FINAL TECHNICAL REPORT
ON
POLLUTION LOAD CARRYING CAPACITY AND SOURCE APPORTIONMENT STUDIES IN CPA RAIPUR

Submitted to

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

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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 Raipur" 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 Raipur, industrial cluster in Chhattisgarh State, is identified as the research area where pollution is an important issue. Raipur industrial cluster refers to Raipur, Urla, and Bhanpuri industrial areas in Raipur district. Initially 18 sample stations were chosen for air monitoring in the Raipur city and the sample code for those station are R01 to R18 (but in later due to lack of electricity sampling could not be carried out in R01 and R14). This industrial cluster is placed in the category of Critically Polluted Area (CPA). Raipur is the capital city of Chhattisgarh state. It is also the largest city in the state. It has experienced rapid industrial expansion and has emerged as a key business centre in central India. Raipur is ranked 7th in Ease of Living Index 2019 and 7th in Municipal Performance Index 2020 by Union Ministry of Housing and Urban Affairs. The total area of the district is 2,891.98 sq. km. The district is situated between the East longitudes 81° 32’ 05” and 82° 59’ 05” and by North latitudes 19° 46’ 35” and 21° 53’ 00”. The Administrative setup of the District is decentralized into 6 Tehsil, 4 blocks, 410 Gram Panchayats, and 32 Police Station. The district is surrounded by Bilaspur and Baloda Bazar, in North Dhamtari district in the south, Mahasamundand and Gariyaband in the east, and Durg in the west. It is the most populous district in the state with a population of 2160876 as per the official census 2011. Three rivers, namely Mahanadi, Kharun and Seonath are flowing in the Raipur district. 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. Raipur has a tropical wet and dry climate, with temperatures being mild all year except March to June, when it can be very hot. The sample IDs in Raipur were R01 to R18.

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; Raipur, 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 18 different sampling stations of Raipur 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 areas of Raipur are known as mining and steel area of Chhatishgarh.

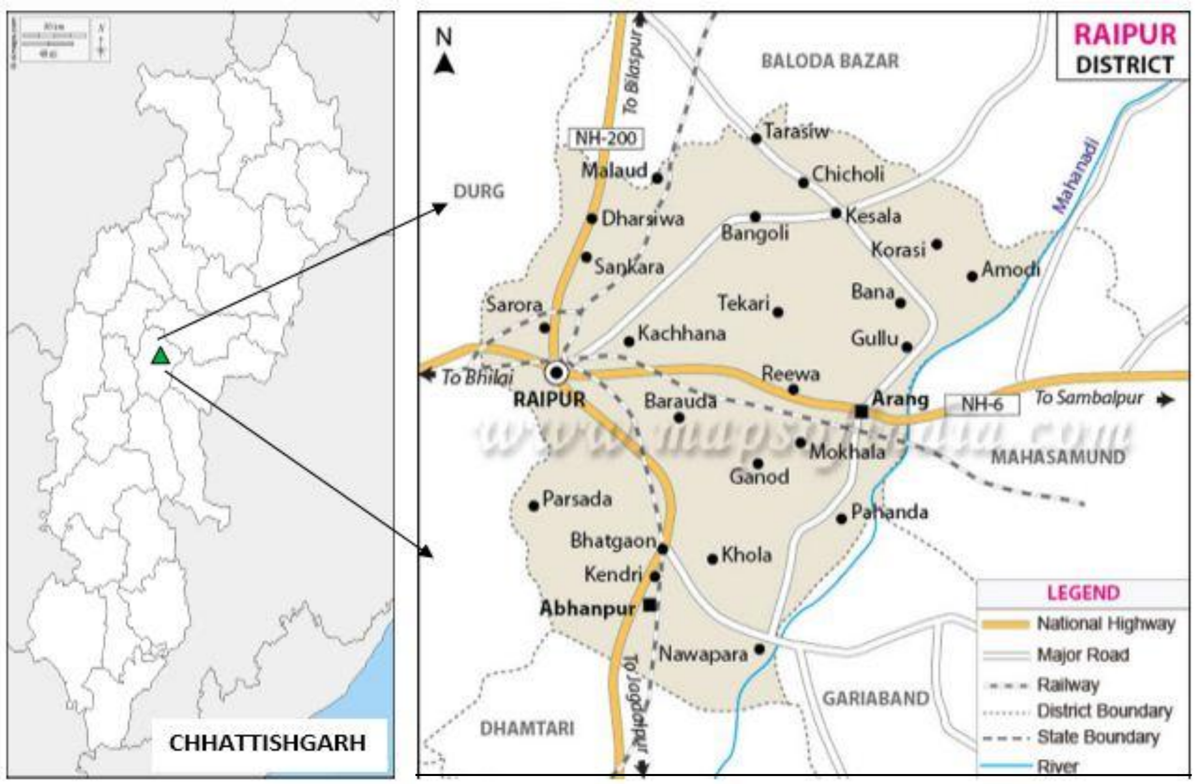


Figure 1.1: Raipur district in Chhattisgarh, India (Source: www.Google.com).

1.2 Objectives

The aim of the project is to conduct the carrying capacity including source apportionment studies in CPA Raipur 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 wastes.

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 18 air quality monitoring stations in Raipur.
- 18 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 ambient air sampling stations in Raipur are presented in Table 1.1 and their geographic location in Topo map is shown in Figure 1.2.

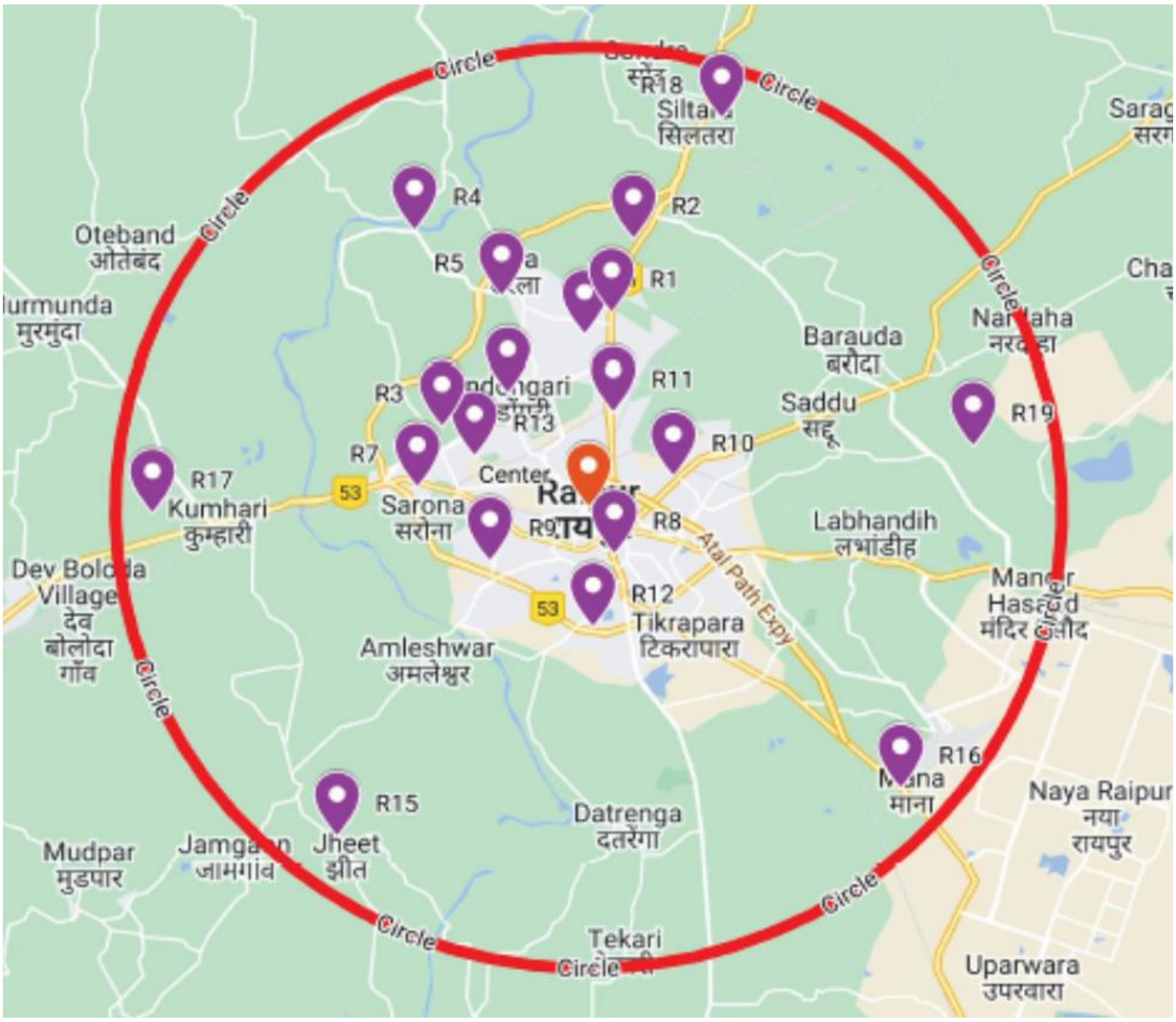


Figure 1.2: Geographical representation of different air sampling stations in Raipur.

Table 1.1: Air Quality Monitoring Stations (18 different places) and type of stations in Raipur are represented in tabular form.

Station Name	Code	Type
Ador Welding Ltd.	R01	Industrial
Ashram	R02	Industrial
Gosala	R03	Commercial
Real Ispat	R04	Residential
Water Treatment Plant	R05	Industrial
Nagar Nigam Birgaon	R06	Silent
AIIMS	R07	Commercial
City Kotwali Police Station	R08	Residential
DD Nagar House	R09	Silent
District Hospital	R10	Commercial
Nagar Nigam Pandri	R11	Commercial
Ravan Bhata Station	R12	Industrial
RO Office	R13	Residential
Uniworth Ltd.	R14	Industrial
Jheet High School	R15	Residential
Mana Panchayat	R16	Residential
Shri Rawtpur Sarkar Institute	R17	Industrial
CIAL-S.D. (Jayasawal Nico)	R18	Industrial

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.

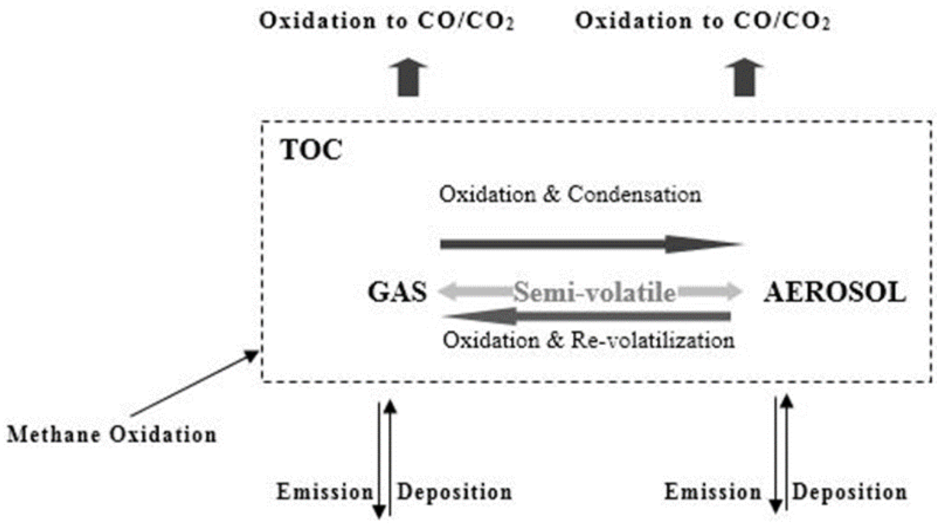


Figure 1.3: Framework for conversion of total organic carbon (TOC) into carbon monoxide (CO) and carbon dioxide (CO_2).

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 2.1.11. 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 (hλ, where $\lambda \leq 410$ nm):

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

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 Raipur 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 volatilization. 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 compound 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 center 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 seasons (winter, summer and pre/post monsoon).

1.4.6.1 Ambient Air Quality: Pre/Post Monsoon

Ambient air quality was monitored at 16 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 16 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 16 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 Raipur (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 fiber 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.

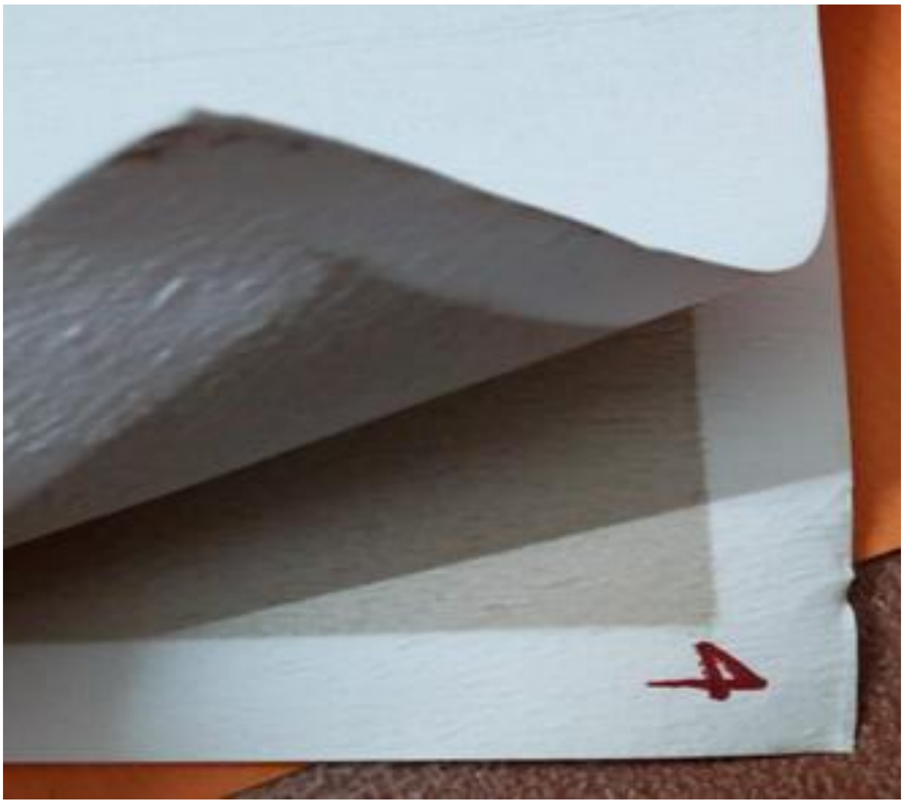


Figure 2.2: Photograph of filter paper of size 25.4 cm × 20.3 cm.

2.2.1.4 Analysis

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

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

C PM_{10} ($\mu g/m^3$) = $(\text{W}_f - \text{W}_\text{i}) \text{ x } 106 \text{ / V}$ (2.3)

Where,

C PM_{10} = Concentration of PM_{10}, $\mu g/m^3$

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

2.2.2 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 impactor. 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 desiccator 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

$C\ PM_{2.5}$ (µg/m^3) = $(W_f - W_i) \times 106 / V$ (2.4)

Where,

$C\ PM_{2.5}$ = Concentration of $PM_{2.5}$, 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

2.2.3 Determination of Sulfur Dioxide 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.

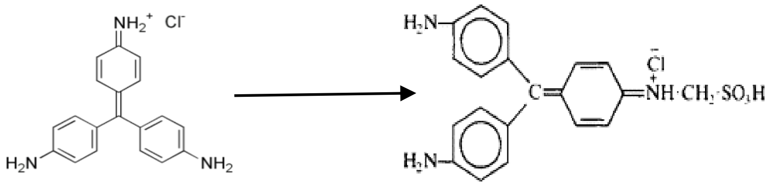
$$HgCl_4^{--} + SO_2 + H_2O \rightarrow HgCl_2.SO_3^{--} + 2Cl^- + 2H^+$$

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. Para-rosaniline hydrochloride is colorless in strong acidic medium. Hydroxymethyl sulphonic acid reacts with it to give purple colored pararosaniline methyl sulphonic acid.

+ $HO.CH_2.SO_3H$ 

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 metabisulphite 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 liter 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 to react for 5.0 min. It titrated with stock sodium thiosulphate solution until a pale-yellow color arrives. Then few drops of starch indicator is added which will give blue color. Again it is titrated until disappearance of color.

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

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)
50 ml 0.01 N Iodine solution is pipette out	
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

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

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

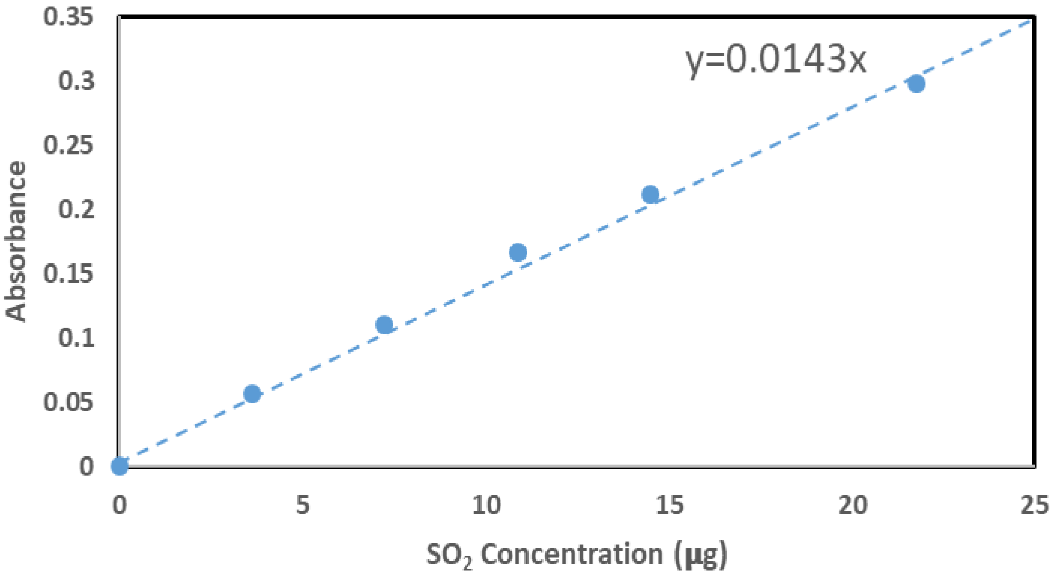


Figure 2.4: Calibration curve of SO_2.

Figure 2.5: Samples of SO_2.

VI) Sampling

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

10.86 gm of Mercuric chloride, 0.066 gm of EDTA

10.86 gm of Potassium chloride, 6.0 gmor sodium chloride and 4.68 gm are dissolved in water and volume is made to the mark in a 1 liter 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 g 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.

4. **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

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

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

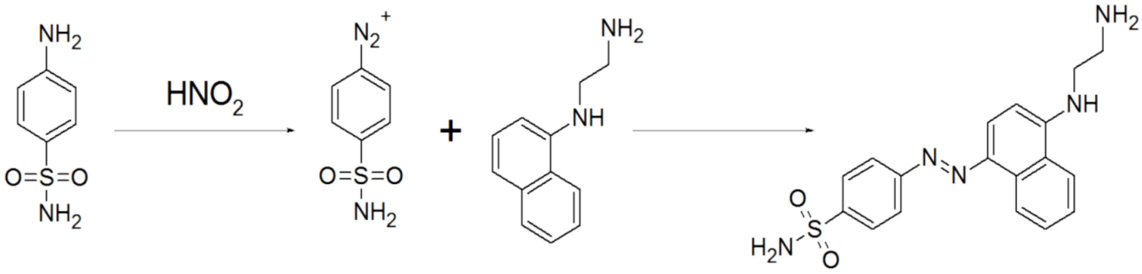
2.2.4 Determination of Nitrogen Dioxide Concentration in Air

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.

2.2.4.3 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, Calibration Factor = 0.019^{-1} = 52.63

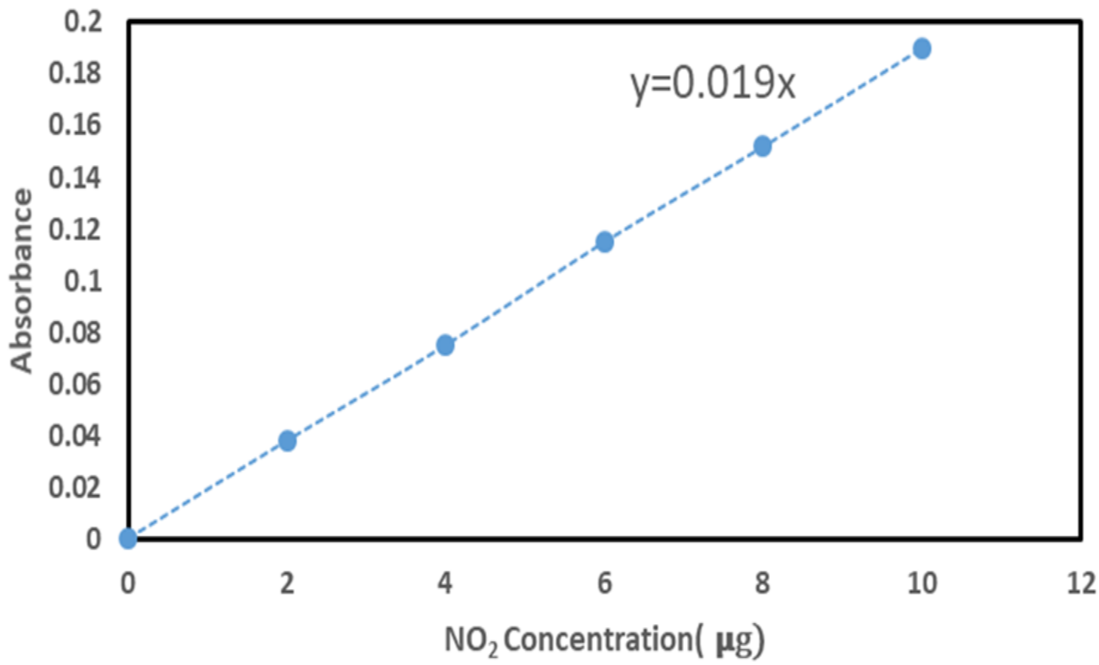


Figure 2.7: Calibration curve of NO_2.

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 litre 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 g 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 g 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 Working Method

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.

2.2.4.9 Calculation

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

Where,

C_{NO_2} = Amount of NO_2, $\mu g/m^3$

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 Concentration in Air (Indophenols Method)

2.2.5.1 Principle

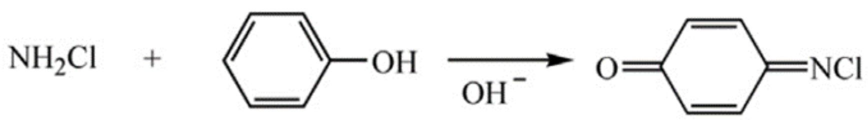
A. When air passes through dilute solution of H_2SO_4, the NH_3 in the air is converted to ammonium sulphate

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

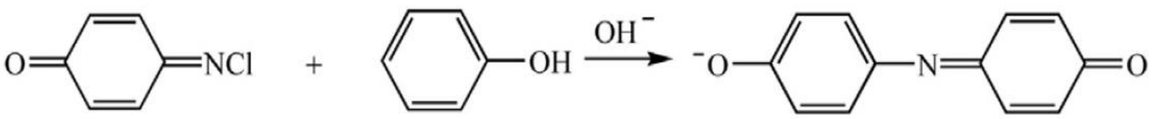
B. The ammonium ion reacts with hypochlorite ion to produce monochloroamine

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

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 concentration 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 adjusted 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

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

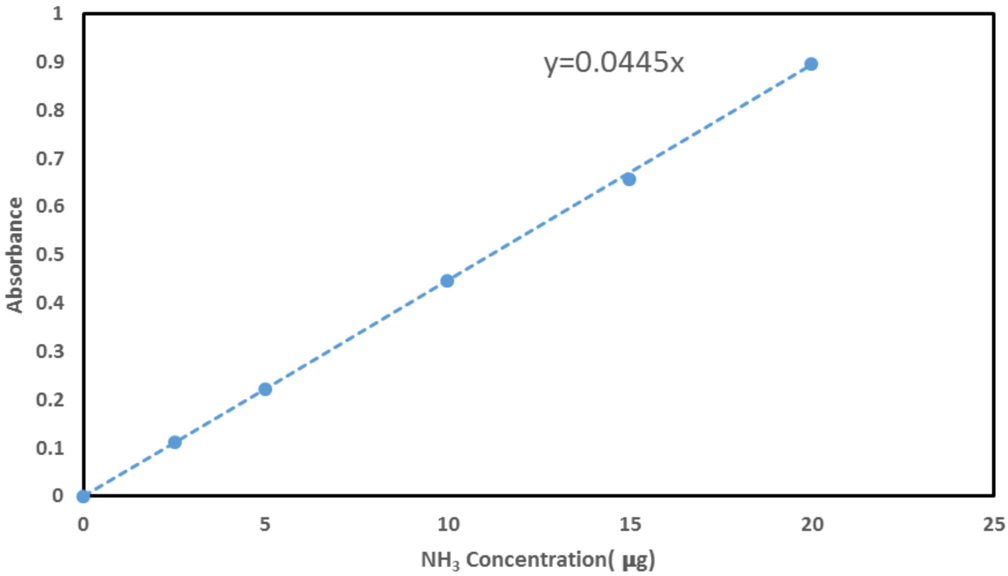


Figure 2.9: Calibration curve of NH_3.

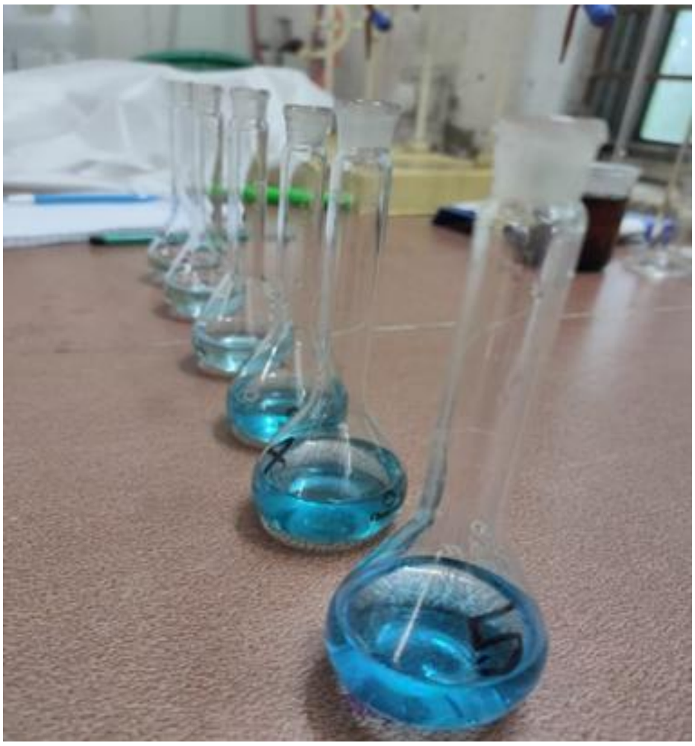


Figure 2.10: Sample of NH_3 for calibration.

2.2.5.5 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 analyzed as soon as possible.

$$\text{Total Volume of air} = [\text{Avg. flow rate (lpm)} \times \text{Time (min)}]\ \text{L} \tag{2.9}$$

$$\text{Flow Rate} = \text{Initial flow (lpm)} + \text{Final flow (lpm)}/2 \tag{2.10}$$

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

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

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 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 spectrophotometry 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.

2.2.6.4 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 curve 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; Calibration Factor = 0.057^{-1} = 17.54

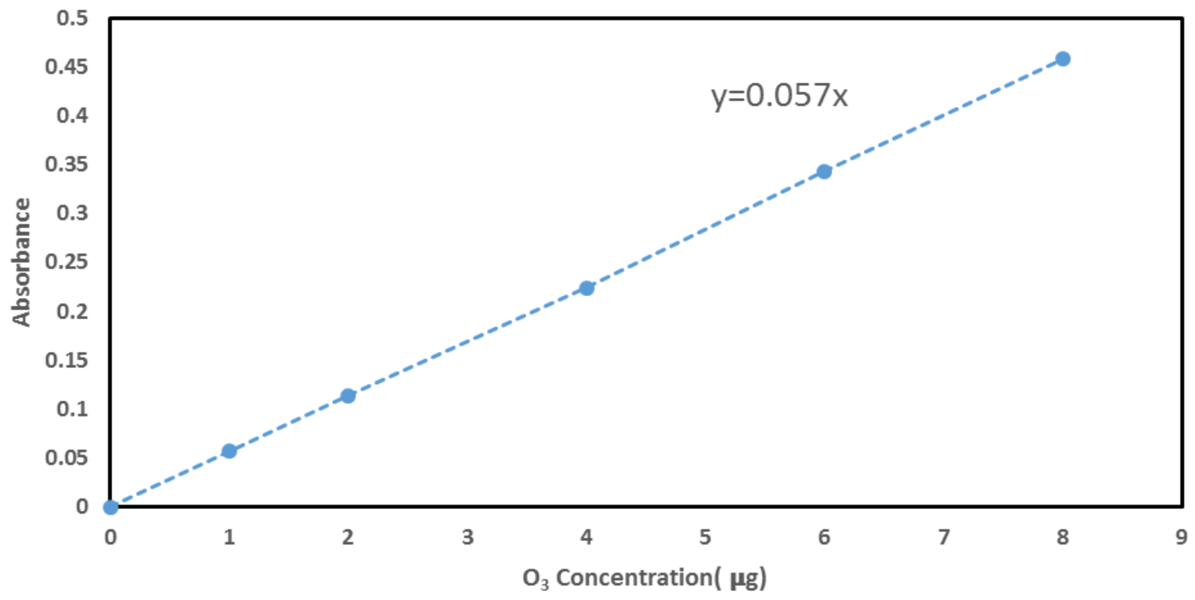


Figure 2.11: Calibration curve of O_3.

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.

2.2.6.8 Calculation

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

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 BTEX sample in a way that results in an enrichment of the relevant substances in the activated charcoal. Desorption of the adsorbed benzene or BTEX are done using carbon disulphide (CS_2). The substances desorbed in the CS_2 are analyzed 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.

2.2.7.2 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 flowmeter 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.

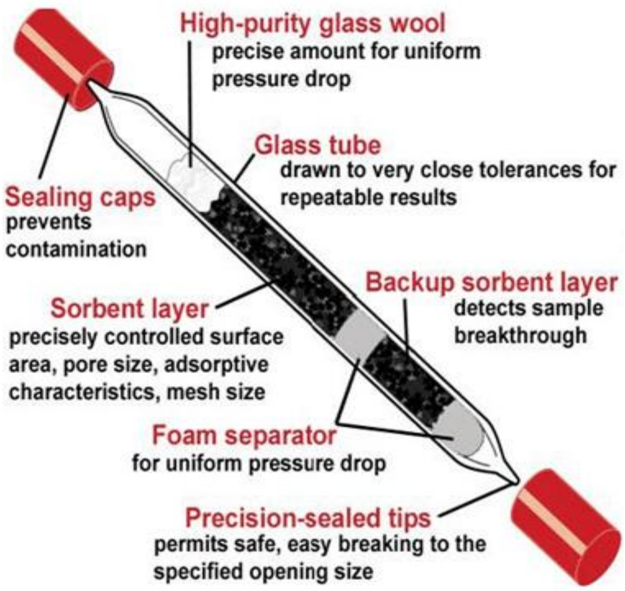


Figure 2.12: VOC sampler. **Figure 2.13:** Adsorption tube used in VOC sampler.

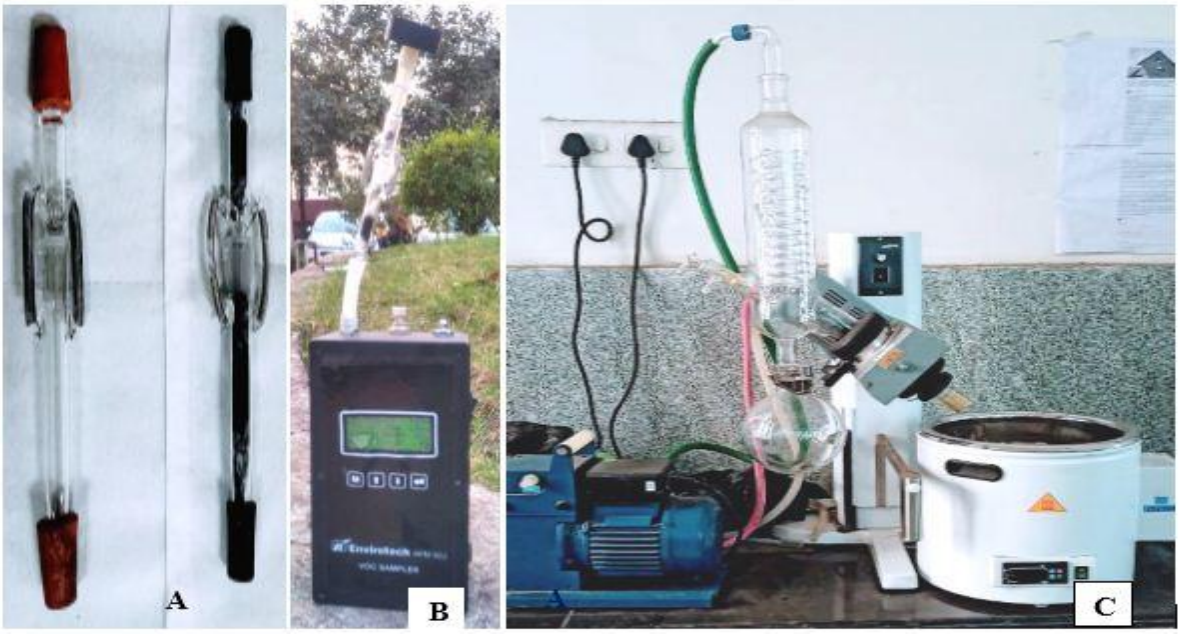


Figure 2.14: [A] Charcoal tube or VOCs sampling tube. Both empty [L.H.S.] and activated charcoal filled [R.H.S.] tubes are shown side by side; [B] VOC sampler and [C] Rotary vacuum evaporator to concentrate the VOC extract in CS_2 solution.

2.2.7.3 Calibration of GC

A mix stock standard solution of benzene, toluene and xylene has been prepared (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 are prepared from stock standard in a clean vial (1 ml final volume) and are injected immediately 1µl standard solution into the injector of GC directly. Finally, plot the curve between the concentration vs response (peak area).

2.1.7.4 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 Fiber 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 analyzed in GC against all standards.

2.2.8.2 Calibration of GC

A PAHs mix Stock Standard solution of 16 compounds including BaP (1000 ng/µl) was prepared in Toluene. Then Working Standard solutions of concentrations 1, 10, 20, 30, 40, 50 ng/µl were prepared from Stock Standard solution in Toluene. 1µl of each Working Standard solutions were injected into GC directly and plot the curve between the concentration and peak area. Gas Chromatography fitted with capillary column and FID detector 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:

Total Sample volume: $V = Q \times T$ (2.14)

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

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

Where; C_s = Concentration BaP 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 analyzed 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:

$$V = Q \times t \tag{2.16}$$

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:

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

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 Sample (Water Extraction and Ion Chromatography Method)

2.2.10.1 Method in Brief

Water soluble ionic species are best analyzed 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 polyatomic 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.

$$C_{air} = \frac{m-B}{V_{air}} \quad (2.18)$$

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 pitot 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.

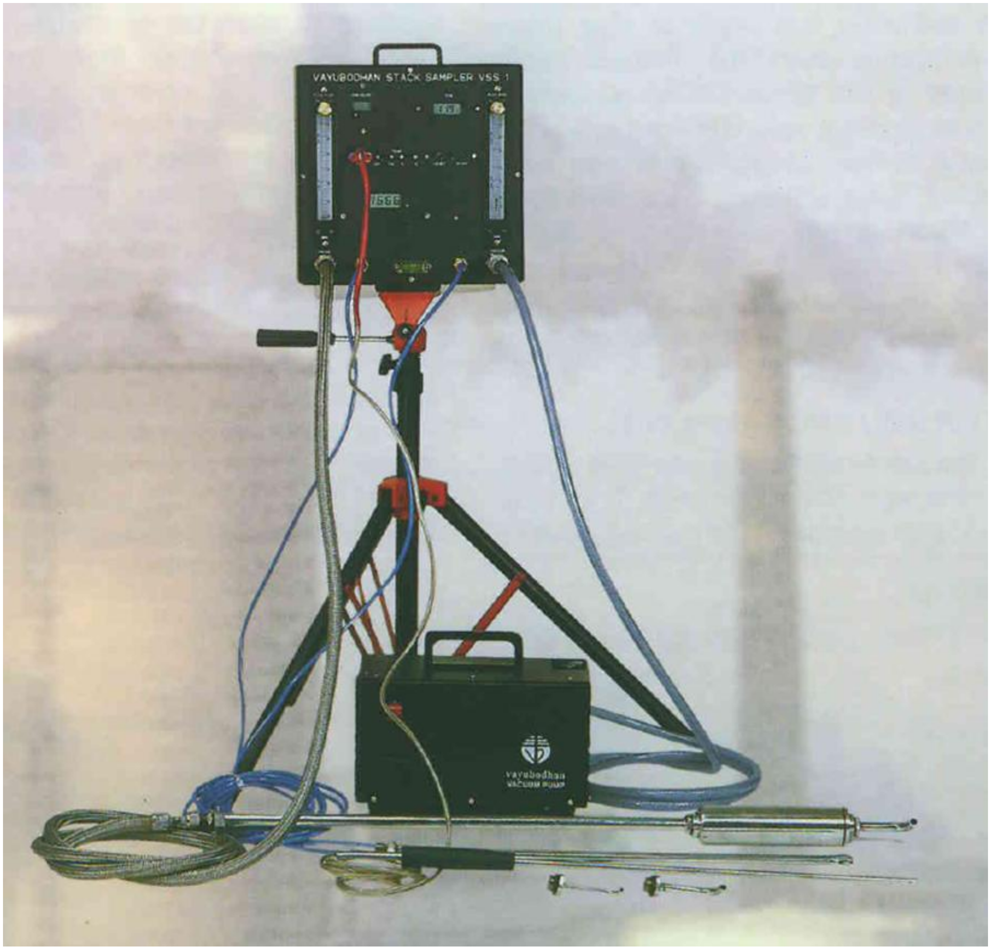


Figure 2.18: Vayubodhan stack sampler.

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 pitot tube along with a digital manometer to measure the velocity of air - stream inside the chimney or duct. The pitot 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-Guage (WG) units. The air velocity can be calculated from the relation.

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

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.

$$\mathrm{Ds} = \frac{\mathrm{Da.Ta}}{\mathrm{Ts}} \tag{2.20}$$

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.

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

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

A set of graphs are available where Equation (2.21) 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 $= 0.1900\ \sqrt{(\mathrm{h\ x\ T_s})}$

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:

$$\mathrm{Qs} = \mathrm{V\ x\ A_n\ x\ 60\ x\ 1000} \qquad (2.22)$$

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,

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

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).

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

Where Q_m = Actual flow rate in LPM

Q'_s = Sampling rate from stack given by Equation (2.23)

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 Bhilai 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:

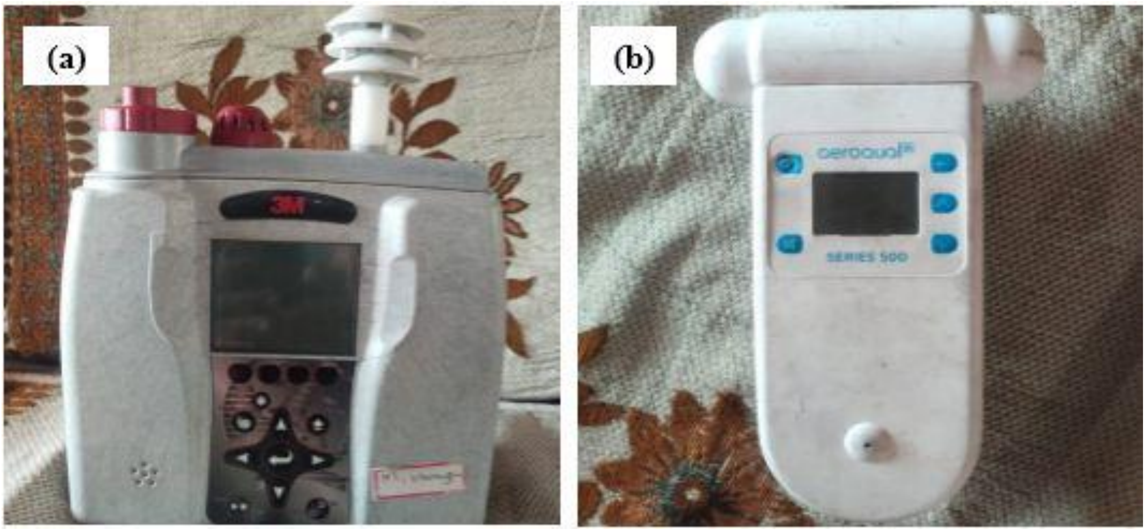


Figure 2.19: Real time air monitoring devices (a) 3M Instrument (b) Aeroqual series 500.

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.

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 18 sampling sites in Raipur. 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.
- Analysis 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 characterise 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 Modeling

A set of mathematical equations called dispersion modeling 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 organisations 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.

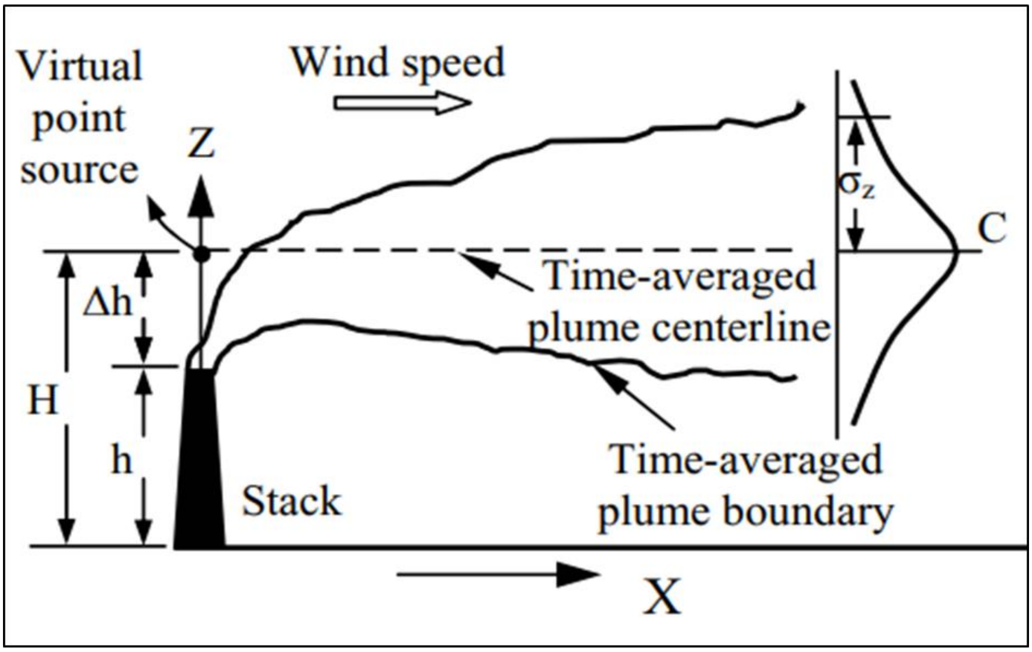


Figure 2.20: Schematic diagram of plume dispersion.

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.

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

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)

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

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

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

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 Modeling

Different software for air dispersion modeling:

A) Model Selection
   ISC 3
   AERMOD – most recent version for Dispersion modeling
   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 Modeling

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 Bhilai 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.

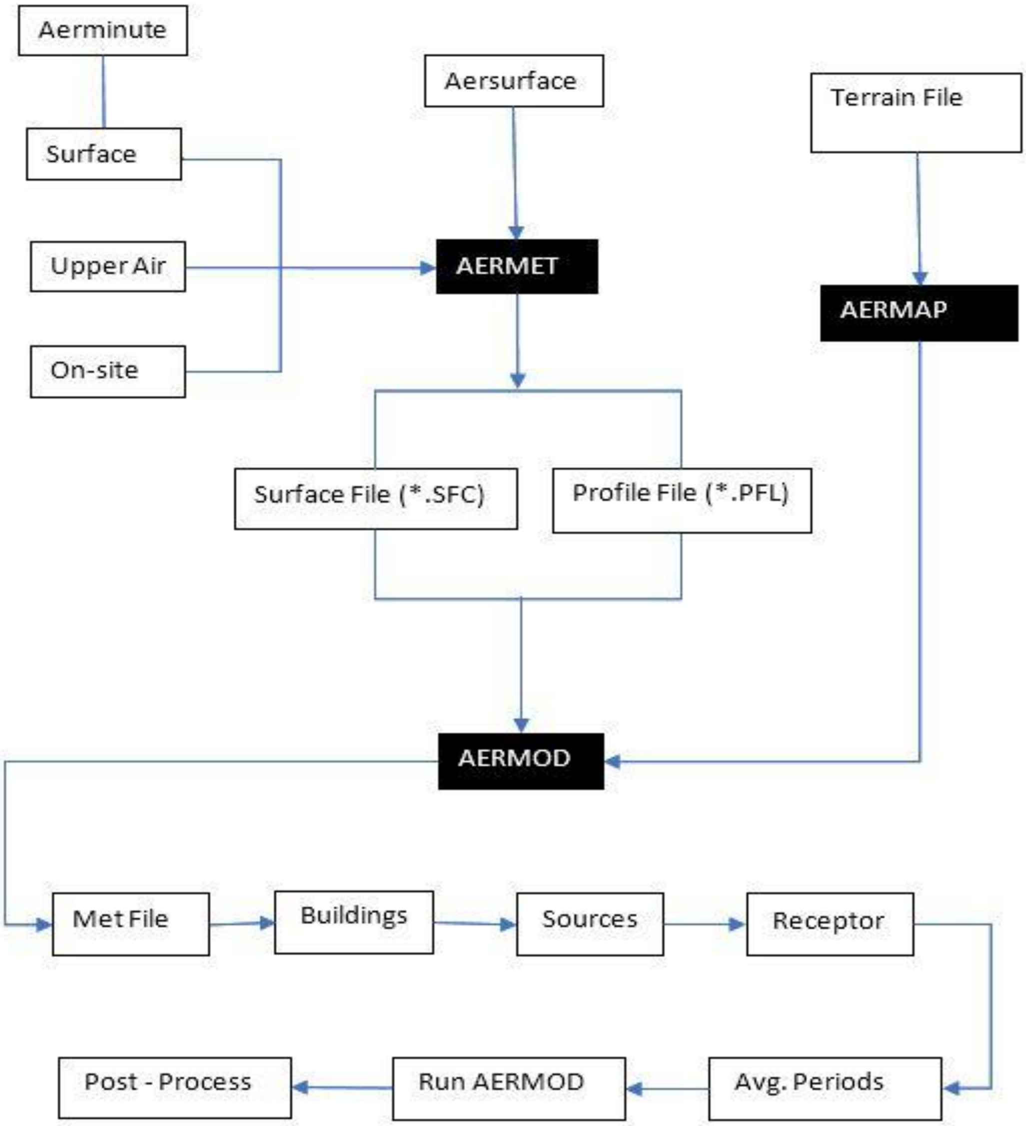


Figure 2.21: Flowchart for input parameters for AERMOD.

