monitoring stations. Carbonaceous compounds are mainly organic or house hold type in Siltara's non-industrial as well as non-traffic stations.

2.3.7 Seasonal VOCs Variation

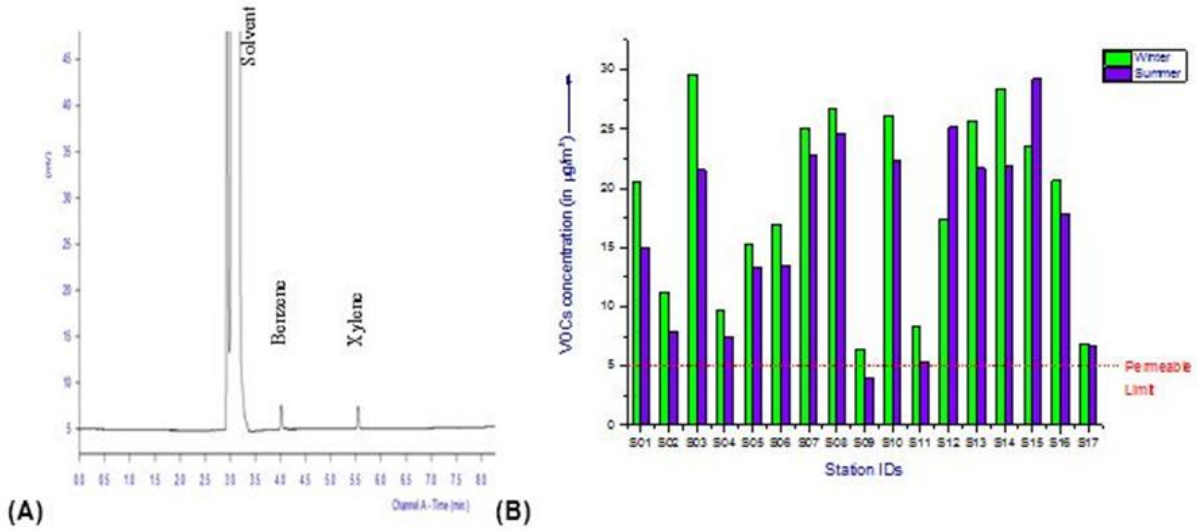


Figure 2.43: (A) GC chromatogram: VOC analysis report of different standard solutions, (B) Seasonal variation of VOCs concentration (in µg/m^3) in the ambient air of Siltara.

Volatile organic compounds (VOCs) are compounds that have high vapour pressure and low water solubility. Generally, VOCs are man-made chemicals that are used as well as produced in the manufacture of paints, pharmaceuticals, and refrigerants. VOCs are typically industrial solvents, like trichloroethylene, fuel oxygenates, such as methyl tert-butyl ether (MTBE) or by-products produced by chlorination in water treatment, such as chloroform. VOCs are often components of petroleum fuels, hydraulic fluids, paint thinners and dry cleaning agents. VOCs are common ground-water contaminants. VOCs may have short- and long-term adverse health effects. VOCs' concentrations are higher indoors (up to ten times) than outdoors. Volatile organic carbons (Benzene, et-Benzene, Xylene and Toluene) in the ambient air of Siltara sampling stations are quite high in winter than summer. In case of Siltara sampling stations, VOCs values were found decreasing day by day with the change of seasons (winter to summer). In winter, average VOCs value has been found as 18.739 µg/m^3 and in summer it has been decreased to 16.476 µg/m^3 (Figure 2.44).

Gaseous pollutants include ozone (O_3), nitrogen oxides (NO_x), carbon monoxide (CO), sulfer dioxide (SO_2), volatile organic compounds and various toxic air pollutants. Ozone generates in ambient air as a result of a chemical reaction between nitrogen oxides and volatile organic compounds in the presence of sunlight (hλ where λ ≤ 410nm):

$$VOC + NO + h\lambda \longrightarrow NO_2 + O_3$$

This reaction also produces many secondary species that from photochemical smog. High concentration of VOCs may effects on human health. Health effects may include: eye, nose and throat irritation; headaches, loss of coordination and nausea. VOCs may damage to liver, kidney, central nervous system and other adverse effects. So, increasing number of compounds (benzene and xylene) and values of VOCs in Siltara area is not good news for the population living there.

2.3.8 Quantification and Variation of PAHs in Ambient Air

We have prepared a Standard mixture solution (100ppb) of different markers (denoted by CPCB, India) with all following 16 components – naphthalene, acenapthylene, fluorene, phenantherene, anthracene, fluoranthene, phenylenepyrene, benzo(a) anthracene, benzo(b) fluoranthene, benzo(k)fluoranthene, benzo (a) pyrene, benzo(e)pyrene, indeno (1,2,3-cd) pyrene, indeno (1,2,3-cd) fluoranthene, picene and diben(a,b)anthracene, respectively [Fig.13]. Then run all extracted samples from PM10-filter papers and above STD mix solution separately and respectively through GC fitted with a capillary column (GB-5, Agilent Technologies, made in USA) and FID detector. Then quantified the identified component(s) present in the extracted samples with respect to the standard solution mixtures' retention time (RT; in min) and area (in uV*Sec) under any peak. Hopens, alkanoic acids were also screened through GC as above but we didn't find any compound in any sampling stations in Siltara surroundings.

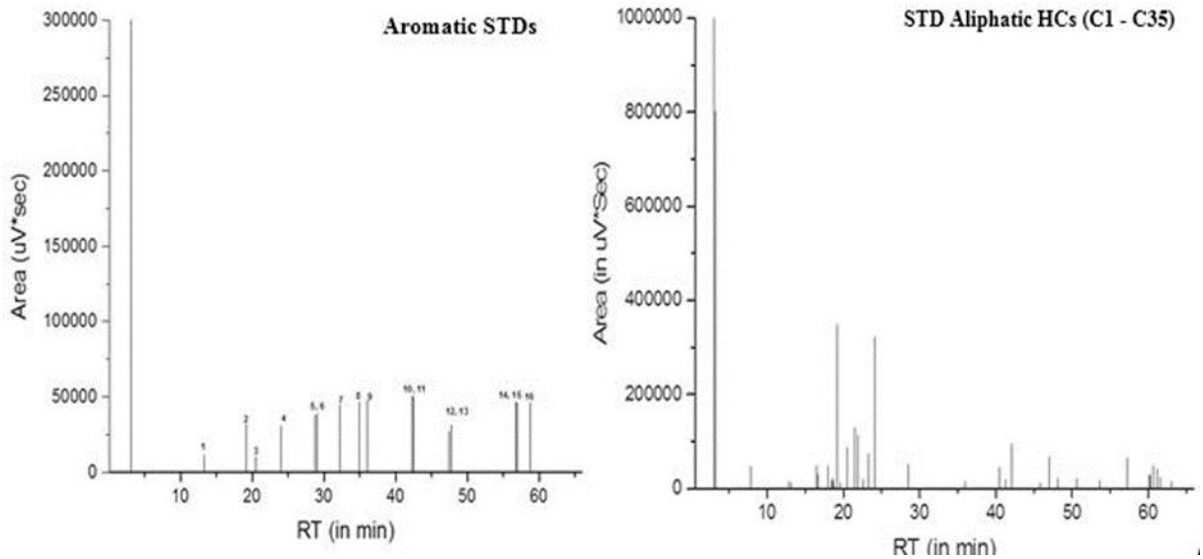


Figure 2.45: Real time curves found during GC analysis of PAHs assay of different aliphatic (C1 to C35) and aromatic (16 selected compounds) standards hydrocarbons.

Here in Figure 2.45, we have shown both standard aromatic and aliphatic hydrocarbons separately. All pure compounds were found with single separate peak as well as respective retention time. They all found with increasing molecular weight and thus increasing boiling point and time in chromatogram. All pure compounds found with certain area under the peak with same retention time (RT in min). Several peaks have been found for poly-aromatic, poly-aliphatic hydrocarbons but no peak has found for hopens or alkanoic acids (except solvent peak) during quantitative analysis or identification. Above chromatogram was found for the sampling station S02 from Siltara. Total 83 peaks are there in the chromatogram but out of them only 6 peaks can be identified with respect to the standard chromatogram (Figure 2.46).Naphthalene (RT=12.89 min), acenaphthene (RT = 19.356 min), acenaphthyele (RT=20.639 min), fluorene (RT=24.05 min), fluorenthene (RT=32.647 min) and benzo(a)anthracene (RT=36.607 min) are identified with concentration range 5-9ng/m^3. Concentrations of all identified PAHs are higher than the value prescribed by CPCB, India (1 ng/m^3). But all these identified PAHs are non-toxic to human. There are near about 78 unidentified peaks in the chromatogram with later retention time. These means some higher PAHs are there in the ambient air of S02 sampling station but are not harmful. Similar trend has also observed in the sampling station no S12. We have identified one extra poly-aromatic hydrocarbon 'benzo (k) fluoranthene' (RT = 42.526) with concentration 0.089 ng/m^3. Likewise Siltara, Siltara and its surrounding areas are free from PAHs toxicity.

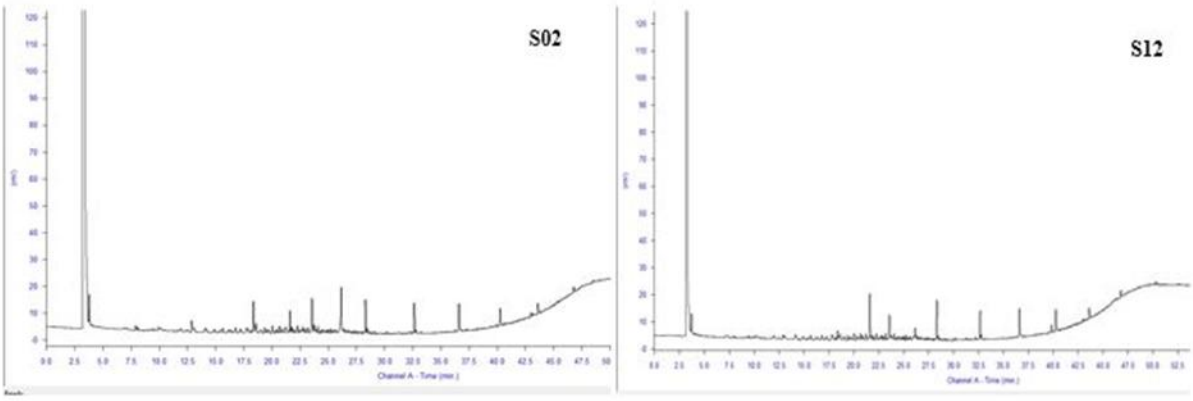


Figure 2.46: GC chromatograms: PAHs identification and quantification from S02 and S12 sampling stations, respectively.

2.3.9 Metal Particulate Matters in the Ambient Air of Siltara

Quantification of heavy metal ions in the ambient air samples have been analyzed instrumentally from the acid leached PM_{10} filter papers' extract. Ambient air of Siltara's sampling stations contain Cu, Fe, Ni, Cr, Zn, Pb, Cd and As in detectable amount but in very low level. 'Fe', 'Zn' and 'Cr' are found in high concentration (µg/m^3) while 'Pd', 'As' and 'Cd' found in ng/m^3 range.

Interestingly, seasonal variations don't effect in the metal ion concentrations of Siltara air. But overall condition has been quite below from the limit level as denoted by CPCB, India. Fe and Zn are found main two ions and only these two are varies up and down. A similar Fe and Zn ion-concentration-wise up and down phenomena have also been found at the nearest Siltara area. In summer, concentration of Fe becomes slightly higher while Zn becomes lower. But other metal ions are blown silently without any concentration variation. Cr and Ni are the third and fourth abundant metal ions in Siltara-air but do not have any variation with the change of seasons. They are very low, near about 0.05 µg/m^3. Though every time we can identify and quantify Pb and As (in every sampling stations as well as in every season) but they are under prescribed level by CPCB, India (in ppb level). But presence of these two metal ions in the ambient air samples of Siltara is not good news for the inhabitants of Siltara.

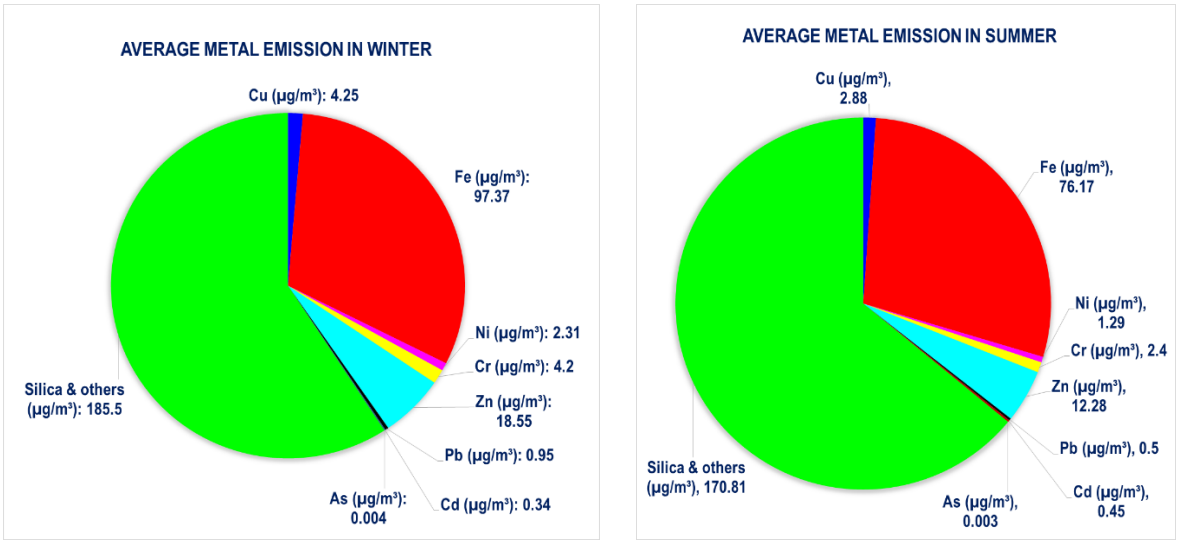


Figure 2.47: Heavy metals concentration (µg/m³) found in the ambient air sample Siltara during winter and summer season.

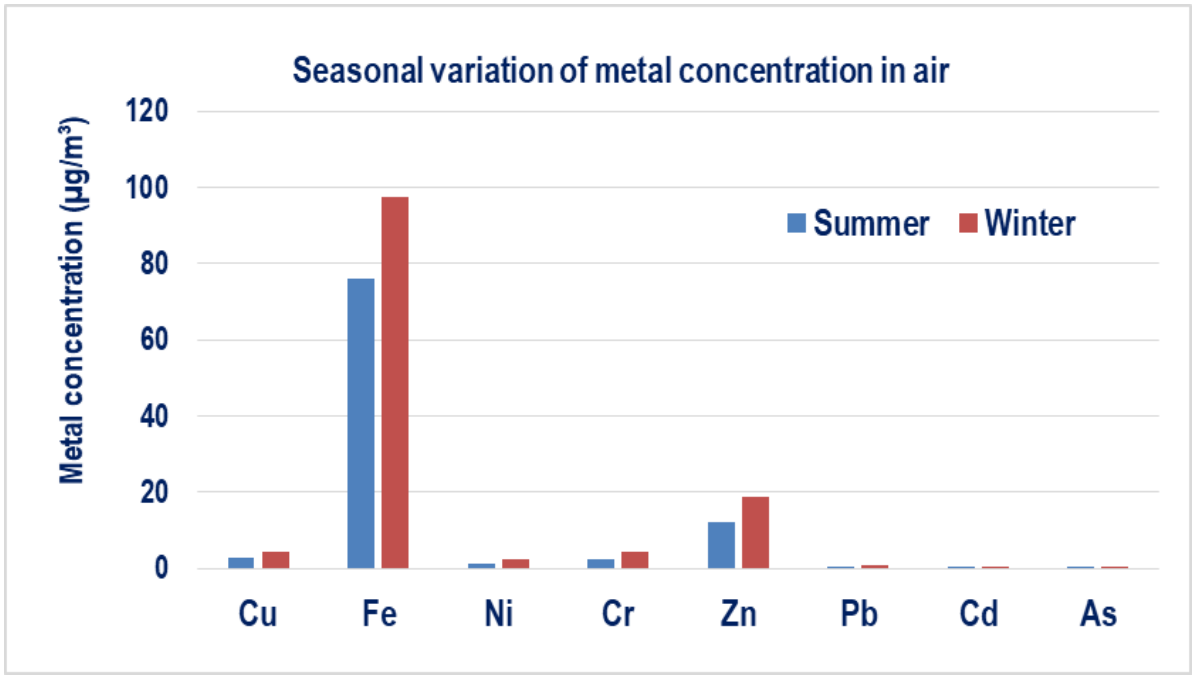


Figure 2.48: Seasonal variation of heavy metal concentration (µg/m³) in ambient air of Siltara.

2.3.10 Polyatomic Ions in Ambient Air of Siltara

Polydentate anions are very important in chelation chemistry. Sometimes it can bind covalently with more than a single metal ion (also known as central metal ion / cation) and thus stabilize the resultant free radicals. We found mainly four poly-atomic anions in the ambient air samples from Siltara sampling stations. Among those, sulphate (SO_4^{-2}) and nitrate (NO_3^-) are abundant. Fluoride (F^-) and chloride (Cl^-) are also available in low concentrations, respectively. Sulphates are a member of chemicals that contain a fully oxidized ionic form in combination with metal and hydrogen ions. Emission of sulphate compounds occur primarily from the combustion of petroleum-derived fuels like, diesel, gasoline. Sulphates can be a significant portion of fine particulate matter, called $PM_{2.5}$, and can induce several adverse health effects. Sulphates helps in acidification of surface water and soil, can generate acid rain and fog that can damage ecosystems (plants and forests). Sulphates can reduce lung function, can induce chronic heart diseases. In addition with these adverse effects of sulphates in ambient atmosphere, sulphates can reflect energy from sunlight back into space due to its scattering effect. This means that sulphates have a cooling influence on climate change. So, higher percentage of sulphate ions in the ambient air of Siltara can cause detrimental effects on residents' and ecosystems health.

Environmental pollution with fluoride compounds is currently one of the most important problems because of its hazardous effect on ecosystems. Fluoride enters in the atmosphere mainly from anthropogenic sources. The principal anthropogenic sources include aluminium smelters, fertilizer factories, and industrial activities such as brick, tile, pottery and cement works, ceramic industries, and glass manufacture. Anthropogenic fluoride emitted into atmosphere is highly reactive and readily hydrolyzes to form hydrogen fluoride. It has been prescribed that fluoride levels in ambient air should be less than 1µg/m^3. Identified fluoride ions from PM2.5 exposed filter papers in the ambient air of Siltara area is in 'ppt' level and people are out of fluoride related toxicity.

Chlorine is one of the most abundant halogen in the atmosphere, where it exists as both inorganic (particulate Cl^- and gas-phase HCl) and organic (CH_3Cl and chlorofluorocarbons), and influences in many atmospheric photochemical reactions. It is well known element and consider as driving factor for global climate change, decrease the atmospheric ozone concentration, participate in the NO_x cycle, may disturb the aerosol acidity. In this investigating area chloride has been found as 4% (0.03 – 0.17 µg/m^3) which is very low and area is out of danger.

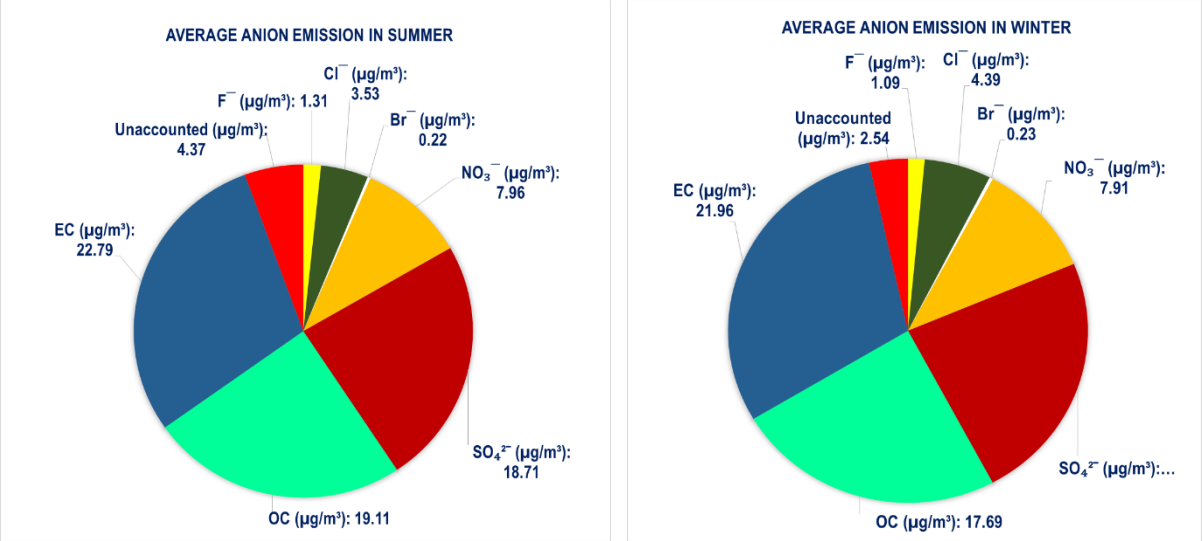


Figure 2.49: Mean concentration (µg/m³) representation of polyatomic anions present in ambient air of different sampling stations of Siltara area.

2.3.11 Stack Monitoring Data

Stack monitoring data for different industries are presented in Table 4.11. Stack monitoring is done for different industries and SPM (suspended particulate matter) value is given above. Higher the SPM value results in higher pollution. As per the CPCB particulate matter emission should not go beyond 150 mg/Nm³.

Table 2.21: Stack monitoring data for Siltara.

Sl.No.	Industry Name	Date	Location of stack	Latitude (°N) and Longitude (°E).	Pitot tube Pressure Drop (mm of H_2O)	SPM (mg/m³)
1	Jayswal (Neco) Industries Ltd. Siltara	24/5/2021	DRI - 1		2.8	22
		25/7/2021	Power plant no-1, Blust furnace gas based		2.3	105
		25/7/2021	Rolling Mill		1.8	34
		25/7/2021	Blust Furnace		2.6	148
		25/7/2021	Central plant		3.2	17

2	Godabari Power & Steel Ltd. Siltara	26/7/2021	KLIN (3& 4) Stack -3-phase-II		2.6	37
		26/7/2021	Fero Stuck - Phase -II		1.6	180
		26/7/2021	PSB bag Filter Stack -Phase-I		2.9	266
3	Devi Iron & Power Pvt. Ltd.	9.04.2022	Kiln-I 100TPD	21.3836287 81.688907	15.6	51.28
		9.04.2022	Stack-II 100TPD*2	21.3838954 81.688641	15.57	25.69
4	Shree Nakoda Ispat Pvt. Ltd.	9.04.2022	6MBA Ferro-alloy	21.359561 81.654325	15.2	148.02
		9.04.2022	12 MW Stack	21.360154 81.650262	15.7	165.6
5	API Ispat & Powertech Pvt. Ltd.	10.04.2022	Kiln 300*2	21.3751119 81.6415784	14.16	25.89
		10.04.2022	Power plant 10 MW	21.3752226 81.6428011	15.3	16.35
6	Aarti Sponge Pvt. Ltd.	3.04.2022	100 TPD stack-2	21.375894 81.638994	17.15	15.54
		3.04.2022	Stack-I 100*2 TPD	21.375747 81.639339	18.2	21.97
7	GR Sponge & Power Pvt. Ltd	3.04.2022	100*2 TPD SID	21.375978 81.653215	18.86	47.72
		3.04.2022	Power 8MW	21.376026 81.653024	16.5	78.78
8	Sarda Energy &Minerals Ltd.	2.04.2022	500*2 TPD	21.364653 81.678494	17.6	49.24
		2.04.22	FAD & 9 MW*2	21.364406 81.683397	16.6	20.08
		2.04.22	Boiler 5 & 6	21.363899 81.683113	16.8	41.66

2.3.12 Real Time Monitoring Data

From the Figure 2.50, here we can clearly note that the highest CO_2 levels have been found in S03, S04 and S13. High concentration CO_2 means high temperature in air which effect the greenhouse also high exposure of CO_2 can cause lung diseases, many heart related problem. The cause of high concentration of CO_2 is mainly because of burning of fossil fuel, transportation, heat etc.

HCHO, H_2S and CO gases concentrations in the ambient air of Siltara are very low and some times those are below detectable limit of measuring instruments.

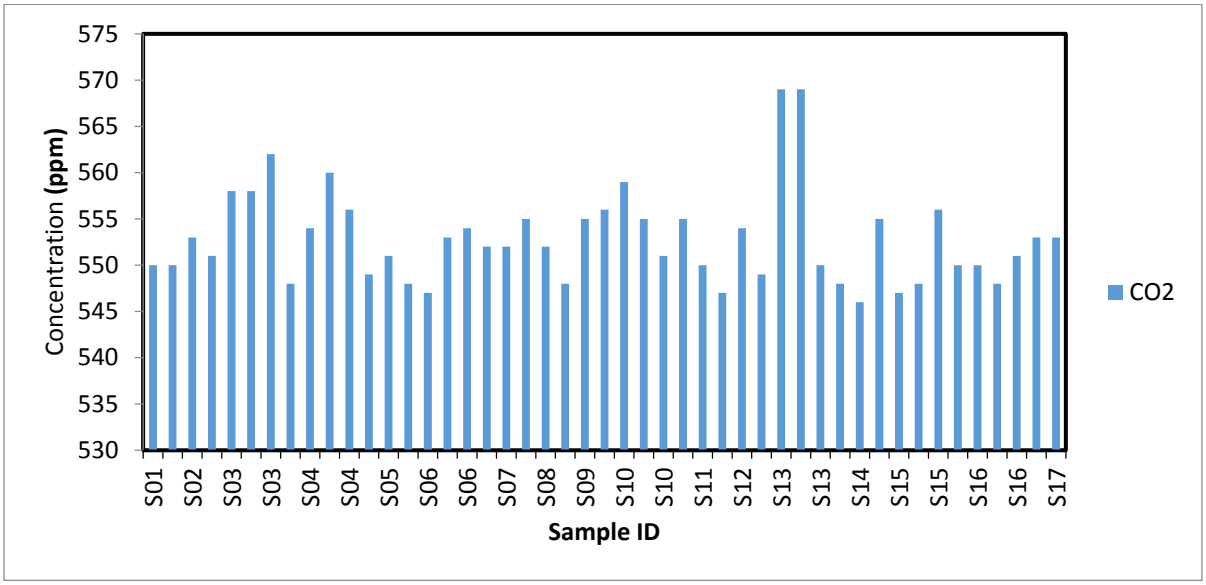


Figure 2.50: CO_2 concentration (in ppm) found using online monitoring system in Siltara.

2.3.13 Air Quality Modelling

2.3.13.1 Windrose Plot

The average angular distribution of wind directions for the period 1 Jan 2022 – 31 Dec 2022 as simulated by WRPLOT View and as observed. Windrose Plot obtained after compiling AERMET for the input meteorological data is shown in Figure 2.51. It can be observed that most of the time the wind is blowing from NW, W and SW direction. However, some wind is from NE and SE. The red coloured line indicated the resultant vector of wind direction and it suggests that most of the pollutants will come from NW sector. The wind speed at the Siltara for year 2022 ranged from 0.0 m/sec to 11.1 m/sec with an annual average wind speed of 2.75 m/sec. The output files surface met data and profile met data are

directly imported into the AERMOD to compile the model. These files included data of all the surface and upper-air parameters of the year 2022.

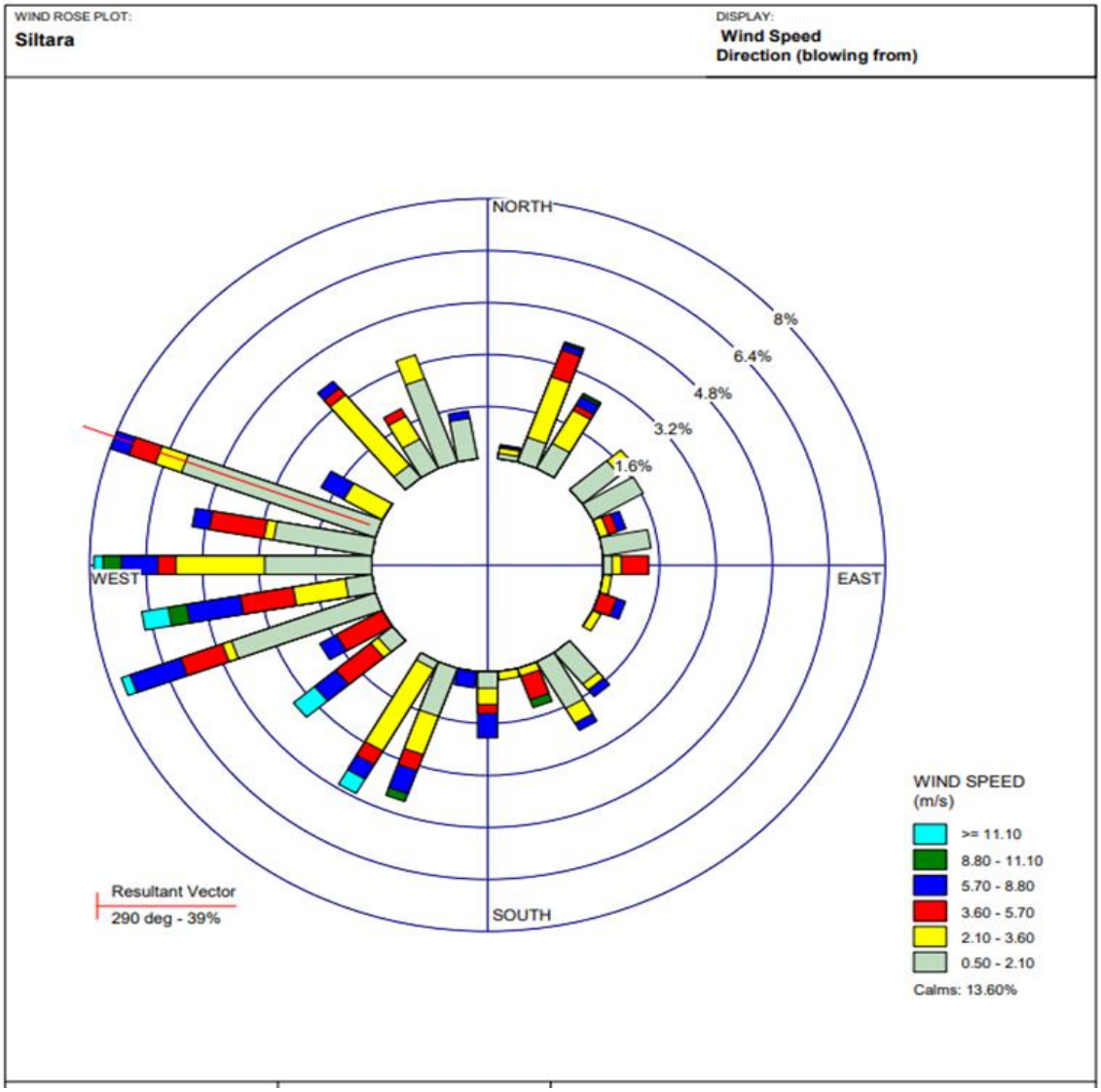


Figure 2.51: Windrose diagram for Siltara.

2.3.13.2 Concentration Dispersion Isopleths

The AERMOD air quality dispersion model was performed to predict the concentration of SO_2, NO_x, SPM, CO, and HC surrounding the industrial area of Siltara, Chhattisgarh. The modeling is carried out using **point**, **line**, and **area source** with different types of emission sources. The emission rate of pollutants of the main 35 industries and their source characteristics for example stack height, stack inside diameter, stack exit temperature and stack exit velocity in the industrial area were obtained from the Siltara monitoring station for the period Jan 2022 – Dec 2022. The industries are classified into different types namely steel, ferro alloy, sponge and power, casting, cement, and agro industries. The location of each industry is referenced to the location of one industry given a reference point (0,0) which

is presented as a red star in isopleths figures for **point sources**. From the **modelling hotspot** are obtained which have high concentration of pollutants. For **point sources modelling**, SPM hotspot are found to be Hatbandh and Mandhar (North latitude 21˚ 20' 9.902', East longitude 81˚ 44' 41.808'') with maximum concentration 24-h obtained as 57.81 µg/m^3. SO_2 hotspot are obtained as Bendari and Donde Khurd (North latitude 21˚ 19' 34.431'', East longitude 81˚ 35' 26.605'') with maximum concentration 24-h 61.85 µg/m^3. NO_x hotspot found to be Bendari, Bana-2, Jarauda, Mandhar, Tor, Donde-Khurd and near above Barauda (North latitude 21˚ 21' 57.973'', East longitude 81˚ 42' 7.782'' m) with maximum concentration 24-h of 49.88 µg/m^3.

For the **line sources modelling**, several roadways, highways, and traffic junctions are considered with emissions from different types of vehicles namely; trucks/dumpers, buses, two-wheeler, four-wheeler. Maximum concentration 24-h of SPM pollutant obtained as 26.92 µg/m^3 with hotspot near by Guru Ghasidas Chowk (North latitude 21˚ 14' 59.911'', East longitude 81˚ 38' 26.744''). Carbon monoxide (CO) hotspot found to Borjhara and Uriyapara (North latitude 21˚ 13' 56.448'', East longitude 81˚ 44' 33.179'') with maximum concentration 8-h of 1119.68 µg/m^3. NO_x maximum concentration 24-h obtained as 47.84 µg/m^3 with hotspot at Kumhari (North latitude 21˚ 23' 47.154'', East longitude 81˚ 40' 51.189''). Guru Ghasidas Chowk (North latitude 21˚ 14' 41.788'', East longitude 81˚ 38' 14.557'') is hotspot due to hydrocarbon (HC) with concentration 24-h of 507.86 µg/m^3.

For the **area source modelling**, we have considered different garbage dumping yard, stone crushers zones in the Siltara city. Here hotspot is found to be Hatbandh (North latitude 21˚ 21' 50.803'', East longitude 81˚ 47' 15.467'') with SPM concentration 24-h of 219.82 µg/m^3.

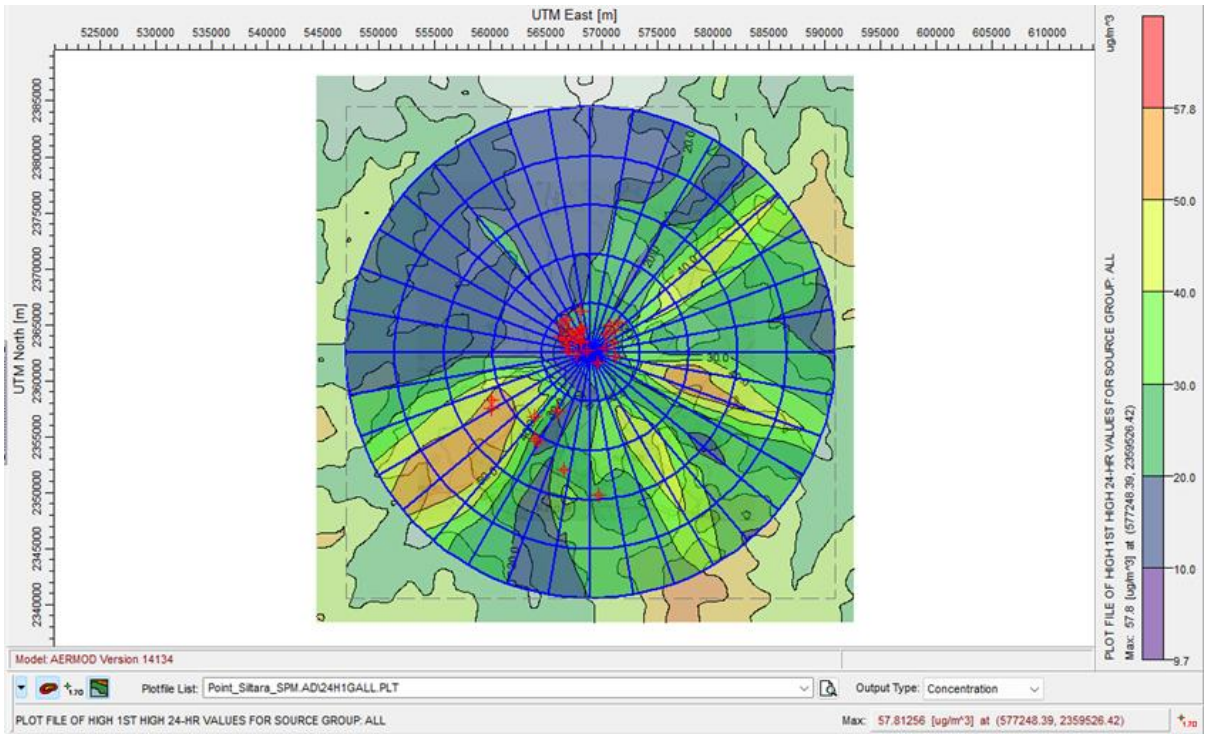


Figure 2.52: Point source isopleths of SPM for 24 hr at Siltara 15 km radius region.

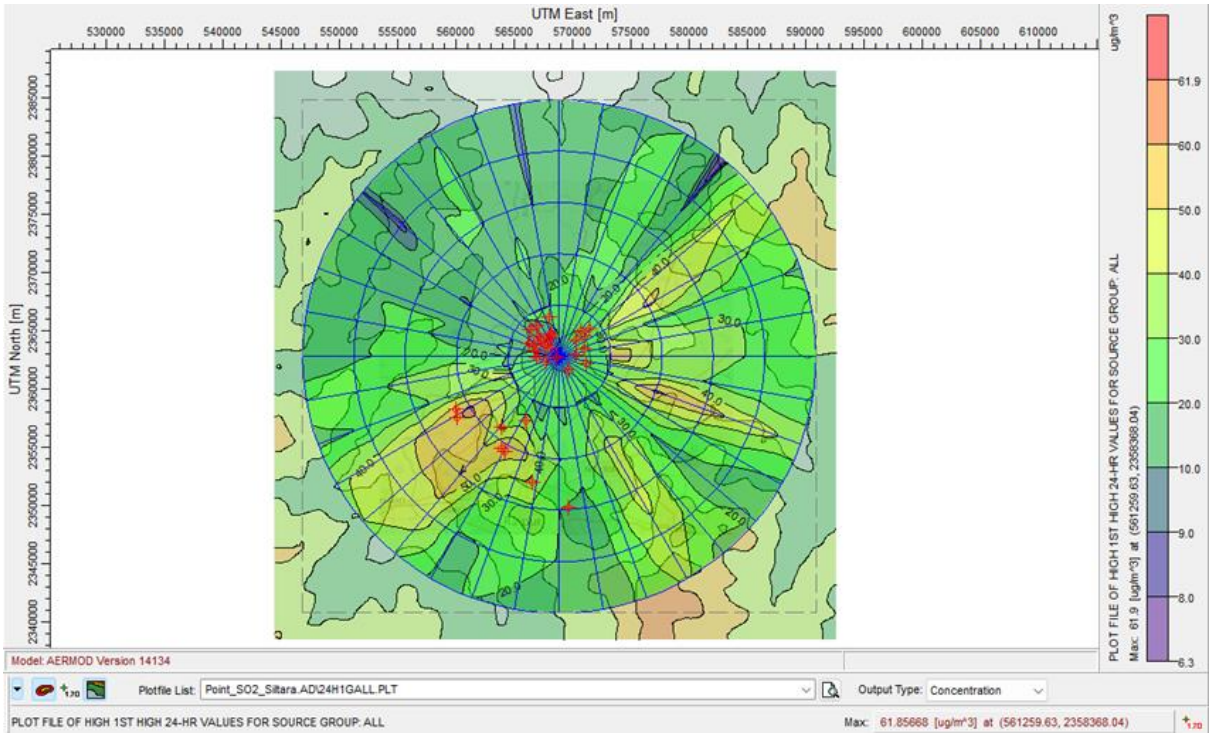


Figure 2.53: Point source isopleths of SO_2 for 24 hr at Siltara 15 km radius region.

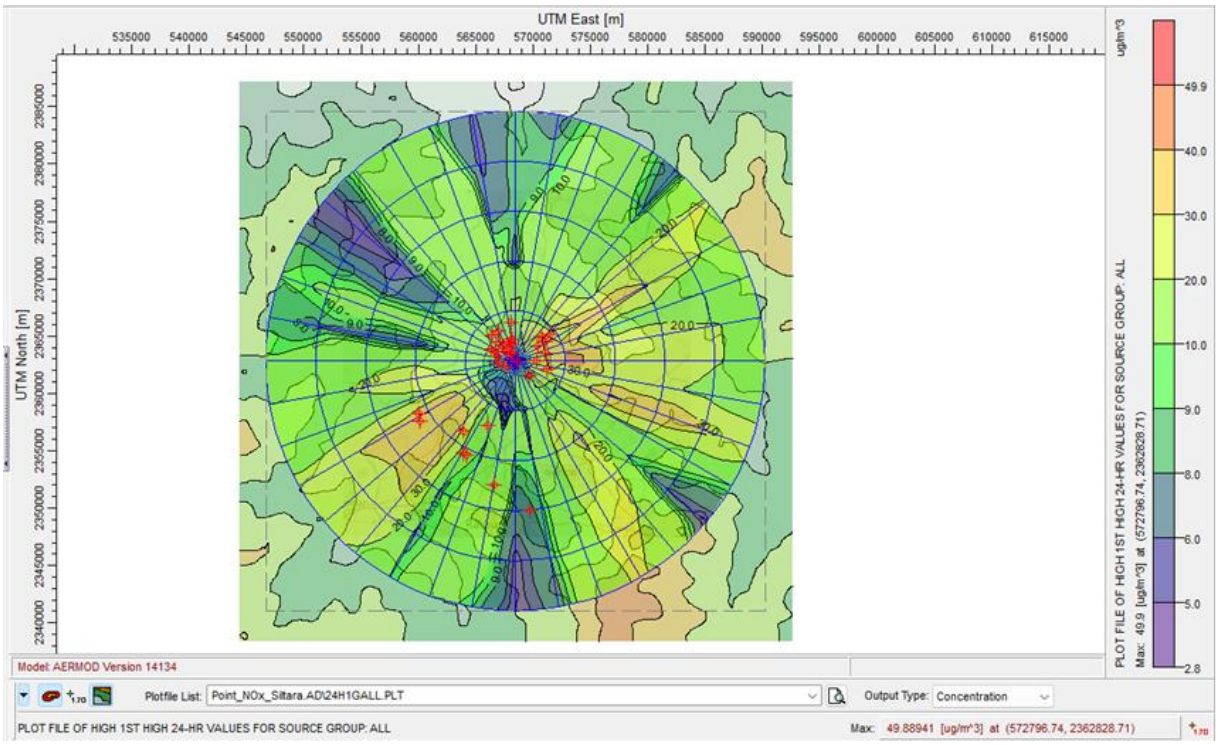


Figure 2.54: Point source isopleths of NO_x for 24 hr at Siltara 15 km radius region.

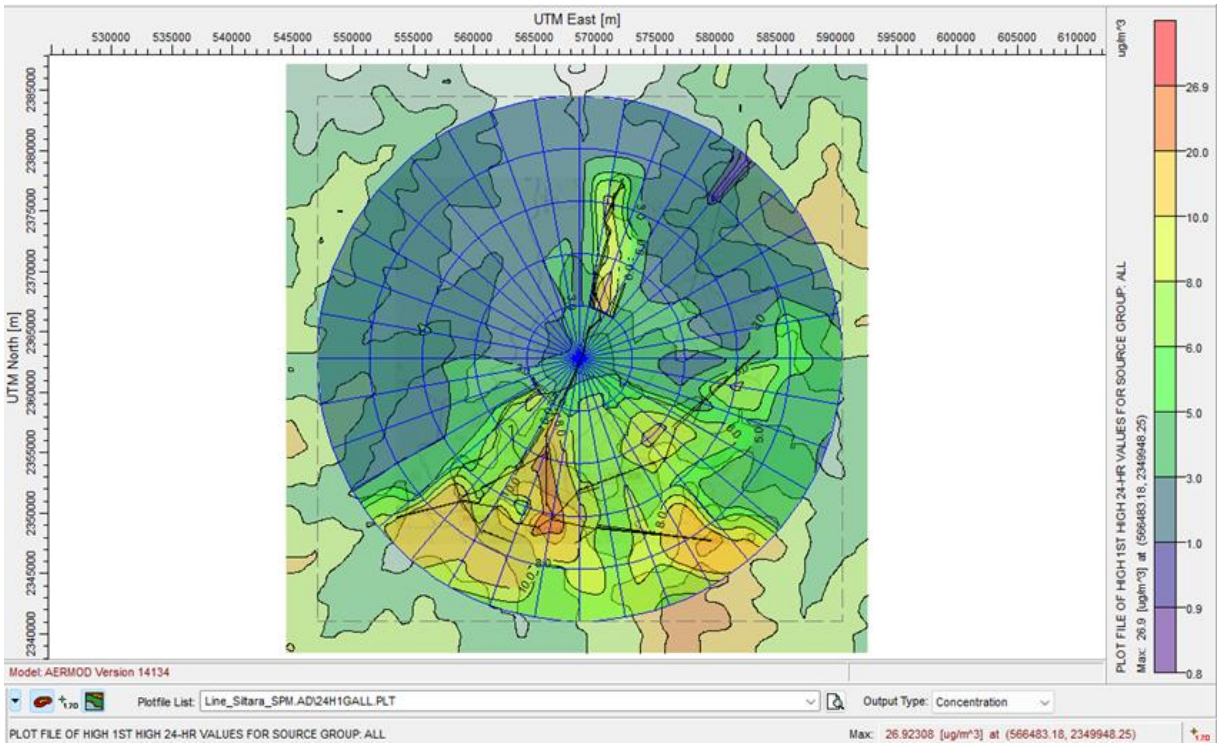


Figure 2.55: Line source isopleths of SPM for 24 hr at Siltara 15 km radius region.

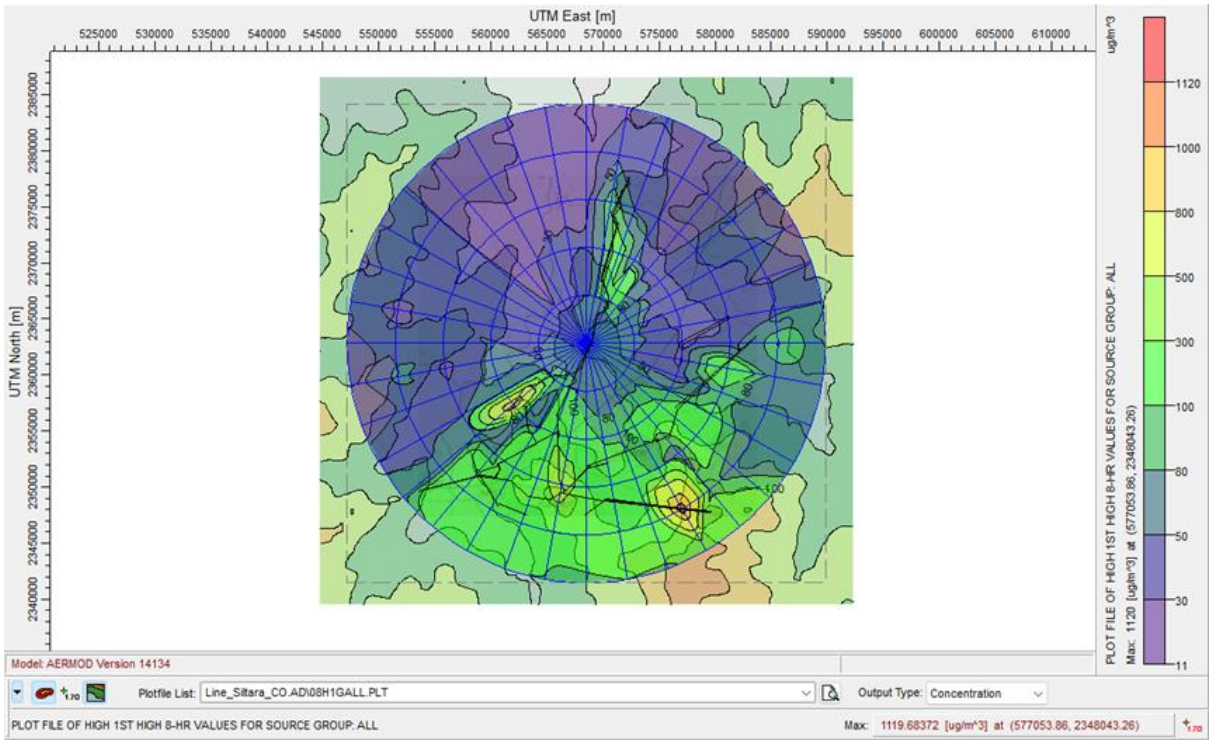


Figure 2.56: Line source isopleths of CO for 8 hr at Siltara 15 km radius region.

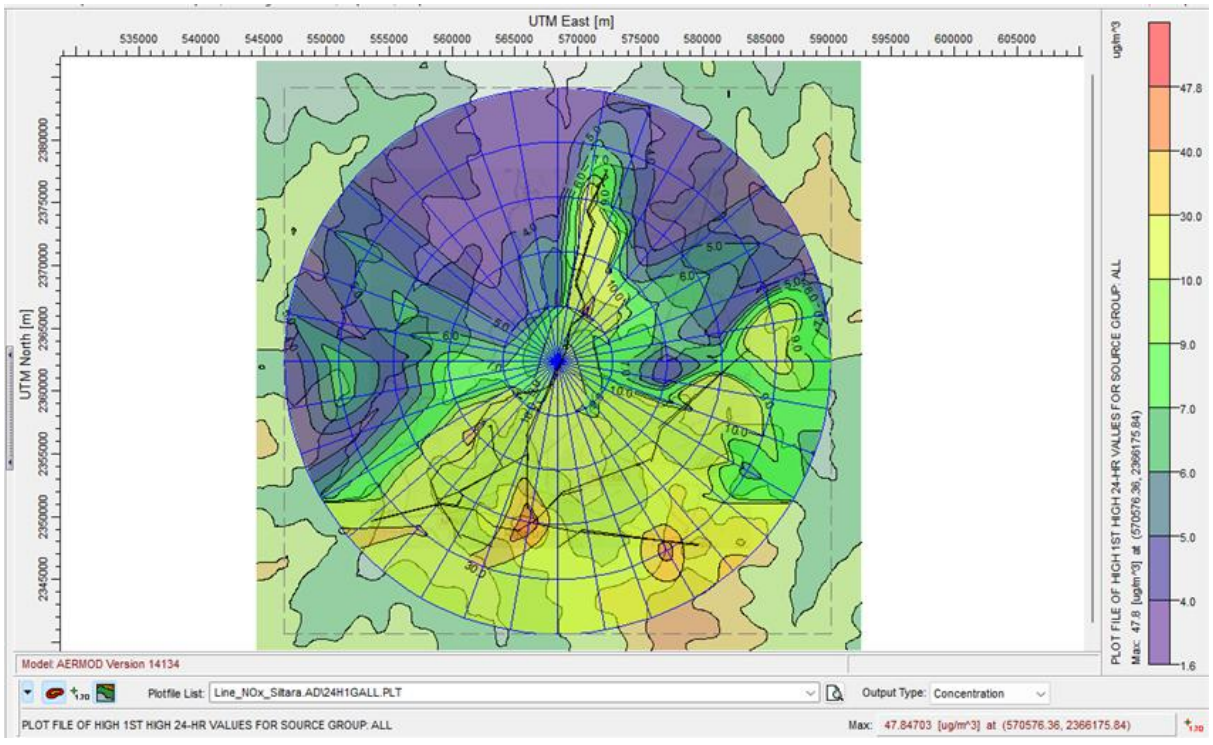


Figure 2.57: Line source isopleths of NO_x for 24 hr at Siltara 15 km radius region.

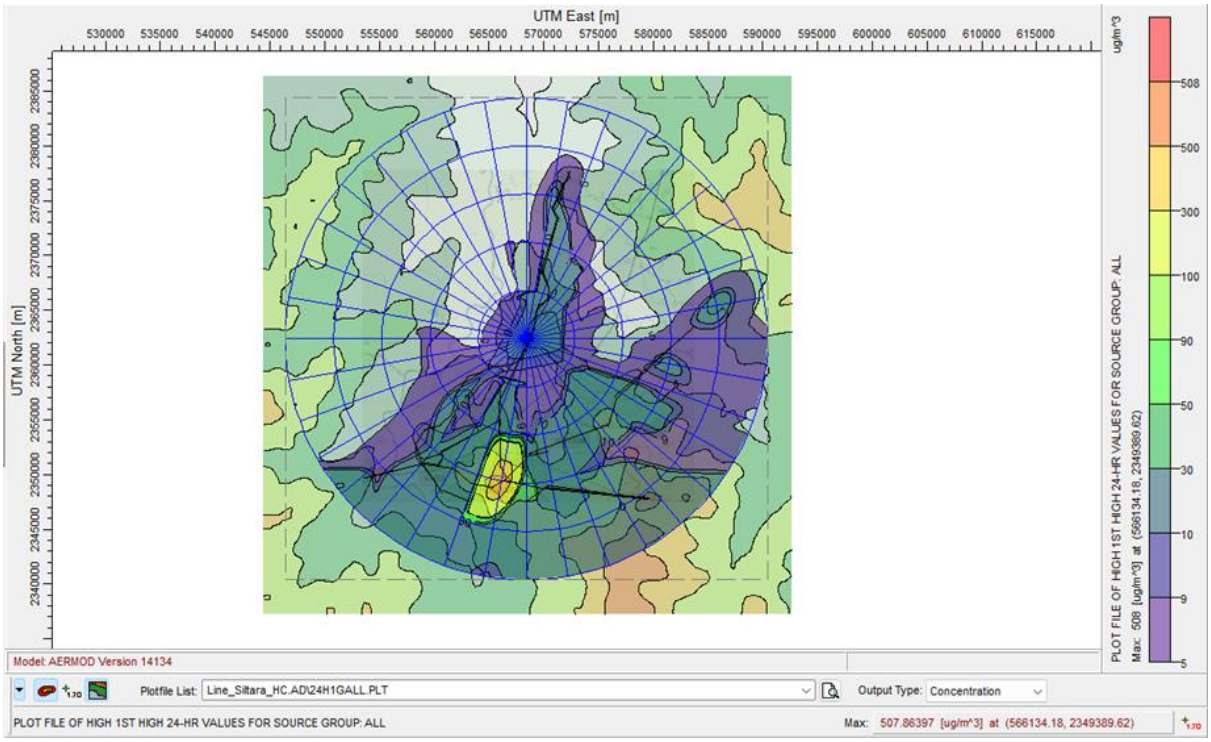


Figure 2.58: Line source isopleths of HC for 24 hr at Siltara 15 km radius region.

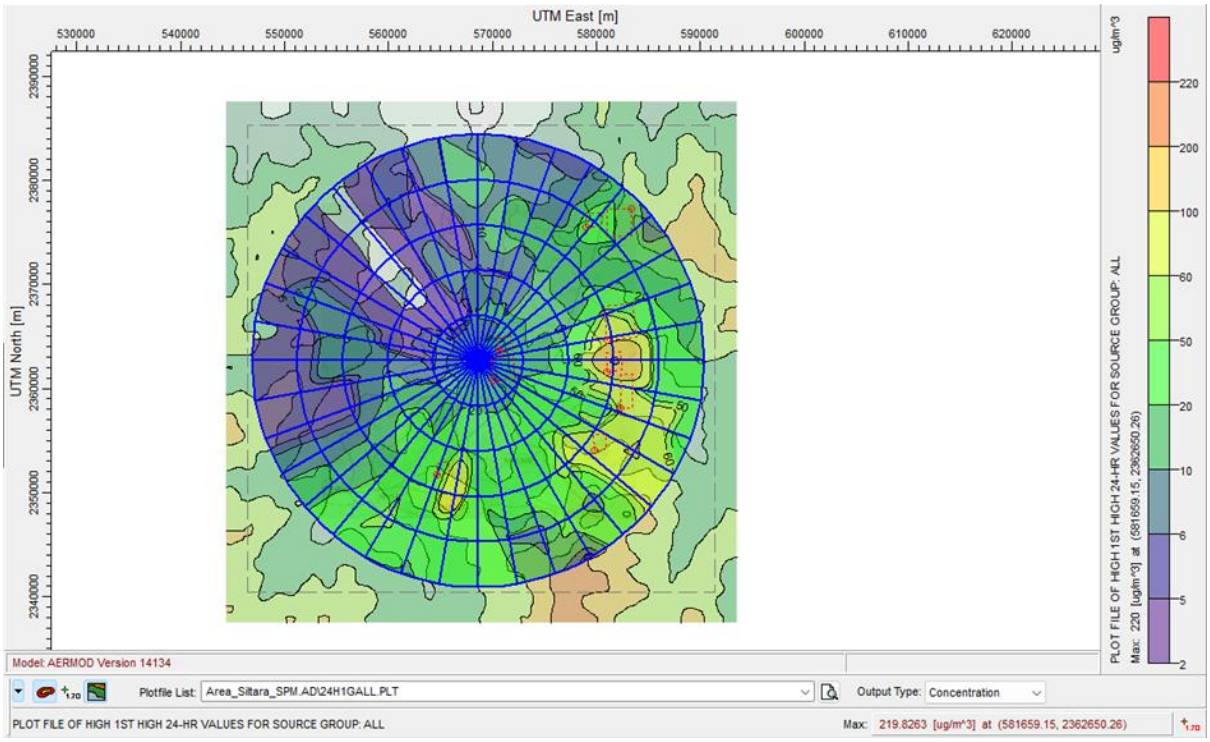


Figure 2.59: Area source isopleths of SPM for 24 hr at Siltara 15 km radius of region.

2.4 Emission Inventory

For emission estimates, 2021 has been considered to be the base year. For transport (tailpipe emission), data available up to 2021 has been used. Detail survey/ reconnaissance of air pollution sources, activities vis a vis population and density within 2 × 2 sq.km area around the selected air quality stations are represented commercial, residential, industrial, kerb site and mixed areas. Also, various reports, research papers and map of Siltara are consulted to understand possible types and density sources of air pollution in Siltara. Delineation of sources has been done after the initial exercise and detail activity data collection has undertaken by conducting field surveys in shortlisted areas. Also, various organizations and govt. departments are approached for collection of secondary activity data. The following major and minor sources of air pollution in Siltara are identified and shortlisted for activity data collection (Table 2.22). Importance and weightage have assigned to the sources based on their possible density, approx. numbers per area and potential of emitting PM_{10} and $PM_{2.5}$.

Table 2.22: Various identified sources and sectors in Siltara.

Sl. No.	Name of Source	Importance/ Weightage	Source of identification	Justification for weightage/ other remarks
1.	Vehicle	High	Source identified from general information, previous reports, RTO and research papers	There are lakhs of registered vehicles in Siltara
2.	Industry/ Manufacturing Units	High	Source identified from previous reports of various organizations, research papers	There are many small and medium industrial manufacturing units in Siltara
3.	Road dust	High	Source identified from previous works of various urban air pollution reports, reconnaissance and research papers	Dust was found to be prevalent over some parts of Siltara roads due to constant inputs from uncovered roadside soils, broken roads etc.
4.	Domestic Fuel Combustion	Low	Source identified from reconnaissance, survey	Population density in Siltara is not very high as compare to other district in C.G There is substantial presence of slums in these cities and wood, kerosene and coal, usage is prominent
5	Construction	High	Source identified from surveys, reconnaissance, previous works of morth.nic.in	Growth of construction sector including urban development activities like flyover and tunnel construction in Siltara
6	Hot Mix Plants	Low	Source identified from primary survey and past knowledge; Meeting with RMC officials	Two permanent RMC controlled Hot Mix plants are operated in Siltara for road laying and repairing; Many other mobile

				ones are used whenever and wherever needed through private contractors and sub-contractors
7	Wastes Burning	Low	Source identified from primary survey, newspaper reports and public interviews	Open burning of MSW (Municipal solid waste) and other waste does exist as an unorganized activity; Smouldering fire is reported from dumpsites at Karun river near sarona and sakri is outside RMC limit but can significantly contribute to city pollution). But, no estimate is available on amount of waste on fire
8	Power Plants	High	Previous works and Power plant company website database	There are various operating power plant and hence this source is considered major in terms of presence
9	Restaurants/ Hotel Kitchens/ Mobile Food Vendors	Low	Source identified from reconnaissance, and research papers	Restaurants and hotels, guest houses and commercial establishments having kitchens, roadside eateries, bhujiawalas and tea shops are commonly found all over Siltara. Many of these eateries use coal, wood, kerosene apart from LPG
10	Crematoria	Low	Source identified from RMC websites, other web sources, and information from stakeholders	There are few crematoria in Siltara
11	Ironing vendors	Low	Source identified from primary survey	According to initial investigation done by our group there are a few ironing vendors in Siltara who use electricity and also coal for warming the ironing machines
12	Brick Kilns	Low	Source identified by primary survey	Few brick kilns are present around the Siltara river sides

2.4.1 Primary Survey

Primary survey was conducted by our team around the selected air quality monitoring stations and many other residential, commercial, industrial, and mixed areas in Siltara to identify major and minor air pollution sources, interview public, customers and vendors to record activity data on fuel consumption in households, hotels and restaurants and other commercial establishments, ironing huts etc. (as shown in figures 2.60 to 2.63). Survey on vehicles was conducted at several petrol pumps in Siltata to record types of vehicles running in the city, their average mileage within RMC, miles ran/unit fuel, vehicle vintage, usage rate (days run per year) etc. for estimation of likely emissions of PM_{10} and $PM_{2.5}$ from vehicular fleet. Further, registered vehicular data with vintage was collected from various RTO offices in Siltara (Pandari, Rawabhata, Tatibandh chowk).

Figure 2.60: Use of coal/char coal by roadside eateries and ironing vendors.

Figure 2.62: Petrol pump survey in the study area.

Figure 2.63: Open burning witnessed in the study area.

2.4.2 Secondary Data Sources

Secondary data on fuel and energy usage in industrial sector was extracted from filed-in consent to operate forms accessed through online database maintained by CECB (http://enviscecb.org/)., list of registered businesses in Siltara including eateries, data on base area of construction (only for residential construction) etc. Secondary data on population was collected census database and from various other reports. The various sources of data collection are summarized in Table 2.23.

Table 2.23: Source of activity data.

Source/Sector	Source of data
Industrial/ Manufacturing units	CECB database,
Transport/Vehicular	RTO databases, Primary surveys
Restaurants/Hotel kitchens/Mobile food vendors	RMC database, CGPCB, Primary survey by our team
Construction	RMC database, other data sources
Road dust	Primary survey, Laboratory analysis, RMC websites on roads, various reports and news
Domestic fuel consumption	Primary survey, Census data on population, Data given by Food and Supplies Dept. of C.G. Govt.
Crematoria	RMC database, Online resources
Ironing vendors	Primary survey
Wastes burning	Primary survey, RMC data on waste generation, Online sources

2.4.3 Methodology for the Preparation of Emission Inventory

The basic logic behind emission inventory calculation involves collection of sector-wise activity data (e.g. type of fuel used and their consumption in various sectors, mileage and vintage of vehicles, their number, rates of production of a commodity, number of industrial units operating in the cities, their hours of operation per day and year, city-wise population etc.) from secondary databases or primary survey or direct estimation and then integrating these with suitable pollutant-specific and activity-specific emission factors (emission per amount of fuel burnt in various sectors/activities /operations, emission per km travelled for vehicles, emission per unit of a commodity produced etc.) and relevant population database to calculate likely emissions of a pollutant from that particular

activity/source/sector. Further, number of operating units like number of households, number and types of registered and on-road vehicles with vintage (registered vehicles in last 5 years i.e. 2018-2022), survival rate of vehicles (type wise vehicle survival rates for registered vehicles in Siltara in last 5 years), number of restaurants/eateries, types and number on industries, number of bodies burnt in crematoria etc. are important information required to develop the emission inventory. For emission inventory estimates, along with reliable activity data, relevant emission factors or emission coefficients that represent emission per unit fuel, production, number of product, vehicle mile ran and so on is required. The calculation methodology for emission estimates is summarized in Table 2.24.

Table 2.24: Summary of methodologies for estimation of sector-wise emissions

Name of Source/Sector	Activity data type	Formula (Emission per year)
Industry/ Manufacturing units	Fuel (diesel, FO, wood, coal, LPG, etc.) consumption per unit time	$E = \sum_{i,j=1}^{n} F_{ij} \times EF_{ij}$ Where, E= Total city emission (kg/y), F= fuel consumption (e.g. MT/y), EF= Relevant emission factor (e.g. kg/MT) i= i^{th} industry j= j^{th} fuel
Transport	Vehicle mileage and vintage, types and numbers of vehicles registered; Vehicle survival rate data with age in India was taken into account for estimating registered vehicles in operation during last 15 years (Ref: Goel and Guttikunda, 2015; DOI: 10.1016/j.atmosenv.2015.01.045)	$E = \sum_{i,j=1}^{n} EF_{ij} \times VKT_{ij}$ E= Total city emission (g/y) EF = Relevant emission factor (g/km) VKT = Vehicle kilometre travelled per year (km/y) i= i^{th} vehicle (vintage considered) j= j^{th} fuel

Restaurants/ Hotel kitchens/ Canteens/ Eating Houses/ Mobile food vendors/ Tea and snacks stalls	Fuels(LPG, wood, kerosene, coal, etc.) consumption per unit time	$E = \sum_{i=1}^{n} F_i \times EF_i \times No.of\ restaurants$ Where, E = Total city emission (kg/y) F_i = Av. Consumption of i^{th} fuel (e.g. LPG/coal/wood/kerosene) in city per restaurant (e.g. MT/y) EF = Relevant emission factor for i^{th} fuel (e.g. kg/MT)
Construction	Base area of construction	$E = \sum_{i=1}^{n} BA_i \times EF$ Where, E = Total city emission (MT/y) BA_i = Base area of construction (acre-month/year) of i^{th} activity (e.g. residential construction/commercial construction/road/flyover) EF = Relevant emission factor (MT/acre-month)
Road dust	Silt content in road dust, average weight of vehicles run of road, mileage per year, vehicle survival rate data with age, RTO database on types and number of vehicles	Total city emission calculated from USEPA formula that is based on road silt loading, Av. weight of on-road vehicles, particle size multiplier for particle size range, emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear, vehicle kilometre travelled. USEPA's model for road dust emissions is the only internationally accepted methodology for estimating road dust emissions and hence, was used, as following: $E=K(sL/2)^{0.65} \times (W/3)^{1.5}$ Where, E= Emission factor (lb/VMT), sL= silt loading (g/m^2), W= Mean vehicle wt (MT), K = particle size multiplier or k factor (lb/VMT)

Domestic	Fuels (LPG, wood, coal, etc.) consumption per unit household per year; Number of households; KMC/HMC population	$E = \sum_{i=1}^{n} F_i \times EF_i \times No.of\ households$ Where, E = Total city emission (kg/y) F_i = Av. Consumption of i^{th} fuel (e.g. LPG/coal/wood) in city per household (MT/y) EF= Relevant emission factor for i^{th} fuel (e.g. kg/MT)
Crematoria	Fuels (wood) consumption per unit time; Number of bodies burnt per unit time	$E = \sum_{i=1}^{n} (F_i \times EF_w) + (B_i \times EF_b)$ Where, E = Total city emission (kg/y), F= Wood consumption (e.g. MT/y) EF_w = Relevant emission factor for wood (e.g. kg/MT), B= Body burnt (number) EF_b = Relevant emission factor for dead body (e.g. kg/body) i= i^{th} crematoria
Ironing vendors	Average fuel (coal) consumption per vendor; Number of vendors, days worked in a year (only coal using ironing vendors data are used)	E = F x EF x No. of ironing vendors Where, E = Total city emission (kg/y) F = Coal consumption per vendor (MT/y) EF = Relevant emission factor for coal (e.g. kg/MT)
Hot Mix plants	Actual PM emission test results (2019) of state owned plants used for total emission estimation of four large plants; Bitumen supplied per year to mobile hot-mix plants by IOCL to Kolkata and Howrah as reported by IOCL (assumed 70% used for road laying, rest for industries). This bitumen amount up-scaled to Hot Mix Asphalt (HMA) by 92% as bitumen in HMA is about 8%.	E = F x EF Where, E = Total city emission (kg/y) F = Bitumen consumption in city (MT/y) EF= Relevant emission factor for HMA (kg/MT HMA)

Wastes burning	Waste generated per year in RMC General extent of open burning; Percent combustible in MSWs	E = F x EF Where, E = Total city emission (kg/y) F= Total waste burnt (MT/y) EF= Relevant emission factor for open burning (kg/MT)
Thermal power plant	There are various Thermal Power Plant running in Siltara.	E = F x EF Where, E = Total emission (kg/y) F= Total coal burnt (MT/y) EF= Relevant emission factor for industrial boiler (kg/MT)
Brick Kilns	Few brick kilns of different size are observed in Raipur.	E = ER / F Where, F = Fuel consumption rate (kg/h), ER = Emission factor (s/h)

Note: Emission factor taken from CPCB (https://cpcb.nic.i n/NGT/Annexure _3.1_27.02.2018. pdf) and USEPA AP-42 (www3.epa.gov/tt n/chief/ap42/ch01/final/c01s01.pdf)

2.4.4 Collection of Activity Data

A glimpse of actual activity data use for RMC is presented in Table 2.25 to highlight the nature of activity data used for development of emission inventory. The activity data is dynamic in nature and represents the scenario at the time of data collection.

Table 2.25: Nature of activity data used for development of emission inventory

Name of Source/Sector	Activity data (RMC)
Industry/ Manufacturing Units	Fuel usage data in by industries /manufacturing units within RMC area were extracted from CECB. Data on specific pollution control devices as found in the database were used for downscaling respective emissions
Transport	Number of registered vehicles with vintage as per RTO department database is detailed in Table 3.7. The database was received on request from RTO/ PVD offices in Siltara, Sundar Nagar
Brick Kilns	These are of different sizes and using different techniques. Use coal for heat generation during brick buring. Also some factory use fly ash as one ingradient of brick. Estimated around 10 different brick kilns present in the Siltara surroundings. Main activities are found during winter season.

Restaurants/ Roadside eateries/ Mobile food vendors/ Office canteens/ Tea stalls/ Sweet makers	Number of roadside eateries Also, data on registered eateries/ restaurants was extracted from RMC database on registered businesses in RMC area. The extracted data on registered eateries pertains to entries as restaurants, fast food centres, eating houses, 3-/4-wheeler mobile eateries, eateries, bank with canteen, boarding house with kitchen, tea stalls, jalpan shops, workshop for food items, sweetmeat/ chips/ chanachur manufacturers, bakeries. This number was found to be about 14694 in RMC. Therefore, a total of 17185 eateries are considered to be present within RMC.
Construction	RMC data on land base area (acre) under residential construction (i.e. dug up land) in 2021 was used for RMC area (271 acres). Construction land area under commercial sector was not available for RMC, hence was assumed to be 30% of residential area (81.3 acre)
Road dust	Silt content of road dust measured at various locations distributed over the cities; Silt loading range was found to be 0.20-0.46 g/m^2
Household/ Domestic	Number of households in RMC area was arrived at by dividing RMC population as per last census data by average number of family members (i.e. 5). Fuel usage per house per day (kg or L) as found in primary survey was used with number of households to estimate total emission
Crematoria	As per survey and RMC data made available for this project, 649.525 MT wood was used and 25,981 numbers of bodies were burnt in crematoria in 2022
Ironing vendors	Ironing vendors using coal as fuel (Note: ironing vendors using electrical ironing machine were not included) was estimated to be about 144 in RMC area (excl. vendors using electricity), which was based on extrapolation of their numbers found in sample study areas. Annual working days are about 315, taking 4 Sunday-offs per month as found during survey

During the primary survey of eateries and restaurants in Siltara conducted by our team, several zones were identified having high density of eateries and restaurants including small, footpath encroaching, food-vending shanties (Table 2.26). These zones have substantial number of temporary eateries (mostly shanties) using substantial amounts of coal, kerosene and wood apart from LPG which is used by only a small proportion of these eateries. Numbers of roadside eateries in RMC areas were provided by SMC.

Table 2.26: List of Areas in Siltara having moderate to high density of restaurants and eateries.

Sejbahar	Bilaspur Road, Birgaon
Shanker Nagar	Metal Park Road, Birgaon,
Dharsiwa	Transport Nagar, Urla,
Girod	Bvanjari Mandir, Urla
Bilaspur Road	Birgaon
Charoda	Kabir Nagar
Giraud	
Urla Road, Birgaon	

Table 2.27: Last 10 year registered vehicle data year wise.

Sl. No.	Vehicle Class	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	Tractor (Commercial)	136	65	33	14	23	21	15	12	119	112
2	Mobile Clinic				0	0	0	0	0	1	
3	Motor Car	8964	8797	8928	9827	10553	11979	13054	10614	13234	15097
4	Tow Truck	0							1		1
5	Vehicle Fitted With Rig	7	2	5	5	5		1	2	2	
6	Three Wheeler (Passenger)	211	254	111	274	273	110	145	44	199	448
7	M-Cycle/Scooter-With Side Car	1						2			8
8	Cash Van	0					0		6	44	73
9	Tower Wagon								2		
10	Trailer (Commercial)	3	4	15	12	21	7	6	13	28	57
11	e-Rickshaw with Cart (G)						0	1	6	122	251
12	Fire Fighting Vehicle	0	0	1			0	0	2		3
13	Trailer (Agricultural)	24	9	26	20	7	74	125	8	653	826
14	Harvester	99	73	62	67	51	38	153	85	165	84
15	Hearses						1				5
16	Excavator (NT)	341	250	222	102	113	176	248	172	206	233
17	Goods Carrier	1658	2479	2928	2784	3407	4948	3634	1738	3072	6217
18	Camper Van / Trailer	1				3	3	0	1	2	1
19	Agricultural Tractor	2641	2110	1835	1934	1726	1659	2332	2074	2025	1611
20	Three Wheeler (Goods)	9	59	71	60	73	70	61	30	140	165
21	Three Wheeler (Personal)	2	1	3	1		3		5	4	28
22	Bus	129	74	89	89	55	56	43	38	17	55
23	Vehicle Fitted With							7	3	1	

	Compressor										
24	Maxi Cab	8	22	12	17	43	75	150	31	52	91
25	Crane Mounted Vehicle	66	51	38	67	95	125	110	64	87	74
26	M-Cycle/Scooter	73951	77591	76073	73340	81922	81308	80346	52519	50888	59631
27	Motorised Cycle (CC > 25cc)						1	3		1	1
28	Articulated Vehicle	2	5	13	145	519	469	250	176	77	672
29	Adapted Vehicle	12	18	16	21	28	33		1	13	11
30	Road Roller		2	1	1	2	4	5	3	7	
31	Moped	5821	5552	5087	6562	5884	4321	2712	1934	2324	3743
32	Animal Ambulance	0	0			1		0			
33	Educational Institution Bus	68	73	112	140	113	127	111	49	6	116
34	Armoured/Specialised Vehicle					37					20
35	Construction Equipment Vehicle	8	9	17	12		71	65	60	168	237
36	Ambulance	162	8	26	75	73	20	33	362	187	2335
37	Earth Moving Equipment	1	1	2	3	32	29	11	7	7	7
38	Fire Tenders							1			1
39	e-Rickshaw (P)				7	100	54	42	21	488	2670
40	Motor Cab	55	41	55	115	211	157	201	124	169	360
41	Private Service Vehicle	2	6	4	5	4	5	5	4	8	18
42	Dumper		0			0	1	1		6	
43	Omni Bus (Private Use)	593	1054	1141	1170	1085	760	747	361	213	164
	Total	94975	98610	96926	96869	106459	106705	104620	70572	74735	95426

Table 2.28: Summary of registered vehicle in last 10 years.

Sr. No.	Vehicle Class	Total
1	Tractor (Commercial)	550
2	Mobile Clinic	1
3	Motor Car	111047
4	Tow Truck	2
5	Vehicle Fitted With Rig	29
6	Three Wheeler (Passenger)	2069
7	M-Cycle/Scooter-With Side Car	11
8	Cash Van	123
9	Tower Wagon	2
10	Trailer (Commercial)	166
11	e-Rickshaw with Cart (G)	380
12	Fire Fighting Vehicle	6
13	Trailer (Agricultural)	1772

14	Harvester	877
15	Hearses	6
16	Excavator (NT)	2063
17	Goods Carrier	32865
18	Camper Van / Trailer	11
19	Agricultural Tractor	19947
20	Three Wheeler (Goods)	738
21	Three Wheeler (Personal)	47
22	Bus	645
23	Vehicle Fitted With Compressor	11
24	Maxi Cab	501
25	Crane Mounted Vehicle	777
26	M-Cycle/Scooter	707569
27	Motorised Cycle (CC > 25cc)	6
28	Articulated Vehicle	2328
29	Adapted Vehicle	153
30	Road Roller	25
31	Moped	43940
32	Animal Ambulance	1
33	Educational Institution Bus	915
34	Armoured/Specialised Vehicle	57
35	Construction Equipment Vehicle	647
36	Ambulance	3281
37	Earth Moving Equipment	100
38	Fire Tenders	2
39	e-Rickshaw(P)	3382
40	Motor Cab	1488
41	Private Service Vehicle	61
42	Dumper	8
43	Omni Bus (Private Use)	7288
	Total	**945897**

Total registered vehicle in last 10 year is **945897** and these data collected from Transport Department, Siltara RTO, Chhattisgarh. Emission from various type of vehicles at different years is shown in Table 2.29 (**Source:** ARAI Emission Factor Report, January 2008)

Table 2.29: Emission from various type of vehicles at different years.

Vehicle Type	Model Year	PM (g/km)
2 Wheelers (2 Strokes) Scooters	1991-1995	0.073
	1996-2000	0.073
	2001-2005	0.049
	2006-2010	0.057
2 Wheelers (2 Strokes) Scooters	2001-2005	0.015
2 Wheelers (2 Strokes) Scooters	2006-2010	0.015
2 Wheelers (4 Stroke) Motorcycle	1991-1995	0.01
	1996-2000	0.015
	2001-2005	0.035
	2006-2010	0.013
3 Wheeler (CNG-4S OEM)	2006-2010	0.015
3 Wheeler Auto-rickshaw (Petrol 2S)	Post 2000	0.045
3 Wheeler Auto-rickshaw (LPG 2S)	Ret-Pre 2000	0.721
	Ret-Post 2000	0.13
3 Wheeler Auto-rickshaw (Diesel)	Post 2000	0.347
	Post 2005	0.091
4 Wheeler (Petrol)	1991-1995	0.008
	1996-2000	0.008
	2001-2005	0.004
	2006-2010	0.002
4 Wheeler(Diesel)	1996-2000	0.145
	2001-2003	0.19
	2003-2005	0.06
	2006-2010	0.015
4 Wheeler (LPG)	1996-2000	0.001
	2001-2005	0.002
	2006-2010	0.002
4 Wheeler (CNG)	2006-2010	0.006
LCVs (Light Commercial Vehicles)	1991-1995	0.998
	1996-2000	0.655
	2001-2005	0.475
	2006-2010	0.475
Large Trucks + MAV	1991-1995	1.965
	1996-2000	1.965
	2001-2005	1.24
	2006-2010	0.42
Buses (Diesel)	1991-1995	2.013
	1996-2000	1.213
	2001-2005	1.075
	2006-2010	0.3

2.4.5 Emission Estimates

Emission estimate has been prepared for important sectors in Siltara. Table 2.30 presents emission estimates from Siltara in decreasing order of PM_{10} from sectors viz. Road, Household, Transport, Industry, Construction, Hot Mix Plants, Open Burning, Restaurants and eateries, Thermal Power, Ironing Vendors, and Crematoria (Table 2.30). The share of various sectors in PM_{10} and $PM_{2.5}$ emissions is presented in Figure 2.64 and 2.54.

Table 2.30: Emissions of $PM_{2.5}$ and PM_{10} (MT/y) from various sectors in Siltara.

Sector	Emission (MT/y)	
	$PM_{2.5}$	**PM_{10}**
Constructions	372.69	761.39
Transport Emission	329.06	290.39
Road Dust	331.48	838.86
Industry	822.55	2160.31
Generator Sets	160.04	107.71
Domestic	74.54	115.99
Brick Kilns	37.28	49.71
Wastes Burning	41.65	41.84
Restaurants, Eateries and Hawkers	19.73	20.71
Crematoria	3.29	4.14
Total	**2192.31**	**4391.05**

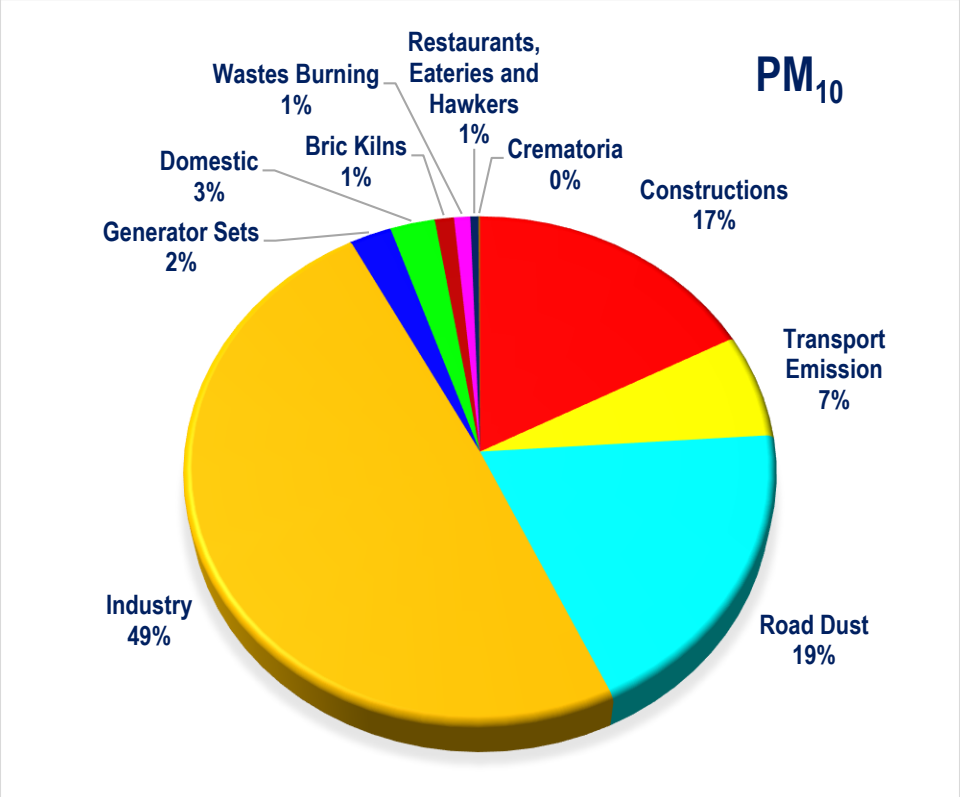


Figure 2.63: PM_{10} emission estimates (% share) from various sectors in Siltara.

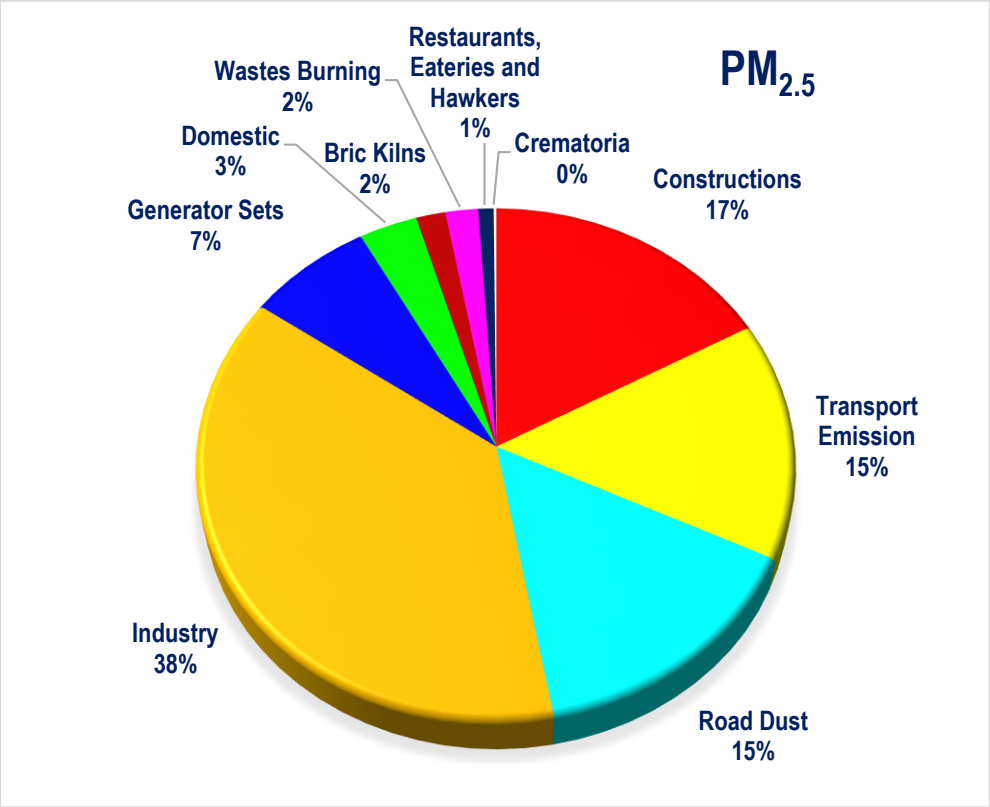


Figure 2.64: $PM_{2.5}$ emission estimates (% share) from various sectors in Siltara.

2.4.6 Spatial Air Pollutant Distribution using Gridded GIS-based Emission Inventory

The aim of this study was to assess the distribution air pollutants specifically particulate matter (PM_{10} and $PM_{2.5}$) in the Siltara area using QGIS software. The study aimed to provide valuable information for policymakers and local authorities to develop effective control measures to mitigate air pollution. The collected data were processed and prepared for analysis in QGIS. Various tools and plugins were employed for spatial analysis, interpolation, and visualization of the air pollutant data. This involved data cleaning, integration, and conversion into compatible formats for spatial analysis and modelling. The existing air quality monitoring stations were mapped, and their locations were considered for data analysis and interpolation. The coverage and density of monitoring stations were assessed to ensure representative results. For spatial distribution of different pollutants, emission per capita, in each ward and village was calculated, as activity data was available on the basis of per capita. Then the emission density in terms of MT/year/m^2 in each ward was calculated based on population and area of the ward for different pollutants

Emission Density (MT/year/m^2) = Emission of Ward (MT/year) / Ward Area (m^2) (3.1)

For calculating emission in a grid which may contain more than one ward, the area of the fraction of each ward falling inside that grid was calculated and with the help of emission density of the ward, the missions were calculated, see below.

$$Grid\ Emission = \sum_{i=1}^{N}(Area\ of\ fraction\ ward\ i\ in\ grid\ X\ emission\ density\ of\ ward, i) \quad (3.2)$$

Where, N= no. of wards in the grid

Using QGIS interpolation tools, the measured air quality data was spatially interpolated to estimate PM_{10} and $PM_{2.5}$ concentrations across the entire study area. This provided a continuous surface of pollution levels, enabling a detailed understanding of pollution hotspots. Source apportionment analysis results were utilized (Table2.30) to identify the major contributors to PM_{10} and $PM_{2.5}$ pollution in Siltara. This involved statistical methods and spatial analysis techniques to determine the relative contributions of various pollution sources.

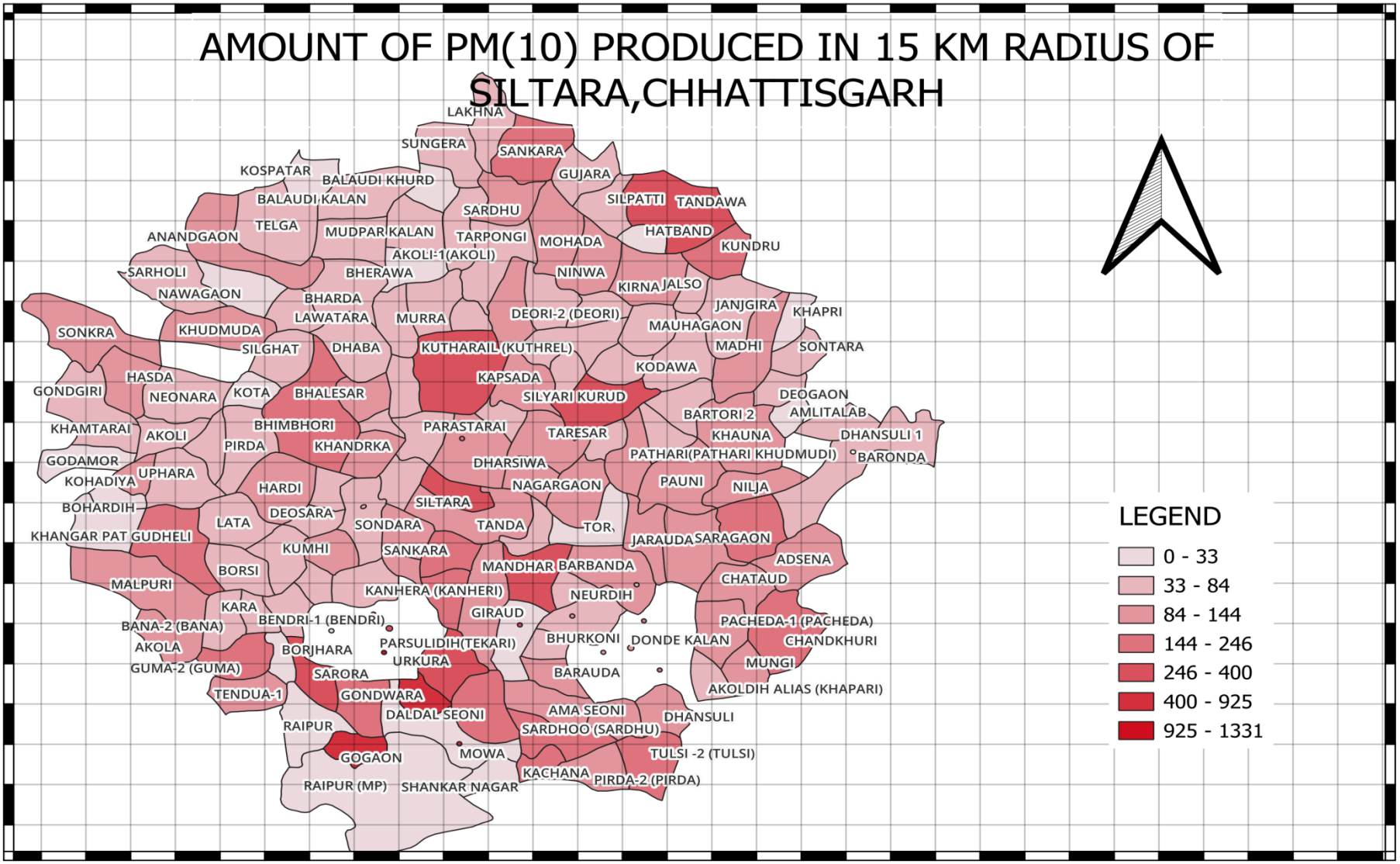


Figure 2.65: 2×2 sq. km gridded spatial distribution of PM_{10} generated from QGIS software for different areas of Siltara.

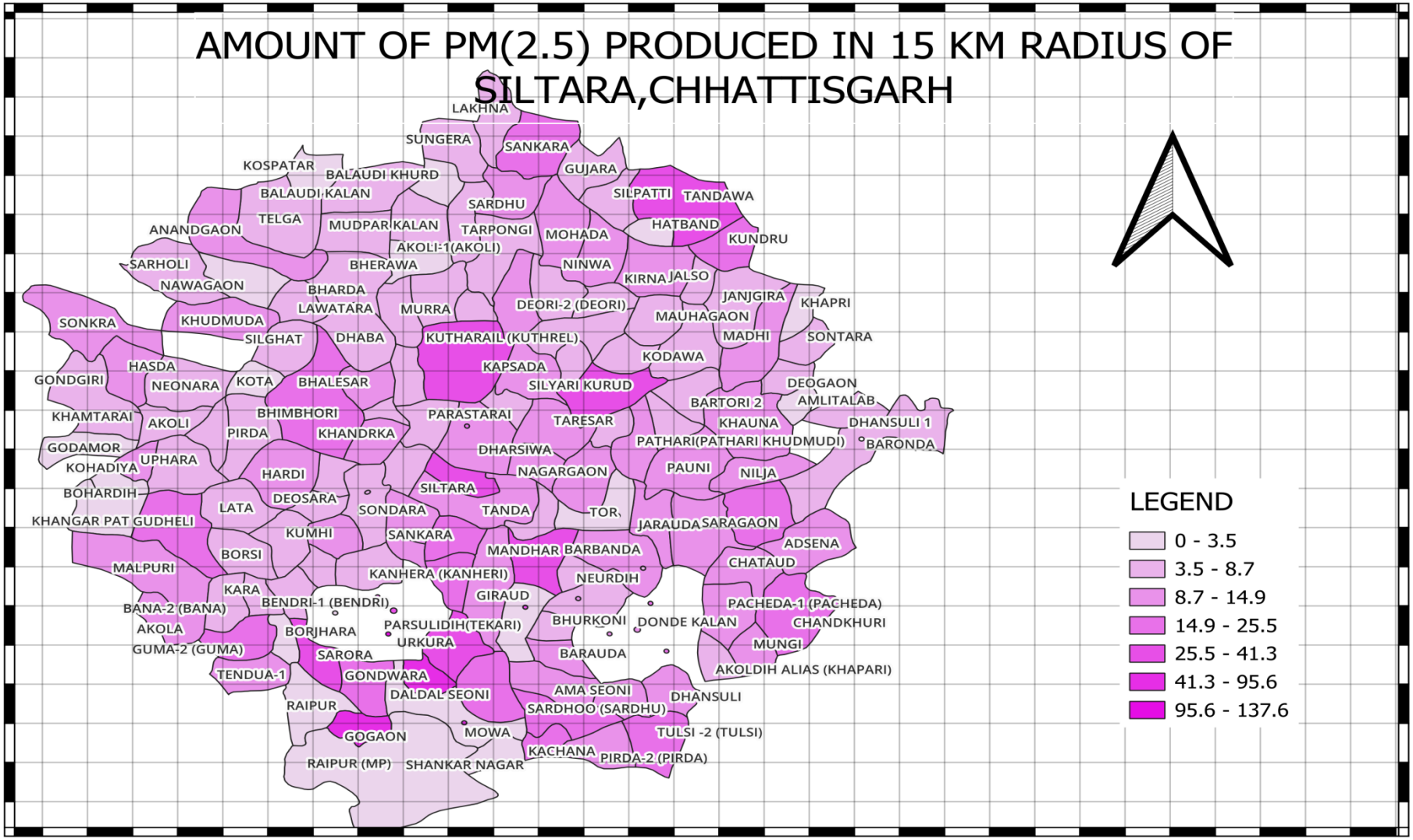


Figure 2.66: 2×2 sq. km gridded spatial distribution of $PM_{2.5}$ generated from QGIS software for different areas of Siltara.

The air pollutant modelling showcased the concentrations of PM_{10} and $PM_{2.5}$ across the study area are presented in Figure 2.66 and 2.67 respectively. The each grid of 2×2 sq. km was prepared to divide the total Siltara region. The interpolated maps provided insights into the spatial patterns of pollution, enabling the identification of high-risk areas. Some of the areas shows very high (> 1571 MT per annum) emission which are taken as the hot spots. Moreover, for $PM_{2.5}$ this value is around 338 MT per annum. However, the hotspot distribution for both PM_{10} and $PM_{2.5}$ in Siltara region is almost identical. Source apportionment analysis identified major pollution sources, assisting in the development of targeted control measures. The findings of this study contribute to evidence-based decision-making for air pollution control in Siltara. Based on the study results, it is recommended to Identify and address the major sources of PM_{10} and $PM_{2.5}$ pollution through targeted control measures, including stricter emission standards, industrial regulations, and pollution control technologies.

2.4.7 Future Emission Scenarios

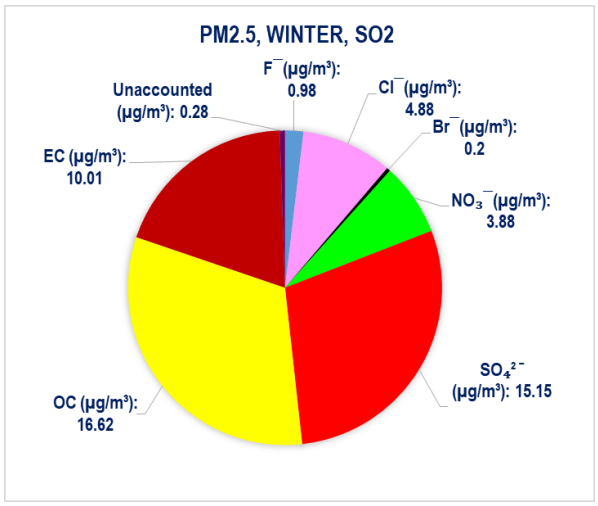
If the number of motorized vehicle will increase in the future than it is expected that PM emissions from transport sector could also increase in spite of advent better engines with lower emissions. It is therefore, necessary to have robust future planning on tailpipe emission control programme as well as better and clean roads to minimize road dust emissions. Numbers of highly emitting vehicular fleet like Goods Carriers are definitely on a conspicuous increasing trend apart other vehicles like commercial and private motor cars and 2-wheelers that take major share in total transport emissions. Possibility on increasing road length within Siltara is limited and hence the existing road length has to accommodate increasing number of vehicles, leading to higher congestion, idling, stoppages and therefore, higher individual tailpipe emissions. On the other hand, existing high population with 17,60,000 of floating population at present that might also surge in future due to increasing business opportunities in Siltara. With population surge, substantial additional demand on local transport (more vehicles on road, increased mileage) might lead to more tailpipe and road dust emissions, also putting increased pressure on other resources (viz. readily cooked food leading to higher fuel usage in domestic and hotel/ restaurant sector). This will also add on to the amount of waste generated in the city, which has a role to play in increasing city emissions through unregulated open burning. So the city population will have to bear the risk of perpetually higher exposure to ambient particulates, if emissions are not minimized.

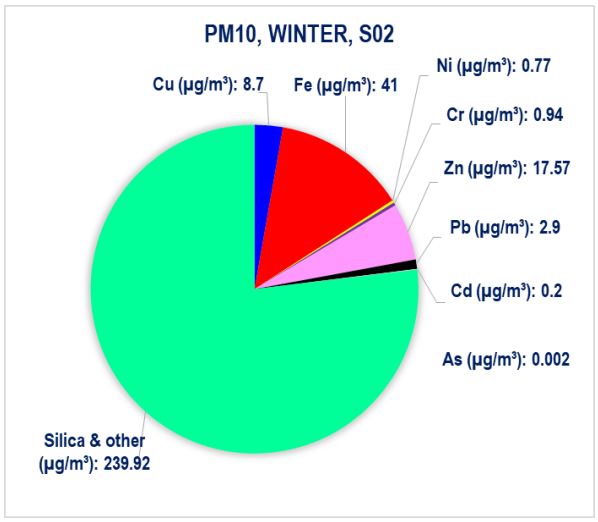
2.4.8 Source Apportionment Analysis via C.M.B. Model

2.4.8.1 Winter Season

We have arranged 17 air-quality monitoring stations in Siltara and have collected air samples in different seasons or though-out the year. Collected air samples are processed and analyzed according to the methods described above. All the analysed data are then arranged in different tabulated '.csv' files and then those files are taken for emission inventory and source apportionment study. After selecting each source or several or composite profiles based on the specificity of the study area and the markers at the receptor the U.S. – E.P.A. – C.M.B. model of version 8.2 is usually run repeatedly.

'S02' is also an 'Industrial'- type station near 'Ashram' (Metal Park). CMB has predicted the major sources of emission are road dust (29%; 42.82 µg/m^3), transports (12%; 16.79 µg/m^3), construction (30%; 43.85 µg/m^3) and wastes buring (14%; 20.93 µg/m^3). Some other minor sources are industry (5%; 6.99 µg/m^3), generator sets fuel combustion (4%; 5.99 µg/m^3) and resaurants, eateries and hawkers fuels combustion (6%; 7.96 µg/m^3) (Figure 2.67).





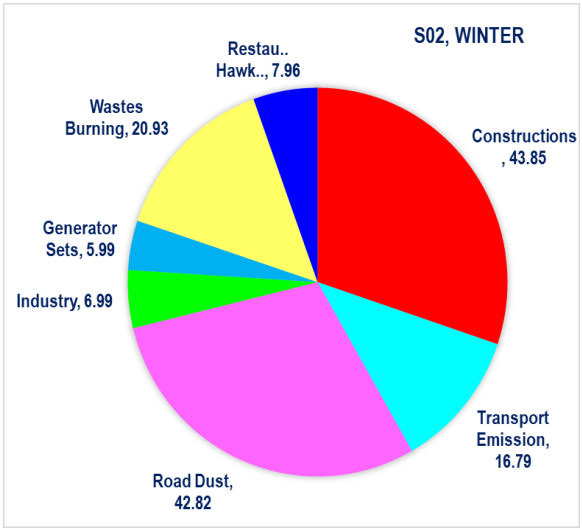
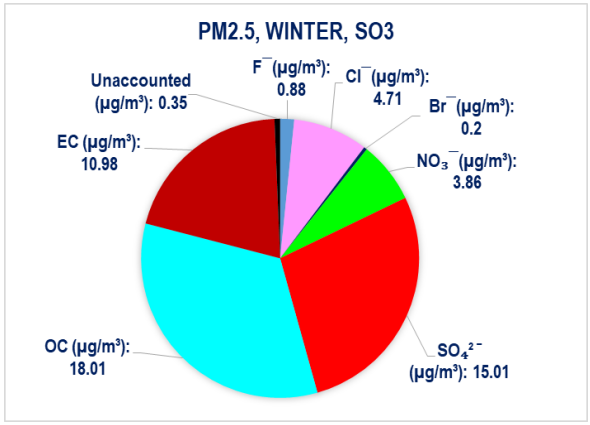
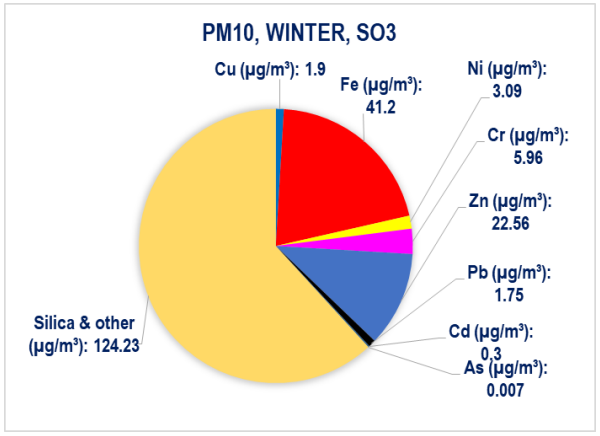


Figure 2.67: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S02' during winter.





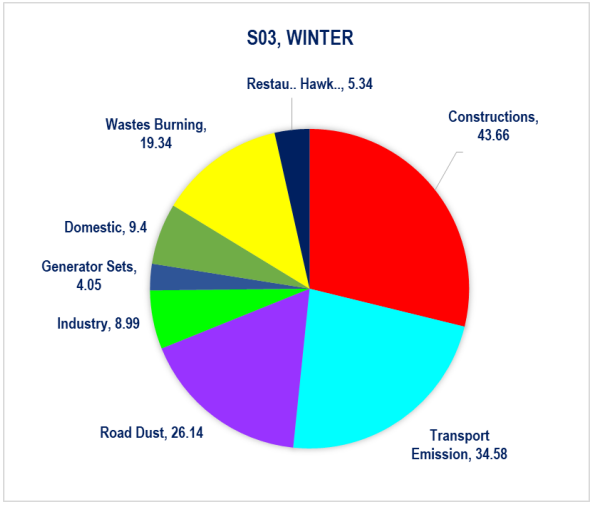
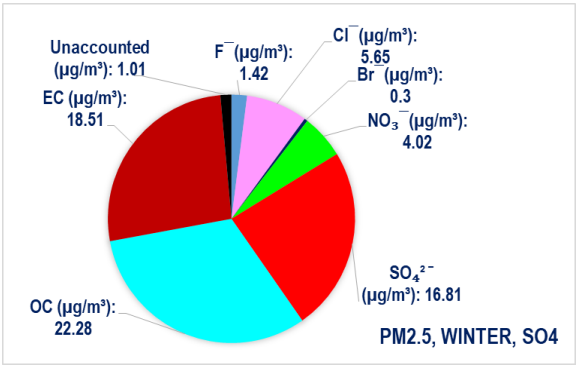
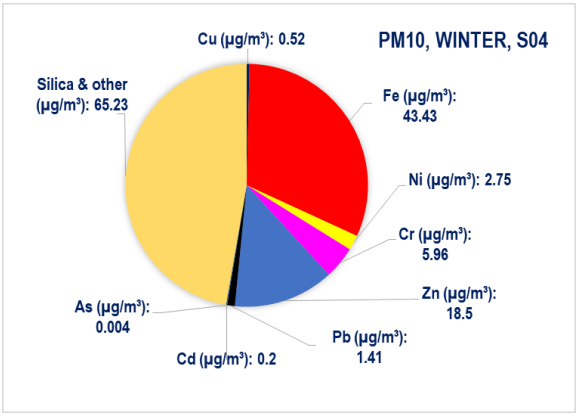


Figure 2.68: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S03' during winter.

'S03' is a 'Commercial' area near 'Gosala' at Hirapur. Major pollutants emission sources are road dust (17%; 26.14 µg/m^3), constructions (29%; 43.66 µg/m^3), transports (23%; 34.58 µg/m^3) and wastes burning (13%; 19.34 µg/m^3) (Figure 2.68).





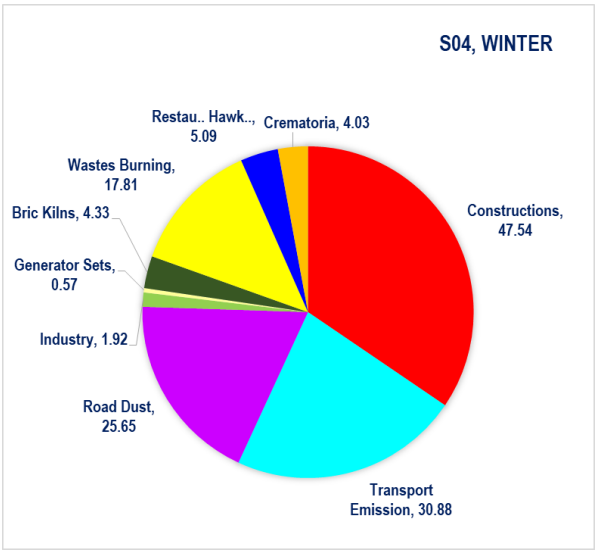


Figure 2.69: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S04' during winter.

'S04' is 'Residential' area of 'Real Ispat' (Kara Panchayat). Major sources of emission in this station are constructions (35%; 47.54 µg/m^3), transports (22%; 30.88 µg/m^3), road dust (19%; 25.65 µg/m^3) and wastes burning (13%; 17.81 µg/m^3) (Figure 2.69).

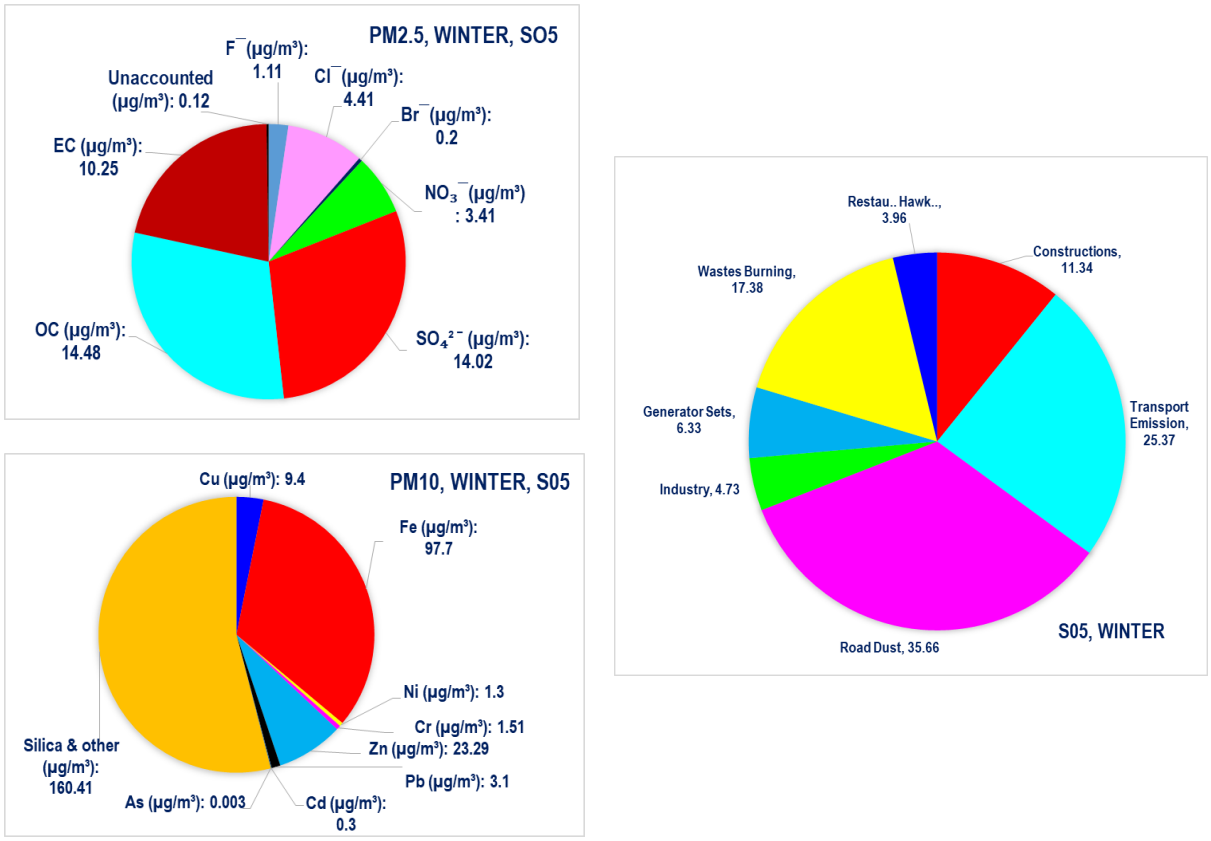


Figure 2.70: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S05' during winter.

Air-quality monitoring station 'S05' is a water treatment plant at 'Urla'. It's an 'Industrial' type sampling station. According to emission inventory study, major contributors are road dust (34%; 35.66 µg/m^3) and transports (24%; 25.37 µg/m^3). Other some minor sources are constructions (11%; 11.34 µg/m^3), wastes burning (17%; 17.38 µg/m^3) and generator sets fuel oil combustion (6%; 6.33 µg/m^3) (Figure 2.70).

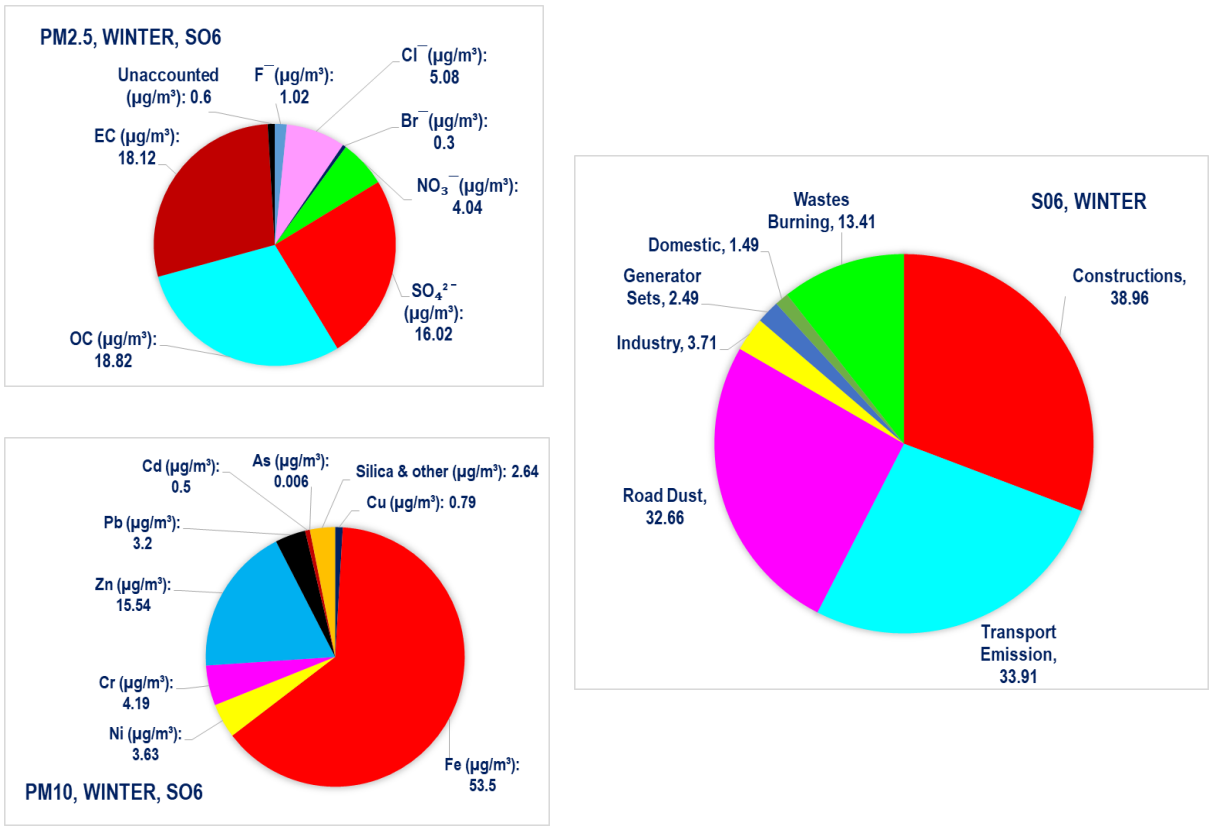


Figure 2.71: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S06' during winter.

'S06' is a 'Silent' type air-quality monitoring station, situated near 'Nagar Nigam Birgaon'. But construction related pollutants are drastically affects the ambient air quality of this station (31%; 38.96 µg/m^3). Some other emission contributors are road dust (26%; 32.66 µg/m^3), transports (27%; 33.91 µg/m^3), wastes burning (10%; 13.41 µg/m^3) and industry (3%; 3.71 µg/m^3). This silent type air quality monitoring station's ambient air quality has been elevated due to intra-sectoral mixing. Especially, different types of construction for social and economic development (Figure 2.71).

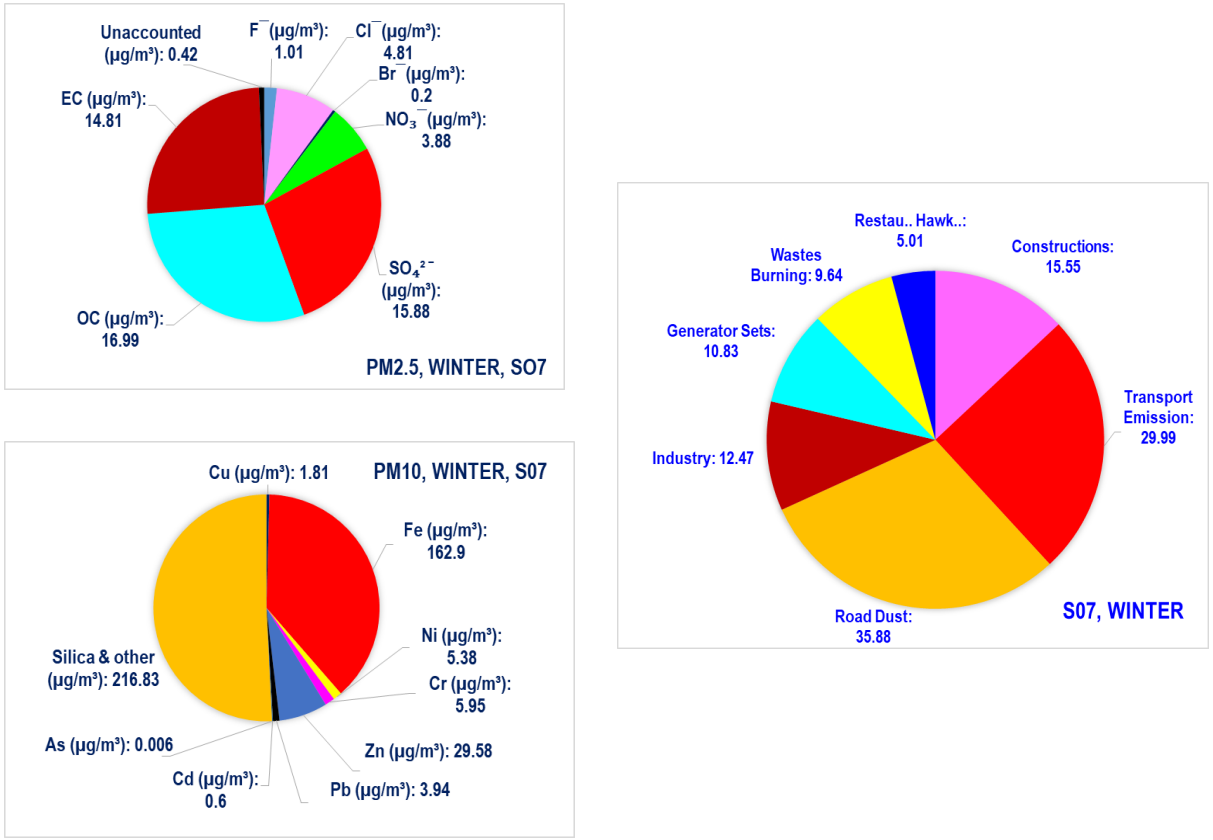


Figure 2.72: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S07' during winter.

'S07' is an 'Industrial' type air-quality monitoring station near 'CIAL-S.D.' (Jayasawal Nico). Emission inventory studies show the sources are road dust (30%; 35.88 µg/m^3), transports (25%; 29.99 µg/m^3), constructions (13%; 15.55 µg/m^3), industry (11%; 12.47 µg/m^3), wastes combustion (8%; 9.64 µg/m^3) and generator sets fuel oil combustion (9%; 10.83 µg/m^3) (Figure 2.72).

Air-quality monitoring station 'S08' is 'Industrial' type sampling station near 'CSIDC'. According to emission inventory study, major contributors are industry (55%; 180.63 µg/m^3), transports (14%; 47.37 µg/m^3) and road dust (22%; 71.52 µg/m^3). Other some minor sources are construction (6%; 18.36 µg/m^3) (Figure 2.73).

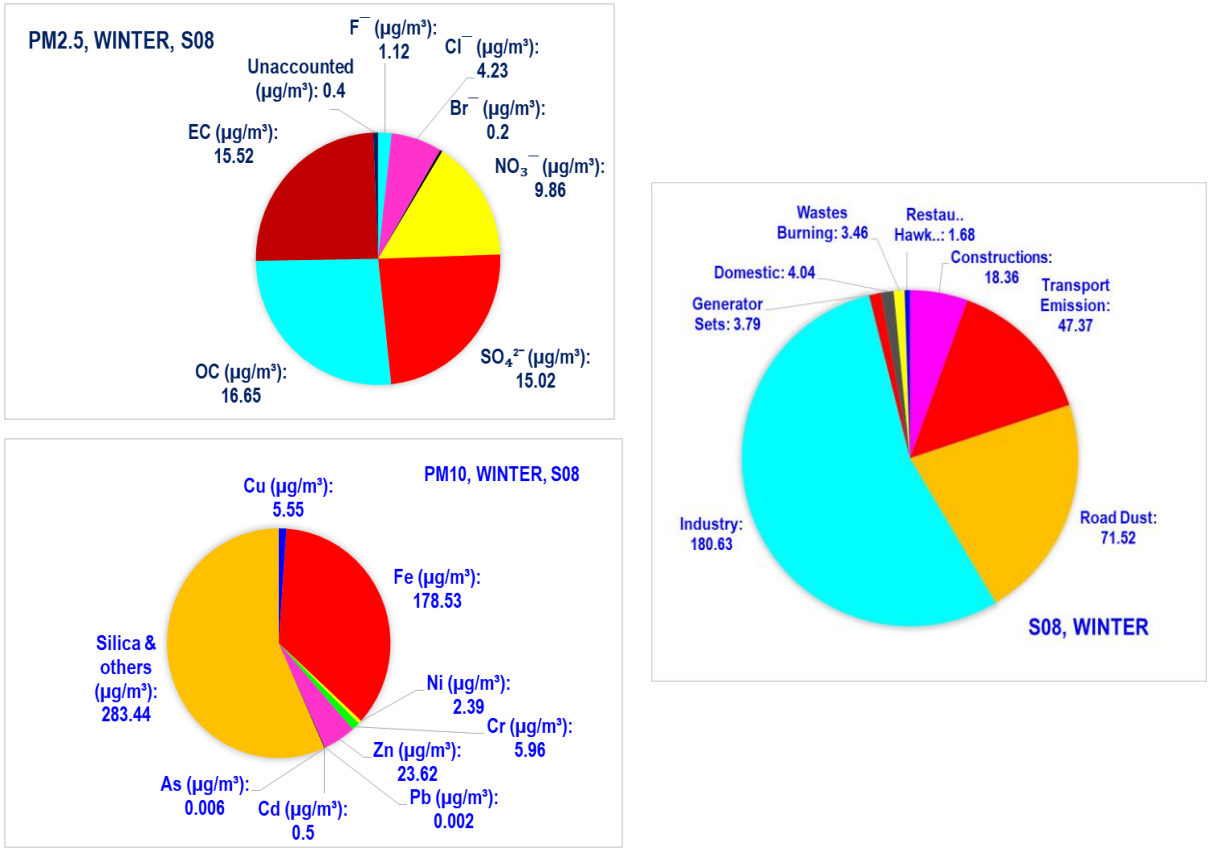


Figure 2.73: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S08' during winter.

'S09' is a 'Silent' type air-quality monitoring station near 'Library' (Education lab). Emission inventory studies show the sources are industry (41%; 67.24 µg/m^3), road dust (28%; 46.11 µg/m^3), construction (12%; 19.37 µg/m^3), transports (12%; 19.94 µg/m^3) and domestic fuel combustion (3%; 4.92 µg/m^3) (Figure 2.74).

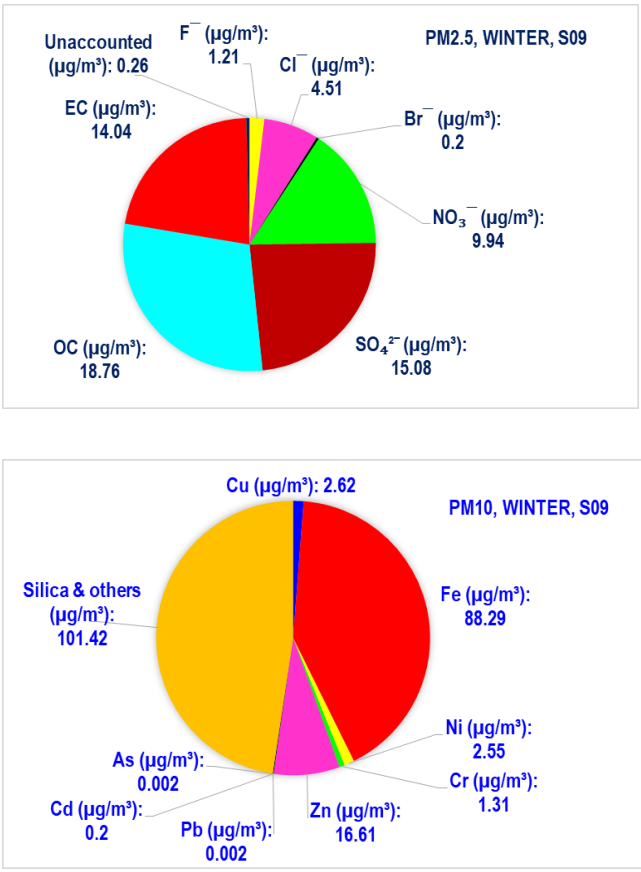


Figure 2.74: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S09' during winter.

'S10' is an 'Industrial' type air-quality monitoring station near 'Mahendra Sponge and Power Ltd.'. Emission inventory studies show the sources are industry (54%; 192.34 µg/m^3), road dust (21%; 74.26 µg/m^3), transports (14%; 48.37 µg/m^3), construction (5%; 18.21 µg/m^3) (Figure2.75).

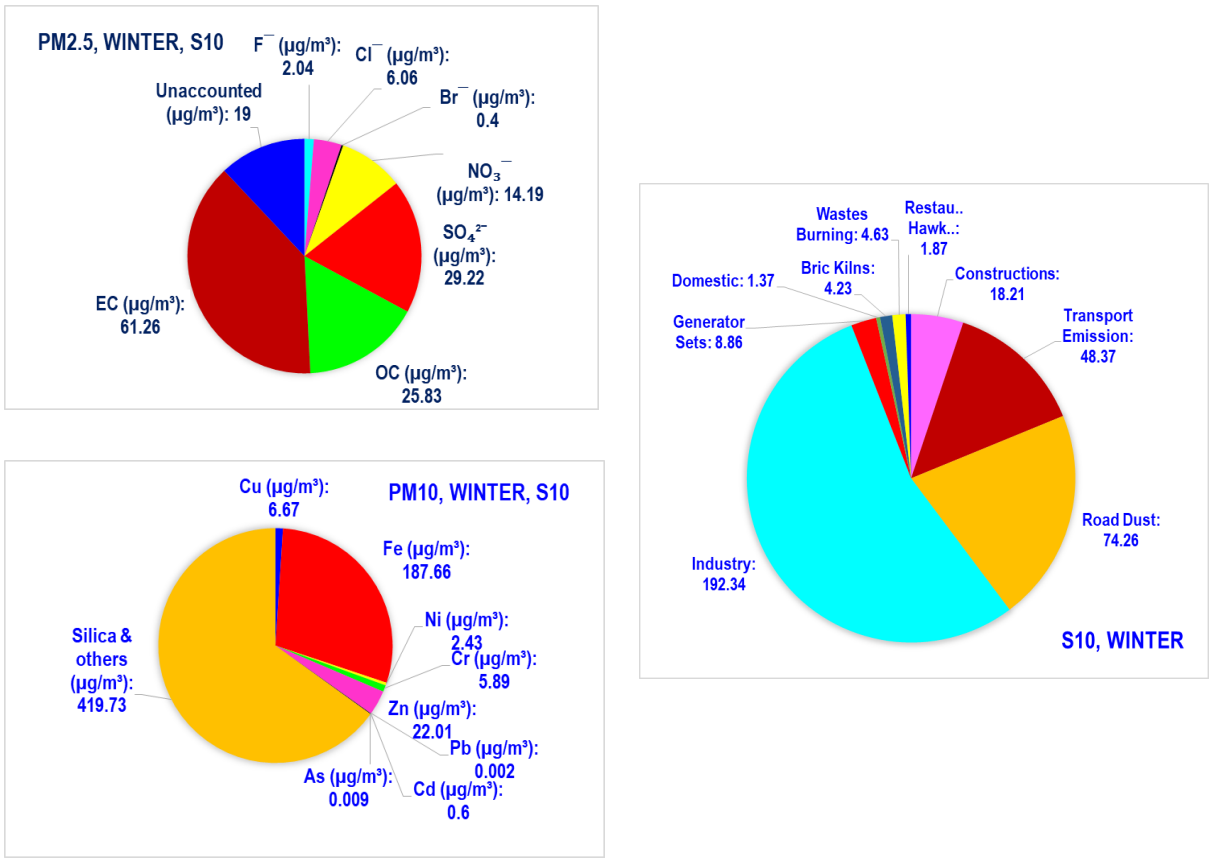


Figure 2.75: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S10' during winter.

'S11' is a 'Silent' type air-quality monitoring station near 'Mohadi High School'. Emission inventory studies show the major sources are industry (36%; 57.04 µg/m^3), road dust (32%; 51.25 µg/m^3), construction (14%; 21.93 µg/m^3) and transports (10%; 15.61 µg/m^3) (Figure 2.76).