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:

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

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 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 Analyzer,
    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. 18 sampling stations of Raipur 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 2.33) has been drawn for clear understating of sampling stations categories and different sources of pollutants are found there in:

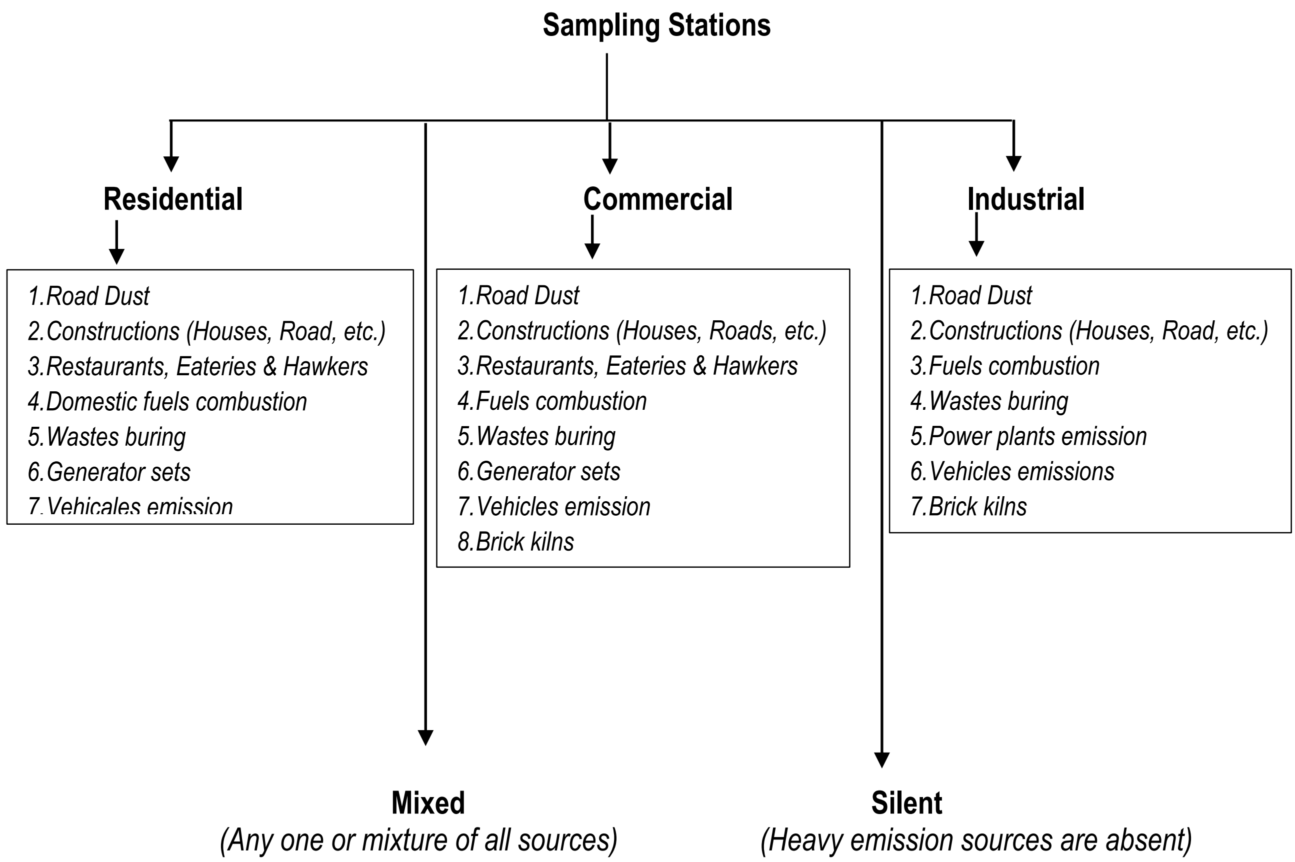


Figure 2.33: Types of different sampling stations and different sources of pollution may present there.

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).

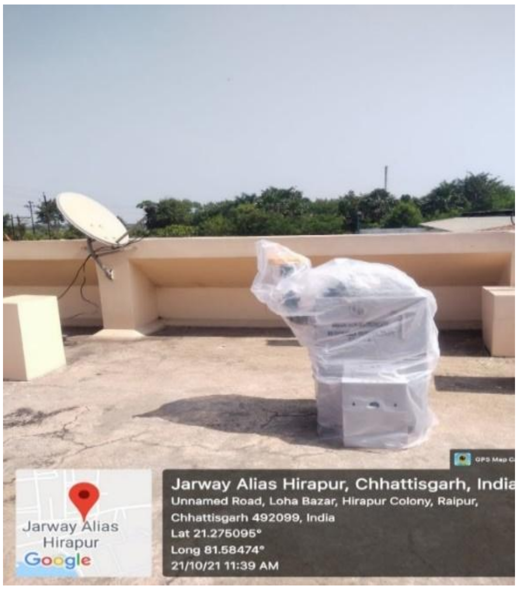
2.3. Results and Discussion

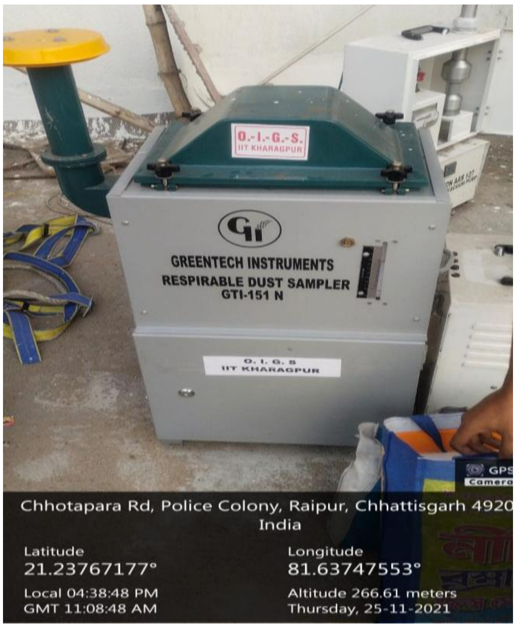
2.3.1 Assembling of Air Quality Monitoring Stations for Measurement of Air Pollution

Following 18 sampling stations has been identified in Raipur industrial cluster for air sampling. But two stations R01 and R14 were shut down later on.

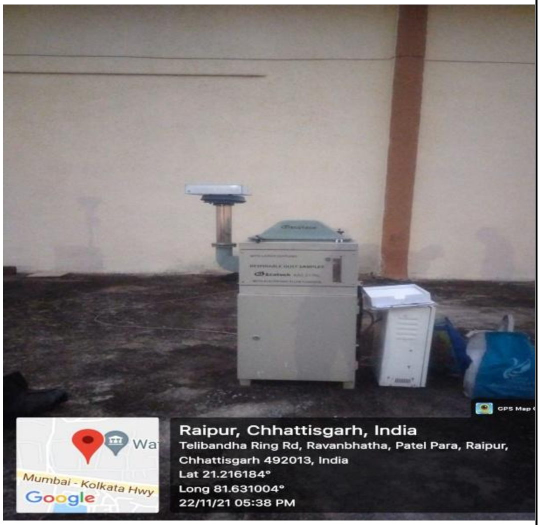
Table 2.11: Air sampling stations at Raipur

Location ID	Location Name	Latitude (°N) & Longitude (°E)	Station View
R01	Ador Welding Ltd.	21.307851, 81.636708	
R02	Ashram	21.329439, 81.643406	

R03	Goshala	21.275095, 81.58474	
R04	Real Ipsat	21.332134, 81.57644	
R05	Water Treatment Plant (Urla)	21.312755,81.602945	

R06	Nagar Nigam, Birgaon	21.301593, 81.62837	
R07	AIIMS	21.25744282, 81.57727570	
R08	City Kotwali Police Station	21.23767177, 81.63747553	

R09	DD Nagar House	21.23566682, 81.59940184	
R10	District Hospital	21.260606, 81.655514	
R11	Nagar Nigam Pandri	21.27922, 81.637126	

R12	Ravan Bhata Station	21.216184, 81.631004	
R13	RO Office	21.26656833, 81.59484166	
R14	Uniworth Ltd.	21.2848576, 81.60492616	

R15	Jheet High School	21.33213423, 81.55273462	
R16	Mana Panchayat	21.16882848, 81.72500002	
R17	Shri Rawatpura Sarkar Institute	21.24967416, 81.49626955	

R18	CIAL- S.D.	21.364876, 81.67029	

2.3.2 Ambient Air Monitoring Data

Table 2.12: Observed sources near sampling site.

Location ID	Location Name	Coordinates	Station Classification	Observed Sources
R01	Ador Welding Ltd.	21.307851° N 81.636708° E	Industrial	Industries, Traffic area, Restaurant, 5-6 Petrol Pumps within 3 km, Lathe works shops, Hotel
R02	Ashram	21.329439° N 81.643406° E	Industrial	Industries, 2-3 petrol pumps, Hotel, Main road (highway)
R03	Goshala	21.275095° N 81.58474° E	Commercial	Plywood and steel industries, Metallic work
R04	Real Ipsat	21.33213423° N 81.57644771° E	Residencial	Shopping mall, Local shops and Roadside food stalls
R05	Water Treatment Plant	21.312755° N	Industrial	Residential area with few Restaurant Srinivas ferro

		81.602945° E		alloy within 1 km, nearby highway within 2.1 km
R06	Nagar Nigam	21.301593° N 81.62837° E	Silent	School, Officies, Restaurants and Local shops
R07	AIIMS	21.25744283° N 81.5772757° E	Commercial	Hospital, Clinics, Pathological laboratories,Traffic, Road side stalls, Road construction, Petrol pump
R08	City Kotwali Police Station	21.23767177° N 81.63747553° E	Residencial	Offices, Traffic, Hotels, Restaurant
R09	DD Nagar House	21.23566682° N 81.59940184° E	Silent	School, Offices, Residential area, Hostels, Gas godown
R10	Distrcit Hospital	21.260606° N 81.655514° E	Commercial	Hospital, Clinics, Pathological laboratories, Traffic, NH 6
R11	Nagar Nigam Pandri	21.27922° N 81.637126° E	Commercial	Repairing shops, Construction, Petrol pump
R12	Ravan Bhata Station	21.216184° N 81.631004° E	Industrial	Industries, Water plant, Construction area, Traffic
R13	RO Office	21.26656833° N 81.59484166° E	Residencial	Offices, Roadside food stalls, Hostels, Restaurants, Talab
R14	Uniworth Ltd	21.28485769° N 81.60492616° E	Industrial	Industries, Traffic
R15	Jheet High School	21.15474378° N 81.55273462° E	Residential	School, Book shops, Grocery stores, Temple
R16	Mana Panchayat	21.16882848° N 81.72500002° E	Residential	Offices, Cyber café, Xerox shops, Traffic, NH 6

R17	Shri Rawatpura Sarkar Institute	21.24967416° N 81.49626955° E	Industrial	School, Book shops, Xerox centre, Stationary shops
R18	CIAL- S.D.	21.364876° N 81.67029° E	Industrial	Industries, Grocery store

2.3.3 Graphical Representation Ambient Air Monitoring Data

2.3.3.1 PM_{10} Variation in Different Season

Air sample collected from 18 stations and the highest PM level were found in R07, R09 and R13 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.

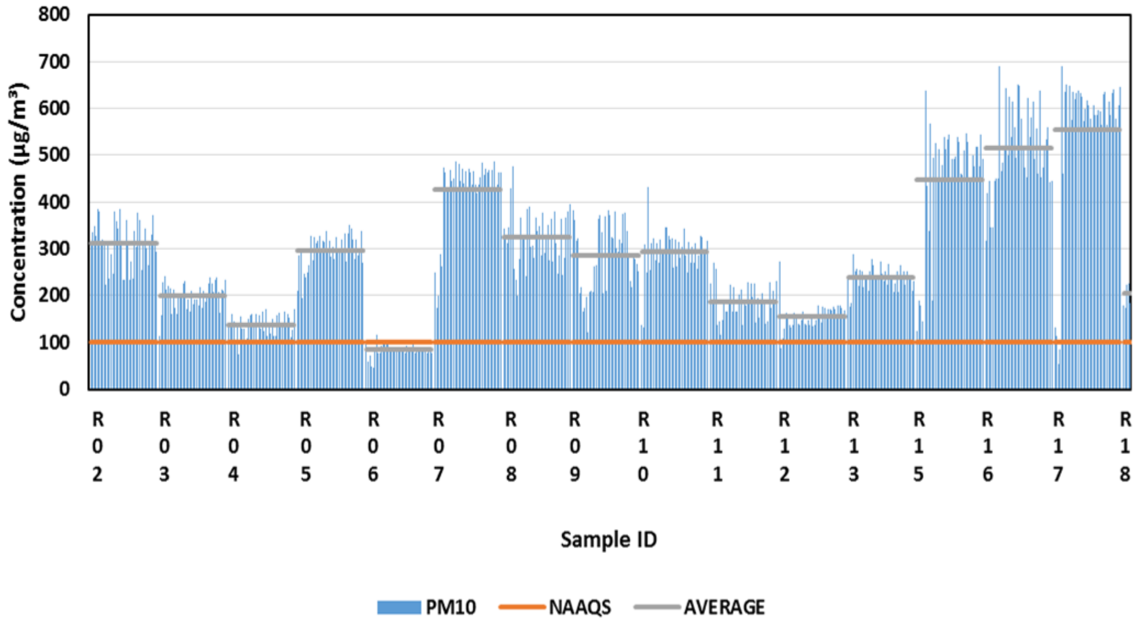


Figure 2.23: Concentration of PM_{10} in winter season.

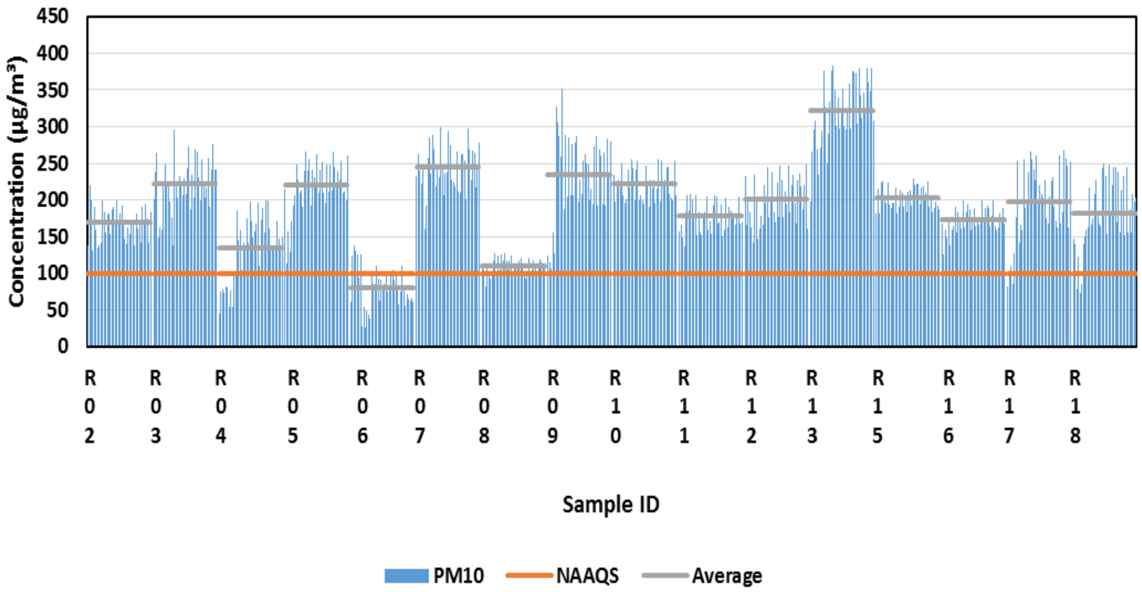


Figure 2.24: Concentration of PM_{10} in summer season.

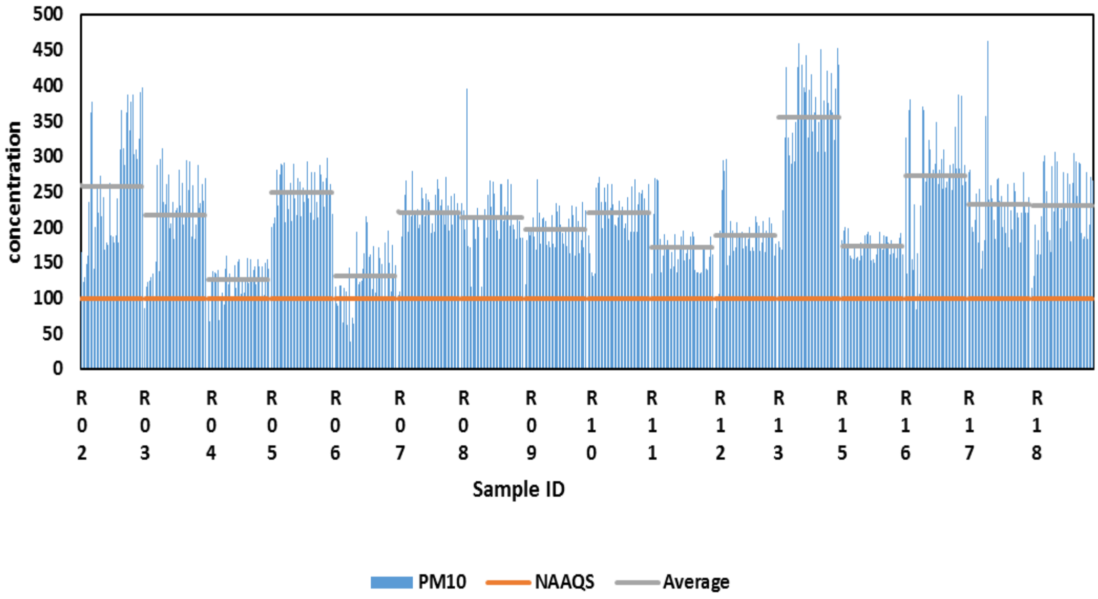


Figure 2.25: Concentration of PM_{10} in pre/post-monsoon season.

2.3.3.2 $PM_{2.5}$ Variation in Different Season

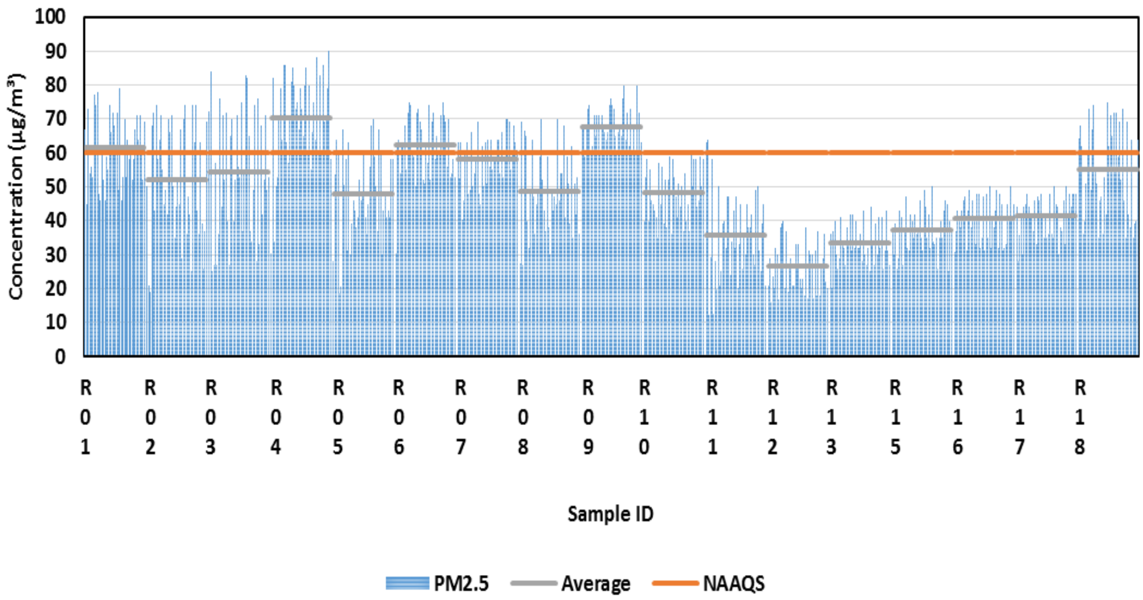


Figure 2.26: Concentration of $PM_{2.5}$ in winter season.

Air sample collected from 15 stations and in the summer season highest $PM_{2.5}$ level were found in R13 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.

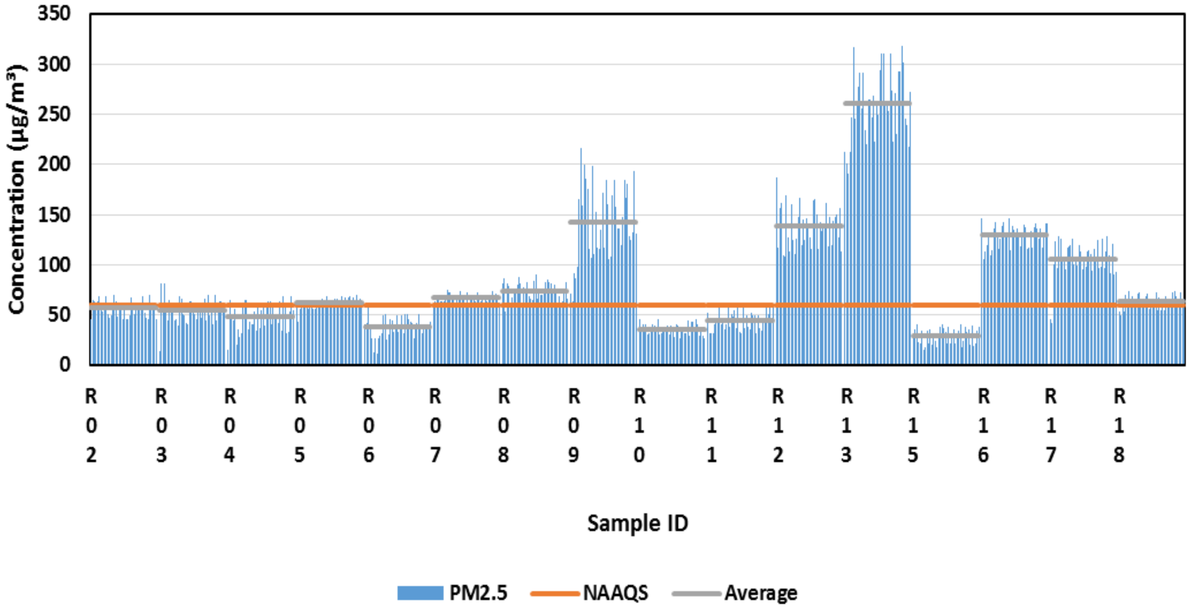


Figure 2.27: Concentration of $PM_{2.5}$ in summer season.

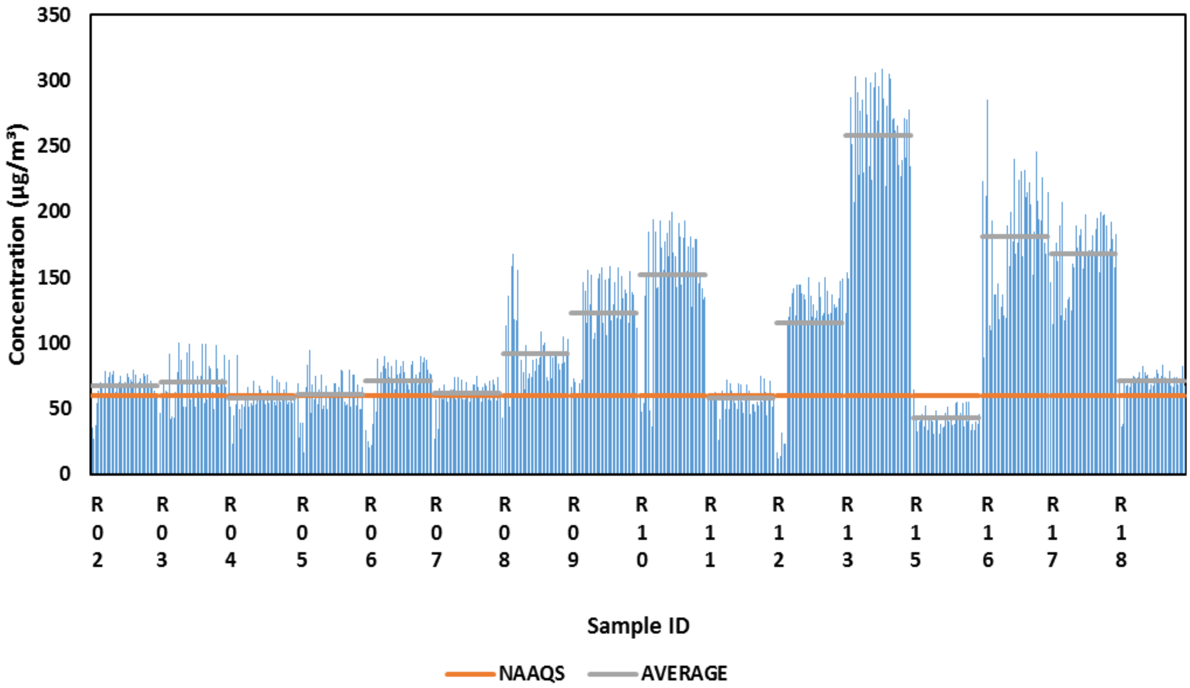


Figure 2.28: Concentration of $PM_{2.5}$ in pre/post monsoon season.

2.3.3.3 SO_2 Variation in Different Season

Air sample collected from different season in Raipur 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 R06, R13, and R18 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.

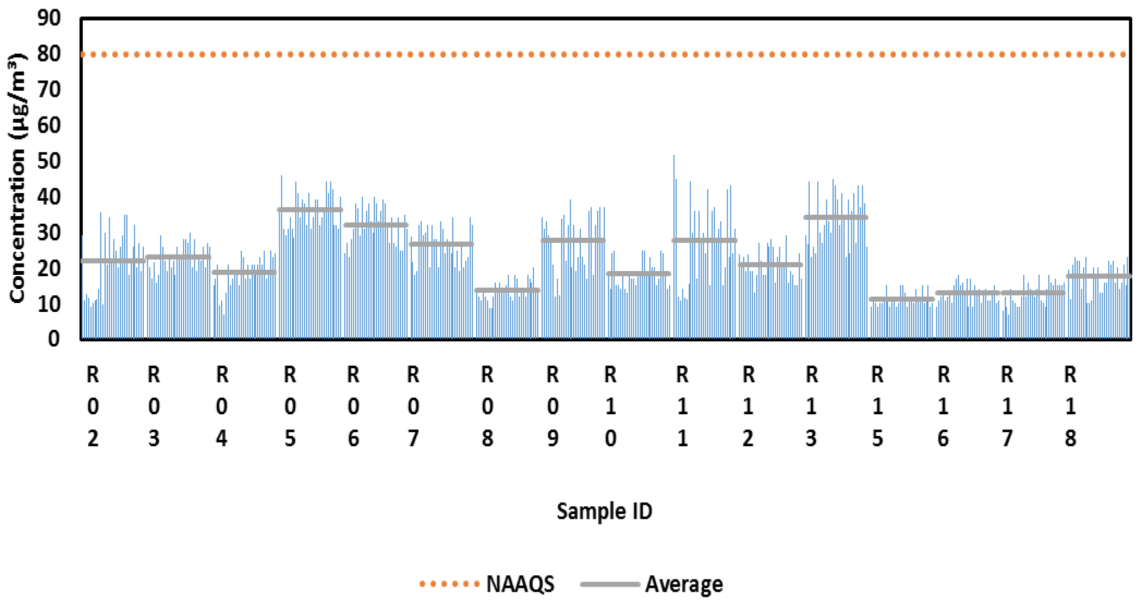


Figure 2.29: Concentration of SO_2 in winter season.

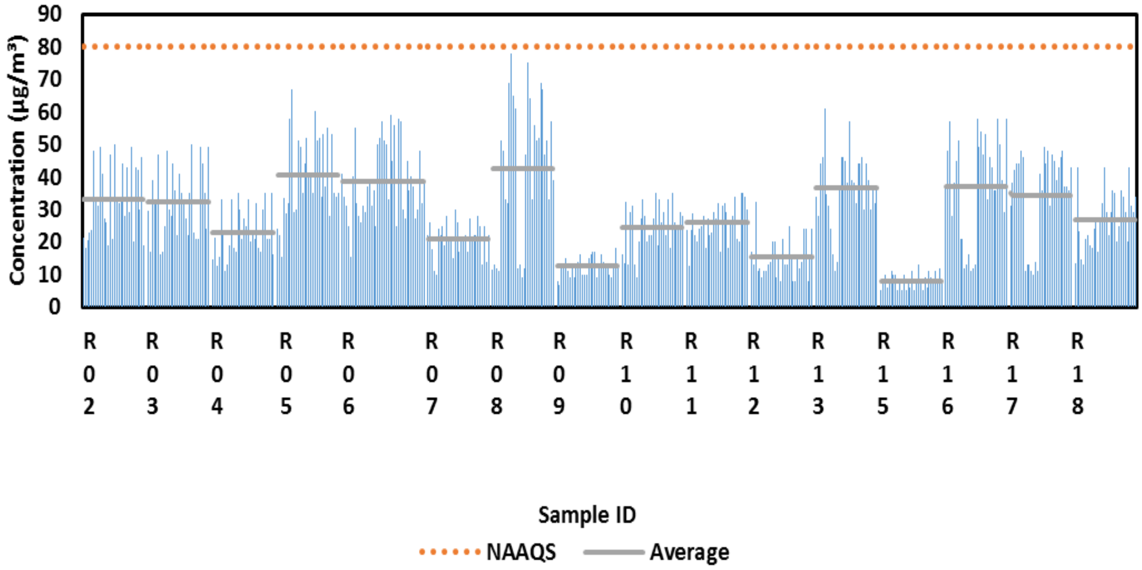


Figure 2.30: Concentration of SO_2 in summer season.

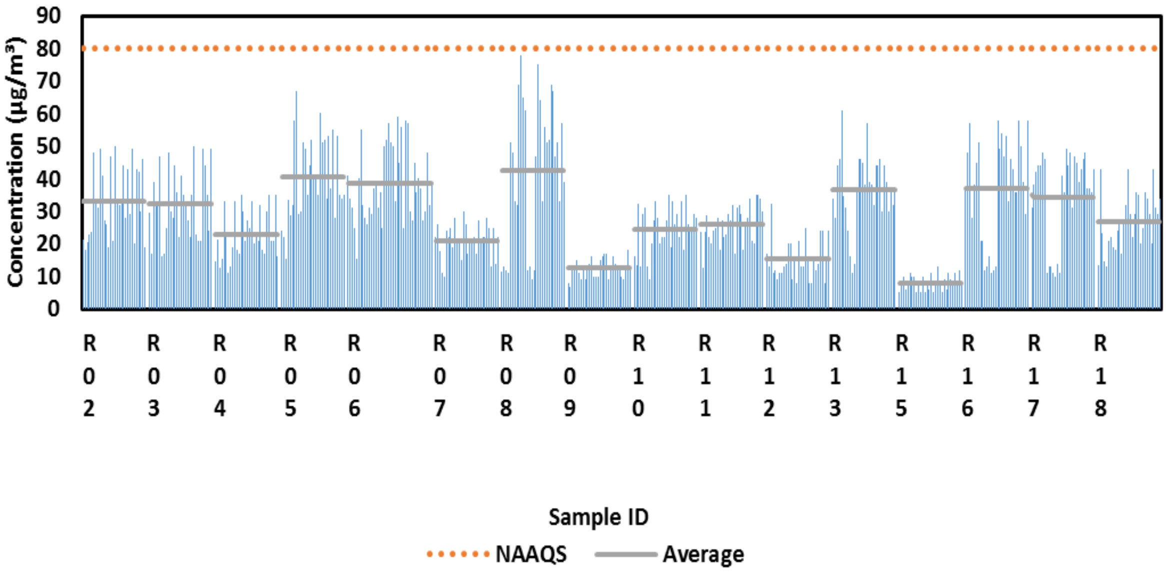


Figure 2.31: Concentration of SO_2 in pre/post-monsoon season.

2.3.3.4 NO_2 Variation in Different Season

Air sample collected from 18 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 were found in R06, R08 and R09 and the main reason could be the nearby industry such as wood industry 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 R08, R18 and R02 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 R08, R09 and R02 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 .

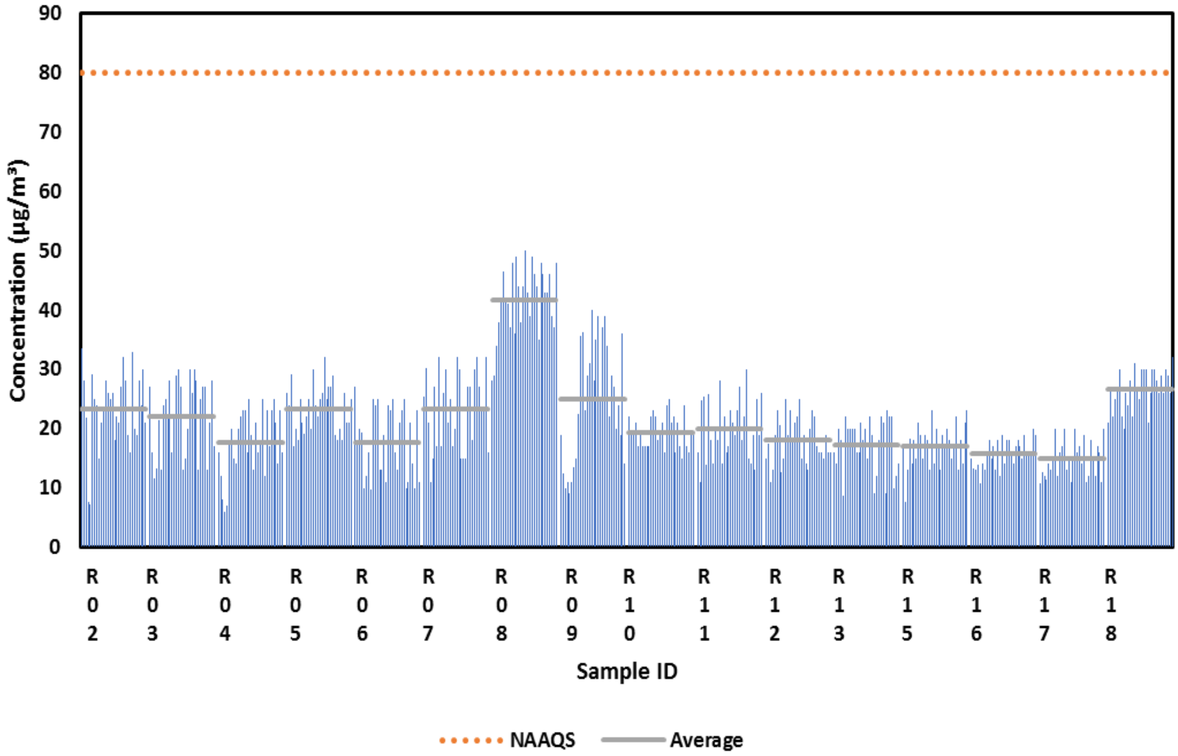


Figure 2.32: Concentration of NO_2 in winter season.

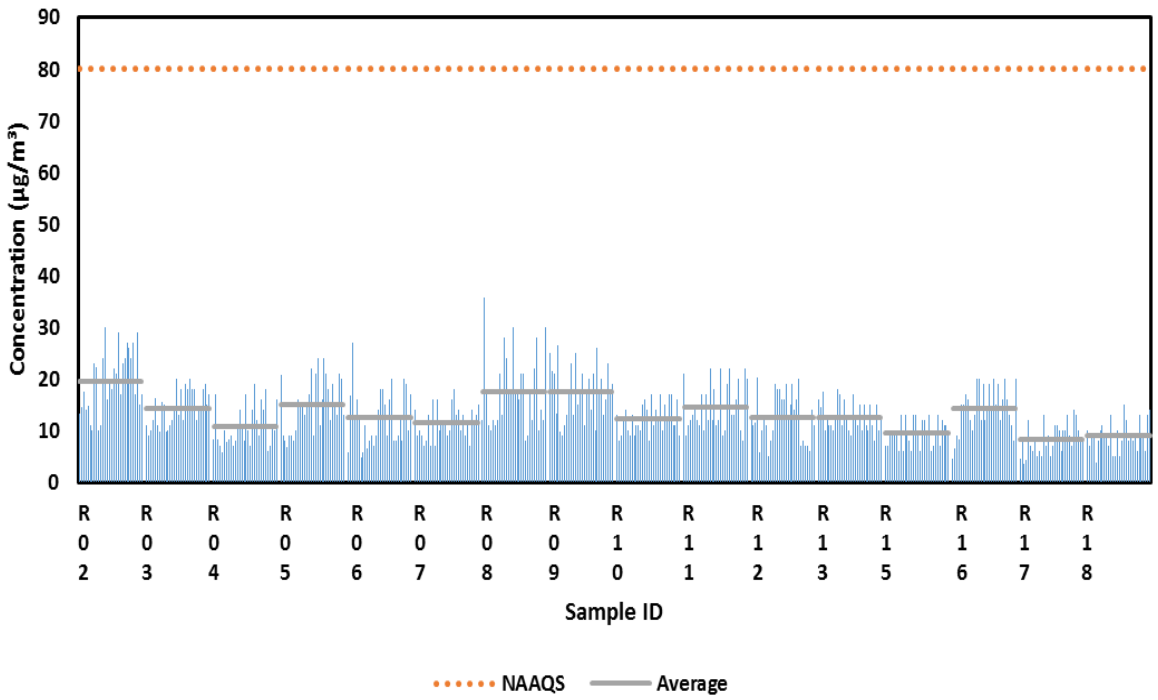


Figure 2.33: Concentration of NO_2 in summer season.

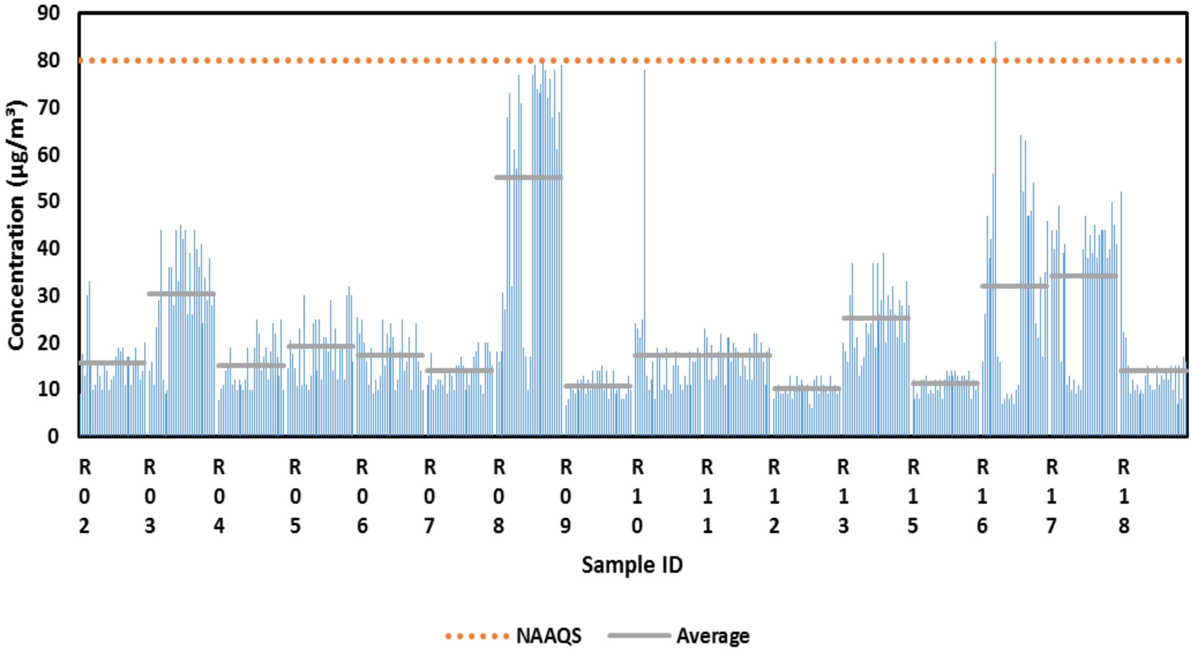


Figure 2.34: Concentration of NO_2 in pre/post monsoon season.

2.3.3.5 NH_3 Variation in Different Season

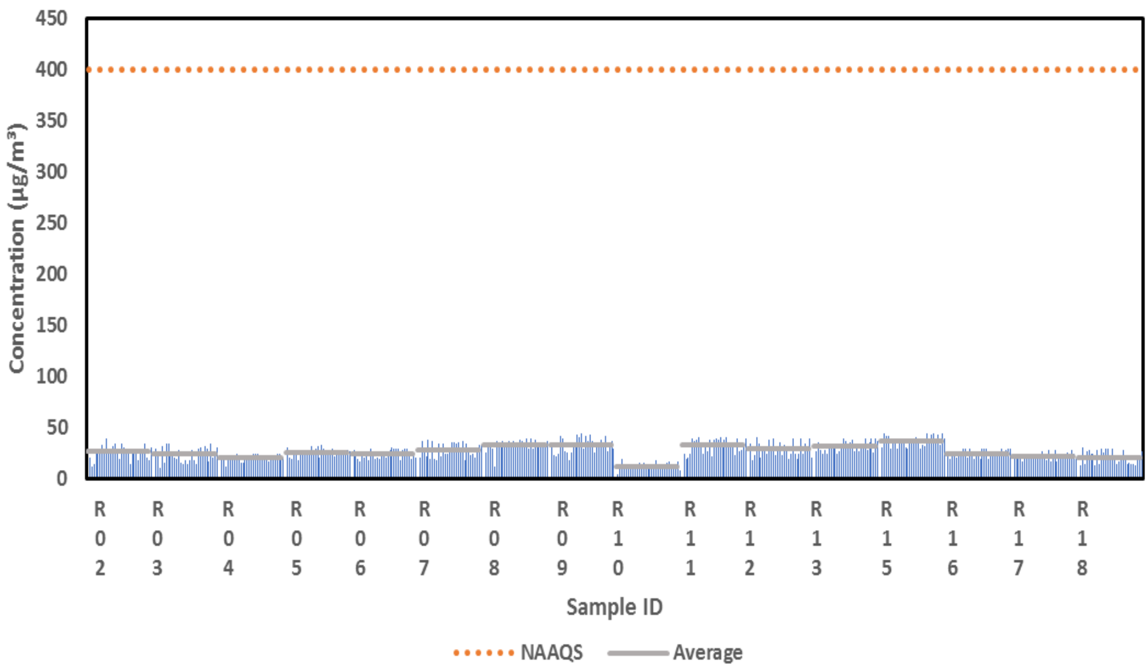


Figure 2.35: Concentration of NH_3 in winter season.

Air sample collected from 18 stations and as we can see Figure 2.35 to 2.37 highest concentration were found in R05, R08 and R11 and it is mainly because of Ferro Alloy 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 R02, R07, and R09 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 R08, R09, and R15 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.

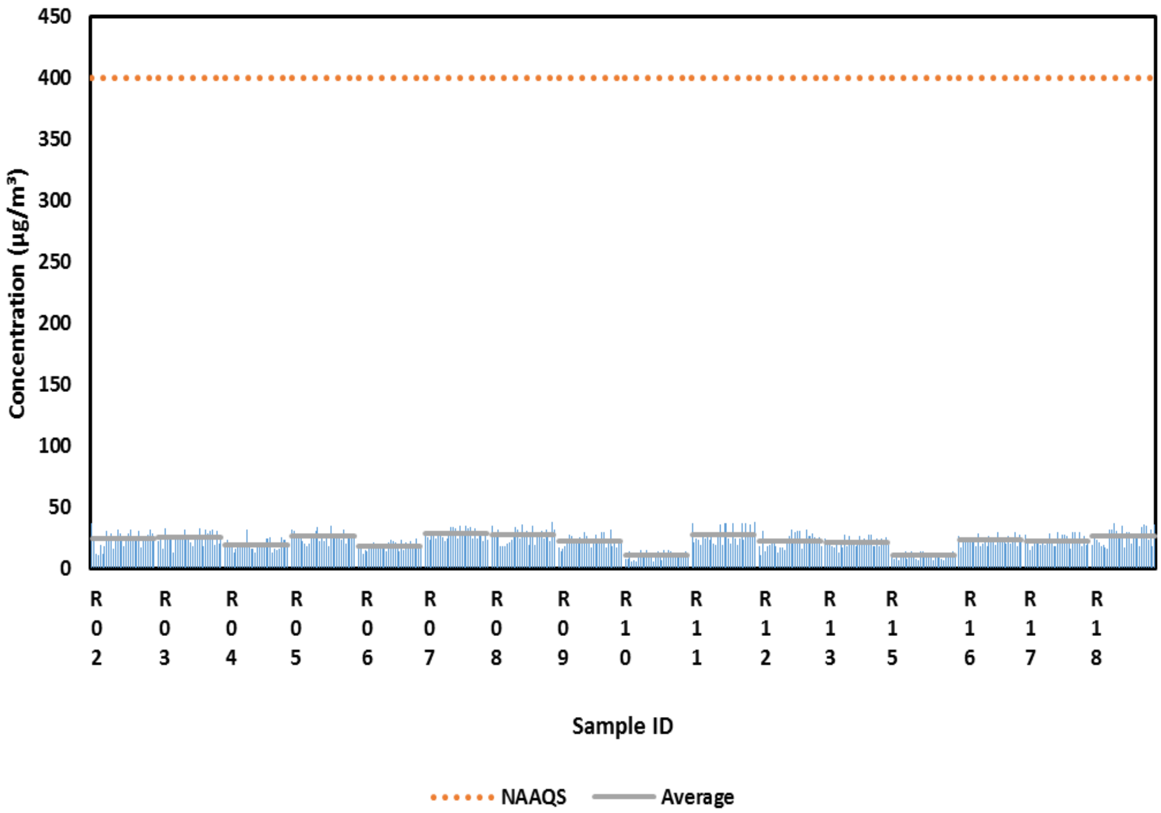


Figure 2.36: Concentration of NH_3 in summer season.