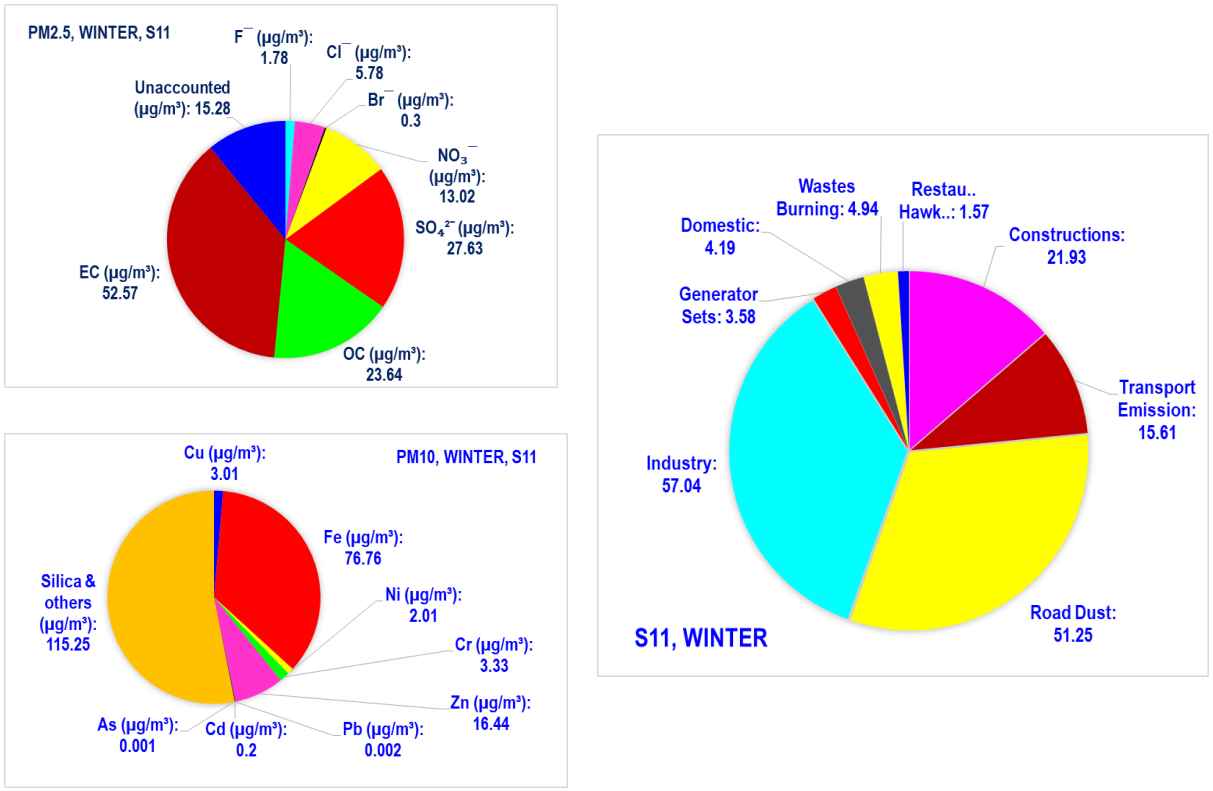


Figure 2.76: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S11' during winter.

Air-quality monitoring station 'S12' is an 'Industrial' type sampling station near 'Nico Jayasawal Industrial Ltd.'. According to emission inventory study, major contributors are industry (55%; 188.72 µg/m^3), road dust (23%; 80.31 µg/m^3) and transport (15%; 51.21 µg/m^3) (Figure 2.77).

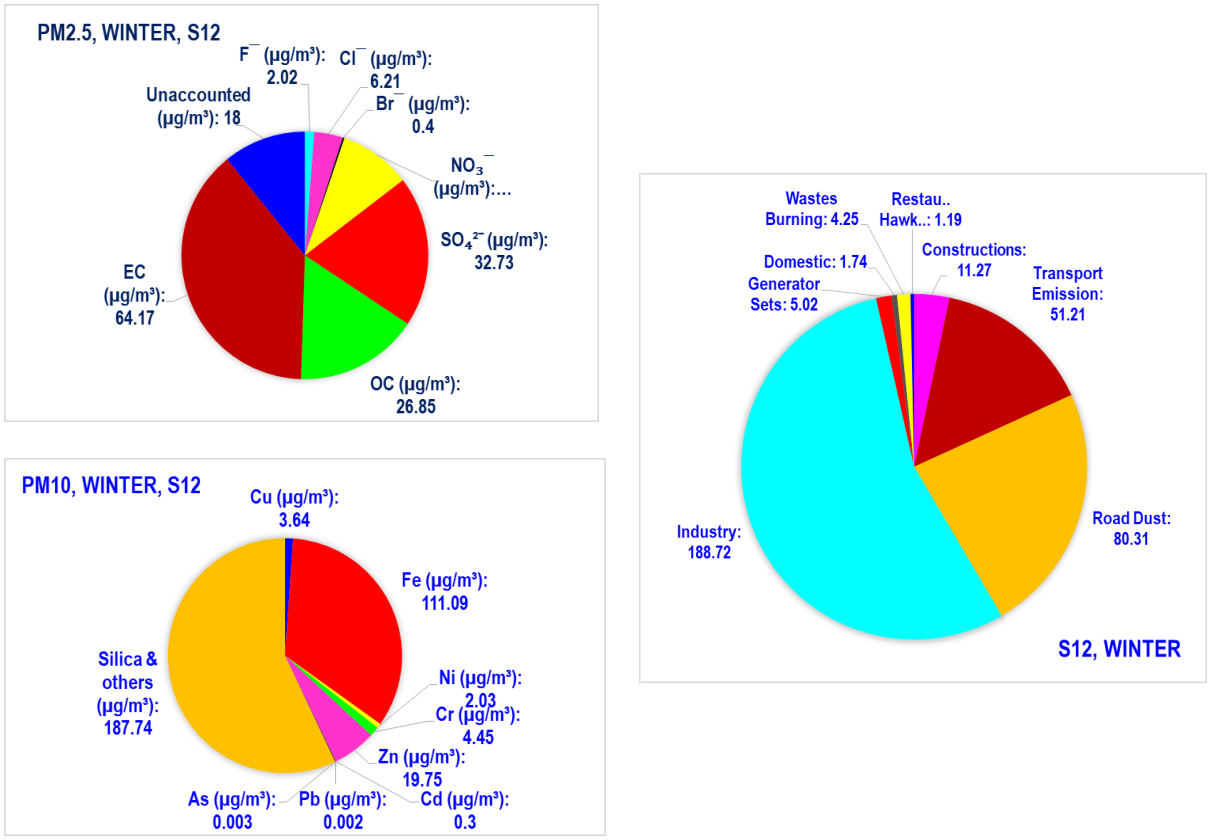


Figure 2.77: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S12' during winter.

Air-quality monitoring station 'S13' is an 'Industrial' type sampling station near "SKS Colony'. According to emission inventory study, major sources are industry (50%; 190.02 µg/m^3), road dust (29%; 109.89 µg/m^3) and transport (14%; 55.35 µg/m^3) (Figure 2.78).

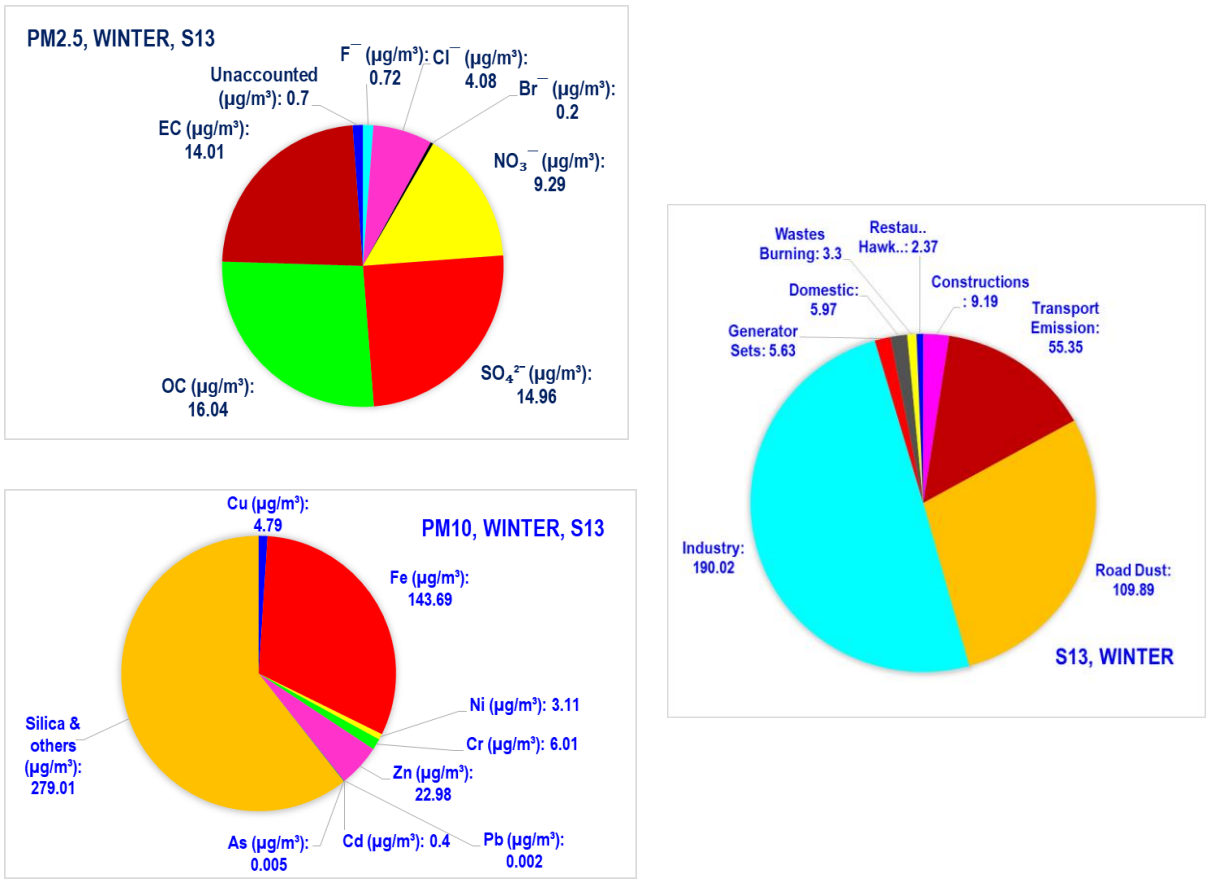


Figure 2.78: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S13' during winter.

Air-quality monitoring station 'S14' is an 'Industrial' type sampling station near 'CG Ispat'. According to emission inventory study, sources are industry (50%; 191.91 µg/m^3), road dust (29%; 113.87 µg/m^3) and transports (13%; 51.03 µg/m^3) (Figure 2.79).

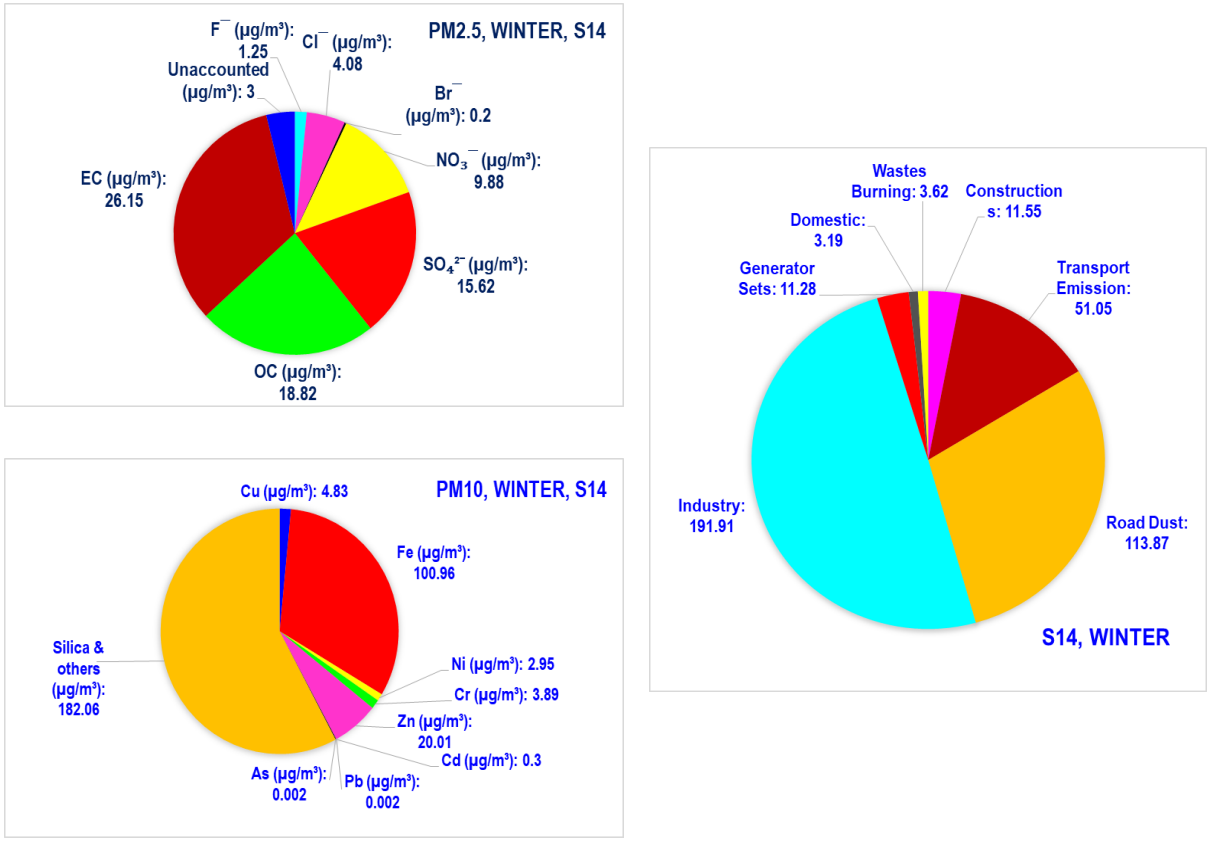


Figure 2.79: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S14' during winter.

Air-quality monitoring station 'S15' is also an 'Industrial' type sampling station near 'Apollo Pipes'. Emission inventory study shows the sources are industry (48%; 192.55 µg/m^3), constructions (4%; 17.07 µg/m^3), road dust (30%; 120.86 µg/m^3), transports (13%; 49.79 µg/m^3) and generator sets fuel combustion (3%; 10.54 µg/m^3) (Figure 2.80).

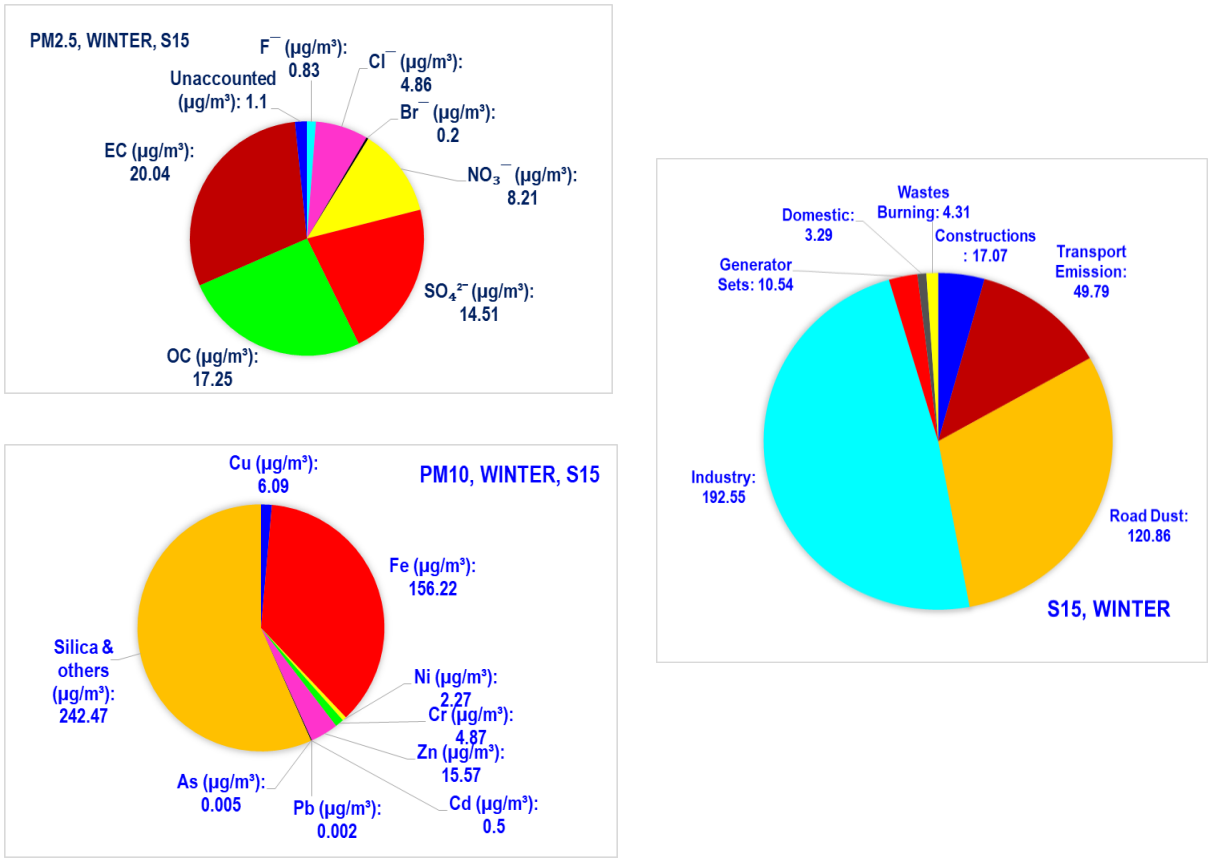
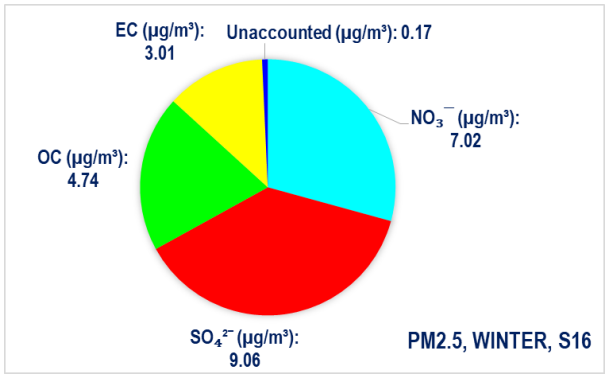
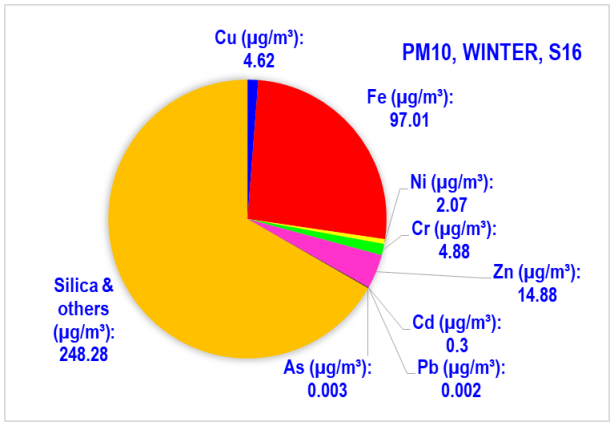


Figure 2.80: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S15' during winter.

'S16' is a 'Mixed' type sampling station near 'Chataud High School'. CMB predicts the sources are industry (47%; 63.83 µg/m^3), road dust (32%; 43.78 µg/m^3) and transports (14%; 19.91 µg/m^3). Minor emission sources are wastes combustion (3%; 3.69 µg/m^3) and generator sets fuel oil combustion (3%; 3.69 µg/m^3) (Figure 2.81).





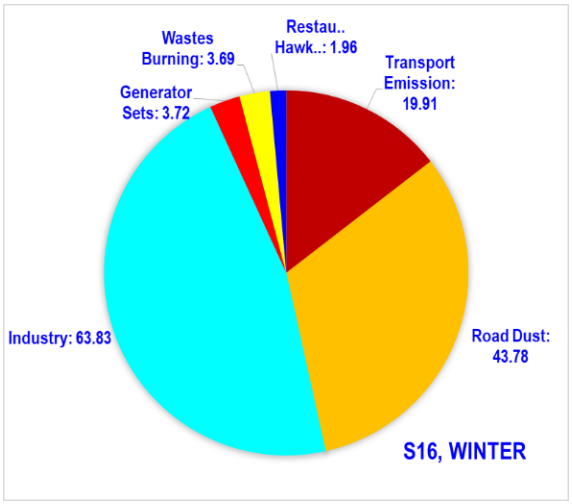


Figure 2.81: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S16' during winter.

Air-quality monitoring station 'S17' is a 'Silent' type sampling station near 'Shaskiya M M Vidyalaya (Khudmud)'. According to emission inventory study by CMB, sources are industry (45%; 64.67 µg/m^3), road dust (31%; 44.29 µg/m^3), transports (11%; 16.41 µg/m^3), construction (9%; 12.48 µg/m^3), wastes burning (2%; 2.65 µg/m^3) and domestic fuel combustion (1%; 1.32 µg/m^3) (Figure 2.82).

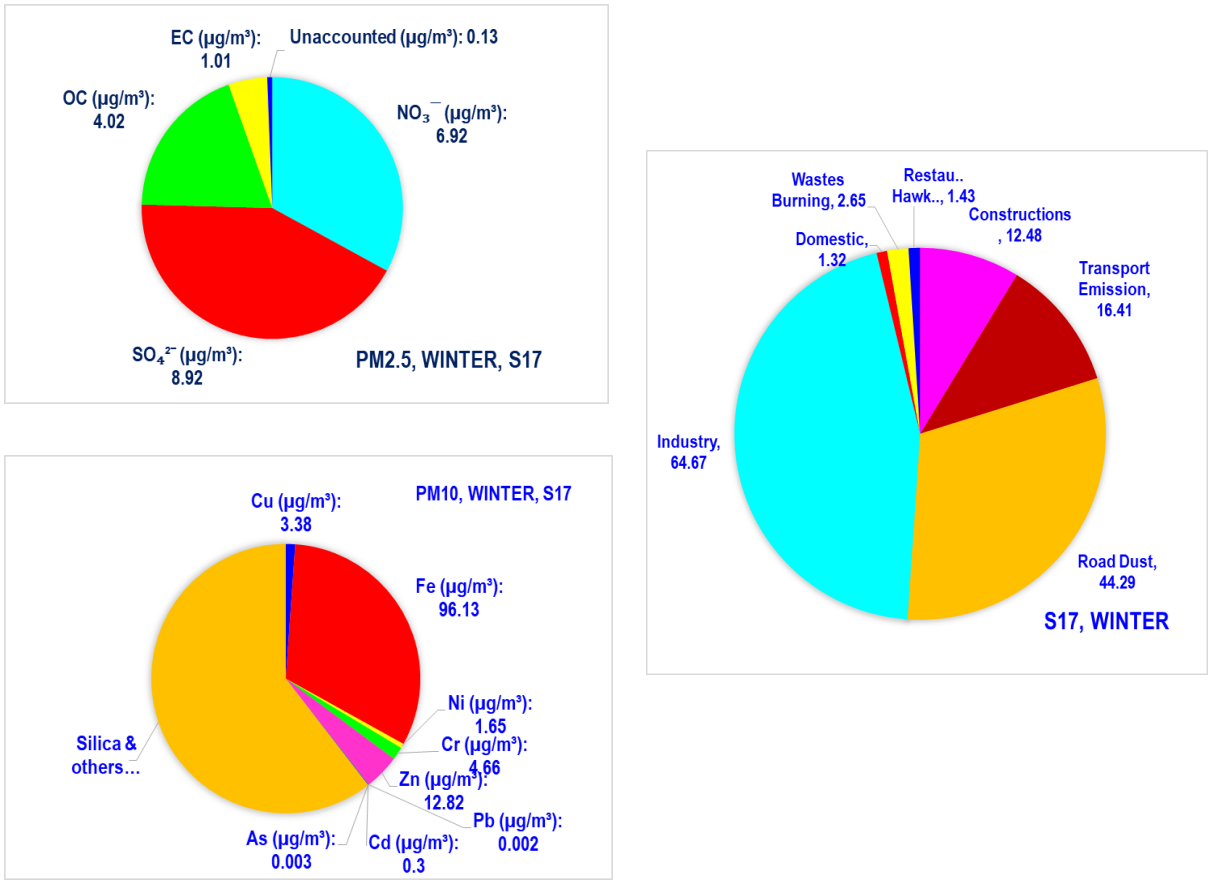


Figure 2.82: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S17' during winter.

Above air-quality monitoring station-wise study shows a clear contribution of different sources of pollutants present there. Those sources of pollutant and their emission are not only changing the ambient air quality of that specific station but also the surrounding areas. As we have found intra-sectoral contamination in the analysis and source apportionment study. Those pollutants are spreading through wind and finally effect in the total ambient air-quality of Siltara.

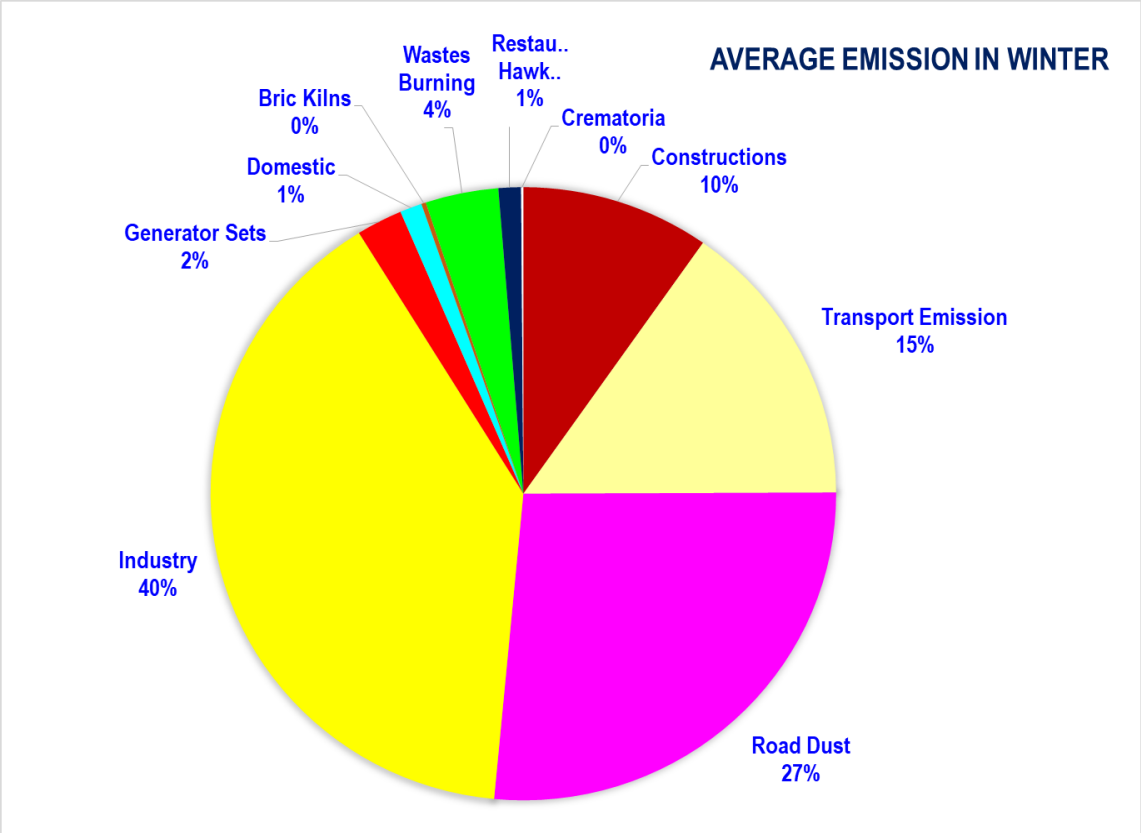


Figure2.83: Different sources of pollutants and their percent contribution in the ambient air pollution of Siltara during winter season.

Emission inventory study by CMB shows, ambient air quality in Siltara is mainly effected by different types of industry (40%; 89.235 µg/m^3). Similarly, CMB predicted other major emission sources are road dust (27%; 59.69 µg/m^3), transports (15%; 34.16 µg/m^3), construction (10%; 21.89 µg/m^3), wastes burning (4%; 8.47 µg/m^3), etc. (Figure 2.83).

2.4.8.2 Summer Season

Air quality monitoring station 'S02' is an 'Industrial'- type station near 'Metal Park'. Emission study shows this station has largely been affected by different types of construction (33%; 45.96 µg/m^3) and road dust (42%; 59.11 µg/m^3). Other sources are transports (10%; 14.43 µg/m^3), industry (6%; 7.91 µg/m^3), generator sets fuel combustion (4%; 4.99 µg/m^3), wastes burning (2%; 2.78 µg/m^3) and restaurants-eateries-hawkers (3%; 4.45 µg/m^3) with their respective emissions of particular matters (Figure 2.84).

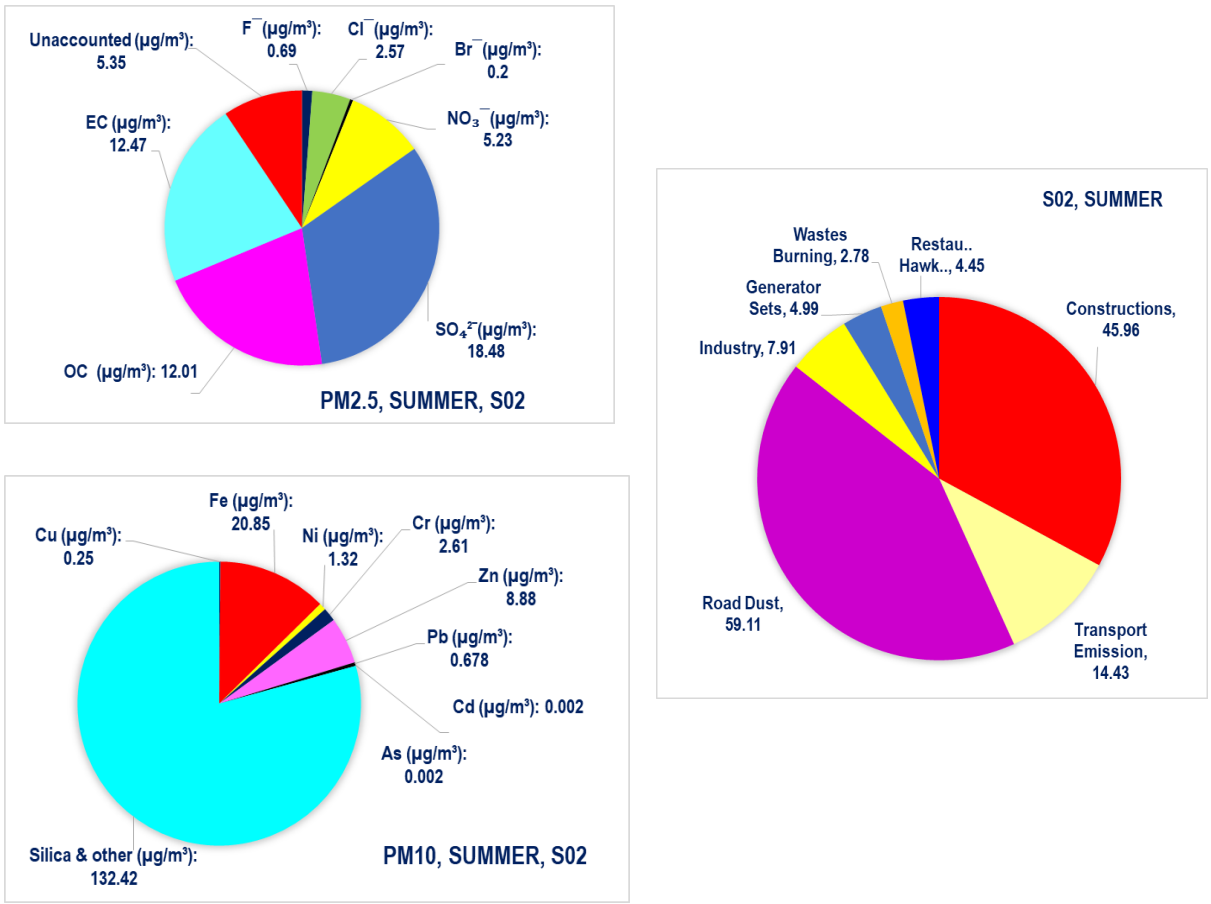


Figure 2.84: Average composition (µg/m^3) of particulate matters and their emission sources in air quality-monitoring station 'S02' during summer.

'S03' is a 'Commercial' area near 'Gosala' at Hirapur. Emission sources are road dust (41%; 32.72 µg/m^3), transports (11%; 9.18 µg/m^3), industry (10%; 7.68 µg/m^3), constructions (24%; 19.11 µg/m^3) and wastes burning (4%; 3.21 µg/m^3) (Figure 2.85).

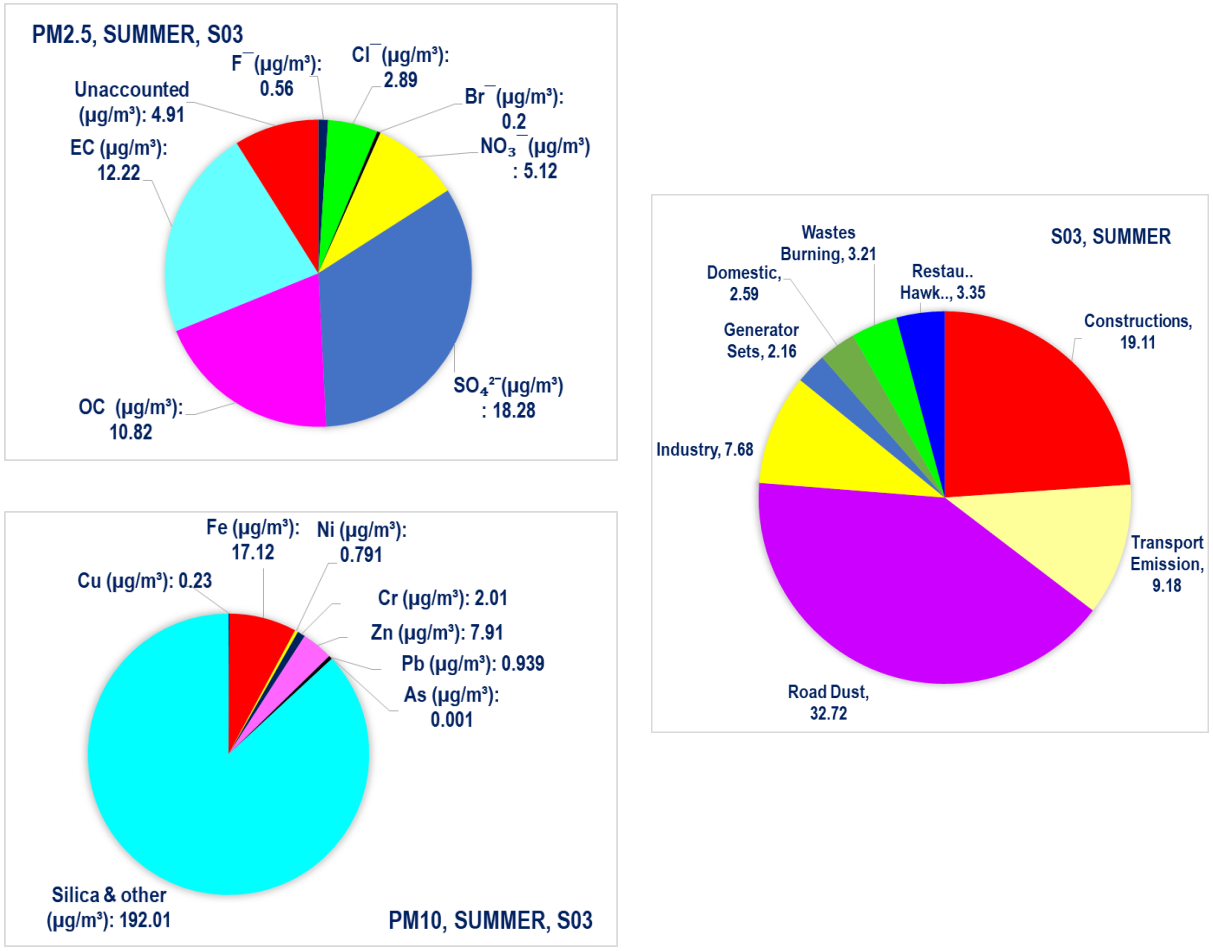
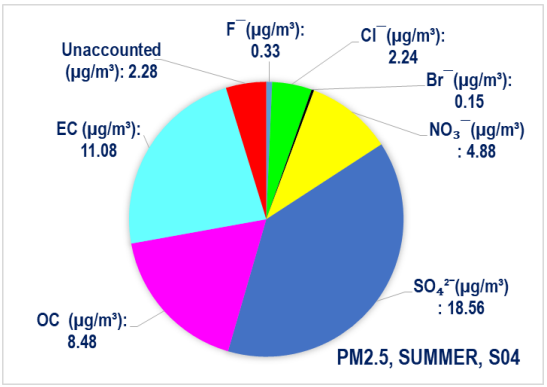
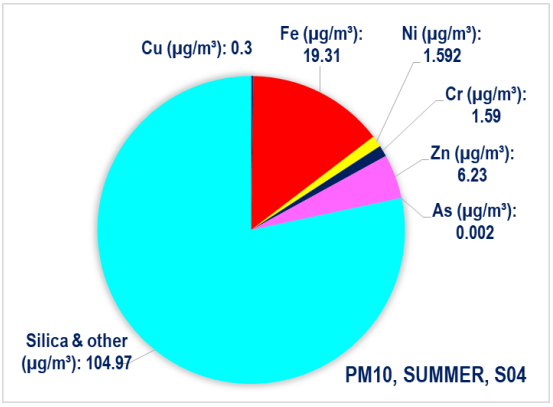


Figure 2.85: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S03' during summer.

'S04' is 'Residential' area of 'Real Ispat' (Kara Panchayat). Sources of emission in this station are constructions (30%; 33.32 µg/m^3), road dust (33%; 36.79 µg/m^3), transports (12%; 36.79 µg/m^3), industry (8%; 9.26 µg/m^3), domestic fuels burning (4%; 4.85 µg/m^3) and generator sets fuel oil combustion (4%; 4.09 µg/m^3) (Figure 2.86).





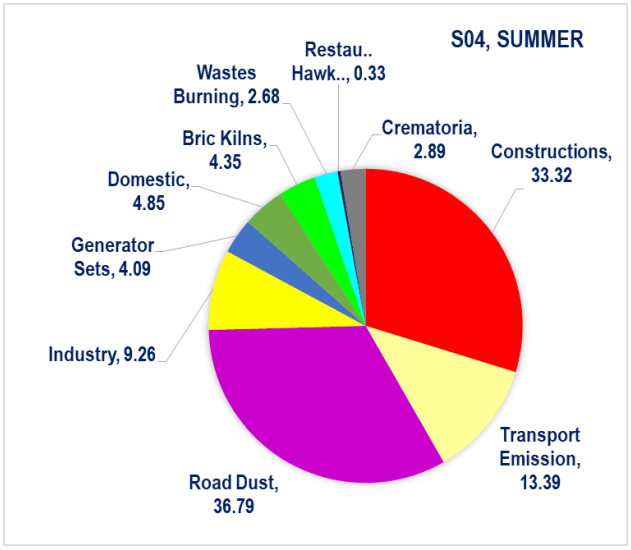


Figure 2.86: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S04' during summer.

Air-quality monitoring station 'S05' is a water treatment plant in 'Urla'. It's an 'Industrial' type sampling station. According to emission inventory study, major contributors are transports (28%; 26.06 µg/m^3) and road dust (31%; 28.18 µg/m^3). Other some minor sources are construction (15%; 13.37 µg/m^3), industry (10%; 9.15 µg/m^3) and generator sets fuel oil combustion (7%; 6.78 µg/m^3) (Figure 2.87).

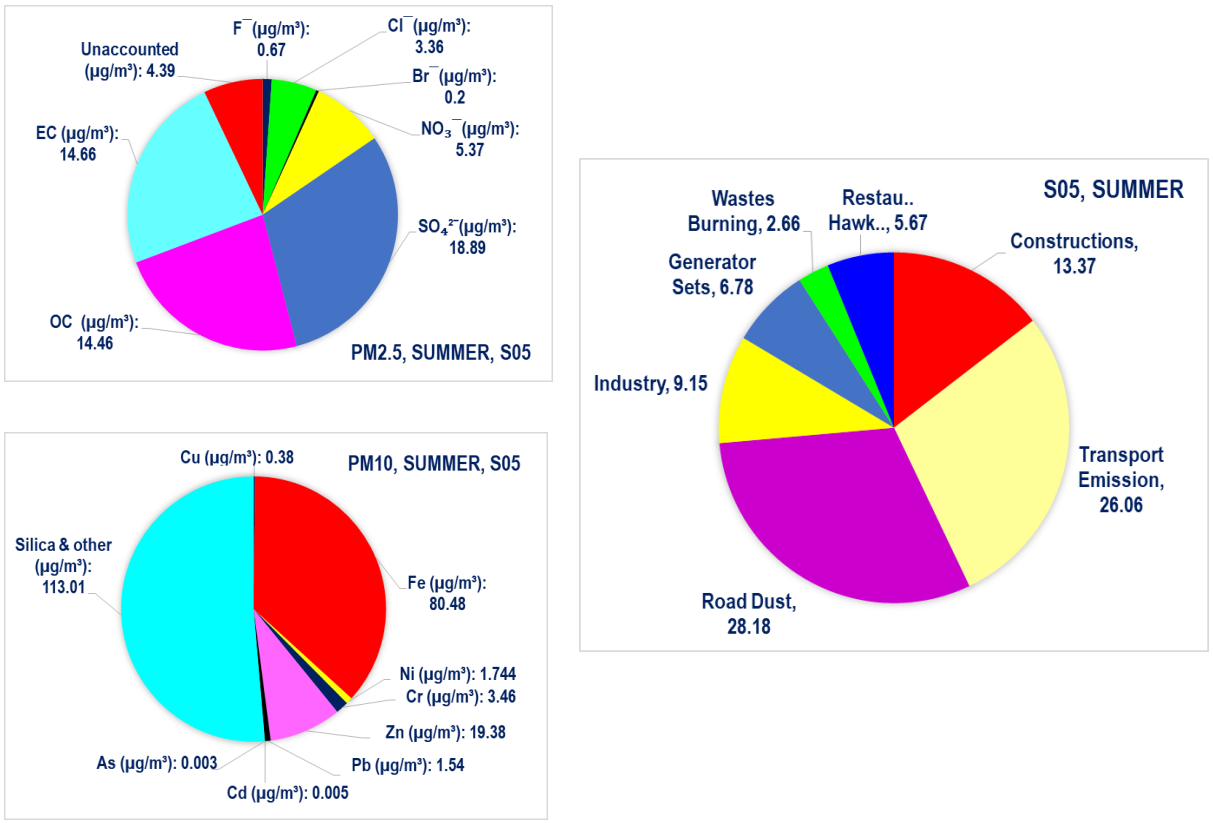


Figure 2.87: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S05' during summer.

'S06' is a 'Silent' type air-quality monitoring station, situated near 'Nagar Nigam Birgaon'. But construction related pollutants are affecting the ambient air quality for this station (30%; 34.51 µg/m^3). Some other emission contributors are road dust (28%; 32.52 µg/m^3), transport (28%; 32.47 µg/m^3), industry (7%; 7.73 µg/m^3) and wastes buring (3%; 3.71 µg/m^3) (Figure 2.88).

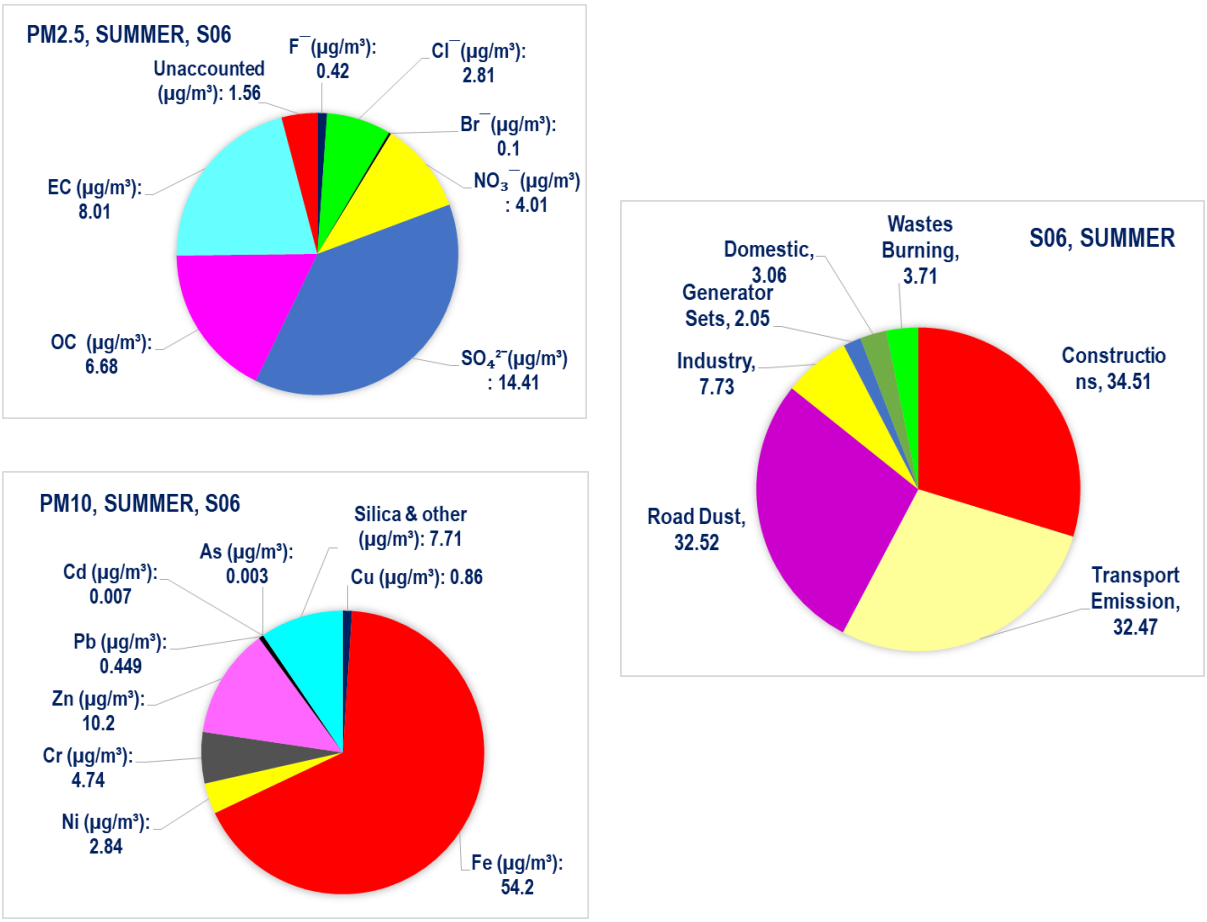
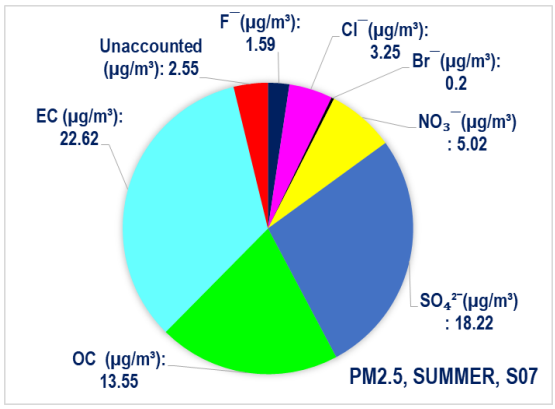
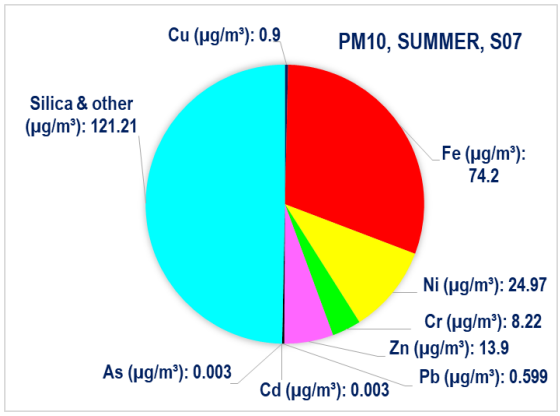


Figure 2.88: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S06' during summer.

'S07' is an 'Industrial' type air-quality monitoring station near 'CIAL-S.D.' (Jayasawal Nico). Emission inventory studies show the sources are road dust (29%; 35.42 µg/m^3), transports (29%; 34.91 µg/m^3), constructions (11%; 12.79 µg/m^3), industry (12%; 14.77 µg/m^3), generator sets fuel oil combustion (12%; 14.21 µg/m^3) and resaurants/ eateries/ hawkers fuels combusion (4%; 4.43 µg/m^3) (Figure 2.89).





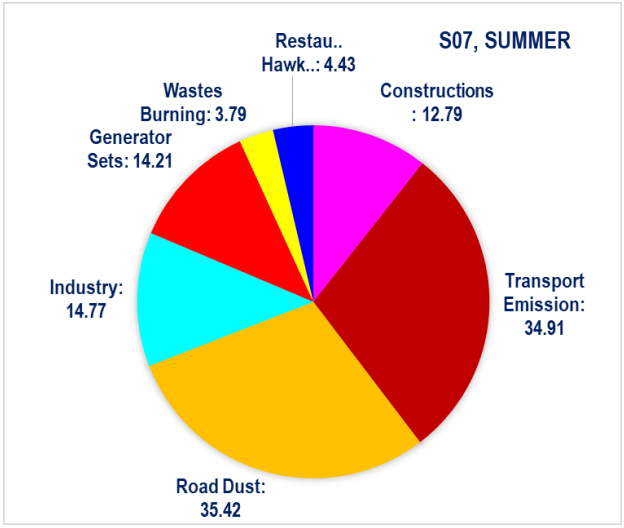


Figure 2.89: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S07' during summer.

Air-quality monitoring station 'S08' is 'Industrial' type sampling station near 'CSIDC'. According to emission inventory study by CMB, major contributors are industry (53%; 156.54 µg/m^3), road dust (22%; 65.36 µg/m^3) and transports (15%; 44.91 µg/m^3). Other some minor sources are generator sets fuel oil combustion (3%; 7.16 µg/m^3), wastes burning (1%; 2.33 µg/m^3) and restaurants/ eateries/ hawkers fuels cobustion (1%; 1.65 µg/m^3) (Figure 2.90).

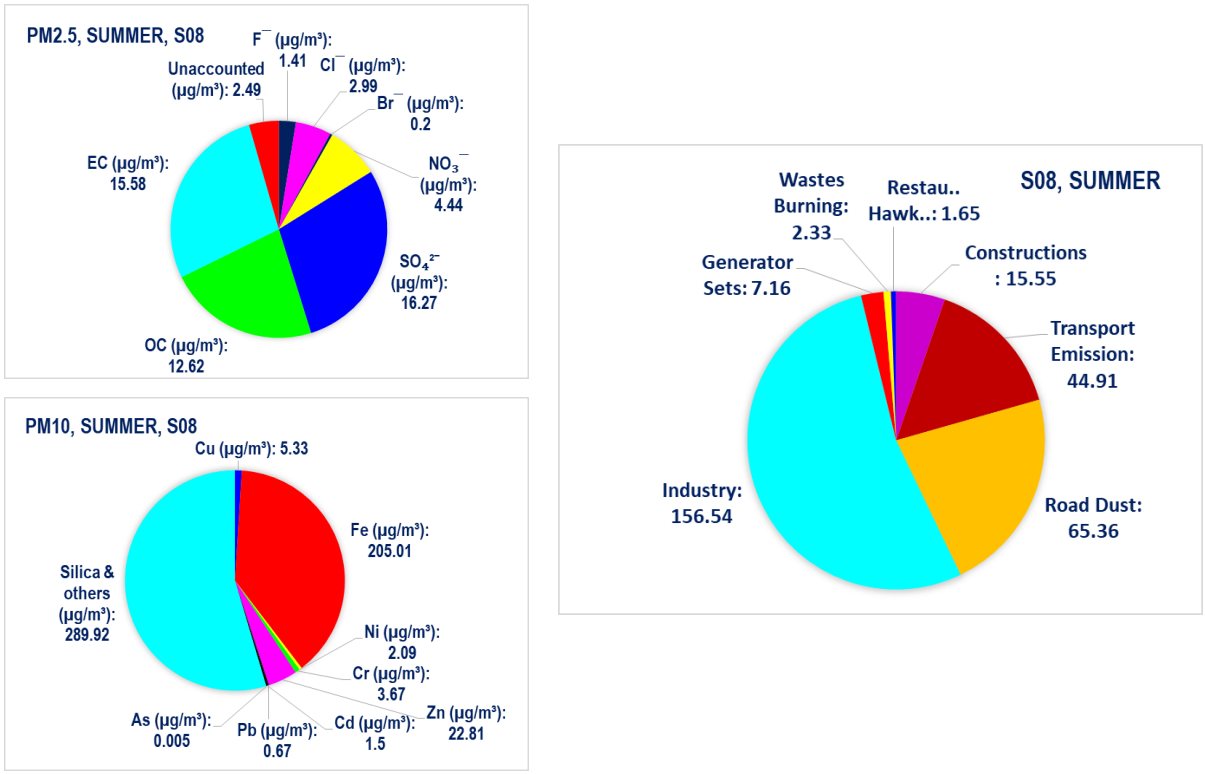


Figure 2.90: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S08' during summer.

'S09' is a 'Silent' type air-quality monitoring station near 'Library' (Education lab). Emission inventory study by CMB predicts the sources are industry (35%; 53.69 µg/m^3), road dust (29%; 44.02 µg/m^3), transports (12%; 18.61 µg/m^3), construction (11%; 16.21 µg/m^3) and generator sets fuel oil combustion (10%; 14.84 µg/m^3) (Figure 2.91).

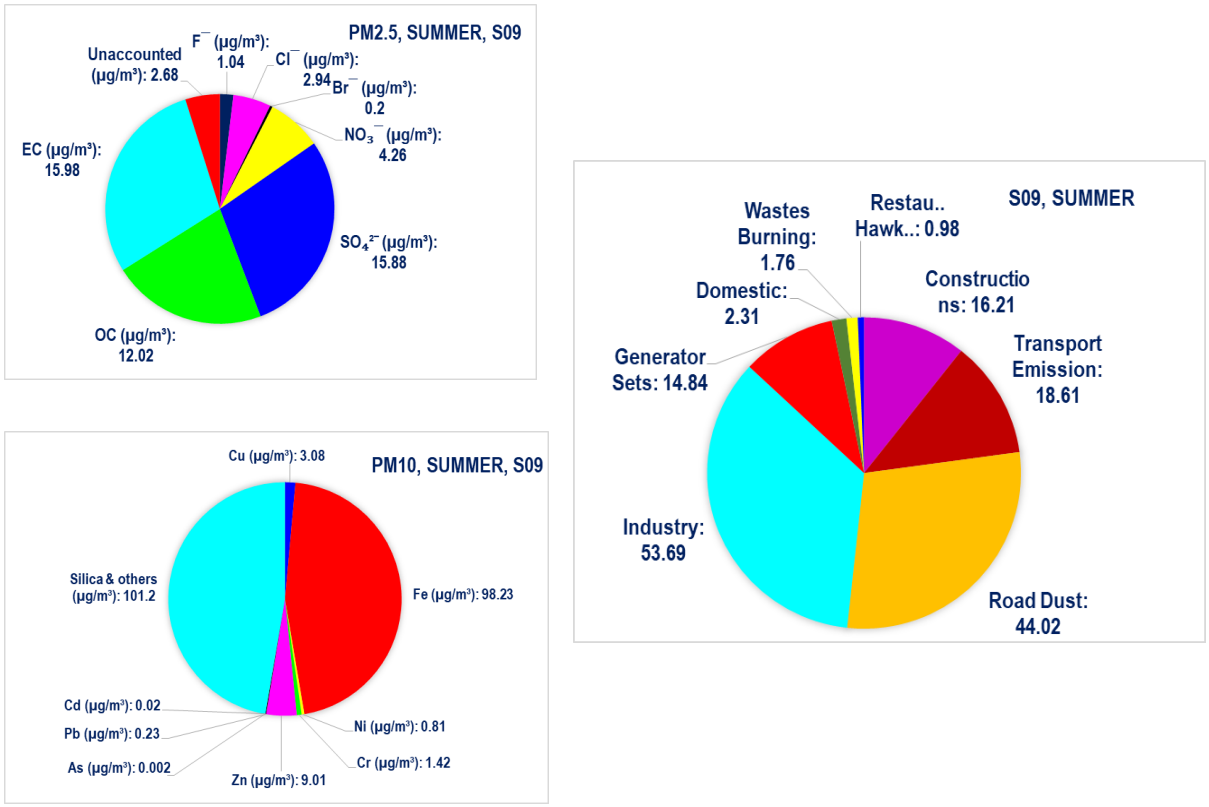


Figure 2.91: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S09' during summer.

'S10' is an 'Industrial' type air-quality monitoring station near 'Mahendra Sponge and Power Ltd.'. Emission inventory studies show the sources are industry (52%; 164.97 µg/m^3), road dust (21%; 66.87 µg/m^3), transports (15%; 46.18 µg/m^3), constructions (5%; 15.12 µg/m^3), domestic fuels combustion (2%; 5.25 µg/m^3) and generator sets fuel oil combustion (4%; 13.52 µg/m^3) (Figure 2.92).

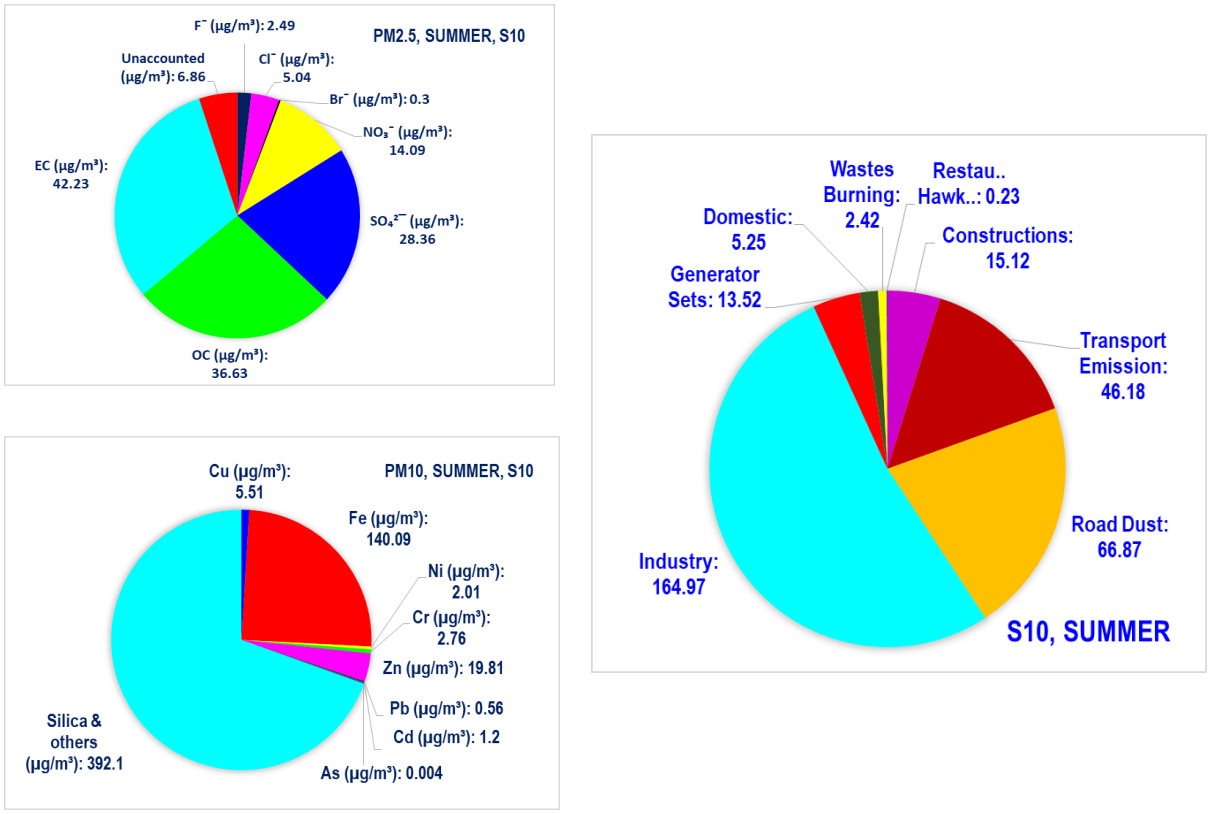


Figure 2.92: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S10' during summer.

'S11' is a 'Silent' type air-quality monitoring station near 'Mohadi High School'. Emission inventory studies show the sources are industry (36%; 50.52 µg/m^3), road dust (30%; 41.33 µg/m^3), transports (10%; 13.53 µg/m^3), constructions (14%; 19.71 µg/m^3) and domestic fuels combustion (6%; 8.94 µg/m^3) (Figure 2.93).

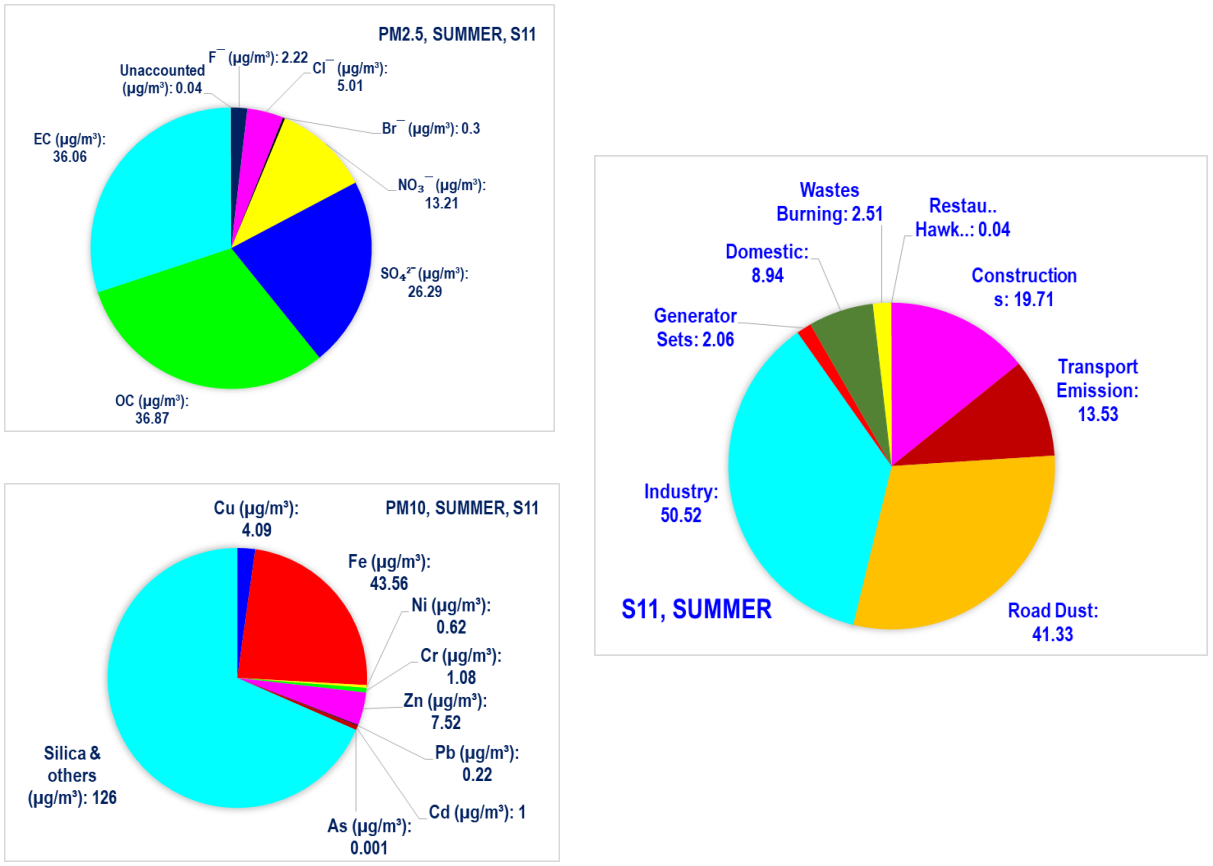


Figure 2.93: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S11' during summer.