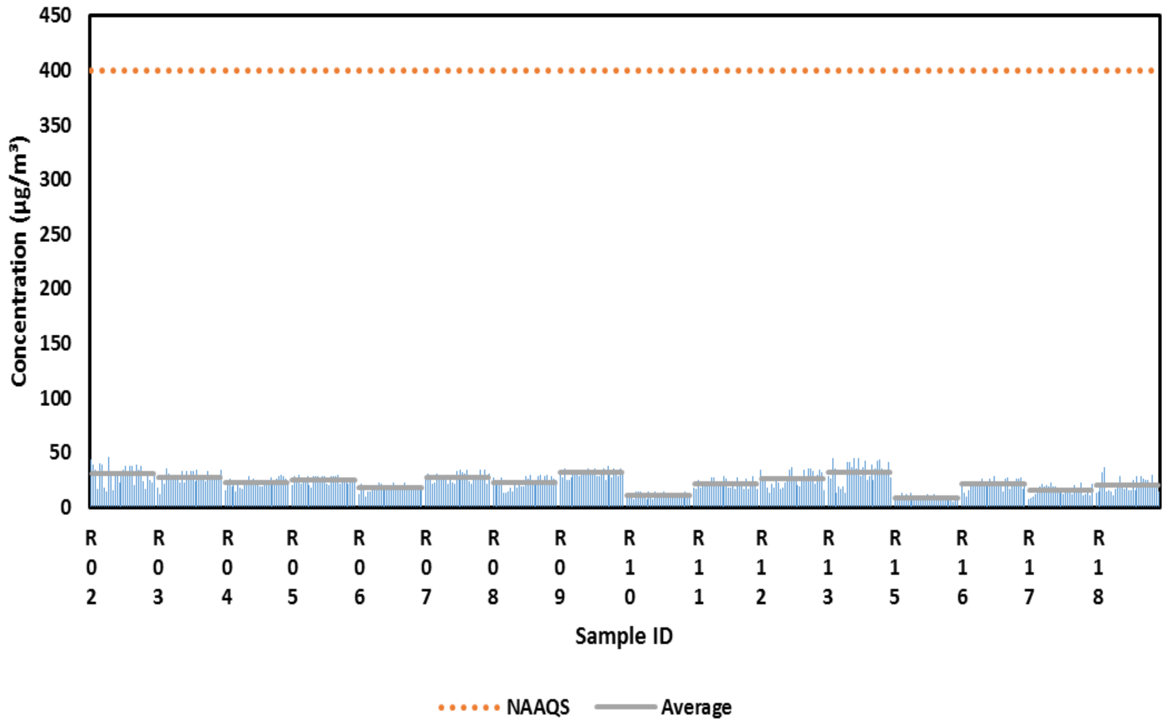


Figure 2.37: Concentration of NH_3 in pre/post monsoon season.

2.3.3.6 O_3 Variation in Different Season

Air sample collected from 18 stations in Raipur in which some shows high concentration of ozone which are R03, R04, and R05 and the main reason could be nearby industries and the heavy traffic in those area as the generation of ozone is mainly because of car, power plant, refineries, chemical plant. High concentration of ozone can cause irritation in eyes resipiratory and heart problem. And also shortness of breath, chest pain, wheezing. In pre/post monsoon air sample collected from 16 station 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 R08, R07 and R13 the reason could be the traffic and nearby industrial areas. High concentration of ozone in winter were found in R04 ,R07 and R15 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.

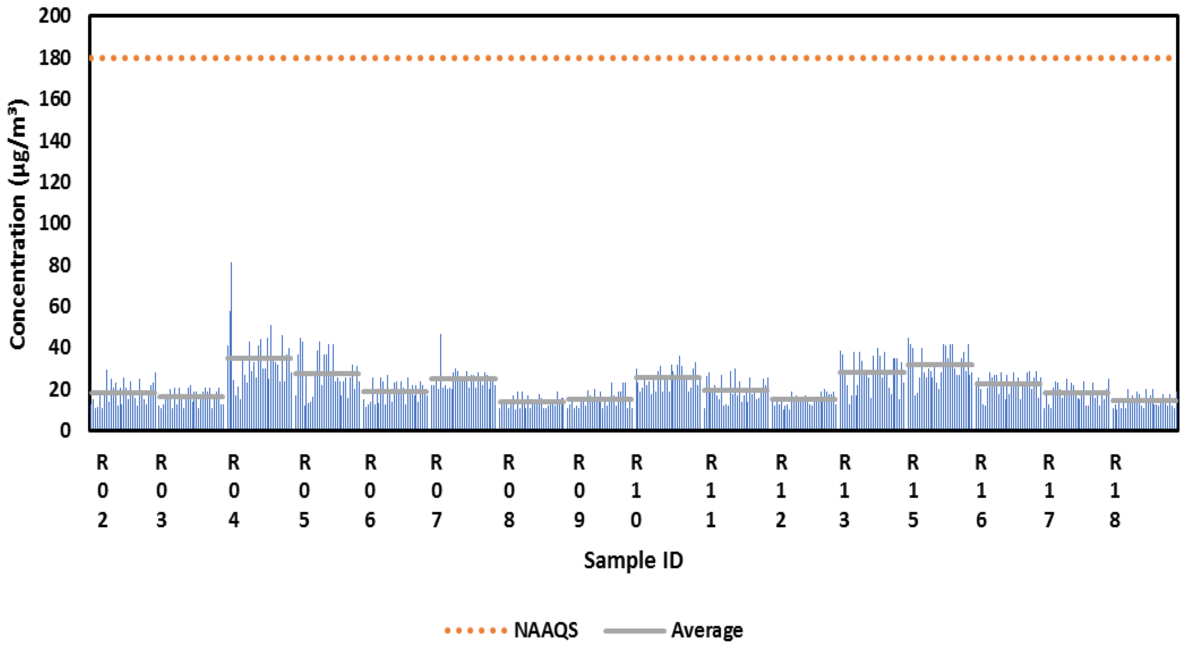


Figure 2.38: Concentration of O_3 in winter season.

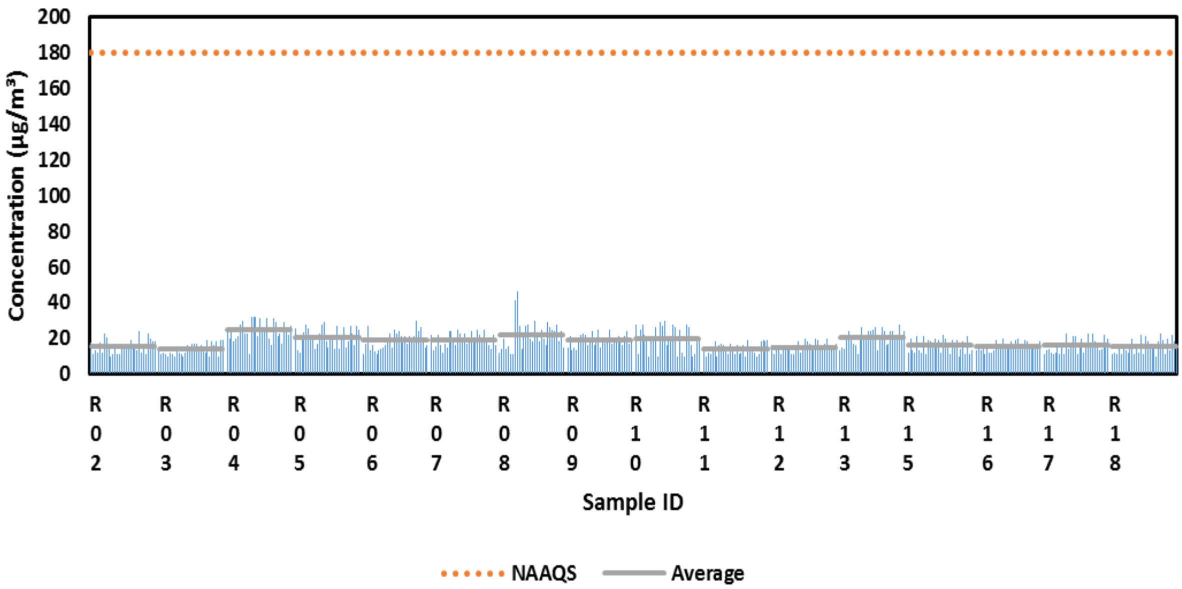


Figure 2.39: Concentration of O_3 in summer season.

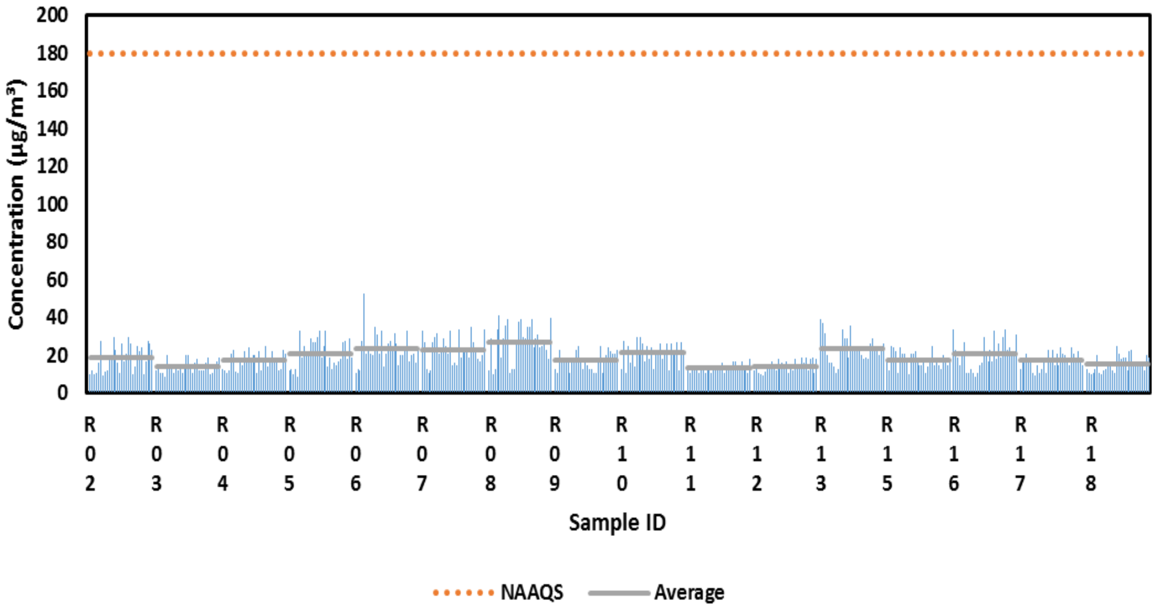


Figure 2.40: Concentration of O_3 in pre/post monsoon season.

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 Pollution Load

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 Raipur district. So, the ambient air quality data has been taken from Raipur 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 Raipur and as per the CPCB guideline we have excluded the monsoon month (July, Aug., Sep.). Estimated total existing PM_{10} Load in Raipur during different months of year 2021 and 2022 is given at Table 2.13.

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

Sl. No.	Month	Estimated load (PM_{10}) (kg)
1	October 2021	165895.75
2	November 2021	243115.76
3	December 2021	318214.35
4	January 2022	275785.77
5	February 2022	208182.89
6	March 2022	186332.18
7	April 2022	248914.34
8	May 2022	219002.19
9	June 2022	255632.21

[Area of Raipur District adopted from District Raipur website https://raipur.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 Raipur district 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 Raipur district during a particular month (y): C X 100 = y kg

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

Table 2.14: Assimilative carrying capacity in Raipur

Sl. No.	Month	Assimilative Carrying Capacity (kg)
1	October 2021	120214.31
2	November 2021	127285.74
3	December 2021	141428.6
4	January 2022	106071.45
5	February 2022	113142.88
6	March 2022	120214.31
7	April 2022	141428.6
8	May 2022	134357.17
9	June 2022	106071.45

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

Month wise supportive carrying capacity of Raipur district, 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 Raipur

Sr. No.	Month	Supportive Carrying Capacity
1	October 2021	-45681.44
2	November 2021	-115830.02
3	December 2021	-176785.75
4	January 2022	-169714.32
5	February 2022	-95040.01
6	March 2022	-66117.87
7	April 2022	-107485.74
8	May 2022	-84645.02
9	June 2022	-149560.75

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

Sr. 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	138	384.2	120214.31	165895.75	-45681.44
2	Nov - 21	706.86	1800	1.8	191	406.2	127285.74	243115.76	-115830.02
3	Dec - 21	706.86	2000	2.0	225	452	141428.6	318214.35	-176785.75
4	Jan - 22	706.86	1500	1.5	260	339	106071.45	275785.77	-169714.32
5	Feb - 22	706.86	1600	1.6	184	361.6	113142.88	208182.89	-95040.01
6	Mar - 22	706.86	1700	1.7	155	384.2	120214.31	186332.18	-66117.87
7	Apr - 22	706.86	2000	2.0	176	452	141428.6	248914.34	-107485.74
8	May - 22	706.86	1900	1.9	163	429	134357.17	219002.19	-84645.02
9	Jun - 22	706.86	1500	1.5	241	339	106071.45	255632.2	-149560.75

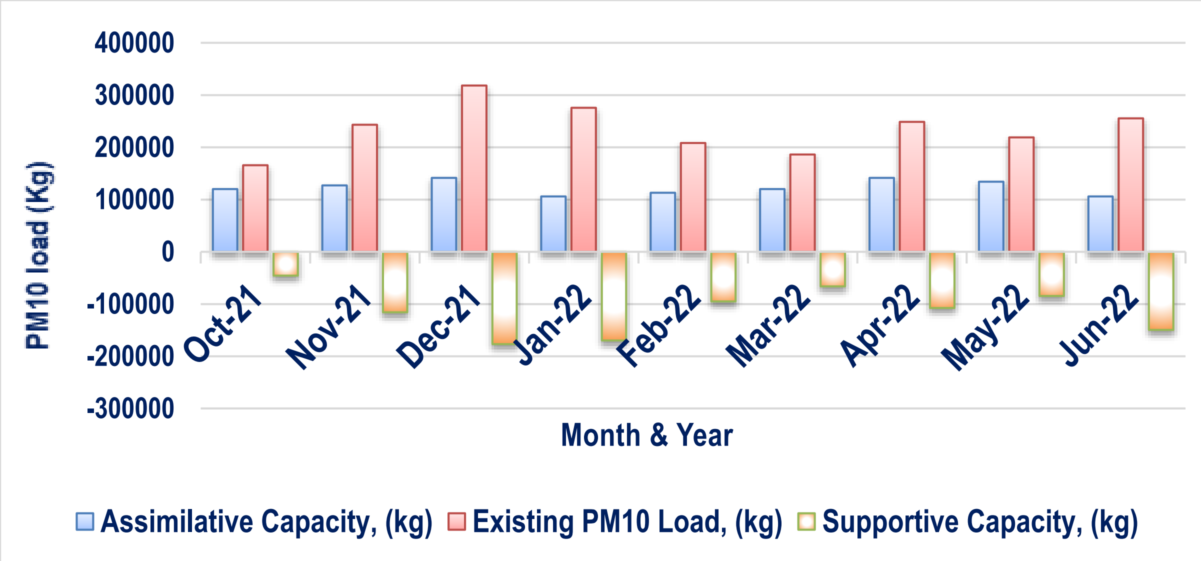


Figure 2.41: Month wise load capacity of PM_{10}.

The final outcome of the assessment with regard to the range of Supportive Carrying Capacity of the ambient air environment in Raipur, 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 Raipur with respect to $PM_{2.5}$

Sr. No.	Month & Year	Area (km²)	Mixing height, (m)	Mixing height, (km)	Avg. $PM_{2.5}$ Conc. (µg/m³)	Volume of Ambient Air, (km³)	Assimilative Capacity, (kg)	Existing $PM_{2.5}$ Load (kg)	Supportive Capacity, (kg)
1	Oct-21	706.86	1700	1.7	46	384.2	72128.58	55298.58	16830.59
2	Nov-21	706.86	1800	1.8	50	406.8	76371.44	63642.87	12728.57
3	Dec-21	706.86	2000	2.0	51	452	84857.16	72128.59	12728.57
4	Jan-22	706.86	1500	1.5	17	339	63642.87	17957.9	45684.97
5	Feb-22	706.86	1600	1.6	45	361.6	67885.73	50914.3	16971.43
6	Mar-22	706.86	1700	1.7	60	384.2	72128.59	72128.59	0
7	Apr-22	706.86	2000	2.0	110	452	84857.16	155571.46	-70714.3
8	May-22	706.86	1900	1.9	84	429.4	80614.3	112860.02	-32245.72
9	Jun-22	706.86	1500	1.5	107	339	63642.87	113496.45	-49853.58
10	Oct-22	706.86	1700	1.7	128	384.2	72128.59	153874.32	-81745.73
11	Nov-22	706.86	1800	1.8	138	406.8	76371.44	175654.32	-99282.88

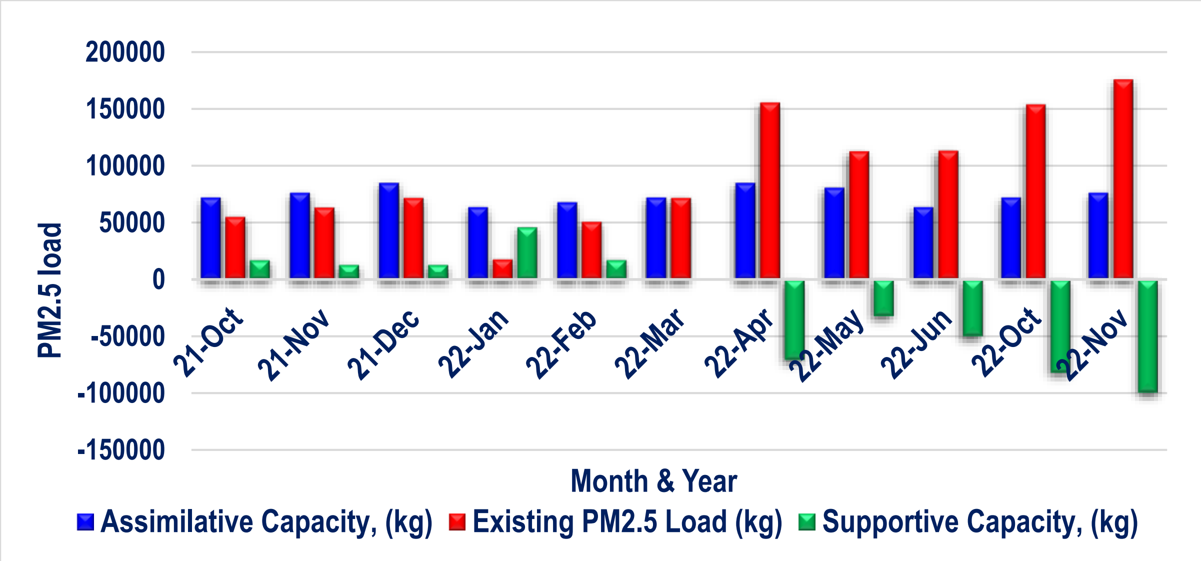


Figure 2.42: Month wise load capacity of $PM_{2.5}$.

The final outcome of the assessment with regard to the range of Supportive Carrying Capacity of the ambient air environment in Raipur, 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 Raipur during study period

Raipur	$PM_{2.5}$			PM_{10}		
	Pre and post monsoon	Summer	Winter	Pre and post monsoon	Summer	Winter
Max	309	318	90	463	383	690
Min	12	11	12	38	25	47
Average	103	84	50	216	193	291
STDV	63	60	16	73	65	148
mean	103	84	50	216	193	291
CV	0.61	0.71	0.32	0.34	0.34	0.51

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

Raipur	SO_2			NO_2		
	Pre and post monsoon	Summer	Winter	Pre and post monsoon	Summer	Winter
Max	78	43	52	84	36	50
Min	5	6	7	6	4	6
Average	28	21	22	21	13	21
STDV	15	9	9	16	5	8
mean	29	21	22	21	13	21
CV	0.52	0.42	0.43	0.74	0.40	0.38

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

Raipur	NH_3			O_3		
	Pre and post monsoon	Summer	Winter	Pre and post monsoon	Summer	Winter
Max	46	38	45	53	46	81
Min	5	6	4	9	10	10
Average	22.90	22.34	26.74	19.13	17.93	21.71
STDV	8.43	7.15	8.05	7.05	5.46	8.88
mean	22.90	22.34	26.74	19.13	17.93	21.71
CV	0.37	0.32	0.30	0.37	0.31	0.41

2.3.6 Carbon impact on environment in Raipur

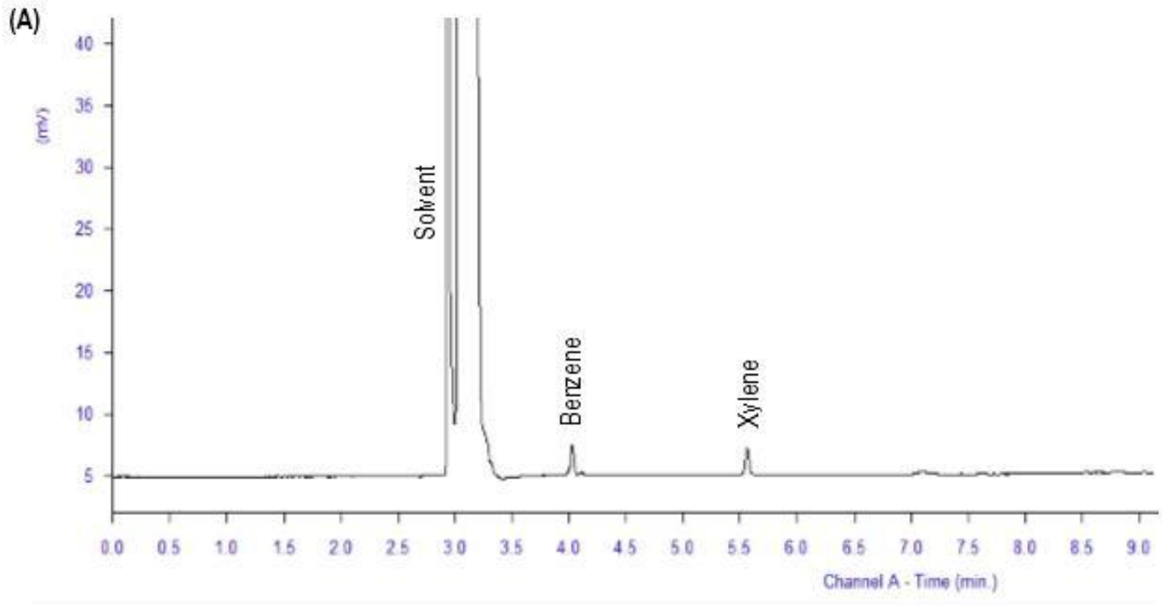
Raipur is a meaningful industrial state and plays significant role on Indian economy. We have selected 18 air quality monitoring stations within the geographical circumstances of Raipur. All those stations are situated within human dwelling areas so that, we can properly study the effects of coal as well as fuel burning, improper agricultural activities, industrial and traffic hazardous on Raipur's population. All these 18 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 0.55 to 0.91 $\mu g/m^3$ among all air quality monitoring stations. Similarly, we have found TC values ranging from 0.61 to 0.101 $\mu g/m^3$ among all air quality monitoring stations. Carbonaceous compounds are mainly organic or house hold type in Raipur non-industrial as well as non-traffic stations.

2.3.7 Seasonal VOCs Variation

Benzene, Ethyl-benzene, Toluene and Xylene are combined known as Volatile Organic Carbons (VOCs). All are colourless liquid at room temperature (27 ± 3°C) and pressure (760 mm-Hg). All has a characteristic aromatic odour, low boiling point and high vapour pressure. Benzene is released in ambient air from both naturally as well as man-made sources and spread rapidly at room temperature. Benzene reacts with hydroxyl, alkoxy and peroxy radicals present in air. Toluene and Xylene are rather reactive than benzene but sometimes present in ambient air with benzene side by side and combined denoted as BTEX. Here, in our case study, VOCs' level variation has been found with the variation of seasons in the ambient air of different sampling stations at Raipur. In winter, toxicity level is increased with the increase amount of VOCs in ambient air of different sampling stations at Raipur. Here we have found both benzene and xylene in winter air samples (Figure 2.43A). Level increases beyond human tolerance level 5μg/m^3 and it have found in range from 5-30 μg/m^3. In summer, toxicity level has been decreased to 3 - 21 μg/m^3 (Figure 2.43B).

Rather than some industrial areas of Raipur, other areas are villages and are full of forests or green. In winter, volatile organic carbons in different sampling stations have found in high range. Not only benzene but also xylene had been found in almost all industrial, traffic and mixed sampling stations with high range (beyond limit). Again in summer season, we have found VOCs values are decreased due high environmental heat (temperature reached up to 44°C in this year). As boiling points of VOCs are low then VOCs vapors may be blown up. Thus resultant value(s) become low.



(B)

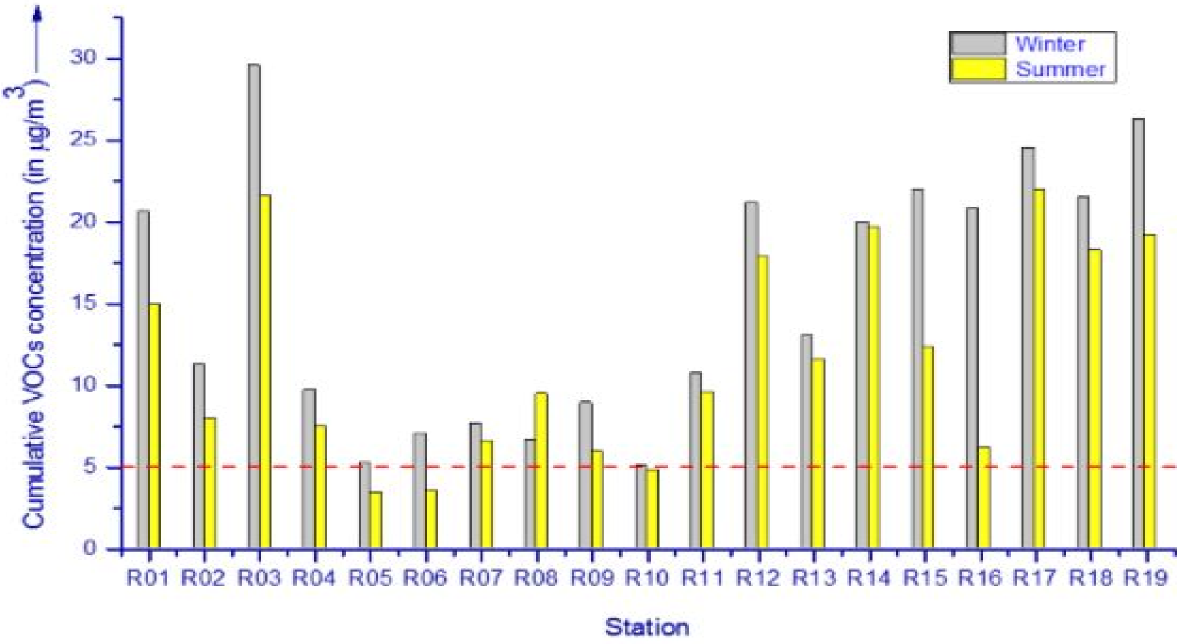


Figure 2.43: (A) GC Chromatogram: VOC analysis of the C-tube extract collected from R08-sampling station, (B) Seasonal variation of VOCs concentration in ambient air of Raipur.

2.3.8 Quantification and Variation of PAHs in Ambient Air

We have prepared a Standard mixture solution (100 ppb) 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 [Figure 4.22]. 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 Raipur surroundings.

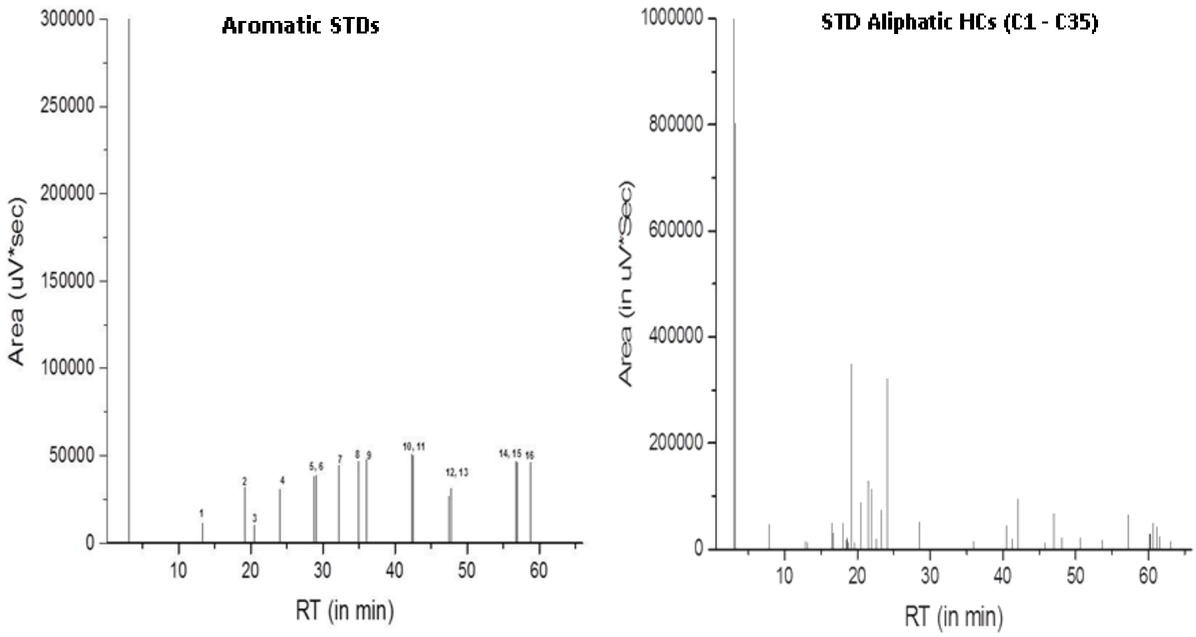


Figure 2.44: GC analysis of PAHs of different aliphatic (C1 to C35) and aromatic (16 selected compounds) standards hydrocarbons.

Here in Figure 2.44, 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 R02 from Raipur. 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 2.44).

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 5-9 ng/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 R02 sampling station but are not harmful. We have found similar trend and got similar real time curve for other sampling stations in Raipur. Raipur is rather clean city and surrounding areas are also free from PAHs related pollution.

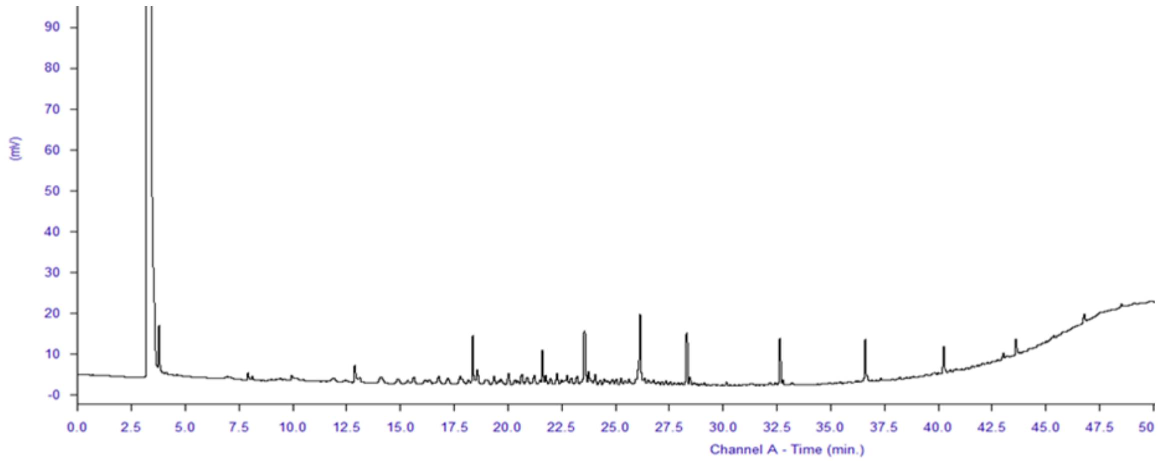


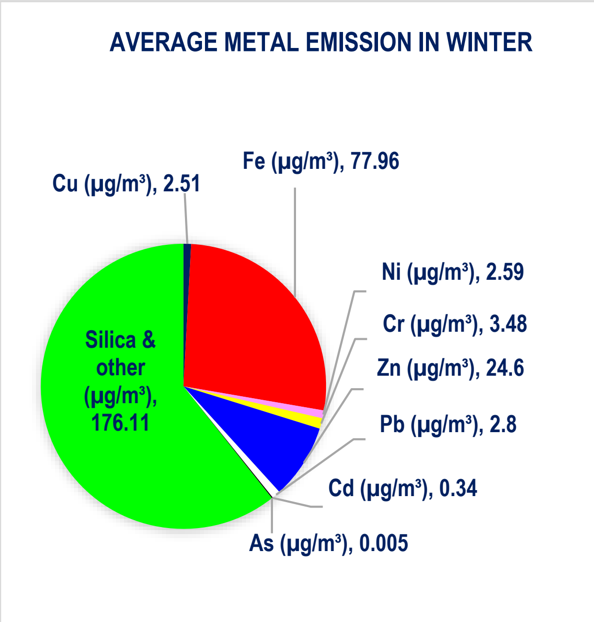
Figure 2.45: GC analysis of PAHs sample collected from R02 Station at Raipur.

2.3.9 Metal Particulate Matters in the Ambient Air

Recent studies indicate that, the composition of particulate matter is associated with increased hospitalizations for cardiovascular and respiratory diseases. Human exposure to ambient heavy-metallic nanoparticles is an area of great interest owing to their potential health impacts. Ambient metallic nanoparticles found in the environment are contributed by combustion engines, wear of brakes, tyres and road surfaces. It has been found that many metallic nanoparticles collected from industrials areas and road sides are rich in iron. The iron-rich nanoparticles can be classified into; (a) high iron content (90 wt%) with each alloying element less than 1 wt%; and (2) moderate Fe content (<75 wt%) with high Mn and Si content. Mn, S and Si being the most important in the high-Fe group. The moderate Fe group also contains Zn, Cu, Ba, Al and Ca.

It is most significant that iron particles play an important role in some atmospheric chemical reactions, including the oxidation of S and on biogeochemical cycles. Deposition of atmospheric iron influences marine productivity and therefore has an influence on the global carbon cycle. But atmospheric iron have adverse effects on human health, being associated with inflammation and DNA damage via oxidative stress. Ambient Zn contributes to worsening pulmonary function in adults. However, information is limited concerning associations between ambient air zinc levels and health care utilization for asthma, especially among children. It has been reported that in humans, ambient air zinc and iron have been associated with worsening pulmonary function tests in susceptible individuals. In addition, some literature indicates that pulmonary toxicity from atmospheric dust samples can be attributed to zinc and copper.

In Raipur, we have 18 ambient air sampling stations. PMx-samples have been collected and are analyzed (the heavy metals from all the acid leached samples) by using AAS and ICP-MS. In winter season, we have got mainly 'Fe' and 'Zn' in these areas and amount are under human toxic level. Other metals like 'Cu', 'Ni', 'Cr' and 'Cd' are also found in ambient air samples but they are in very low amount. While in summer, we have found 'Fe' and 'Zn' along with 'Cr'as well as 'Ni'. Other metal ions like 'Cu', 'Cd', 'Pb' and 'As' were also present in ambient air samples in detectable amount. At sampling station 'R07' all metal ions are under permeable level except 'Pb'. 'Pb' has been found 11 ng/m^3. It's good to see that we have never ever found 'Hg' in any case. But everywhere and every season we have found 'Pb' and 'As' in ambient air sample. Though, their concentrations are very low.



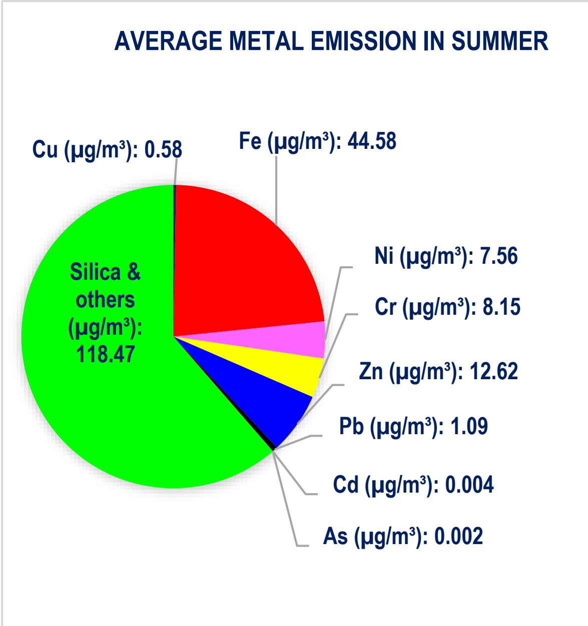


Figure 2.46: Heavy metals concentration (µg/m³) found in the ambient air sample Raipur during winter and summer season.

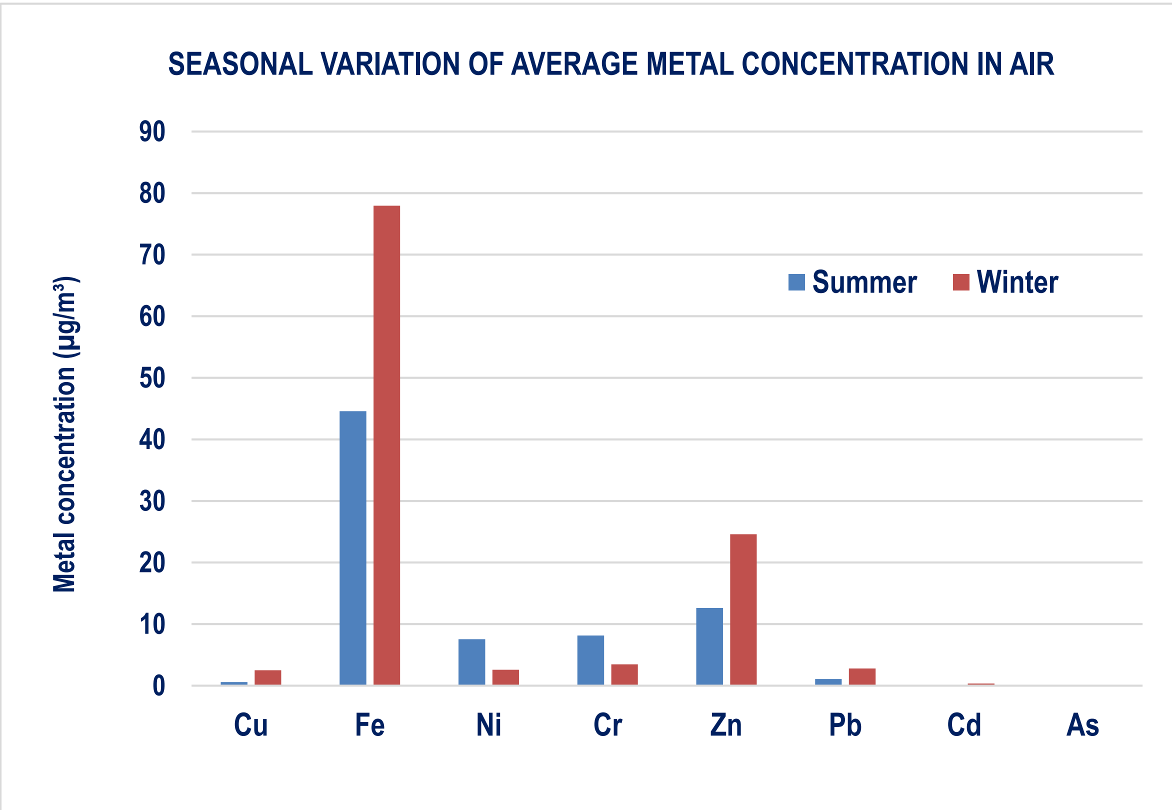


Figure 2.47: Seasonal variation of heavy metal concentration (µg/m³) in ambient air of Raipur.

2.3.10 Polyatomic Ions in Ambient Air

Polyatomic ion, play a vital role in chelation and molecular stabilization, covalently bonded with two or more central metal ions to make a stable metal-complex. These poly-atomic ions are negatively charged (anions) and formed salt with metal (cations). These salts or metal-poly-atomic complexes are then started to fly in ambient air and become respirable, started to enter within human body. Thus may exert toxic effect in human body beyond certain level. In winter, we have found mainly SO_4^{-2} and NO_3^- in the collected air samples in Raipur and are 95% among all poly-atomic anions. Fluoride and chloride are also present in detectable amount but are very low and under permeable level (Figure 2.48 [B]).Similar results are also found in summer but average SO_4^{-2} ion concentration has been increased slightly (Figure 2.48 [A]).

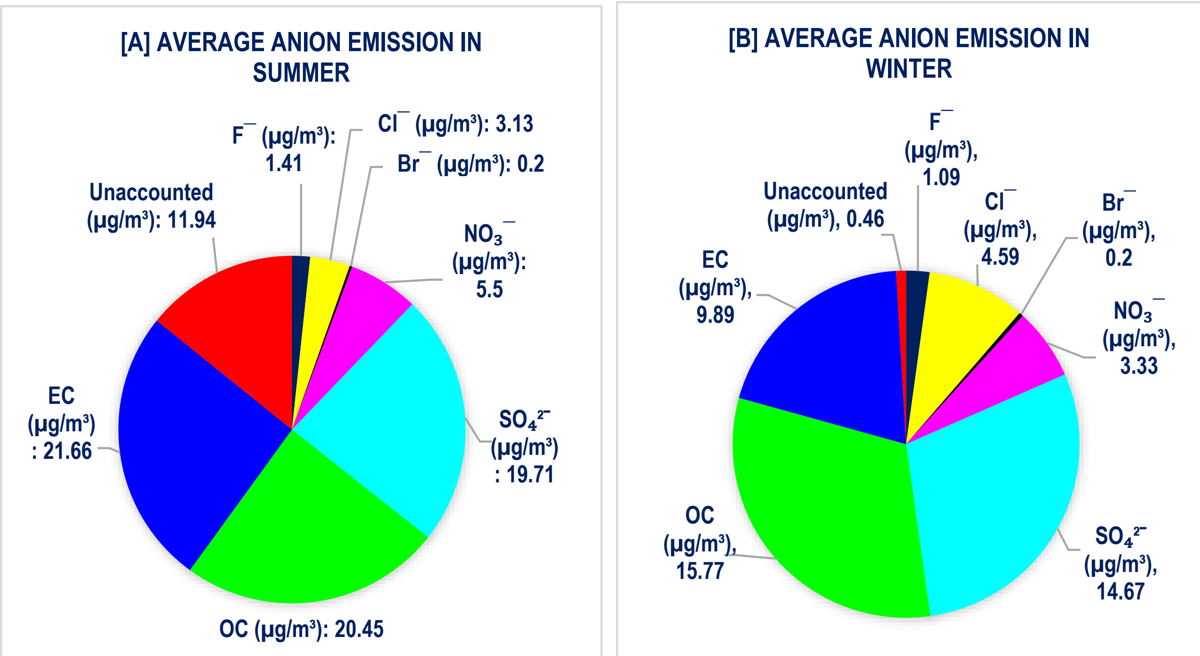


Figure 2.48: Polyatomic ions present (µg/m³) in the ambient air of Raipur: [A] summer and [B] winter.

Sulphate is an important secondary aerosol from photochemical reactions of sulfur dioxide (SO_2) emissions in the atmosphere. In summer peaks in sulphate concentrations are common for most of the areas due to solar insulation, chemical reactions facilitated in high relative humidity environments and stagnation events. Sulphate can activate cloud-condensation nuclei and in cloud microphysical processes, interacts directly with incoming shortwave radiation and thereby contributes to global cooling but is potentially harmful to human health. So, higher percentage of sulphate ion in the ambient air of Raipur areas is not good for local population and ecosystems.

Nitrate aerosols are chemically formed in the atmosphere and their main precursors are ammonia and nitric oxide. The major identified sources of ammonia include excreta from domestic and wild animals, synthetic fertilizers, oceans, biomass burning, crops, human populations and pets, soils, industrial processes and fossil fuel combustion. The steady increase of nitrate aerosols since industrialization increases its role as a non-greenhouse gas forcing agent. The formation of nitrate and ammonium aerosol also effects tropospheric chemistry and thus the global tropospheric ozone mass can be reduced through the interaction between gas-phase species and mineral dust aerosol. In Raipur surroundings we found 31% nitrate in the ambient air. This may be played an important atmospheric indicator for future atmospheric pollution related effects.

2.3.11 Stack Monitoring Data

Stack monitoring data for different industries are presented in Table 2.21. 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/Nm^3.

Table 2.21: Stack monitoring data for Raipur.

Sl. No.	Location of stack	Location of stack	Date	Latitude and Longitude	Stack Temperature (K)	Pitot Tube Pressure Drop (mm of H_2O)	SPM (mg/m^3)
1	Real Ispat and Power Ltd.	Power Plant and Spong Iron Stack	9 FEB 2021	21.3190° N, 81.5792° E	383	7.6	132
2	Bajrang TMT and Power Ltd.	Power Plant stack	9 MAR 2021	81° 40' 9.3" E, 21° 26' 4.81"N	329	2.3	189.5
3	Hira Power Ltd. Stack -1	Power Plant Stack -1	9 MAR 2021	81° 37' 11.39” E, 21°19'18.33” N	340	21.3	69.44
4	Hira Power Ltd. Stack -2	Power Plant Stack -2	9 MAR 2021	81° 37' 11.39” E, 21°17'15.23” N	403	9.3	162.31
5	Hira Fero Alloy Ltd.	Power Plant Stack	9 APR 2021	81° 37' 11.39” E, 21°19'18.33” N	394	3.9	383.33
6	Sivalaya Ispat and Power	Kiln II	10 APR 2021	21.3238501° N 81.5790738° E	319	6.8	30.33

2.3.12 Real Time Monitoring Data

From the Figure 2.49, we can clearly note that the highest CO_2 levels were found in R03, R04, R08, R11 and R12. 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.

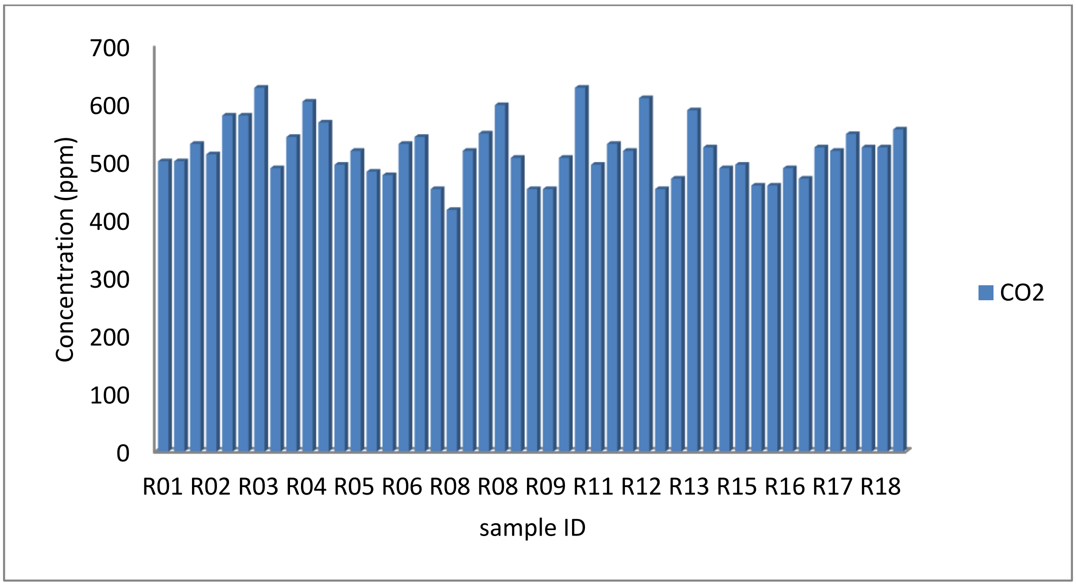


Figure 2.49: CO_2 concentration (in ppm) found using online monitoring system in Raipur.

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 2.50. As expected, the meteorology does not change much from one location to another. It can be observed in Figure 2.50 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 Raipur for year 2022 ranged from 0.0 m/sec to 11.1 m/sec with an annual average wind speed of 2.83 m/sec.

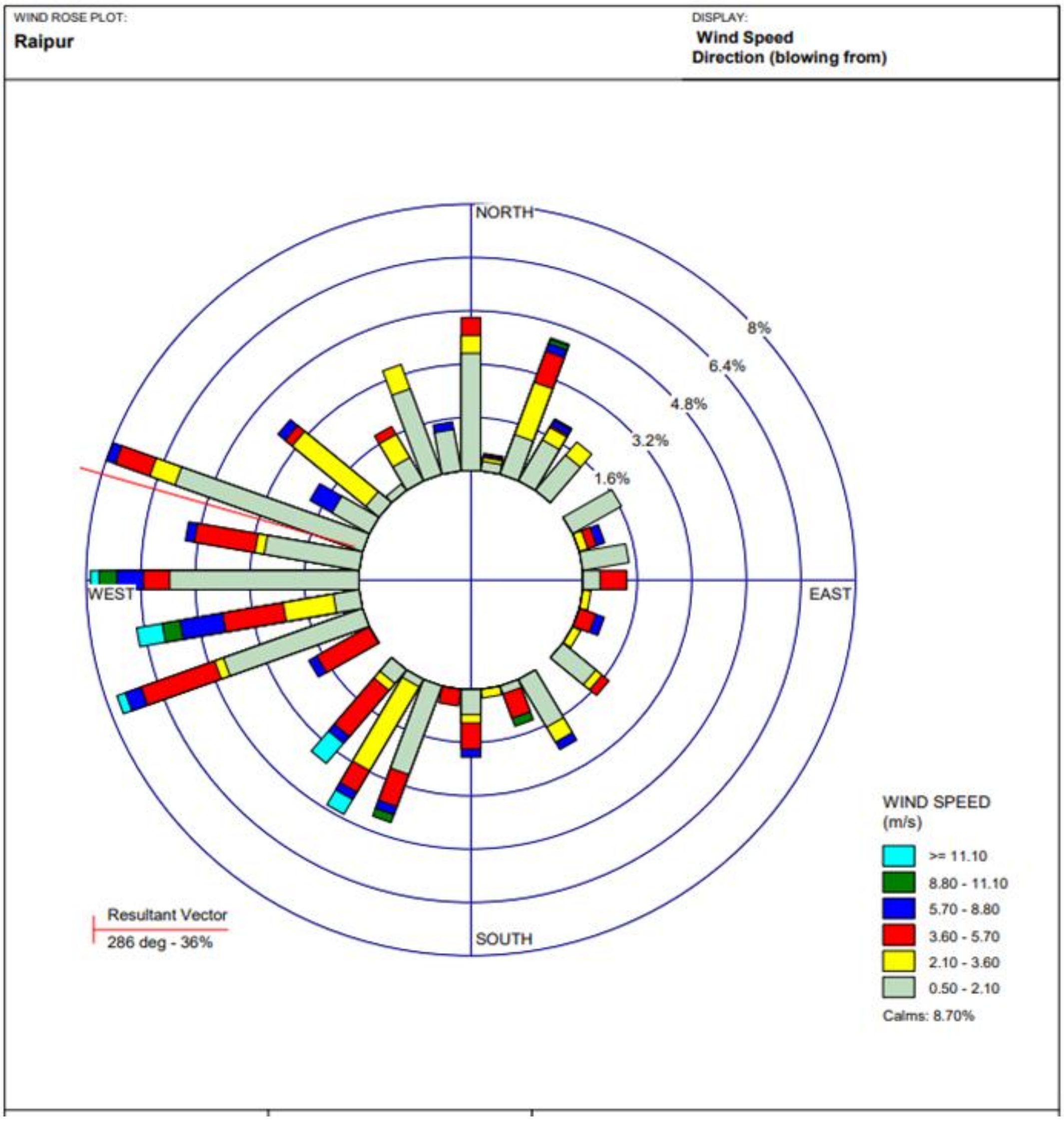


Figure 2.50: Windrose diagram for Raipur.

2.3.1.2 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 Raipur, Chhattisgarh as shown in Figures 2.51 to 2.58. The modelling is carried out using point, line, and area source with different types of emission sources. The emission rate of pollutants of the main 30 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 Raipur 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 Kumhari (North latitude 21˚ 15' 10.371'', East longitude 81˚ 32' 51.3'') and maximum concentration 24-h obtained as 62.32 µg/m^3. SO_2 hotspot are obtained as Bhanpuri (North latitude 21˚ 17' 23.724'', East longitude 81˚ 37' 46.113'') and maximum concentration 24-h 48.746 µg/m^3. NO_x hotspot found to be Bendari and Jarauda (North latitude 21˚ 19' 41.59'', East longitude 81˚ 35' 58.101'') with maximum concentration 24-h of 49.755 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 108.91 µg/m^3 with hotspot near by Chhattisgarh Housing Board Office (North latitude 21˚ 16' 32.406'', East longitude 81˚ 35' 38.921''). Carbon monoxide (CO) hotspot found to be Rohini Puram Amanaka (North latitude 21˚ 14' 7.436'', East longitude 81˚ 35' 36.072'') with maximum concentration 8-h of 744.77 µg/m^3. NO_x maximum concentration 24-h obtained as 53.658 µg/m^3 with hotspot at Daganiya (North latitude 21˚ 14' 6.304'', East longitude 81˚ 35' 19.172''). Sondongari and Mathpurena (North latitude 21˚ 14' 5.888'', East longitude 81˚ 37' 15.2'') hotspot due to hydrocarbon (HC) with concentration 24-h of 168.90 µg/m^3. For the **area source modelling**, we have considered different garbage dumping yard, stone crushers zones in the Raipur city. Here hotspot is found to be Birgaon (North latitude 21˚ 13' 37.451'', East longitude 81˚˚ 39' 48.492'') with SPM concentration 24-h of 361.57 µg/m^3.

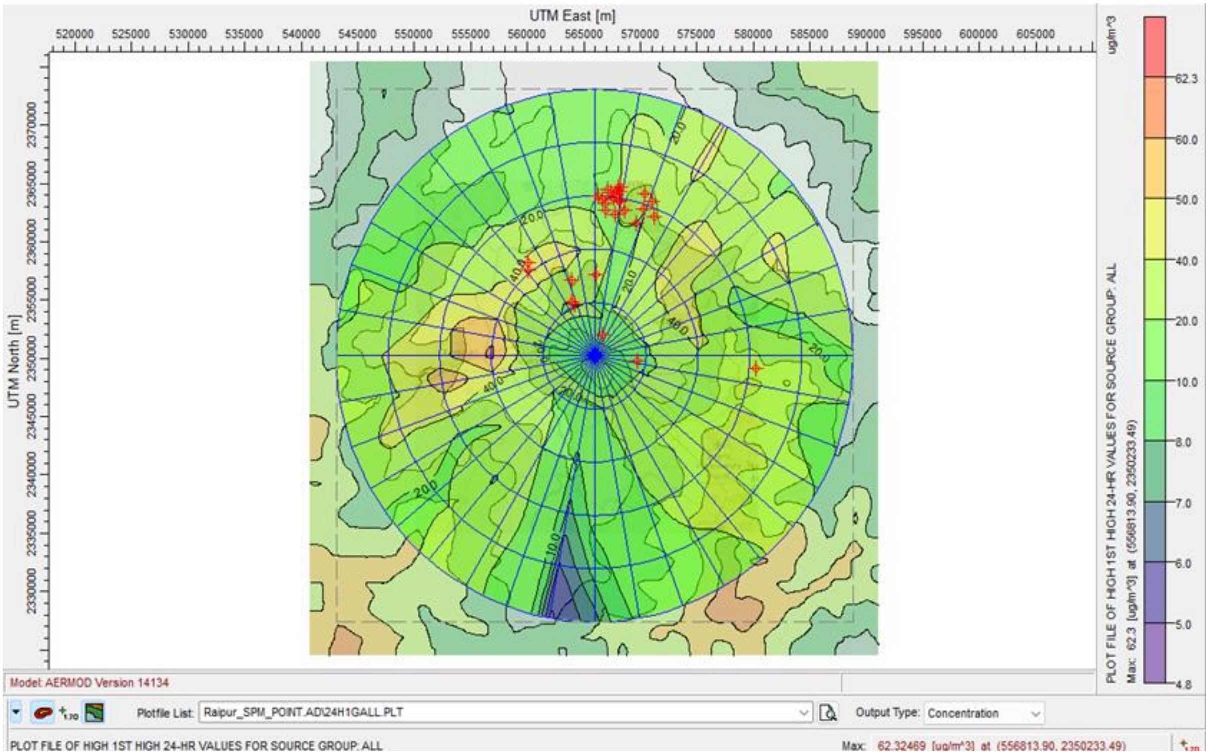


Figure 2.51: Point source isopleths of SPM for 24 hr at Raipur 15 km radius region.

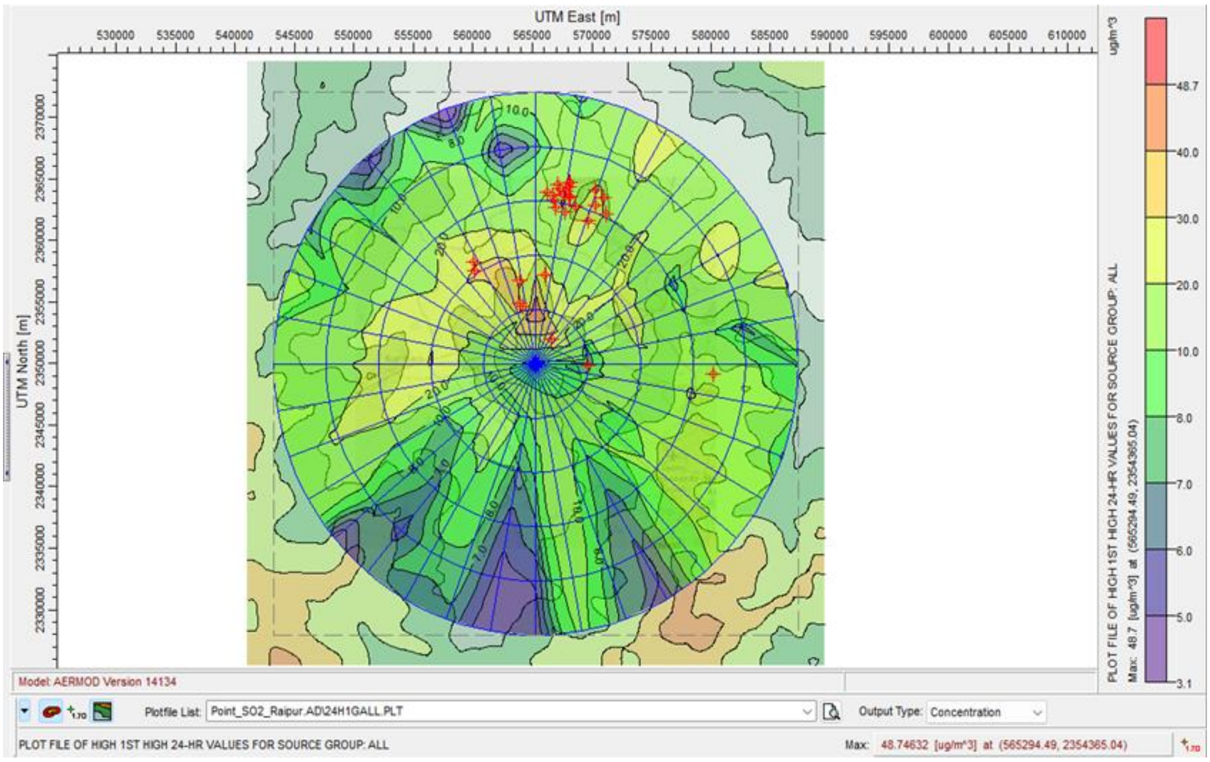


Figure 2.52: Point source isopleths of SO_2 for 24 hr at Raipur 15 km radius region.

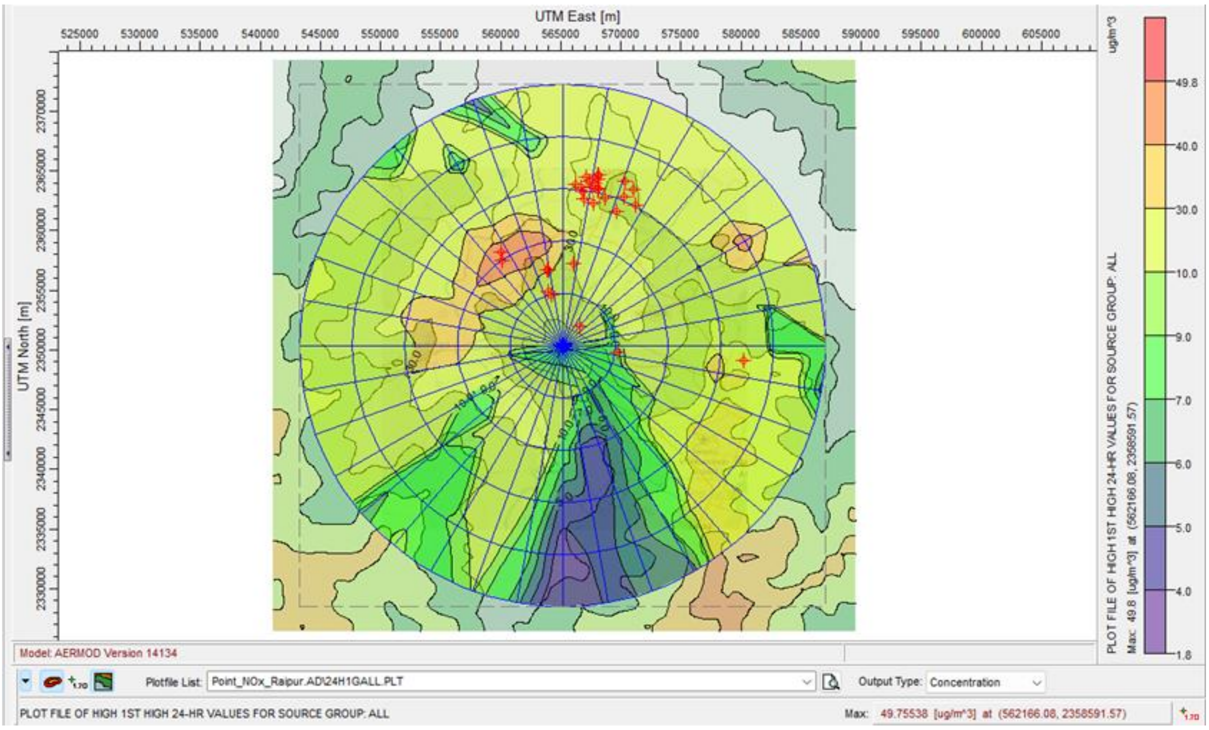


Figure 2.53: Point source isopleths of NO_x for 24 hr at Raipur 15 km radius region.

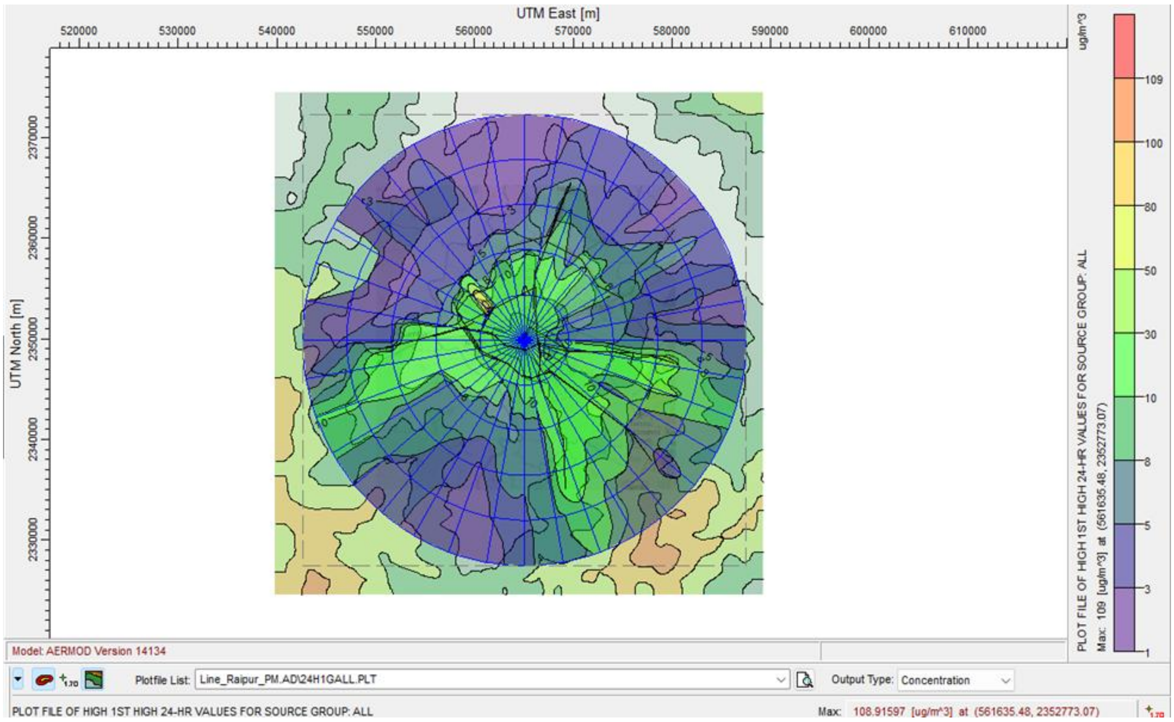


Figure 2.54: Line source isopleths of SPM for 24 hr at Raipur 15 km radius region.

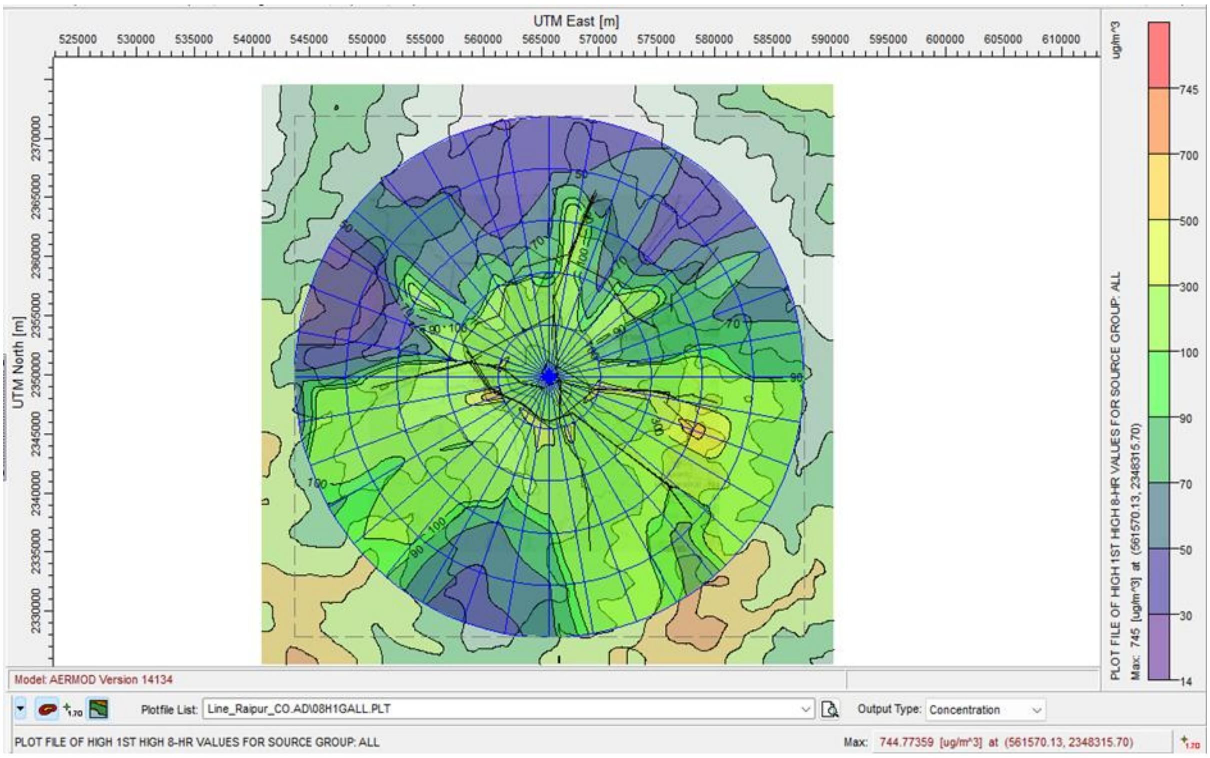


Figure 2.55: Line source isopleths of CO for 8 hr at Raipur 15 km radius region.

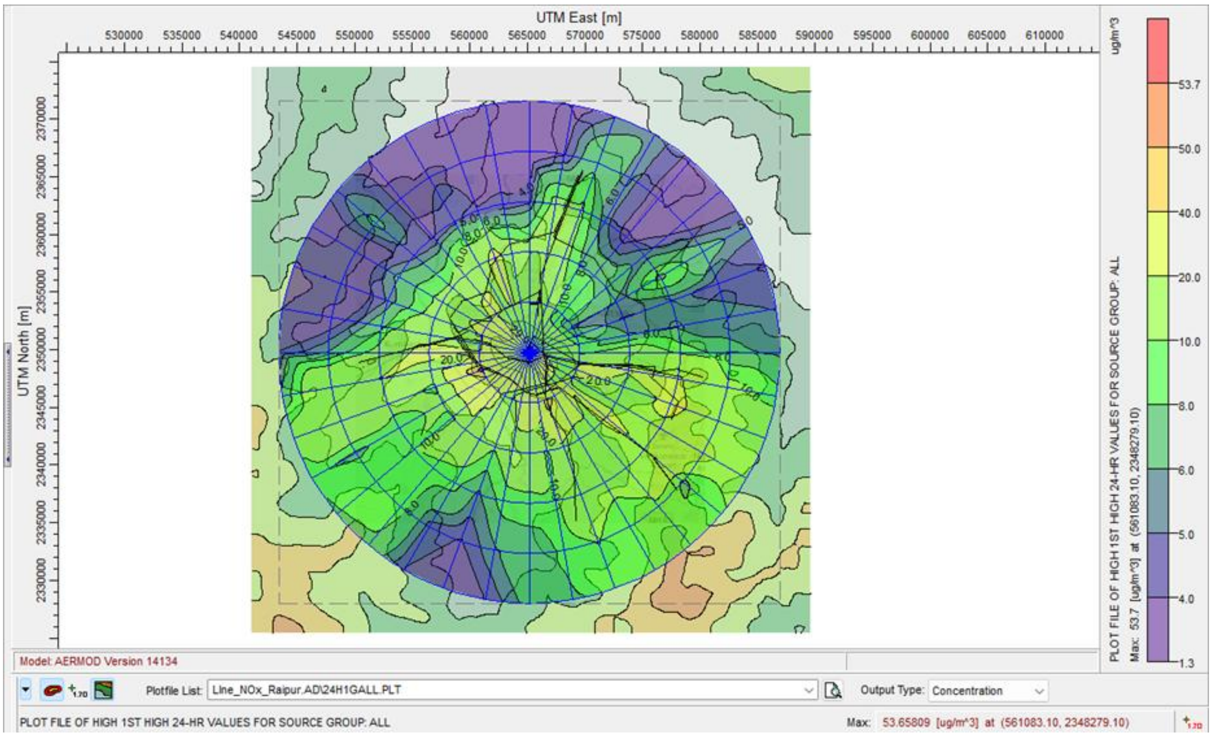


Figure 2.56: Line source isopleths of NO_x for 24 hr at Raipur 15 km radius region.

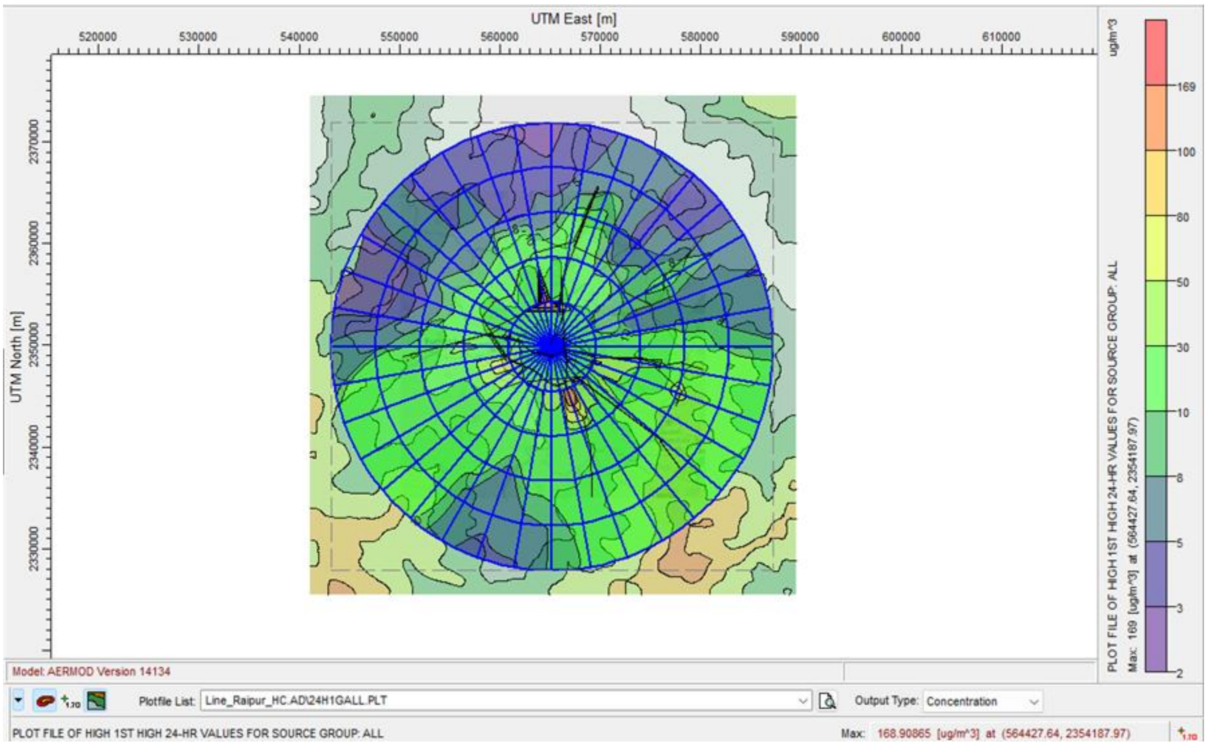


Figure 2.57: Line source isopleths of HC for 24 hr at Raipur 15 km radius region.

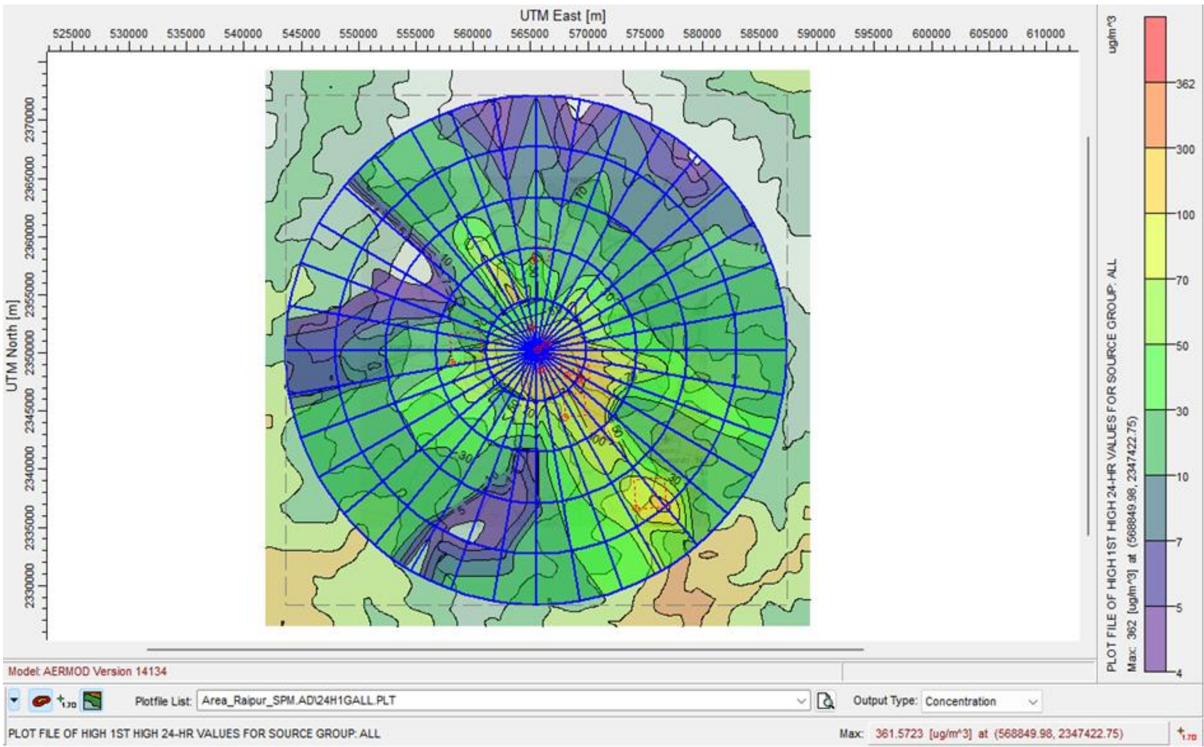


Figure 2.58: Area source isopleths of SPM for 24 hr at Raipur 15 km radius of region.

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 in the two cities are conducted and also in many other areas that represented commercial, residential, industrial, kerb site and mixed areas. Also, various reports, research papers and map of Raipur are consulted to understand possible types and density sources of air pollution in Raipur. Delineation of sources has done after the initial exercise and detail activity data collection are 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 Raipur have been identified and shortlisted for activity data collection (Table 2.22). Importance and weightage have been 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 Raipur

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 of RTO and research papers.	There are lakhs of registered vehicles in Raipur.
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 Raipur.
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 Raipur 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 Raipur is 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	Moderate	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 Raipur
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 Raipur 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	Low	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 Raipur. 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 Raipur
11	Ironing Vendors	Low	Source identified from primary survey	According to initial investigation done by our group there are a few ironing vendors in Raipur who use electricity and also coal for warming the ironing machines

12	Brick Kilns	Low	Source identified from both primary and secondary surves, reports of CECB.	There are few brick kilns of different sizes are present in the study area of Raipur.

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 Raipur 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. Survey on vehicles was conducted at several petrol pumps in Raipur 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 Raipur (Pandari, Rawabhata, Tatibandh chowk).

Figure 2.59: Use of coal by roadside eateries and ironing vendors.

Figure 2.60: Petrol pump survey in the study area.

Figure 2.61: 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 Raipur 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 CG govt.
Crematoria	RMC database, Online resources
Brick kilns	CECB database, Primary survey
Ironing vendors	Primary Survey
Open burning	Primary Survey, RMC data on waste generation, Online sources

2.4.3 Methodology for 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 (Figure 3.3). 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 Raipur 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	Fuels (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.	$$E = \sum_{i,j=1}^{n} EF_{ij} \times VKT_{ij}$$ 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 = Average 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 = Average 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	Fuel (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 Thermal Power Plants in Raipur.	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 Naya Raipur, Sundar Nagar
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
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 12 different brick kilns present in the Raipur surroundings. Main activities are found during winter season.

During the primary survey of eateries and restaurants in Raipur 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 RMC.

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

Anupam garden	Great eastern road
NIT raipur	MG road
Budha talab	Avanti Vihar
Telibandha talab	Aamapara
Katora talab	Near Moti bagh
Jora	
Shankar nagar	
Bajnath para	

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

Sr 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 Compressor							7	3	1	
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, Raipur RTO, Chhattisgarh. Emission from various types 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 Raipur. Table 2.29 presents emission estimates from Raipur 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 3.4 and 3.5.

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

Sector	Emission (MT/y)	
	$PM_{2.5}$	**PM_{10}**
Constructions	380.04	1103.42
Transport Emission	220.03	373.09
Road Dust	293.38	901.64
Industry	85.56	279.82
Generator Sets	50.12	90.16
Domestic	85.57	124.36
Brick Kilns	52.56	30.95
Wastes Burning	39.12	93.27
Restaurants, Eateries and Hawkers	13.57	37.31
Crematoria	2.44	6.22
Total	**1222.39**	**3040.24**

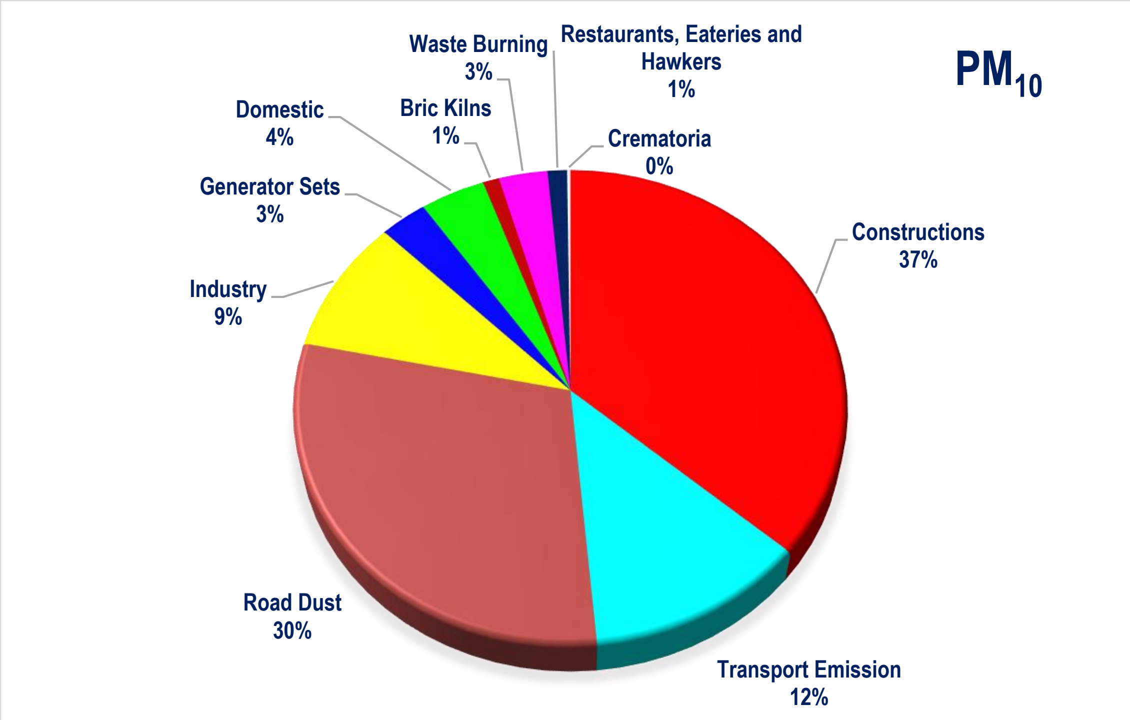


Figure 2.62: PM_{10} emission estimates (% share) from various sectors in Raipur.

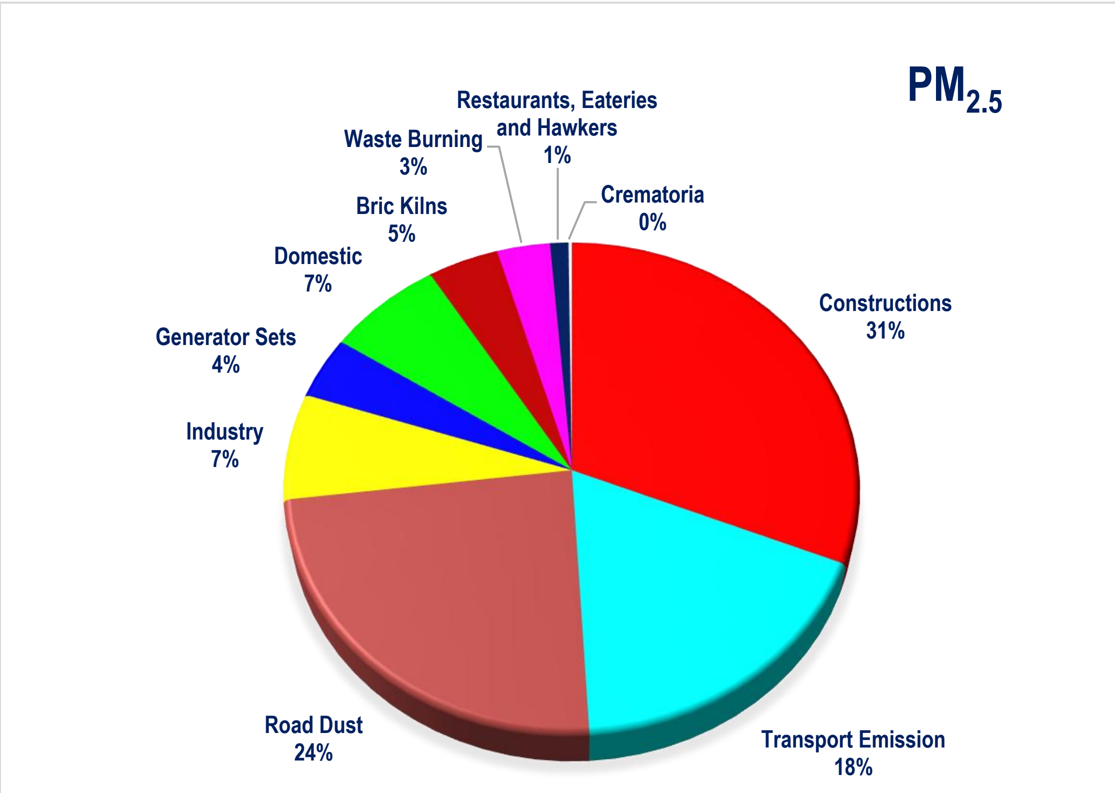


Figure 2.63: $PM_{2.5}$ emission estimates (% share) from various sectors in Raipur.

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 Raipur 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

$$\text{Emission Density (MT/year/m}^2\text{)} = \text{Emission of Ward (MT/year) / Ward Area (m}^2\text{)} \quad (3.1)$$

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 result were utilized (Table 3.9) to identify the major contributors to PM_{10} and $PM_{2.5}$ pollution in Raipur. This involved statistical methods and spatial analysis techniques to determine the relative contributions of various pollution sources.

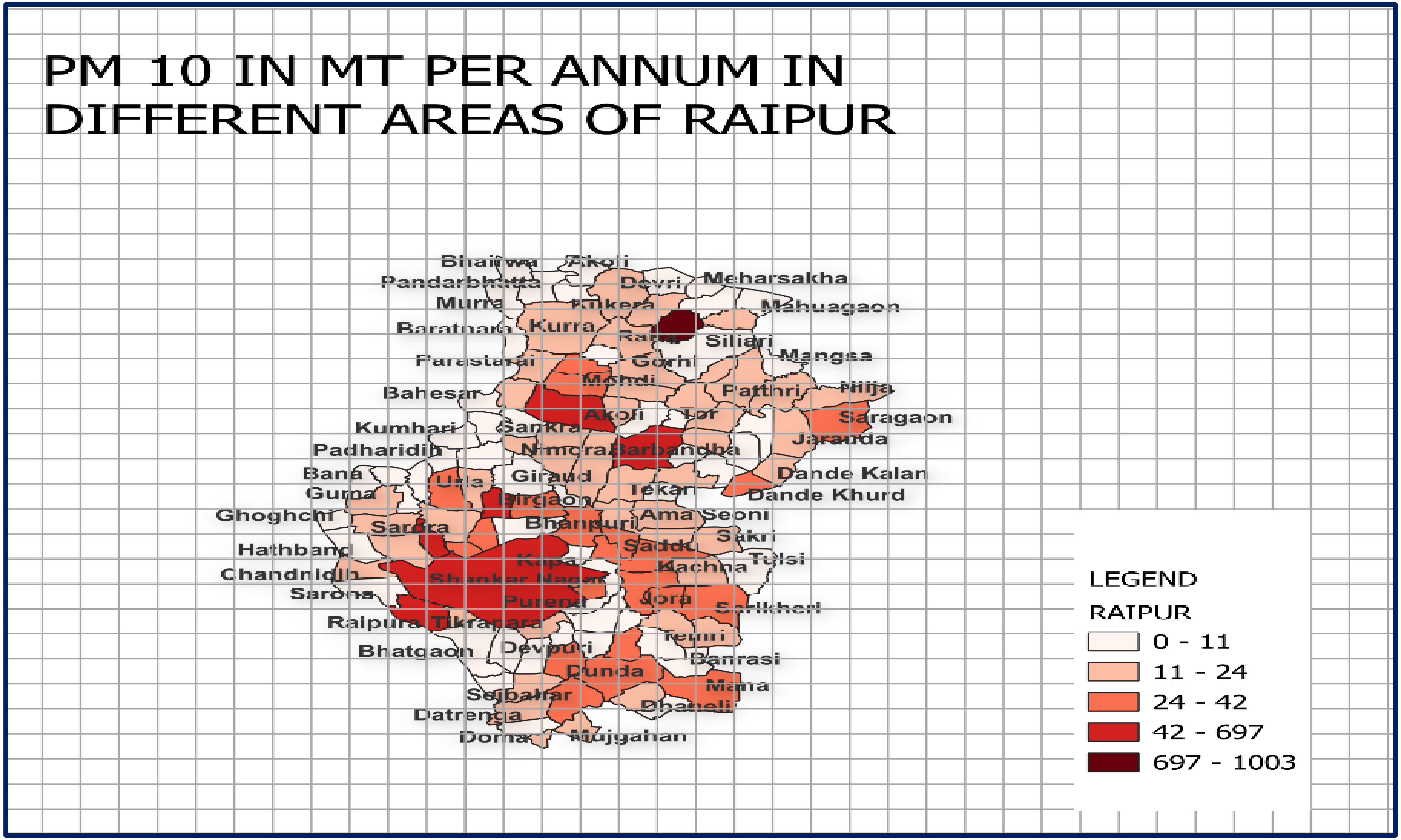


Figure 2.64: 2×2 sq. km gridded spatial distribution of PM_{10} generated from QGIS software for different areas of Raipur.

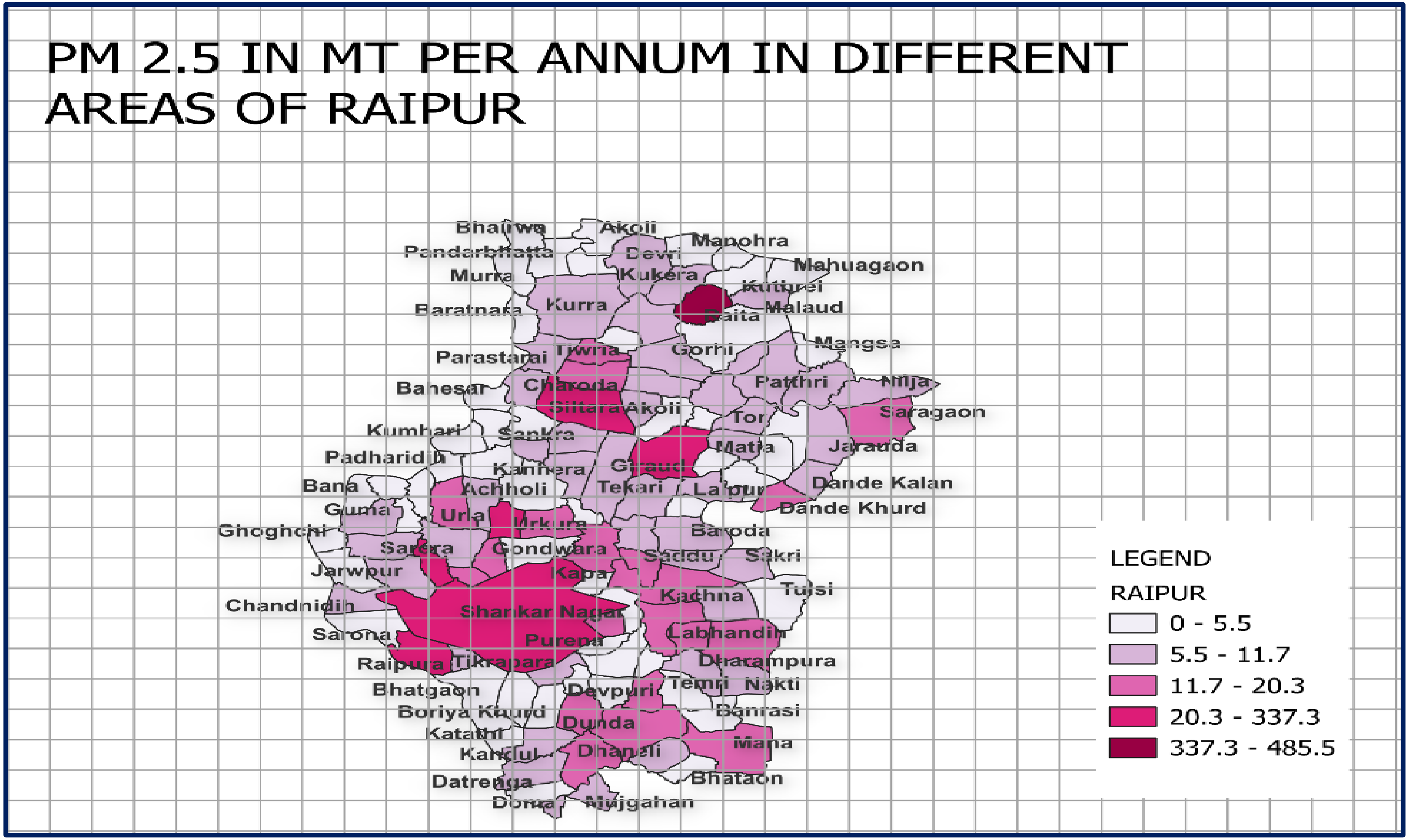


Figure 2.65: 2×2 sq. km gridded spatial distribution of $PM_{2.5}$ generated from QGIS software for different areas of Raipur.