Air-quality monitoring station 'S12' is an 'Industrial' type sampling station near 'Nico Jayasawal Industrial Ltd.'. According to emission inventory study, contributors are industry (52%; 160.66 µg/m^3), road dust (23%; 72.42 µg/m^3), constructions (3%; 8.09 µg/m^3), transports (16%; 48.77 µg/m^3), generator sets fuel oil combustion (2%; 7.67 µg/m^3), domestic fuels combustion (2%; 7.49 µg/m^3), wastes buring (1%; 1.92 µg/m^3) and restaurants/ eateries/ hawkers (1%; 2.97 µg/m^3) (Figure 2.94).

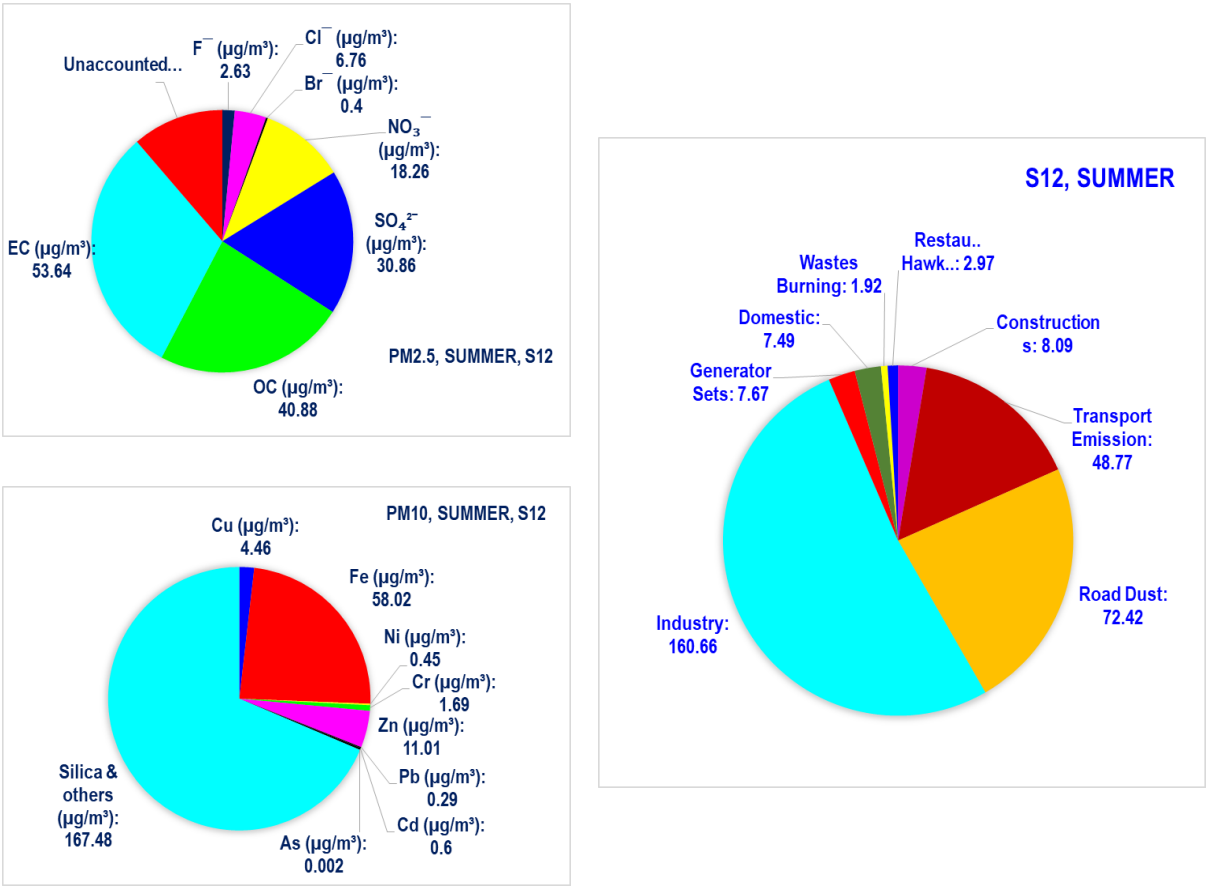


Figure 2.94: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S12' during summer.

Air-quality monitoring station 'S13' is an 'Industrial' type sampling station near "SKS Colony'. According to emission inventory study, sources are industry (52%; 176.58 µg/m^3), transports (14%; 46.31 µg/m^3), road dust (29%; 97.34 µg/m^3), constructions (2%; 6.85 µg/m^3), wastes burning (1%; 2.76 µg/m^3) and generator sets fuel oil combustion (2%; 7.31 µg/m^3) (Figure 2.95).

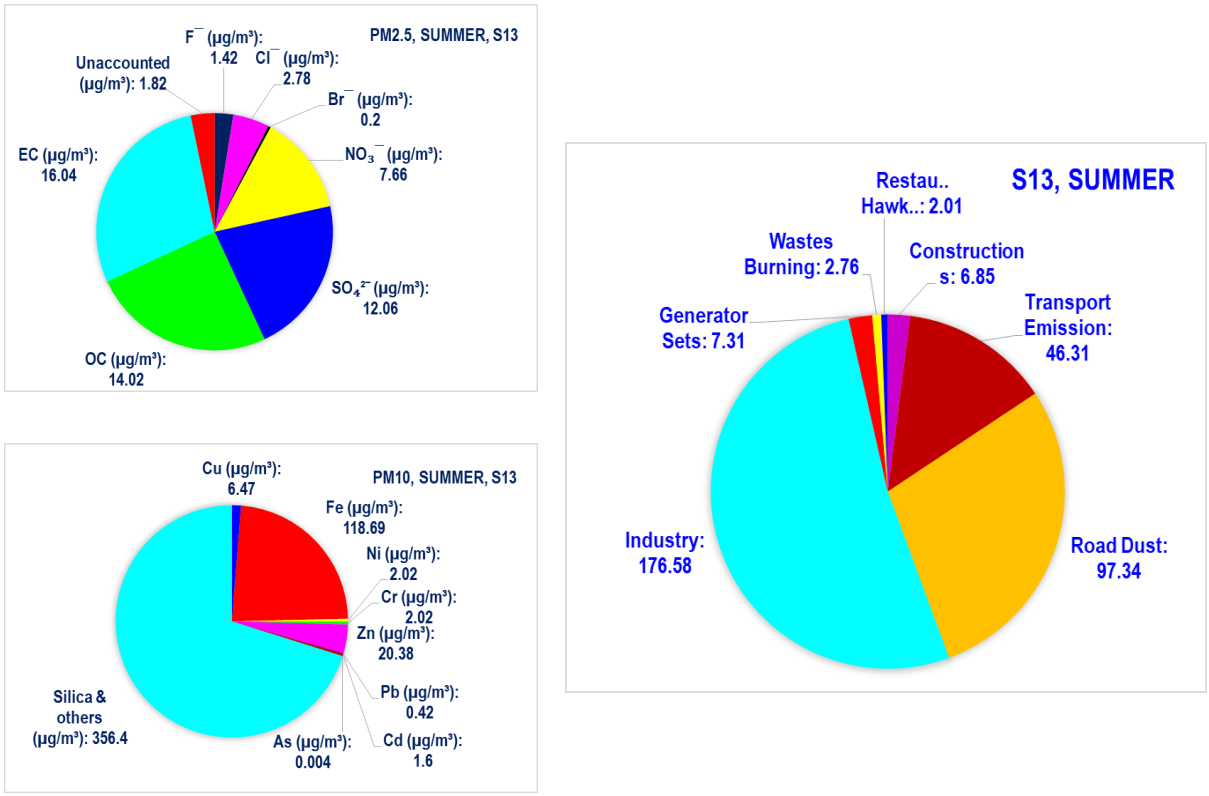


Figure 2.95: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S13' during summer.

Air-quality monitoring station 'S14' is an 'Industrial' type sampling station near 'CG Ispat'. According to emission inventory study, sources are industry (51%; 192.16 µg/m^3), road dust (26%; 97.44 µg/m^3), constructions (3%; 9.34 µg/m^3), transports (13%; 49.19 µg/m^3) and generator sets fuel oil combustion (4%; 14.38 µg/m^3) (Figure 2.96).

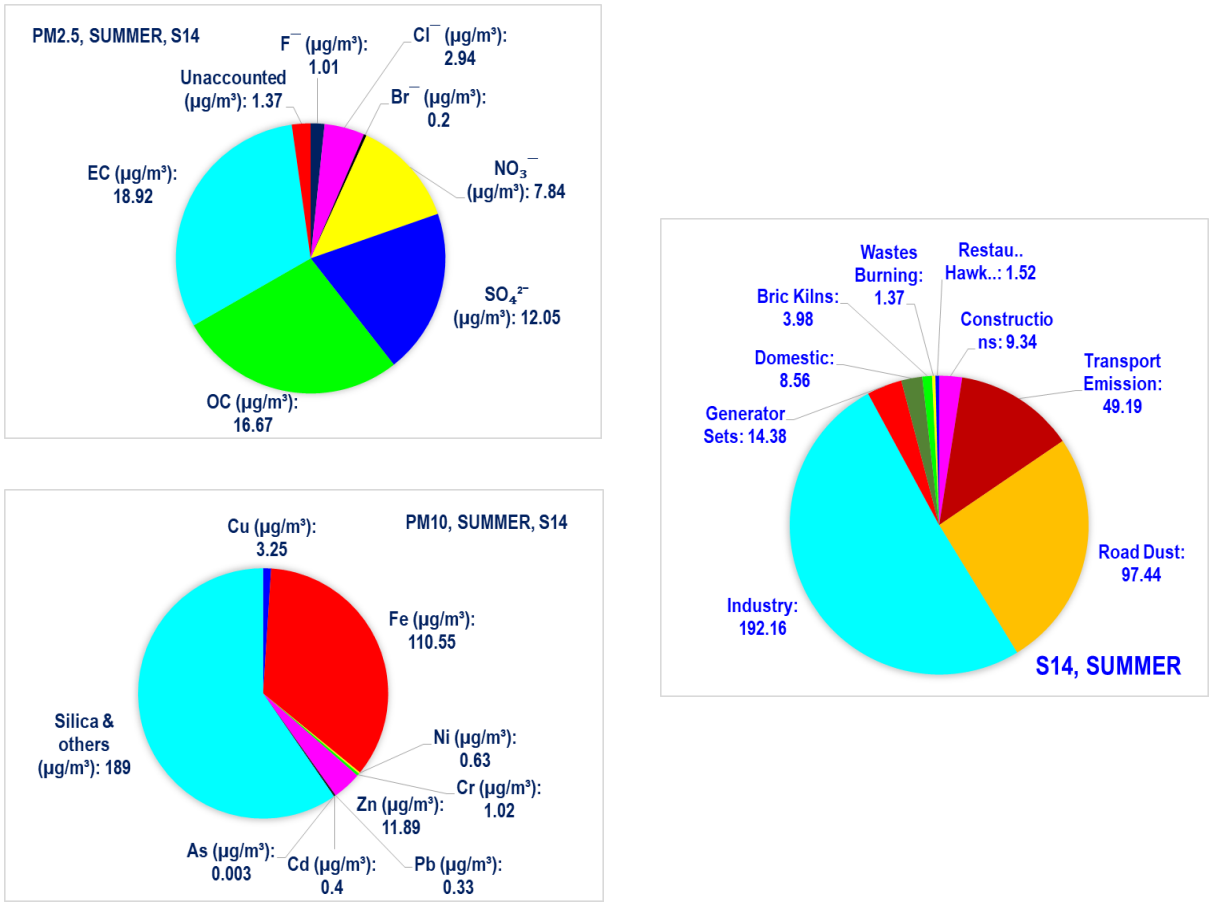


Figure 2.96: Average composition (µg/m^3) of particulate matters and their emission sources in air-quality monitoring station 'S14' during summer.

Air-quality monitoring station 'S15' is also an 'Industrial' type sampling station near 'Apollo Pipes'. Emission inventory study shows the sources are industry (46%; 152.29 µg/m^3), constructions (5%; 15.94 µg/m^3), road dust (30%; 99.73 µg/m^3), transports (14%; 46.66 µg/m^3) and generator sets fuel oil combustion (3%; 9.91 µg/m^3) (Figure 2.97).

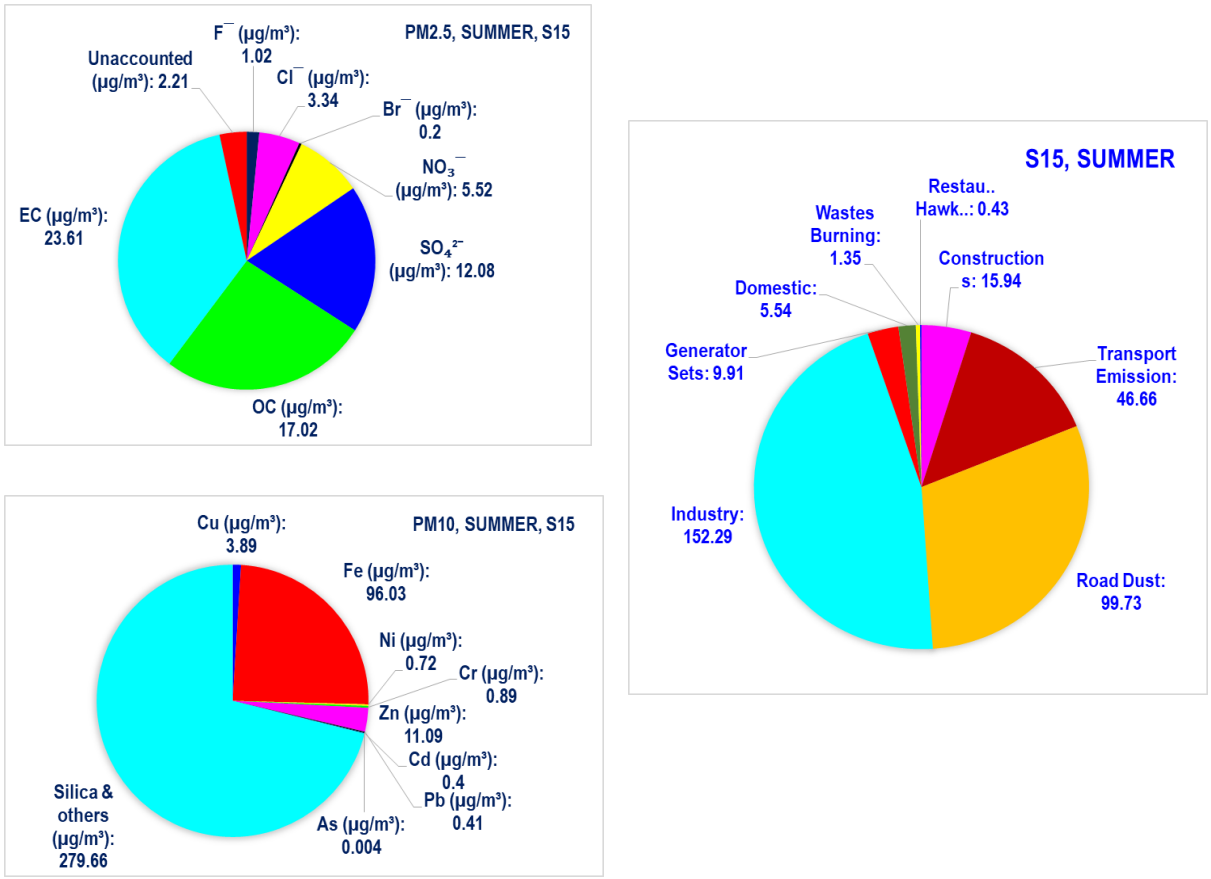


Figure 2.97: Average composition (µg/m^3) of particulate matters and their emission sources in air-quality monitoring station 'S15' during summer.

'S16' is a 'Mixed' type sampling station near 'Chataud High School'. CMB predicts the sources are industry (35%; 43.03 µg/m^3), road dust (33%; 40.78 µg/m^3), transports (14%; 16.89 µg/m^3), construction (8%; 9.98 µg/m^3) and domestic fuel combustion (8%; 9.31 µg/m^3) (Figure 2.98).

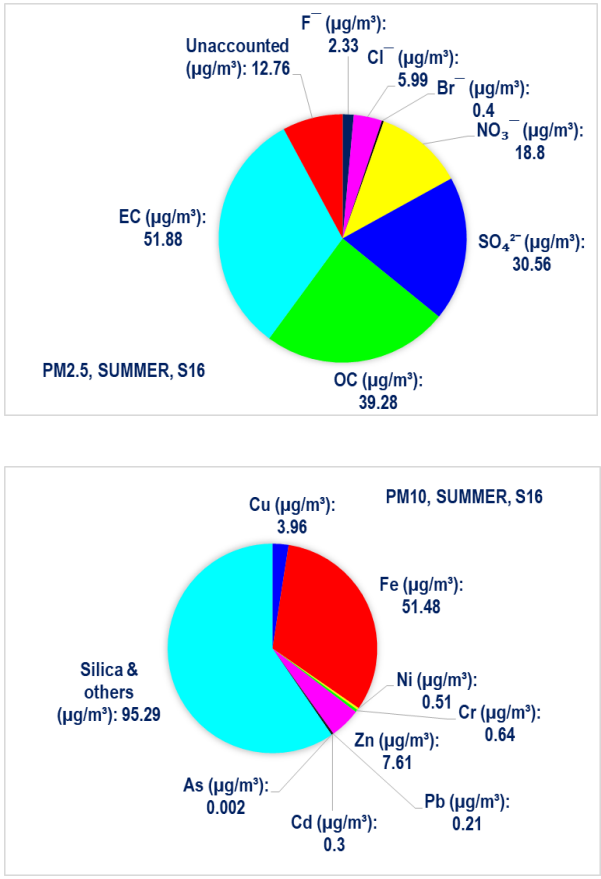


Figure 2.98: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S16' during summer.

Air-quality monitoring station 'S17' is a 'Silent' type sampling station near 'Shaskiya M M Vidyalaya (Khudmud)'. According to emission inventory study, sources are industry (39%; 49.66 µg/m^3), road dust (32%; 41.02 µg/m^3), transports (12%; 15.51 µg/m^3), construction (8%; 10.41 µg/m^3), domestic fuels combustion (4%; 4.79 µg/m^3) and generator sets fuel oil combustion (3%; 3.61 µg/m^3) (Figure 2.99).

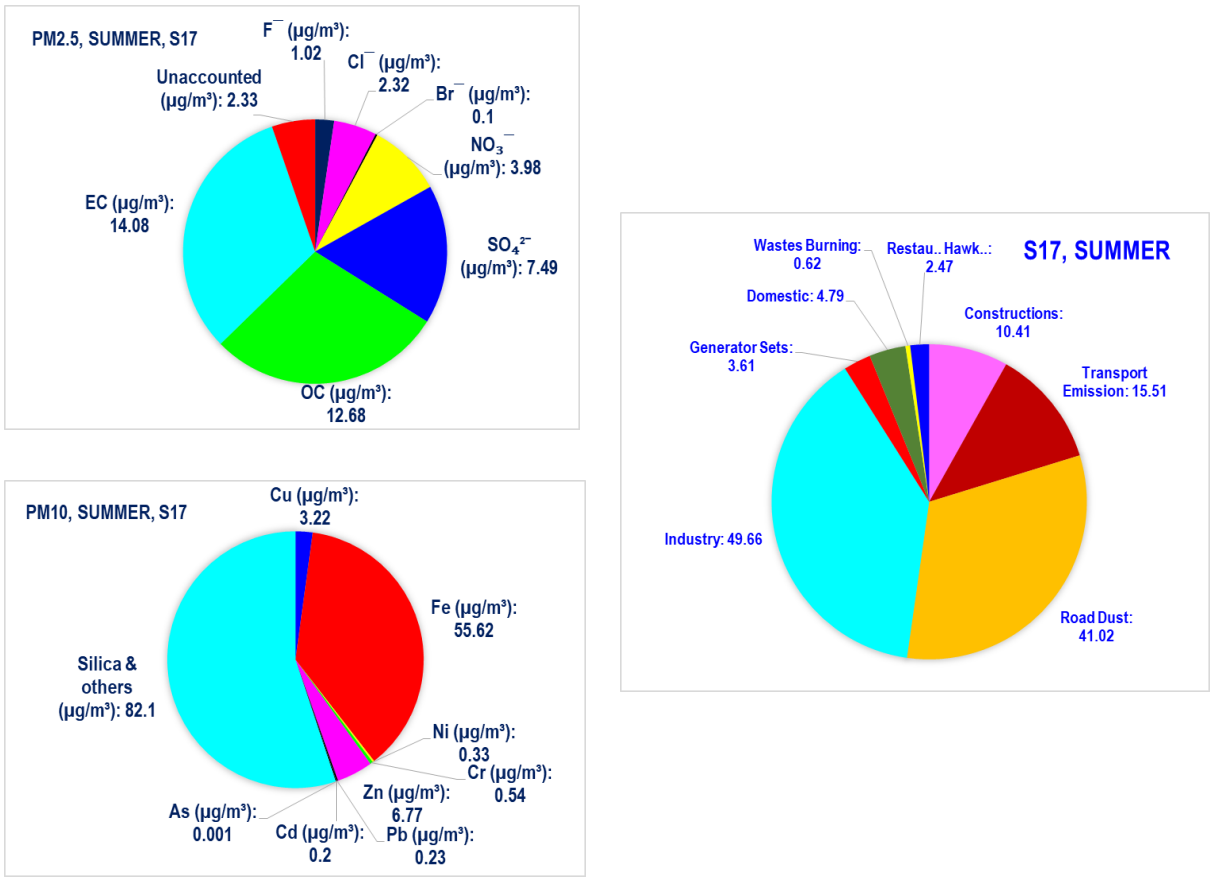


Figure 2.99: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'S17' during summer.

Above air-quality monitoring station-wise study shows a clear contribution of different sources of pollutants present there. Those sources of pollutant and their emission are not only changing the ambient air quality of that specific station but also the surrounding areas. As we have found intra-sectoral contamination in the analysis and source apportionment study. Those pollutants are spreading though wind and finally effect in the ambient air-quality of Siltara.

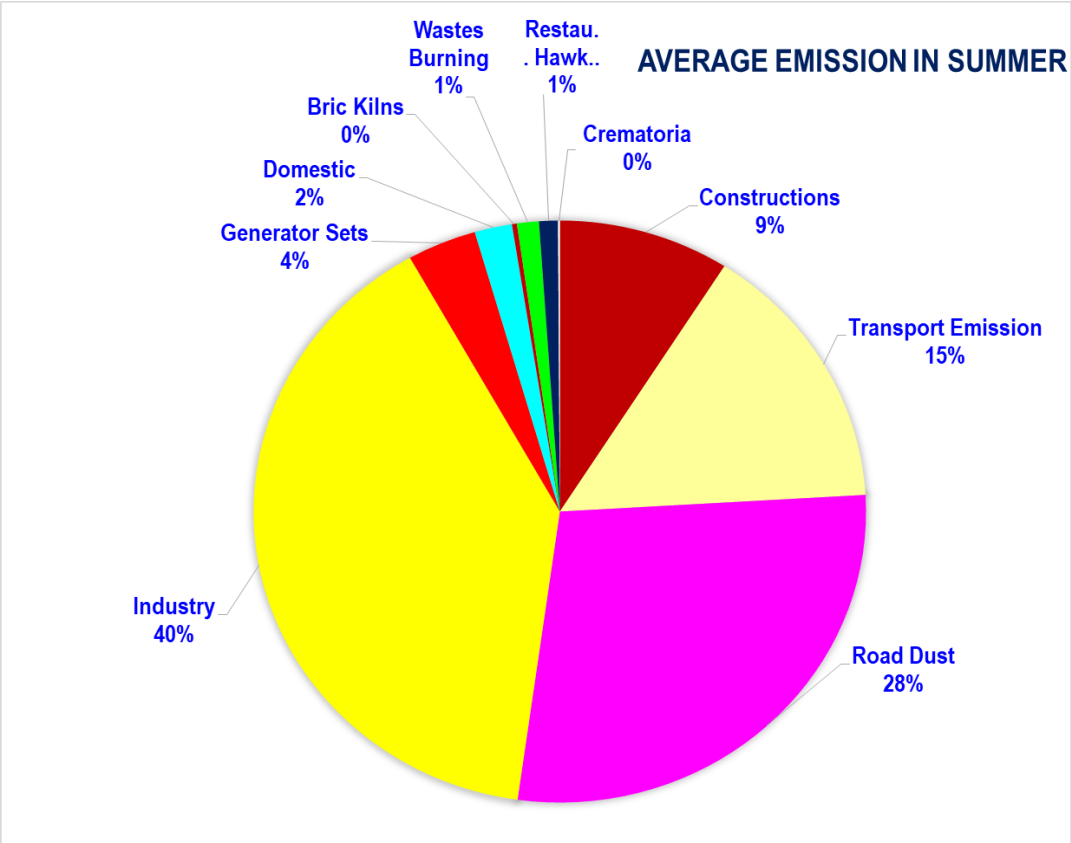
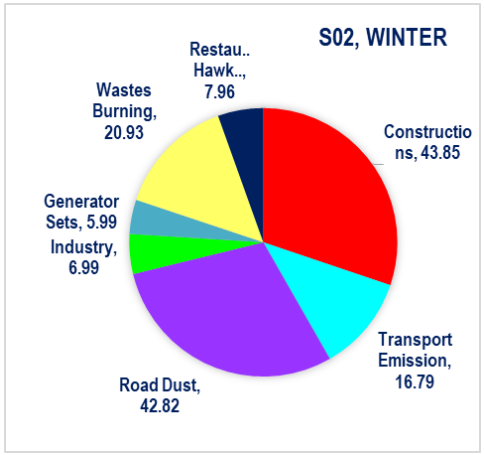


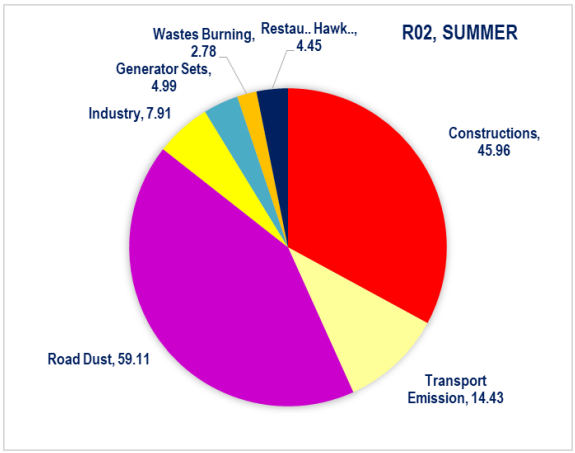
Figure 2.100: Different sources of pollutants and their percent contribution in the ambient air pollution of Siltara during summer season.

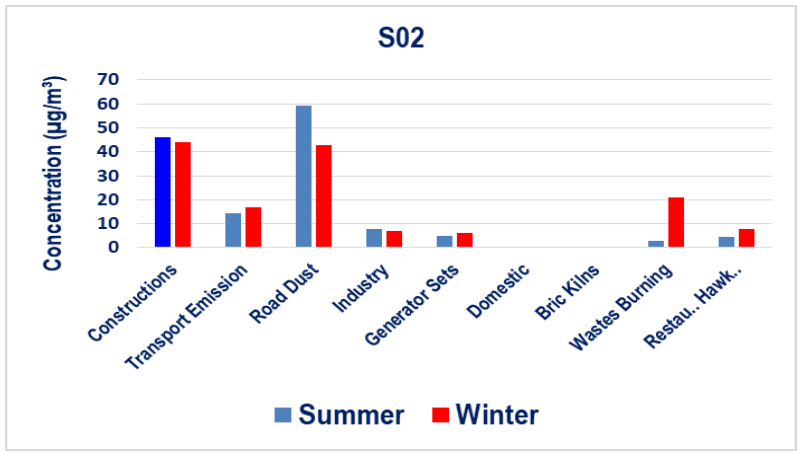
Emission inventory study shows, ambient air quality in Siltara is mainly effected by different types of industry or manufacturing units. Particulate matters emission from different types of industry have been predicted by CMB as 40% (78.54 µg/m^3). Similarly, CMB predicted other major emission sources are road dust (28%; 55.69 µg/m^3), transports (15%; 29.81 µg/m^3), construction (9%; 17.89 µg/m^3), generator sets fuel oil combustion (4%; 7.24 µg/m^3), wastes burning (1%; 2.18 µg/m^3), etc. (Figure 2.100).

2.4.8.3 Seasonal Variation

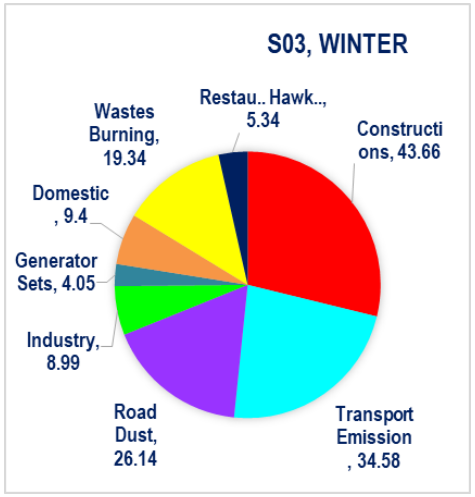
WINTER | **SUMMER** | **SEASONAL VARIATION**

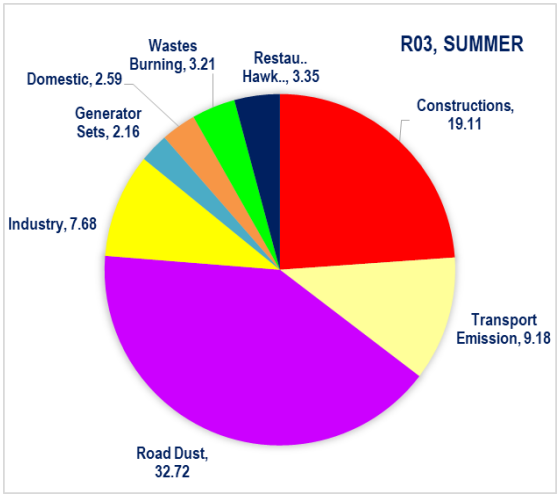


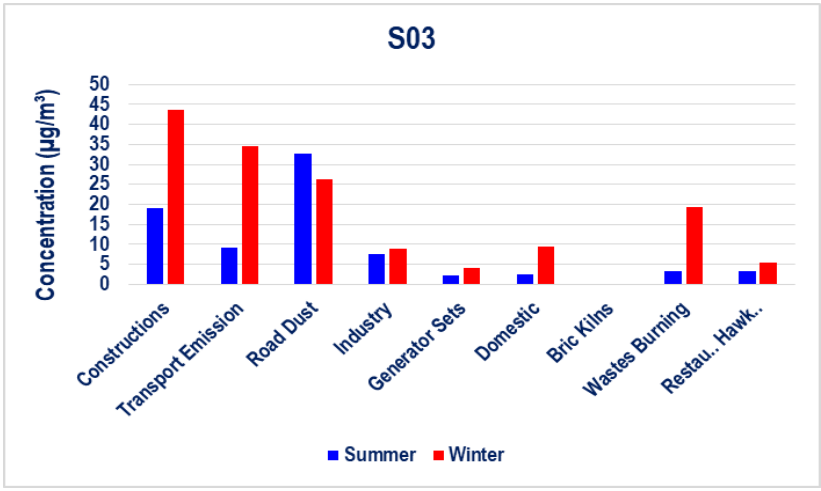




S02





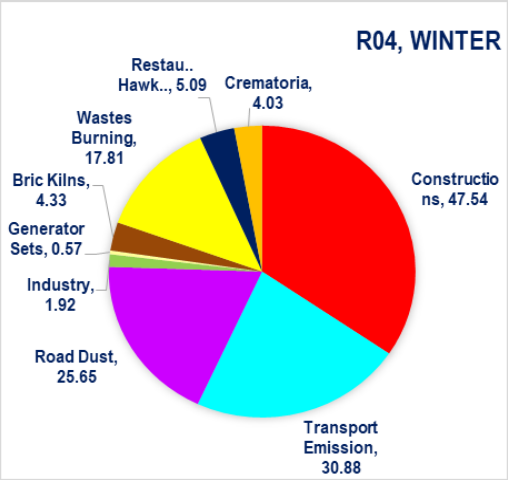


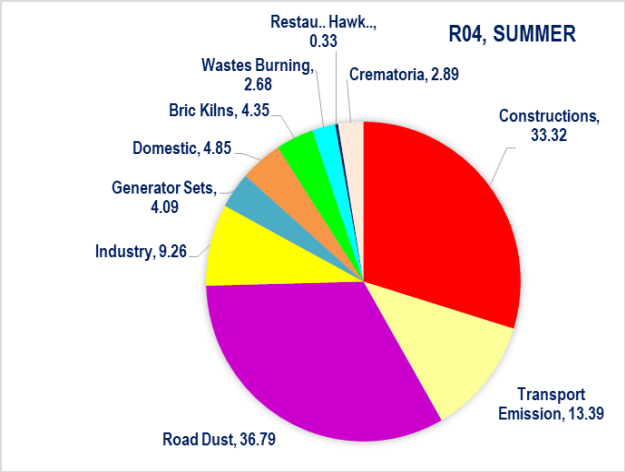
S03

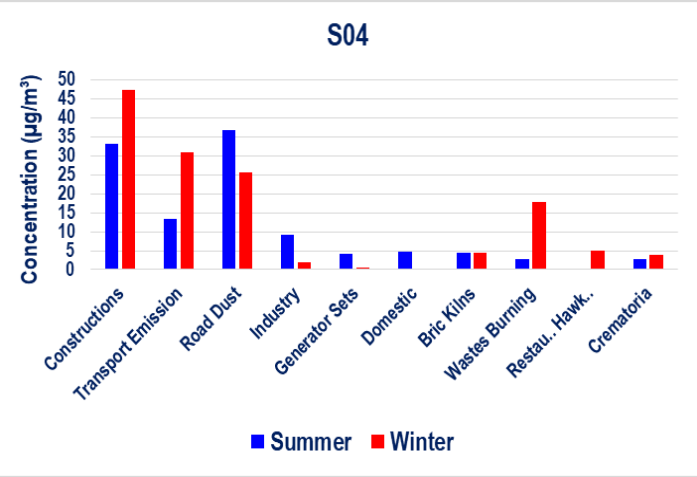
WINTER

SUMMER

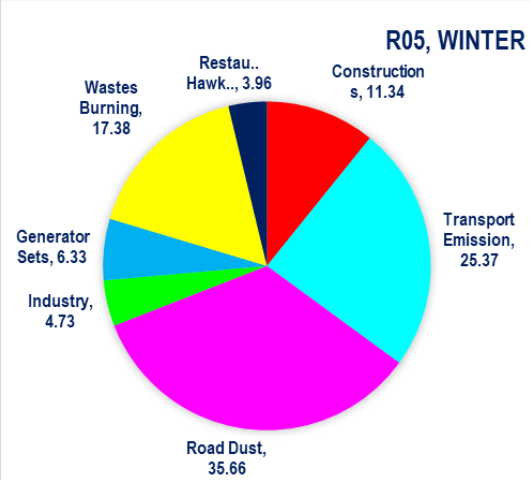
SEASONAL VARIATION

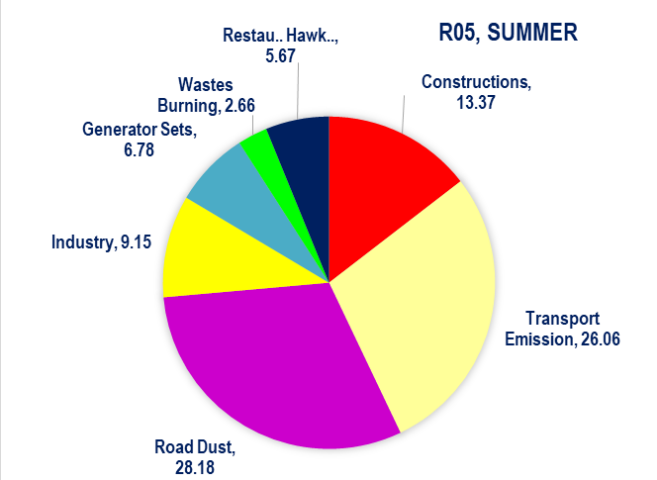


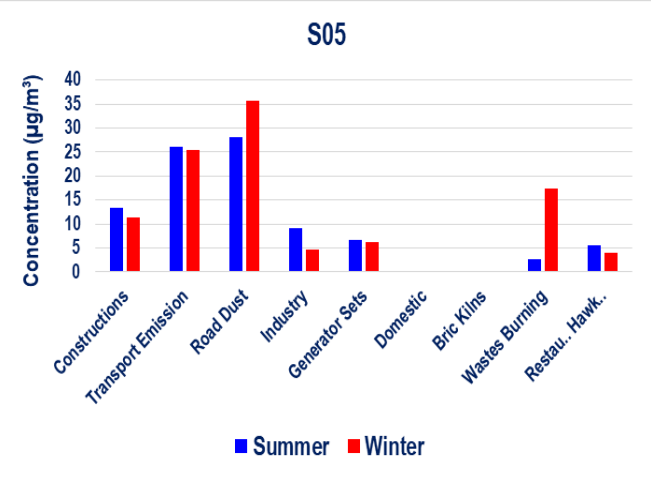




S04







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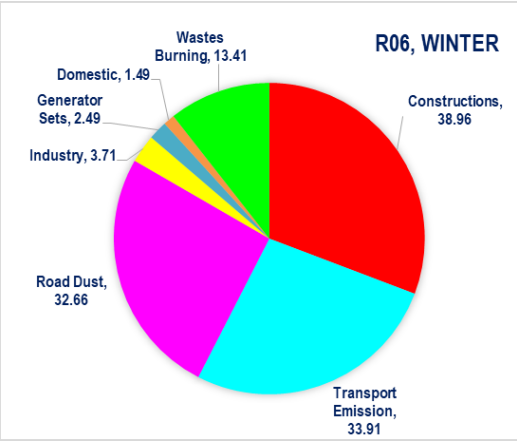

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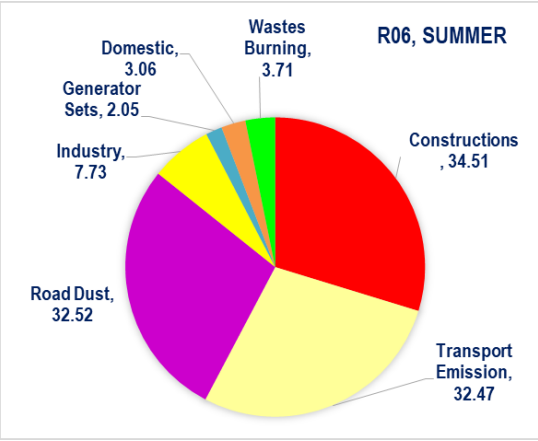

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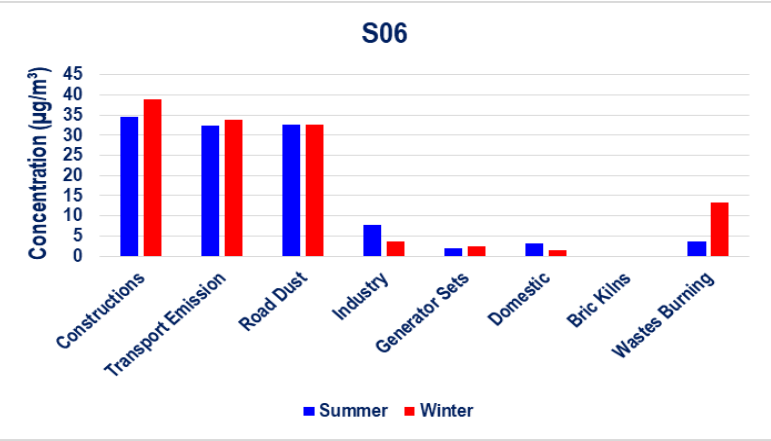

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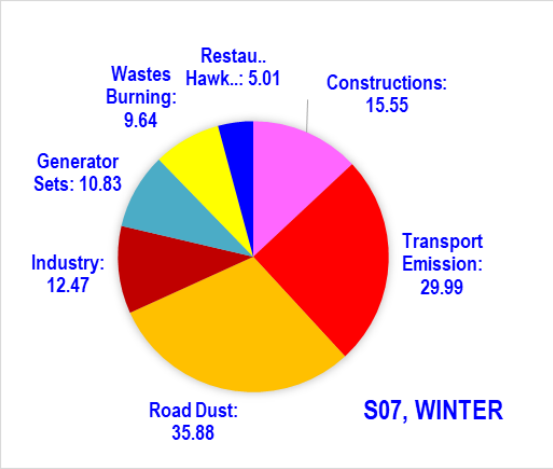

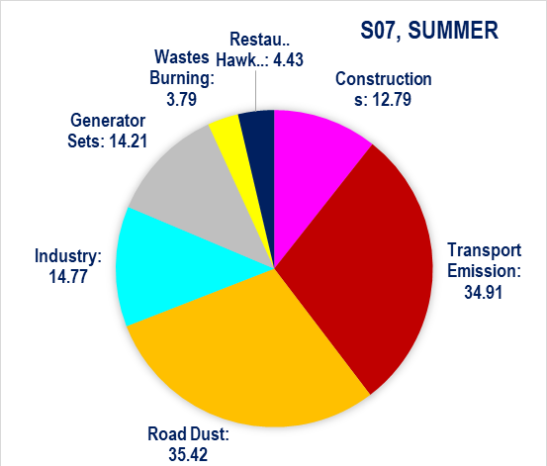

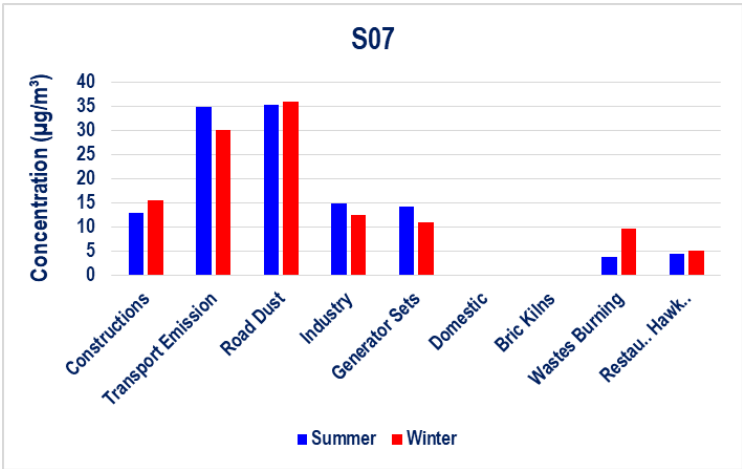

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WINTER

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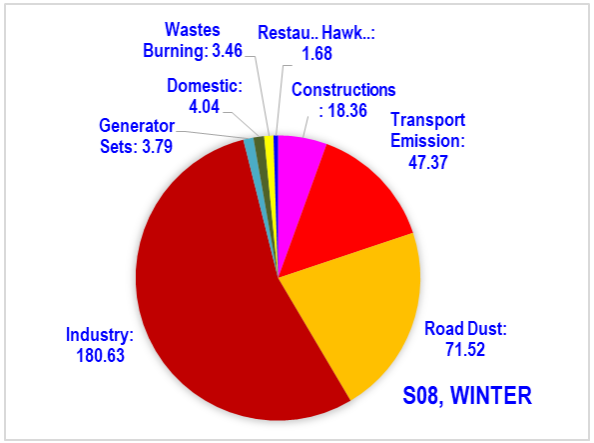

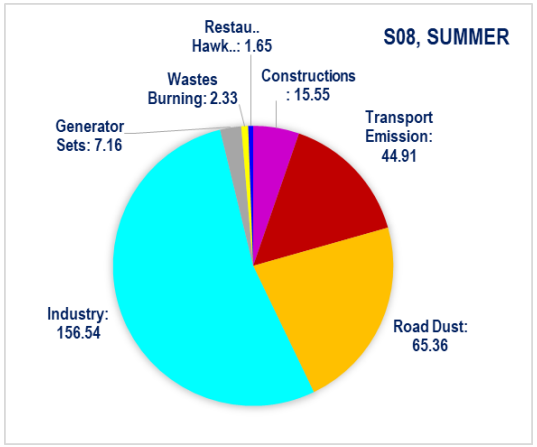

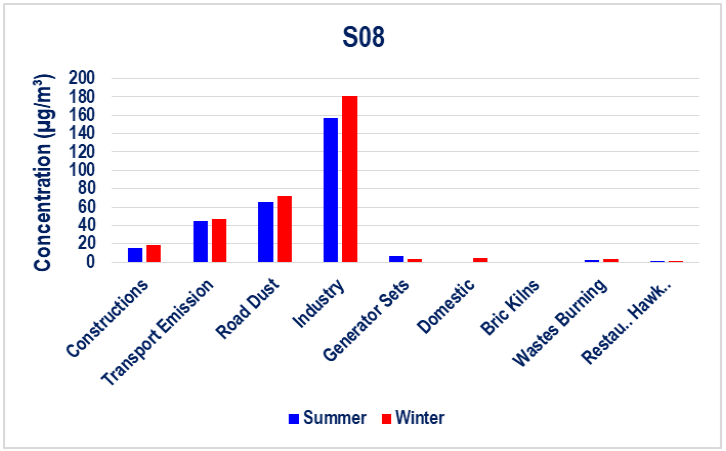

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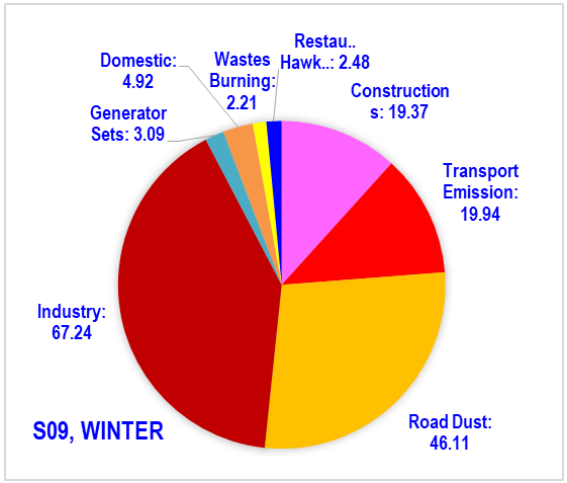

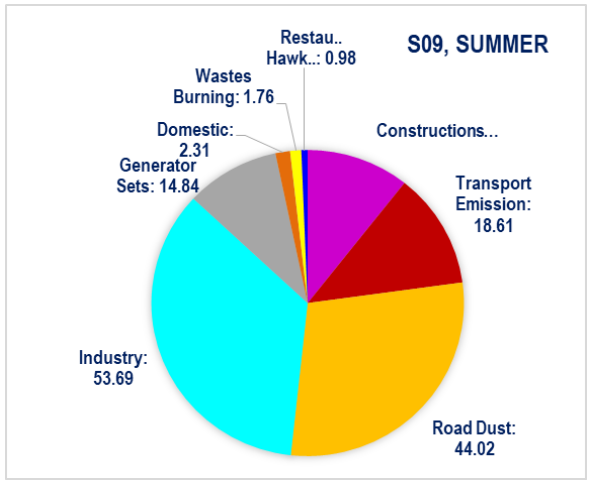

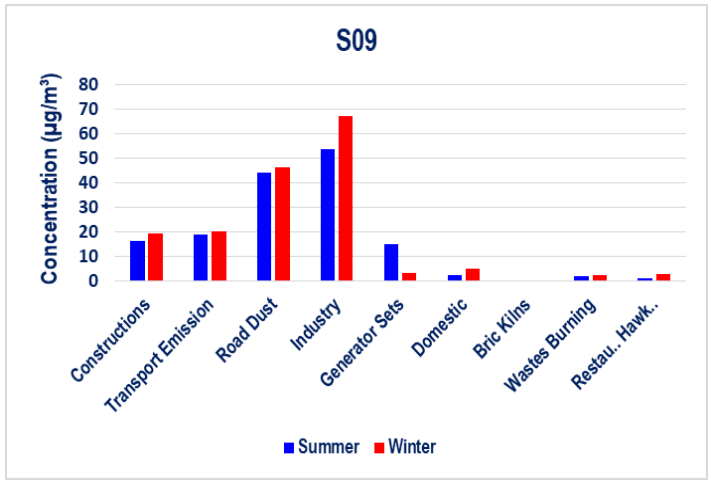

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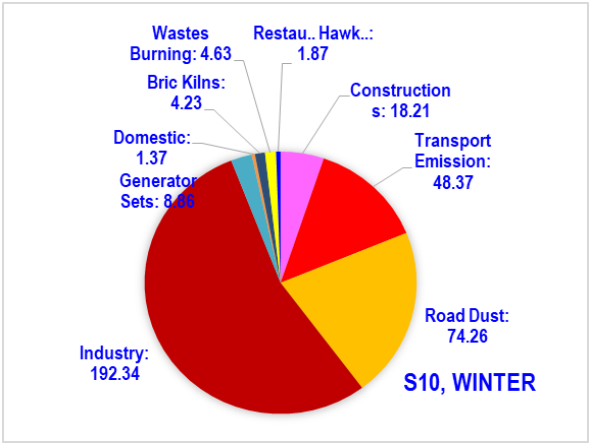
WINTER



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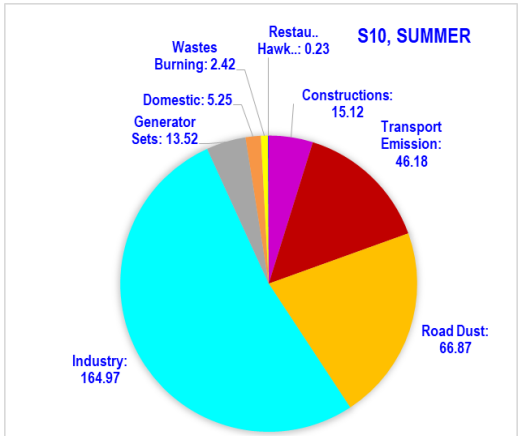

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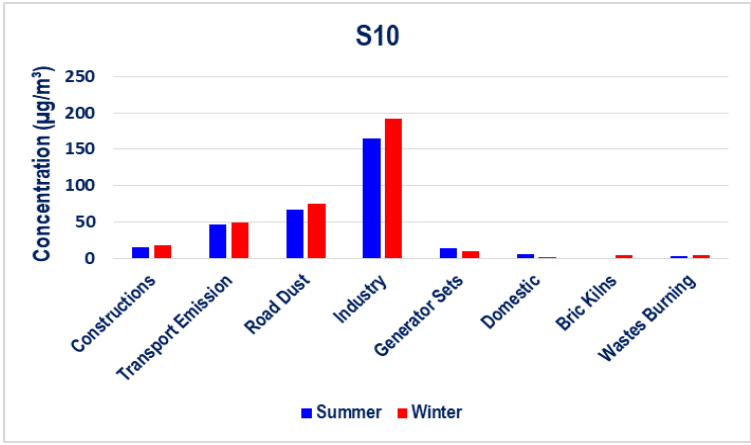

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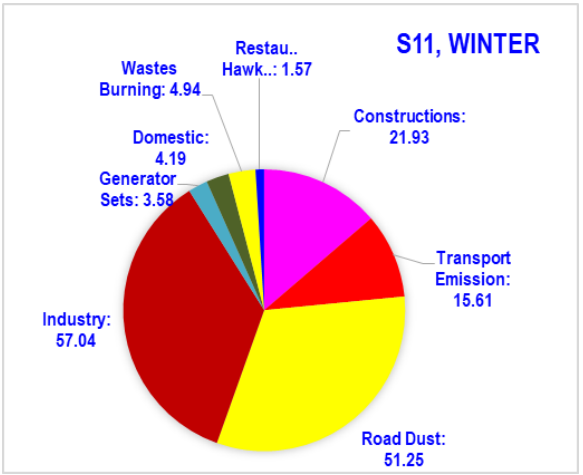

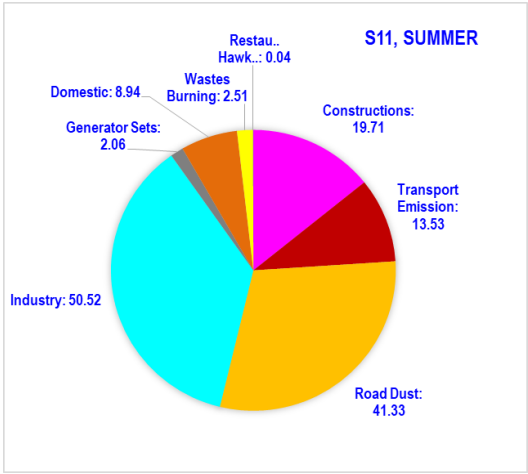

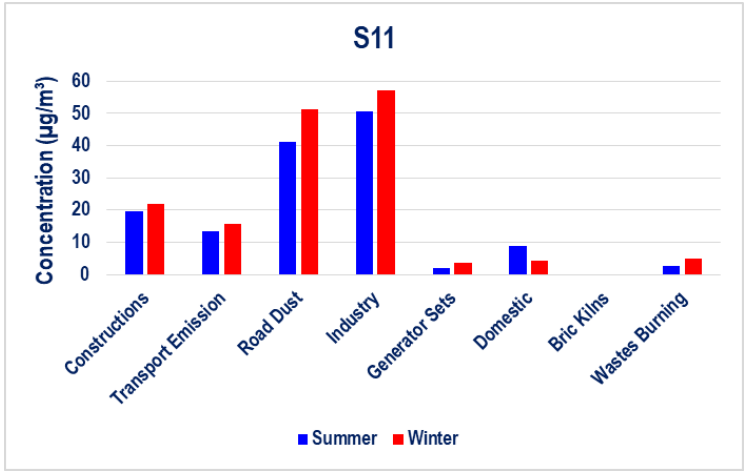

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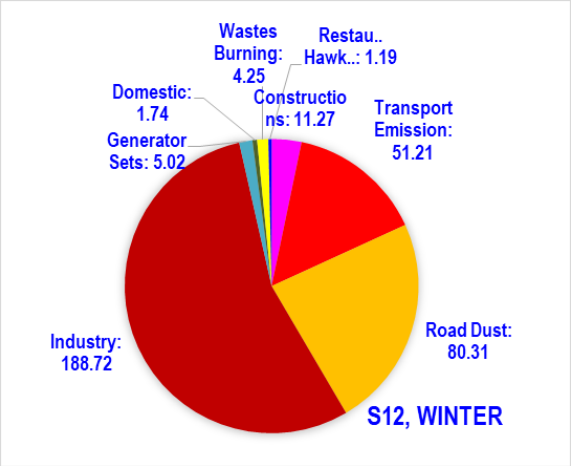

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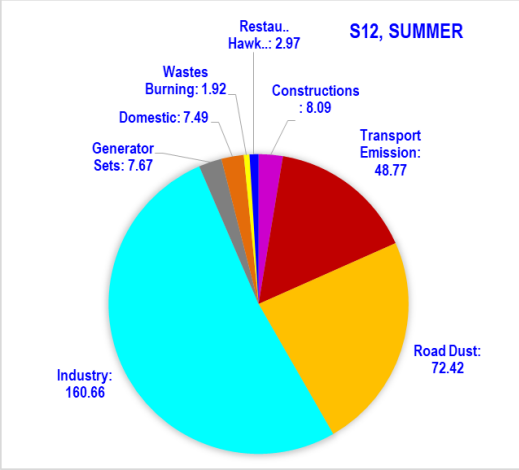

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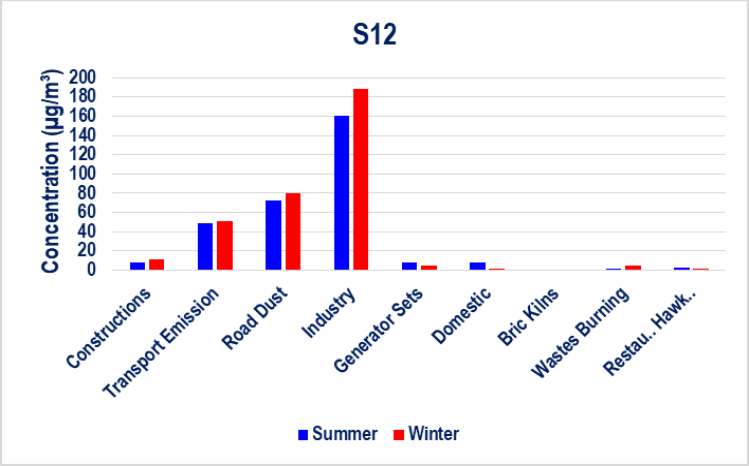

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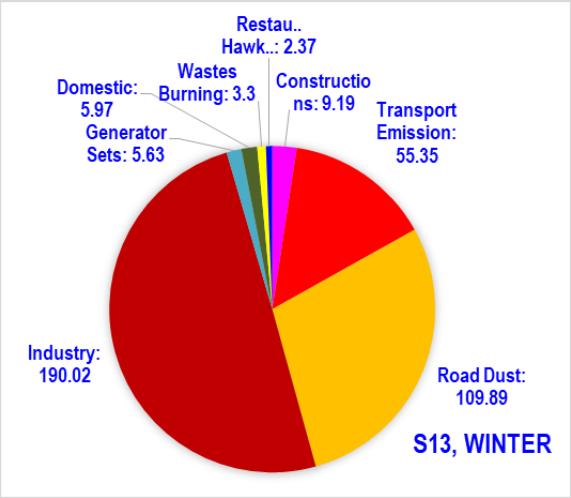

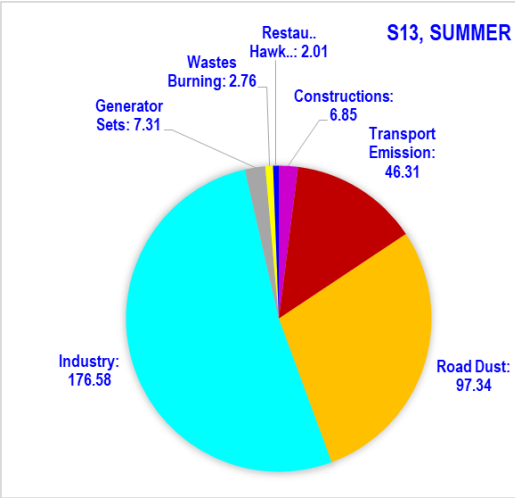

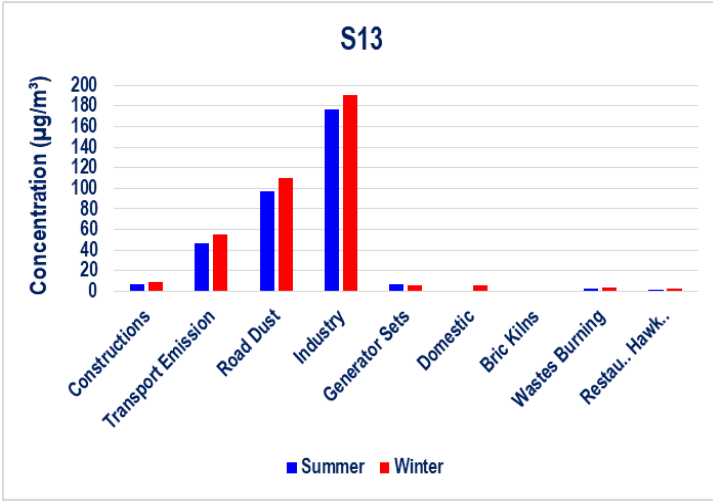

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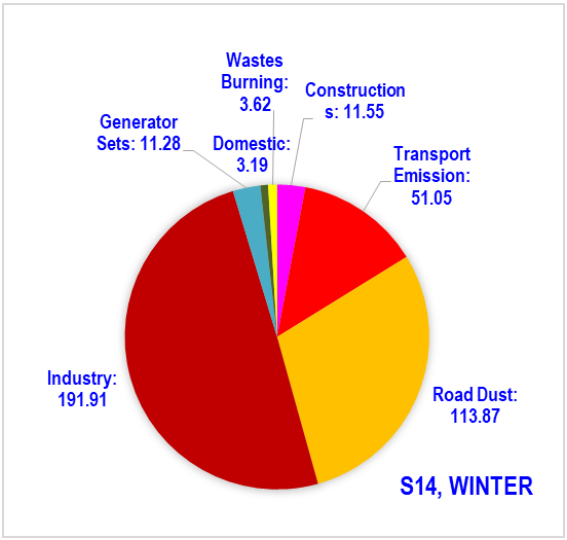

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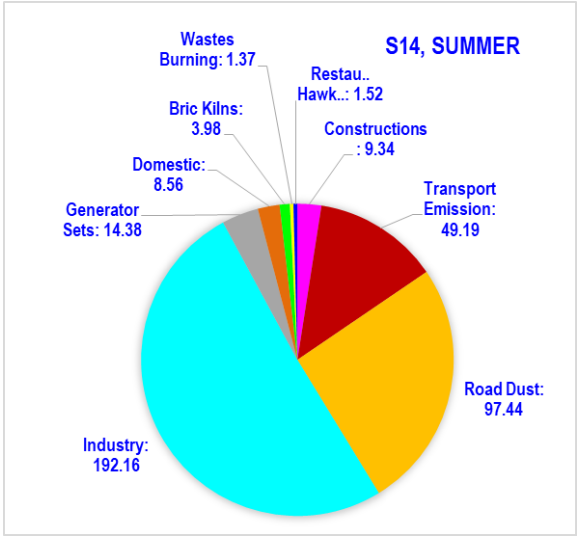

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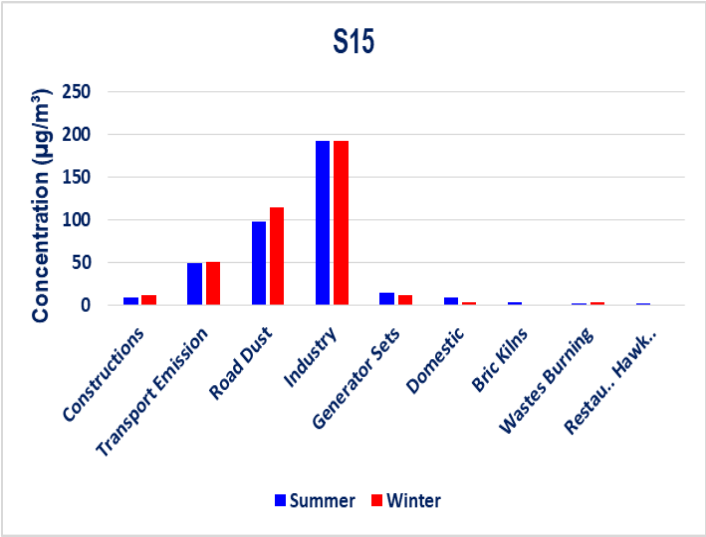

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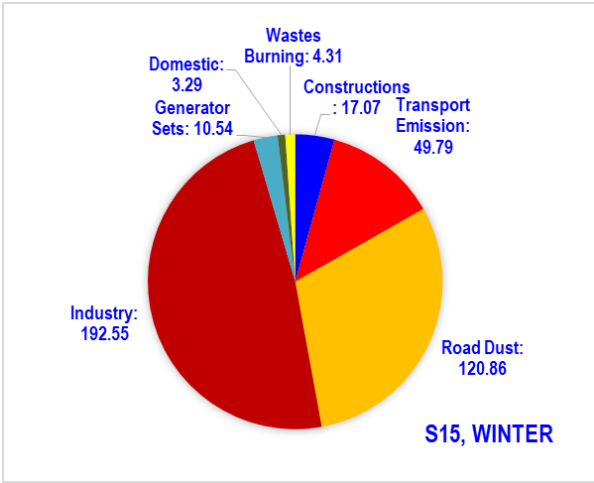