The air pollutant modelling showcased the concentrations of PM_{10} and $PM_{2.5}$ across the study area are presented in Figure 2.64 and 2.65 respectively. The each grid of 2×2 sq. km was prepared to divide the total Raipur 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 Raipur 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 Raipur. 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 Raipur 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 Raipur. 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 18 air-quality monitoring stations in Raipur 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 analyzed 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.

'R02' is also an 'Industrial'- type station near 'Ashram' (Metal Park). CMB predicted the sectoral sources of emission are generator sets (4%; 5.99 µg/m^3), road dust (33%; 47.82 µg/m^3), different types of construction (30%; 43.85 µg/m^3), industry (12%; 16.99 µg/m^3), transport emission (11%; 16.79 µg/m^3), wastes burning (5%; 7.93 µg/m^3) and resturants, eateries and road side hawkers (5%; 7.96 µg/m^3) (Figure 2.67). 'R03' is a 'Commercial' area near 'Gosala' at Hirapur. Major emission sources are transport emission (21%; 34.58 µg/m^3), industry (12%; 18.99 µg/m^3), road dust (24%; 39.14 µg/m^3) and constructions (27%; 43.66 µg/m^3) (Figure 2.68). 'R04' is 'Residential' area of Real Ispat (Kara Panchayat). Major sources of emission in this area are constructions (33%; 47.54 µg/m^3), transports emission (21%; 30.88 µg/m^3), road dust (28%; 39.65 µg/m^3) and industry or some manufacturing units (6%; 7.92 µg/m^3) (Figure 2.69).

Air-quality monitoring station 'R05' is a water treatment plant at Urla. Major emissions are coming from transport (24%; 25.37 µg/m^3), constructions (11%; 11.34 µg/m^3), road dust (38%; 39.66 µg/m^3) and manufacturing units or industry (14%; 14.73 µg/m^3) (Figure 2.70). 'R06' is a 'Silent' type air-quality monitoring station, situated near 'Nagar Nigam Birgaon'. But different types of construction related pollutants are drastically affects the ambient air quality of this station (30%; 38.96 µg/m^3). Some other emission contributors are transport emission (26%; 33.91 µg/m^3), road dust (29%; 37.66 µg/m^3), industry (11%; 13.71 µg/m^3), etc. (Figure 2.71).

Air-quality monitoring station 'R07' is 'AIIMS' hospital. It has been categorized as 'Commercial'. The sources of emission are road dust (39%; 39.41 µg/m^3), different types of transport (28%; 28.61 µg/m^3), constructions (15%; 15.28 µg/m^3), resturants, eateries and hawkers (7%; 7.53 µg/m^3) (Figure 2.72). 'R08' is a 'Residential' area near Kotwali Police Station. Major sources are transports (18%; 19.47 µg/m^3), road dust (45%; 49.33 µg/m^3), different types of construction (16%; 17.41 µg/m^3), etc. (Figure 2.73). 'R09' is a 'Silent' type air-quality monitoring station near DD Nagar House. Major sources are road dust (31%; 29.17 µg/m^3), transports (16%; 15.34 µg/m^3), constructions (26%; 24.61 µg/m^3) (Figure 2.74).

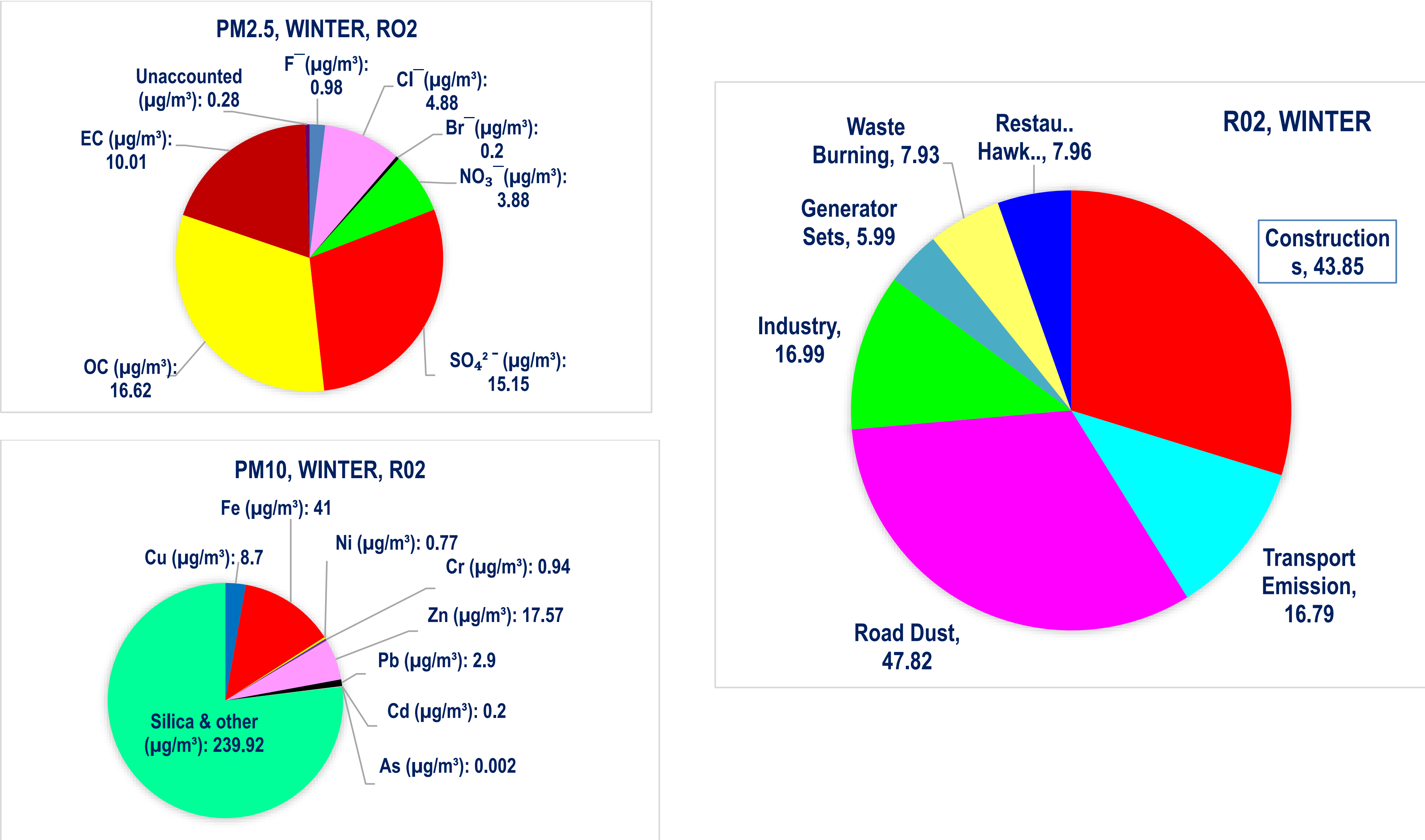


Figure 2.67: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R02' during winter.

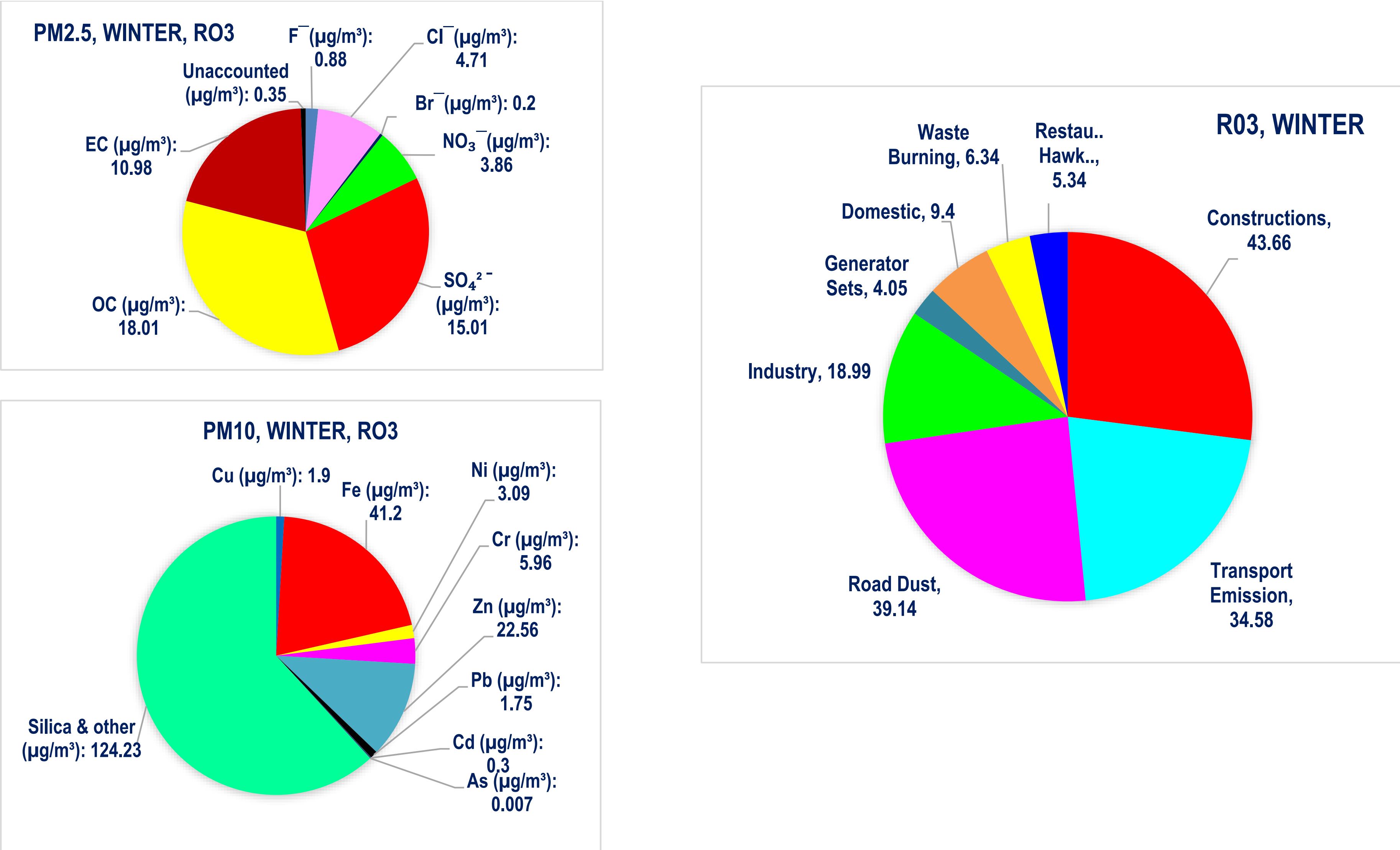
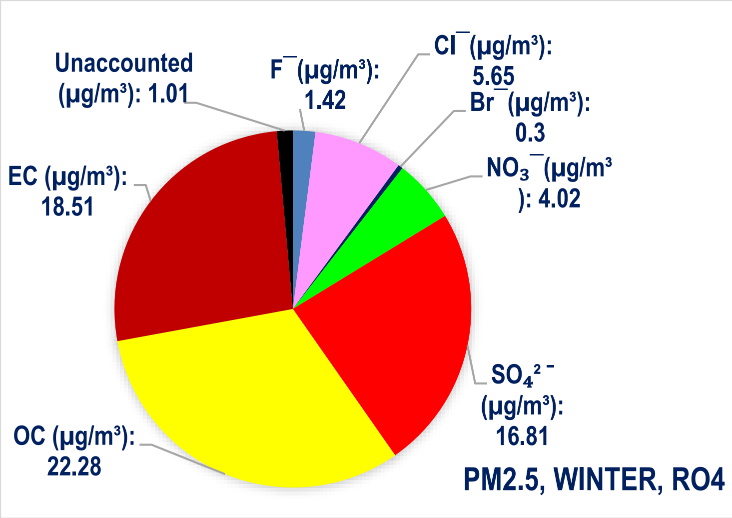
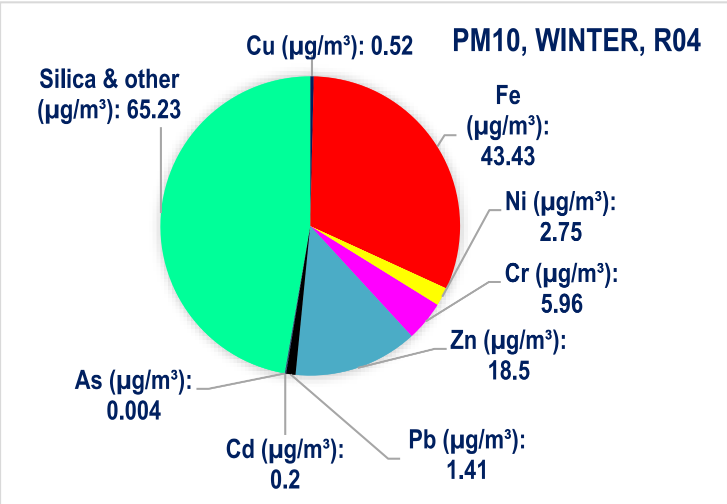


Figure 2.68: Average composition (μg/m³) of particulate matters and their emission sources in air quality monitoring station 'R03' during winter.





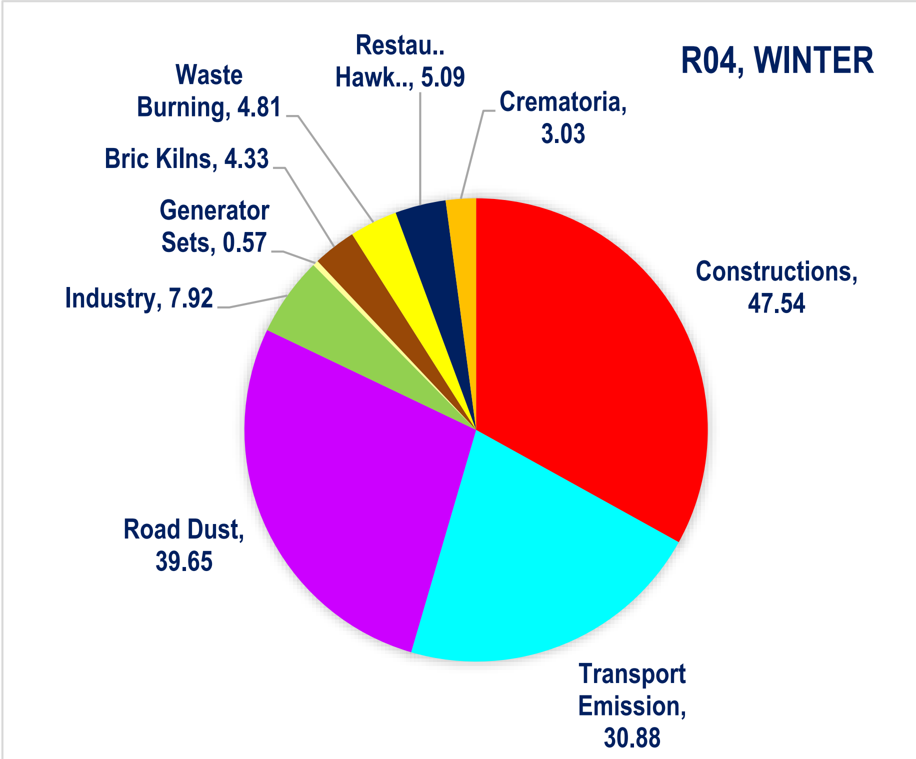
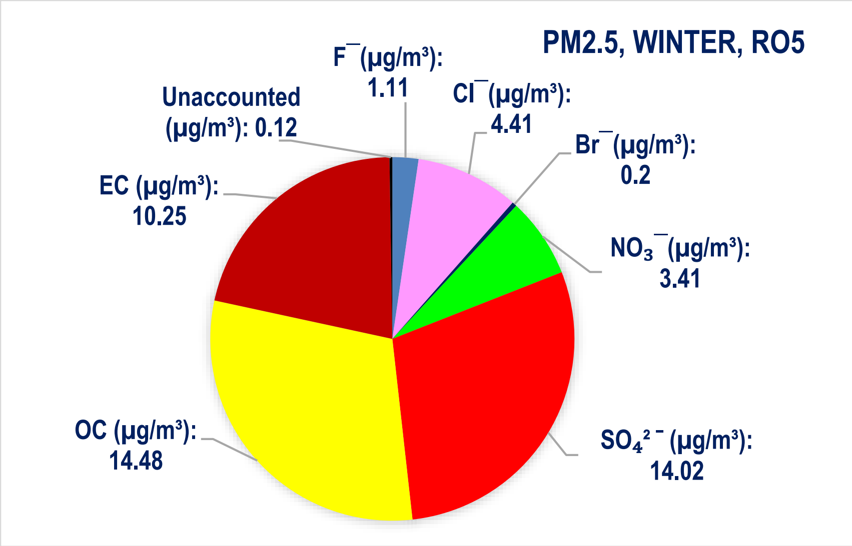
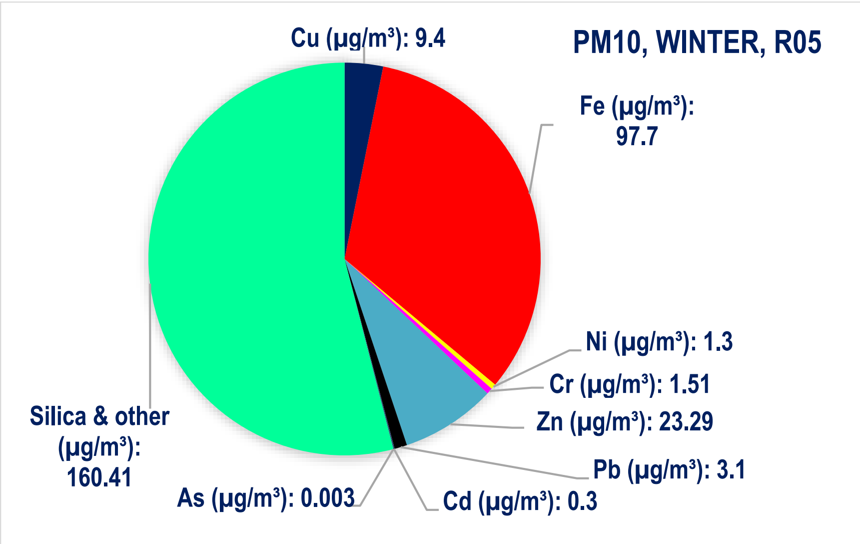


Figure 2.69: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R04' during winter.





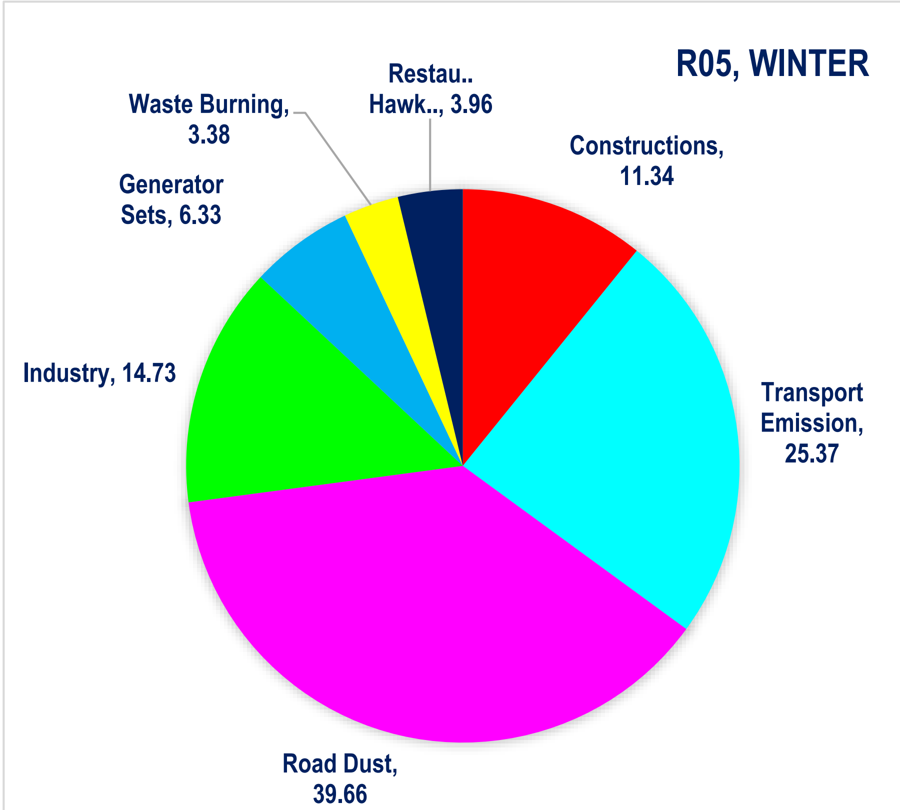


Figure 2.70: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R05' during winter.

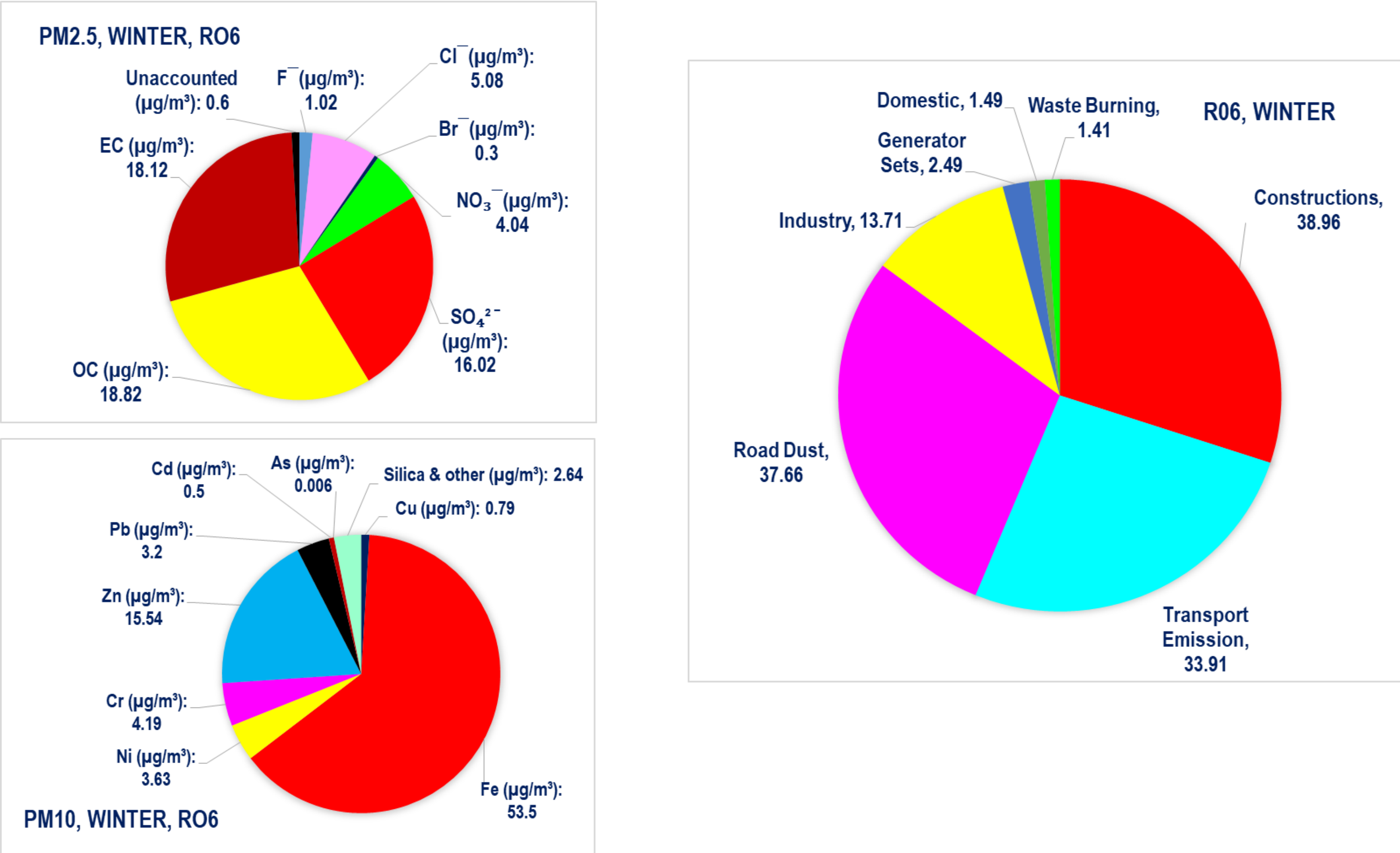


Figure 2.71: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R06' during winter.

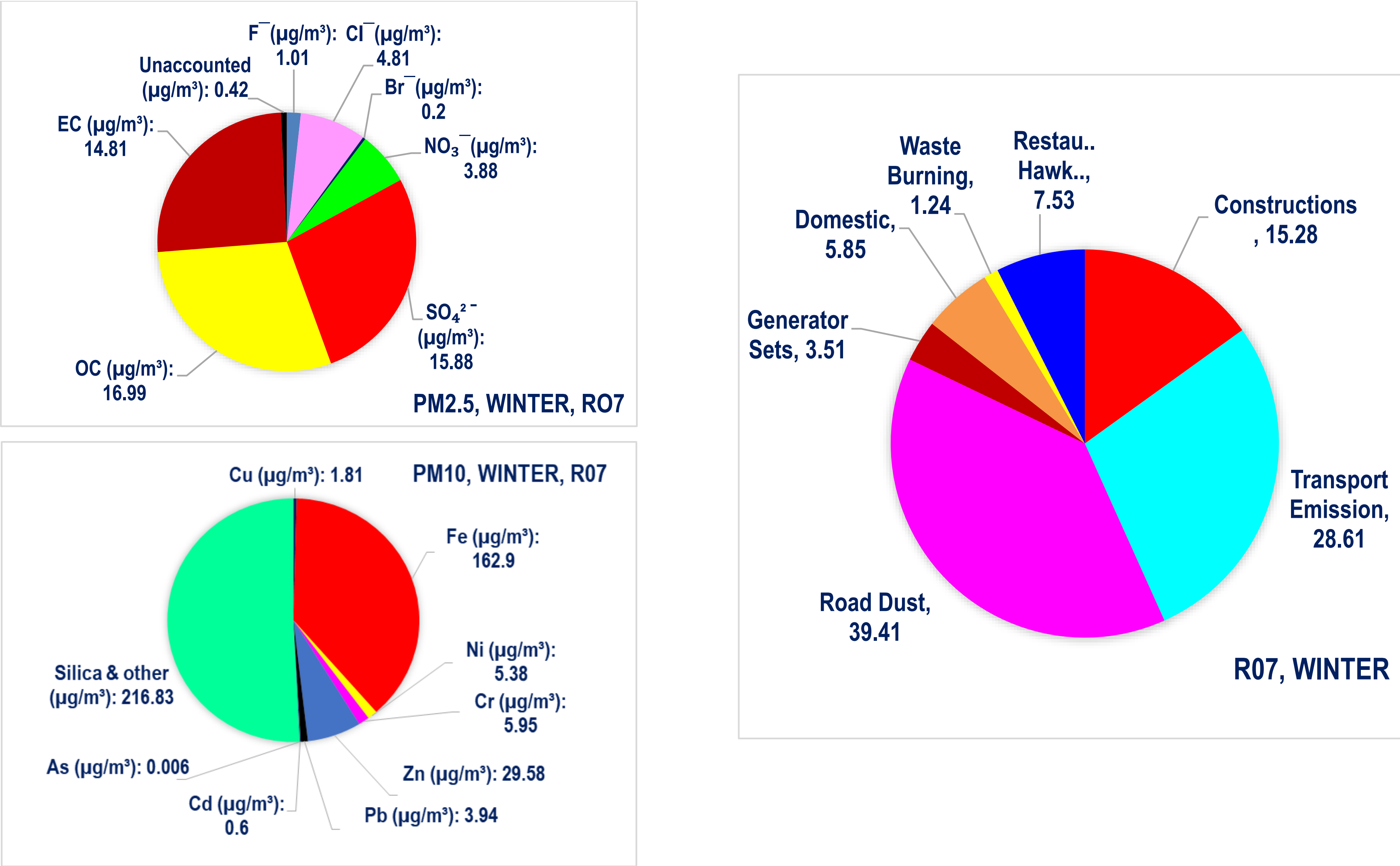


Figure 2.72: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R07' during winter.

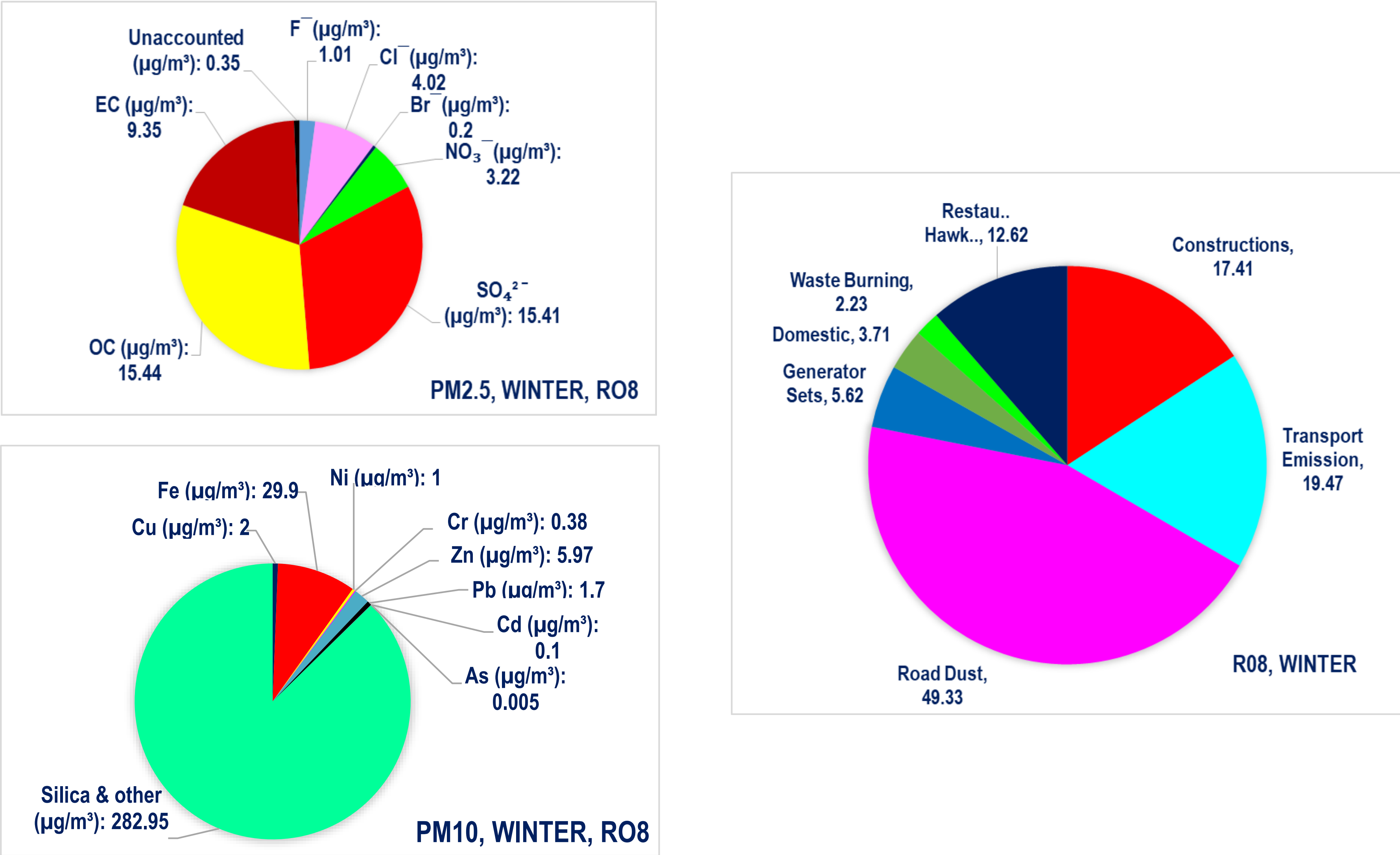


Figure 2.73: Average composition (μg/m³) of particulate matters and their emission sources in air quality monitoring station 'R08' during winter.

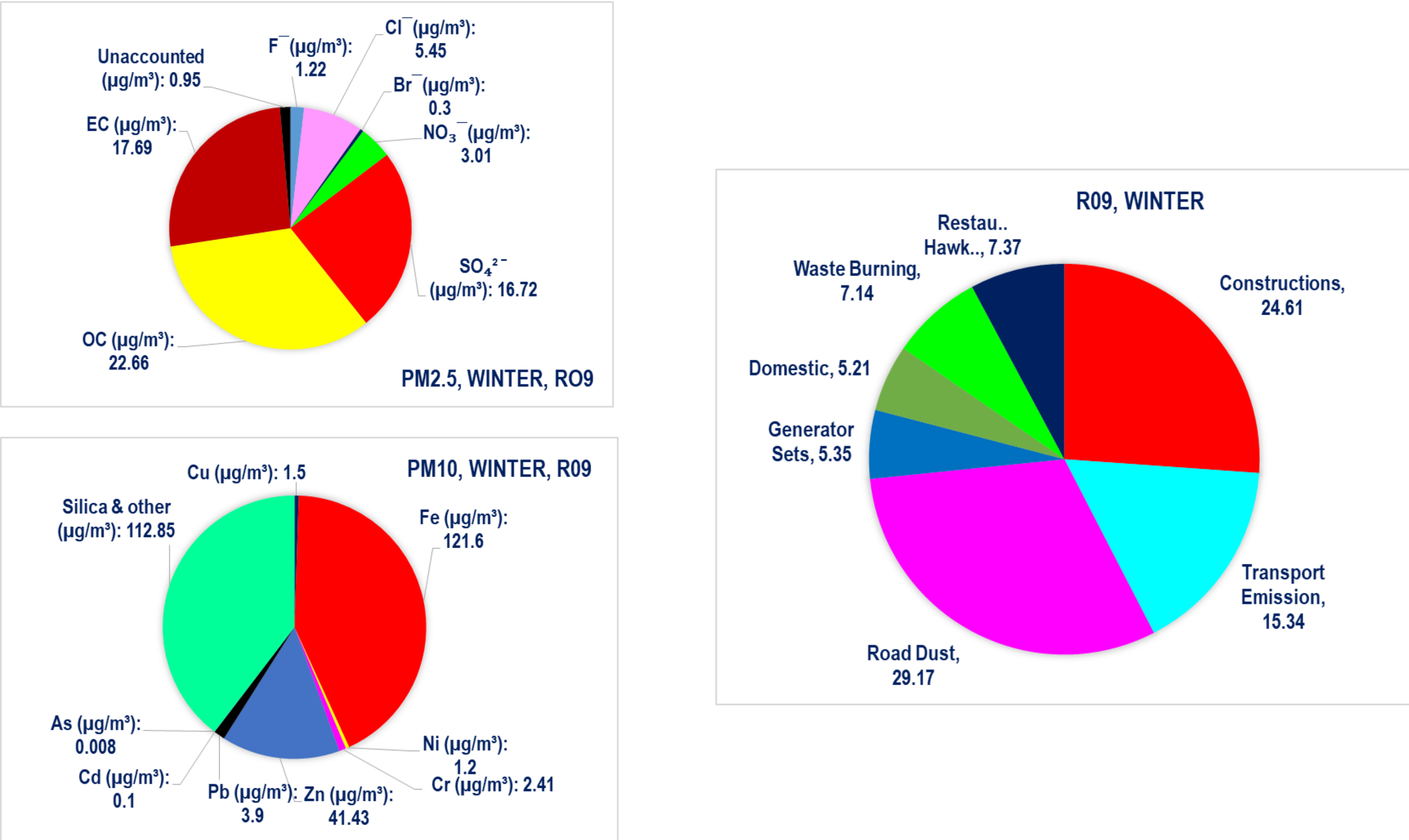


Figure 2.74: Average composition ($\mu g/m^3$) of particulate matters and their emission sources in air quality monitoring station 'R09' during winter.

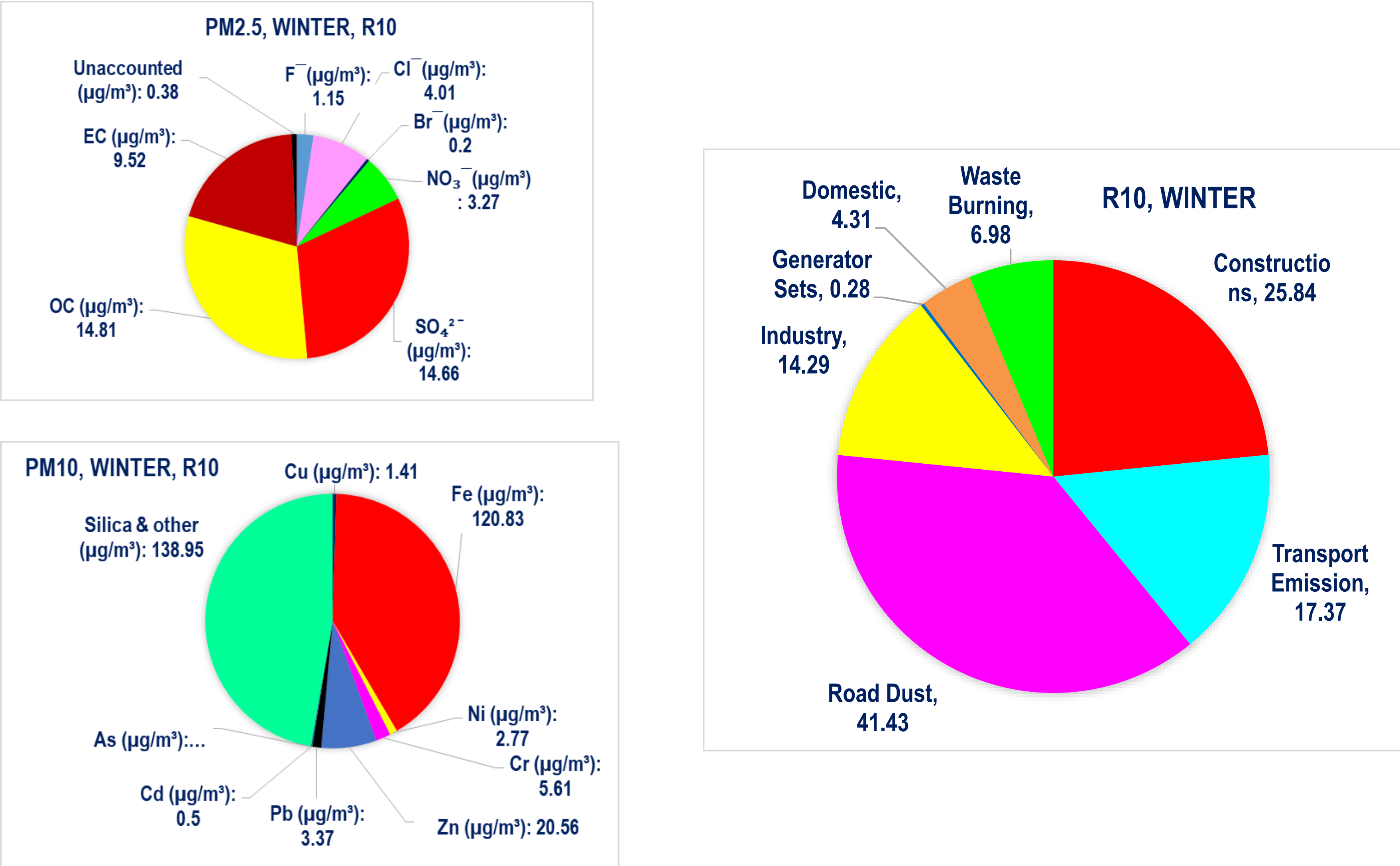


Figure 2.75: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R10' during winter.

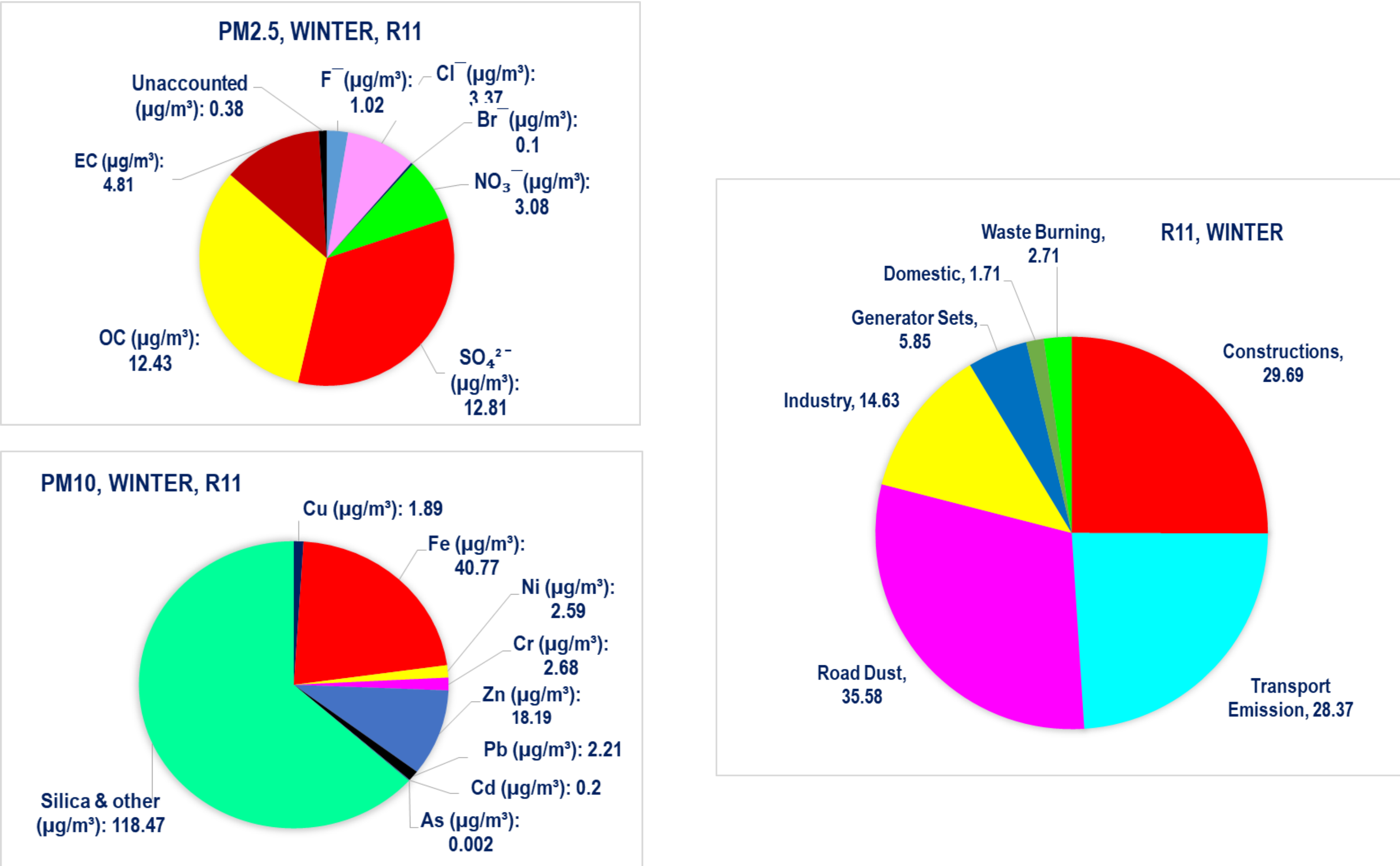


Figure 2.76: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R11' during winter.

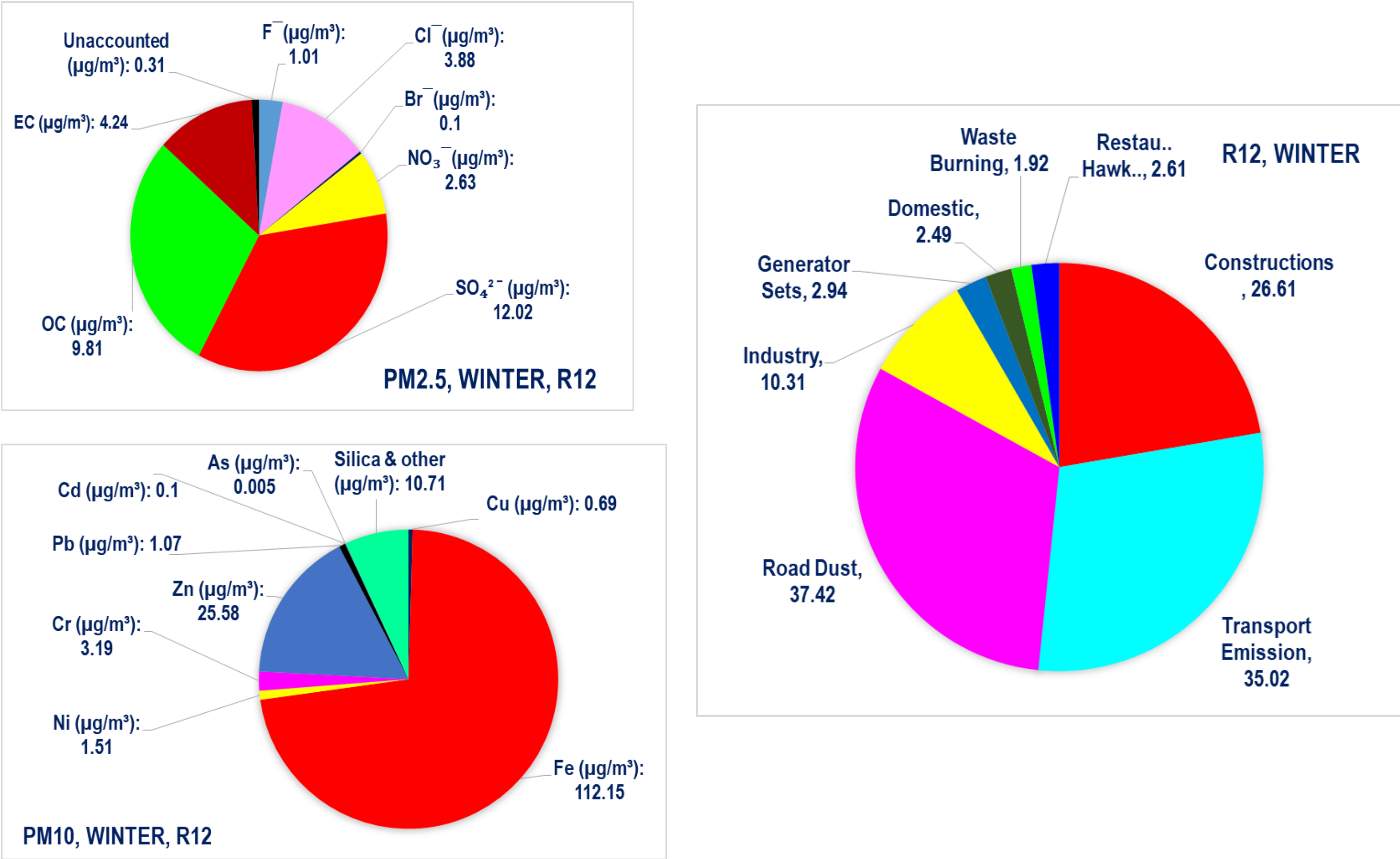


Figure 2.77: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R12' during winter.

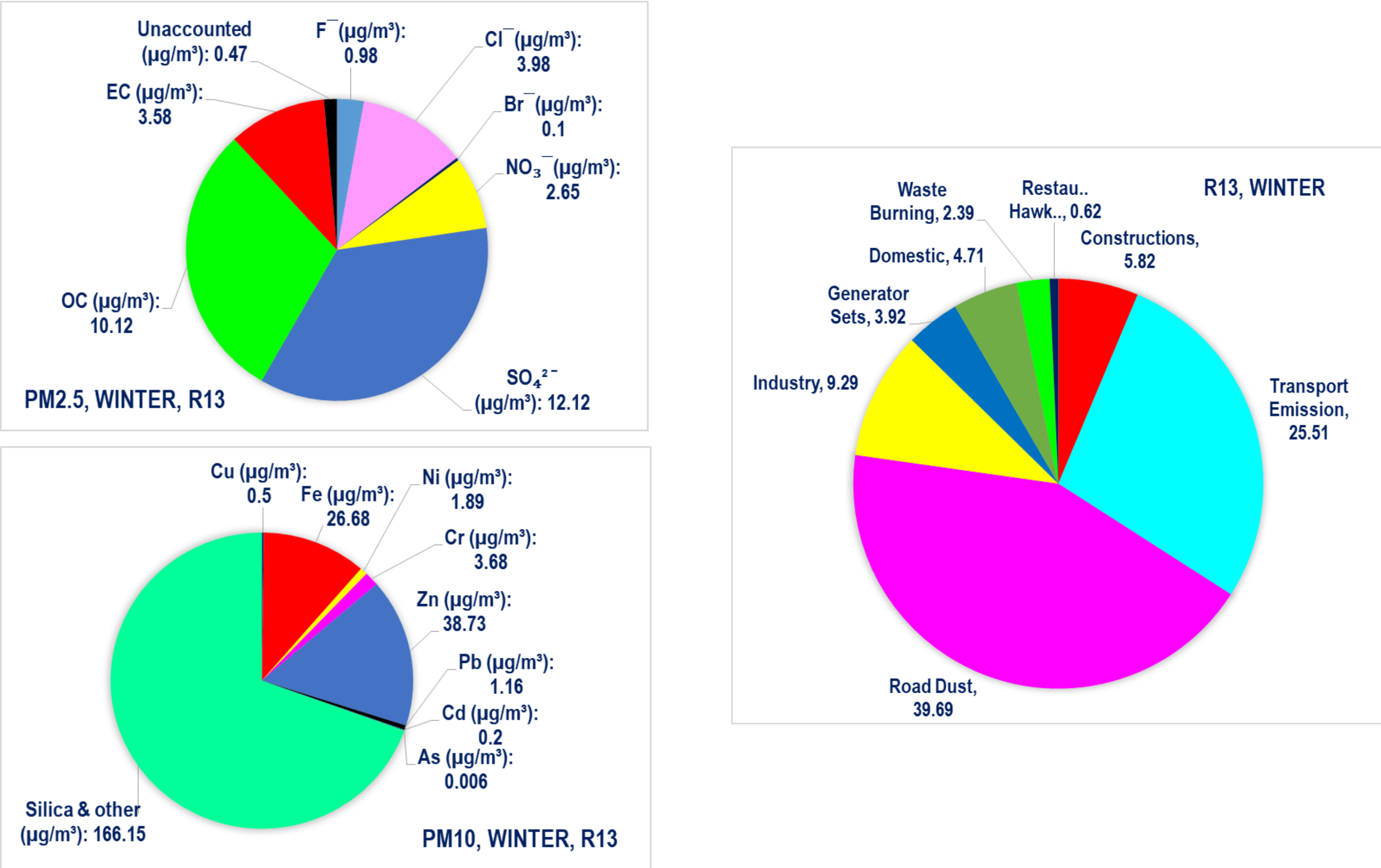


Figure 2.78: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R13' during winter.

‘R10’ is a ‘Commercial’ type air-quality monitoring station on the roof of District Hospital. CMB predicted major sources of emission are road dust (38%; 41.43 μg/m^3), constructions (23%; 25.84 μg/m^3), transport (16%; 17.37 μg/m^3) and industry (13%; 14.29 μg/m^3) (Figure 2.75). ‘R11’ is an air-quality monitoring station near “Nagar Nigam Pandri” and is a ‘Commercial’ type station. Major sources are road dust (30%; 35.58 μg/m^3), constructions (25%; 29.69 μg/m^3), transport (24%; 28.37 μg/m^3), industry (12%; 14.63 μg/m^3) (Figure 2.76). ‘R12’ is an ‘Industrial’ area near “Ravan Bhata Station”. Sources of emission are road dust (31; 37.42 μg/m^3), transport (29%; 35.02 μg/m^3), constructions (22%; 26.61 μg/m^3) and industrial (9%; 10.31 μg/m^3) (Figure 2.77). ‘R13’ is a ‘Residential’ type air-quality monitoring station on the roof of ‘RO Office’. CMB predicted major sources are road dust (43%; 39.69 μg/m^3), transport (28%; 25.51 μg/m^3), constructions (6%; 5.82 μg/m^3) (Figure 2.78).

‘R15’ is a ‘Residential’ type air-quality monitoring station on the roof of ‘Jheet High School’. Major sources are road dust (23%; 33.16 μg/m^3), transports (18%; 25.88 μg/m^3), constructions (23%; 33.38 μg/m^3) (Figure 2.80). ‘R16’ is also a ‘Residential’ type air-quality monitoring station under ‘Mana Panchayat’. Predicted emission sources are road dust (18%; 29.22 μg/m^3), transports (22%; 35.51 μg/m^3), constructions (29%; 46.66 μg/m^3), domesticl combustion (13%; 21.19 μg/m^3), etc. (Figure 2.81).

‘R17’ is an ‘Industrial’ type air-quality monitoring station on the roof of “Shri Rawtpur Sarkar Institute”. Emission sources in this station are transports (22%; 37.34 μg/m^3), road dust (21%; 35.87 μg/m^3), constructions (16%; 26.76 μg/m^3), industrial or small manufacturing units (9%; 14.98 μg/m^3) and brick kilns (15%; 24.48 μg/m^3) (Figure 2.82). ‘R18’ is also an ‘Industrial’ type air-quality monitoring station on ‘CIAL-S.D.’ (Jayasawal Nico). CMB predicted sources are industry (14%; 17.47 μg/m^3), road dust (33%; 39.88 μg/m^3), constructions (13%; 15.55 μg/m^3) (Figure 2.83).

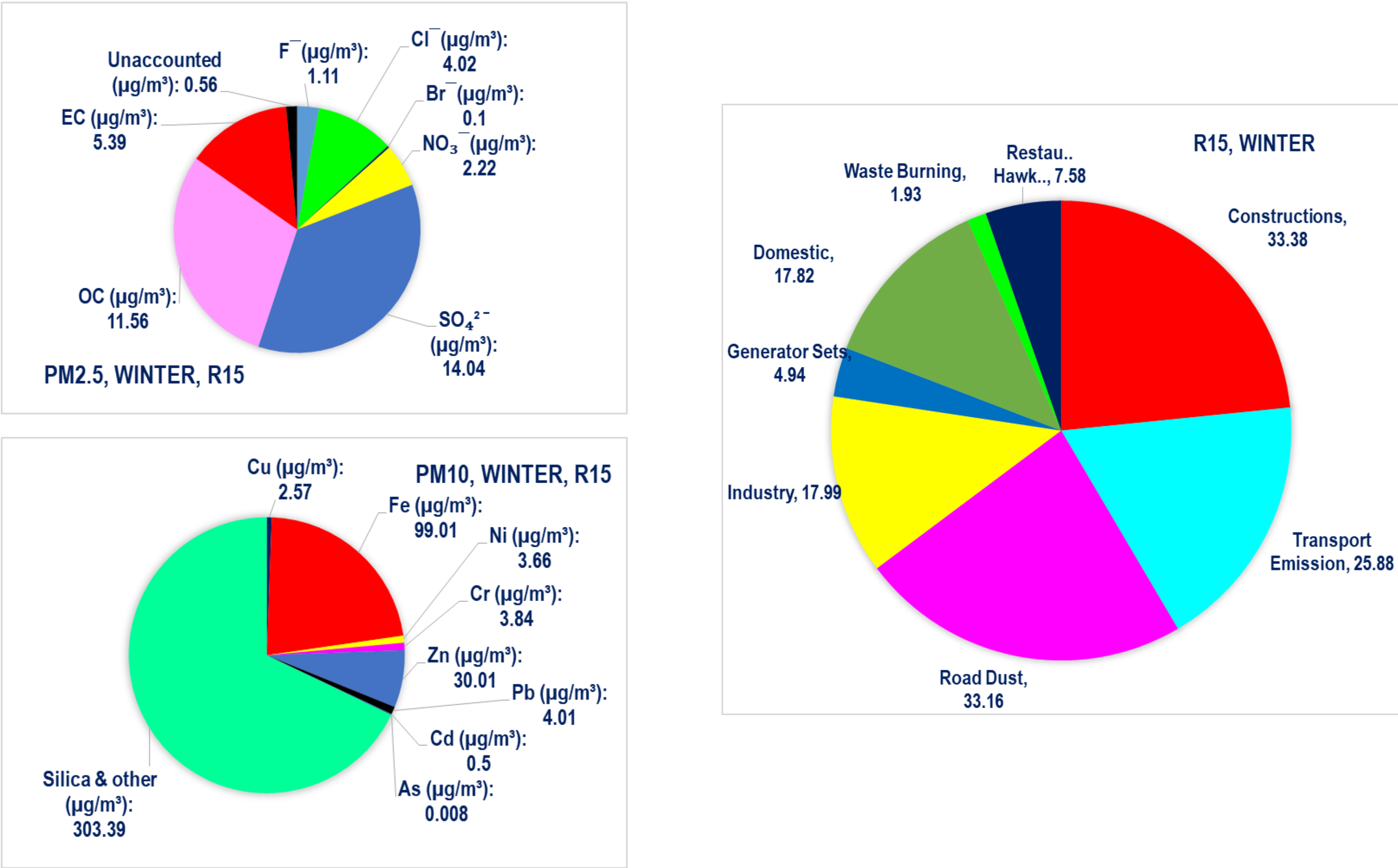


Figure 2.80: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R15' during winter.

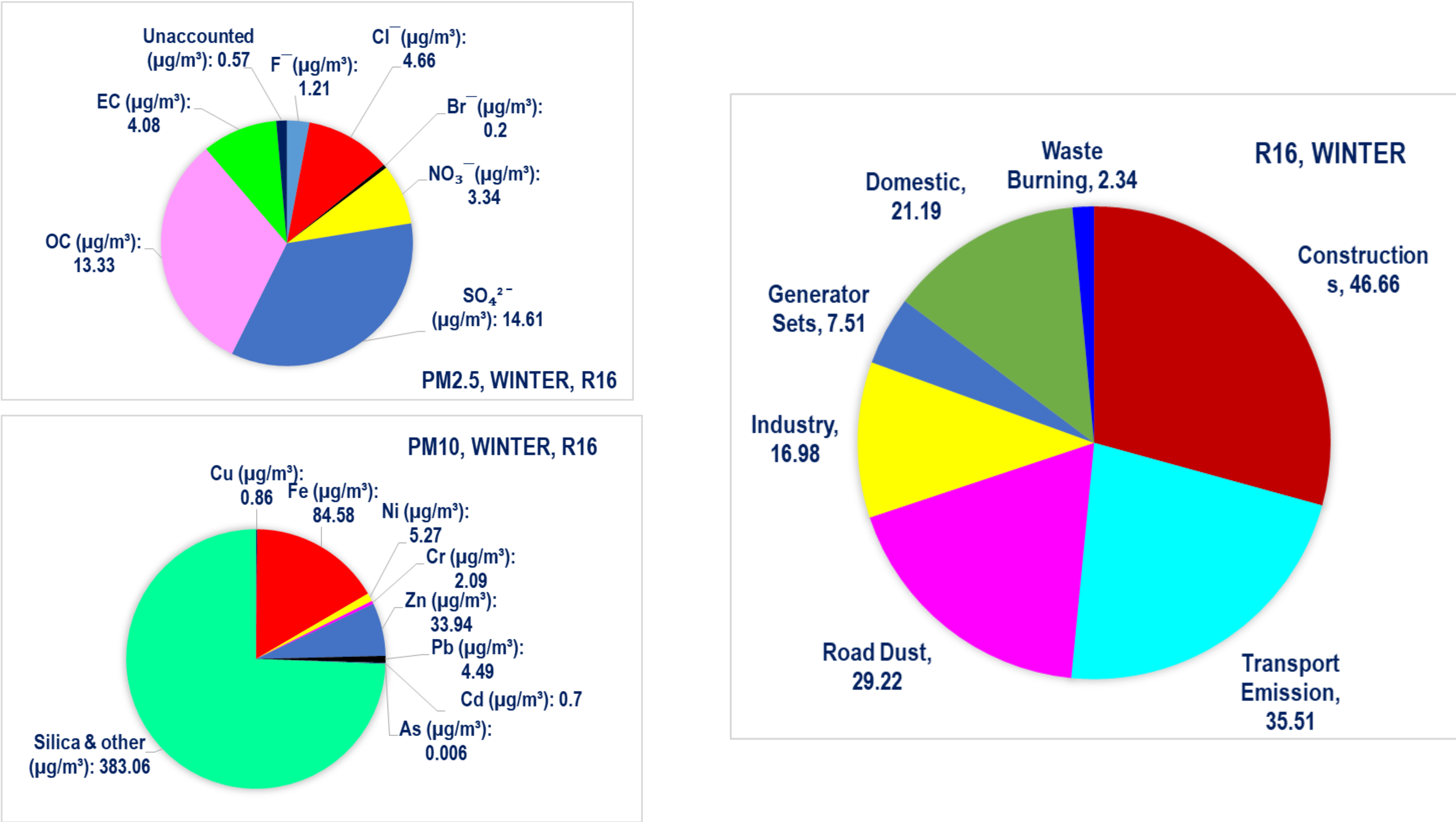
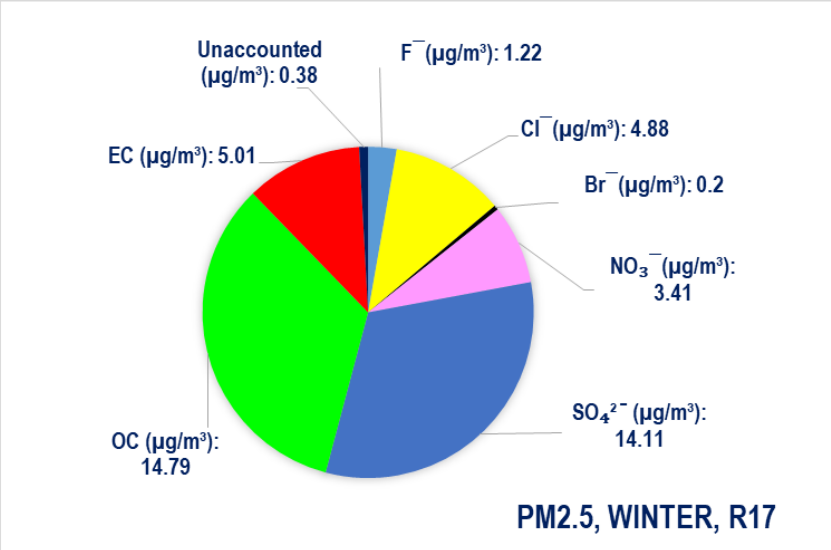
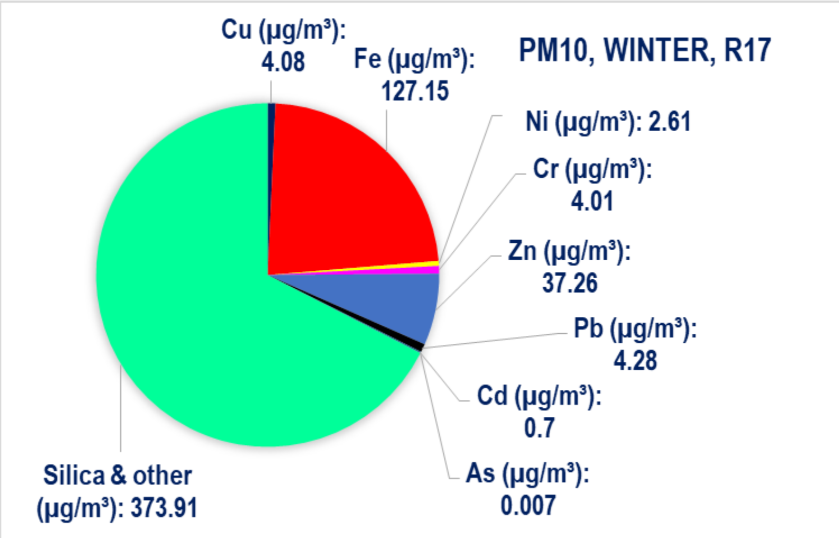


Figure 2.81: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R16' during winter.





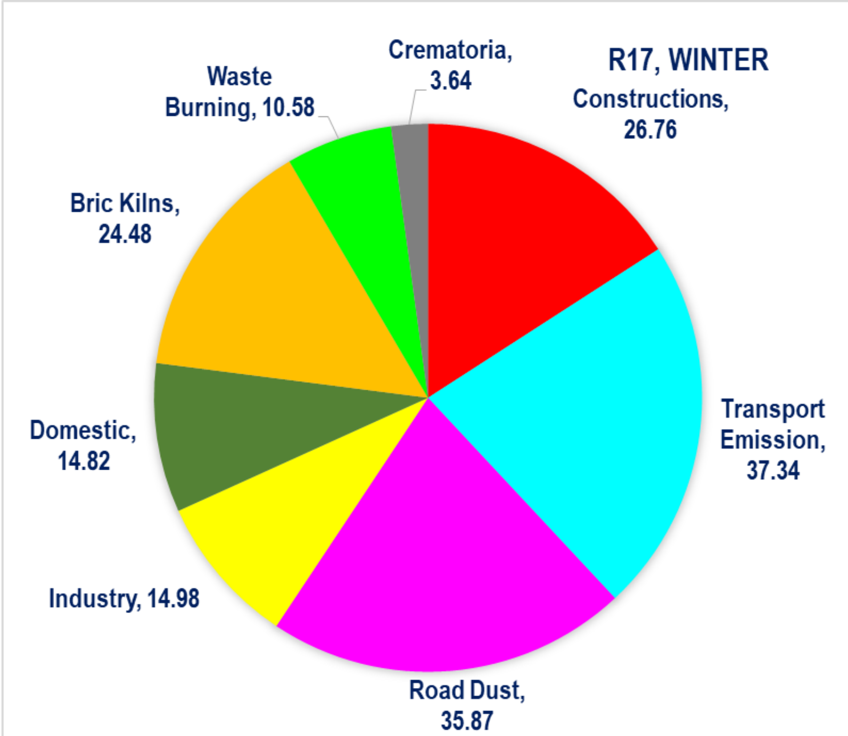


Figure 2.82: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R17' during winter.

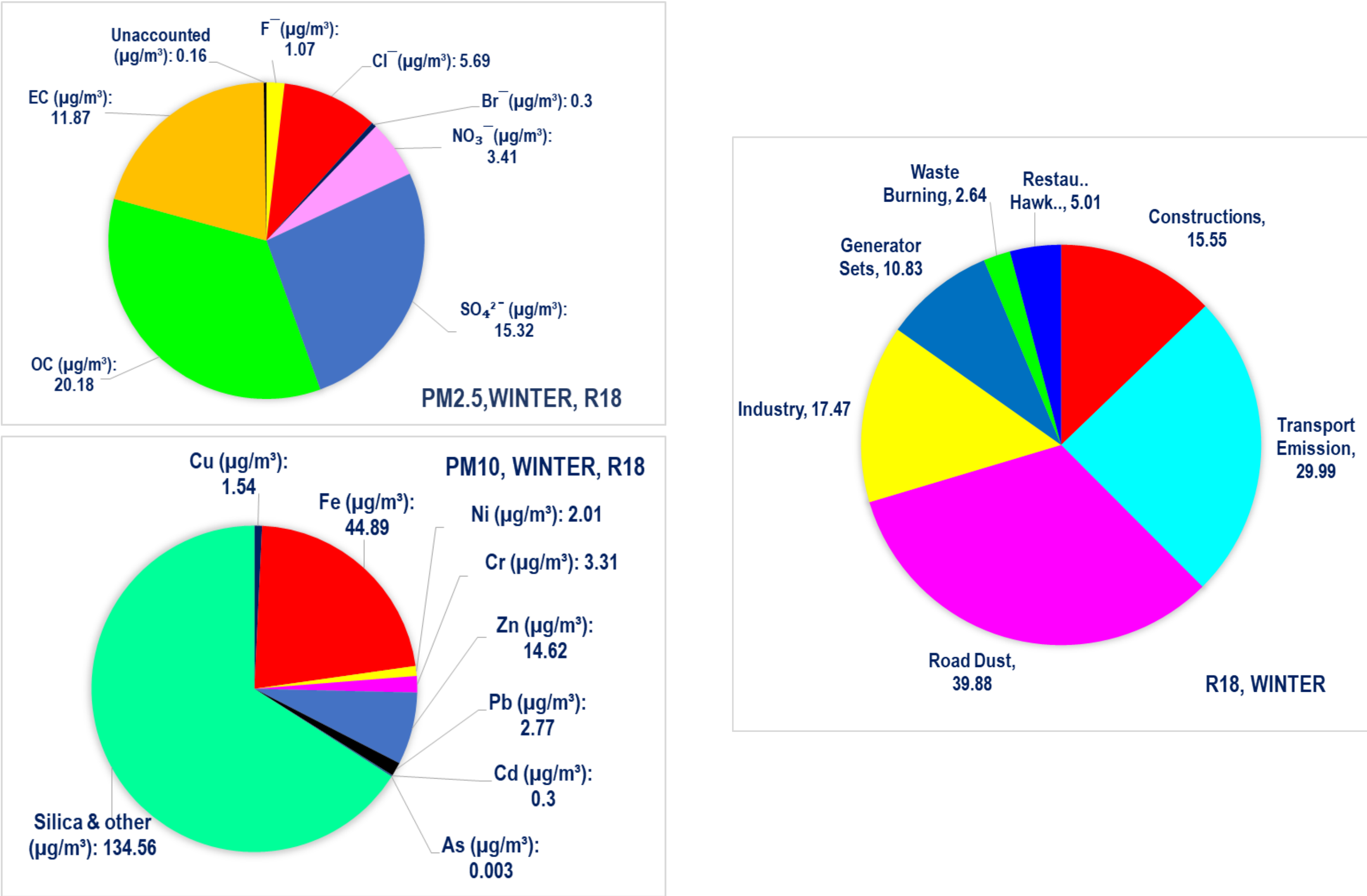


Figure 2.83: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R18' during winter

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 though wind and finally effect in the ambient air-quality of Raipur.

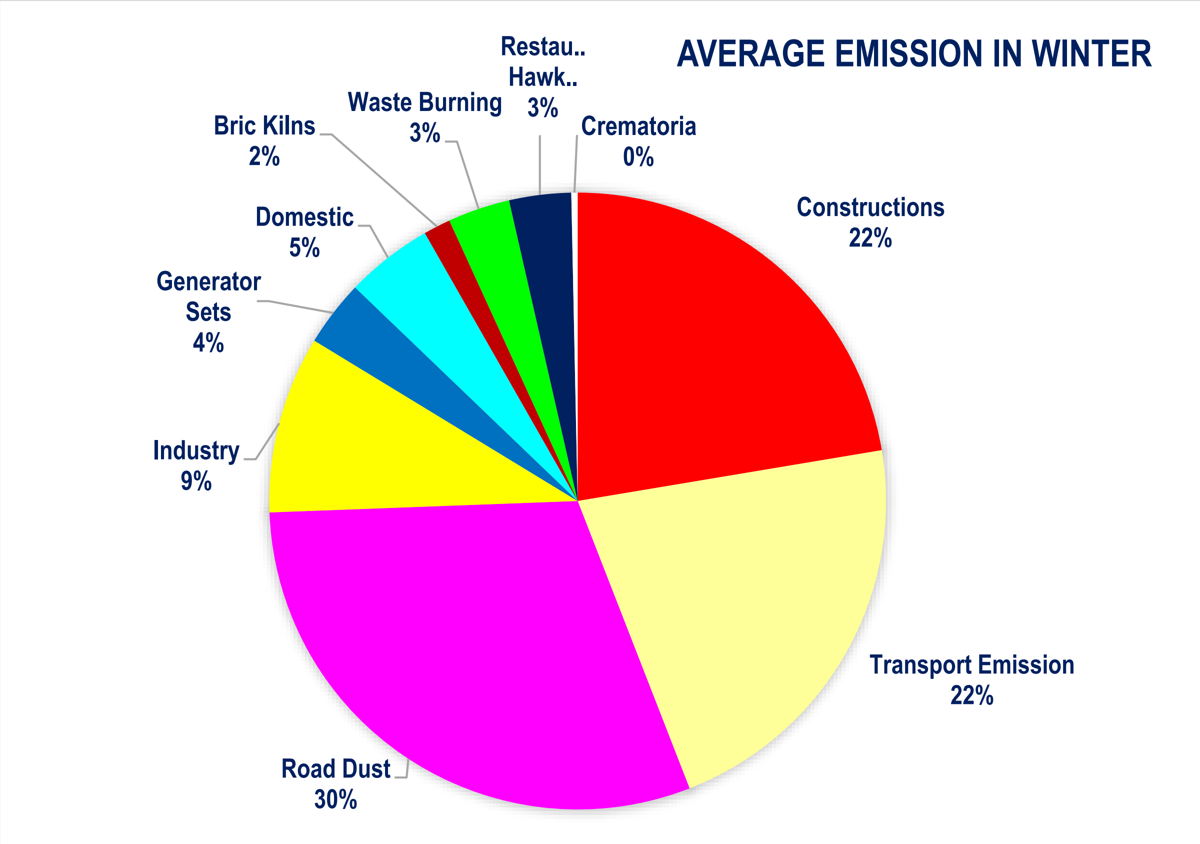


Figure 2.84: Different sources of pollutants and their percent contribution in the ambient air pollution of Raipur during winter season

Emission inventory study shows, ambient air quality in Raipur is mainly effected by different types of construction (like; road constructions, bridge constructions, building constructions which include both domestic as well as industrial buildings, different types of structural constructions and so on). Particulate matters emission from different types of construction have been predicted by CMB as 22% (28.31 $\mu g/m^3$). Similarly, CMB predicted other major emission sources are road dust (30%; 38.38 $\mu g/m^3$), industry (9%; 11.77 $\mu g/m^3$), transport emission (22%; 27.49 $\mu g/m^3$), etc. (Figure 2.84).

2.4.8.2 Summer Season

'R02' is an 'Industrial'- type station near 'Ashram' (Metal Park). CMB predicted sources of emission are road dust (42%; 59.11 μg/m^3), transports (10%; 14.43 μg/m^3), constructions (33%; 45.96 μg/m^3) and industry (6%; 7.91 μg/m^3) (Figure 2.86). 'R03' is a 'Commercial' area near 'Gosala' at Hirapur. Emission sources are road dust (41%; 32.72 μg/m^3), constructions (24%; 19.11 μg/m^3) and transports (11%; 9.18 μg/m^3) (Figure 2.87). 'R04' is 'Residential' area near 'Real Ispat' (Kara Panchayat). Major sources in this area are constructions (30%; 33.32 μg/m^3), road dust (33%; 36.79 μg/m^3), transports (12%; 13.39 μg/m^3), industry (8%; 9.26 μg/m^3), etc. (Figure 2.88).

Air-quality monitoring station 'R05' is a water treatment plant at Urla. It's an 'Industrial' type sampling station. Major sources are road dust (31%; 28.28 μg/m^3), transport (28%; 26.06 μg/m^3), different types of construction (15%; 13.37 μg/m^3) and industry (10%; 9.15 μg/m^3) (Figure 2.89). R06' is a 'Silent' type air-quality monitoring station, situated near 'Nagar Nigam Birgaon'. Major emission sources are constructions (30%; 34.51 μg/m^3), transports (28%; 32.47 μg/m^3), road dust (28%; 32.52 μg/m^3) (Figure 2.90). 'R07' is 'AIIMS' hospital. It has been categorized as 'Commercial'. CMB predicted major sources are road dust (39%; 58.11 μg/m^3), transports (19%; 27.72 μg/m^3), constructions (10%; 14.44 μg/m^3), restaurants, eateries and hawkers (16%; 24.28 μg/m^3) (Figure 2.91).

'R08' is 'Kotwali Police Station' and major sources as per CMB are transports (31%; 29.73 μg/m^3), road dust (28%; 27.13 μg/m^3), constructions (19%; 18.24 μg/m^3), restaurants, eateries and hawkers (10%; 10.01 μg/m^3) (Figure 2.92). 'R09' is a 'Silent' type air-quality monitoring station near 'DD Nagar House'. According to emission inventory study, major sources are road dust (21%; 16.83 μg/m^3), transports (39%; 31.05 μg/m^3), constructions (23%; 18.21 μg/m^3) (Figure 2.93). 'R10' is a 'Commercial' type air-quality monitoring station on the roof of District Hospital. Predicted sources are transports (22%; 23.28 μg/m^3), road dust (28%; 30.46 μg/m^3), constructions (26%; 27.61 μg/m^3) (Figure 2.94).

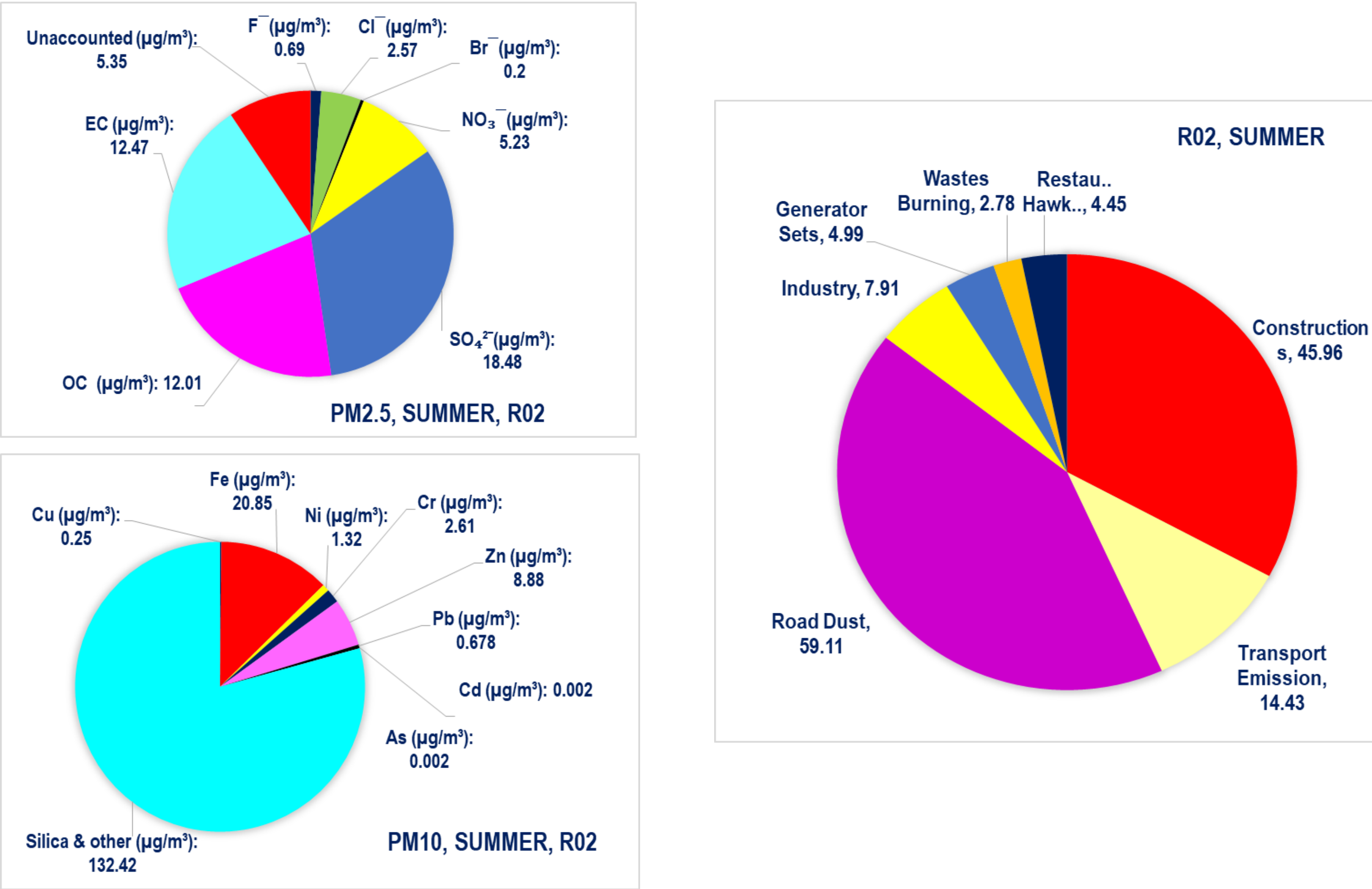


Figure 2.86: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R02' during summer.

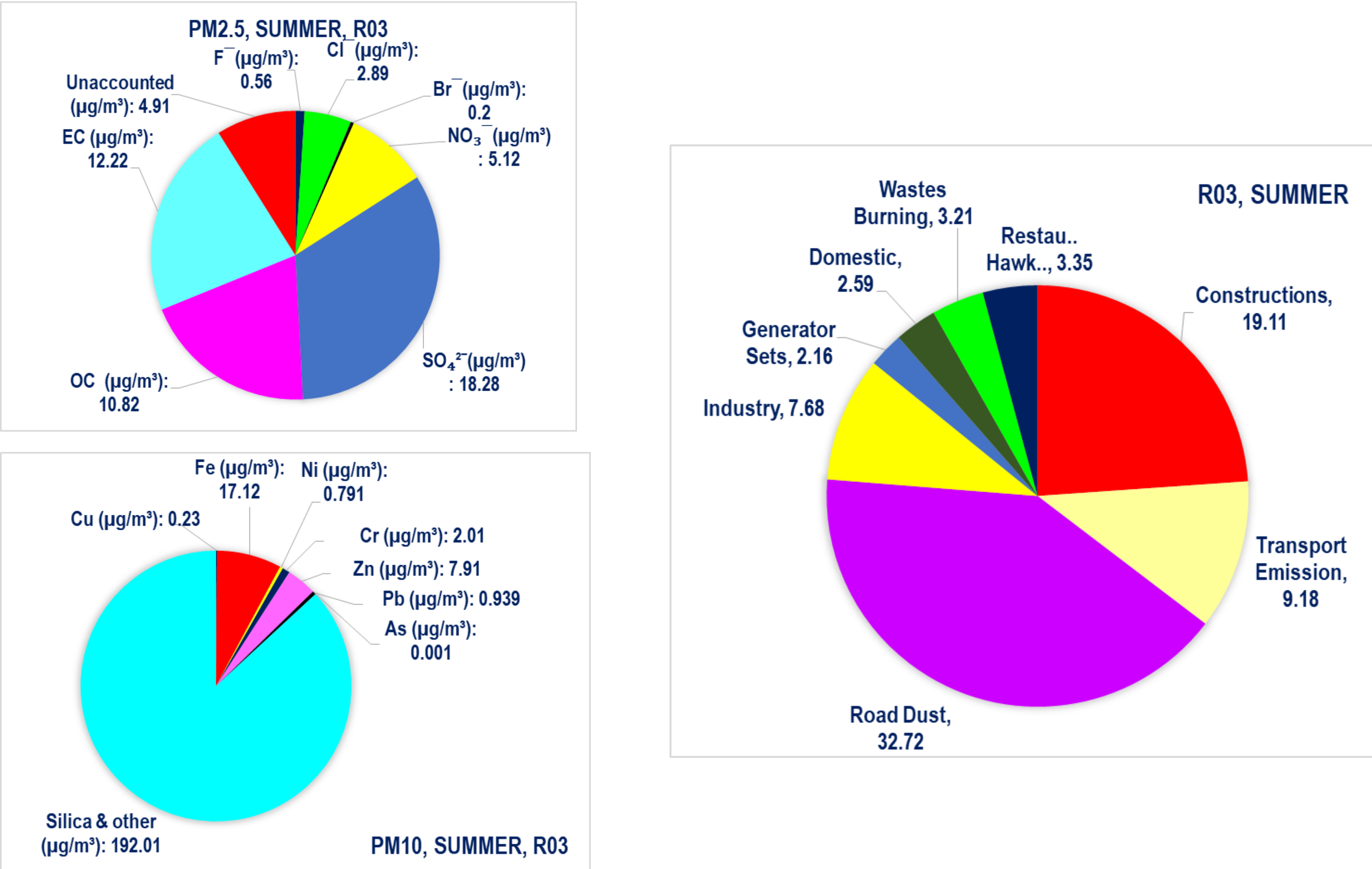


Figure 2.87: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R03' during summer.

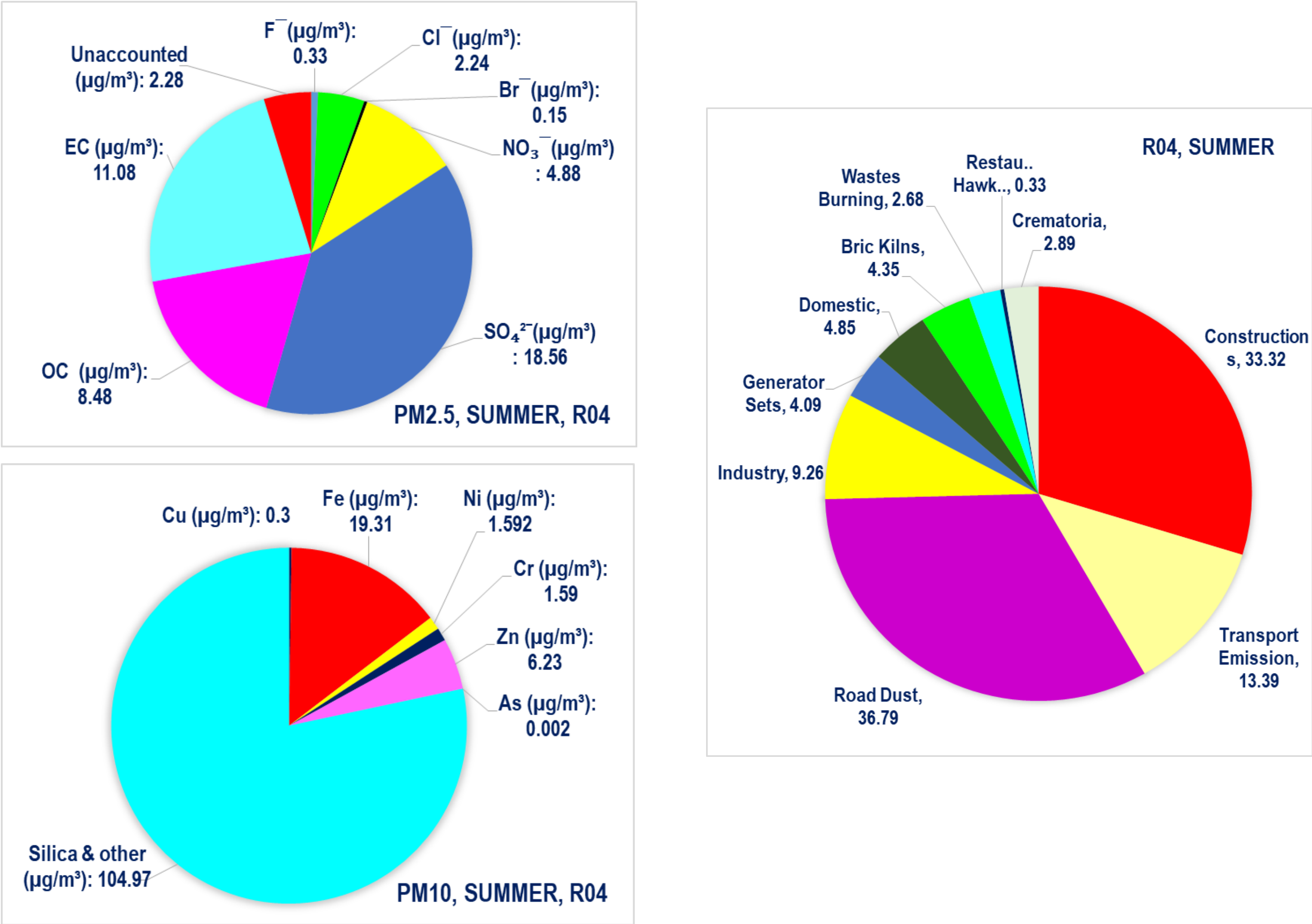


Figure 2.88: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R04' during summer.

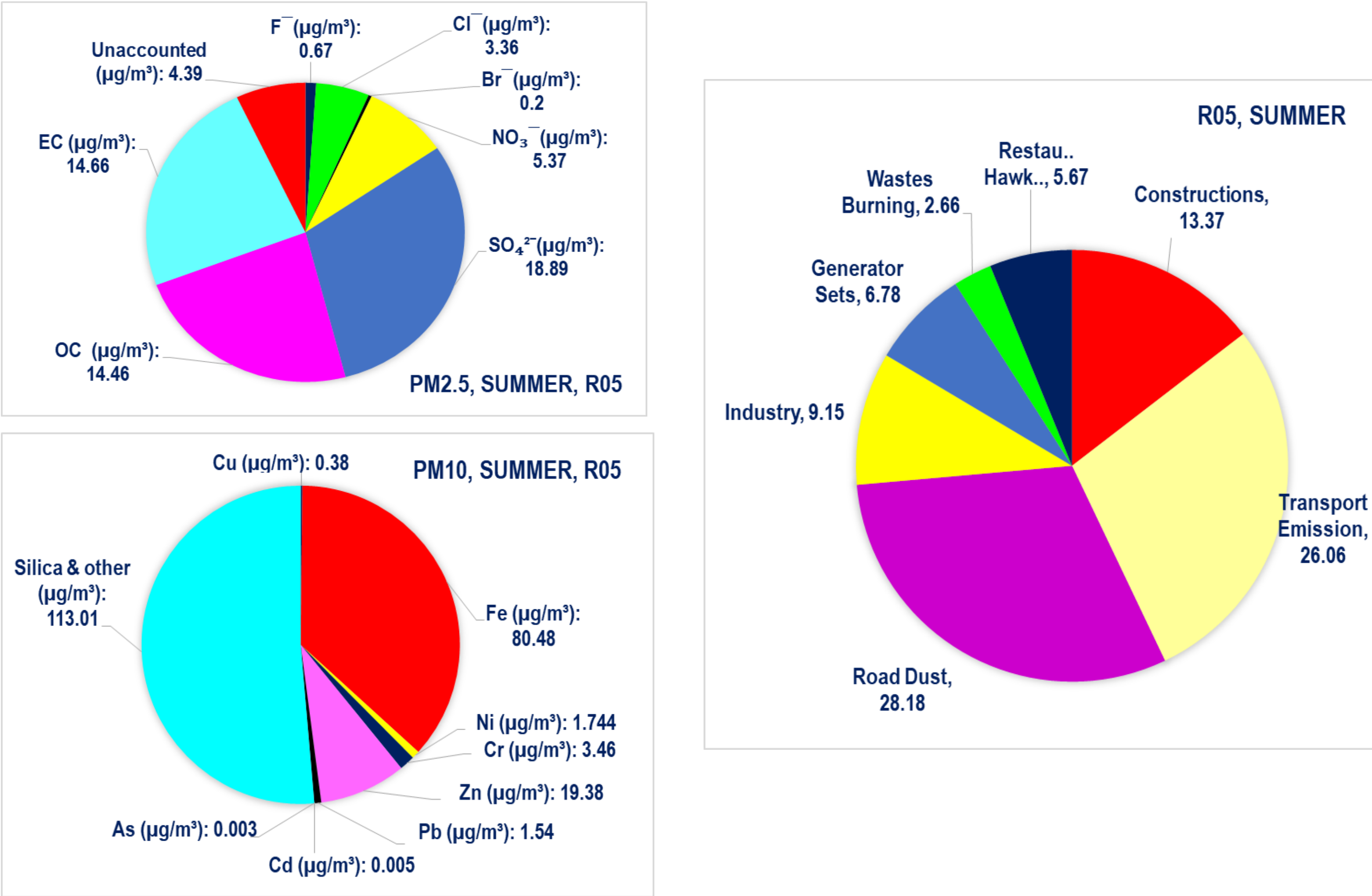


Figure 2.89: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R05' during summer.