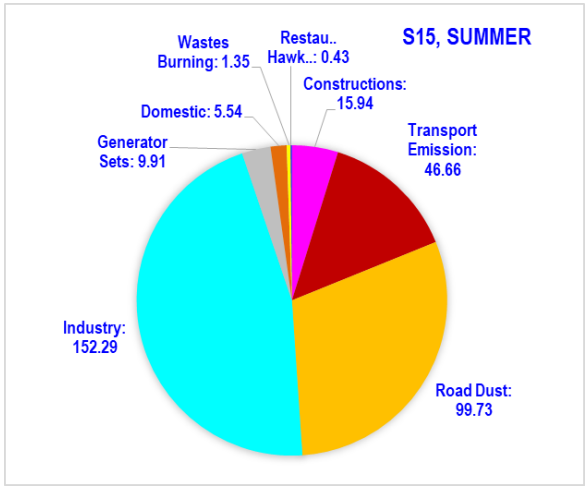

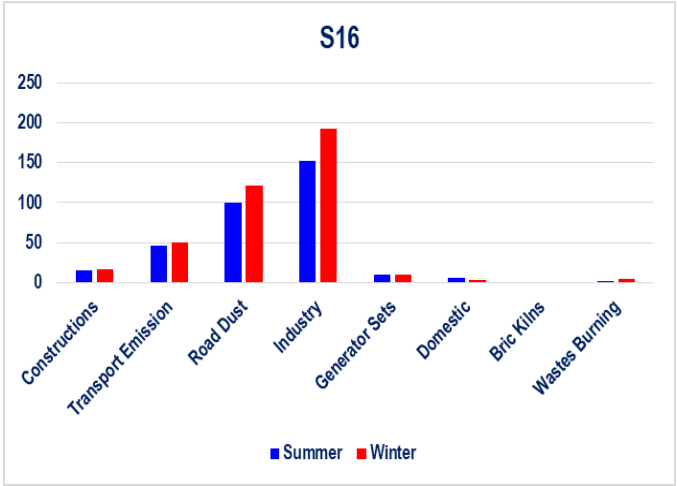

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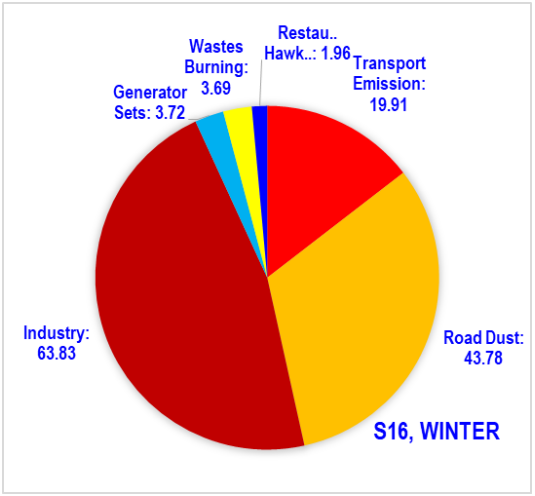

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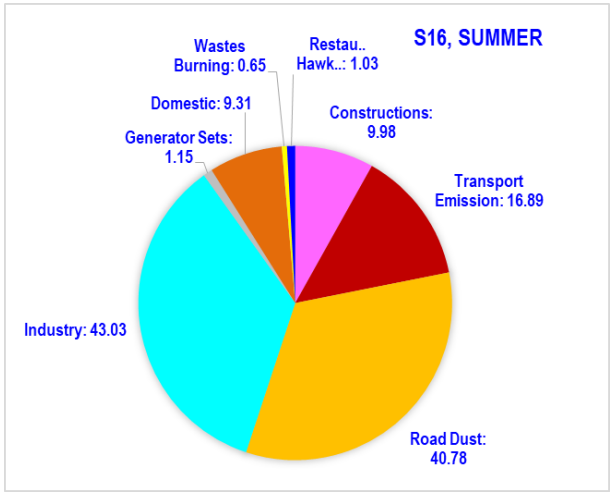

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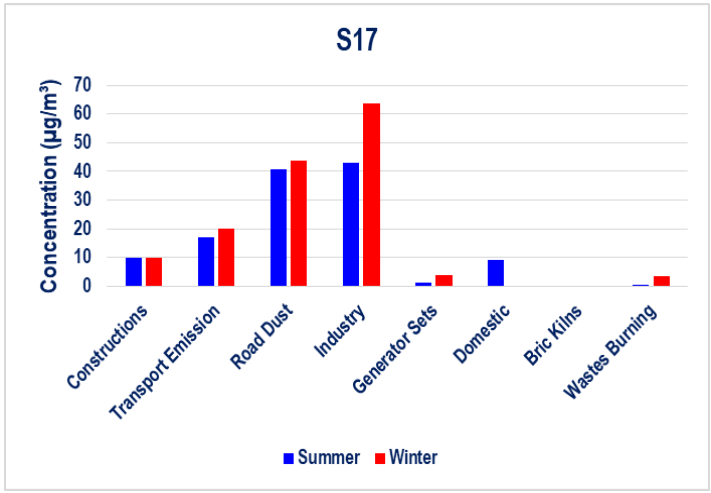

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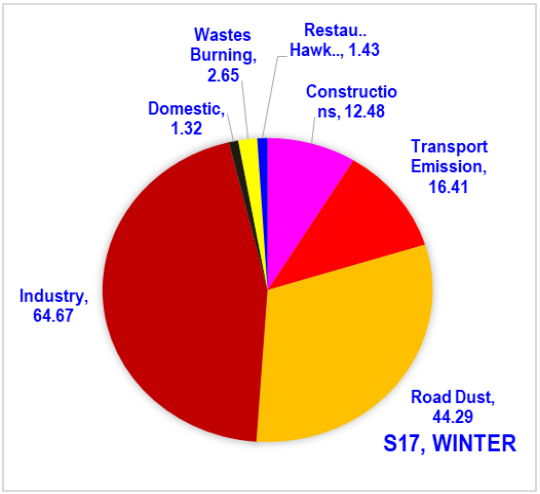

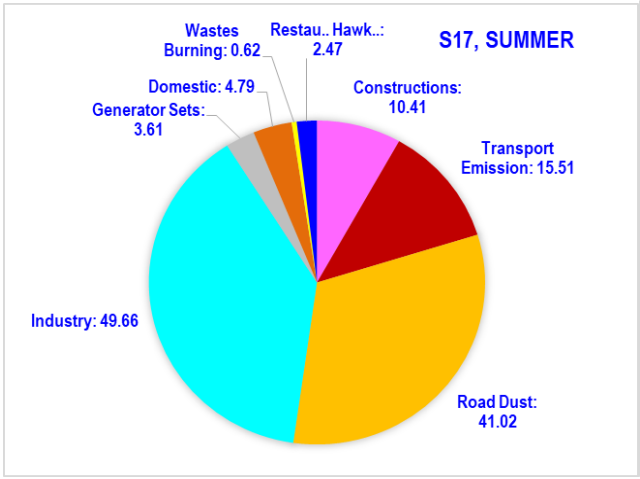

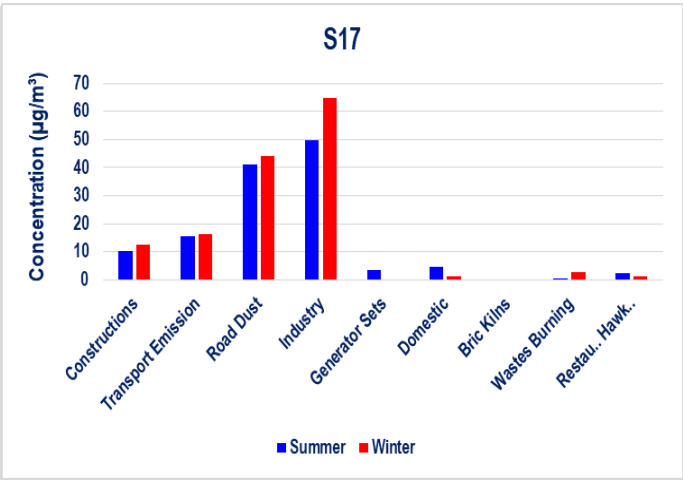

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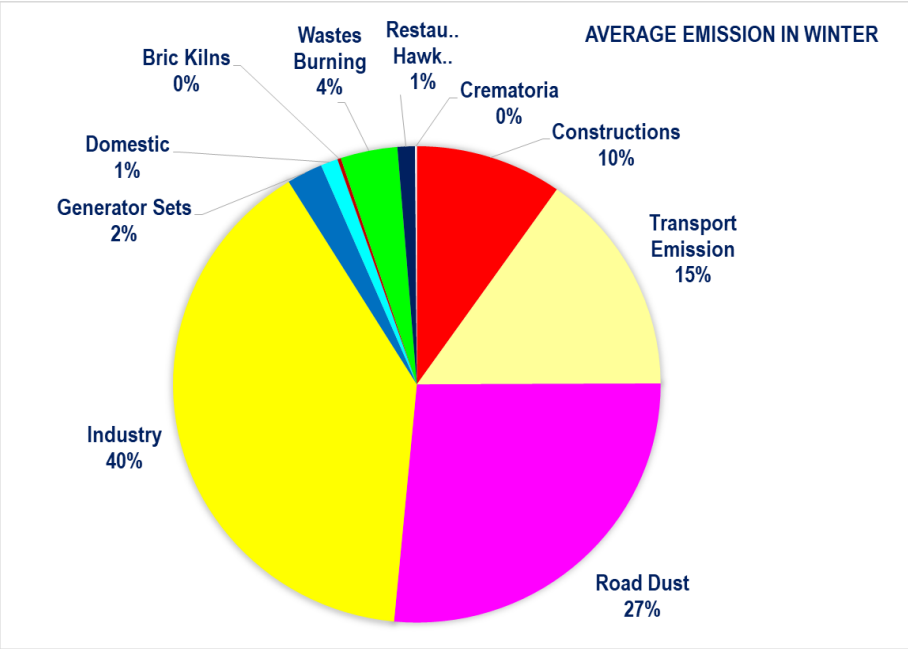

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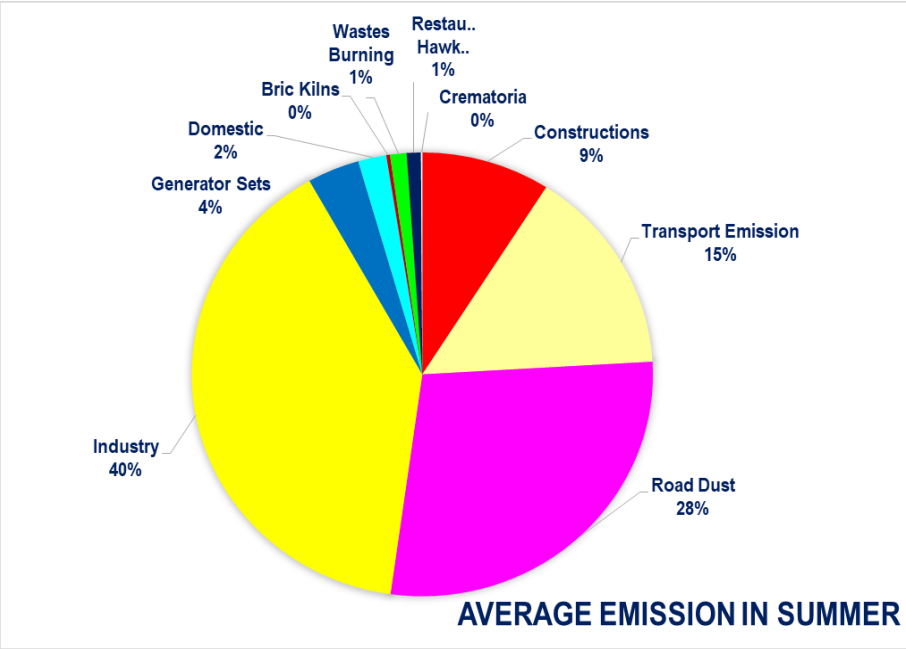


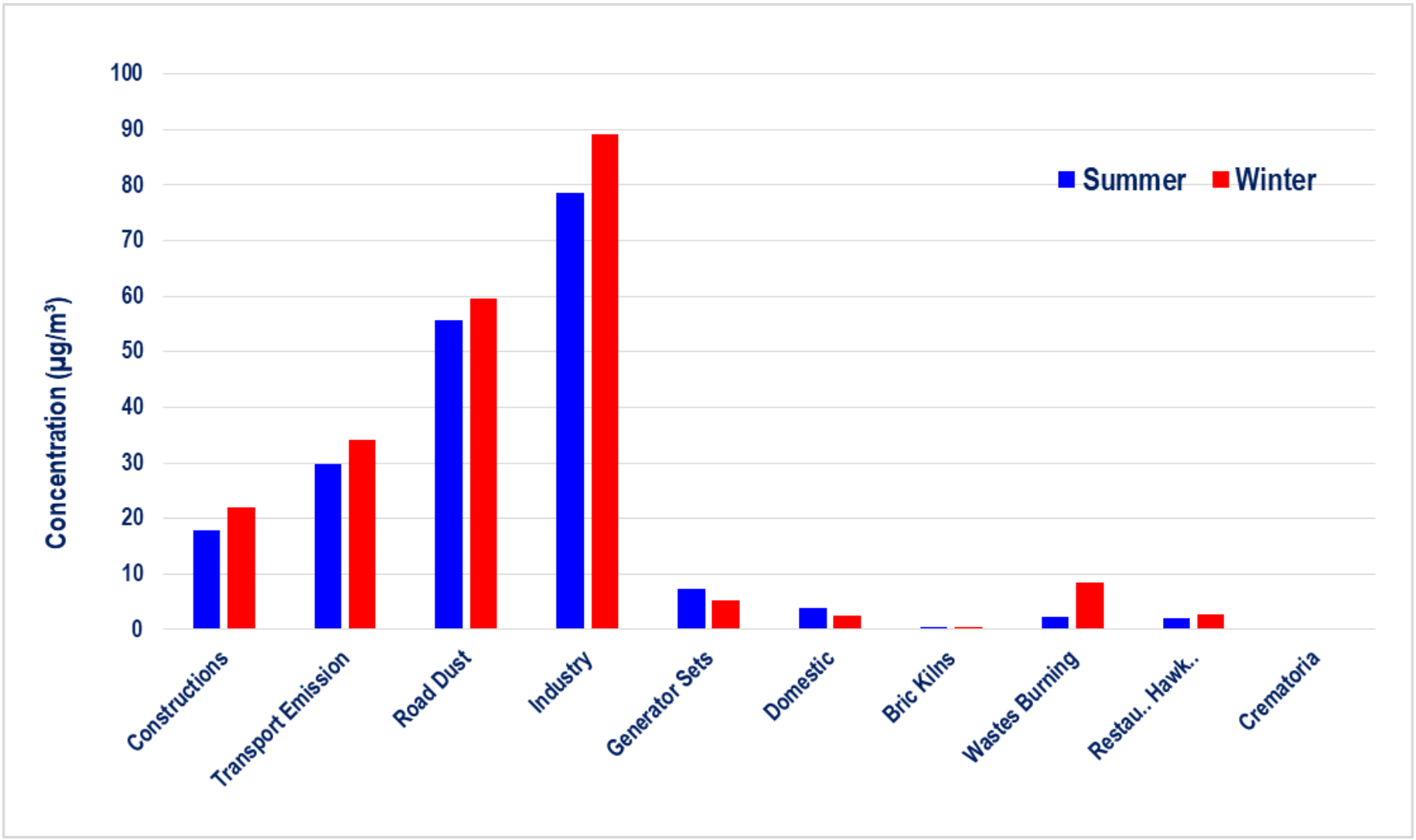


Figure 2.101: Sector wise emission variation with the change of seasons is shown graphically and separately.

CHAPTER-III

WATER ENVIRONMENT

3.1 Introduction

A superior quality of water is crucial to the economic, health, and social well-being of the people. Monitoring the quality of water and testing it regularly is very important to maintain reliable and safe water sources and eliminate the potential health risks related to water contamination. Some importance of such assessment includes: (a) To check whether the water quality is in compliance with the standards, and hence, suitable or not for the designated use. (b) To monitor whether water quality is in compliance with rules and regulations. One of the most important aspects of analysis is the preparation of reagent water to be used for dilution of reagents and for blank analysis. Reagent water is water with no detectable concentration of the compound or element to be analysed at the detection level of the analytical method. Reagent water should be free of substances that interfere with analytical methods. The quality of water required is related directly to the analysis being made. Requirements for water quality may differ for organic, inorganic, and biological constituents depending on the use(s) for which the water is intended. Any method of preparation of reagent water is acceptable provided that the requisite quality can be met. Improperly maintained systems may add contaminants. Reverse osmosis, distillation, and deionization in various combinations all can produce reagent water when used in the proper arrangement. Different materials and methods used for analysing the water sample are described in the following sections.

3.2. Material and Methods

3.2.1 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand determines the amount of oxygen required for chemical oxidation of organic matter using a strong chemical oxidant such as Potassium dichromate under reflux conditions. This test is used for the determination of the efficiency of the treatment plant, pollution

$$2K_2Cr_2O_7 + 8\,H_2SO_4 \rightarrow 2K_2SO_4 + 2Cr_2(SO_4)_3 + 8\,H_2O + 3O$$

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6\,H_2O$$

$$Cr_2O_7^{--} + 6\,Fe^{++} + 14\,H^+ \rightarrow 6Fe^{+++} + 2Cr^{+++} + 7\,H_2O$$

3.2.1.1 Reagent used for analysis

A reagent is a substance or compound added to a system to cause a chemical reaction, or added to test if a reaction occurs. The following reagents are used for COD analysis of water sample.

1. Standard Potassium Dichromate Solution, 0.25 N (0.04167 M)

12.259 gm dried Potassium dichromate is dissolved in 1000 ml distilled water.

2. Sulphuric Acid Reagent

10 gm of Silver sulfate is dissolved in 1000 mL concentrated H_2SO_4 and it is allow to stand for one to two days for complete dissolution.

3. Standard Ferrous Ammonium Sulphate approx. 0.25N (0.25M)

98 gm Ammonium ferrous sulfate hexa hydrate is dissolved in about 400 mL distilled water. Then 20 mL concentrated Sulfuric acid is added and dilute to 1000 mL.

4. Ferroin Indicator Solution

5. Mercuric Sulphate

3.2.1.2 Working Method

20 ml of water sample is taken into COD digestion tube. Then 0.4 gm of Mercuric Sulphate is added into the water sample. After that 10 ml of Potassium dichromate is added into the mixture. Then 30 ml of concentrated Sulphuric acid is added into the mixture. Then this tube is placed into COD incubator for 2 hrs. at 150 ^oC. After that heated solution is cooled at room temperature. 10 ml of this cooled sample is taken for titration which is titrated against standard ammonium ferrous sulphate using 2-3 drops of Ferroin indicator. A colour change from blue green to reddish brown is indicated the completion of titration. Procedure for COD analysis is shown in Figure 3.1.

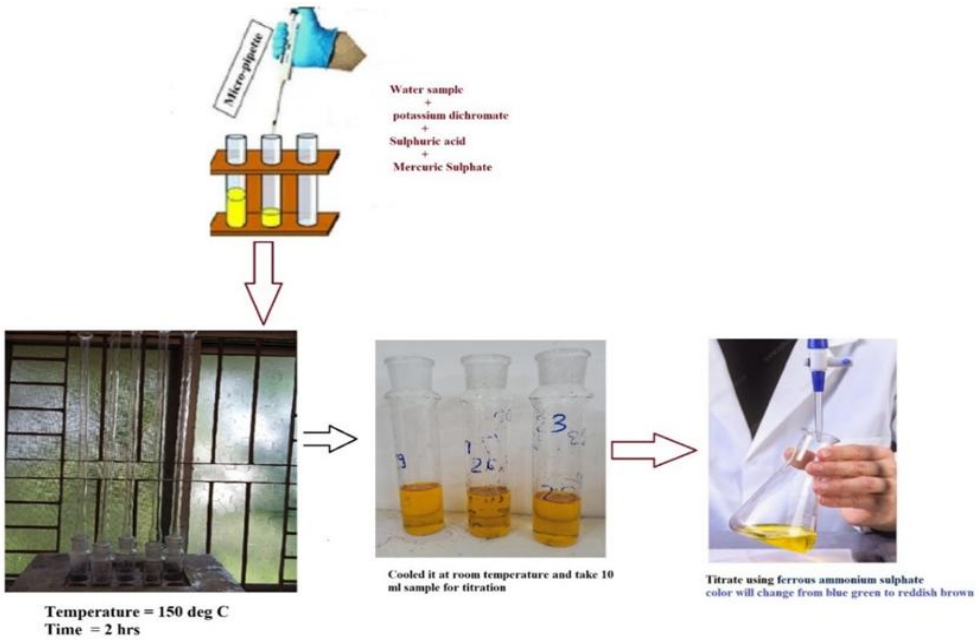


Figure 3.1: Procedure for COD analysis.

3.2.1.3 Calculation

The following are the equations which are used for the calculation of COD.

$$COD\ (\frac{mg}{L}) = \frac{(a-b) \times Normality\ of\ ferrous\ ammonium\ sulphate \times 8000}{ml\ of\ sample}$$

Where, a = ml of ferrous ammonium sulphate used for blank

b = ml of ferrous ammonium sulphate used for sample

8000 = Mili equivalent weight of oxygen * 1000

3.2.2 Hardness

Hardness of water is a measure of its capacity to precipitate soap and is caused mainly by the presence of divalent cations of calcium and magnesium. Total hardness is defined as the sum of the calcium and magnesium concentration, both expressed as Calcium carbonate, in mg/L. The degree of hardness of drinking water has been classified in terms of the equivalent Calcium carbonate concentration as follows:

Soft (0-60 mg/L)

Medium (60-120mg/L)

Hard (120-180mg/L)

Very hard (>180mg/L)

3.2.2.1 EDTA Titration Method

Hardness is determined by the EDTA method in alkaline condition; EDTA and its sodium salts from a soluble chelated complex with certain metal ions. Calcium and Magnesium ions develop wine red color with Eriochrome black T in aqueous solution at pH 10.0 ± 0.1. When EDTA is added as a titrant, Calcium and Magnesium divalent ions get complexes resulting in sharp change from wine red to blue which indicates end-point of the titration.

3.2.2.2 Reagents used for Analysis

1. Buffer Solution

16.9 gm. Ammonium chloride is added in 143 ml Ammonium hydroxide. Then 1.25 gm magnesium salt of EDTA is added to obtain sharp change in colour of indicator.780 mg Magnesium sulfate is added to 50 ml distilled water and dilute to 250 ml.

2. Inhibitor

4.5 gm Hydroxylamine hydrochloride is dissolved in 100 ml 95% ethyl alcohol or isopropyl alcohol. Rubber stopper is tightly fitted to exclude air. This inhibitor deteriorates through air oxidation.

3. Eriohrome Black T Indicator

4. Murexide Indicator

5. Sodium Hydroxide 2 N

80 gm Sodium hydroxide is dissolved in distilled water and dilute to 1000 ml.

6. Standard EDTA Solution 0.01 M

3.723 gm EDTA sodium salt is dissolved and dilute to 1000 ml distilled water. This solution is Standardize against standard Calcium solution 1 ml = 1 mg $CaCO_3$.

7. Standard Calcium Solution

1 gm. Calcium carbonate (AR grade) and transfer to 250 mL conical flask. Funnel is placed in the neck of a flask and 1+1 HCl is added till the complete dissolution of Calcium carbonate. After that 200 ml distilled water is added and it is boiled for 20-30 minutes to expel carbon dioxide. After cooling few drops of methyl red indictor is added. Then 8N Ammonium hydroxide is added drop-wise till intermediate orange colour develops. This solution is diluted to 1000 ml to obtain 1 mL = 1 mg $CaCO_3$.

3.2.2.3 Procedure

These are the following steps which are used for determination of Total hardness and Calcium hardness.

A. Total Hardness

As shown in Figure 3.2, following steps are required for the analysis of Total hardness

1. 50 ml well mixed sample in taken into the conical flask.
2. Addition of 1-2 ml buffer solution followed by 1mL inhibitor is done after that.
3. A pinch of Eriochrome Black T is then added
4. The above solution is then titrate with standard EDTA (0.01M) till wine red colour changes to blue.
5. A colour change from wine red to blue indicated the completion of titration.

B. Calcium Hardness

As shown in Figure 3.3, following steps are required for the analysis of calcium hardness

1. 50 ml well mixed sample in taken into the conical flask.
2. Addition of 1 ml NaOH is done to raise pH to 12.0
3. A pinch of Murexide indicator is then added.
4. The above solution is then titrated immediately with EDTA till pink colour changes to purple.
5. A colour change from pink to purple indicated the completion of titration.

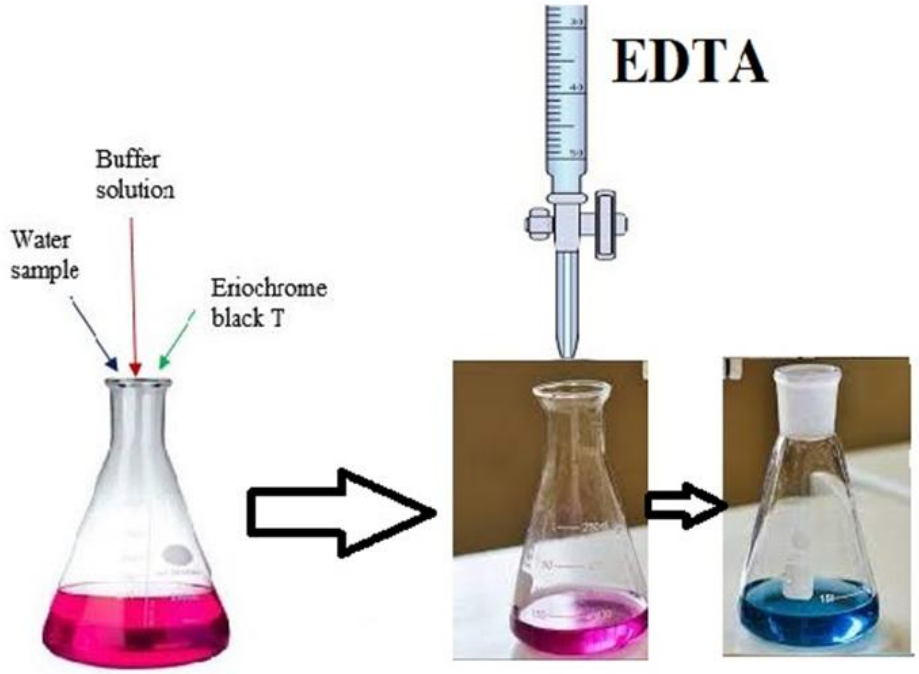


Figure 3.2: Procedure for total hardness analysis.

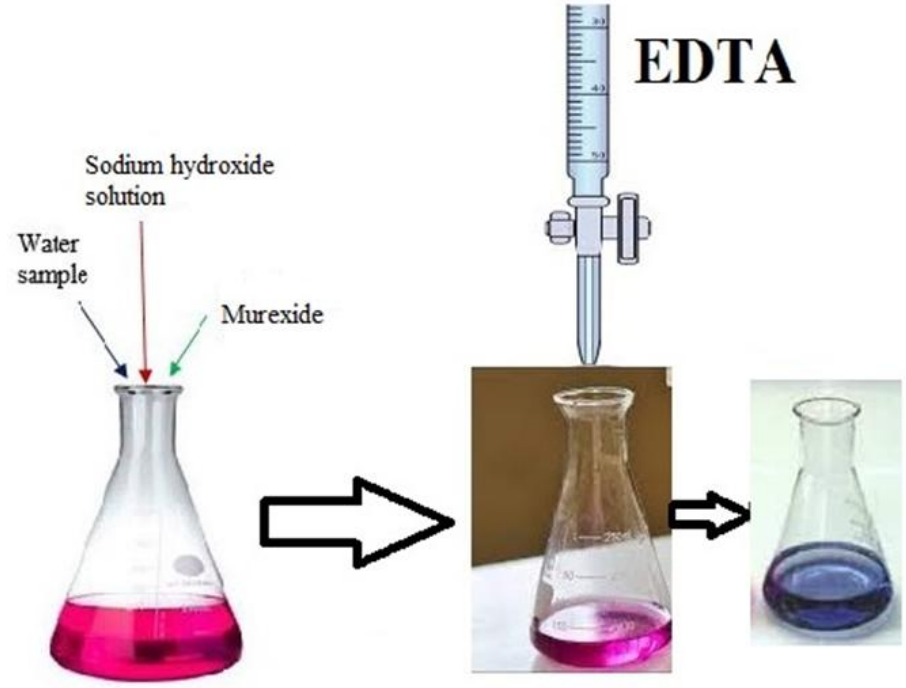


Figure 3.3: Procedure for calcium hardness analysis.

3.2.2.4 Calculation

The Total and calcium hardness is determined using the following equations.

EDTA required by sample, C = (Volume of EDTA required by sample A − Volume of EDTA required by blank B).

EDTA required by sample, C^1 = (Volume of EDTA required by sample A^1 − Volume of EDTA required by blank B^1)

a. Total hardness as $CaCO_3$ mg/L = C x D x 1000 / mL sample

Where, C = volume of EDTA required by sample and D = mg $CaCO_3$ equivalent to 1 ml EDTA titrant.

b. Calcium hardness $CaCO_3$ as mg/L = C^1 x D x 1000 / mL sample

Where, C^1 = volume of EDTA used by sample and D = mg $CaCO_3$ equivalent to 1ml EDTA titrant.

c. Magnesium hardness = Total hardness as $CaCO_3$, mg/L – Calcium hardness as $CaCO_3$, mg/L

3.2.3 Alkalinity

The buffering capacity of a water body; a measure of the ability of the water body to neutralize acids and bases and thus maintain a fairly stable pH level The alkalinity of water is a measure of how much acid it can neutralize. If any changes are made to the water that could raise or lower the pH value, alkalinity acts as a buffer, protecting the water and its life forms from sudden shifts in pH value. This ability to neutralize acid, or H+ ions, is particularly important in regions affected by acid rain.

Total alkalinity is affected by environmental factors; rain, acidic sanitizers, addition of fill water and other product applications can all change the alkalinity over time. Most alkalinity in surface water comes from calcium carbonate, $CaCO_3$, being leached from rocks and soil. This process is enhanced if the rocks and soil have been broken up for any reason, such as mining or urban development. Limestone contains especially high levels of calcium carbonate and when used to decrease acidity in homes can runoff into surface waters and increase alkalinity. Alkalinity is significant in the treatment of wastewater and drinking water because it will influence treatment processes such as anaerobic digestion. Water may also be unsuitable for use in irrigation if the alkalinity level in the water is higher than the natural level of alkalinity in the soil.

3.2.3.1 Reagents used for Analysis

The following reagents are used for the analysis of alkalinity of the given water sample.

1. **Standard Sulfuric Acid, 0.02 N**

   0.1N Sulfuric acid is prepared by diluting 3 ml conc. Sulfuric acid to 1000 ml distilled water. Then it is standardize against standard 0.1N Sodium carbonate solution. Dilute Then Appropriate volume of Sulfuric acid is diluted to 1000 ml to obtain standard 0.02 Sulfuric acid.

2. **Phenolphthalein Indicator**

   0.5 gm in 500 ml 95% ethyl alcohol. Then 500 ml distilled water is added. 0.02 N Sodium hydroxide is added drop wise till faint pink colour appears (pH 8.3).

3. **Methyl Orange Indicator**

   0.5 gm methyl orange is dissolved in 1000 ml with CO_2 free distilled water (pH 4.3-4.5).

3.2.3.2 Procedure

As shown in Figure 2.25, following steps are required for alkalinity determination:

1. 50 ml sample is taken in a conical flask
2. Addition of 2-3 drops of phenolphthalein indicator is carried out.
3. After addition of the above indicator if pink color develops then titrates this with 0.02N Sulphuric acid till disappears or pH is 8.3.
4. Then Addition of 2-3 drops of methyl orange to the same flask is done.
5. After that the above solution is titrated till yellow color changes to orange.
6. If pink color does not come into view after addition of phenolphthalein continue as above.

Phenolphthalein end-point **Methyl orange end-point**

Figure 3.4: Procedure for alkalinity analysis.

The following pH values are suggested as equivalence points for corresponding alkalinity as $CaCO_3$ mg/L (Table 3.1).

Tale 3.1: End point pH values suggested as equivalence points for corresponding alkalinity as $CaCO_3$ mg/L.

Alkalinity range and Nature of sample	End point pH	
	Total Alkalinity	Phenolphthalein Alkalinity
Alkalinity, $CaCO_3$ mg/L: 30	4.9	8.3
150	4.6	8.3
500	4.3	8.3
Silicates, phosphates known or suspended	4.5	8.3
Industrial waste or complex system	4.5	8.3
Routine or automated analyses	4.5	8.3

3.2.3.3 Calculations

Alkalinity is determined by the following equations,

Calculate total (T), phenolphthalein (P) alkalinity as follows:

P-alkalinity, as mg $CaCO_3$/L = A x 1000/mL sample

T-alkalinity, as mg $CaCO_3$/L = B x 1000/mL sample

In case Sulfuric acid is not 0.02 N apply the following formula:

Alkalinity, as mg $CaCO_3$/L = A/B x N x 50000 / mL of sample

Where,

A = mL of H_2SO_4 required to bring the pH to 8.3

B = mL of H_2SO_4 required to bring the pH to 4.5

N = normality of H_2SO_4

Once, the phenolphthalein and total alkalinities are determined, three types of alkalinities, i.e. hydroxide, carbonate and bicarbonate are easily calculated from the Table 3.2 given as under:

Table 3.2: Type of alkalinity

Values of P and T	Type of Alkalinity		
	OH^-	CO_3^{--}	HCO_3^-
P = O	0	0	T
P<1/2T	0	2P	T-2P
P = 1/2T	0	2P	0
P >1/2T	2P-T	2(T-P)	0
P = T	T	0	0

Once carbonate and bicarbonate alkalinities are known, then their conversions to milligrams CO_3^- or HCO_3^-/L are possible.

CO_3^- mg/L = Carbonate alkalinity mg $CaCO_3$/L x 0.6

mg HCO_3 = Bicarbonate alkalinity mg $CaCO_3$/L x 1.22

From above, molar concentration may be obtained as follows:

$[CO_3^{--}]$ = mg/L CO_3 / 60000

$[HCO_3^-]$ = mg/L HCO_3^- / 61000

3.2.4 Chloride (Cl^-)

Chloride is a naturally occurring element that is common in most natural waters and is most often found as a component of salt (sodium chloride) or in some cases in combination with potassium or calcium. The presence of chloride in groundwater can result from a number of sources including the weathering of soils, salt-bearing geological formations, deposition of salt spray, salt used for road de-icing, contributions from wastewaters and in coastal areas, intrusion of salty ocean water into fresh groundwater sources. In PEI, chloride levels in groundwater are relatively usually fairly low, but can become elevated in areas near the coast, or in areas of heavy salting of roads.

3.2.4.1 Reagents used for Analysis

The reagent listed below are used for the determination of Chloride

1. **Potassium Dichromate Indicator**

   50 gm Potassium dichromate is added in distilled water. Then Silver nitrate is added till definite red precipitate is formed. This solution is allow to stand for 12hrs. After that filter it and dilute to 1000 ml.

2. **Silver Nitrate, 0.0141N**

   2.395 gm Silver nitrate and dilute to 1000mL.Standardise against Sodium chloride 0.0141N; 1ml of 0.0141N Silver nitrate = 0.5 mg Cl^-.

3. **Sodium Chloride, 0.0141N**

   824.1 mg Sodium chloride (dried at 40°C) is added and dilute to 1000 ml 1mL = 0.5 mg Cl^-

3.2.4.2 Procedure

As shown in Figure 3.5, Chloride 50 ml well mixed sample adjusted to pH 7.0-8.0. Then 1 ml potassium dichromate is added to the water sample. Then solution is titrated with standard silver nitrate solution it will continue till $AgCrO_4$ starts precipitating as pale red precipitate.

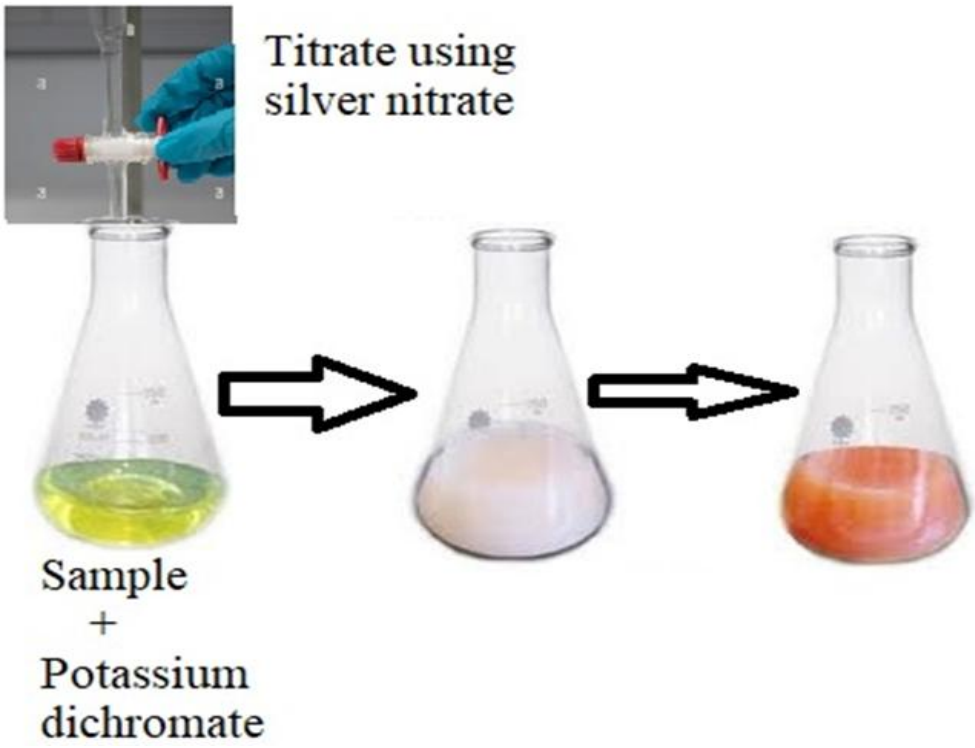


Figure 3.5: Procedure for chloride analysis.

3.2.4.3 Calculation

The following equations are utilized for determination of chloride.

$$\text{Chloride mg/L as } Cl^- = (A - B) \times N \times 35.45 \times 1000 / \text{mL sample}$$

Where,

A = mL Silver nitrate required for sample

B = mL Silver nitrate required for blank

3.2.5 Dissolved Oxygen (DO)

Dissolved oxygen (DO) is the amount of oxygen that is present in water. Water bodies receive oxygen from the atmosphere and from aquatic plants. Running water, such as that of a swift moving stream, dissolves more oxygen than the still water of a pond or lake. All living organisms are dependent upon oxygen in one form or the other to maintain the metabolic processes that produce energy for growth and reproduction. Aerobic processes are of great interest, which need free oxygen for wastewater treatment. Dissolved Oxygen (DO) is also important in precipitation and dissolution of inorganic substances in water. DO levels in natural waters and wastewaters depend on physical, chemical and biological activities in water-body. The solubility of atmospheric oxygen in fresh water ranges from 14.6mg/L at 0°C to about 7.0mg/L at 35°C under normal atmospheric pressure. Since it is poorly soluble gas, its solubility directly varies with the atmospheric pressure at any given temperature. Analysis of DO is a key test in water pollution control and wastewater treatment processes.

$$MnSO_4 + 2KOH \rightarrow \quad Mn(OH)_2 + K_2SO_4 \text{ (White ppt)}$$

$$2Mn(OH)_2 + O_2 \rightarrow \quad 2MnO(OH)_2 \text{ (Brown ppt)}$$

$$MnO(OH)_2 + 2H2(SO_4)_2 + 3\,H_2O$$

$$Mn(SO_4)_2 + 2KI \rightarrow MnSO_4 + K_2SO_4 + I_2$$

$$2Na_2S_2O_3.5H_2O + I_2 \rightarrow Na_2S_4O_6 + 2NaCl + 10H_2O$$

$$2NaN_3 + H_2SO_4 \rightarrow 2HN_3 + Na_2SO_4$$

$$HNO_2 + HN_3 \rightarrow N_2 + N_2O + H_2O$$

3.2.5.1 Reagents used for Analysis

These are the following reagent which is used for determination of dissolved oxygen.

1. **Manganese sulphate**

   480 gm Manganese sulfate tetra hydrate or 400gm manganese (II) sulfate dehydrate is dissolved in distilled to 1000 ml. This solution should not give color with starch when added to an acidified solution of Potassium iodide.

2. **Alkali Iodide-azide Reagent**

   a. **For saturated or less than saturated samples**

      500 gm Sodium hydroxide (or 700 gm Potassium hydroxide) and 150 gm Potassium iodide (or 135 gm Sodium iodide) is dissolved in distilled water and dilute to 1000 ml. Then add 10 gm sodium azide dissolved in 40 ml distilled water. This solution should not give color with starch solution when diluted and acidified.

   b. **For supersaturated samples**

      10 gm sodium azide is dissolved in 500 ml distilled water. Add 480 gm Sodium hydroxide and 750 gm Sodium iodide and stir to dissolve the contents.

3. **Sulphuric acid**

   1 ml of concentrate sulfuric acid is equivalent to about 3mL alkali-iodide-azide reagent.

4. **Starch indicator**

   1 gm of soluble starch powder is taken and making paste or solution of it using distilled water and 0.2gm salicylic acid is added as preservative in it. Pour this solution in 100 ml boiling distilled water. Continue boiling for a few minutes, cool and then use.

5. **Stock Sodium Thiosulphate, 0.1 N**

   24.82 gm Sodium thiosulfate pentahydrate is dissolved in distilled water. It is preserved by adding 0.4 gm solid Sodium hydroxide or 1.5 ml of 6 N Sodium hydroxide and dilute to 1000mL.

6. **Standard Sodium Thiosulphate, 0.025 N**

   250 ml stock sodium thiosulphate solution is diluted to 1000 ml with freshly boiled and cooled distilled water. Add preservative before making up the volume. (This should be standardized with standard dichromate solution for each set of titrations).

2.2.5.2 Procedure

As shown in Figure 3.6 water sample is collected in a BOD bottle. Addition of 1 ml manganese sulfate is carried out followed by 1 mL of alkali-iodide-azide reagent to a sample collected in 250 to 300 ml bottle up to the brim. Then bottle is covered using the stopper immediately. After that mixing is done by inverting the bottle 2-3 times and allow the precipitate to settle. The precipitate is white if the sample is devoid of oxygen, and becomes increasingly brown with rising oxygen content. At this point 1 ml concentrate sulfuric acid is added then replaces the stopper and mix well till precipitate goes into solution. At the end 201 ml of this solution is taken in a conical flask and titrate against standard sodium thiosulfate solution using starch (2 ml) as an indicator.

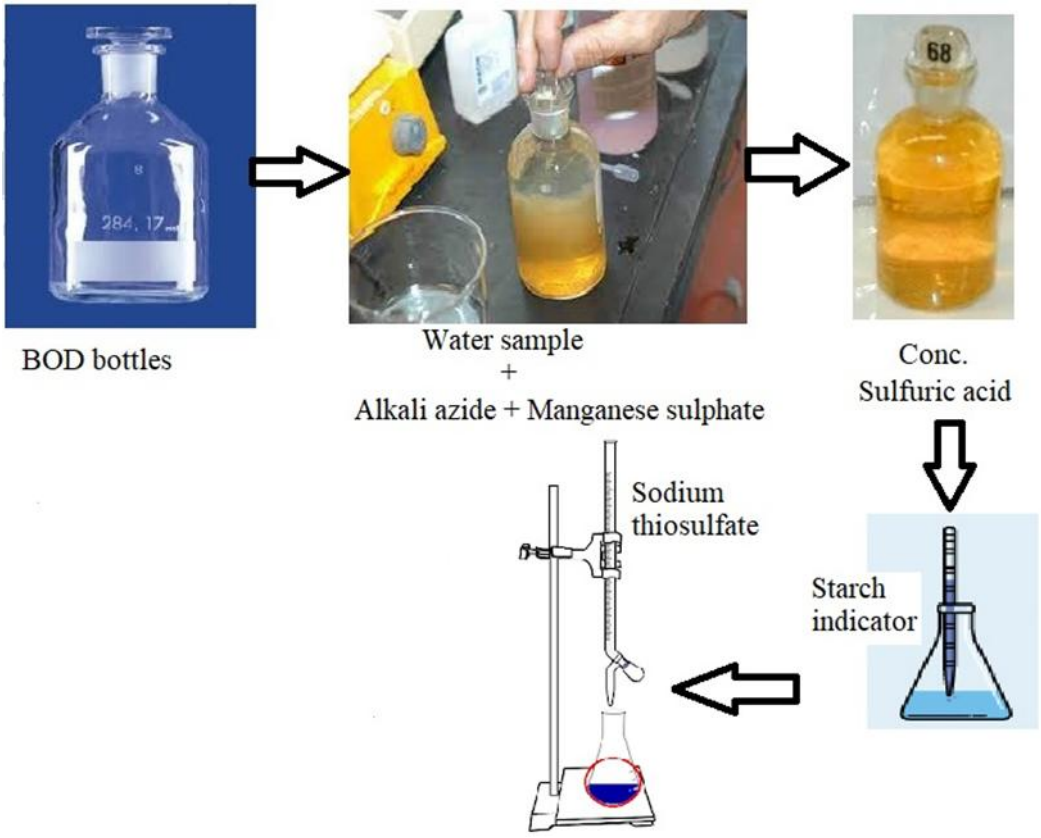


Figure 3.6: Procedure to calculate dissolved oxygen in water sample.

3.2.5.3 Calculation

The following equations are used for determination of dissolved oxygen.

1 ml of 0.025 N Sodium thiosulfate = 0.2 mg of O_2

DO in mg/L = (0.2 x 1000) x (0.025 N) ml of thiosulphate / 200

3.2.6 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic (oxygen is present) conditions at a specified temperature. The common lake or stream contains small amounts of oxygen in the form of dissolved oxygen (DO). Dissolved oxygen is a crucial component of natural water bodies, maintaining the aquatic life and quality aesthetic of streams and lakes. The decay of organic matter in water is measured as biochemical oxygen demand. Environmental stresses and other human-induced factors can lessen the amount of dissolved oxygen in a water body, however. Biological oxygen demand is essentially a measure of the amount of oxygen required to remove waste organic matter from water in the process of decomposition by aerobic bacteria. To comply with BOD limits, commercial production and manufacturing industries are required to implement a wastewater pre-treatment or disposal program. The BOD value is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C and is often used as a surrogate of the degree of organic pollution of water. Guidelines obtained from CPCB are listed in Table 3.3.

Table 3.3: Guideline BOD values for classification of raw untreated water.

Quality class	Designated best use	BOD value	Note
A	Drinking water source without conventional treatment but with chlorination	2 or less	Could cause problems in treatment, larger Cl_2 demand and residual taste/odour problem.
B	Drinking water source with conventional treatment	3 or less	

3.2.6.1 Reagents used for Analysis

The following reagents are used for BOD analysis:

1. **Manganese Sulphate**

   480 gm Manganese sulfate tetra hydrate or 400 gm manganese (II) sulfate dihydrate is dissolved in distilled to 1000 ml. This solution should not give color with starch when added to an acidified solution of Potassium iodide.

2. **Alkali Iodide-azide Reagent**

   a. **For saturated or less than saturated samples**

      500 gm Sodium hydroxide (or 700 gm Potassium hydroxide) and 150 gm Potassium iodide (or 135 gm Sodium iodide) is dissolved in distilled water and dilute to 1000 ml. Then add 10 gm sodium azide dissolved in 40 ml distilled water. This solution should not give color with starch solution when diluted and acidified.

   b. **For supersaturated samples**

      10 gm Sodium azide in dissolved in 500 ml distilled water. Add 480 gm Sodium hydroxide and 750 gm Sodium iodide and stir to dissolve the contents.

3. **Sulphuric acid**

   1 ml of concentrate sulfuric acid is equivalent to about 3 mL alkali-iodide-azide reagent.

4. **Starch Indicator**

   1 gm of soluble starch powder is taken and making paste or solution of it using distilled water and 0.2 gm salicylic acid is added as preservative in it. Pour this solution in 100 ml boiling distilled water. Continue boiling for a few minutes, cool and then use.

5. **Stock Sodium Thiosulphate, 0.1N**

   24.82 gm Sodium thiosulfate pentahydrate is dissolved in distilled water. It is preserved by adding 0.4 gm solid Sodium hydroxide or 1.5 ml of 6 N Sodium hydroxide and dilute to 1000 ml.

6. **Standard Sodium Thiosulphate, 0.025 N**

   250 ml stock Sodium thiosulphate solution is diluted to 1000 ml with freshly boiled and cooled distilled water. Add preservative before making up the volume. (This should be standardized with standard dichromate solution for each set of titrations).

3.2.6.2 Method

There are a few methods approved for determining biological oxygen demand, although one of them is used overwhelmingly by the analytical community. It is known as Standard Methods 5210B. This method analyses the difference in dissolved oxygen from a sample for five days. A known volume of sample has its initial DO content recorded and after a five day incubation period at 20°C, the sample is removed from the BOD incubator and the final DO content is taken. The BOD incubator is shown in Figure 3.7. Water sample is collected in a BOD bottle. Addition of 1ml manganese sulphate is carried out followed by 1 mL of alkali-iodide-azide reagent to a sample collected in 250 to 300 ml bottle up to the brim. Bottle is covered using the stopper immediately. After that mixing is done by inverting the bottle 2-3 times and allow the precipitate to settle. The precipitate is white if the sample is devoid of oxygen, and becomes increasingly brown with rising oxygen content. At this point, 1 ml concentrate sulfuric acid is added then replaces the stopper and mix well till precipitate goes into solution. At the end 201 ml of this solution is taken in a conical flask and titrate against standard sodium thiosulfate solution using starch (2 ml) as an indicator.

Figure 3.7: BOD incubator used in analysis.

The BOD value is then calculated from the depletion and the size of the sample used. The DO readings are usually in parts per million (ppm). Higher BOD indicates more oxygen is required, signifying lower water quality. Low BOD means less oxygen is being removed from water, so the water is usually more pure. Since cold water retains oxygen better than warmer water, DO is usually lower in summer months.

3.2.6.3 Calculations

The following equations are used for BOD determination.
BOD of water sample is calculated using the following equations:

When dilution water is not seeded

$$\text{BOD as } O_2 \text{ mg/L} = \{(D_1 - D_2) \times 100\} / \% \text{ dilution}$$

Where, D_1 = DO of sample immediately after preparation, mg/L
D_2 = DO of sample after incubation period, mg/L

3.2.7 Measurement of Heavy Metals in Water (Atomic Absorption Spectrophotometer and Inductively Coupled Plasma – Mass Spectrometry Methods)

Methods: 1.IS 5182 (Part 23) (Method of Measurement of Air Pollution: PM_{10} cyclonic flow technique),
2. Method IO-2.1 (Sampling of Ambient Air for SPM and PM_{10} using High Volume (HV) Sampler),
3. Method 501 (Air Sampling and Analysis, 3rd Ed. Lewis Pub. Inc.), and
4. Standard Method- American Public Health Association (APHA), 20th Ed. 1998.

3.2.7.1 Methods in Brief

The method is based on acidification with Conc. HNO_3 (final pH of the water sample should be ≤ 2) and filtration.

3.1.7.2 Calibration of AAS and ICP-MS

A standard of mixture of different heavy metals was serially diluted to different concentrations in µg/ml. The calibration graph was prepared by plotting absorbance vs. concentrations. The method is based on acidification with Conc. HNO_3 (final pH of the water sample should be ≤ 2) and filtration. A standard of

mixture of different heavy metals was serially diluted to different concentrations in µg/ml. The calibration graph was prepared by plotting absorbance vs. concentrations. Then metal concentrations were calculated by plotting the absorbance values found from AAS in the calibration graph. ICP-MS with used standard solution is shown in Figure 3.8.

Figure 3.8: ICP-MS with used standard solution [FINAR-92] for instrument internal calibration.

3.2.8 Water Environmental Carrying Capacity Assessment beyond 10 years

The connotation of water carrying capacity

- That a habitat can support without permanently impairing the habitat's productivity
- Carrying capacity is an indicator of regional sustainability
- Interprets that the ability of a region to support the threshold of human activities during a definite state or condition for a defined period of time
- The water environmental carrying capacity evaluation model is established according to simulations of socio-economic activity
- Model forecasts the value of assessment indicators to represent their impact degree n ecology, carrying capacity is defined as the maximum population of a species

3.2.8.1 Methodology

The model used for water carrying capacity is STELLA software to explore the consequent interactions; social, ecological, and economic domains and then simulated the development. Environmental water carrying capacity includes four subsystems:

Water resources subsystem

Industry system with industrial water use pattern and recycling

Population system and its growth rate

Water pollution system, which is contaminated by various pollutants

In this study, chemical oxygen demand (COD) and ammonia nitrogen NH_3-N were selected as target pollutant indicators, which are strongly interrelated with discharge volume and pollutant density. The interaction model is developed for the water carrying capacity is presented in following Figure 3.9.

3.2.8.2 Index for Environmental Water Carrying Capacity

It is seemingly impossible to assess all activities to determine environmental water carrying capacity. Therefore it is necessary to build an index to select the typical and quantifiable indicators that represent the practical status. The indicators are presented in following Table 3.4.

Table 3.4: Different Indicators and units used in environmental water carrying capacity

Indicator	**Units**
COD emission quantity of unit value of total industrial output (**C1**)	kg/Lac Rupees
NH_3-N emission quantity of unit value of total industrial output (**C2**)	kg/Lac Rupees
Coefficient of industrial water sewage reuse (**C3**)	%
Ration for water supply and water demand (**C4**)	%
Water consumption of unit value of total industrial output (**C5**)	kg/Lac Rupees
Index of water carrying pollutants COD (**C6**)	%
Index of water carrying pollutants NH_3-N (**C7**)	%

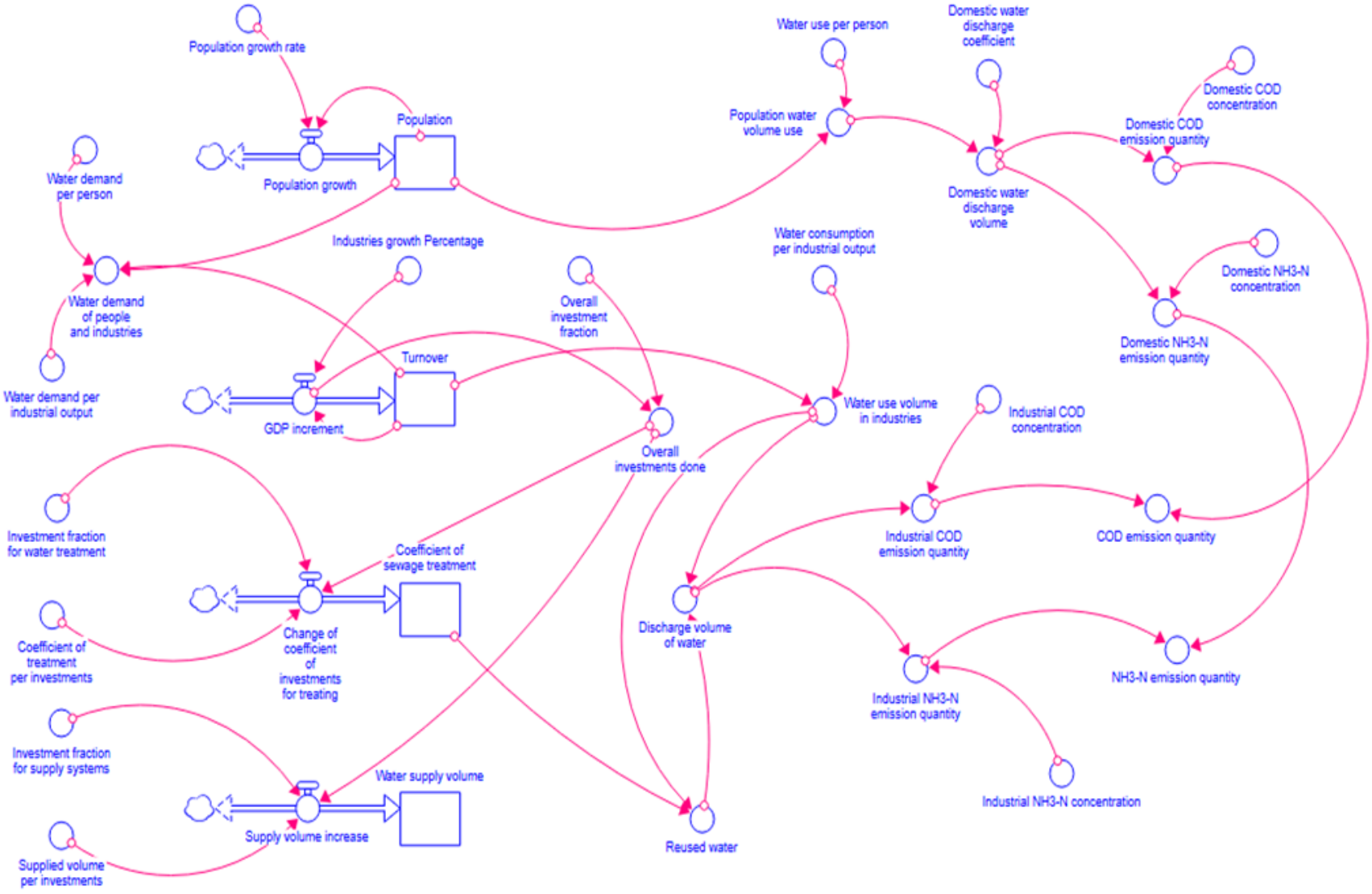


Figure 3.9: Development of water carrying capacity model by STELLA software.

3.2.8.3 Valuating Method

- Based on the aforementioned index, assessing environmental water carrying capacity involves three steps:
    - Calculating the value of each indicator
    - Determining the weight of each indicator
    - Determining the comprehensive value of environmental water carrying capacity
- To eliminate the discrepancy among the indicators in each indicator unit, the order of magnitude, and data quality, it was necessary to perform standardization
- Raw data matrix is $X=\{x_{ij}\}_{m\times n}$, and the standardized matrix is $Y=\{y_{ij}\}_{m\times n}$

Positive Indicator

$$y_{ij}=\begin{cases}1 & x_{ij}=x_{\max}\\ \dfrac{x_{ij}-x_{\min}}{x_{\max}-x_{\min}} & x_{\min}<x_{ij}<x_{\max}\\ 0 & x_{ij}=x_{\min}\end{cases}$$

Negative Indicator

$$y_{ij}=\begin{cases}1 & x_{ij}=x_{\min}\\ \dfrac{x_{\max}-x_{ij}}{x_{\max}-x_{\min}} & x_{\min}<x_{ij}<x_{\max}\\ 0 & x_{ij}=x_{\max}\end{cases}$$

Valuating method – Entropy Method

First, to avoid the insignificance of entropy values, a nonnegative process was applied to each indicator. The handling function is as follows:

$$X'_{ij} = \frac{X_{ij} - \min(X_{ij})}{\max(X_{ii}) - \min(X_{ii})}$$

$$P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{n} X'_{ij}} (i = 1, 2, \ldots, n; j = 1, 2, \ldots m)$$

Subsequently, we calculated the weight of indicator j in year i occupies the total weight of all of the indicators in year i:

The entropy value of indicator j

$$e_j = -1 / \ln(n) \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) (e_j > 0) .$$

Finally, we calculated the weight of each indicator:

$$w_j = \frac{1 - e_j}{m - \sum_{j=1}^{m} e_j} (1 \le j \le m)$$

The comprehensive value of environmental water carrying capacity was determined by the following function:

$$Si = \sum_{j=1}^{m} w_j y_{ij}$$

3.3. Results and Discussion.

Different locations for water sample collection are identified and presented in Table 3.5.

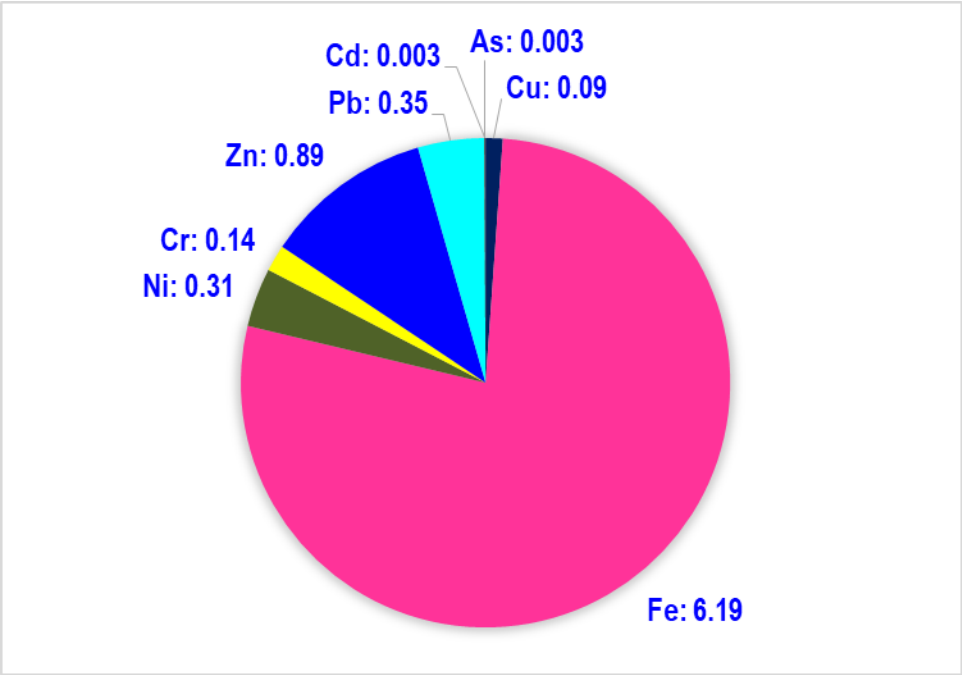
Table 3.5: Water sample collection location in Siltara

Location ID	Location name	Latitude (°N)	Longitude (°E)
SIW006	Dharsiva Hand Pump	21.412	81.672
SIW007	Maraya Talab	21.411	81.673
SIW008	Daburi Talab	21.410	81.672
SIW009	Maie Talab	21.409	81.674
SIW010	Dhrsi Maawell	21.409	81.673
SIW011	Gopal Daburi Talab	21.401	81.672
SIW012	Bada Talab	21.351	81.658
SIW013	Maghi Talab	21.357	81.652
SIW014	Sundra Hand Pump	21.360	81.646
SIW015	Neia Talab	21.360	81.646
SIW016	Badri Taria Talab	21.398	81.673
SIW017	Sonu Monu Talab	21.374	81.661
SIW018	Daburi Talab	21.336	81.666
SIW019	Dharsiva Hand Pump	21.412	81.669
SIW020	Prithi Talab	21.419	81.668
SIW021	Vaswan Talab	21.428	81.660
SIW022	Dari Talab	21.426	81.666
SIW023	Kari Talab (Charoda) 1	21.393	81.668
SIW024	Kari Talab (Charoda) 2	21.393	81.668
SIW025	Chandi Mandir Chowk (Charoda) (H.P)	21.394	81.672
SIW026	Ram Sagar Talab (Charoda)	21.394	81.675
SIW027	Kolia Daburi Talab (Mohali)	21.386	81.701
SIW028	Bibhudaburi Talab (Mohali)	21.387	81.700
SIW029	Mandhra village	21.348648	81.704516
SIW030	Arobondha talab	21.351502	81.710628
SIW031	Khusbu banjari	21.362635	81.726829
SIW032	Bondhua tarri	21.386948	81.712172
SIW033	Mahua talab	21.386954	81.706850
SIW034	Viyas talab 1	21.304323	81.635948
SIW035	Viyas talab 2	21.304323	81.635948
SIW036	Dhab talab	21.309505	81.632697
SIW037	Boritariya talab	21.342290	81.655011
SIW038	Dhaneli (H.P.)	21.337412	81.653172

SIW039	Totra talab	21.333258	81.658358
SIW040	Puria bhanda talab	21.330335	81.678874
SIW041	Dongia talab	21.334800	81.679201
SIW042	Mandir talab	21.339134	81.677955
SIW043	Pachri talab	21.338549	81.681220
SIW044	Patharidihi chowk 1	21.340040	81.595735
SIW045	Patharidihi chowk (H.P.) 2	21.341258	81.595368
SIW046	Patharidihi chowk kharun river	21.349419	81.587232
SIW047	Naya talab	21.364105	81.565735
SIW048	Paytho talab	21.364149	81.565848
SIW049	Borsi (H.P.) 1	21.362784	81.551587
SIW050	Borsi sitara talab	21.323658	81.604363
SIW051	Purna talab	21.366898	81.570224
SIW052	Borsi (H.P.)	21.366996	81.568024
SIW053	Dubri talab (hardi)	21.384098	81.585380
SIW054	Hardi bora talab	21.403118	81.581749
SIW055	Hardi (H.P.)	21.389880	81.586455
SIW056	Dhari talab	21.289631	81.641175
SIW057	Chatwa talab	21.287043	81.641593
SIW058	Bandwa talab	21.289709	81.642722
SIW059	Mandhar	21.348476	81.698405
SIW060	Mandhari (well)	21.347163	81.697828
SIW061	Mandhar naya talab	21.339618	81.702276
SIW062	Sitala mata talab	21.347954	81.704127
SIW063	Mandhar (well)	21.356153	81.692696
SIW064	Gardhiw talab (barbandha)	21.348245	81.719722
SIW065	Gardhiw (well) barbandha	21.354523	81.724162
SIW066	Chhapar talab	21.353139	81.744004
SIW067	Pankhatia talab	21.353139	81.744004
SIW068	Dewal talab	21.355907	81.730713
SIW069	Tor talab	21.363240	81.731351
SIW070	Nagar gaon	21.369208	81.732377
SIW071	Siltarai talab	21.390401	81.668834
SIW072	Charoda gaon	21.390452	81.669621
SIW073	Khabti talab	21.390710	81.666434
SIW074	Dhatahi charoda	21.391139	81.652651
SIW075	Gopal talab	21.401266	81.671233
SIW076	Sai sadhan (H.P.)	21.404360	81.670590
SIW077	Sai talab	21.396348	81.675585

SIW078	Mandir talab	21.404839	81.669731
SIW079	Chuhiya talab	21.405358	81.669129
SIW080	Dharsiba (H.P.)	21.411138	81.675585
SIW081	Dabri talab	21.411401	81.666001
SIW082	Dharsiwa gaon	21.411133	81.668053
SIW083	Shivnath talab	21.424917	81.670109
SIW084	Parastara (H.P)	21.413124	81.661317
SIW085	Hanuman mandir	21.413189	81.661289
SIW086	Bholenath talab	21.413158	81.661287
SIW087	Parostari (H.P.)	21.391139	81.652651
SIW088	Parostari (H.P.)	21.412021	81.663605
SIW089	Siltara road	21.377903	81.667879
SIW090	Siltara chowk (H.P.)	21.371336	81.668110
SIW091	Naba talab	21.369309	81.671489
SIW092	Hatim talab	21.371115	81.674254
SIW093	Siltara gaon (H.P.)	23.370167	81.676459
SIW094	Siltara village	21.370994	81.676420
SIW095	Dubri talab	21.370678	81.680252
SIW096	Hirapur (H.P.)	21.371607	81.687173
SIW097	Dubri talab	21.376798	81.685713
SIW098	Tanda village	21.380078	81.685960
SIW099	Gpil road (H.P.)	21.380911	81.685881
SIW100	Khadan talab	21.420164	81.677777
SIW101	NN Road bypass (H.P)	21.420260	81.677798
SIW102	Khanha vera talab	21.419950	81.679435

3.3.1 Heavy Metals Concentrations in Water



.**Figure 3.10:** Average metals concentration (in ppm) in water samples collected from Siltara.

Percentage of heavy metals present in different water samples are presented in Figure 3.10. Water samples from Siltara are acidified with concentrated nitric acid (Conc. HNO_3) and filtered. Each collected sample is then analyzed by AAS and ICP-MS, respectively. Most of the water samples have high concentration of Iron (Fe). Zn, Ni, Cr and Pb but are under lethal concentration (in ppm).

3.3.2 Physical and Chemical Analysis of Water Samples

Water sample collected from different location in Siltara. Five parameter i.e. temp., PH, Salt, TDS, Conductivity is measured by conductivity or PH meter.where salt and TDS value are very high in almost all the sample. Conductivity of these sample ranges from 300 to 1000 (µs/cm). Then exeperiment was done to calculate the COD, BOD, DO ,Alkalinity, chloride, hardness of the water. from the Figure 4.39 we found that hardness in all the sample is within the limit except these four sample i.e. SIW14 ,10 ,6,8., whose values are more than 180 mg/l.COD level is within the limit of 200 mg/l. DO level was found within 10 mg/l. alkalinity range of sample were found to be within 200 mg/l except some sample which shows high alkalinity of 350 mg/l. However high alkalinity is good for health but within the limit. BOD level were found

above the limit. Chloride values of sample are within 170 mg/l .high chloride value in water means high pollution,and also high chloride in human body can kidney stone.

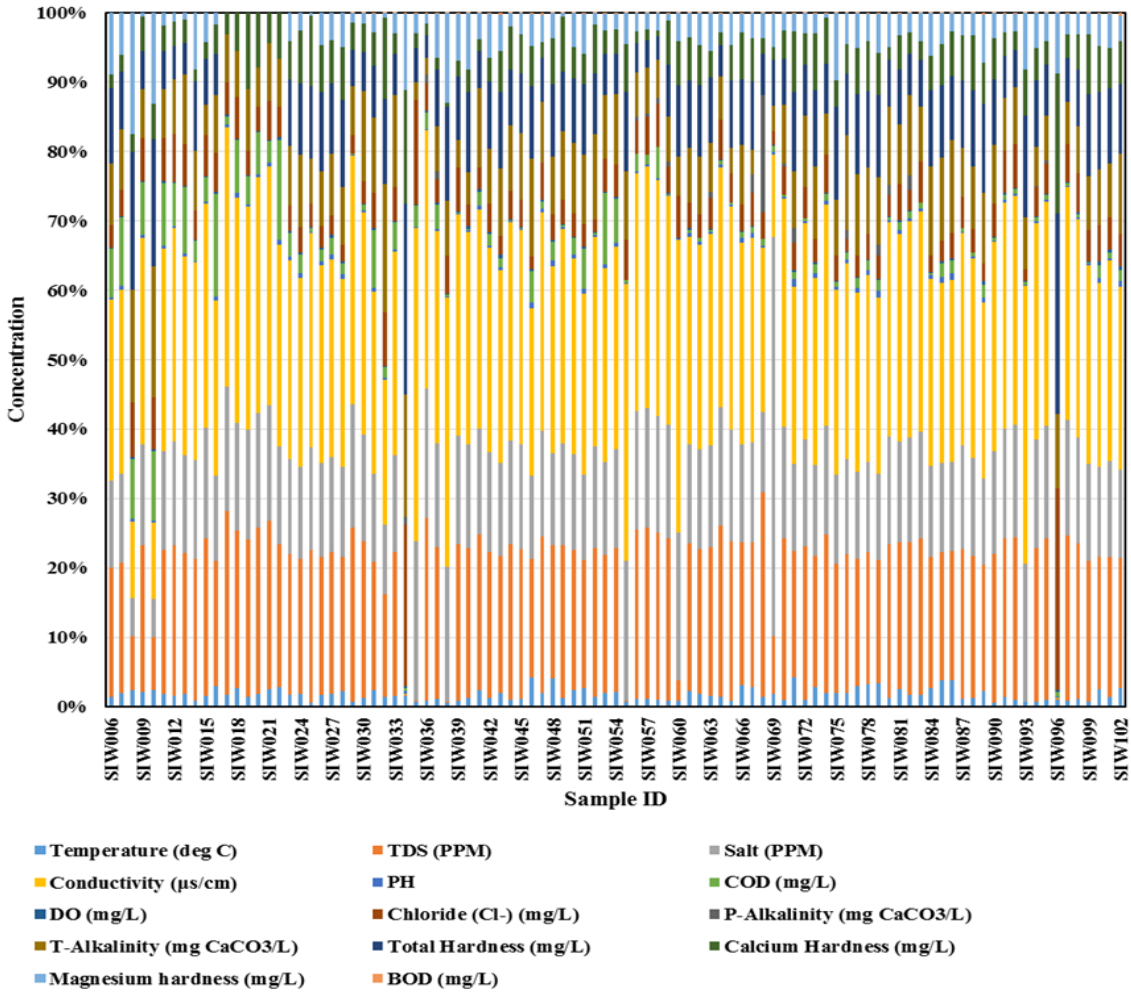


Figure 3.11: Different parameter percentile plot of different water samples collected from Siltara (Marked as SIW).

3.3.3 Statistical Analysis of the Water Samples

The statistical analysis for the data collected of all the Temperature, TDS, salt, Conductivity, pH, COD, DO, Cl^-, P alkalinity, T alkalinity, Total hardness, calcium hardness, magnesium hardness and BOD is shown in Table 3.6.

Table 3.6: Statistical analysis of water parameters in Siltara during study period

	Temperature (° C)	TDS (PPM)	Salt (PPM)	Conductivity (µs/cm)	pH	COD (mg/L)	DO (mg/L)
Max	33.4	995	948	1827	9.09	180	8.8
Min	19.8	1.09	1.21	2.38	5.63	2	1
Average	29.53	394.10	321.50	636.65	7.26	42.13	3.52
STDV	3.15	245.64	212.63	406.09	0.75	48.97	2.02
Mean	29.53	394.10	321.50	636.65	7.26	42.13	3.52
CV	0.10	0.62	0.66	0.63	0.10	1.16	0.57
	Chloride (Cl^-) (mg/L)	**P Alkalinity (mg $CaCO_3$/L)**	**T Alkalinity (mg $CaCO_3$/L)**	**Total Hardness (mg/L)**	**Calcium Hardness (mg/L)**	**Magnesium hardness (mg/L)**	**BOD**
Max	814	364	392	808	562	612	5.6
Min	12	10	40	64	20	10	0.1
Average	107.44	7.54	171.62	194.63	103.17	91.14	1.47
STDV	109.23	37.72	84.05	136.83	86.35	88.07	1.29
Mean	107.44	7.54	171.62	194.63	103.17	91.14	1.47
CV	1.016	5.00	0.48	0.70	0.83	0.96	0.878

3.3.4 Water Environmental Carrying Capacity Assessment Beyond 10 years

3.3.4.1 Simulation Result of Indicated Value

The simulation results obtained are shown in Table 3.7 (I-VI). These values are utilized to attain different indicators and units used in environmental water carrying capacity.

Table 3.7 (I): Result of simulations for the indicated values of coefficent of sewage treatment

Year	Coefficient of sewage treatment	Population (Person)	Turnover (Lac Rupees)	Water supply volume (m^3)	Change of coefficient of investments for treating ($\times 10^{-3}$)	GDP increment (Lac Rupees)
2021	0.800	13900	21000	2600000	1.99	399
2022	0.802	14280	21399	2618731	2.03	406
2023	0.804	14671	21805	2637818	2.07	414
2024	0.806	15073	22218	2657267	2.11	422
2025	0.808	15485	22640	2677084	2.15	430
2026	0.810	15909	23070	2697278	2.19	438
2027	0.813	16344	23508	2717856	2.23	446
2028	0.815	16792	23954	2738823	2.27	455
2029	0.817	17251	24408	2760189	2.32	463
2030	0.819	17723	24871	2781960	2.36	472
2031	0.822	18209	25344	2804145	2.40	481
2032	0.824	18707	25824	2826750	2.45	490
2033	0.827	19219	26315	2849784	2.50	499
2034	0.829	19745	26814	2873256	2.54	509
2035	0.832	20285	27323	2897173	2.59	519
2036	0.834	20840	27841	2921544	2.64	528
2037	0.837	21411	28370	2946377	2.69	538
2038	0.840	21997	28908	2971682	2.74	549
2039	0.842	22599	29457	2997466	2.80	559
2040	0.845	23217	30016	3023741	2.85	570

2041	0.848	23852	30585	3050513	2.90	580
2042	0.851	24505	31166	3077794	2.96	591
2043	0.854	25176	31757	3105593	3.01	603
2044	0.857	25865	32360	3133919	3.07	614
2045	0.860	26573	32974	3162783	3.13	626
2046	0.863	27300	33600	3192194	3.19	638
2047	0.866	28047	34238	3222164	3.25	650
2048	0.869	28815	34887	3252702	3.31	662
2049	0.873	29603	35549	3283820	3.37	675
2050	0.876	30414	36224	3315529	3.44	687
2051	0.880	31246	36911	3347839	3.50	699

Note: Gross Domestic Product (GDP)

Table 3.7 (II): Result of simulations for the indicated values of COD emission quantity

Population growth (Person)	**Supply volume increase (m^3)**	**COD emission quantity (kg)**	**Coefficient of treatment per investments (1/Lac Rupees)**	**Water demand per industrial output (m^3/Lac rupees)**	**Water demand per person (m^3/person)**	**Discharge volume of water (m^3)**
380	18731	24574	0.0005	65	0.06	273000
391	19087	24791	0.0005	65	0.06	275409
402	19449	25002	0.0005	65	0.06	277758
413	19818	25208	0.0005	65	0.06	280041
424	20194	25407	0.0005	65	0.06	282253
435	20577	25599	0.0005	65	0.06	284388

447	20968	25784	0.0005	65	0.06	286441
460	21366	25961	0.0005	65	0.06	288404
472	21771	26129	0.0005	65	0.06	290271
485	22184	26288	0.0005	65	0.06	292035
498	22605	26437	0.0005	65	0.06	293690
512	23034	26575	0.0005	65	0.06	295227
526	23471	26702	0.0005	65	0.06	296638
540	23917	26818	0.0005	65	0.06	297915
555	24371	26920	0.0005	65	0.06	299051
570	24833	27008	0.0005	65	0.06	300034
586	25305	27083	0.0005	65	0.06	300856
602	25785	27141	0.0005	65	0.06	301508
618	26274	27184	0.0005	65	0.06	301978
635	26773	27209	0.0005	65	0.06	302255
653	27281	27216	0.0005	65	0.06	302329
671	27799	27203	0.0005	65	0.06	302187
689	28326	27170	0.0005	65	0.06	301817
708	28864	27115	0.0005	65	0.06	301207
727	29412	27038	0.0005	65	0.06	300342
747	29970	26936	0.0005	65	0.06	299208
768	30538	26809	0.0005	65	0.06	297791
789	31118	26654	0.0005	65	0.06	296076
810	31709	26472	0.0005	65	0.06	294045
832	32310	26259	0.0005	65	0.06	291683

Note: Chemical Oxygen Demand (COD)

Table 3.7 (III): Result of simulations for the indicated values for domestic COD emission quantity

Domestic COD concentration (kg/m^3)	Domestic COD emission quantity (kg)	Domestic water discharge coefficient	Domestic water discharge volume (m^3)	Domestic NH_3-N concentration (Kg/m^3)	Domestic NH_3-N emission quantity (kg)
0.005	3.614	0.8	723	0.003	2.168
0.005	3.713	0.8	743	0.003	2.228
0.005	3.815	0.8	763	0.003	2.289
0.005	3.919	0.8	784	0.003	2.351
0.005	4.026	0.8	805	0.003	2.416
0.005	4.136	0.8	827	0.003	2.482
0.005	4.250	0.8	850	0.003	2.550
0.005	4.366	0.8	873	0.003	2.620
0.005	4.485	0.8	897	0.003	2.691
0.005	4.608	0.8	922	0.003	2.765
0.005	4.734	0.8	947	0.003	2.841
0.005	4.864	0.8	973	0.003	2.918
0.005	4.997	0.8	999	0.003	2.998
0.005	5.134	0.8	1027	0.003	3.080
0.005	5.274	0.8	1055	0.003	3.164
0.005	5.418	0.8	1084	0.003	3.251
0.005	5.567	0.8	1113	0.003	3.340
0.005	5.719	0.8	1144	0.003	3.431
0.005	5.876	0.8	1175	0.003	3.525
0.005	6.036	0.8	1207	0.003	3.622

0.005	6.202	0.8	1240	0.003	3.721
0.005	6.371	0.8	1274	0.003	3.823
0.005	6.546	0.8	1309	0.003	3.927
0.005	6.725	0.8	1345	0.003	4.035
0.005	6.909	0.8	1382	0.003	4.145
0.005	7.098	0.8	1420	0.003	4.259
0.005	7.292	0.8	1458	0.003	4.375
0.005	7.492	0.8	1498	0.003	4.495
0.005	7.697	0.8	1539	0.003	4.618
0.005	7.908	0.8	1582	0.003	4.745
0.005	8.124	0.8	1625	0.003	4.874

Note: Ammoniacal nitrogen (NH_3-N)

Table 3.7 (IV): Result of simulations for the indicated values for industrial COD emission quantity

Industries growth Percentage	**Population growth rate**	**Industrial COD concentration (kg/m^3)**	**Industrial COD emission quantity (kg)**	**Industrial NH_3-N concentration (Kg/m^3)**	**Industrial NH_3-N emission quantity (kg)**
0.0188	0.027	0.09	24570	0.075	20475
0.0188	0.027	0.09	24787	0.075	20656
0.0188	0.027	0.09	24998	0.075	20832
0.0188	0.027	0.09	25204	0.075	21003
0.0188	0.027	0.09	25403	0.075	21169
0.0188	0.027	0.09	25595	0.075	21329
0.0188	0.027	0.09	25780	0.075	21483

0.0188	0.027	0.09	25956	0.075	21630
0.0188	0.027	0.09	26124	0.075	21770
0.0188	0.027	0.09	26283	0.075	21903
0.0188	0.027	0.09	26432	0.075	22027
0.0188	0.027	0.09	26570	0.075	22142
0.0188	0.027	0.09	26697	0.075	22248
0.0188	0.027	0.09	26812	0.075	22344
0.0188	0.027	0.09	26915	0.075	22429
0.0188	0.027	0.09	27003	0.075	22503
0.0188	0.027	0.09	27077	0.075	22564
0.0188	0.027	0.09	27136	0.075	22613
0.0188	0.027	0.09	27178	0.075	22648
0.0188	0.027	0.09	27203	0.075	22669
0.0188	0.027	0.09	27210	0.075	22675
0.0188	0.027	0.09	27197	0.075	22664
0.0188	0.027	0.09	27164	0.075	22636
0.0188	0.027	0.09	27109	0.075	22591
0.0188	0.027	0.09	27031	0.075	22526
0.0188	0.027	0.09	26929	0.075	22441
0.0188	0.027	0.09	26801	0.075	22334
0.0188	0.027	0.09	26647	0.075	22206
0.0188	0.027	0.09	26464	0.075	22053
0.0188	0.027	0.09	26251	0.075	21876
0.0188	0.027	0.09	26007	0.075	21673

Table 3.7 (V): Result of simulations for the indicated values for investment fraction for treatment

Overall investment fraction	Investment fraction for supply systems	Investment fraction for treatment	Overall investments done (Lakh Rupees)	NH3-N emission quantity (kg)	Population water volume use (m^3)
0.02	0.5	0.5	7.896	20477	904
0.02	0.5	0.5	8.046	20658	928
0.02	0.5	0.5	8.199	20834	954
0.02	0.5	0.5	8.354	21005	980
0.02	0.5	0.5	8.513	21171	1007
0.02	0.5	0.5	8.674	21332	1034
0.02	0.5	0.5	8.839	21486	1062
0.02	0.5	0.5	9.007	21633	1091
0.02	0.5	0.5	9.178	21773	1121
0.02	0.5	0.5	9.352	21905	1152
0.02	0.5	0.5	9.529	22030	1184
0.02	0.5	0.5	9.710	22145	1216
0.02	0.5	0.5	9.894	22251	1249
0.02	0.5	0.5	10.082	22347	1283
0.02	0.5	0.5	10.273	22432	1319
0.02	0.5	0.5	10.468	22506	1355
0.02	0.5	0.5	10.667	22568	1392
0.02	0.5	0.5	10.869	22617	1430
0.02	0.5	0.5	11.076	22652	1469
0.02	0.5	0.5	11.286	22673	1509

0.02	0.5	0.5	11.500	22678	1550
0.02	0.5	0.5	11.718	22668	1593
0.02	0.5	0.5	11.941	22640	1636
0.02	0.5	0.5	12.167	22595	1681
0.02	0.5	0.5	12.398	22530	1727
0.02	0.5	0.5	12.634	22445	1775
0.02	0.5	0.5	12.873	22339	1823
0.02	0.5	0.5	13.118	22210	1873
0.02	0.5	0.5	13.367	22058	1924
0.02	0.5	0.5	13.620	21881	1977
0.02	0.5	0.5	13.879	21678	2031

Table 3.7 (VI): Result of simulations for the indicated values for water consumption per industrial output

Reused water (m^3)	Supplied volume per investments (m^3/Lakh Rupees)	Water consumption per industrial output (m^3/Lakh Rupees)	Water demand of people and industries (m^3)	Water use per person (m^3/Person)	Water use volume in industries (m^3)
1092000	4700	65	1365834	0.065	1365000
1115495	4700	65	1391762	0.065	1390905
1139543	4700	65	1418181	0.065	1417301
1164157	4700	65	1445103	0.065	1444198
1189353	4700	65	1472535	0.065	1471606
1215146	4700	65	1500489	0.065	1499534
1241551	4700	65	1528973	0.065	1527992
1268586	4700	65	1557997	0.065	1556990

1296267	4700	65	1587573	0.065	1586538
1324612	4700	65	1617711	0.065	1616647
1353638	4700	65	1648420	0.065	1647328
1383364	4700	65	1679713	0.065	1678590
1413809	4700	65	1711600	0.065	1710446
1444992	4700	65	1744092	0.065	1742907
1476933	4700	65	1777201	0.065	1775984
1509654	4700	65	1810938	0.065	1809688
1543176	4700	65	1845317	0.065	1844032
1577520	4700	65	1880347	0.065	1879028
1612710	4700	65	1916043	0.065	1914688
1648769	4700	65	1952417	0.065	1951024
1685721	4700	65	1989481	0.065	1988050
1723592	4700	65	2027250	0.065	2025779
1762407	4700	65	2065735	0.065	2064224
1802192	4700	65	2104951	0.065	2103399
1842975	4700	65	2144911	0.065	2143317
1884784	4700	65	2185630	0.065	2183992
1927648	4700	65	2227122	0.065	2225440
1971598	4700	65	2269402	0.065	2267674
2016664	4700	65	2312485	0.065	2310709
2062878	4700	65	2356386	0.065	2354561
2110274	4700	65	2401121	0.065	2399246

3.3.4.2. Predicted Value of Environmental Index for Water Carrying Capacity

Different indicators and units used in environmental water carrying capacity are shown in Table 3.8. The predicted value of the environmental indicators as shown in Table 3.9 and the corresponding trend with time for the next 30 years are depicted in Figure 3.12 to 3.18. This analysis applied a dynamic system combined with index assessment to evaluate the environmental water carrying capacity. We considered two parts, people and industry. Our results indicate that the environmental water carrying capacity displays a decreasing trend, but it is maintained at an acceptable level.

Table 3.8: Different indicators and units used in environmental water carrying capacity**.**

Indicator	**Unit**
COD emission quantity of unit value of total industrial output (**C1**)	kg/Lakh Rupees
NH3-N emission quantity of unit value of total industrial output (**C2**)	kg/Lakh Rupees
Coefficient of industrial water sewage reuse (**C3**)	%
Ration for water supply and water demand (**C4**)	%
Water consumption of unit value of total industrial output (**C5**)	kg/Lakh Rupees
Index of water carrying pollutants COD (**C6**)	%
Index of water carrying pollutants NH_3-N (**C7**)	%

Table 3.9: Yearly predicted values of environmental indicators for water carrying capacity.

Year	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
2021	1.170	0.975	0.800	1.904	13.000	0.599	0.623
2022	1.159	0.965	0.802	1.882	12.870	0.598	0.623
2023	1.147	0.955	0.804	1.860	12.738	0.598	0.623
2024	1.135	0.945	0.806	1.839	12.604	0.598	0.623

2025	1.122	0.935	0.808	1.818	12.467	0.598	0.623
2026	1.110	0.925	0.810	1.798	12.327	0.598	0.623
2027	1.097	0.914	0.813	1.778	12.185	0.598	0.623
2028	1.084	0.903	0.815	1.758	12.040	0.598	0.623
2029	1.070	0.892	0.817	1.739	11.892	0.598	0.623
2030	1.057	0.881	0.819	1.720	11.742	0.598	0.623
2031	1.043	0.869	0.822	1.701	11.588	0.598	0.623
2032	1.029	0.858	0.824	1.683	11.432	0.598	0.623
2033	1.015	0.846	0.827	1.665	11.273	0.598	0.623
2034	1.000	0.833	0.829	1.647	11.110	0.598	0.623
2035	0.985	0.821	0.832	1.630	10.945	0.598	0.623
2036	0.970	0.808	0.834	1.613	10.777	0.598	0.623
2037	0.955	0.795	0.837	1.597	10.605	0.598	0.623
2038	0.939	0.782	0.840	1.580	10.430	0.598	0.623
2039	0.923	0.769	0.842	1.564	10.252	0.598	0.623
2040	0.906	0.755	0.845	1.549	10.070	0.598	0.623
2041	0.890	0.741	0.848	1.533	9.885	0.598	0.623
2042	0.873	0.727	0.851	1.518	9.696	0.598	0.622
2043	0.856	0.713	0.854	1.503	9.504	0.598	0.622
2044	0.838	0.698	0.857	1.489	9.308	0.597	0.622
2045	0.820	0.683	0.860	1.475	9.108	0.597	0.622
2046	0.802	0.668	0.863	1.461	8.905	0.597	0.622
2047	0.783	0.652	0.866	1.447	8.698	0.597	0.622
2048	0.764	0.637	0.869	1.433	8.487	0.597	0.622

2049	0.745	0.620	0.873	1.420	8.271	0.597	0.622
2050	0.725	0.604	0.876	1.407	8.052	0.597	0.622
2051	0.705	0.587	0.880	1.394	7.829	0.597	0.622

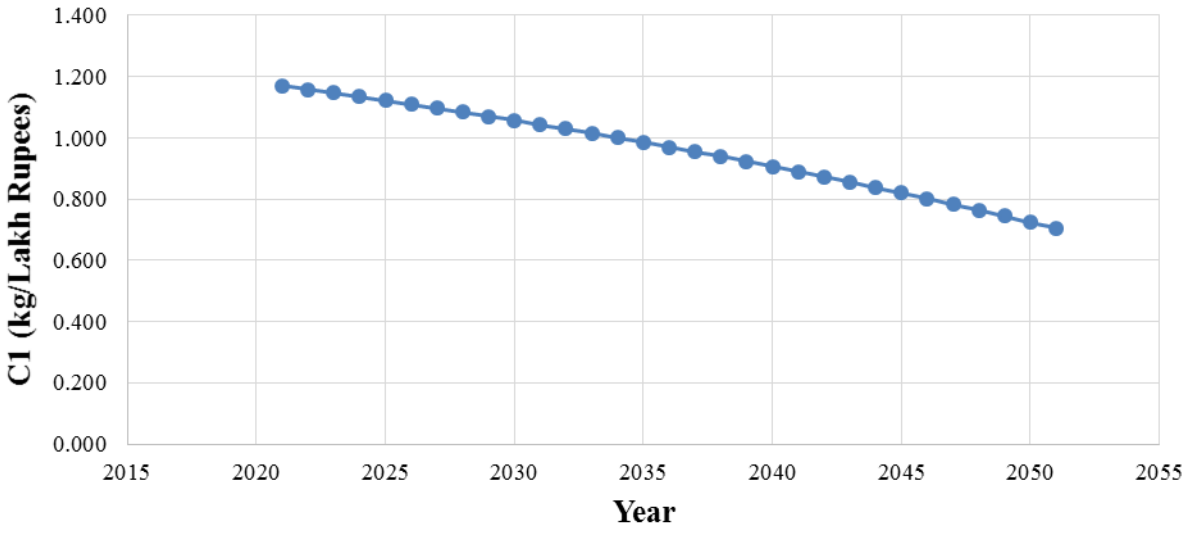


Figure 3.12: Predicted annual variation of indicator C1 for the next 10 years.

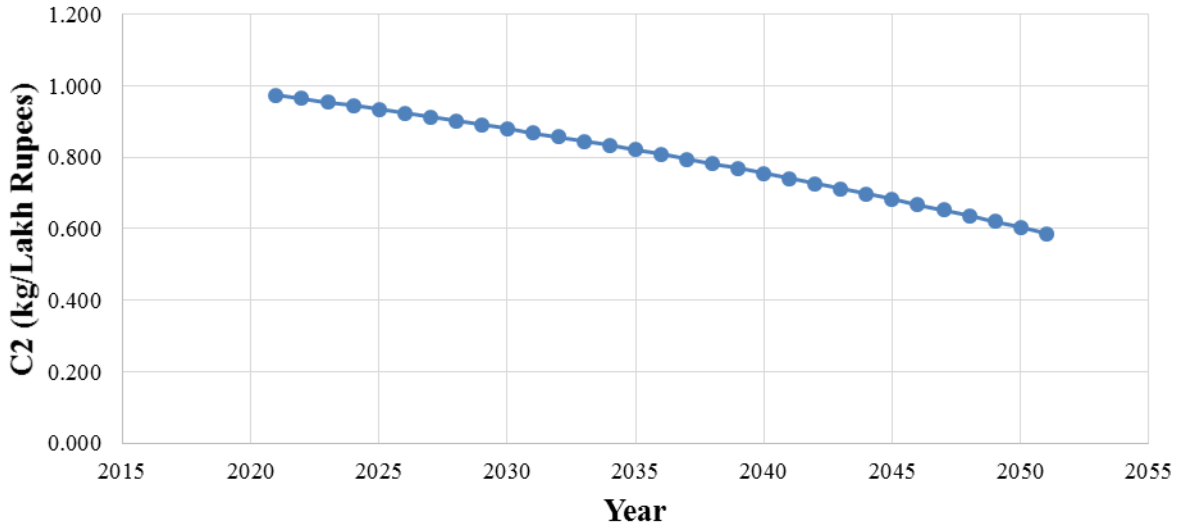


Figure 3.13: Predicted annual variation of indicator C2 for the next 10 years.

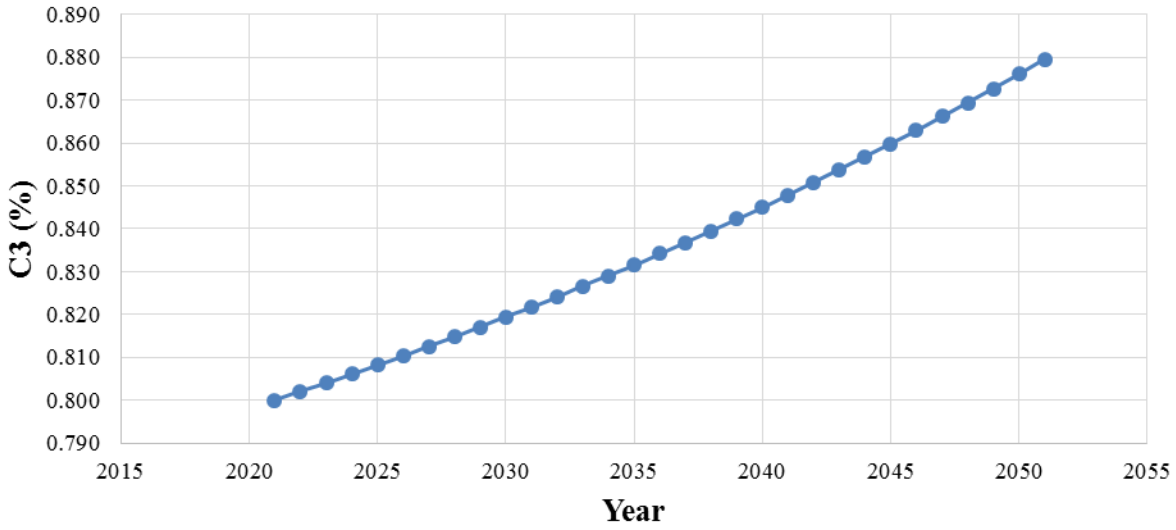


Figure 3.14: Predicted annual variation of indicator C3 for the next 10 years.

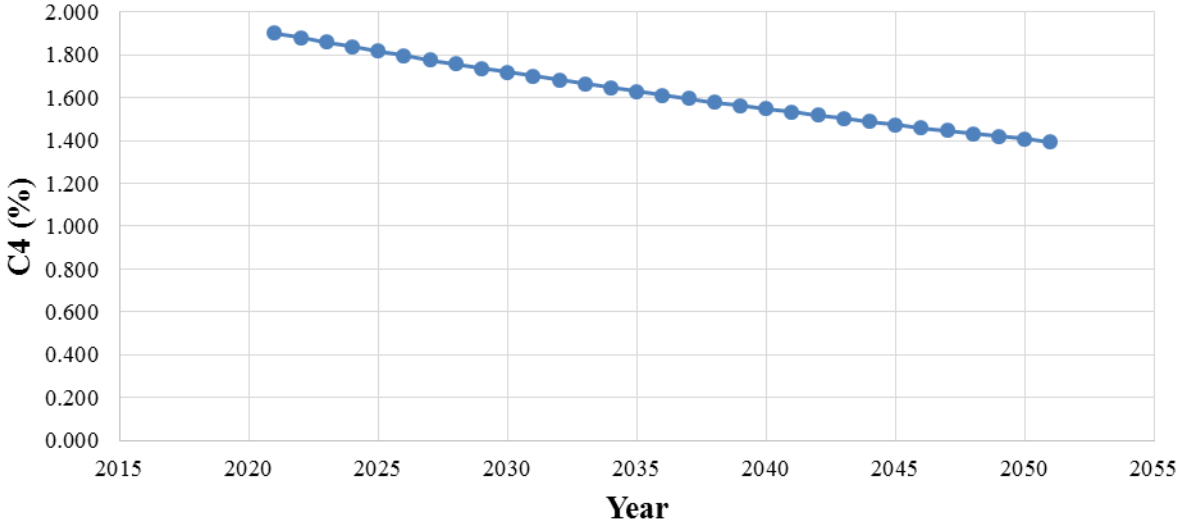


Figure 3.15: Predicted annual variation of indicator C4 for the next 10 years.

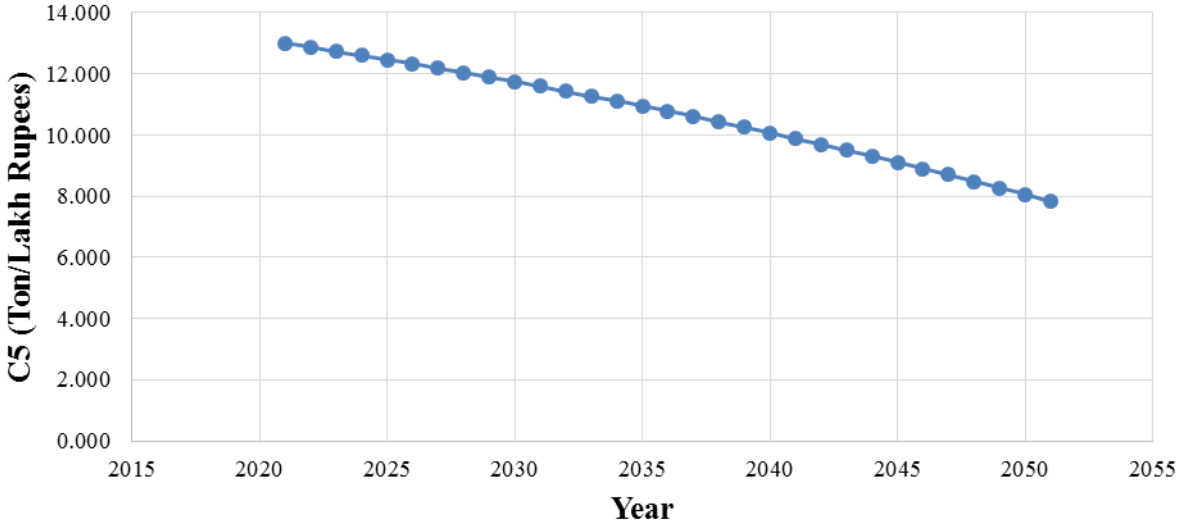


Figure 3.16: Predicted annual variation of indicator C5 for the next 10 years.

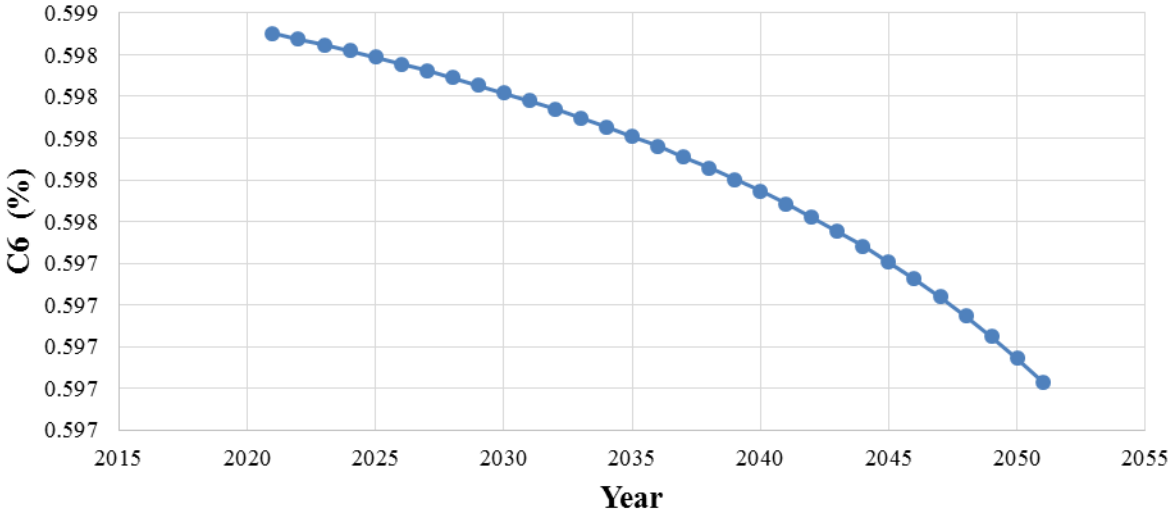


Figure 3.17: Predicted annual variation of indicator C6 for the next 10 years.

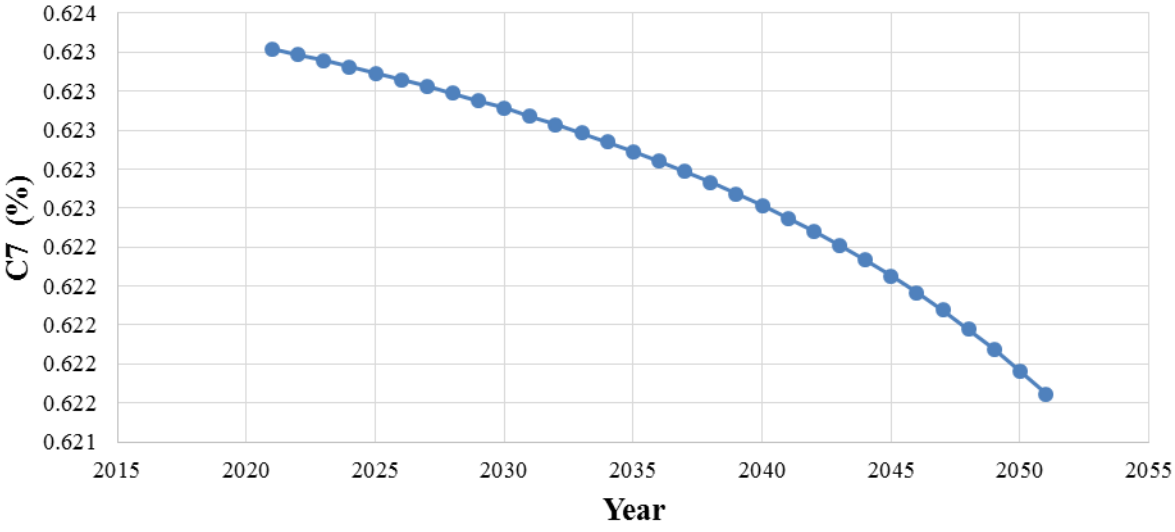


Figure 3.18: Predicted annual variation of indicator C7 for the next 10 years.

Table 3.10: Predicted weight of each indicator for water carrying capacity at Siltara.

Indicator	C1	C2	C3	C4	C5	C6	C7
Weight	0.2637	0.6374	0.0158	0.0372	0.0418	0.0037	0.0004

Table 3.11: Predicted entropy of each indicator for water carrying capacity at Siltara.

Indicator	C1	C2	C3	C4	C5	C6	C7
Entropy	0.9781	0.9471	0.9987	0.9969	0.9965	0.9997	1.0000

Table 3.12: Predicted value of comprehensive environmental water carrying capacity at Siltara.

Year	Comprehensive Value
2021	0.783
2022	0.770
2023	0.758
2024	0.745
2025	0.732
2026	0.718
2027	0.705
2028	0.691
2029	0.677
2030	0.663
2031	0.648
2032	0.634
2033	0.618
2034	0.603

2035	0.588
2036	0.572
2037	0.556
2038	0.539
2039	0.522
2040	0.505
2041	0.488
2042	0.470
2043	0.452
2044	0.434
2045	0.416
2046	0.397
2047	0.377
2048	0.358
2049	0.338
2050	0.317
2051	0.297
2021	0.783

Predicted values of the weight and entropy change of each indicator for water carrying capacity at Siltara is shown in Table 3.10 and 3.11. Moreover, the obtained values for the comprehensive environmental water carrying capacity at Siltara for the next 30 year i.e. up to 2051 is presented in Table 3.12 and is also depicted in Figure 3.19. Based on the WECC state classification method the calculated comprehensive value, was divided into five categories to enable the quantitative and qualitative analysis of WECC. The WECC from "weak" to "excellent" were: "weak" ranges between 0 and 0.2, "poor" ranges between 0.2 and 0.4, "normal" ranges between 0.4 and 0.6, "positive" ranges between 0.6 and 0.8, and "excellent" ranges between 0.8 and 1.

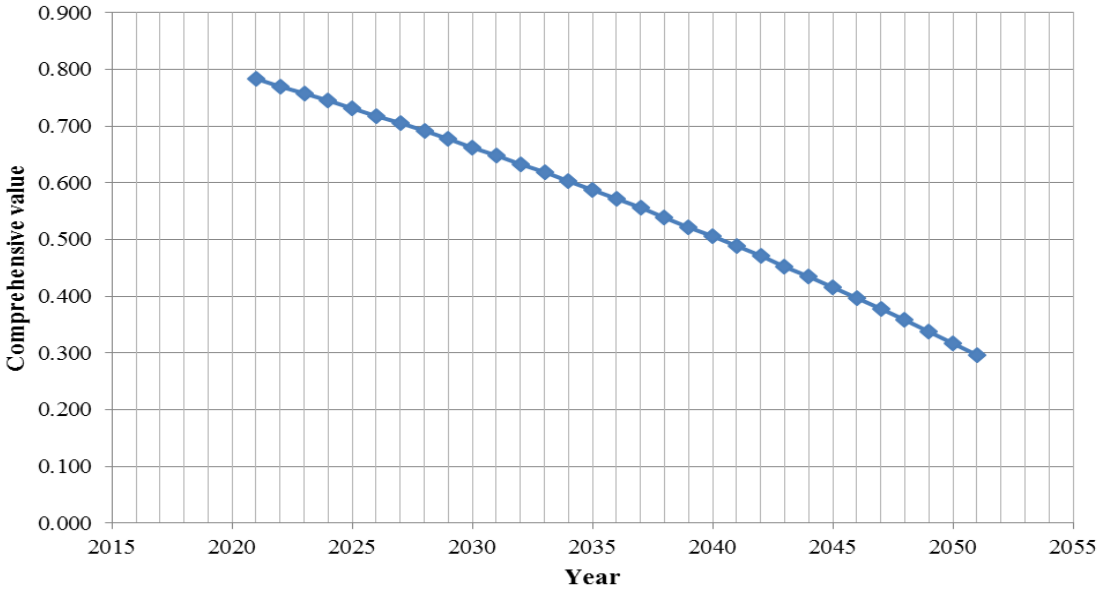


Figure 3.19: Predicted comprehensive environmental water carrying capacity of Siltara for the next 10 years.

From Table 3.12 we can see the comprehensive value is 0.783 in 2021, it falls to 0.618 in 2033. At 2045 it reaches the value of 0.416 after that it crosses the normal comprehensive value and goes to the poor comprehensive value. Therefore, we need to take appropriate steps to maintain the value in normal range or else in upcoming years it can fall to poor values. Our results indicate that the environmental water carrying capacity displays a decreasing trend. Therefore, the proper management planning is needed for long term use and further industrial developments. In this regard, a series of measures, such as water saving and water recycling, may curb the negative trend. Moreover, the pollution intensity can be further related to sectors' or plants' technological level, productivity, and capital intensity. The WRCC can significantly improve by vigorously developing energy conservation and environmental protections and

promoting the construction of a conservation-oriented society. We need to ensure the harmonious development of economy, society, water resources and water environment, which is the suitable development scenario.

3.3.5 Delineation of Water Environment Management Plan

Following delineation management plan for municipal and industrial waste needs to be implemented:

1. Effluent from industrial activities mainly from coal fired thermal power plant and other industries, should not be discharged directly to surface water or land, which may contaminate the water.
2. Near by industries should not dump the solid waste materials including fly -ash un-scientific matter in open lands, which may degrade the quality of water in the study area.
3. It has been found from the water sample analysis data that the concentration of various toxic materials are much below the permissible limit as presubscribed by WHO and CPCB. However, in few places the presence of high concentration of iron reported and this mater needs some oxidation and sedimentation pre-treatment for separation. The presence of few toxic and hazardous materials may lead to health hazards. Those waters should be avoided for use and proper treatment methods should be adopted for removal of such contaminates.
4. The rain water harvesting, water reservoir, modification of existing lake/ponds to hold enough water may be attempted.
5. General cleanliness of drains, surrounding areas of ponds, lake, river is lacking. Different awareness programme by Govt. level may change the scenario. Thro wing plastic, water bottles, paper, other un-desirable materials near water bodies are not acceptable.
6. Regular monitoring of water quality of river, lake, ponds, tube well, under ground water etc should be tested periodically through an organization of nati onal repute and enlisted third party as notified by CPCB by CECB to ensure that toxic compounds are not present in the water bodies of Siltara. The appropriate action plan should be taken after the review of report asapplicable.

Therefore, delineation action plan must consider all above aspects.

CHAPTER-IV

LAND ENVIRONMENT

4.1. Introduction

Waste is the useless by product of human activities which physically contains the same substance that are available in the useful product. Wastes have also been defined as any product or material which is useless to the producer. Wastes are materials that people would want to dispose of even when payments are required for their disposal. Although, waste is an essential product of human activities, it is also the result of inefficient production processes whose continuous generation is a loss of vital resources. A substance regarded as a waste to one individual, may be a resource to another. This is because the classification of a material as a waste will form the foundation for the regulations required to safeguard the populace and the environment where the wastes are being processed or disposed.

Most human activities generate wastes and the production of wastes remains a major source of concern as it has always been since pre historic period. As the volume and the variety of the waste increases (unlike the pre historic period where wastes are merely a source of nuisance), that needed to be disposed of under proper management. In ancient days, the environment is easily absorbed the volume of waste produced without any form of degradation but a substantial increase in volume of wastes generation has begun in the sixteenth century when people are started to move from rural areas to cities as a result of industrial revolution. This migration of people to cities has led to population explosion and that in turn has led to a surge in the volume as well as variety in composition of wastes generation in cities.

The materials such as metals, glass and plastic have begun to appear in large quantities in municipal waste stream. The large population of people in cities and communities are rising to indiscriminate littering and open dumps. These dumps in turn have been formed breeding grounds for rats and other vermin, posing significant risks to public health. The unhealthy waste management practices are resulted in several outbreaks of epidemics with high death tolls. Today, however, most of these countries have effectively addressed much of the health and environmental pollution issues associated with wastes generation. In contrast, the increasing rate of urbanisation and developments in emerging countries is now leading to land pollution.

Land is the space carrier of human activities, the most basic production factor for human social and economic development, and the most basic survival resource for urban and rural residents. Since the 1960s, the problem of land pollution has gradually attracted widespread attention. Humans have paid

attention to the causes of land pollution from the aspects of wastes treatment, mining, urbanization, agrochemicals and soil erosion. They have also explored the impact of land pollution from the aspects of socio-economic development, ecological environment as well as human health and has explored ways to control land pollution from the aspects of pollution reduction and land restoration. Therefore, the challenge of land pollution is how to solve the relationship between meeting human needs and maintaining the long-term ability of the biosphere to provide goods and services.

There are two approaches to defining land pollution: (i) soil pollution in a narrow sense and (ii) land pollution in a broad sense. Soil pollution focuses on factory chemicals or sewage and other wastewater, including garbage and industrial waste, agricultural pesticides and fertilizers, the impact of mining and other industrial firms, the undesirable consequences of urbanization, and the systemic destruction of soil by over-intensive agriculture. As an important factor affecting human health, land pollution control poses a great challenge to the function of the ecosystem, which has a significant impact on human. How to take effective measures to deal with the deteriorating land pollution and improve the quality of land resources?

This report presents an assessment of the real-time situation regarding solid waste management in Siltara, Chhattisgarh, with a focus on municipal solid waste, industrial waste, hazardous waste, and e-waste generated by factories and industries in the region. The report aims to evaluate the existing land use pattern, quantify waste generation, assess waste disposal procedures, analyze pollutant loads and environmental quality, propose a comprehensive road plan for improving the land environment, estimate assimilative capacity, and develop inventory and management plans for various waste categories.

4.2. Methodology

4.2.1 Steps to be followed for Land Allocation

1. Firstly, background information research and pre-requisites are checked. It's important to gather knowledge of place, history, methods of operation, team, approach, precautions, etc.
2. With the help of GIS, Satellite imagery etc. technologies and Field Survey, Topography, etc. mapping is done to study the location and eliminate all the unsuitable regions for dumping/ land filling/ incinerating etc.

3. Visualization and interpretation of site and how the whole city would be covered based on preliminary work carried out.
4. Then from the available regions the best ones are selected based on parameters like that of soil/ land cover, network of transport, society around, environment (humans, animals, water bodies, etc.), financial estimates, depth of ground water source, less spread of contaminants, slope or height of site and other factors are to be studied thoroughly.
5. The sites with best combination of all the factors can then be selected for disposing off wastes so that pollution can be controlled to an extent.
6. Now, collection of waste from residential houses, Industries, markets, agricultural farms and other places can be done.
7. Transportation, Clustering, Segregation, Processing, recycle, landfill, disposing off etc. can then be done with the help of different disposing techniques for different category of pollutants and wastes.
8. In addition, monitoring of the disposed wastes and subsequent steps is important.

4.2.2 Measurement of Heavy Metals

X-ray fluorescence analysis allows direct and non-destructive analysis of soil samples. Another advantage is that instruments can be built with micro focusing capabilities, which allows for the single soil particles. Method is suited for all elements heavier than oxygen. However, detection limits are relatively high when compared to other methods, in particular for the lighter elements. Samples are dried at room temperature to become moist free. Then aggregates are crushed by means of crushers or mortars, and finally passed through a sieve with 100 mesh size. Samples are ready for analysis. X-ray Fluorescence Spectrometer used for soil analysis is shown in Figure 4.1.

Figure 4.1: X-ray fluorescence spectrometer for soil analysis.

4.3 Results and Discussion

4.3.1 Land Pollution & Wastes in Siltara

Point to note is that this site is overloaded (capacity) and simple land filling method is adopted for disposing solid wastes here. Collection, Transport and Disposing off of waste from the city is a major challenge and has several loop holes. However, even bigger challenge is to bring awareness and knowledge in society reading same. Particularly in Siltara, the municipal garbage collecting vehicles visits every door and collects the waste from residential areas, hotels, markets, small scale industry, public places, etc. The waste collecting van is divided in two sections for collecting separately the dry and wet wastes, likewise each family, house, store, Individuals are provided with two different dust bins from government (green and blue). This is to ensure that garbage/ wastes are collected separately. This would ease in disposing step as wet degradable waste are filled in pits and bio-energy is created with its help while the other wastes are sent for recycling and suitable wastes for incinerating and dumping (this was the proposed plan).

But unfortunately, in Siltara the waste is collected in mixed form and direct dumping is done in more than 90% cases. This is one of the reasons for land pollution in Siltara apart from the other prominent ones like Vehicle dust and exhaust, open burning, human and animal faeces, hospital wastes, hazardous and toxic wastes, commercial, Industrial, automobiles are impacting soil, water, land and whole environment adversely. Particularly site selection is important, since wastes have critical environmental effects like land pollution and wastes from kitchen are complex and their decomposition requires much more time thus proper management is required in such cases. The benefits of GIS include overall lesser cost time saving less cumbersome, provides a structured way and plan to carry out the process, a data too is stored in backend thus monitoring gets simpler. Hence these are the modern solution which involves analysis of problem deciding the pathway to operate digitalizing monitoring and updating the technology and path.

4.3.2 Major Industries in Siltara and their Wastes Generation

Some of the major waste producing industries in Siltara are as follows:

1. SKS ISPAT & POWER LTD
2. G.R. MINERALS AND INDUSTRIES PVT.LTD
3. TRANSRAILSTRUCTURES & TOWERS
4. G.R. SPONGE AND POWER LTD.
5. VASWANI INDUSTRIES LTD.
6. DROLIA ELECTROSTEELS(P) LTD. STEEL DIVISION
7. MARUTI AGRO PRODUCTS P. LTD.
8. JAYASWAL NECO INDUSTRIES LTD. (STEEL PLANT DIVISION) (SINTER PLANT & FLY ASH BRICKS PLANT)
9. M/S NARMADA INDUSTRIES
10. M/S NIRMAL INDUSTRIES
11. M/S KONARK METALLIC INDIA PVT. LTD.
12. NANDAN STEELS AND POWER LTD.
13. AARTI SPONGE & POWER LIMITED
14. VIHAR INDUSTRIES (PROP. RAIPUR COAL FEEDER PVT. LTD.)
15. M/S THE METALIC ALLOYS,
16. SARDA ENERGY & MINERALS LTD.

17. VIGHNESHWAR ISPAT PVT. LTD.
18. M/S PRITAM MINERALS
19. SUNIL SOPNGE PVT. LTD.
20. MAA USHA URJA LIMITED (BIO-MASS POWER PLANT)
21. FORTUNE METALS LIMITED
22. N.R. SPONGE PVT. LTD.
23. JAGDAMBA POWER & ALLOYS LTD.
24. EARTHEN CERAMICS PVT. LTD.
25. INDIAN STEEL & POWER (P) LTD.
26. M/S SIVAM ALLOYS & FUELS LLP
27. M/S R.S. PYROCHEM INDUSTRIES
28. M/S TUSHAR AGRO INDUSTRIES
29. M/S O.P.G. PHARMA
30. M/S SUDARSHAN METALLIC PVT. LTD.
31. M/S NIKITA METACHEM PVT.LTD.
32. M/S SHIVAM METALLURGICALS PVT.LTD
33. RAMA UDYOG (PVT) LIMITED
34. GREEN PETRO FUELS LLP
35. M/S RYB POWER INDUSTRIES
36. SHANTI STEELS
37. ANAND STEELS
38. J.K STEEL WIRE INDUSTRIES
39. G.R. SPONGE AND POWER LIMITED UNIT II

4.3.3 Assessing the Existing Pattern of Land Use by Field Surveying and Satellite Imageries

Land use mapping is the most basic and widely used methodology for assessing and observing the natural resources present in any region and gives details about the existing land use pattern too, which in turn is beneficial for predicting the better use of land in future and present. With advancements in satellite sensors and analysing techniques, the remote sensing systems have become much more realistic, efficient and attractive for implementing in research and management of natural resources and land. Land use is the

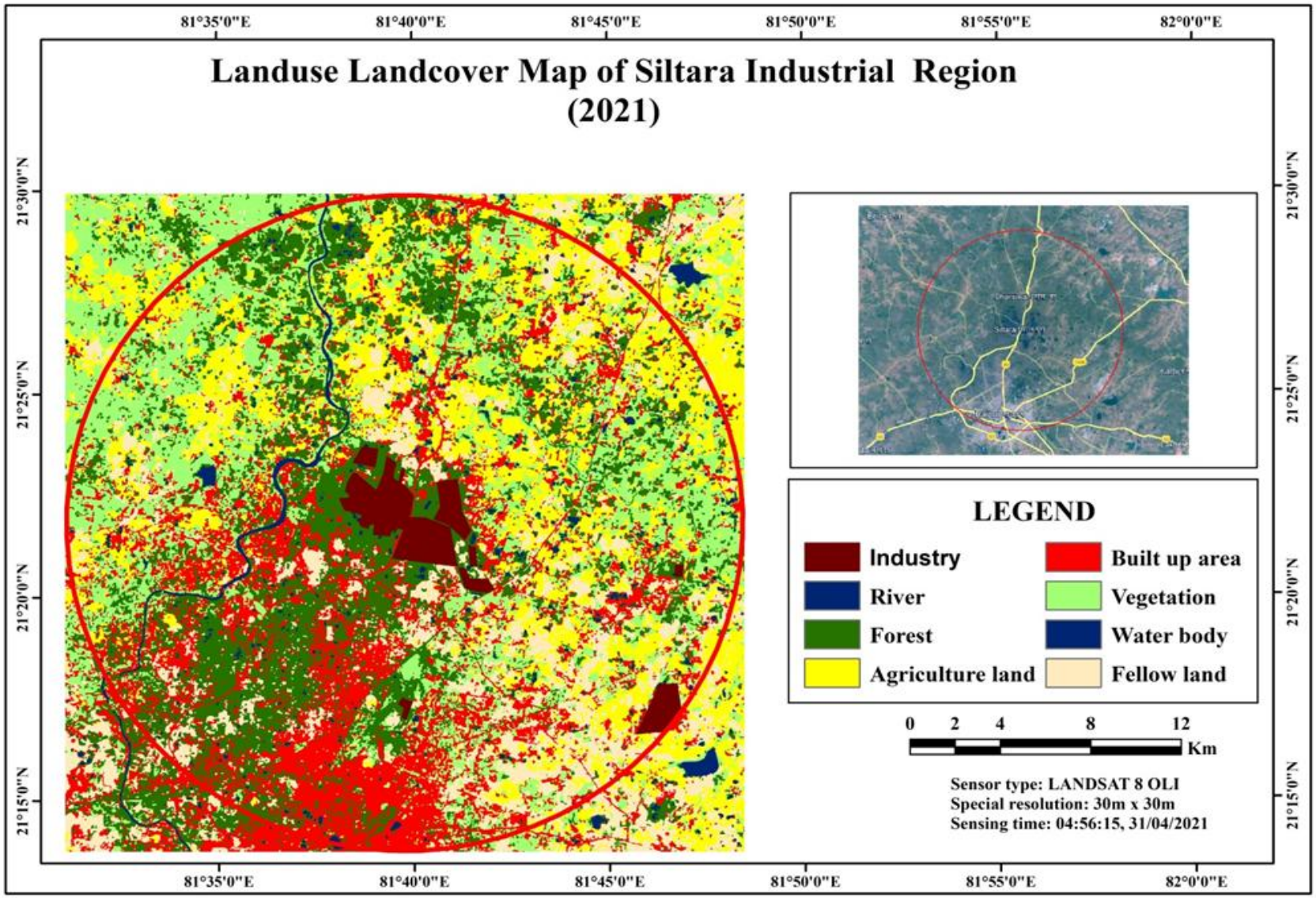
activities carried out by humans on earth (land). These activities are decided by the physical, climatic, economics and social condition of region. Land cover reveals the natural and man-made structures (mountain, house, buildings, cliff, hills, commercial constructions, etc.) covering the land surface. Combination of Remote sensing and GIS techniques can serve the purpose of land use/land cover plan and map development in real time as well as for long-term monitoring of the environment. The information generated from this technique will prove to be of immense importance in the forming of action plans for pollution control and waste management. Land use distribution in Siltara is shown in Table 4.1.

Table 4.1: Land use distribution in Siltara.

LULC of Siltara region with 15km radius		
LULC Classes	**Area (sq. km.)**	**Area (%)**
River	11.56	1.64
Forest	129.43	18.32
Agriculture land	143.66	20.33
Built up area	142.99	20.24
Vegetation	209.03	29.58
Water body	12.64	1.79
Fellow land	37.06	5.24
Industry	20.21	2.86
Total area coverage	**706.58**	**100.00**

4.3.4 Land use land cover Pattern in Siltara

LULC (Land use land cover) studies provide better economics and ensure growth, development and stability of the area/ city/ state/ country in general. It aids in predicting the adjustments that is to be made in accordance to the changing land cover and land use pattern over the years. It is essential for best possible utilization of land present/ available for better planning and policy making. The LULC map of the Siltara Industrial area for the year 2021 is shown in Figure 4.2. Particularly site selection is important, since wastes have critical environmental effects like land pollution and wastes from kitchen are complex and their decomposition requires much more time thus proper management is required in such cases. In Siltara, 18.32% of land is forest cover which account to 129.43 sq. km. The industries occupy the 2.86% of land that is 20.21 sq. km. However, great portion of land is being utilized for different purposes. Residential, transportation, commercial, public & semi-public areas land use will keep rising while the industrial land use would certainly decrease due to the environmental concerns and shifting in future from Siltara.



.**Figure 4.2:** LULC map of the Siltara industrial area for the year 2021.

Some of the major land use distribution areas are as follows:

- **Residential Area:** Majority of area is utilized as residential housing in the city. As shown in Table 4.1, with increasing population and shifting of people from rural areas to urban city like Siltara, land use for residential purpose is rising.

- **Commercial/ Market Area:** Siltara is known as the commercial hub or trade hub and has good portion of land being utilized in this sector and will keep increasing in future with increasing population but somehow sluggish as online marketing and shopping flourishing.

- **Industrial Area:** Significant amount of land is being utilized as industrial land since the era of industrialization in Siltara by small scale and medium scale industries in majority. However, this trend of land use won't increase much unlike the other sectors since in accordance to the smart city program and environmental concerns Industries shall be shifted outside the city thus either decline or constant land use for Industrial area in future.

- **Transportation Area:** Road, railway, airport, bus stand, taxi stand, future metro, etc. kind of public transport facilities covering certain percent of land and would certainly increase in future too because of development programs being carried out.

- **Public/ Semi-Public Areas:** Parks, gardens, temples, government offices, schools, hospitals, banks, playground, etc. kind of land use.

4.3.5 Current Waste Disposal/ Management Practice in Siltara

The void between waste generating and its disposal is the sole reason for mismatch in waste management system and pollution. More than 600 tonnes per day of solid waste is generated in Siltara city where 1.2 million people reside, out of which the residential/ household wastes contribute about 55%, commercial and market wastes account for 16%. While, Industrial waste is a major contributor and relatively small quantities of hospital waste, biomedical Wastes, hazardous wastes, construction debris, etc. account for rest of the part. The disposal process starts itself from the waste collection as if now, there is no segregation or separation of different wastes according to their category while collecting in Siltara. The trenching ground of

Sarona ring road 2 occupies an area of 8.5 hectares nearby Kharun river in the proximity of 4km. Following are the major observations for trenching ground of Sarona:

- Simple landfilling method is adopted for disposal of waste and
- Direct dumping is done.
- No segregation at collection points most of the time.

RMC (Raipur Municipal Corporation), RWMPL (Raipur Waste Management Private Limited) undertakes the responsibility of municipal solid waste management and disposal in Siltara industrial area. Following are the significant point about these waste management units:

- Door to door waste collection from the residence, public places, commercial markets, hotels, government offices and organisations by mini vans, mini trucks and trucks. In addition, the waste collection from different waste points and public bins located throughout the city is done.
- Maintaining the secondary storage points at different places for temporary collection/ storage/ transport to ensure hygiene, cleanliness and ease of process.
- Collected Municipal Solid Waste (MSW) is transported to disposal facility.
- The wet wastes are buried by excavating to form compost while the dry wastes like metal, plastic, etc. are sold to the waste recycle plants and remaining fractions like debris, dusts, useless day to day solid waste are finally dumped at SLRM (Solid Liquid Resource Management)/ landfilled/ incinerated, etc.
- Digging out the existing landfilled and dumped waste accumulated at the current dumping sites and transporting them to the respective processing sites and processing the waste and ultimately disposing off.
- Routine maintenance and cleanliness of the waste processing and disposal facilities from vehicles, machines to plants.

Figure 4.3: Sarona Trenching Ground at Siltara.

Table 4.2: Solid waste collected per day by Siltara Municipal Corporation for the year 2017.