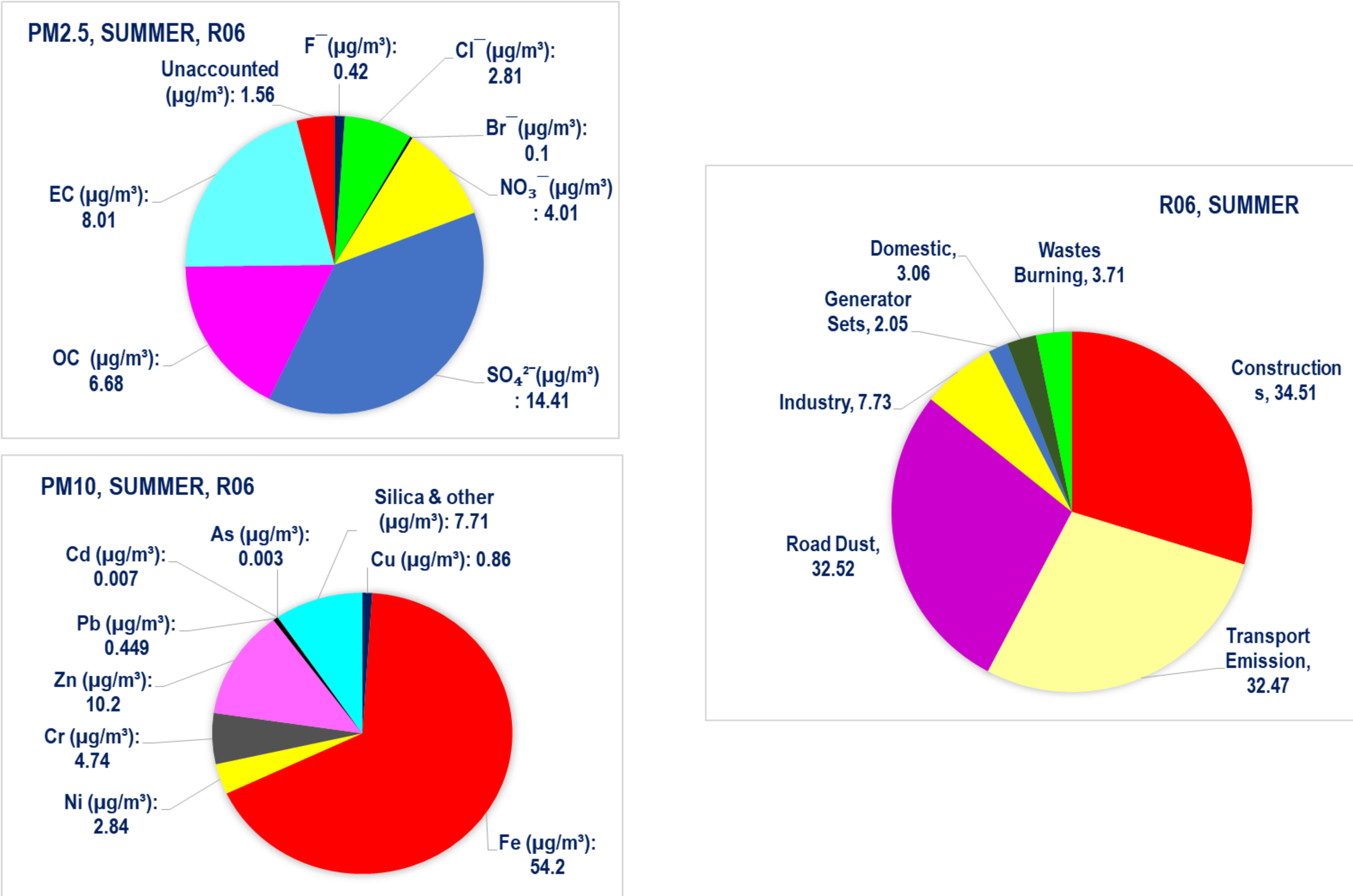


Figure 2.90: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R06' during summer.

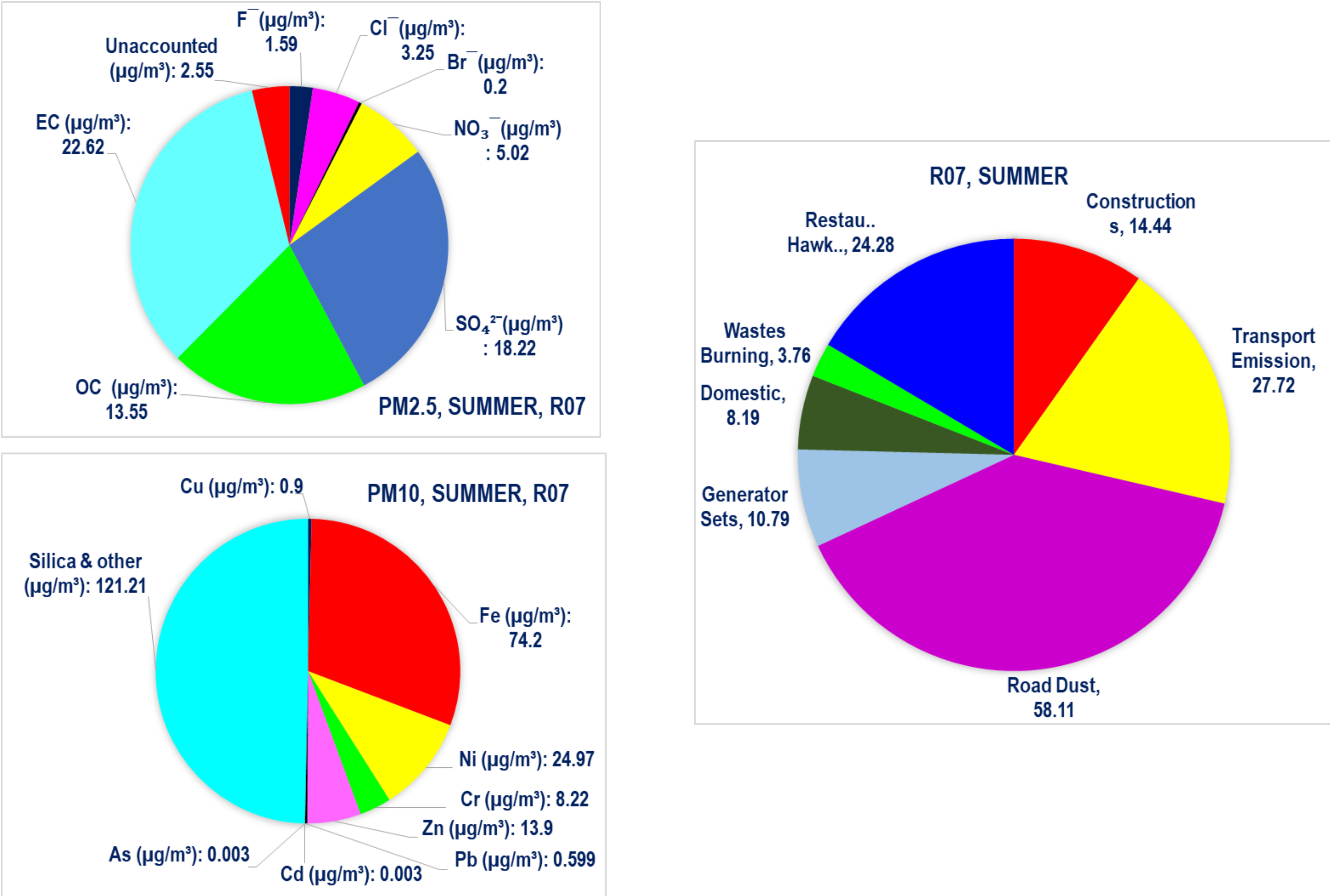


Figure 2.91: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R07' during summer.

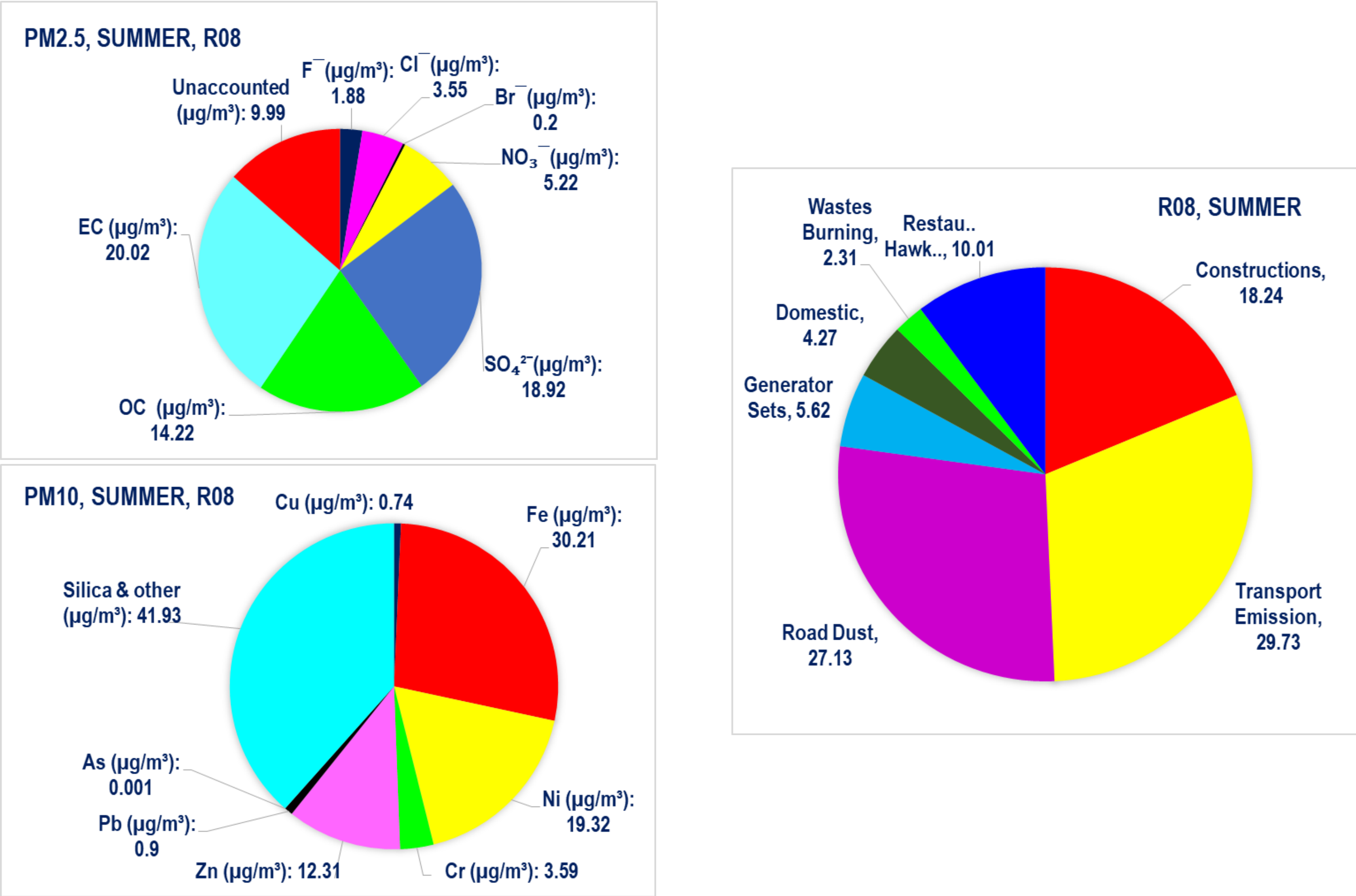


Figure 2.92: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R08' during summer.

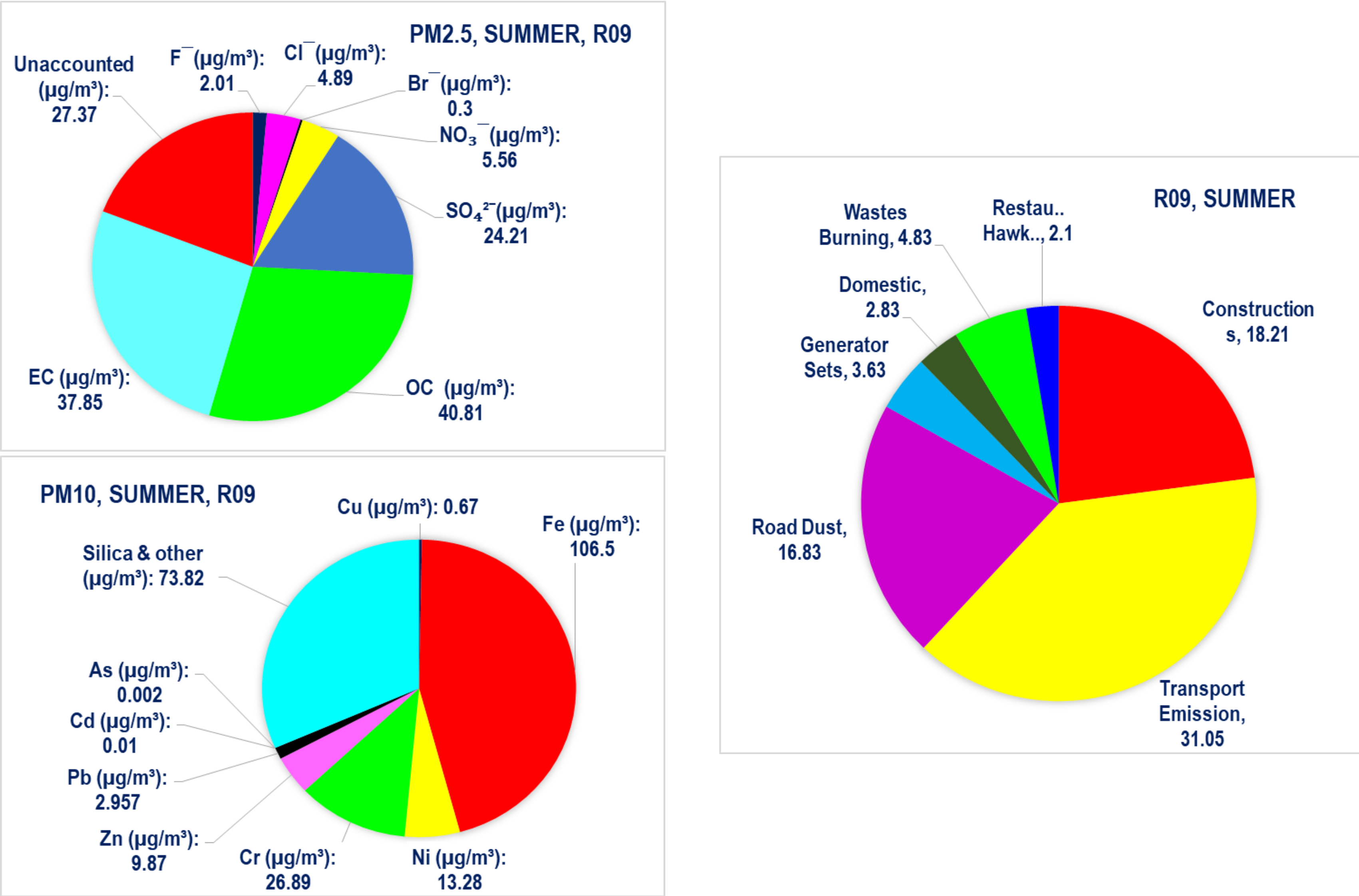


Figure 2.93: Average composition (μg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R09' during summer.

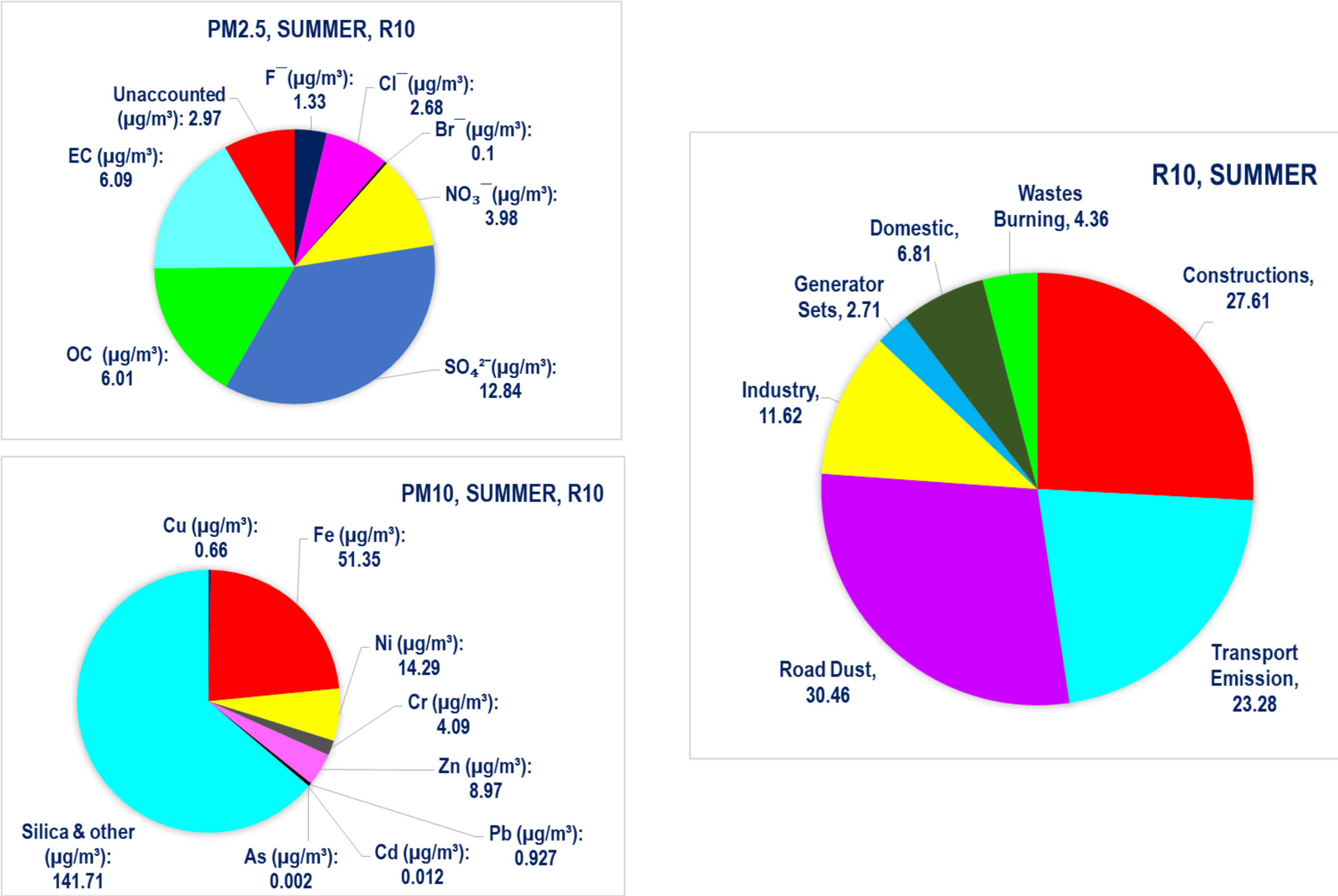


Figure 2.94: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R10' during summer.

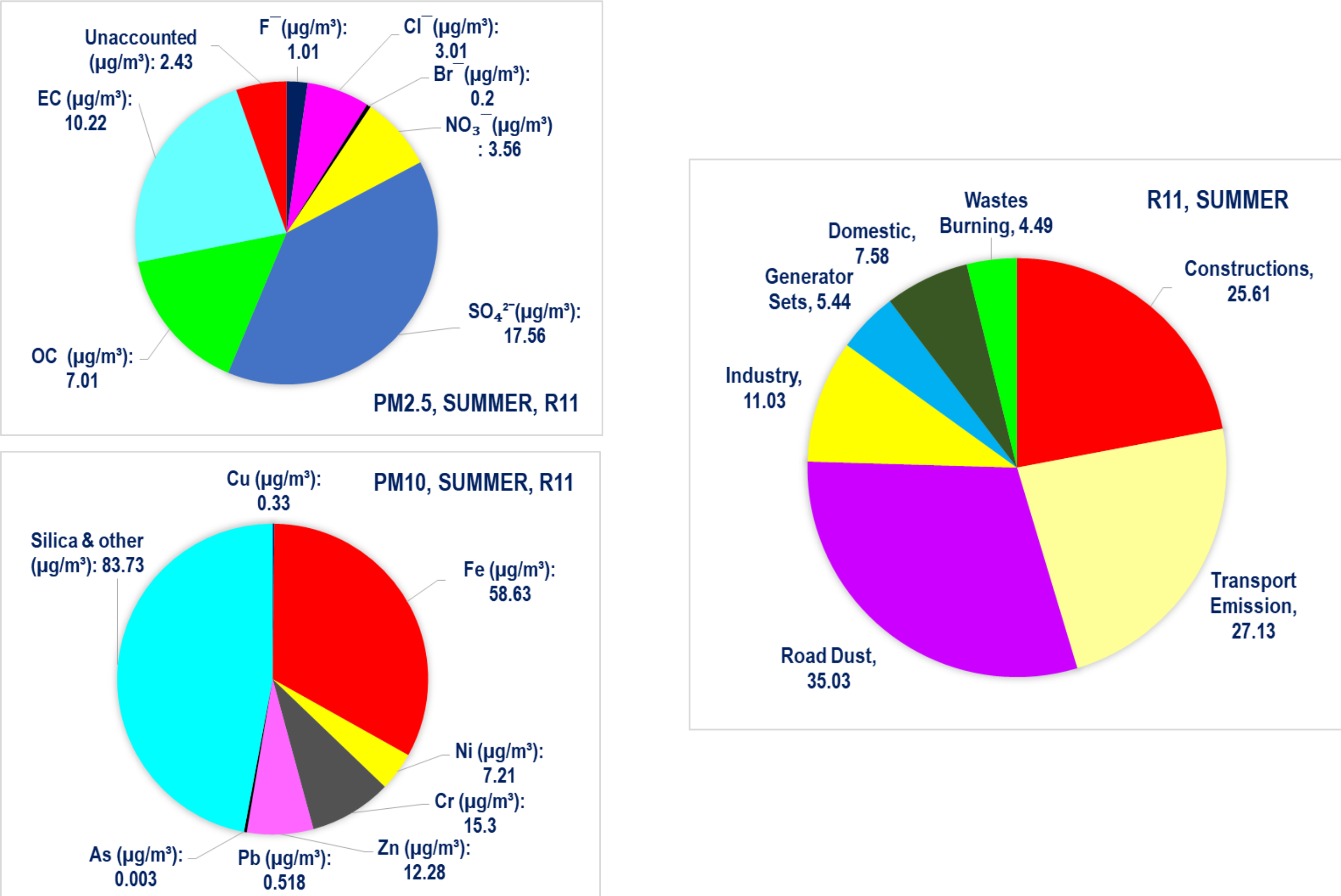


Figure 2.95: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R11' during summer.

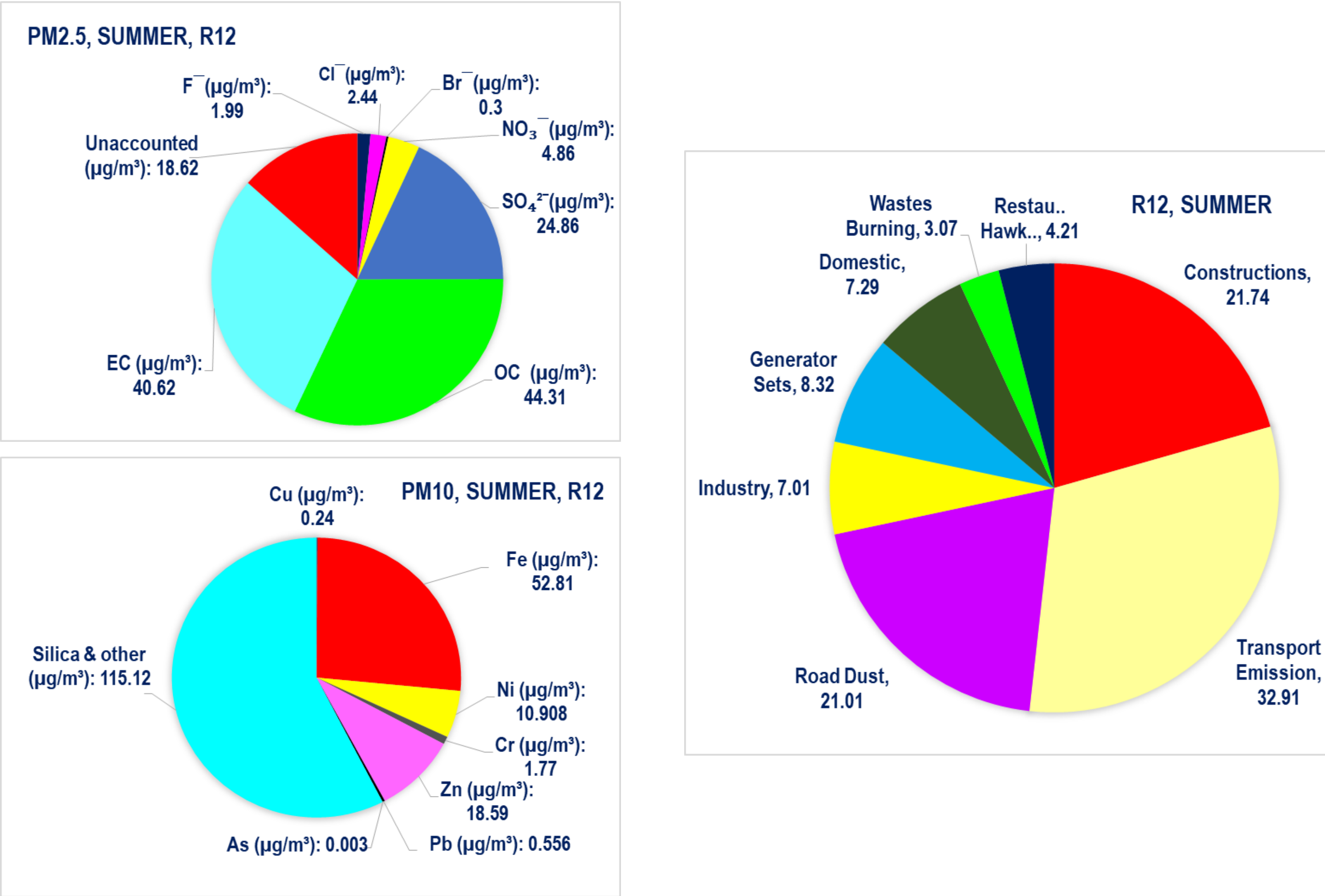


Figure 2.96: Average composition (μg/m^3) of particulate matters and their emission sources in air quality monitoring station 'R12' during summer.

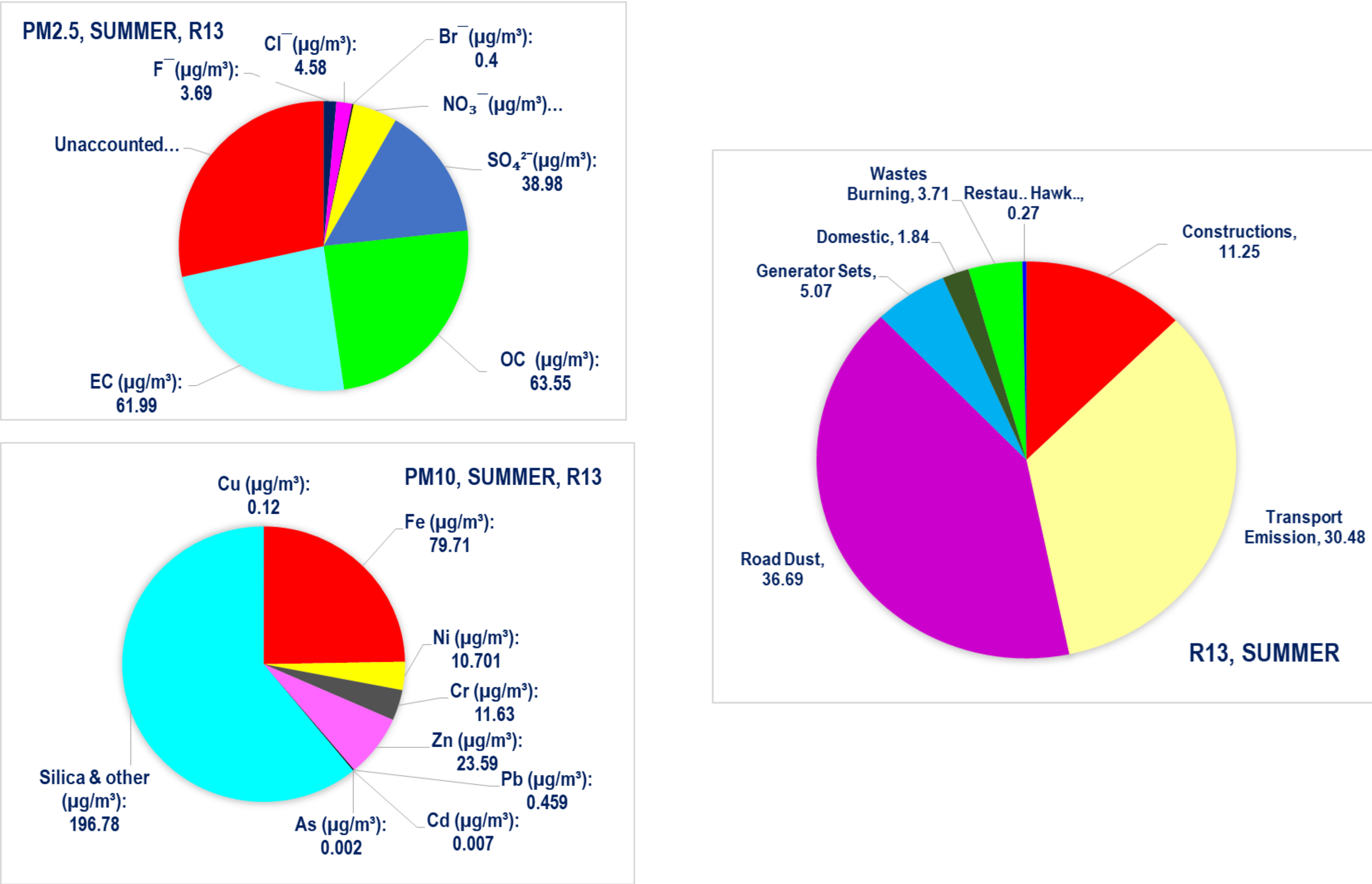


Figure 2.97: Average composition ($\mu g/m^3$) of particulate matters and their emission sources in air quality monitoring station 'R13' during summer.

‘R11’ is an air-quality monitoring station near “Nagar Nigam Pandri” and is a ‘Commercial’ type station. CMB-predicted the major sources are road dust (30%; 35.03 μg/m^3), constructions (22%; 25.61 μg/m^3), transports (23%; 27.13 μg/m^3) and industry (9%; 11.03 μg/m^3) (Figure 2.95). ‘R12’ is an ‘Industrial’ area near “Ravan Bhata Station”. Sources of emission around this station are transports (31%; 32.91 μg/m^3), road dust (20%; 21.01 μg/m^3), constructions (20%; 21.74 μg/m^3), industry (7%; 7.01 μg/m^3), generator sets (8%; 8.32 μg/m^3), etc. (Figure 2.96). ‘R13’ is a ‘Residential’ type air-quality monitoring station on the roof of ‘RO Office’. Emission inventory study shows the sources are road dust (41%; 36.69 μg/m^3), transports (34%; 30.48 μg/m^3), constructions (13%; 11.25 μg/m^3) (Figure 2.97).

‘R15’ is a ‘Residential’ type air-quality monitoring station on the roof of ‘Jheet High School’. Emission sources are road dust (24%; 24.11 μg/m^3), transport emission (23%; 23.02 μg/m^3), constructions (13%; 13.26 μg/m^3), domestic combustion (22%; 21.84 μg/m^3) (Figure 2.99). ‘R16’ is also a ‘Residential’ type air-quality monitoring station under ‘Mana Panchayat’. CMB predicted major emission-sources are road dust (29%; 33.69 μg/m^3), transports (29%; 33.72 μg/m^3), constructions (11%; 13.25 μg/m^3), domestic combustion (14%; 16.44 μg/m^3) (Figure 2.100).

‘R17’ is an ‘Industrial’ type air-quality monitoring station on the roof of “Shri Rawtpur Sarkar Institute”. Major emission sources in this station are road dust (24%; 33.56 μg/m^3), transports (22%; 31.53 μg/m^3), constructions (15%; 20.47 μg/m^3), small manufacturing units (8%; 11.67 μg/m^3), brick kilns (14%; 18.98 μg/m^3) (Figure 2.101). ‘R18’ is an ‘Industrial’ type air-quality monitoring station on ‘CIAL-S.D. (Jayasawal Nico). Emission inventory studies show the major emission sources are road dust (29%; 35.42 μg/m^3), transports (29%; 34.91 μg/m^3), constructions (10%; 12.79 μg/m^3), industry (10%; 11.77 μg/m^3) (Figure 2.102).

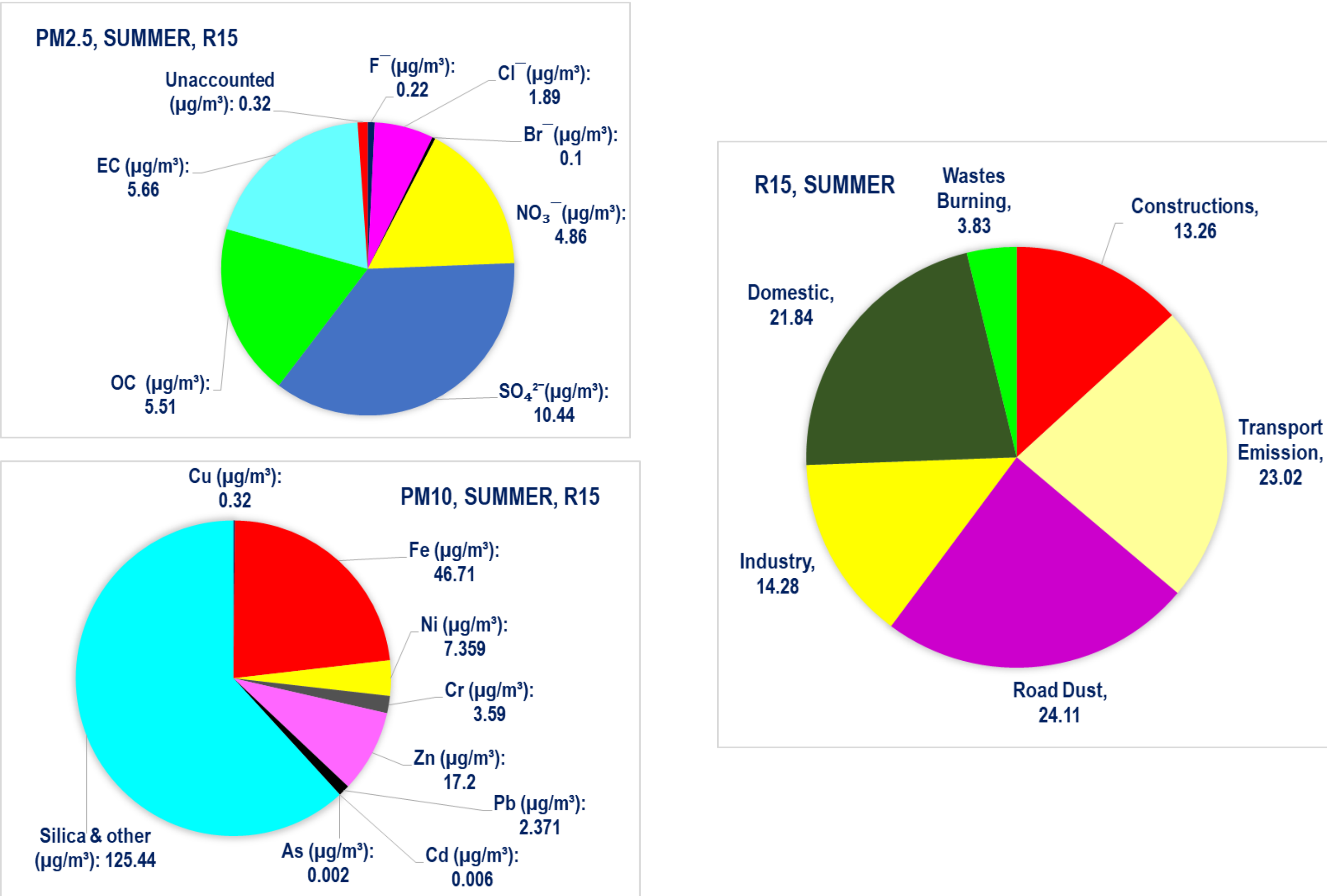


Figure 2.98: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R14' during summer.

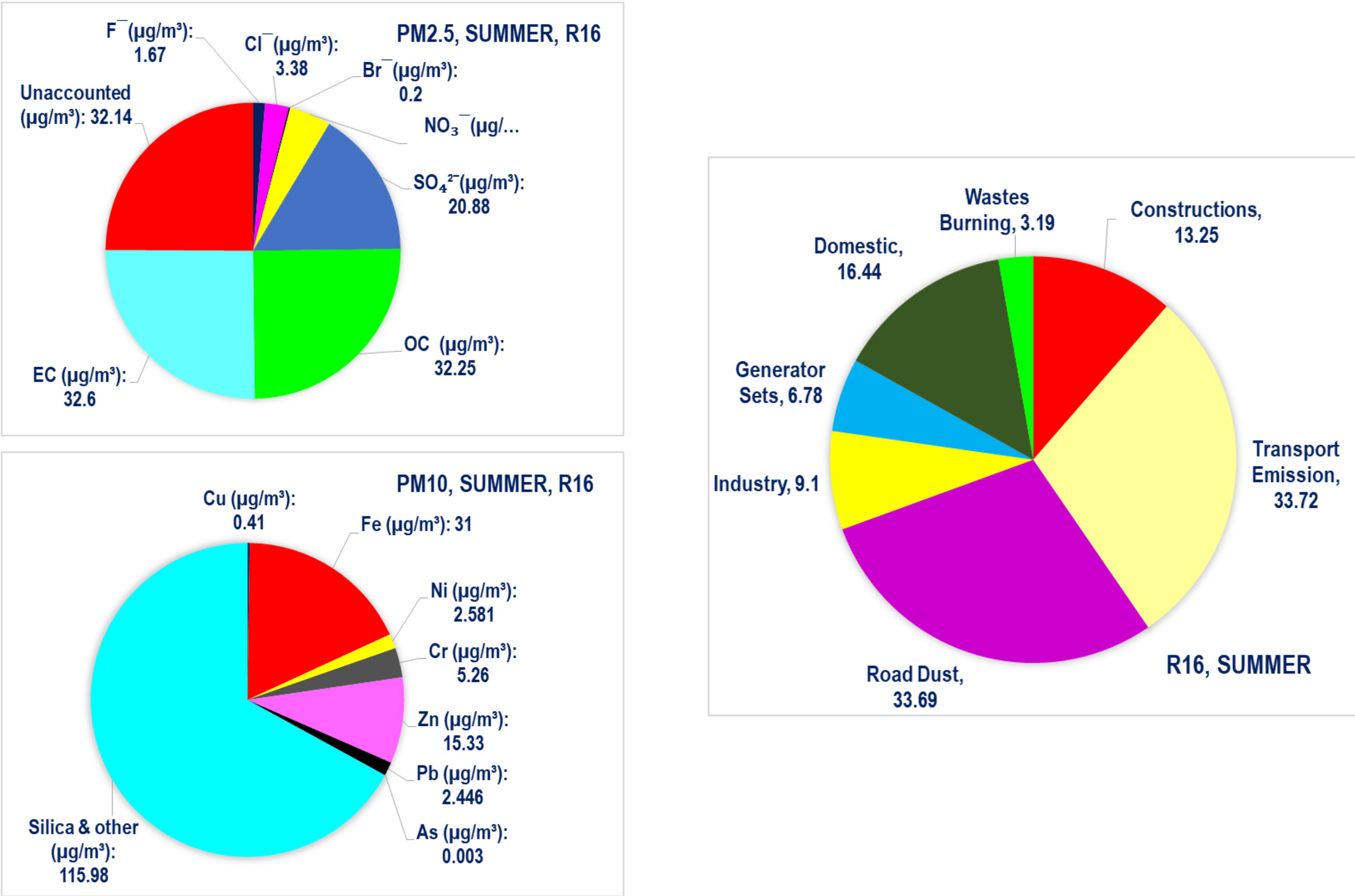
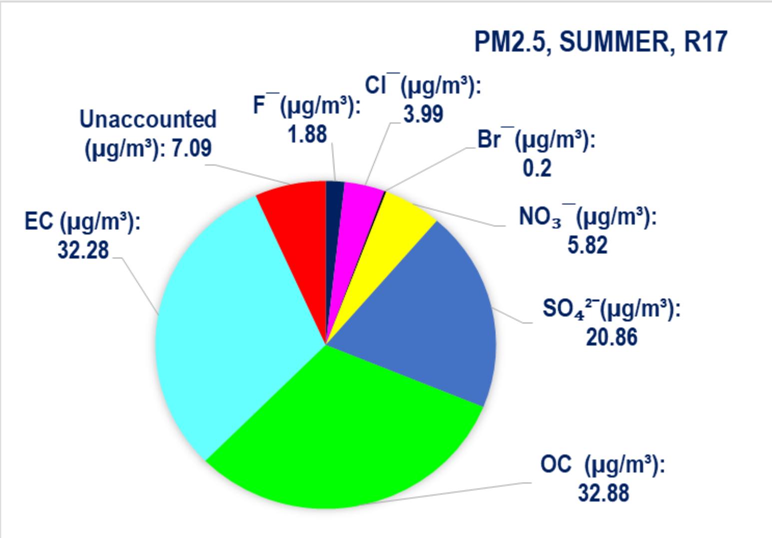
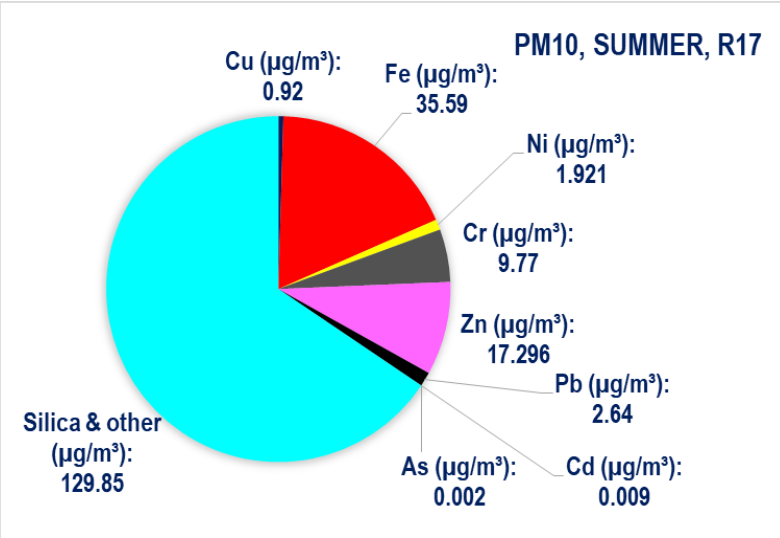


Figure 2.99: Average composition ($\mu g/m^3$) of particulate matters and their emission sources in air quality monitoring station 'R15' during summer.





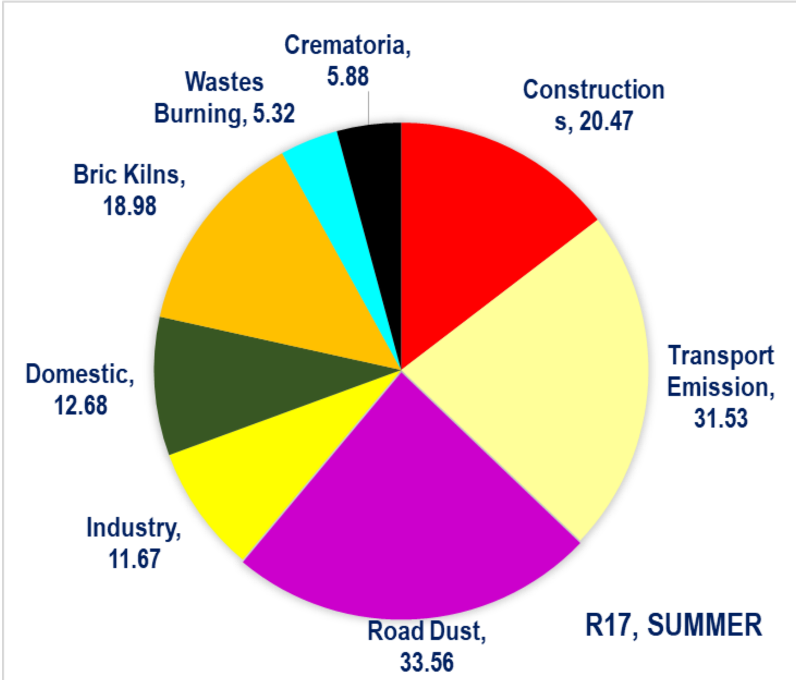


Figure 2.100: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R16' during summer.

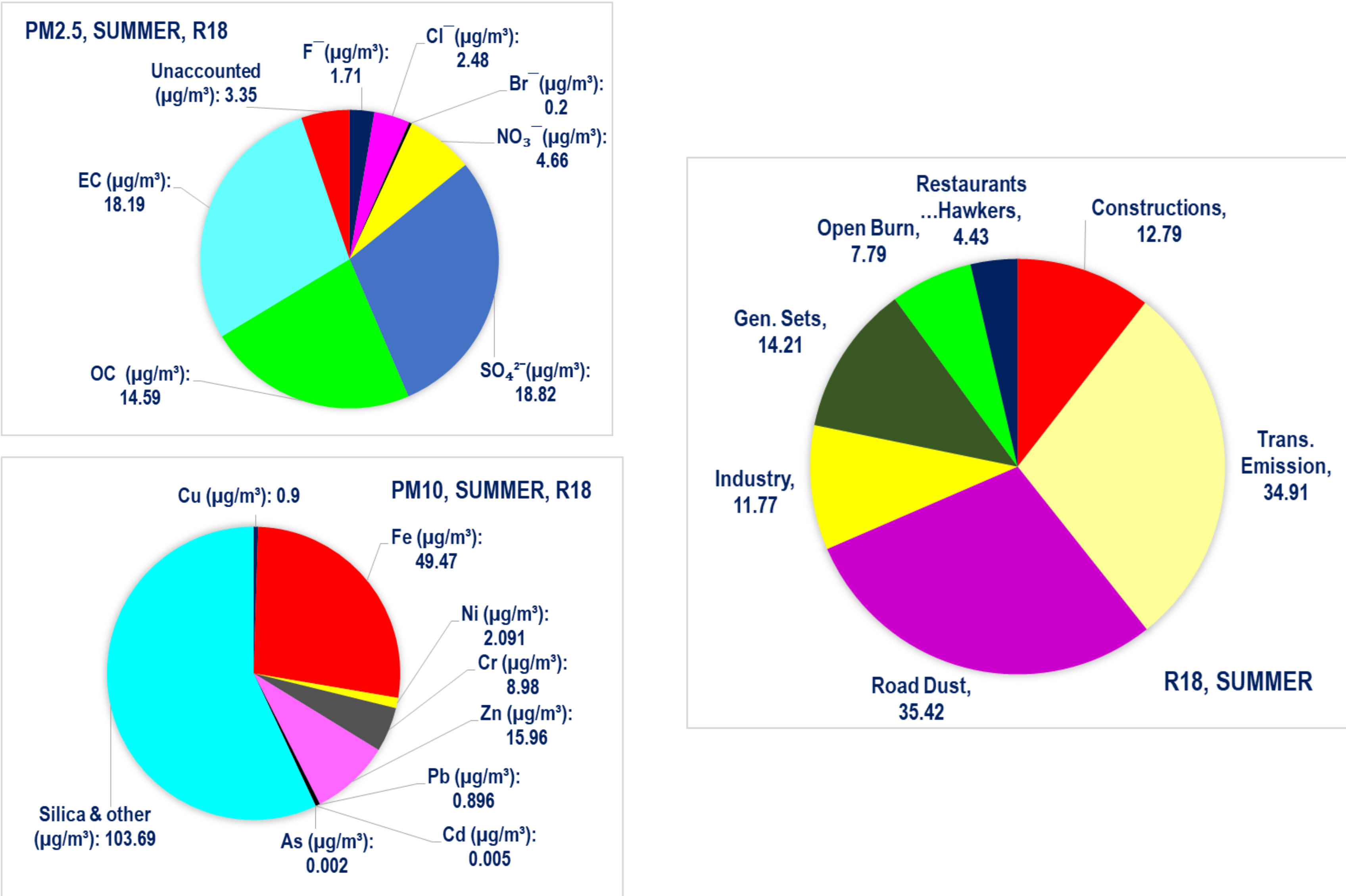


Figure 2.101: Average composition (µg/m³) of particulate matters and their emission sources in air quality monitoring station 'R17' during summer.