Sr. No.	Source of Waste	Quantity (TPD)
1.	Households	220
2.	Hotels	36
3.	Markets	33
4.	Commercial Area	65
5.	Institutional Area	3
6.	SWM from Industries	12
7.	Debris	25
8.	Miscellaneous	14
	Total	**408**

4.3.6 Proposed Model being implemented in Siltara for Disposal

Since 11/06/2020 Integrated Solid Waste Processing Facility for disposal by sanitary landfilling has been started in Siltara under Mission Clean City. In addition, to look after the existing dumping sites, the bio-mining technology. DPRs (Detailed Project Reports) are being utilised for the studying the rectification of the loaded dumping sites in Siltara. RMC in association with company- Kivar Environ Private Limited of Bangalore and RWMPL for integrated City Sanitation and Municipal solid waste management in Siltara will be working on a PPP (Public Private Partnership) model for a 30-year term. They will take care of waste collection, disposal, sanitation, operation, maintenance and engineering of the waste processing techniques, machine, facilities, etc. Some of the disposal methods proposed by RMC for waste disposal in Siltara according to agreement in detail are as follows:

- **Land filling**: Although it isn't the right way of disposal keeping in mind long term effects, but it helps in eliminating the odour, waste locally from land. They are dangerous because of it lying in open discomforts humans and animals, the burning of waste by excavating underground leads to depletion of groundwater resources, global warming effect, etc. This primitive method is practised in Siltara for disposal.

- **Incineration**: Incineration is the conversion of solid waste collected to heat, steam, residue, flue gases, etc. under thermal conditions (>1000 ºC) of heating. It doesn't eliminate landfilling but helps in reducing the volume of solid waste by 30%. However, disadvantageous because of higher organic, moisture and inert content present in Municipal solid waste/. It is also referred to as waste to energy facility.

- **Recycling**: It's the collection; treatment, processing and reusing of the waste disposed which are capable with some processing by selling to the companies or in processing plant.

- **Composting**: Beneficial for converting kitchen, biodegradable, organic, excreta, wet, etc. kind of solid wastes. These wastes are transformed to highly nutritious manures to be used in plant growth and recharging soil fertility. Generally composting occurs in absence of Oxygen and bacterial /microbial environment presence.

- **Anaerobic Digestion**: It's similar to composting but oxygen is supplied and no need of microbes for conversion.

New Approach for Waste Management

Inventory Maintenance
Treatment at Source
Modification in Existing Methods & Adopting New Ones
Reducing the Toxicity, Volume & Fraction of Wastes Released to Decrease Harmful Consequences.
Waste to Energy Conversion (Wastes that can't be Recyced/ Reused is converted to Heat/ Electricity Energy via. recovery of Landfill Gas, Pyrolysis, Gasification, Anaerobic Digestion)

Figure 4.4: An overview of new approach for waste management.

- Emphasis on reduction of waste released and development of efficient method and technology for disposal of the unavoidable wastes being generated. We know "Prevention is always better than curing". Therefore, measures should be taken with utmost priority.

- A popular and widely used strategy is Integrated Waste Management i.e., minimize the waste generated at source itself, safeguard environment with proper disposal and treatment plants and carrying out remedial/ healing work for already damaged land and environment.

- Some new points to ensure:
  - Monitoring: GPS enabled vehicles should collect and transport the wastes to ensure for proper tracking and monitoring of the waste. Especially in case of E- Wastes and Hazardous wastes, Biomedical and Industrial wastes, since they are much more dangerous and possess greater threat. Moreover, wastes like E-Waste are quite useful and advantageous thus risk of theft.
  - Separate vehicles/ container and processing tools should be used for different kinds of wastes- normal wastes, compost forming waste, hazardous, biomedical, Industrial waste to avoid any kind of transfer and mixing and future problems.
  - Using the sign conventions and boards for indicating waste dumping sites, points and vehicles, more emphasis on hazardous and industrial waste carrying vehicles and collection points- danger symbols can be used to indicate such vehicles and points at dumping sites.
  - Transportation in closed manner, this can be achieved by using lids (replaceable) over the vans.

- Eye on disposal process of different kind of wastes in accordance to the method allotted/ instructed.
- Industries shall carry out waste storage process in an isolated place for some days within industrial premises to ensure that the harmful effects are not spread.
- Maintaining the records of generated waste- hazardous/ recyclable/ industrial etc. in accordance with the CPCB guidelines to ease in monitoring and tracking.

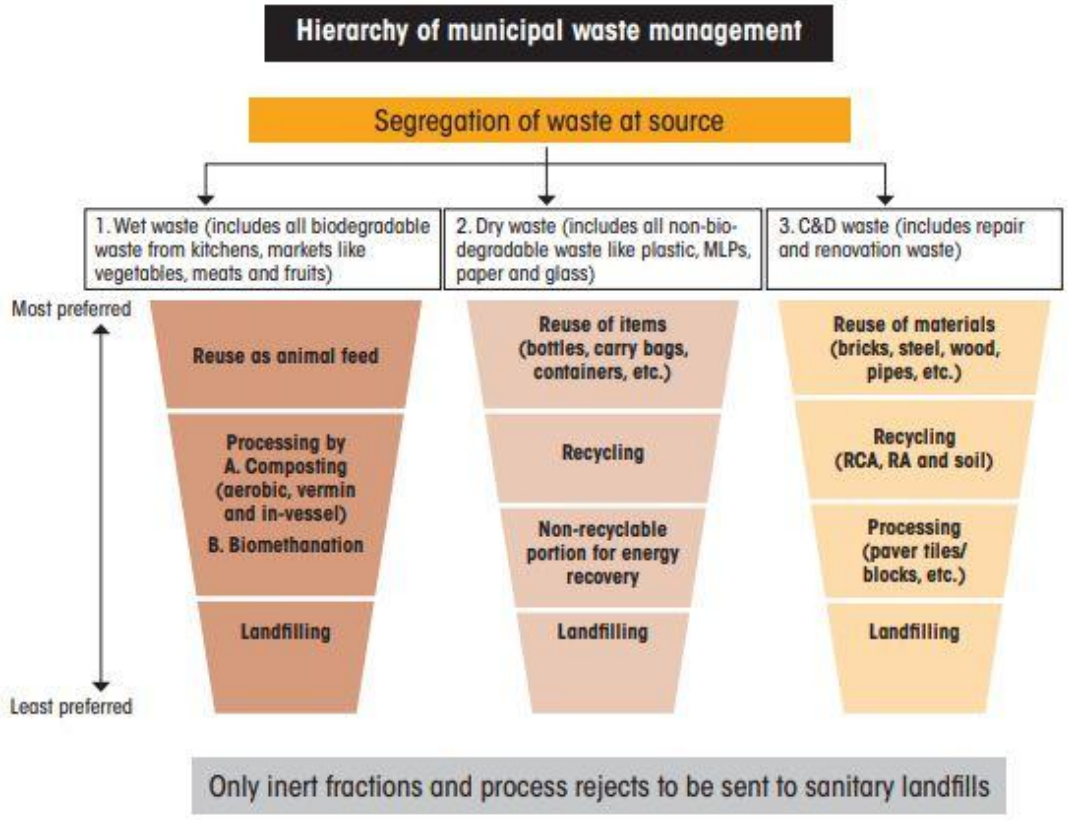


Figure 4.5: The hierarchy of Municipal wastes management

4.3.7 Management Plan for Hazardous Wastes

Hazardous wastes pose significant risks to human health and the environment due to its toxic, flammable, corrosive, or reactive nature. Effective management of hazardous waste in Siltara requires the following theoretical considerations:

a. Waste Minimization: Implement waste minimization techniques to reduce the generation of hazardous waste at its source. This includes process optimization, material substitution, and implementing cleaner production practices.
b. Segregation and Storage: Develop proper segregation and storage facilities to ensure the separation of hazardous waste streams and prevent cross-contamination. Implement labelling and colour-coding systems for easy identification and safe handling.
c. Transportation and Treatment: Establish a dedicated transportation system to safely transport hazardous waste to treatment, storage, and disposal facilities. Select appropriate treatment methods such as incineration, chemical treatment, or physicochemical processes, considering the nature and characteristics of the waste.
d. Facility Design and Operation: Design and operate hazardous waste treatment facilities with strict adherence to safety protocols, including containment systems, pollution control measures, and emergency response plans. Regular inspections, monitoring, and maintenance should be conducted to ensure safe operation.
e. Regulatory Compliance and Enforcement: Enforce compliance with hazardous waste management regulations and guidelines through rigorous monitoring, inspections, and penalties for non-compliance. Strengthen regulatory frameworks to address the safe handling, transportation, and disposal of hazardous waste.

Short Term Plan:

For short term focus on reducing and discarding the waste rather than processing & treatment.

1. Control regular hazardous waste generating activities and release from industries and labs. Moreover, temporary storing of these wastes within premises for certain period of time (hours/ day/ months) before transporting it for disposal and processing to diminish the effect.
2. Environmental compensation, wherein resource-based compensation is taken instead of monetary fine for harming environment. However, not practical and less successful plan.
3. Disposal (out of the city).

Long Term Plan:

1. Separate collections of such waste in special containers.
2. Segregation in case required.
3. Transporting to the site allotted.
4. Carrying out processing- making it less hazardous by dilution, recovery, separation.
5. And finally disposing it off.
6. Properly sealing/ closing the fills.
7. Stricter rules and policies, especially for hazardous waste.
8. Monitoring is really important for these wastes before and post disposal too.

Table 4.3: Industry-wise total quantum of Hazardous waste generation, waste sub-categories such as **l**and fallible and recyclable.

Name of the unit	Hazardous waste generation in MTA	Disposable in landfills (MTA)	Recyclable (MTA)
M/s Akruti Trexim Pvt Ltd	0.2 MT/Year	1.0 MT/Year	0.2 MT/Year
M/s Aster Teleservices Pvt. Ltd.	100 MT/Year	90 MT/Year	
M/s Godawari Power & Ispat Limited	0.75 MT/Year	-	0.75 MT/Year (Sold to registered recyclers)
M/s Indian Oil Corporation Ltd	0.45 MT/Year	-	0.45 MT/Year (Sold to registered recyclers)
M/s Jayaswals Neco Industries Ltd. Siltara	1.8 MT/Year	-	1.8 MT/Annum (Sold to registered recyclers)
M/s John Distilleries Limited	0.108 MT/Year	_	0.108 MT/Annum (Sold to registered recyclers)
M/s. Sarda Energy & Minerals Ltd.	0.816 MT/Year	-	0.816 MT/Year (Sold to registered recyclers)
M/s SKS Ispat & Power Ltd.	1.8 MT/Year	-	1.8 MT/Year (Sold to registered recyclers)
M/s Teja Electicals	48 MT/Year	11 MT/Year	2.5 MT/Year (Sold to registered recyclers)
M/s Vandana Global Limited	0.5 MT/Year	-	0.5 MT/Year (Sold to registered recyclers)

4.3.8 E-Waste Management

Effective management of electronic waste (e-waste) is crucial to prevent environmental contamination and recover valuable resources. The theoretical framework for e-waste management in Siltara should include the following considerations:

a. Collection and Segregation: Set up collection points or dedicated e-waste collection centers to facilitate the proper disposal of discarded electronic devices. Implement procedures for the segregation of hazardous components from reusable or recyclable materials.
b. Recycling and Recovery: Establish e-waste recycling facilities to recover valuable resources from discarded electronic devices. Collaborate with authorized recyclers to ensure environmentally sound recycling practices and the safe handling of hazardous components.
c. Awareness and Outreach: Conduct awareness campaigns to educate the public about the hazards of improper e-waste disposal and promote responsible e-waste management practices. Encourage the adoption of e-waste collection drives and provide information on authorized collection points.
d. Extended Producer Responsibility (EPR): Advocate for the implementation of EPR programs, where manufacturers and importers are responsible for managing the entire lifecycle of their electronic products. Encourage producers to design products with recycling and resource recovery in mind.

Categories of E-Waste Generated along with their Quantity

Table 4.4: Amount of E-Waste in Tonnes produced per annum

Sr. No.	Producer Name	Code	Qty. MT/ Year
1.	Jayaswal Neco Industries ltd Siltara growth centre Bilaspur Road Siltara Raipur	ITEW6, ITEW2	0.3

Table 4.5: Amount of E-wastes in Tonnes of different categories

Sr. No.	Category of waste	Quantity of Waste (in tons)
1	Cellular Phones	272.08
2	Fixed line phones	259.55
3	Computers	11361.66
4	Printers	1369.84
5	Televisions	47347.94
6	Air Conditioners	521.58
7	Washing Machines	588.62
8	Refrigerators	666.58

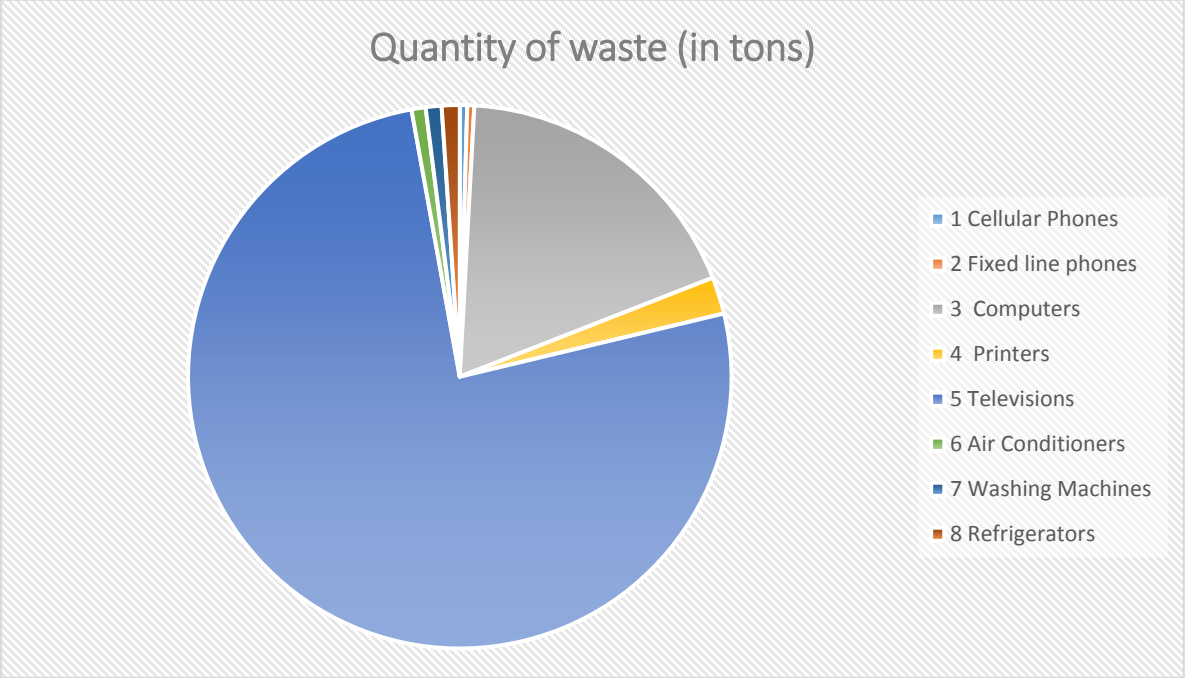


Figure 4.6: Quantity of E-wastes of different categories produced in Siltara region.

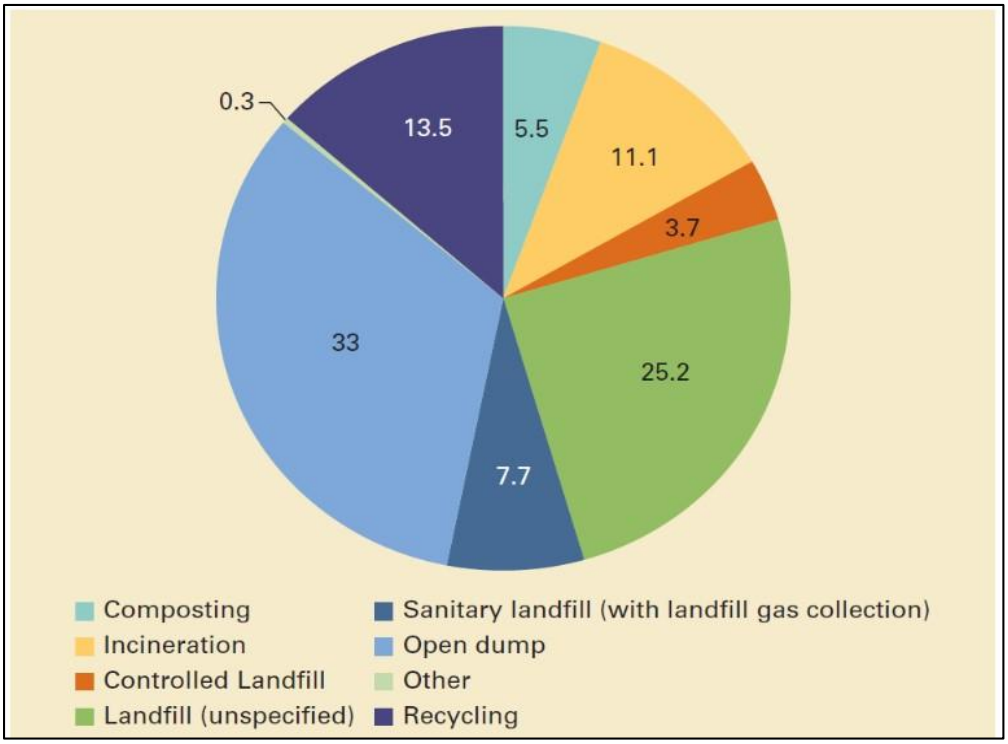


Figure 4.7: Treatment and disposal of waste (in percentage) in Siltara.

4.3.9 Municipal Solid Wastes Management

Efficient management of municipal solid wastes (MSW) is crucial for maintaining cleanliness and promoting public health in Siltara. The theoretical framework for MSW management includes the following considerations:

a. Waste Segregation: Encourage waste segregation at the source into categories such as organic waste, recyclables, and non-recyclables. Implement public awareness campaigns to promote proper waste segregation practices.
b. Collection and Transportation: Establish an organized and efficient collection system that covers all residential and commercial areas. Use separate collection vehicles for different waste streams and ensure regular collection schedules.
c. Treatment and Disposal: Evaluate appropriate treatment methods for different types of MSW, such as composting for organic waste, recycling for recyclables, and landfilling with proper lining and leachate collection systems for non-recyclables. Encourage waste-to-energy conversion as a sustainable option.

d. Resource Recovery and Recycling: Promote recycling initiatives by establishing recycling centres and supporting waste-to-resource programs. Collaborate with local industries and entrepreneurs to facilitate the efficient recycling of waste materials.
e. Public Participation and Education: Engage the community through public participation programs, awareness campaigns, and educational initiatives. Foster a sense of responsibility and encourage individuals to adopt sustainable waste management practices.

Short Term Plan:

1. Door to door waste collection from the residence, public places, commercial markets, hotels, government offices and organisations by mini vans, mini trucks and trucks. In addition, the waste collection from different waste points and public bins located throughout the city is done.
2. Maintaining the secondary storage points at different places for temporary collection/ storage/ transport to ensure hygiene, cleanliness and ease of process.
3. Collected Municipal Solid Waste (MSW) is transported to disposal facility.
4. The wet wastes are buried by excavating to form compost while the dry wastes like metal, plastic, etc. are sold to the waste recycle plants and remaining fractions like debris, dusts, useless day to day solid waste are finally dumped at SLRM (Solid Liquid Resource Management)/ landfilled/ incinerated, etc.
5. Digging out the existing landfilled and dumped waste accumulated at the current dumping sites and transporting them to the respective processing sites and processing the waste and ultimately disposing off.
6. Routine maintenance and cleanliness of the waste processing and disposal facilities from vehicles, machines to plants.

Long Term Plan:

1. Currently, RMC doesn't have enough facility for the MSW disposal within Siltara industrial area. Thus, the ties up companies are given the responsibility to do the needful. Nearby village Sakri situated at about 20 kilometres from Siltara towards the north east direction on NH 6 and SH 9 connecting ring road 3, about 27.04 hectares of land is taken on lease for processing and landfill facility set up for waste disposal.

2. SWMPL will manage the waste collection and transportation within the Siltara City and would be transporting it to the plant setup in Sakri under RMC for further processing in association with kivar group. The processing shall be done by:

- **MRF (Material Recovery Facility):** Separation of useful recyclable materials, hard wastes, etc. to be used as raw material in re-manufacturing processes, those which can form some new material, can be recycled and used again.
- **Accelerated Aerobic Composting:** Composting with continuous aid of microbes, bacteria, fungi, actinomytes environment and producing minerals and energy, organic substrates, etc.
- **Refuse Derived Technology (RDF):** It is quite surprising but the left material which is unused, unidentified, with series of processing, heating, mechanical processes along with additives like rice husk, bagasse can be used as a heating fuel source.
- **Construction Debris and Allied Wastes:** Stones, bricks, dust, sand, concrete, debris, ash rejects, etc. can be used as sand landfilling since they are inert.
- **Sanitary Landfilling:** An engineered landfilling technique which disallows inert wastes, non-biodegradable and other unfit wastes, thus is a much better way of land filling with modern engineering principles
- **Landfilling:** Although it isn't the right way of disposal keeping in mind long term effects, but it helps in eliminating the odour, waste locally from land. They are dangerous because of it lying in open discomforts humans and animals, the burning of waste by excavating underground leads to depletion of groundwater resources, global warming effect, etc. This primitive method is practised in Siltara for disposal.
- **Incineration:** Incineration is the conversion of solid waste collected to heat, steam, residue, flue gases, etc. under thermal conditions (>1000 ºC) of heating. It doesn't eliminate land filling but helps in reducing the volume of solid waste by 30%. However, disadvantageous because of higher organic, moisture and inert content present in Municipal solid waste/. It is also referred to as waste to energy facility.
- **Recycling:** It's the collection; treatment, processing and reusing of the waste disposed which are capable with some processing by selling to the companies or in processing plant.
- **Composting:** Beneficial for converting kitchen, biodegradable, organic, excreta, wet, etc. kind of solid wastes. These wastes are transformed to highly nutritious manures to be used in plant growth and

recharging soil fertility. Generally composting occurs in absence of Oxygen and bacterial /microbial environment presence.

- **Anaerobic digestion:** It's similar to composting but oxygen is supplied and no need of microbes for conversion.
- Monitoring, record maintenance and data check.
- Awareness to common people.
- Stricter rules and policies to ensure rules are obeyed.

4.3.10 Bio-Medical Waste Management Plan

Proper management of bio-medical waste is essential to prevent the spread of infectious diseases and protect public health. The theoretical framework for bio-medical waste management in Siltara should include:

a. Waste Segregation and Collection: Develop guidelines for the segregation of bio-medical waste at the point of generation, including sharps, pathological waste, pharmaceutical waste, and infectious waste. Establish a separate collection system to ensure safe handling and transportation.
b. Treatment and Disposal: Select appropriate treatment methods for bio-medical waste, such as autoclaving, microwave treatment, or incineration. Ensure compliance with regulatory requirements for the safe disposal of treated waste.
c. Safety Measures and Training: Implement safety measures, including the provision of personal protective equipment (PPE) for healthcare workers and waste handlers. Conduct regular training programs to enhance awareness and understanding of bio-medical waste management protocols.
d. Monitoring and Compliance: Establish monitoring mechanisms to ensure adherence to bio-medical waste management guidelines. Conduct regular inspections and audits to evaluate the effectiveness of waste management practices in healthcare facilities.

Table 4.6: Bio-medical waste generation around Siltara region

Month	2019		2020		2021	
	Daily Average (kg)	Total (tonnes)	Daily Average (kg)	Total (tonnes)	Daily Average (kg)	Total (tonnes)
January	3413	106	2551	79	6229	193
February	3809	107	2586	75	5463	153
March	3817	118	2358	73	5611	174
April	3803	114	1805	54	6925	204
May	3898	117	2042	61	6176	191
June	3689	111	2762	83	5286	159
July	4388	136	3221	100	5457	169
August	4665	140	3655	110	5192	161
September	4651	140	4283	128	4968	149
October	4551	137	4410	137	4851	150
November	5390	162	3600	108	4801	144
December	5390	162	3774	117	5261	163
Total	**4457**	**1548**	**3256**	**1125**	**5687**	**2015**

4.3.11 Estimation of Assimilative Capacity of the Land Environment

Assimilative capacity depicts the ability/ extent of absorption of pollutants in any environment without any kind of detrimental or harmful impacts, popularly referred to as receiving capacity or as environmental capacity. It is utilized as a parameter in a variety of environment examination and analysis test and researches carried out on lakes, rivers, oceans, cities, wastes, air, atmosphere and soils. The assimilative capacity is often accompanied by carrying capacity in order to ensure the sustainable development of any environment. Carrying capacity is the peak industrialization that any area can sustain at maximum rate of the consumption of resources or by discharge of waste. It is a linkage in between the assimilative and supportive capacity. Assimilative capacity can also be understood as the ability of environment to heal itself from damages caused as a result of man-made activities and circumstances, its capacity to digest waste and toxic substances without getting damaged/ affected. The level of assimilative capacity isn't always constant; it depends on the current pollution amount, history of pollution in the region, activities being carried out in the region, etc.

Solid Wastes Carrying Capacity

The well-being of humans in present as well as existence of life in future requires immediate and effective actions from our side. Dedicated actions, management plan, strategy and awareness should be the utmost priority to reverse the present trend of resources being depleted and environmental degradation being taking place. We can collect past data of 10-20 years, see its trend by plotting the curve/ graph and hence prediction of future waste in any particular year can be done. Represent, segregate, divide and utilize the data received. The mathematical relation of solid waste carrying capacity is shown below:

$$\mathrm{SWECC} = \frac{\mathrm{SWM_{EF}} + \mathrm{RC}}{\mathrm{SWG}}$$

Where,

SWECC is Solid Waste Environment Carrying Capacity in tons.

SWM_{EF} is Solid Wastes Managed in Eco-Friendly way (Recycled+ Incinerated+ Re-used+ Processed+ Landfilling) in tons.

RC is Remaining Capacity & SWG is Solid Waste Generated in tons.

Validation of the assimilated information can be done from the official detailed data from the respective organization. While, interpretation and conclusions can be drawn from the collected data by plotting graphs and analyzing past data, comparing to the present scenario and predicting the future situation with its help and taking necessary actions accordingly. In June 2020, under ISWM plan, a processing plant costing 127- 197 crore under PPP model was set up for treating the wastes from Siltara and Bilaspur cities. On an average 500 tons of waste is treated every day and electricity is generated from it. This serves dual purpose: (i) waste treatment (ii) Energy recovery. Predictions of waste amounts that shall be generated in coming years in Siltara using Forecast function of excel. Data was collected for 2007, '10, '14,'16,'18,'20 waste generated data in tonnes per day from different sources and utilized it to predict future values. The annual waste generated in TPD in Siltara along with the predicted values till 2031 is shown in Figure 4.52. The forecasted waste generation trend along with upper and lower confidence bound for the analysis is shown in Figure 4.53.

Table 4.7: Waste generation of the industries established near Siltara region

Year	Waste Generated in TPD(approx)
2007	62
2010	74
2014	102
2016	116
2018	122
2020	140

Table 4.8: Excel Table Attachment depicting the prediction of waste generation

YEAR	TOTAL SW	Prediction Using forecast function
2010	74	Known Values From year 2010-2020
2014	102	
2016	116	
2018	122	
2020	140	
2021	145.2432432	Unknown Values From year 2023-2033
2022	150.7580751	
2023	157.0147751	
2024	165.0120498	
2025	170.1443181	
2026	176.8513296	
2027	183.5509251	
2028	189.9881535	
2029	196.1169996	
2030	202.8550012	
2031	209.2445071	

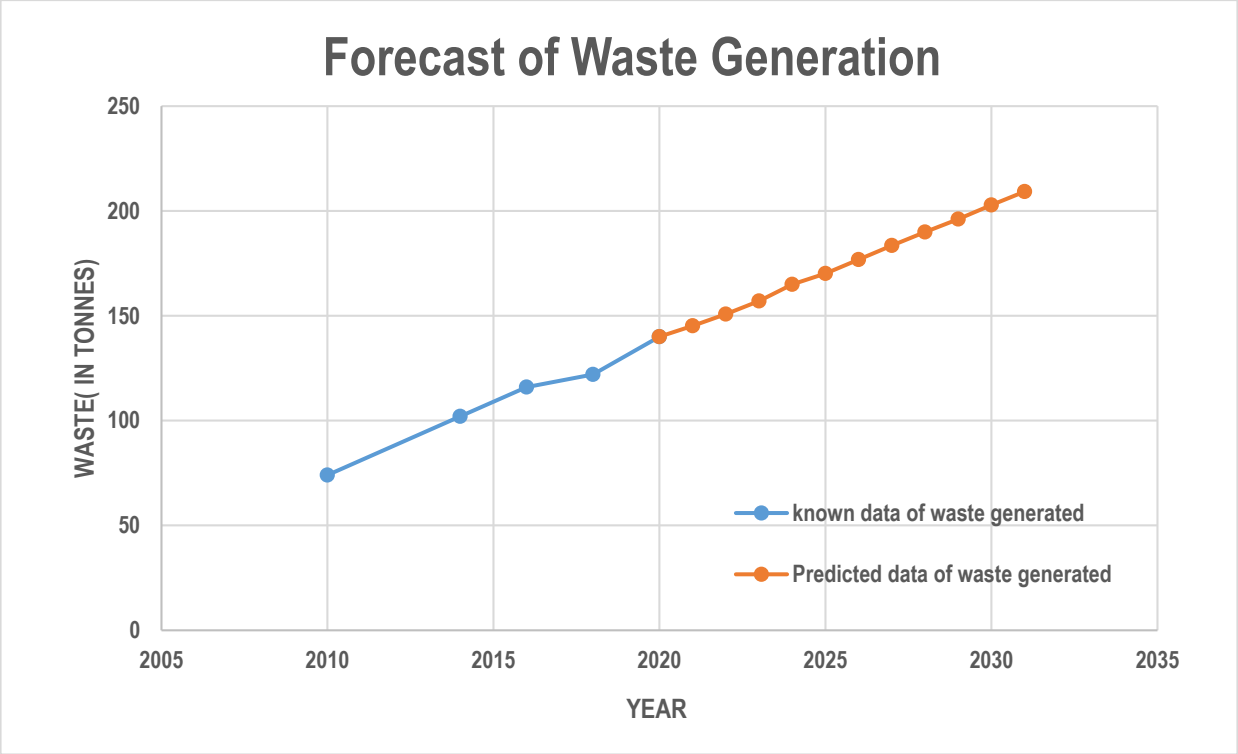


Figure 4.8: Linear graph chart of the analysis of waste generation in Siltara region over the years.

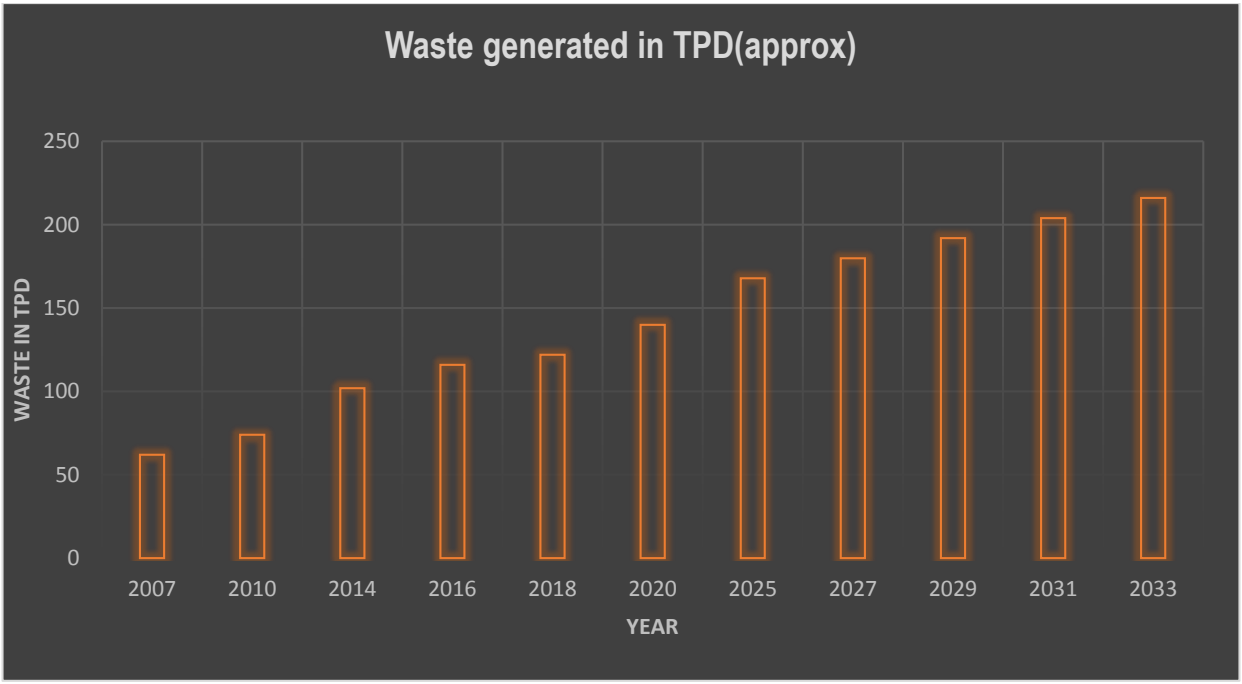


Figure 4.9: Column chart of the analysis of Waste Generation in Siltara region over the years.

4.3.12 Assessing the Existing Pattern and Predicting the Critical Values of Waste Generation in Accordance with Land Available

- According to EPA chapter 4 for Solid waste Management, 100 tons of waste requires 24000 sq. ft of area approximately if a pile height of 50-60 feet is considered. Thus, implementing this mathematical approach:
- Conversion: 24000 ft^2 means 2229.67 m^2
- 2229.67 m^2 area can store 100 tonnes of waste therefore, 2039 .8 m^2 will accommodate 91.4 tonnes of waste approx. Hence, we are generating about 48.6 tonnes extra waste as of 2020 in accordance with the land available in Siltara for waste disposal.
- In 2033 the rate is expected to be 216.03 tons per day, so:
- 48.6/91.4 = 0.5317 = 53.17%
- Now, 216.03 × 53.17% = 114.86 tones per day i.e., this would be the maximum permissible value. However, in future our infrastructure shall be improved and land allocation too would be more so obviously the waste storing capacity shall increase too which means a little higher waste generation relaxation can be considered.
- May be 1.2- 1.5% based on impacts the plans have i.e., 138 to 172 tonnes per day of waste in 2050 shall be handled with minimum complications and maximum efficiency.
- Thus, 216-138 = 78 & 216-172= 44 i.e., 20.37% to 36.11% decrease in the predicted value (216 TPD) shall be disposed off in 2033 effectively.

Table 4.9: Extrapolated data on how much solid waste will be produced in the future with lower and upper confidence bound.

YEAR	WASTE GENERATED IN T	Forecast(WA	Lower Confidence Boun	Upper Confidence Boun
2007	62			
2010	74			
2012	88			
2014	102			
2016	116			
2018	122			
2020	140	140	140.00	140.00
2022		151.5089489	147.53	155.49
2024		164.2961472	160.32	168.27
2026		177.0833455	173.11	181.06
2028		189.8705437	185.89	193.85
2030		202.657742	198.68	206.64
2032		215.4449403	211.47	219.42
2034		228.2321386	224.25	232.21
2036		241.0193369	237.04	245.00
2038		253.8065351	249.83	257.78
2040		266.5937334	262.62	270.57
2042		279.3809317	275.40	283.36
2044		292.16813	288.19	296.15
2046		304.9553282	300.98	308.93
2048		317.7425265	313.76	321.72
2050		330.5297248	326.55	334.51

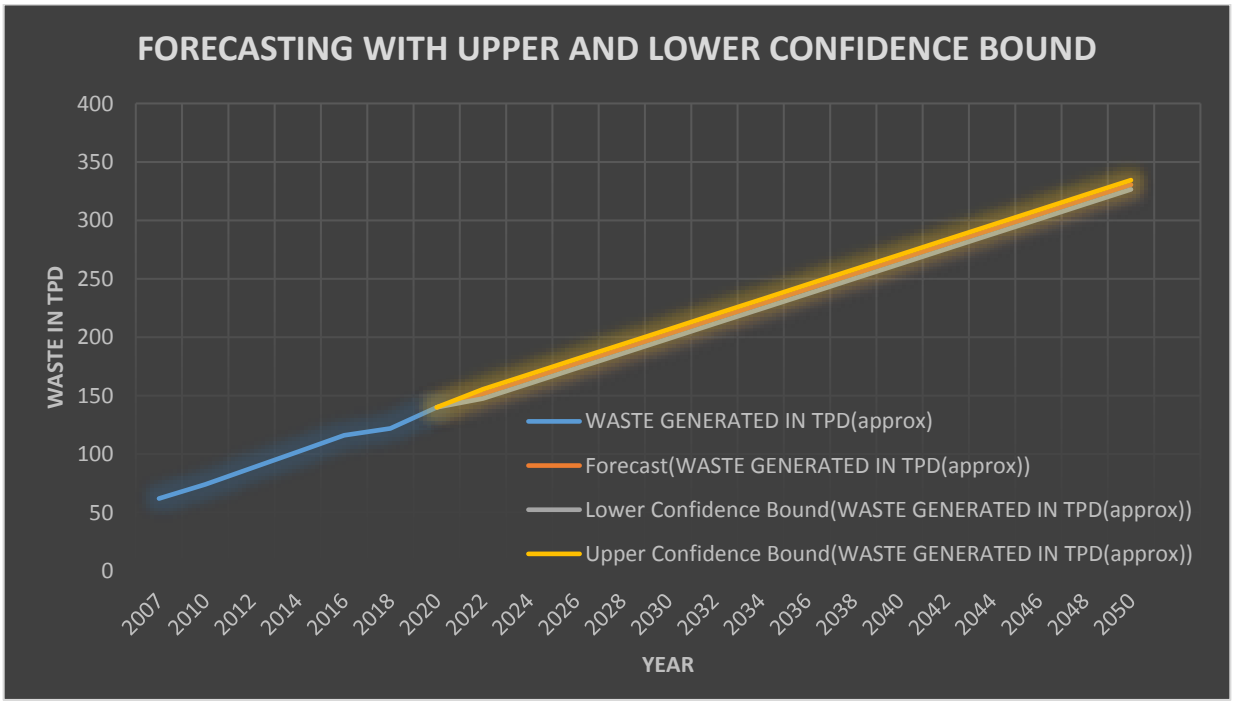


Figure 4.10: Graph showing the amount of Solid Waste produced per year by forecast function with lower and upper confidence bound

4.3.13 Analysis of Soil in the Siltara Region

Soil monitoring data are presented in Table 4.10.

Table 4.10: Different soil samples collecting places at Siltara

Sampling ID	Place	Latitude (°)	Longitude (°)
SIS 006	Dnrsiva	21.410833	81.671667
SIS 007	Dnrsiva	21.408333	81.673889
SIS 008	Sondra	21.361733	81.643329
SIS 009	Chorodh	21.388741	81.670211
SIS 010	Bada khet	21.397010	81.675085
SIS 011	Kundara	21.420067	81.668292
SIS 012	Kunra	21.429944	81.659819
SIS 013	Kunra marg	21.420374	81.666949
SIS 014	Kunra ganv	21.428262	81.660990
SIS 015	Mandhra village	21.352016	81.710451
SIS 016	Mandhra village 1	21.352293	81.716899
SIS 017	Mandhra village 2	21.357410	81.723670
SIS 018	Khushbu banjari	21.362370	81.727324
SIS 019	Dihan chowk	21.330237	81.676556
SIS 020	Borsi	21.323005	81.606076
SIS 021	Lata	21.358955	81.567138
SIS 022	Lata 1	21.349419	81.587232
SIS 023	Kumhi	21.364404	81.598539
SIS 024	Kumhi 1	21.349419	81.587232
SIS 025	Hardi talab	21.369660	81.651966
SIS 026	Barbandha	21.363290	81.731351
SIS 027	Barbandha1	21.358517	81.733061
SIS 028	Gidhauri	21.374508	81.725204
SIS 029	Naga ganv	21.380619	81.723827
SIS 030	Mohadi ganv	21.381034	81.717670
SIS 031	Nardha village	21.296820	81.749163
SIS 032	Apacheda road	21.302958	81.761512
SIS 033	Nardha	21.308373	81.773746
SIS 034	Chattaud	21.333694	81.793241
SIS 035	Khudmuda	21.448152	81.578661
SIS 036	Silghat	21.436106	81.587541
SIS 037	Hanuman mandir nardha	21.312674	81.780013
SIS 038	Pachedi village	21.318647	81.792052
SIS 039	Kruti main campus	21.294763	81.745099
SIS040	Bendri village	21.337848	81.596722
SIS041	Kandarka village	21.354154	81.586181
SIS042	Khudmuda	21.307719	81.596274

SIS043	Khudmuda road	21.438359	81.585859
SIS044	Silghat road	21.427531	81.590509
SIS045	Bhimbowri ganv	21.410821	81.594558
SIS046	Bhimbowri road	21.404846	81.602308
SIS047	Khudmudi village	21.396954	81.616997
SIS048	Khudmudi village (deosara)	21.397972	81.625889
SIS049	Munrethi village	21.388779	81.629821
SIS050	Charoda (bilaspur road)	21.392817	81.676196
SIS051	Charoda	21.386746	81.681665
SIS052	Mohadi village	21.386548	81.700523
SIS053	Siltara (industrial area)	21.385543	81.688471
SIS054	Chataud village	21.339681	81.793480
SIS055	Chataud village	21.345246	81.788693
SIS056	Jarauda nardha	21.351333	81.781681
SIS057	Saragaon village	21.356817	81.791395
SIS058	Chanda lake Industrial area	21.391210	81.655745
SIS059	Gon pharsaiwa road	21.396571	81.657087
SIS060	Gon pharsaiwa road 1	21.390228	81.671478
SIS061	Parastarwi	21.408740	81.658965
SIS062	Parastarwi ganv	21.405448	81.652623
SIS063	Kharun river	21.402925	81.642366
SIS064	Ram mandir	21.396838	81.637854
SIS065	Govt. H. S. School	21.385847	81.635771
SIS066	Sponge iron plant	21.383005	81.643606
SIS067	Bilaspur road	21.377747	81.667241
SIS068	Bilaspur bypass road	21.402079	81.672604
SIS069	Karna	21.420008	81.668055
SIS070	Shivnath Jagdambe School	21.421805	81.667028
SIS071	Tanu bartan bhandari	21.435008	81.657444
SIS072	Tanu bartan Bhandari 2	21.435008	81.657444
SIS073	Kurma marg	21.448893	81.683799
SIS074	Kurma marg road	21.465834	81.648527
SIS075	Govt nursery	21.329916	81.673958
SIS076	Girod goan	21.328317	81.683114
SIS077	Grampanchayt girod	21.332967	81.672505
SIS078	Dhaneli ring road	21.333112	81.660524
SIS079	Dhaneli ring road 3	21.329053	81.662268
SIS080	Dhaneli gaon	21.333112	81.660524
SIS081	Dhaneli ring road 1	21.344063	81.650254
SIS082	Kanhera	21.340967	81.646831
SIS083	Kanhera by pass road	21.334434	81.627654
SIS084	Kanhera	21.319927	81.603677
SIS085	Unnamed road	21.314940	81.607446
SIS086	Satnami para	21.371502	81.66686
SIS087	SHL siltara	21.374949	81.669082

SIS088	XGP kanhara	21.333199	81.617722
SIS089	Unnamed road	21.341151	81.621490
SIS090	Sankra road	21.341151	81.621490
SIS091	Kanhera road	21.364950	81.624230
SIS092	Kanhera	21.364950	81.624230
SIS093	D65 kumhari 1	21.367785	81.643406
SIS094	Bilaspur road	21.353463	81.690643
SIS095	Mandar	21.343852	81.698170
SIS096	P5R mandar	21.331348	81.699539
SIS097	Unnamed road	21.331348	81.699539
SIS098	Bhurkoni gaon	21.314189	81.703987
SIS099	B3V bhurkoni road	21.295113	81.707066
SIS100	Baroda road	21.311077	81.694749

4.3.14 Heavy Metals in Soil Samples Collected from Siltara

Soil samples were collected from different sampling stations of Siltara. Soil samples were dried initially in sunlight and processed for XRF analysis. Using XRF we found more than 20 metals in detectable condition. Collected data were tabulated and presented in graphical format in Figure 4.11 and 4.12. Soils from Siltara region are free from any toxic metals like Hg, Pd and As. Maximum percentage among all identified metals is iron (Fe) and found about 26%. Each and every metals present mainly in their oxide form, along with Silica (Si). Categorically this kind of soil is known as Laterite or red soil. We have collected both from of this type of soil in soil and rock conditions. Aluminium has also been found other Laterite component in small amount (about 4%) side by side. Rather than heavy metals other plant-fertilizing or plant growth promoting factors like N, P and K are also present is usual condition. Thus collected soil sample from different sampling stations of Siltara region are fertile and free from any human toxic metal. They are red Laterite soil.

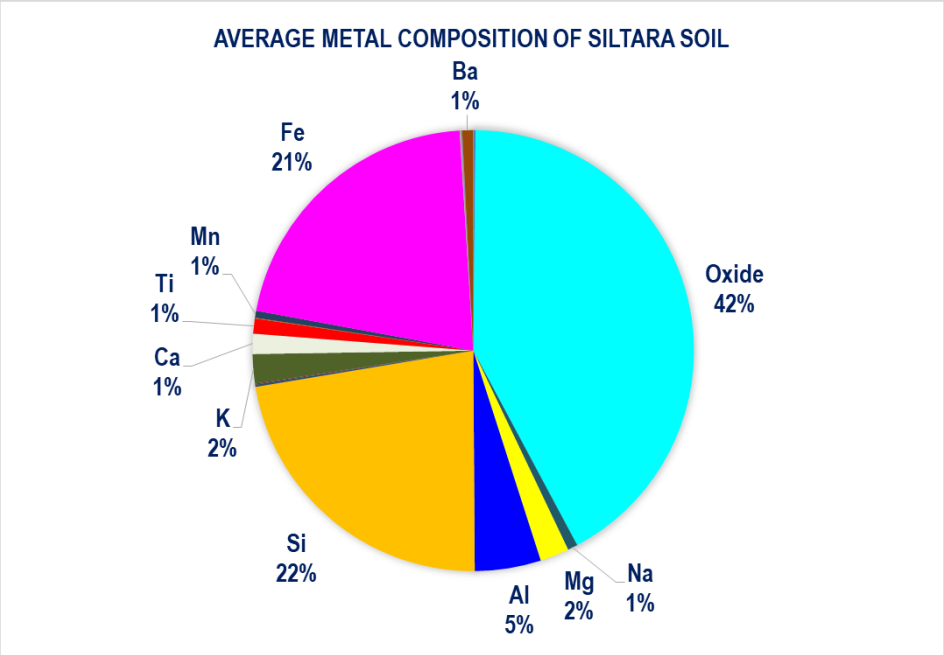


Figure 4.11: Mean metal percentile plot found for the Siltara soil samples.

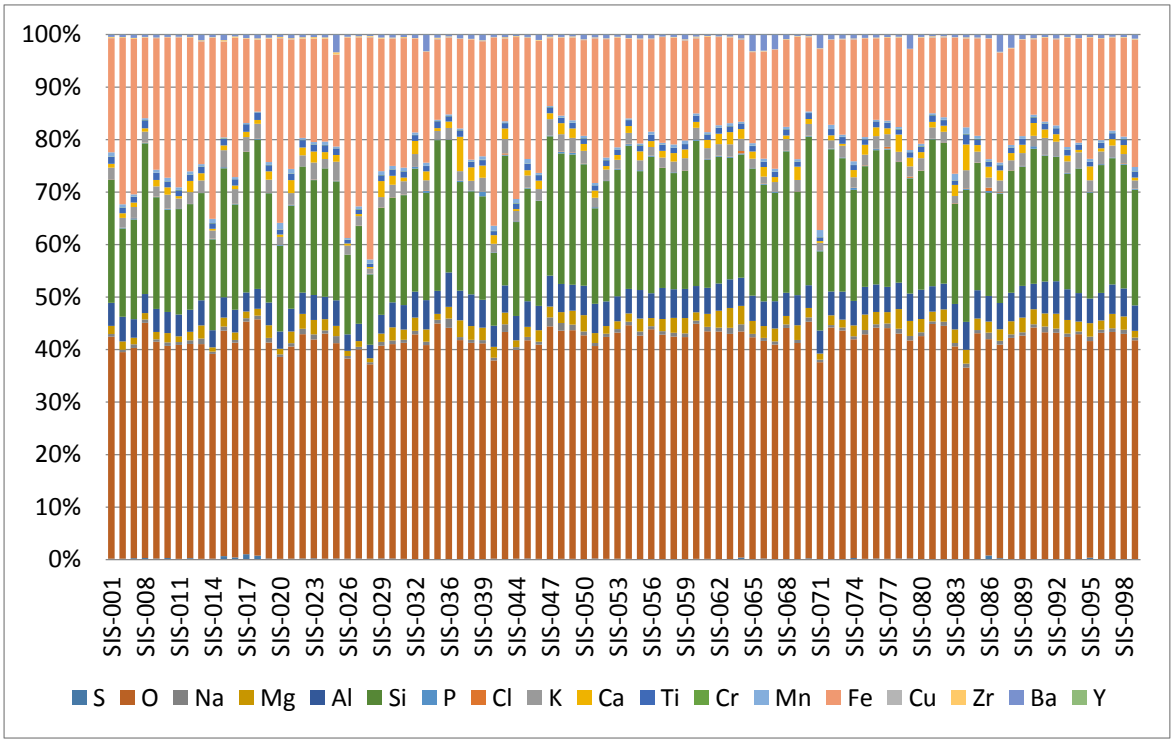


Figure 4.12: Station wise representation of metals composition in the Siltara soil samples

CHAPTER-V

NOISE ENVIRONMENT

5.1. Introduction

Sound can be measured in the air using a sound level meter, a device consisting of a microphone, an amplifier, and a time meter. Sound level meters can measure noise at different frequencies (usually A- and C-weighted levels).There are two settings for response time constants, fast (time constant = 0.125 seconds, similar to human hearing) or slow (1 second, used for calculating averages over widely varying sound levels). Sound level meter used in study.is shown in Figure 5.1.

Figure 5.1: Sound level meter used in this study.

Noise pollution is a significant environmental issue that can have detrimental effects on human health and well-being. It is crucial to measure and assess noise levels accurately to identify areas of concern and develop effective mitigation strategies. Sources of noise pollution include transportation systems (such as road traffic, aircraft, and trains), industrial activities, construction sites, recreational activities, and even household appliances. The negative impacts of noise pollution are diverse and far-reaching. Prolonged exposure to high noise levels can lead to physical and psychological health issues, including hearing loss, sleep disturbances, stress, hypertension, reduced cognitive performance, and impaired communication. Additionally, noise pollution can disrupt wildlife habitats, interfere with natural ecosystem functions, and disturb the balance of various ecosystems. To address the detrimental effects of noise pollution effectively, it is crucial to accurately measure and assesses noise levels in different environments. The purpose of this report is to present the findings of a study conducted on noise with following objectives:

i) To determine the relation between the noise levels and the traffic flow parameters namely vehicle flow (Q), Percentage of heavy vehicles (P), and the distance of measurement (d).

ii) To propose a mathematical or empirical relation satisfying all the functional parameters of the present study using Multiple Regression model

5.2. Methodology

For the noise level analysis of different location of Siltara city, we divided it in 4 zone Based on the Road passes through that location. For example: Urla Industrial Complex, Birgaon Urla Road, Budhwari Bazar, Birgaon, Urla Basti Birgaon. These location lies on Benbdri Road Hirapur to Urla, so taken them as zone 4 as Benbdri Road Hirapur to Urla & similar way for other zone. For each sample, the following parameters were simultaneously measured:

a) The quantity of cars, motorcycles, trucks and buses that have passed by the observer during the time interval of each measurement;

b) The equivalent and statistical levels in dB(A): L_{eq}, L_{10} and L_{90}, emitted by the traffic at a distance of 10 feet from the center of the nearest road band to the observer.

5.2.1 Equivalent Level (L_{eq})

The noise levels are variable over time, going up and down continuously, making it difficult to evaluate. To make things easier the equivalent level was defined as a continuous sound level that would produce the same effect on the human ear if compared to the actual noise observed during the measurement, with all the variations. So, the L_{eq} can substitute by a single value all the variations of the noise level.

L_{10}: It is the sound level exceeded in 10% of the measurement periods.

L_{90}: It is the sound level exceeded in 90% of the measurement period.

So, this value is often surpassed, being normally considered as the background noise level. To calculate L_{eq} "Griffiths and Langdon Method" was used as per the following equations:

$$\mathrm{Leq} = \mathrm{L_{50}} + 0.01(\mathrm{L_{10}} - \mathrm{L_{90}})^2 \quad (2.31)$$

$$\mathrm{L_{10}} = 61 + \log(\mathrm{Q}) + 0.15\mathrm{P} - 11.5\log(\mathrm{d}) \quad (2.32)$$

$$L_{50} = 44.8 + 10.8\,log(Q) + 0.12P - 9.6log(d) \quad (2.33)$$

$$L_{90} = 39.1 + 10.5\log(Q) + 0.06P - 9.3\log(d) \quad (2.34)$$

Where: P= Percentage of heavy vehicles

Q = Traffic volume in vehicles per hour

d = Distance from the observation point to center of the traffic lane in feet

5.2.2 Noise Pollution Level (NPL)

The Noise pollution level (NPL) can be calculated using L10, L50 and L90 values obtained previously and is based on a following mathematical equation:

$$NPL = L_{50} + (L_{10} - L_{90}) + \frac{(L_{10}-L_{90})^2}{60} \quad (2.35)$$

5.2.3 Mathematical Model for Basic Noise Emission Level

Since heavy vehicle is responsible for stronger noise than a light vehicle, a factor has been taken into account for such vehicles. In Calixto model by considering Q as real hourly vehicle flow, P as the percentage of heavy vehicles and n as weighting factor, Q_{eq} is given by following equation

$$Q_{eq} = Q\left(1 + n \times \frac{P}{100}\right) \quad (2.36)$$

And the term $10\log(Q_{eq})$ will be transformed into

$$L_{eq} = 10\log\left[Q\left(1 + n \times \frac{P}{100}\right)\right] \quad (2.37)$$

Weighting factor is calculated by using largest correlation coefficient between L_{eq} observed values and the factor given by above equation and found at n= 5

$$L_{eq} = 10\log\left[Q\left(1 + 5 \times \frac{P}{100}\right)\right] \quad (2.38)$$

Using the observed data, a new model with weighting factor n= 5 has been developed by calibrating Calixto model. Microsoft excel spread sheet has been used for estimating the values using above equation. The estimated values were then compared with observed values to get the regression equation as follows. Mathematically, this curve can be represented by:

$$y = a \times x + k \tag{2.39}$$

By applying the variables on the straight line equation, we get:

$$L_{eq} = a \times 10log[Q(1 + 5 \times \frac{P}{100})] \tag{2.40}$$

The values for the constants a and k, found after the statistical methods of linear regression had been applied, are: a = 2.28, k = 70.62. This way, the expression that mathematically represents the adjusted curve and can predict the equivalent levels for the road noise as:

$$L_{eq} = 2.28 \log\left[Q\left(1 + 5 \times \frac{P}{100}\right)\right] + 70.62 \tag{2.41}$$

5.3. Measurement of Noise Pollution

Noise levels of different locations are measured and present in Table 5.1.

Table 5.1: Noise monitoring data at different station in Siltara.

Sampling ID	Place	Latitude (°N)	Longitude (°E)	Noise level (dB(A))
SIN 001	Narsima Bus Stand	21.408056	81.669167	52.3
SIN 002	Charoda Chock	21.393889	81.671389	71.5
SIN 003	Charoda Chock	21.387778	81.670278	71.5
SIN 004	Satara Chock	21.344764	81.655398	71.5
SIN 005	(Industrial Rd) Nimahi Chock	21.359340	81.652534	67.3
SIN 006	Tereyachock	21.419666	81.675240	66.7
SIN 007	Santara(Highway)	21.634850	81.657670	73.3
SIN 008	Siltara Chowk	21.372249	81.667044	62.5
SIN 009	Vidhan Sabha Road	21.337259	81.650451	81.2
SIN 010	Barsari Chowk	21.314126	81.639334	77.8
SIN 011	Bhanpuri Chowk	21.295278	81.636112	76.3
SIN 012	Pachari Chowk	21.357475	81.686980	85.4
SIN 013	Siltara Chowk	21.363673	81.664364	70.3
SIN 014	Patharidi Chowk	21.339853	81.595581	70.9
SIN 015	Atari Ring Road	21.265317	81.566100	89.5
SIN 016	Tatibandh Chowk	21.259872	81.567533	96.9
SIN 017	Bhimbouri Chowk	21.377912	81.586110	58.3
SIN 018	Dhaneli Ring Road	21.334493	81.658669	73.2

SIN 019	Dhaneli Nala	21.33616291	81.65047648	70.8
SIN 020	Birgaon Urla Road	21.30627125	81.62838702	69.3
SIN 021	Budhwari Bazar	21.30627125	81.62838702	77.5
SIN 022	Rawbhata Block	21.30627125	81.628387	77.5
SIN 023	Urla Industrial Complex	21.3103315	81.60987892	68.7
SIN 024	Urla Basti Birgaon	21.315584	81.60898226	77.4
SIN 025	Birgaon	21.31508972	81.59617922	67.2
SIN 026	Guma 2	21.30584408	81.56528043	65.4
SIN 027	Sarara Road Urla	21.29336358	81.6131578	70.1
SIN 028	Sondra Chowk	21.35874302	81.64933927	60.3
SIN 029	Industrial Road	21.3663247	81.65052984	72.5
SIN 030	Sondra Industrial Road	21.37392816	81.63903095	74.6
SIN 031	Bohesar 2	21.37395449	81.63505928	68.6
SIN 032	Bohesar Chowk	21.38674031	81.6336486	64.5
SIN 033	G.R. Group Industry	21.37490911	81.65357493	70.1
SIN 034	Bilaspur Bypass	21.37197735	81.66636841	75.7
SIN 035	Sankara	21.37577069	81.6665772	63.1
SIN 036	SKS Colony Howk	21.38184124	81.65837962	76.3

Sound or noise monitoring done at several locations in Siltara is shown in Figure 5.2. The highest level of sound was found in SIN012, SIN015 and SIN016, which are above 85 dB(A). These areas are the one of the most crowded areas and heavy traffic area. The permissible limit for residential area at day time is 55 dB(A) and in commercial area it is 65 dB(A) and for industrial area it is 80 dB(A). As per the result we can clearly see it is way more than the limit. (Source: Noise Pollution (Regulation and Control) Rules, 2000 (ismenvis.nic.in)). The Hierarchy of Controls concept is often used to reduce noise in the environment or the workplace. Engineering noise controls can be used to reduce noise propagation and protect individuals from overexposure. When noise controls are not feasible or adequate, individuals can also take steps to protect themselves from the harmful effects of noise pollution. If people must be around loud sounds, they can protect their ears with hearing protection (e.g., ear plugs or ear muffs). Noise from roadways and other urban factors can be mitigated by urban planning and better design of roads. Roadway noise can be reduced by the use of noise barriers, limitation of vehicle speeds, alteration of roadway surface texture, limitation of heavy vehicles, use of traffic controls that smooth vehicle flow to reduce braking and acceleration, and tire design.

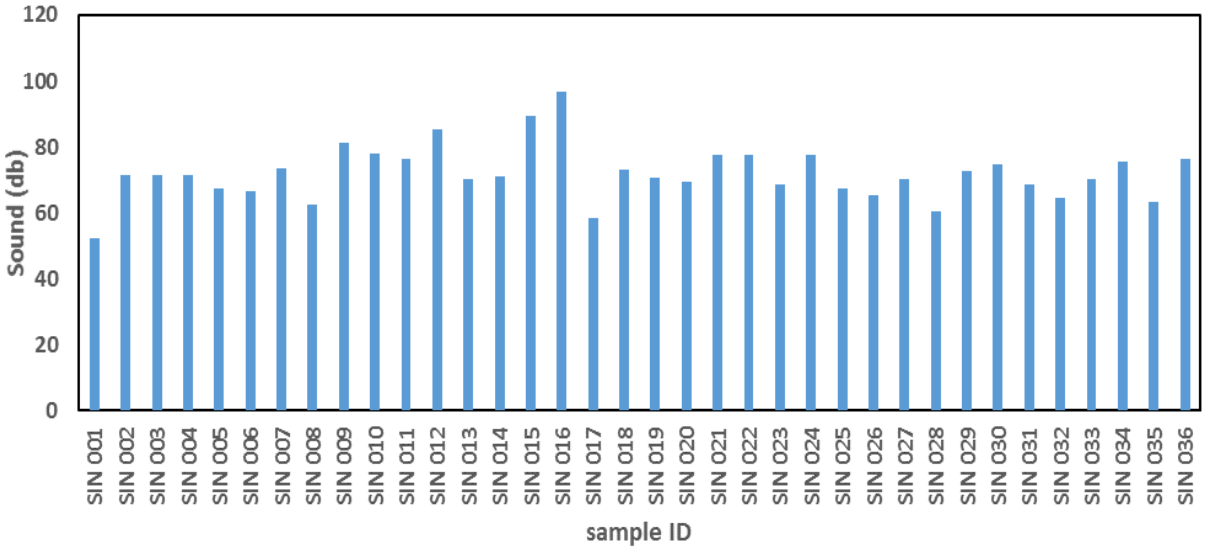


Figure 5.2: Sound level recorded at different monitoring stations at Siltara.

Moreover, to find the Equivalent noise level (L_{eq}) by using "Griffiths and Langdon Method" at various location in Siltara city. The data collected from various monitoring stations SIN001 to SIN036 is combined to form 4 zones based on the road passes through that location. For example Urla Industrial Complex, Birgaon Urla Road, Budhwari Bazar, Birgaon, Urla Basti Birgaon. These location lies on Benbdri Road Hirapur to urla so taken them zone 4 as Benbdri Road Hirapur to Urla. Similarly, other zone were formed taking into account different monitoring stations falling under them. Therefore, the list of different zones along with their road/ traffic junction is presented in Table 5.2. Furthermore, the comparison of observed L_{eq} with noise pollution level (NPL) of different zone is shown in Figure 5.3. The regression analysis of observed L_{eq} with calculated L_{eq} is depicted in Figure 5.4. For the validity of newly developed road traffic noise prediction model is then compared with observed values and the obtained values are shown in Table 5.2.

Table 5.2: Classification of different road network in Siltara city along with observed and calculated noise level in these zones.

Zone	Road Network /Traffic junction	Total No. of Vehicles/hour (Q)	Percentage of Heavy Vehicles (P)	Observed (L_{eq}) (dB(A))	Calculated (L_{eq}) (Db(A))
1	Ring Road 2 Tatibandh to Bhanpuri Road	2516	26.86804	79.18	78.30
2	Road No. 30 Raipur Bilaspur Express	4360	14.72477	76.86	79.48
3	Road No 130 B Pandari to Semariya Road	3646	4.223807	75.03	77.46
4	Benbdri Road Hirapur to Urla	186	12.90323	64.17	66.17

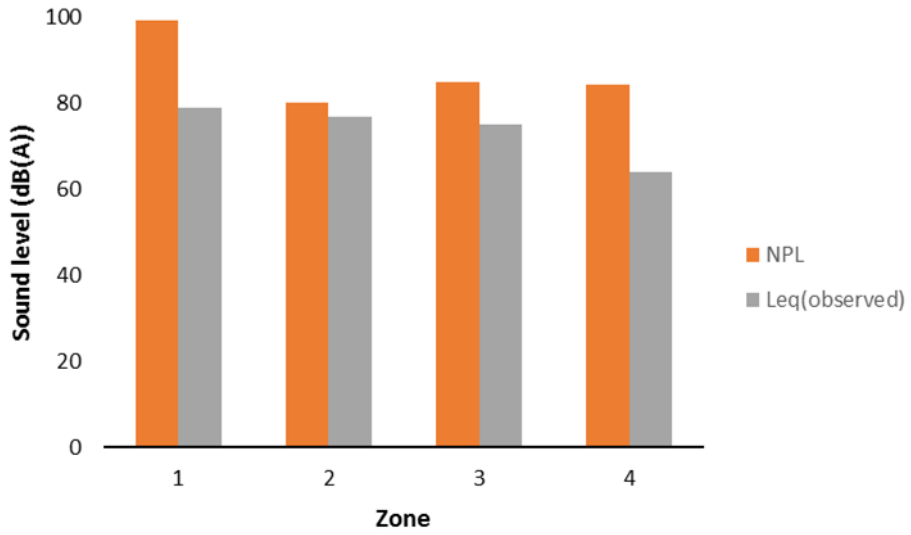


Figure 5.3: Comparison of averaged L_{eq} with Noise Pollution level (NPL) of different zone in Siltara.

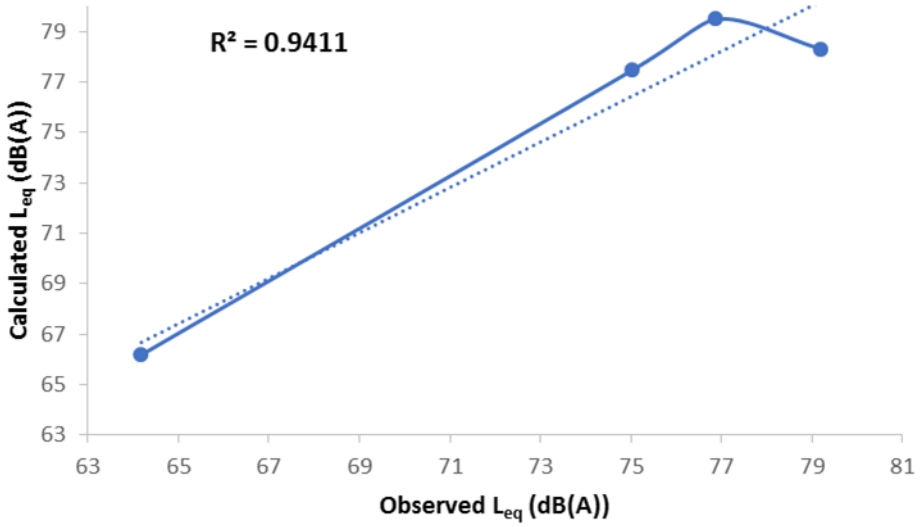


Figure 5.4: Comparison of observed L_{eq} with calculated L_{eq} sound level in the Siltara region.

The scatter plot for model validation is shown in Figure 4.58 has coefficient of determination (R^2) of the 45^0 line is 0.9411. Thus, the equation used for estimating the traffic noise levels for Indian condition is giving comparable result as with the observed values. R^2 of 1.0 is considered to be the best fit, where as any value above 0.7 is considered to be good. Therefore, the model developed in the present report can be used for noise prediction for an existing busy highway or a proposed new highway. Hence, using Calixto model a weighting factor is calculated that represents weightage of heavy vehicles over average noise emission level and using regression analysis to correlate the different traffic parameters a new road transportation noise prediction model is developed for Indian

conditions. From Figure 4.47, the highest Noise pollution level (NPL > 90) is observed at Zone 1. This consist of Ring Road 2 Tatibandh to Bhanpuri Road. Moreover, from Figure 4.57, it can be seen that for most of the locations the noise readings are within the prescribed limits of 80 dB(A) except for places near heavy traffic area and construction areas. It clearly indicates that most of the data are well acceptable for future planning of industrial development. However, the locations where the noise level exceeds its limit need attention to minimize the noise level.

5.4 Delineation of Source Specific Noise Management Plan to minimize the Impact of Noise and Vibration

The following measures may be taken care:

1. The condition of roads in traffic junctions is not good and need proper maintenance, which reduce the horn used by automobiles.
2. The use of horn needs to be minimized if the road is made two lane with dividers.
3. Plantation on either side of road will result in absorption of sound pressure and minimize the propagation of noise.
4. The construction and transport vehicles should use the silencer and maintenance of the goods truck is essential.
5. In industrial areas, where the limit exceeds the 80 dB(A), should wear air plugs to avoid any health concern.

CHAPTER-VI

BIOLOGICAL ENVIRONMENT

6.1. Assessment of Biological Environment

6.1.1 Flora and Fauna in Siltara

Most of the area covered under plantation of Khair (*Acacia catechu*), Amla (*Phyllanthus emblica*) and Anjan (*Hardwikia binata*). Few patches of old plantations of Anjan (*Hardwikia binata*) and Eucalyptus (*Eucalyptus sp*.) can also be observed. Other associated tree species are Bel (*Agele marmelos*), Arjun (*Terminalia Arjuna*), Karra (*Cleistaethus collinus*), Mahua (*Madhuca indica*), Tendu (*Diospyros melan oxylon*) etc. Which provides a substratum for various bird's nests, for many insects and butterfly. Species like *Azadirachta indica*, *Phyllanthus embilica*, *Madhuca longifolia* provides the food base for various faunal species. Mesophytic species like *Argemone maxicana*, *Bauhinia malabarica*, *Ziziphus mauritina*, *Calotropis procera* also mark their presence.

During the survey it was also found that plant species like *Acacia auriculiformis*, *Dendrocalamus strictus*, *Ficus religiosa*, *Butea monosperma*, *Diopyros malanoxylon* etc. accounts for good litter fall in the region this is turn will enrich the soil with nutrients in the long course of time during the decay processes. Other shade and avenue tree species like *Anthocephalus cadamba*, *Hardwickia binata*, *Azadirachta indica*, etc. Also mark their prescence. In addition to the flora, alluring aquatic species like *Nymphaea pubescens*, *Utricularia aurea*, the letter being aquatic carnivorous plant, are also present. Many other herb, shrub and aquatic species are found plenty in the area. Different herbs and shurbs found in Siltara are shown in Table 6.1. Moreover, different tress, grases and sedge found in Siltara are shown in Table 6.2 and different medicinal plants are shown in Table 6.3.

Table 6.1: Different herbs and shrubs found in Siltara

Sr. No.	Scientific name	Local Name	Family	Plant form
1.	*Agave sisalana [Perr.]*	Sisal Agave	*Agavaceae*	Shrub
2.	*Alternanthera sessilis [L.]*	Guroo	*Amaranthaceae*	Herb
3.	*Blumea sp. DC.*	Kakronda	*Compositae*	Herb
4.	*Tridax procumbens [L]*	Khal-muriya	*Compositae*	Herb
5.	*Exacum [L.]*	Persian violet	*Gentianaceae*	Herb
6.	*Ziziphus jujuba [Lamk.]*	Jujube	*Rhamnaceae*	Shrub/ Tree

7.	*Ziziphus mauritina [Lamk.]*	Ber	*Rhamnaceae*	Shrub/ Tree
8.	*Ziziphus oenoplia [L.]*	Makoya	*Rhamnaceae*	Shrub
9.	*Lantana camara [L.]*	Putus/ Kuri	*Verbenaceae*	Shrub
10.	*Crotolaria spectabilis [Roth.]*	Dhandhani	*Papilionaceae*	Shrub
11.	*Phoenix acaulis [Buch.]*	Bhui chhind	*Arecaceae (Palmae)*	Shrub
12.	*Ammania multiflora [Roxb.]*	Many Flowered Ammannia	*Lythraceae*	Herb
13.	*Hyptis suaveolens [L.]*	American Mint	*Labiatae*	Shrub
14.	*Eriocaulon quinquangulare [L.]*	Pipeworts	*Eriocaulaceae*	Grass
15.	*Jatropha gossypifolia [L.]*	Ratanjoti	*Euphorbiaceae*	Shrub
16.	*Caesulia axillaris [Roxb.]*	Pink Node Flower	*Compositae*	Herb
17.	*Calotropis procera [Ait.]*	Akua	*Asclepiadaceae*	Shrub
18.	*Ipomea carnea [L.]*	Beshram	*Convolvulaceae*	Shrub
19.	*Merremia emarginata [Burm.f.]*	Musakani	*Convolvulaceae*	Creeping Herb
20.	*Sphaeranthus indicus [L.]*	Gorakhmundi	*Compositae*	Herb
21.	*Calotropis gigantea [L.]*	Aak	*Asclepiadaceae*	Shrub
22.	*Croton bonelandianum [Baillon.]*	Jungle tulsi	*Euphorbiaceae*	Herb
23.	*Lippia javanica [Burm.f]*	Spreng	*Verbenaceae*	Shrub
24.	*Dendrocalamus strictus [Roxb.]*	Baans	*Gramineae*	Shrub with Woody Culms

Table 6.2: Different tress, grasses and sedge found in Siltara

Sr. No.	Scientific name	Local name	Family	Plant form
1	*Acacia catechu [L.]*	Khair	Leguminosae sub. fam. Mimosoideae	Tree
2	*Acaia auriculiformis [A. Cunn.]*	Earleaf acacia	Leguminosae sub. fam. Mimosoideae	Tree
3	*Acacia nilotica [L.] Wild. Ssp. Indica [Benth.]*	Baloon	Leguminosae sub. fam. Mimosoideae	Tree
4.	*Aegle marmelos [L.]*	Bel	*Rutaceae*	Tree
5.	*Eragrostis tenella [L.]*	Canegrass	*Gramineae*	Grass
8.	*Azadirachta indica [A. Juss.]*	Neem	*Meliaceae*	Tree
9.	*Anthocephalus cadamba [Miq.]*	Kadamb	*Rubiaceae*	Tree
11.	*Bahunia variegata [L.]*	Kachnar	*Caesalpiniaceae*	Tree
12.	*Bahunia racemosa [L.]*	Phalesa	*Caesalpiniaceae*	Tree
13.	*Bahunia pupurea [L.]*	Koliari	*Caesalpiniaceae*	Tree
14.	*Blumea sp. DC.*	Kakronda	*Compositae*	Herb
15.	*Phyllanthus emblica [L.]*	Aonla	*Euphorbiaceae*	Tree
16.	*Eucalyptus lanceolatus*	Nilgiri	*Myrtaceae*	Tree
17.	*Gmelina arborea [Roxb.]*	Khamhar	*Verbenaceae*	Tree
18.	*Hardwickia binata [Roxb.]*	Anjan	*Leguminosae sub. fam.Caesalpiniaceae*	Tree
19.	*Heteropogon contortus [L.]*	Sukla ghass	*Gramineae*	Grass
20.	*Madhuca longifolia [koen.]*	Mahua	*Sapotaceae*	Tree
21.	*Mangifera indica [L.]*	Aam	*Anacardiaeae*	Tree
22.	*Psidium guajava [L.]*	Bihi	*Myrtaceae*	Tree
23.	*Terminalia belleirica [Gaertn.]*	Bahera	*Combretaceae*	Tree
25.	*Tectona grandis [L.]*	Sagon	*Verbenaceae*	Tree

26.	*Ficus religiosa [L.]*	Peepal	*Moraceae*	Tree
.	*Ficus racemosa [L.]*	Gular	*Moraceae*	Tree
29.	*Panicum sp. [L.]*	Panicgrass	*Gramineae*	Grass
37.	*Bridelia squamosa [l.]*	Kasai	*Euphorbiaceae*	Tree
38.	*Terminalia tomentosa [Wt. & Arn.]*	Saja	*Combretaceae*	Tree
40.	*Phoenix sylvestris [L.]*	Khujuri	*Arecaceae (Palmae)*	Tree
41.	*Diopyros melanoxylon [Roxb.]*	Tendu	*Ebenaceae*	Tree
42.	*Pterocarpusmarsupiun [Roxb.]*	Bija	*Papilionaceae*	Tree
43.	*Cleistanthus collinus [Benth.]*	Karra	*Euphorbiaceae*	Tree
45.	*Butea monosperma [Lamk.]*	Palas	*Papilionaceae*	Tree
47.	*Pennisetum pedicellatum [Trin.]*	Dinanath Grass	*Gramineae*	Grass
48.	*Annona squamosa [L.]Cult.*	Shareefa/ Sitafal	*Annonaceae*	Tree
49.	*Scirpus articulatus [L.]*	Grassweed	*Cyperaceae*	Sedge
50.	*Eriocaulon quinquangulare [L.]*	Pipeworts	*Eriocaulaceae*	Grass
51.	*Scirpus juncoides [Roxb.]*	Sedge	*Cyperaceae*	Sedge
52.	*Cyperus procerus*	Prosea	*Cyperaceae*	Sedge
57.	*Mimusops elengi [L.]*	Maulsari	*Sapotaceae*	Tree
61.	*Mitragyna parviflora [Korth.]*	Mundi	*Rubiaceae*	Tree
63.	*Ficus benghalensis [L.]*	Bar	*Moraceae*	Tree

Table 6.3: Different medicinal plants found in Siltara

Sr. No.	Scientific name	Local name	Family	Plant form
1.	*Asparagus racemosus*	Satawar	*Asparagaceae*	Medicinal herb
2.	*Phyllanthus emblica*	Anwala	*Phyllanthaceae*	Medicinal herb
3.	*Curculigoorchioides*	Kali mauli	*Hypoxidaceae*	Medicinal herb
4.	*Chlorophytum borivilianum*	Safed mauli	*Asparagaceae*	Medicinal herb
5.	*Andrographis paniculata*	Bhul neem	*Acanthaceae*	Medicinal herb
6.	*Tinospora cordifolia*	Glloy	*Menispermaceae*	Medicinal herb
7.	*Aegle marmelos*	Bael	*Rutaceae*	Medicinal herb
8.	*Boerhaviadiffusa*	Punwana	*Nyctaginaceae*	Medicinal herb
9.	*Semecarpus anacardium*	Bhelwa	*Anacardiaceae*	Medicinal herb
10.	*Phyllanthus niruri*	Bhul anwala	*Phyllanthaceae*	Medicinal herb
11.	*Terminalia chebula*	Harra	*Combretaceae*	Medicinal herb
12.	*Ocimumtenuiflorum*	Tuali	*Mints*	Medicinal herb
13.	*Terminalia bellirica*	Baheda	*Combretaceae*	Medicinal herb
14.	*Hellenia speciosa*	Koekand	*Zingiberaceae*	Medicinal herb
15.	*Curcuma amada*	Amhaldi	*Zingiberaceae*	Medicinal herb
16.	*Senegalia catechu*	Khair	*Legumes*	Medicinal herb
17.	*Senna tora*	Charota bhaji	*Fabaceae*	Medicinal herb
18.	*Euphorbia hirta*	Dudhi asthama plant	*Euphorbiaceae*	Medicinal herb
19.	*Vachellianilotica*	Babul	*Fabaceae*	Medicinal herb
20.	*Cuscutareflexa*	Amar bhel	*Convolvulaceae*	Medicinal herb

Green Sarpagandha Medicinal Plant

Rudraksha Plant

***Eriocaulon aquaticum* (Common Pipewort)**

***Eucalyptus globules* (Nilgiri)**

***Acacia catechu* (Khair)**

***Ipomoea aquatica* (water morning glory)**

Figure 6.1: Different flora growing in the Siltara.

Table 6.4: Different aquatic plants growing in the Siltara

Sr. No.	Scientific name	Local name	Family	Plant form
1.	*Butomopsis lanceolata [Kunth.]*	Butomopsis	*Butomus*	Aquatic Plant
2.	*Ipomoea aquatica [Forsk.]*	Water Morning Glory	*Convollvulaceae*	Aquatic Plant
3.	*Vallisneria spiralis [Amt.]*	Aquarium plant	*Hydrocharitaceae*	Aquatic
4.	*Utricularia aurea [Lour.]*	-	*Lentibulariaceae*	Aquatic
5.	*Polygonum glabrum [Willd.]*	Golden bladderwort	*Polygonaceae*	Aquatic
6.	*Nymphaea rubra [Roxb.]*	Lal ratalu	*Nymphaceae*	Aquatic Plant
7.	*Nymphaea pubescens [Willd.]*	Safed ratalu	*Nymphaceae*	Aquatic Plant

Asparagus racemosus (satawar)

Tinospora cordifolia (Giloy)

Brown Ashwagandha

Mahua Plant

Figure 6.2: Different flora growing in the Siltara.

The migratory birds are common in winters some of the species are Common Green Shank (*Tringa nebularia*), Common Sandpiper (*Actitis hypoleucos*), Wood Sandpiper (*Tringa glareola*) etc. In mammals, most frequently observed species are Thre-striped Palm Squirrel (*Funambulus palmarum*), common Indian Flying Fox (*Pteropus giganteus*), Indian Hare (*Lepus nigricollis*) etc. Most commonly found reptiles are Brahminy Worm Snake (*Ramphotyphlops braminus*), Indian Rat Sanke (*Ptyas mucosa*), Bengal Monitor Lizard (*Varanus bengalensis*), Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Gaur (*Bos gaurus*), Sambhar (*Cervus unicolor*), Chital, Nilgai (*Boselaphustragocamelus*) and Wild Boar (*Sus scrofa*). Major wildlife species include blue bull, Chinkara, black buck, Sambhar, Barking Deer, wild dog, wild boar, jackals, hyena, and crocodiles etc.

Table 6.5: Occurrence of different fauna in Siltara

Sr. no.	Scientific name	Local name	Family
1.	*Sus scrota (Linnaeus)*	Wild Boar ; Suar, Barba,	*Suidae*
2.	*Axis axis (Erxleben)*	Spotted Deer, Axis Deer ; Chital	*Cervidae*
3.	*Cervus unicolor (Kerr)*	Sambar (Eng.); Sambhar	*Cervidae*
4.	*Muntiacus muntjak (Zimmermann)*	Indian Muntjak, Barking Deer, Rib-faced Deer	*Cervidae*
5.	*Gazella bennett;; (Sykes)*	Indian Gazelle, Chinkara	*Bovidae*
6.	*Felis chaus*	Jungle cat	*Felidae*
7.	*Vulpes vulpes*	Fox	*Canidae*
8.	*Pythonidae*	Python	*Pythonidae*
9.	*Varanus Merrem*	Monitar lizard	*Varanidae*
10.	*Naja naja*	Cobra	*Elapidae*
11.	*Pholidota*	Pangolins	*Manidae*
12.	*Chamaeleo zeylanicus*	Indian chameleon	*Chamaeleonidae*
13.	*Semnopithecus*	Langur	*Colobinae*
14.	*Erethizontidae*	Porcupine	*Erethizontidae,*
15.	*Canis aureus*	Jacakal	*Canidae*

16.	*Pteromyini*	Flying squarriel	*Sciuridae*
17.	*Hyaena hyaena*	Striped hyenas	*Hyaenidae*
18.	*Tetracerus quadricornis*	Chausingha	*Bovidae*
19.	*Antilope cervicapra*	Black buck	*Bovidae*
20.	*Melursus ursinus*	Sloth bear	*Ursidae*
21.	*Daboia russelii*	Russell viper	*Viperdae*
22.	*Python molurus*	Inian rock python	*Pythonidae*
23.	*Indotyphlops braminus*	Brahminy Worm Snake	*typhlopidae*

Galloperdix spadicea (Red spur fowl)

Ardeidae (Heron)

Naja naja (Cobra)

Hyena

***Melursus Ursinus* (Sloth bear)**

Figure 6.3: Different wild animals found in the Siltara

6.1.2 Wild life sanctuaries and avifauna in the Siltara region

During the survey 12 species of Mammals, 18 species of reptiles, and 76 species of birds were found in the region. This region's land is covered in a mass forest of about 370 ha. The state of Chhattisgarh has 3 national parks and 11 wildlife sanctuaries. Its housing of some rare species of floras and fauna .The area harbours different migratory and resident birds, mammals and reptiles. Some of the resident birds are white Eye Buzzard (*Butastur teesa*), Rose Ringned Parakeet (*Psittacula krameri*), Plum Headed Parakeet (*Psittacula cyancephala*), Indian Eagle Owl (*Bubo bengalensis*) etc. The migratory birds are common in winters some of the species are Common Green Shank (*Tringa nebularia*), Common Sandpiper (*Actitis hypoleucos*), Wood Sandpiper (*Tringa glareola*) etc. In mammals, most frequently observed species are Thre-striped Palm Squirrel (*Funambulus palmarum*), common Indian Flying Fox (*Pteropus giganteus*), Indian Hare (Lepus nigricollis) etc. Most commonly found reptiles are Brahminy Worm Snake (*Ramphotyphlops braminus*), Indian Rat Sanke (*Ptyas mucosa*), Bengal Monitor Lizard (Varanus bengalensis), Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Gaur (*Bos gaurus*), Sambhar (*Cervus unicolor*), Chital (*Axis axis*), Nilgai (Boselaphustragocamelus) and Wild Boar (Sus scrofa).Major wildlife species include blue bull, Chinkara, black buck, Sambhar, Barking Deer, wild dog, wild boar, jackals, hyena, and crocodiles etc. Following are some of the wildlife sanctuary and national parks which contains vast diversity in wildlife and avifauna.

Achanakmar Wildlife Sanctuary

Of all the Wildlife Sanctuaries in Chhattisgarh, the Achanakmar Wildlife Sanctuary boasts of a rich fauna. Some of the animals that can be spotted here include wild animals such as Leopard, Blackbuck, Chital, Tetracerus quadricornis or four-horned antelope, Wild Boar, Wild Bear, Canis aureus jackal, Indian wild dog Cuon alpinus, sloth bear Melursus ursinus, nilgai Boselaphus tragocamelus, striped Hyaena, Tiger Panthera, Chinkara, Chital Axis axis, and others

Barnawapara Wildlife Sanctuary

Barnawapara Wildlife Sanctuary is one of the premium and significant wildlife sanctuaries in Chhattisgarh. Established in July, 1976 the sanctuary with an area of 24466 ha .The sanctuary falls within the Biogeographic Zone of Deccan Peninsula with Tropical Dry Deciduous Forests. The chief wildlife include Sloth Bear, Tigers, Flying Squirrels, Four - horned Antelopes, Jackals, Leopards, Black Buck, Chinkara, Jungle Cat, Porcupine, Barking Deer, Monkey, Striped Hyena, Bison, Wild Dogs, Sambar, Chital, Nilgai, Muntjac, Gaur, Wild Boar, Python, Cobra to name a few. Barnawapara Wildlife Sanctuary also has a considerable bird population with well-known being the Bulbul, Parrots, White -

rumped Vultures, Lesser Kestrels, Green Avadavat, Peafowl, Racket - tailed Drongos, Wood Peckers, Herons and Egrets to name few.

Indravati National Park

Indravati National Park is the most famous and finest wildlife parks of Chhattisgarh. Indravati National Park is situated in Dantewada district, Chhattisgarh. The Park draws its name from Indravati River, with the entire area of roughly 2799.08 sq km. There are also prosperous patches of exceptional grasslands providing a great deal of fodder to Wild buffalos, Barking Deer, Chital, Gaurs, Nilgai & other herbivores of the park. The most frequently found trees are Lendia, Teak, Salai, Tendu, Mahua, Semal, Ber, Jamun and Haldu. Major wildlife comprises of the rare Wild Buffalos, Tigers, Barasinghas, Leopards, Nilgai, Gaurs Sambar, Sloth Bear, Chausingha Dhole, Striped Hyena, Chausingha, Muntjac, Flying Squirrel, Wild Boar, Porcupine, Pangolins, Langurs and Monkeys among many others. The frequently found reptiles are Freshwater Crocodile, Indian Chameleon, Monitor Lizard, Common Krait, Cobra, Russell's Viper and Indian Rock Python to name a few.

Udanti Sanctuary

Situated in Siltara, Chhattisgarh, the Udanti Wildlife Sanctuary is a small but significant wildlife sanctuary in the district. Recognized in the year 1983 under Wildlife Protection Act, 1972, Udanti Sanctuary covers an area of roughly 232 sq km. The wildlife found in Udanti Sanctuary comprises of Wild Buffalos, Tigers, Panthers, Chital, Chinkara, Four - horned Antelopes, Black Buck, Nilgai, Sambar, Jungle cat, Sloth bear, Barking Deer, Gaur, Porcupine, Wild dog, Monkey, Bison, Jackals, Striped Hyena, Cobras, Fox, Pythons etc. Udanti Sanctuary also has a considerable population of birds with well - known being the Bulbul, Parrots, Peafowl, Egrets, Racket - tailed Drongos, Heron, Lesser whistling Teal, Magpie robin, Pintail, Herons and Rollers to name few.

Kanger Ghati National Park

Situated amidst the 34 kilometer long and picturesque Kanger Valley, Kanger Valley National Park is one of the most fine-looking and quaint national parks of India Major Wildlife of Kanger Valley National Park are the Leopards, Tigers, Mouse Deer, Chital, Wild Cat, Sambar, Jackals, Barking Deer, Langurs, Sloth Bear, Rhesus Macaque, Flying Squirrel, Striped Hyena, Wild Boar, Rabbits, Cobra, Pythons, Crocodiles, Snakes and Monitor Lizards to name a few. The avian fauna comprises of Hill Myna, Red Jungle Fowls, Spotted Owlet, Racket - tailed Drongos, Parrots, Peacocks, Steppe Eagles, Phakta, Red Spur Fall, Bhura Teeter, Heron and Tree Pie among many others.

6.1.3 Terrestrial and Aquatic Ecosystem of Siltara

Though, not much of research and documentation of existing flora and fauna in these wetlands has been done in the State, but preliminary documentation done in major rivers by ZSI and few domestic ponds of the State by the IGAU, Siltara does provide an insight into the diverse aquatic flora and fauna in these wetlands. The numerous rivers, streams. drains, ponds and ditches harbour a number of water-loving species, in and around it, and these are generally grouped together as aquatic plants. However, the exact interpretation or circumscription of this group is debatable since there are numerous border- line species which grow both in marshy lands and water, and still others which grow in drains and ditches, which are temporarily filled during rains. The 85 species mentioned below have been choosen as aquatic in a more strict sense and have been classified into six categories on the basis of their general habit. The wetland hydrophytes, pretty large in number, have been excluded.

I. **Free-floating Bydrophytes:**
   - *Azolla pinnata*
   - *Wolffia globosa*
   - *Lemnaperpusil!a*
   - *Spirodelapolyrhiza*
   - *Pitia stratiotes*
   - *Trapa natans var. bispinosa*
   - *Eichhornia crassipes*

II. **Suspended submerged Bydrophytes :**
   - *Ceratophyllumdemersum,*
   - *Utricularia aurea*
   - *U. exoleta.*

III. **Anchored submerged Bydrophytes:**
   - *Polypleurumstylosum*
   - *Myriophyllumoliganthum*
   - *Blyxaaubertii*
   - *B. octandra*
   - *Hydrilla verticillata*
   - *Vallisneria natans*
   - *Nechamandra alternifolia*

- *Cryptocoryneretrospiralis*
- *Najasgraminea*
- *N. indica*
- *Aponogeton crispus,*
- *Potamogeton crispus*
- *P. mucronatus*
- *P. pectinatus*

IV. Anchored Hydrophytes with Floating shoots :

- *Neptunia oleracea*
- *Ludwigiaadscendens*
- *Ipomoea aquatica*
- *Alternan- thera philoxeroides*
- *Hygroryzaaristata*
- *Cyperus platystylis*

V. Anchored Hydropbytes with Floating leaves:

- *Marsilea minuta,*
- *Nelumbo nucifera,*
- *Nymphaea pubescens,*
- *N. nouchali,N. rubra,*
- *Nymphoideshydrophylla,*
- *N. indica,*
- *OtteliaalismoidesMonochorla vaginalis,*
- *Sagittariaguayanensis ssp.lappula*
- *Caldesia parnassifolia*
- *Tenagocharislatifolia*
- *Aponogetonnatans*
- *Potamogetonnodosus.*

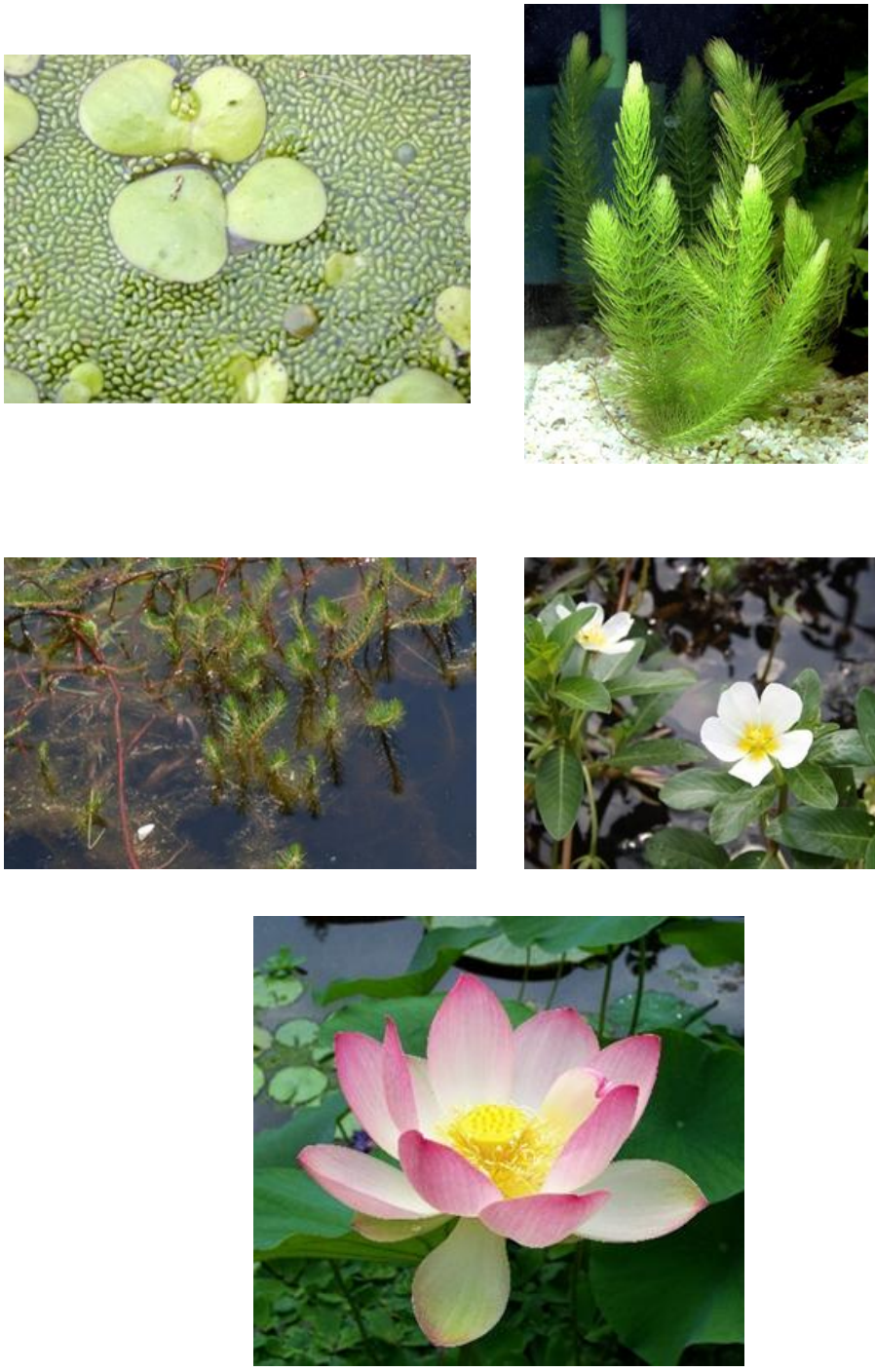


Figure 6.4: Different hydrophytes found in aquatic ecosystem of Siltara.

Table 6.6: Different fishes found in Indravati, Vardia and Kumhari rivers

Sl. No.	Scientific name	Local name	English name
1.	*Notopterus notopterus* (Ham.)	Patola	Feather back
2.	*Notopterus Chitala* (Hamilton)	Patola	Humped feather
3.	*Labeo rohita* (Ham- Buch)	Rohu	Rohu
4.	*Labeo boga* (Bloch)	Lohi	Boga Labeo
5.	*Hypophthalmichthys molitrix*	Silvar carp	Silvar carp
6.	*Arichtisthys nobilis* (Bloch)	Bighead	Big head
7.	*Ctenopharyngodon idella*	Grass carp	Grass carp
8.	*Cyprinus carpio* (Linn)	Carpio	Common carp
9.	*Puntius sarana* (Ham-Buch)	Kotra	Olive barb
10.	*Puntius sophore* (Ham.)	Kotri	Stigma barb
11.	*Puntius ticto* (Ham)	Kotri	Ticto barb
12.	*Amblypharyngodon mola* (Ham)	Mohroli	Mola carplet
13.	*Catla catla* (Ham.)	Katla	Catla
14.	*Cirrhinus mrigala* (Ham.)	Mrigal	Mrigal
15.	*Cirrhinus reba* (Ham)	Borai	Reba carp
16.	*Parluciosoma daniconius* (Ham-Buch)	Dandai	Blackine Rasbora
17.	*Danio devario* (Ham.-Buch.)	Amac-haini or Kotri	Devario danio
18.	*Ompok bimaculatus* (Bloch)	Bolia	Butter cat fish
19.	*Wallago attu* (Schneider)	Padhin	Fresh water shark
20.	*Mystus seenghala* (Sykes)	Tengra	Gaint river cat fish
21.	*Eutropiichthys vacha* (Ham-Buch)	Bachra	Vacha
22.	*Pangasius pangasius* (Ham.)	Pagaj	Pangash
23.	*Heteropneutes fossilis* (Bloch)	Singhi	Stinging cat fish
24.	*Clarias batrachas* (Linn.)	Mangur	Air breathing cat fish
25.	*Clarias gariepinus*	Thailand magur	North Africa Catfish
26.	*Chanda nama* (Ham.)	Chan-deni	Glassy perchlet
27.	*Chanda ranga* (Ham.)	Chan-deni	Glassy perchlet
28.	*Oreochromis mossambicus* (Peters)	Tilapia	Mozambi-que tilapia
30.	*Oreochromis niloticus* (Linnaeus)	Tilapia	Nile tilapia
31.	*Anabas testudineus* (Bloch)	Kimi	Climbing perch
32.	*Anabas oligolepis* (Bleeker)	Kinni	Gangetic koi
33.	*Colisa fasciatus* (Bl. & Schm).	Gourami	Bandel colisa
34.	*Glossogobius giuris* (Ham)	Dheshra	Bareyed goby

6.1.4 Impact of Industries on Flora and Fauna in Siltara

Industrialization is essential to meet up upcoming demands of evolution. All the industrial activity releases some amount of by-products as pollution into the environment. The iron and steel industry is one of the major heavy industries of Chhattisgarh and is considered resource-intensive and pollution prone and added pollution to air, water resources, and precious land. In central India, many of the integrated iron and steel industry is highly polluting, non-compliant and resource-inefficient. It found a thick layer of grey dust coating trees and pathways, and noted that the factories stored iron ore and waste in the open; these are carried away by the wind.

A recent spread in developmental activities, urbanisation, and addi-tional land acquirements for farming and grazing etc. are resulting in severe damage to natural habitats, thus threatening the very survival of several species. The necessity of conserving these and others that are being over-exploited for their miscellaneous utilities is now well recognised. Various Organisations like the International Union for Conservation of Nature and Natural Resources (IUCN), the National Committee on Environmental planning and Coordination (NCEPC) and the National Committee on Man and Biosphere (MAB) are interested in a listing of species threatened With extinction and measures for their conservation it may be emphasised that in a country like India where the flora is insufficiently known, the number of Botanic Gardens are limited, and the masses are not yet awakened to the needs of conservation

6.1.5 Rare and Endangered species in the Region

Plants

- Tree fern (*Cyatheales*)
- As safed musli (*Chlorophytum borivilianum*)
- Kali Haldi (*Curcuma Coesia*)
- Van Haldi (*Curcuma Aromatic*)
- Tikhur (*Curcuma Angestifolia*)
- Kalihari (*Gloriosa Superb*)
- Sarpgandha (*Rouwalfia Sarpentina*)
- Kalmegh (*Andrographis Paniculata*)

Animals

Wild Buffalo *(Babulus babulis arnee)*, the state animal Of Chhattisgarh The State's forests and biodiversity face a number of threats from agriculture, industrial and urban expansion, unsustainable collection of fuel wood, harvesting of medicinal plants and Non-timber forest products (NTFPs), diversion of forest lands for non-forestry purposes, and grazing.

Birds

- Cinereous Vulture (*Aegypius monachus*)
- Laggar Falcon (*Falco jugger*)
- Pallid Harrier (*Circus macrourus*)
- Black-bellied Tern (*Sterna acuticaud*)
- River Tern (*Sterna aurantia*)
- Curlew Sandpiper (*Calidris ferruginea*)
- Black-tailed Godwit (*Limosa limosa*)
- Eurasian Curlew (*Numenius arquata*)
- River Tern (*Sterna aurantia*)
- Curlew Sandpiper (*Calidris ferruginea*)
- Black-tailed Godwit (*Limosa limosa*)
- Eurasian Curlew (*Numenius arquata*)
- Himalayan Griffon (*Gyps himalayensis*)
- Indian Vulture (*Gyps indicus*)
- White-rumped Vulture (*Gyps bengalensis*)
- Red-headed Vulture (*Sarcogyps calvus*)
- Bristled Grassbird
- Chaetornis striata

6.1.6 Measures for Protection and Conservation of Biodiversity

Flora

a) Introduction of Grass species since they are drought tolerant and can colonize fast in low nutrient soil due to the presence of fibrous roots.
b) Plant more native plants.
c) Long term plans like Forest fire protection plan.

d) Development of Wetland habitat.
e) Monitoring of conservation and management action plans and continued updation whenever required.

Fauna including Wildlife

a) To collect and survey all the information about wildlife, especially, their number and growth.
b) To protect habitat by protecting forests.
c) To delimit the areas of their natural habitat.
d) To protect wildlife from pollution and from natural hazards.
e) To impose complete restriction on hunting and capturing of wildlife.
f) To impose restrictions on export and import of wildlife products and severe punishment to be given to those who indulge in this activity.
g) To make special arrangements to protect those species whose number is very limited.

Migratory Avi-fauna

a) Fostering bird-friendly farmland.
b) Reduce your plastic food print.
c) Protect birds from cats.
d) Keep your woods wild.
e) Making renewable energy bird-safe.
f) Ending illegal bird killing by changing attitudes.

Rare and Endangered Species

a) Learn about endangered species in this area.
b) Create a backyard wildlife habitat. Put bird feeders and other wildlife attractants, such as bird houses and baths.
c) Minimize use of herbicides and pesticides.
d) Do not buy plastic products.
e) Don't litter and destroy sensitive habitats, which may be home to native/visiting species that are endangered or threatened.
f) Never purchase products made from endangered species.

Medicinal Plants

***In-situ* conservation**

a) Conservation of a given species in its natural habitat or in the area where it grows naturally is known as in-situ conservation.
b) It includes Gene bank / Gene sanction, Biosphere reserves, national parks, sacred sites, Sacred grooves etc.
c) It is only in nature that plant diversity at the genetic, species and eco-system level can be conserved on long-term basis.
d) It is necessary to conserve in distinct, representative biogeographic zones inter and intra-specific genetic variation.

***Ex-situ* Conservation**

Conservation of medicinal plants can be accomplished by the ex-situ i.e., outside natural habitat by cultivating and maintaining plants in botanic gardens, parks, other suitable sites, and through long term preservation of plant propagules in gene banks (seed bank, pollen bank, DNA libraries, etc.) and in plant tissue culture repositories and by cryopreservation).

6.1.7 Green Belt Development Plan

Greenbelt means planting of special type of plants suitable to that particular agroclimatic zone and soil characteristics in a place which will make the area cooler, reduce air pollution, prevent soil erosion and further improve the soilfertility status. A green belt around the periphery of boundary and road side will be created to avoid erosion of soil, prevention of landslides, minimize the air pollution and noise pollution in the project area. The green plants are capable of absorbing air pollutants and forming sinks for pollutants. Leaves with their vast area in a tree crown, absorb pollutants on their surface, effectively reducing their concentration and noise level in the ambient.

6.1.8 Selection of Plant Species for Green Belt Development

The selection of plant species for the development depends on various factors such as climate, elevation and soil. The plants would exhibit the following desirable characteristics in order to be selected for plantation.

1. The species should be fast growing and providing optimum penetrability.

2. The species should be wind-firm and deep rooted.
3. The species should form a dense canopy.
4. As far as possible, the species should be indigenous and locally available.
5. Species tolerance to air pollution like SO_2 and NO_2 should be preferred.
6. The species should be permeable to help create air turbulence and mixing within the belt.
7. There should be no large gaps for the air to spill through.
8. Trees with high foliage density, leaves with larger leaf area and hairy on both the surfaces.
9. Ability to withstand conditions like inundation and drought.
10. Soil improving plants (Nitrogen fixing rapidly decomposable leaf litter).
11. Attractive appearance with good flowering and fruit bearing.
12. Bird and insect attracting tree species.
13. Sustainable green cover with minimal maintenance.
14. The species should be perennial and evergreen.
15. The trees should maintain regional ecological balance and conform to soil and hydrological conditions. Indigenous species should be preferred.

6.1.9 Native Plants for Afforestation

Biogeographically, the state falls in Deccan bio-region comprising representative fauna and flora .The recorded forest area in the state is 59,772 km2 which is 44.21 of its geographical area. Reserved, Protected and Unclassed Forests constitute 43.13%, 4021% and 16.65% of the total forest area respectively. Dantewara has maximum forest cover while janjgir-champa has lowest forest cover. The forests of the state fall under two major forest types, i.e., Tropical Moist Deciduous forest and the Tropical Dry Deciduous forest. The state of Chhattisgarh is endowed with about 22 varied forest sub-types existing in the state.

Tropial Moist Decidous Forests (Sal Forests)

These forests are found in areas of moderate rainfall of 100 to 200 cm per annum, mean annual temperature of about 27°C and the average annual relative humidity of 60 to 75 per cent. Found in southern part of Chattisgarh. The trees of these forests drop their leaves for about 6-8 weeks during the spring and early summer when sufficient moisture for the leaves is not available. The sub-soil water is not enough to enable the trees to retain their leaves throughout the year. These are very useful forests because they yield valuable timber and several other forest products. The main species found in these forests are , sal, padauk, laurel, white chuglam, badam, dhup, chikrosi, kokko, haldu, rosewood,

mahua, bijasal, lendi, semul, irul, dhaman, amla, kusum, tendu, paula, jamun, bamboo, etc. It is comparatively easy to exploit these forests due to their high degree of gregariousness.

Tropical DryDecidous Forests (Teak Forests)

These are similar to moist deciduous forests and shed their leaves in dry season. The major difference is that the species of dry deciduous forests can grow in areas of comparatively less rainfall of 100-150 cm per annum. They represent a transitional type; on the wetter side, they give way to moist deciduous and on the drier side they degenerate into thorn forests. Such forests are characterised by closed and rather uneven canopy, composed of a mixture of a few species of deciduous trees, rising upto a height of 20 metres or so. Enough light reaches the ground to permit the growth of grass and climbers. Bamboos also grow but they are not luxuriant. The important species are teak, axlewood, tendu, bijasal, rosewood, amaltas, palas, haldu, kasi, bel, lendi, common bamboo, red sanders, anjair, and harra.

Mixed Forests

The maximum Chattisgarh Forests and Vegetation are covered is that of mixed forests, which includes teak or sal mixed with other species like saja, bija, lendia , haldu ,dhaora , salai , aonla , amaltas , gamhar , etc. Dazzling white kulu trees scattered around stand out conspicuously among the various hues of green. The ground is covered with maze of grasses, plants, bushes and saplings. Pterocarpusmarsupium is also used for control of blood sugar in Diabetes since ancient times in India.

6.1.10 Environmental Management Plan for Biodiversity

From the study it has concluded that due to the development activities in the past decade there has been a great deal of deforestation as shown in the classified satellite landuse maps prepared using Remote Sensing Technology. Studies have shown that there has been a decrease in the vegetation cover of Siltara. Measures to reduce the extent of deforestation and promote afforestation have been identified with the help of 'Environmental Impact Assessment Reports' of various mining companies. According to the land conditions many native species have been identified for plantation and greenbelt development and mitigatory measures were taken. Delineation of appropriate environmental management programme plan for development of 'Green Cover' in the study region has done based on government policies and environmental impact assessment reports. Following are the points needs to be focused for the Environmental Management Plan for Biodiversity:

1. An updated management plan has to be prepared for all the sanctuaries.
2. Wild ungulates need large tract of undisturbed forest with grassy opening preferably with moist and marshy patches and perennial water. This need be ensured in all management applications and disturbance factors should not be ignored.
3. The possibility of shifting forest villages from the sanctuary need be explored as it will be good for wild ungulates.
4. There should be restriction on the number of livestock and these should be fed rather than allowed to graze freely in the forest.
5. The water tanks that have been made for wild ungulates must be kept free from human and livestock disturbances.
6. Cultivation of fodder in the wasteland may be initiated to minimize the grazing pressure.
7. All the domestic cattle around the sanctuary must be inoculated every year to minimize spreading of contagious diseases.
8. Eco-development programme should be taken up in the buffer area of the sanctuaries to reduce the biotic pressure and shifting of the inhabitants by providing alternatives.
9. Forest corridor around the sanctuaries need to be strengthened.
10. The interface conflicts within the sanctuary need be monitored regularly.
11. The local inhabitants should be involved in several management activities of the sanctuary leading towards conservation of nature.
12. Man-made forest fire during summer has been reported to be a common feature. Due to lack of proper anti fire measures, lot of habitat is getting destroyed. Proper measures may be initiated to protect the habitat for better survival of the wild ungulates.

CHAPTER-VII

CONCLUSION AND ACTION PLAN

7.1 Conclusion

A comprehensive carrying capacity including source apportionment study has been carried out within a radius of 15 km from the centre of CPA Siltara. This assimilative capacity with respect to air, water, land, noise, biological and socio-economic component of environment assess the current situation and provide appropriate management plan for the sustainable development of this region. Air environment has been monitored at 17 sampling stations in the Siltara region during summer, winter, and pre/post monsoon seasons. The highest PM level were found in S08, S10, S13, and S16 as the main reason could be the nearby industries and transport sources. Moreover, the highest $PM_{2.5}$ level were found in S10, S12 and S16 as it is very heavily traffic area and there nearby locations constructions are also going on The PM_{10} and $PM_{2.5}$ can be originated from anthropogenic sources mainly from industry, natural and transport sources. PM_{10} sources are classified as mechanically generated aerosol originated from windblown dust, emission, volcanoes, plant pollen, rock blasting in mining zone etc. while $PM_{2.5}$ are complex particulate matters because of size and nature of formation. The $PM_{2.5}$ particles can grow in size because of chemical conversion of gases to low volatility vapors over primary particles. Monsoon rains are the major factor for low concentration of particulate matter during July to September as rain shower washes out them efficiently. The enormous biomass burning especially during night time in winter days due to the use of combustible goods like wooden blocks, fire wood and cow dung cake as bonfire in the open space by the people to keep themselves warm in winter season, resulting in significant quantities of ashes in the atmosphere. So the highest PM levels were found in winter followed by summer and lowest in monsoon. The final outcome of the assessment with regard to the range of Supportive Carrying Capacity of the ambient air environment in Siltara, shows that there is no supportive carrying capacity and the pollution load in terms of PM_{10}, is exceeding the Assimilative Carrying Capacity.

The SO_2 values observed at these stations are well within the NAAQS limit of 80 µg/m^3 but the stations S10 and S05 that is mainly because of alloy industry and other industries. Furthermore, the NO_2 variation in different seasons are within the limit of 80 µg/m^3. However high concentration were found in S10 and S13. The main reason for it could be the nearby industry such as wood and others as the main cause of NO_2 in air because of vehicles, power plant, and industrial emission etc. In Siltara carbonaceous particulate matters are mainly organic and may come from open or uncontrolled burning. Peoples' awareness about environment pollution and protection is very essential to control this carbon pollution. We have found OC values ranges from 0.35 µg/m³ to 0.61 µg/m³ among all air quality monitoring stations. Similarly, we have found TC values ranging from 0.71 µg/m³ to 0.139 µg/m³

among all air quality monitoring stations. Carbonaceous compounds are mainly organic or house hold type in Siltara's non-industrial as well as non-traffic stations. Due to higher OC in the ambient air, the amount of CO_2 and related pollution gradually increases. In Siltara carbonaceous particulate matters are mainly organic and may comes from open or uncontrolled burning. Peoples' awareness about environment pollution and protection is very essential to control this carbon pollutionIn case of Siltara sampling stations, VOCs values were found decreasing day by day with the change of seasons (winter to summer). In winter, average VOCs value has been found as 18.739 μg/m^3 and in summer it has been decreased to 16.476 μg/m^3.

Ambient air of Siltara's sampling stations contain Cu, Fe, Ni, Cr, Zn, Pb, Cd and As in detectable amount but in very low level. Fe, Zn and Cr were found in high concentration (in μg/m^3) while Pd, As and Cd found in ng/m^3 range. Interestingly, seasonal variations don't effect in the metal ion concentrations of Siltara air. But overall condition has been quite below from the limit level as denoted by CPCB, India. Fe and Zn are found main two ions and only these two are varies up and down. These particulate matters emission have been studies through Receptor Modelling (CMB) in every season. Sources Apportionment Assay predicts that ambient air pollution in Siltara is generally decreasing with season (winter to summer) while industrial resources related emission increases. Major emission sources are industrial resources and different types of constructions (e.g., industrial, non-industrial, domestic, road constructions, etc.) PM emissions from these types of sources are huge and concentration in ambient air going beyond the human tolerance level.

Ultimate prediction by Receptor Model (CMB) is, pollution levels are gradually decreasing in summer than winter. Traffic and domestic emission sources contribution are decresed but higher emission has been found in both industrial resources and open burning sections. The level of pollution can vary depending on the location, sources of pollution and local weather patterns. However, in general, winter tends to have higher levels of air pollution compared to summer in many regions, particularly in urban areas. During the winter months, people tend to use more heating sources, such as wood-burning stoves, fireplaces, and gas-powered heating systems, which can release pollutants such as particulate matters, carbon monoxide, and nitrogen oxides into the air. Additionally, cold weather and stable atmospheric conditions can lead to temperature inversions, which trap pollutants close to the ground and can cause pollution to accumulate. Weather patterns play a significant role in the seasonal change of pollution. During the winter months, cold air can trap pollutants close to the ground, making it harder for them to disperse. Human activities such as heating, transportation, and industrial processes can also contribute to the seasonal changes in pollution levels. For example, in the

winter months, people tend to use more heating sources, which can release pollutants into the air. During the summer months, there is often more traffic on the roads, which can lead to higher levels of pollution. Agricultural practices such as crop burning and fertilizer use can also contribute to seasonal changes in pollution levels. For example, in the spring months, farmers may burn crops to clear fields, which can release smoke and particulate matter into the air. Air pollution tends to be more severe during the winter months when there is less ventilation, and people rely more on heating sources such as wood-burning stoves, fireplaces, and coal-fired power plants. This is particularly true for areas that experience temperature inversions, which occur when warm air sits on top of a layer of cooler air, trapping pollutants close to the ground.

Furthermore, the spatial distribution of SO_2, NO_x, SPM, CO and HC from main industrial point sources, line sources and area sources of Siltara was modelled using AERMOD software. The proposed study is an attempt towards better understanding on the nature of the air pollution within the developing industrial region. The simulation results can help the policy makers to identify the areas of high pollution exposure risk for the EIA guidelines. From the AERMOD modelling result hotspot are obtained which have high concentration of pollutants. For point sources modelling, SPM hotspot are found to be Hatbandh and Mandhar with maximum concentration 24-h obtained as 57.81 µg/m^3. SO_2 hotspot are obtained as Bendari and Donde Khurd with maximum concentration 24-h 61.85 µg/m^3. NO_x hotspot found to be Bendari, Bana-2, Jarauda, Mandhar, Tor, Donde-Khurd and near above Barauda with maximum concentration 24-h of 49.88 µg/m^3. For the line sources modelling, several roadways, highways, and traffic junctions are considered with emissions from different types of vehicles namely; trucks/dumpers, buses, two-wheeler, four-wheeler Maximum concentration 24-h of SPM pollutant obtained as 26.92 µg/m^3 with hotspot near by Guru Ghasidas Chowk. For the area source modeling, we have considered different garbage dumping yard, stone crushers zones in the Siltara city. Here hotspot is found to be Hatbandh with SPM concentration 24-h of 219.82 µg/m^3. Evidently, the findings of this study can facilitate and assist the local government authorities in managing the ambient air quality. Moreover, this study shows that the AERMOD model can be applied to environmental impact assessment management

Another critical environmental receiving component is water which is essential to sustain the living being in any region. The sampling of various water resources (surface and ground) is done at 102 locations within Siltara. Five parameters i.e. Temperature, pH, salt, TDS, conductivity is measured and salt and TDS value are very high in almost all the samples. Conductivity of these sample ranges from 300 to 1000 (µs/cm). Moreover, hardness in all the samples is within the limit except for samples except

these four sample i.e. SIW14, 10, 6, and 8 whose values are more than 180 mg /l.COD level is within the limit of 200 mg/l. COD level is within the limit of 200 mg/l. DO level was found within 10 mg/l. However high alkalinity is good for health but within the limit. BOD level were found above the limit. Subsequently, water environmental carrying capacity assessment values for comprehensive environmental water carrying capacity shows a decreasing trend. Therefore, the proper management planning is needed for long term use and further industrial development. The comprehensive value is 0.783 in 2021, it falls to 0.618 in 2033. At 2045 it reaches the value of 0.416 after that it crosses the normal comprehensive value and goes to the poor comprehensive value. Thus till 2045 whatever the industrial and people activities that are present does not affect the environment significantly, but after that it starts to affect the environmental water carrying capacity highly. Therefore, we need to take appropriate steps to maintain the value in normal range or else in upcoming years it can fall to poor values.

Furthermore, the land pollution and waste generated in Siltara are also analysed. Currently, the urban solid wastes coming from houses, small scale industries and market in Siltara are dumped nearby a village in Sarona in the vicinity of Kharun River. LULC mapping of Siltara has been done to calculate the best possible utilization of land present/ available for better planning and policy making. In Siltara, 18.32% of land is forest cover which account to 129.43 sq. km. The industries occupy the 2.86% of land that is 20.21 sq. km. However, great portion of land is being utilized for different purposes. Residential, transportation, commercial, public & semi-public areas land use will keep rising while the industrial land use would certainly decrease due to the environmental concerns and shifting in future from Siltara industrial arae. Subsequently, the short and long term plan for hazardous, e-waste, municipal, and industrial waste have been proposed and discussed. Subsequently, assimilative capacity of the land environment was estimated which predicted 215 TPD of waste will be generated by 2033. Moreover, the Soil of Siltara analyzed through XRF by collecting it from 100 sampling stations. Maximum percentage among all identified metals is iron (Fe) and found about 26%. Each and every metals present mainly in their oxide form, along with Silica (Si). Aluminium has also been found other Laterite component in small amount (about 4%) side by side. Rather than heavy metals other plant-fertilizing or plant growth promoting factors like N, P and K are also present is usual condition. Thus collected soil sample from different sampling stations of Siltara region are fertile and free from any human toxic metal. They are red Laterite soil.

The noise pollution was measure at 36 monitoring station in Siltara. The highest level of sound was found in SIN012, SIN015 and SIN016, which are above 85 dB(A). These areas are the one of the

most crowded areas and heavy traffic area. Moreover, to find the Equivalent noise level (L_{eq}) by using "Griffiths and Langdon Method" at various location in Siltara city. The highest Noise pollution level (NPL > 90) is observed at Zone 1. This consists of Ring Road 2 Tatibandh to Bhanpuri Road. Moreover, it can be seen that for most of the locations the noise readings are within the prescribed limits of 80 dB(A) except for places near heavy traffic area and construction areas. It clearly indicates that most of the data are well acceptable for future planning of industrial development. However, the locations where the noise level exceeds its limit need attention to minimize the noise level. Furthermore, the biodiversity in Siltara region was also analyzed through field survey. This shows different flora and fona in the region. There are some adverse effect of the increasing environmental pollution on these biodiversity. However, measures like afforestation and preserving of wetlands are the mesure which are needed to conserve the biodiversity of Siltara. Altogether, the assimilative capacity of all the component of environment namely, air, water, land, noise, biological and socio-economic are thoroughly analysed and estimated. The result shows within range values of the obtained parameters. However, there are certain areas where there is an urgent need for policy making and government intervention. Therefore, in this regard a detailed environmental management plan is presented in the subsequent section.

According to the above studies on different types of environment (air, water, land and noise), it may be concluded that both PM_{10} and $PM_{2.5}$ loads in Siltara industrial area are above the limit. Both PM_{10} and $PM_{2.5}$ carrying capacities are negative. But CMB studies predicts that industrial, road dust and transports emissions are mainly responsible for negative air carrying capacity of this city. Therefore, there are scopes for setting up new industries, provided State Government take appropriate plan to reduce other sources like; road dust and transports emission.

7.2 Delineation of Environmental Management Plans (EMP)

On the basis of baseline data of different environmental components, identification, prediction and evaluation of impact, appropriate strategies needs to be formulated for each environmental components for minimization of adverse impact. The following are the components and appropriate management plans.

Table 7.1: Action plans

Source group	Action	Responsible agency	Timeline	Expected budget	Priority
Vehicles	Restriction on using more 15 years old in the industry premises	Individual Industry	6 months	-	High
	Regular checking of vehicular emission and issue of pollution under control certificate	Transport Department and Police Department	Regular	-	High
	Periodic calibration test of vehicular emission monitoring instrument	Transport Department	After every 6 months		High
	Good traffic management including redirection of traffic movement to avoid traffic congestion	Transport Department and Police Department	6 months		High
	Promotion and operationalization of E-rickshaw	Transport Department and Urban Administration and Development	12 months		
	Monitoring on vehicle fitness	Transport Department	6 months		High
	Checking of fuel adulteration	Food and Civil Supply Department / Oil Companies	Immediate		High
	Restriction on overloading of vehicles	Transport Department	6 months		Medium
Road dust	Identification of main roads in Siltara industrial area and making	CSIDC/ Construction	24 months	5 Cr	High

	pucca / concreted drain to drain	companies			
	Regular cleaning of road dust in the industrial and commercial cluster.	CSIDC/ CGPWD/ Urban Administration and Development/NHAI/ Panchayat and Rural Development Department / Construction companies	As and when needed	10 lakhs	High
	Water spraying on roads through tankers in the polluted cluster.	CSIDC / CGPWD/ Urban Administration and Development /NHAI/ Panchayat and Rural Development Department	As and when needed	25 lakhs	Medium
	Maintenance of road to avoid dust emission	CSIDC / CGPWD/ Urban Administration and Development /NHAI/ Panchayat and Rural Development Department	As and when needed	5 Cr	High
	Plantation /green belt development in open areas, garden parks /community places, schools and housing societies.	Concern Government Department / Urban Administration and Development / Construction companies / Industrial Units/ Panchayat and Rural	24 months	2 Cr	Medium

		Development Department/ CECB			
	Plantation /green belt development in open areas of Siltara industrial area.	CSIDC/ Industrial Units/ Sponge Iron Association / Construction companies	24 months		Medium
	Introduction of water fountain /water mist /fogging system at major traffic intersection	Urban Administration and Development / CSIDC/ Construction companies / Panchayat and Rural Development Department	12 months	25 lakhs	Medium
Construction activities	Covering of construction site	Urban Administration and Development/ Town and Country Planning Department / CSIDC	As and when needed	-	High
	Transportation of construction materials like sand ,soil, stone chips etc. in covered system	Transport Department and Police Department	As and when needed	-	High
	Restriction on storage of construction material along the road	Urban Administration and Development / Town and Country Planning Department / CSIDC/ Panchayat and Rural	6 months	-	High

		Development Department			
Biomass and garbage burning	Restriction on open burning of municipal solid waste , biomass, plastic horticulture waste etc.	Urban Administration and Development/ CSIDC/ Panchayat and Rural Development Department	6 months	-	High
	Transportation of municipal solid wastes, construction material and debris in covered system	Urban Administration and Development/ Panchayat and Rural Development Department	6 months	-	Medium
	Ensuring promotion and use of cleaner fuel for commercial purposes like local dhabas/ eateries.	District Administration / Oil Companies	6 months	12 lakhs	Medium
	Attempt may be done for generation of electricity by mechanized digester system and separation of other recyclable materials	Municipalities and PHE	48 months	20 Cr.	Low
Industries	Ensuring installation and effective operation of pollution control devices, ensuring emission standards in industries and taking stringent action against violating industries	CECB	12 months	-	High
	Control of fugitive dust emission from industries • Assessment of installed bag filters by third party and up-gradation / modification of bag filter as per requirement in sponge iron plant, power	All Industries / CECB	As and when needed	25 lakhs	High

	plant and ferro alloys plant.				
	• Minimizing the height of raw materials/ coal/ solid wastes drop to the stockpile and ensuring water spray system	All Industries / CECB	6 months	10 lakhs	Medium
	• Use of water spray system/ dust suppression system/ chemical fog system/ rain guns in crusher, coal crusher, ground hopper/ screen, raw materials, fuel, solid wastes storage areas and yards and handling / conveying system	All Industries / CECB	12 months	50 lakhs	Medium
	• Storage of solid wastes from pollution control system like bag filter/ scrubber in pucca and covered area and ensuring environmentally safe disposal of these wastes through transportation in covered vehicles.	All Industries / CECB	6 months	-	Medium
	• Ensuring transportation of iron ore, sponge iron, coal, fly ash, washed coal / reject coal in covered vehicle.	All Industries / CECB	6 months	-	Medium
	• Ensuring short time storage of solid waste within premises and regular disposal in environmentally safe manner.	All Industries / CECB	12 months	-	Medium
	• Ensuring properly maintained pucca internal roads. Ensuring regular cleaning of dust and water sprinkling on internal roads through fixed sprinklers/ water tankers.	All Industries / CECB	As and when needed	10 Cr	High
	• Use of mechanized sweeping machine at integrated steel plants sponge iron plant and power plants.	All Industries / CECB	As and when needed	50 kakhs	Medium

	Increasing the height of all stacks attached to emission sources such as auxiliary process equipment/ bag filter/ scrubber to minimum 30 meter.	All Industries / CECB	6 months	50 lakhs	Medium
	Ensuring use of all treated effluent within plant premises and no discharged outside the premises of any effluent. Ensuring no mixing of any treated / untreated effluent from industries in any nala/ Kharun river.	All Industries / CECB	3 months	-	High
	Provision of wind breaking wall, installation of rain gun, wheel washing arrangement, treatment of wash water and arrangement of CCTV cameras at coal / washed coal/ reject coal handling and storage areas, entrance and exit gates in all coal washeries.	All Coal Washeries / CECB	12 months	25 lakhs	Medium
	Ensuring proper collection and disposal of municipal solid waste as per MSW Rules, 2016 generated from industries through Local Bodies.	Urban Administration and Development / All industries / CECB	12 months	-	Low
	Prohibition of storage of solid wastes (such as Char, dolochar, ESP dust, fly ash etc.) storage area established and operating in and nearby Siltara industrial area.	CECB	6 months	-	Medium
	Making pucca road / area at all entrance of Industrial area from National Highway.	NHAI	24 months	5 Cr	High
	Plantation in between the area of industry boundary (outside) and road	ALL Industries / CSIDC/ Construction companies	12 months	2 Cr	Low
Sewage Treatment	Cleaning of drains before monsoon.	Nagar Palika Nigam	6 months	25 lakhs	Medium

	Prohibition of disposal of municipal solid waste and plastic waste in river as well as in municipal drains and levy of fine in case found violation.	Nagar Palika Nigam	6 months	-	Medium
	Requirement of E-flow in the river must be maintained.	State Water Resources Department	As and when needed	-	Low
Strengthening of Monitoring	Installation of two CAAQMS in industrial cluster area.	CECB/ Industrial Units	12 months		High
	Installation of two CWQMS in Kharun River.	CECB/ Industrial Units	6 months		High
	Measurement of flow of river and record maintained.	State Water Resources Department	6 months		High
	Requirement of E-flow in the river must be maintained.	State Water Resources Department	As and when needed		Medium
	Collection of information on irrigation water used per hectare for different crops by Agriculture Department and evaluate whether use of irrigation water per hectare has decreased or not? Based on the data obtained techniques like drip irrigation etc. should be promoted.	Agriculture Department	12 months		Medium
Public Awareness	Issue of advisory to public for prevention and control of air pollution.	CECB	6 months	-	Medium
	Involvement of school and other academic institution in awareness program.	CECB	12 months	-	Medium
Others	To ensure rain water harvesting by the industrial by the industrial, commercial and other institutions to promote ground water recharging. water reservoir, modification of existing lake/ponds to hold enough water	Govt. of C.G.	96 months	100 Cr	Medium

	may be attempted				
	Plantation in flood zone in available spaces.	Forest Department / Nagar Palika Nigam	12 months	10 lakhs	Low
	Providing web portal for redressal of public complaints.	CECB	6 months	-	Low
	Third party environmental quality monitoring for CEPI evaluation.	CECB	6 months	25 lakhs	low
	Carrying capacity study including source apportionment study.	CECB	24 months	-	Medium

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