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 Raipur.

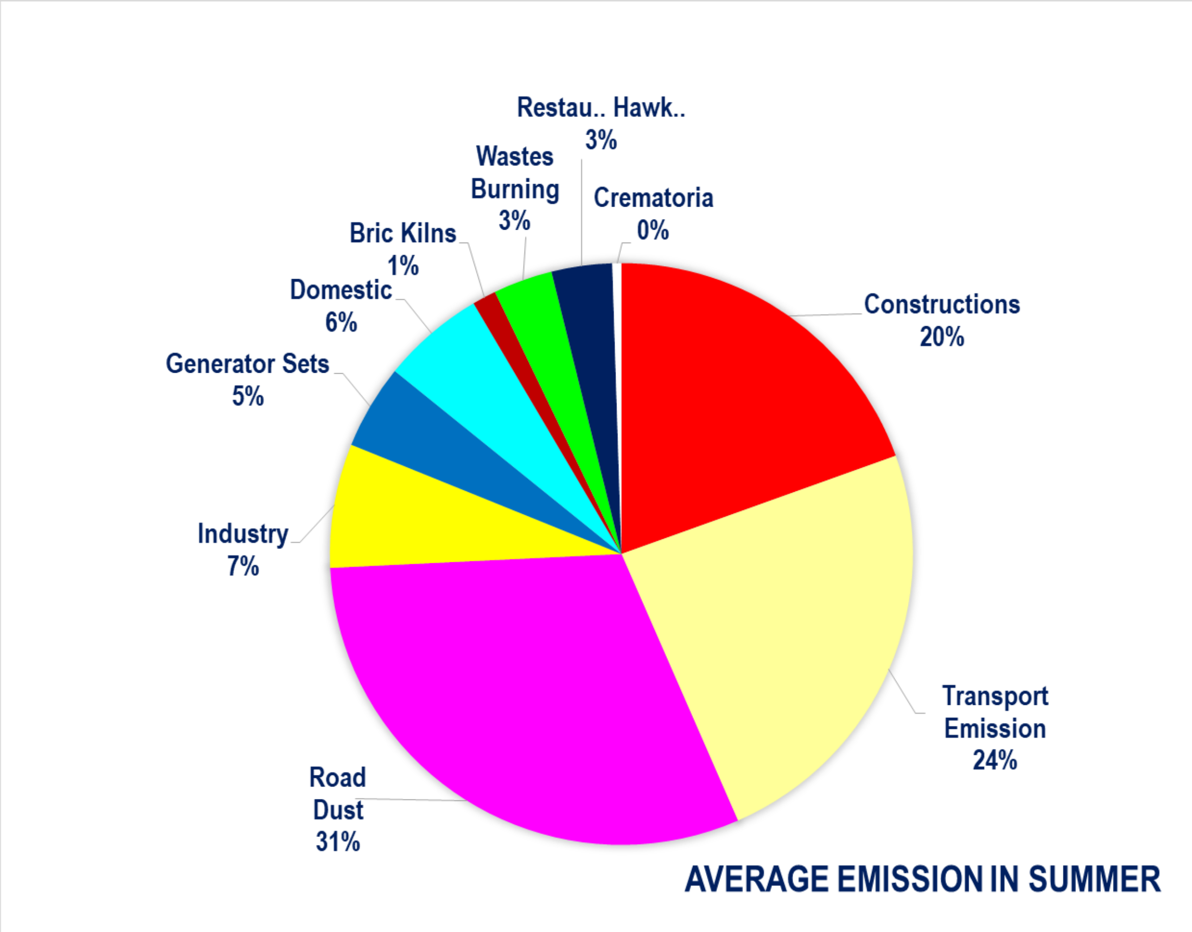
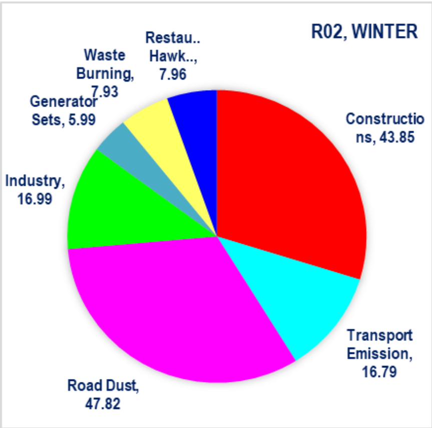


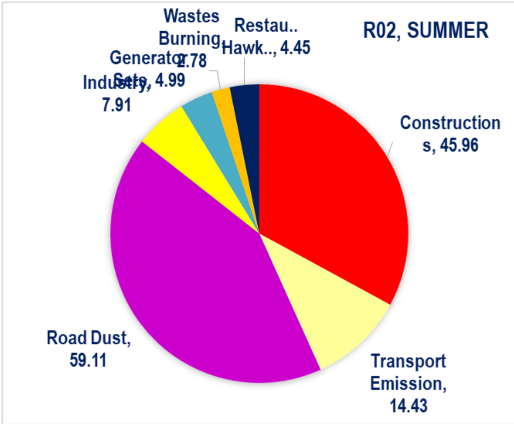
Figure 2.103: Different sources of pollutants and their percent contribution in the ambient air pollution of Raipur during summer season.

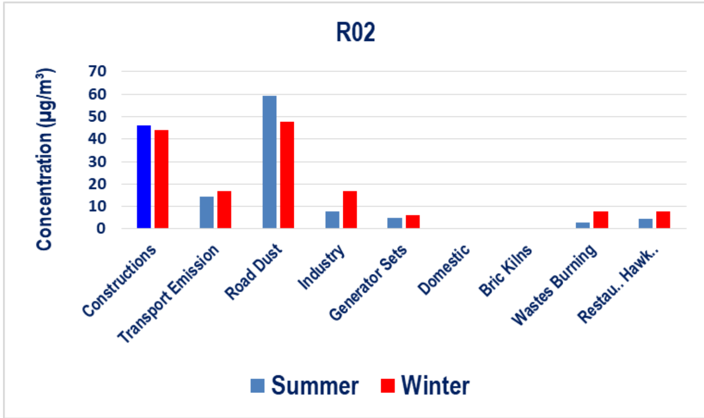
Emission inventory study shows, ambient air quality in Raipur is mainly effected by different types of construction (like; road constructions, bridge constructions, building constructions which include both domestic as well as industrial buildings, different types of structural constructions and so on). Particulate matters emission from different types of construction have been predicted by CMB as 20% (21.44 µg/m^3). Similarly, CMB predicted other major emission sources are road dust (31%; 33.83 µg/m^3), transports (24%; 26.31 µg/m^3), industry or small manufacturing units (7%; 7.58 µg/m^3), etc. (Figure-2.103).

2.4.8.3 Seasonal Variation

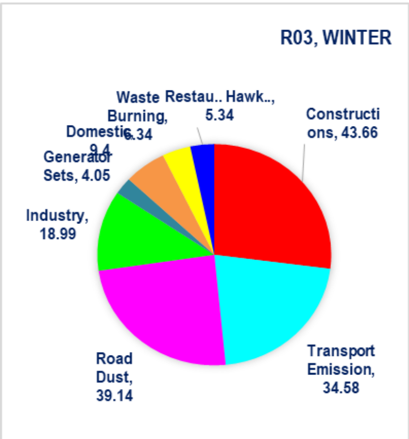
WINTER **SUMMER** **SEASONAL VARIATION**

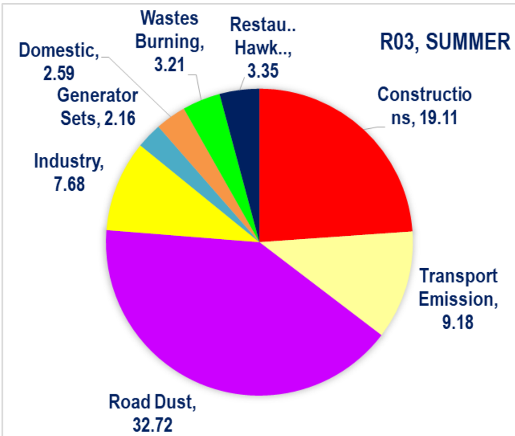


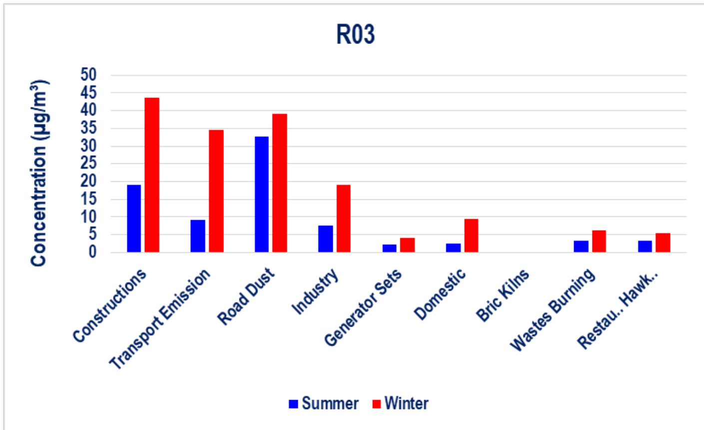




R02

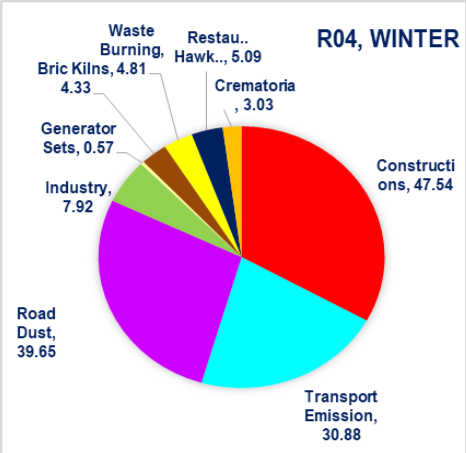


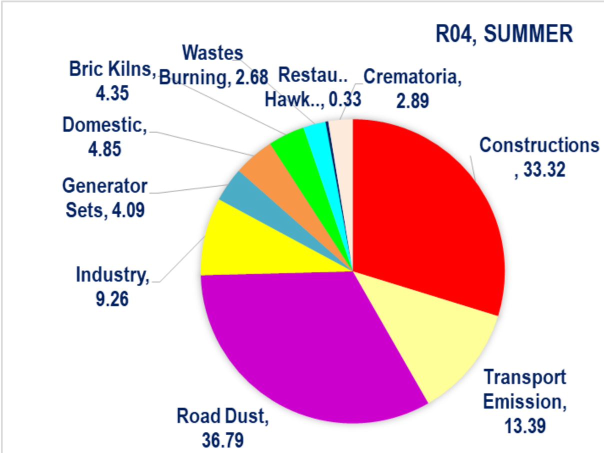


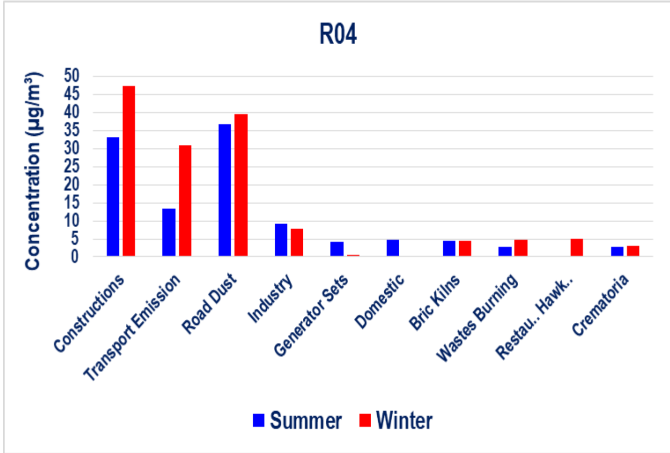


R03

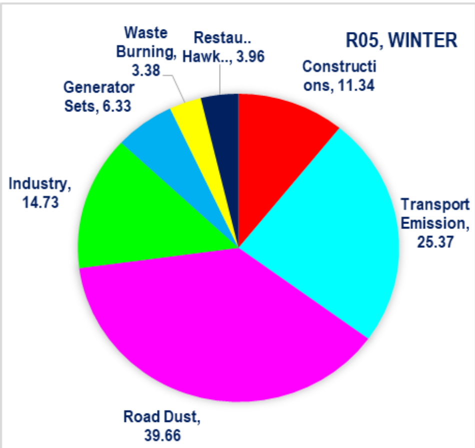
WINTER | SUMMER | SEASONAL VARIATION

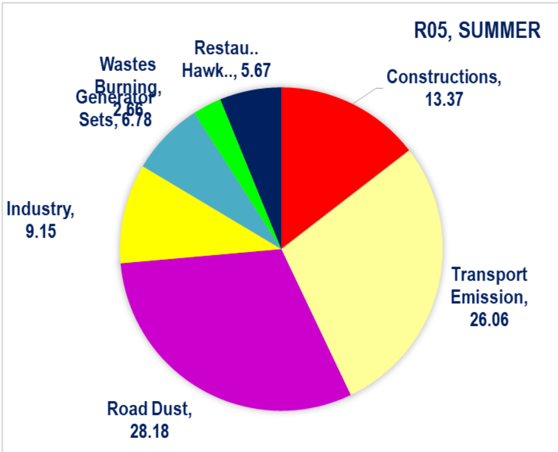


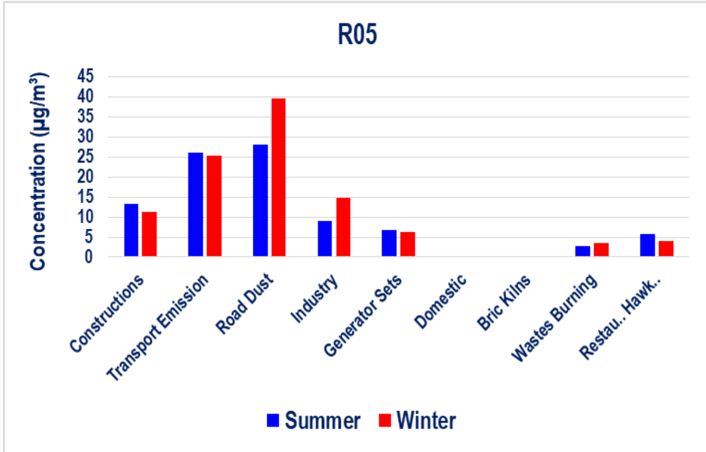




R04







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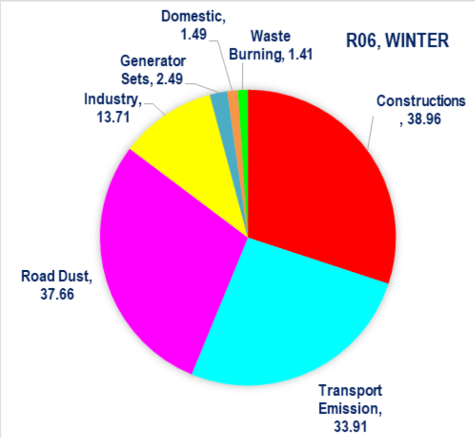
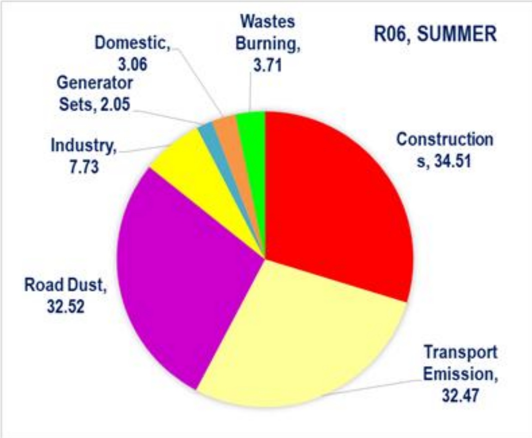
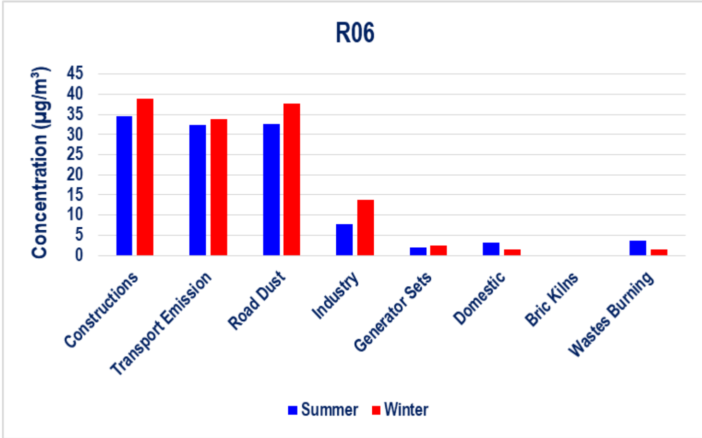
WINTER | **SUMMER** | **SEASONAL VARIATION**







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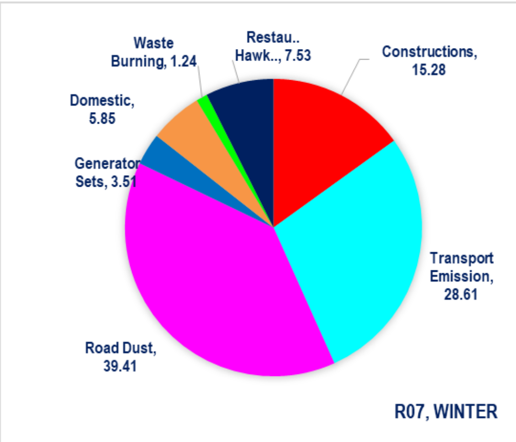

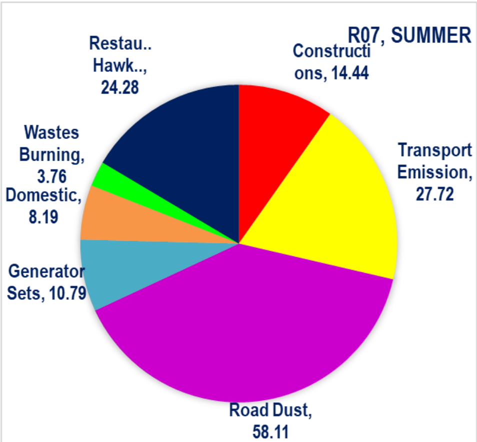

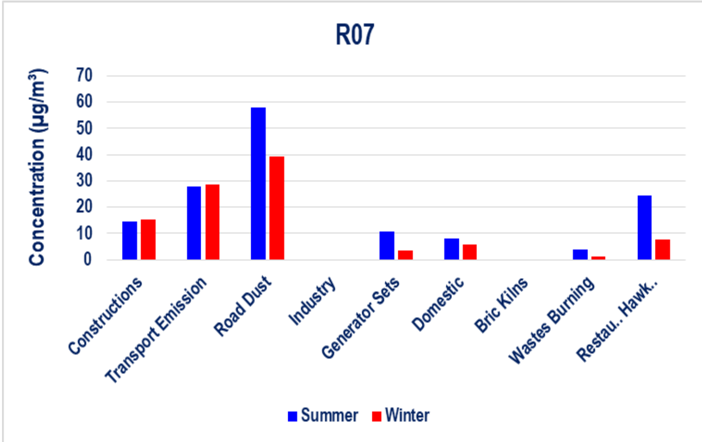

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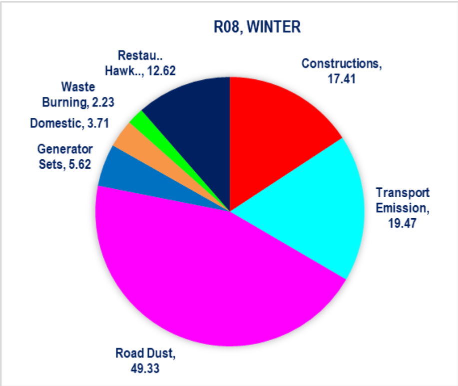

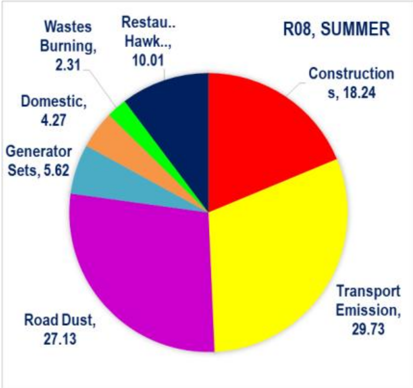

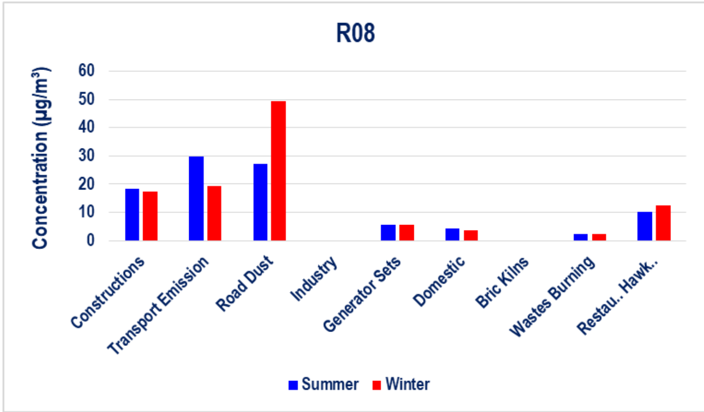

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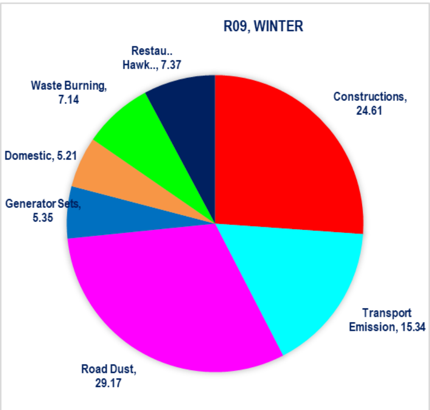

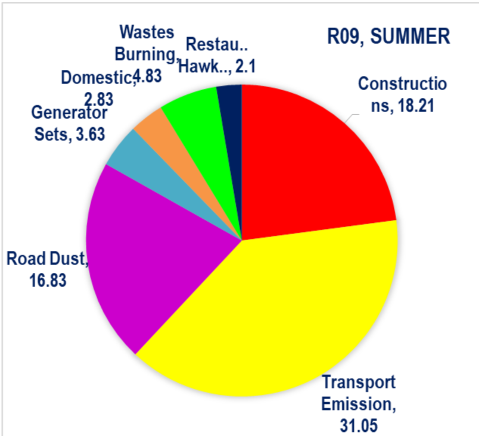

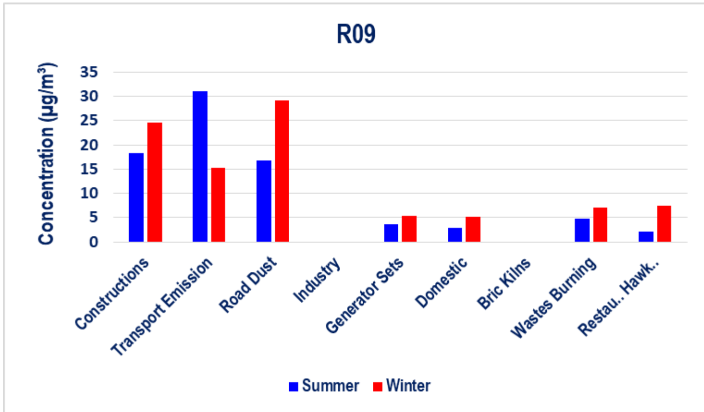

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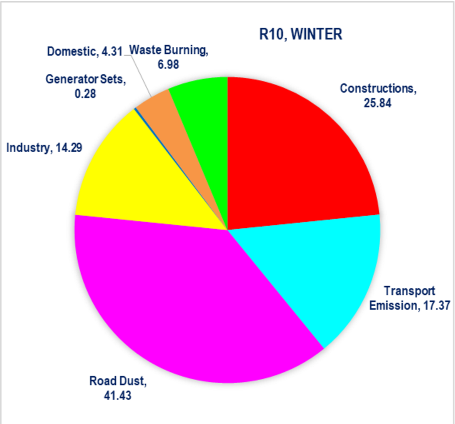

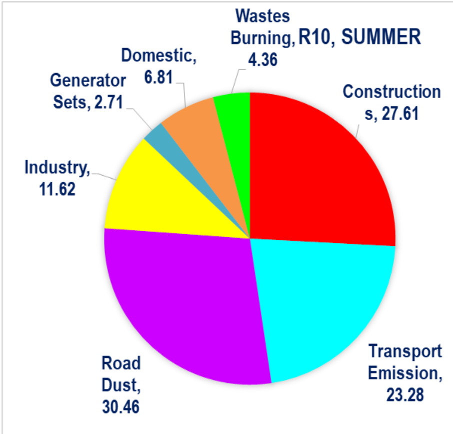

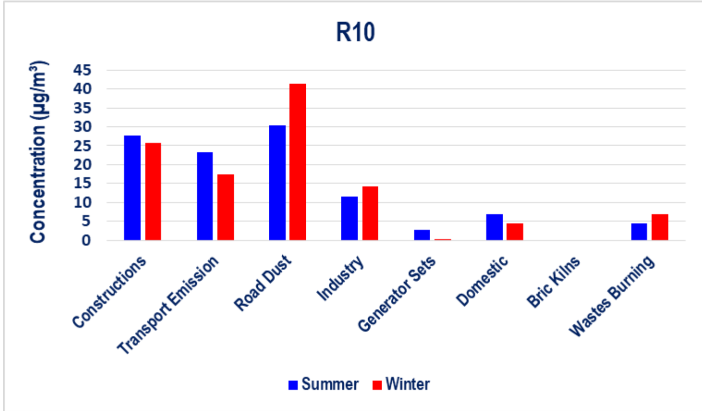

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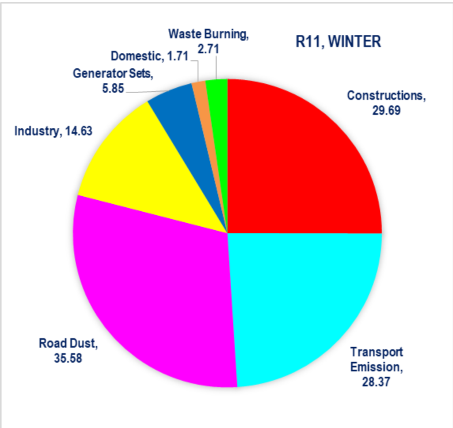

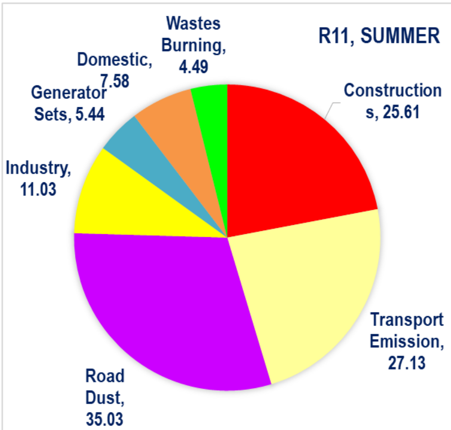

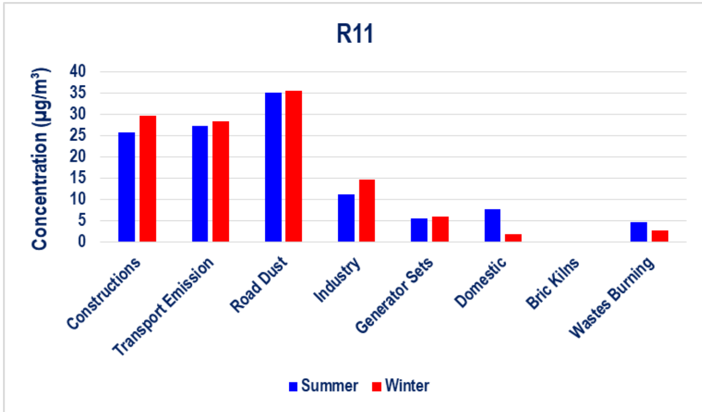

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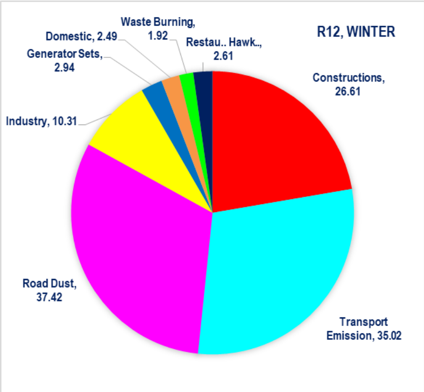

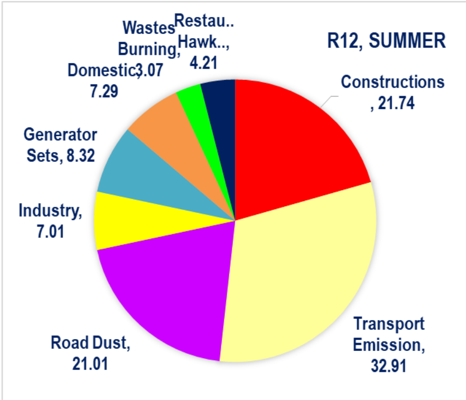

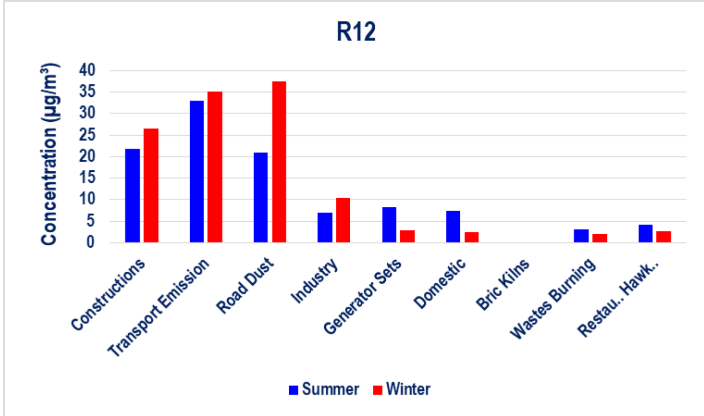

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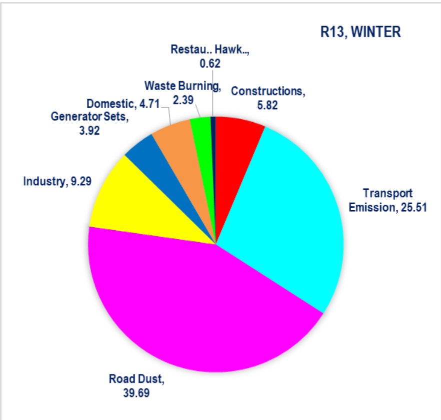

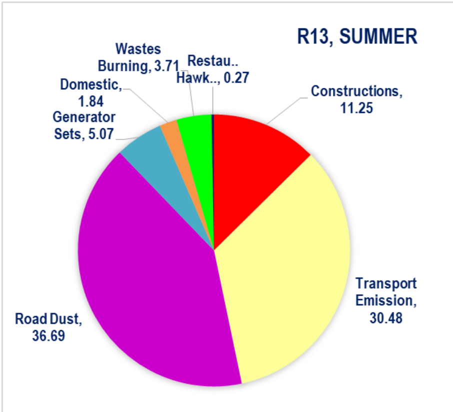

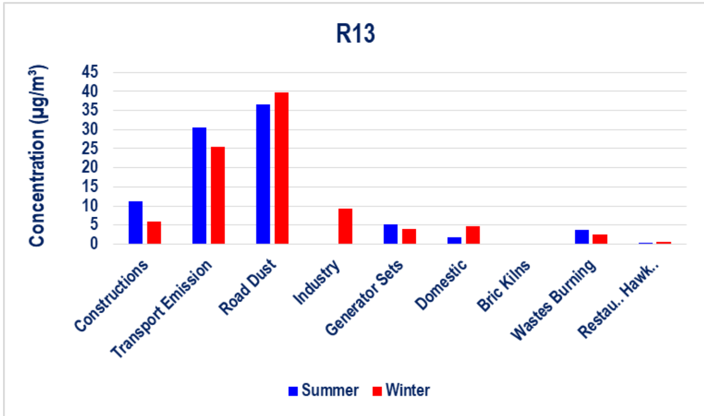

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SUMMER

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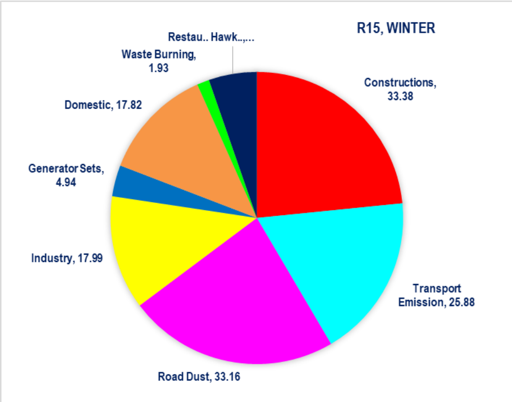

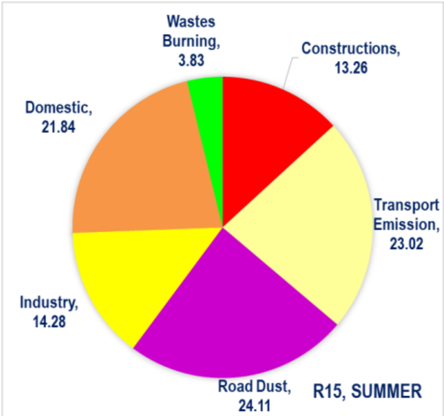

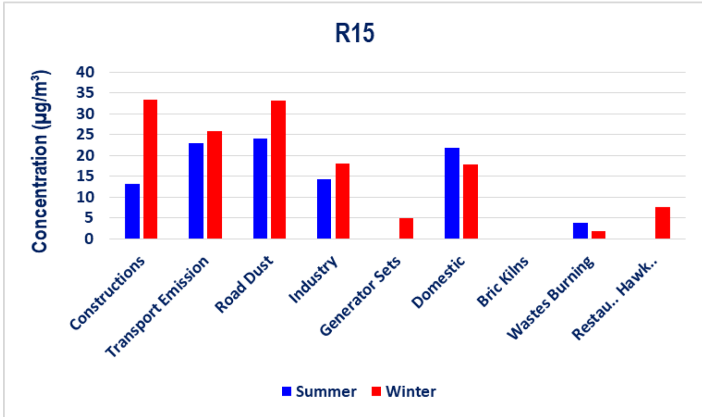

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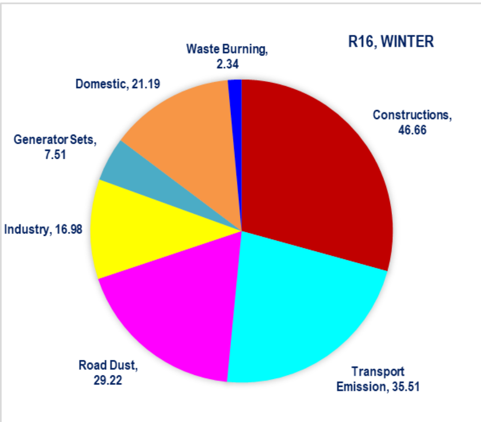

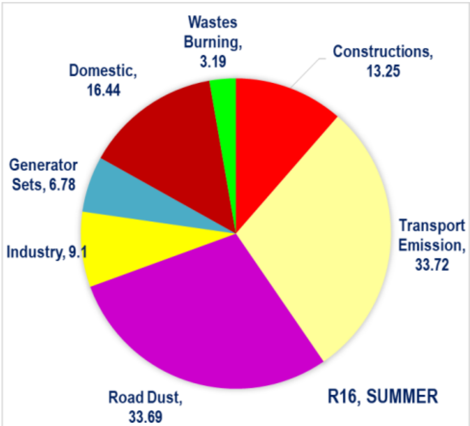

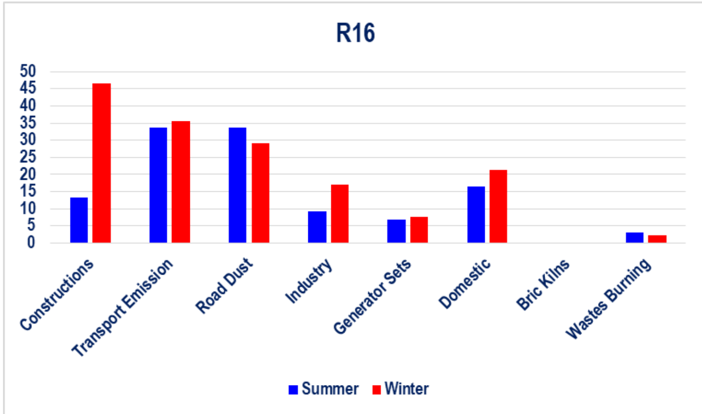

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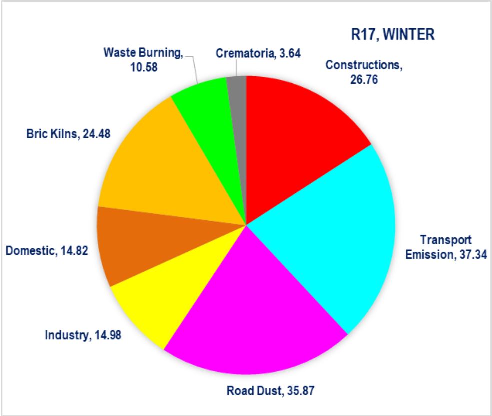

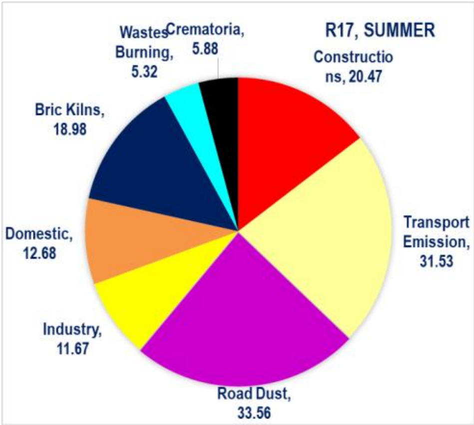

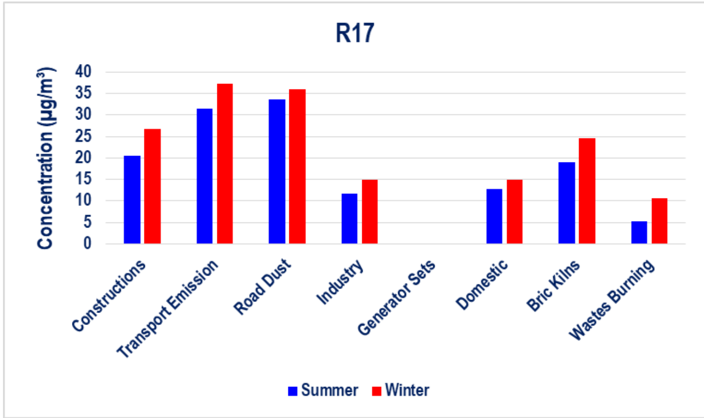

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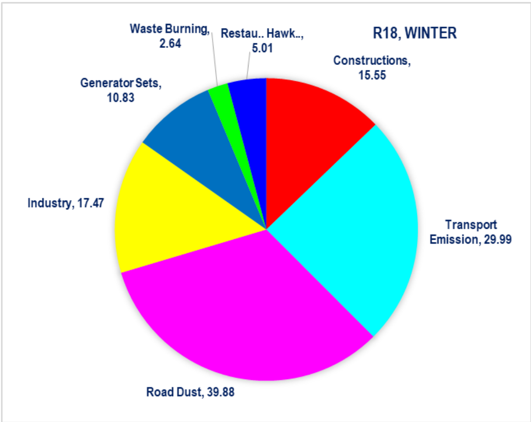

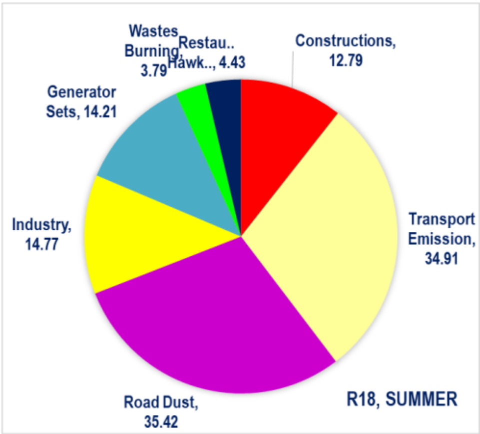

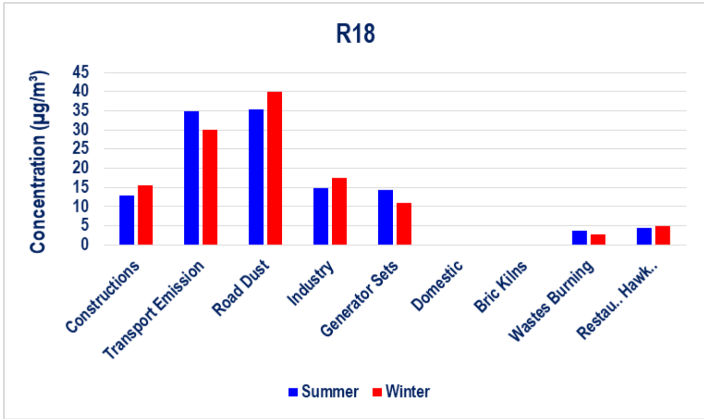

R18

Figure 2.104: Station wise emission variations of each station with the change of seasons are shown graphically and separately.

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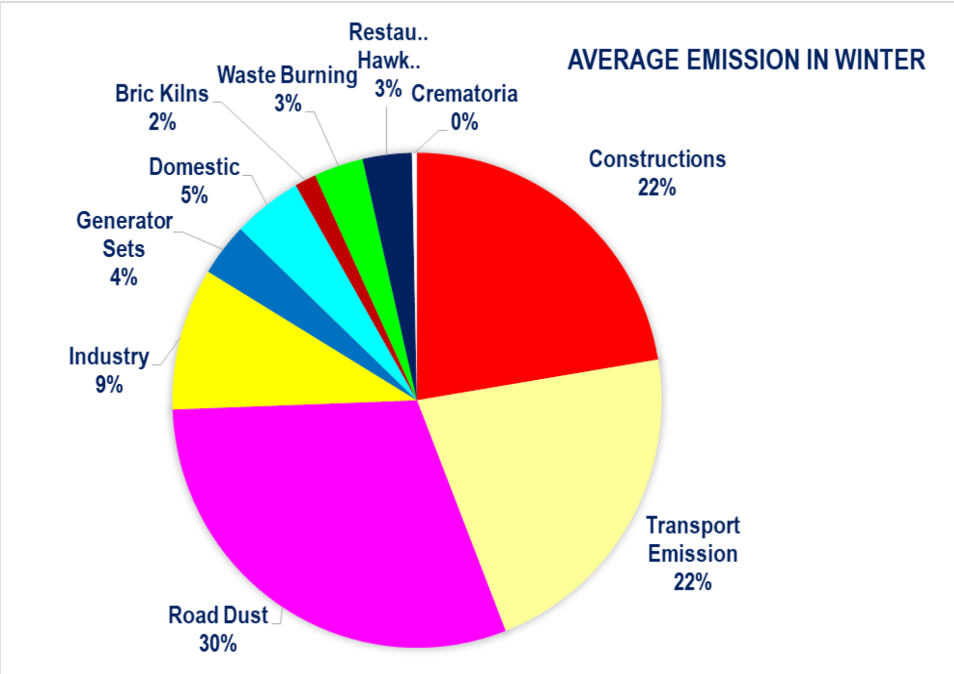

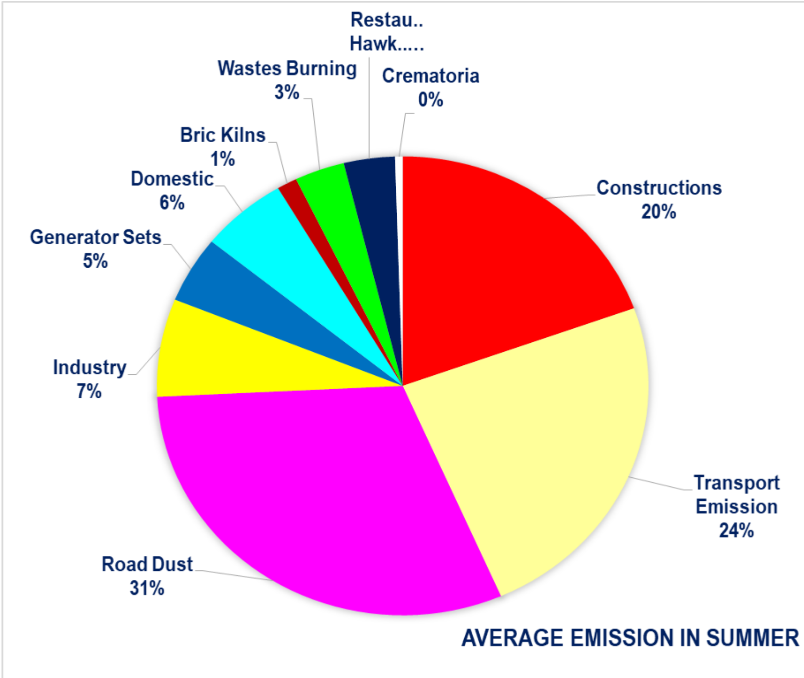

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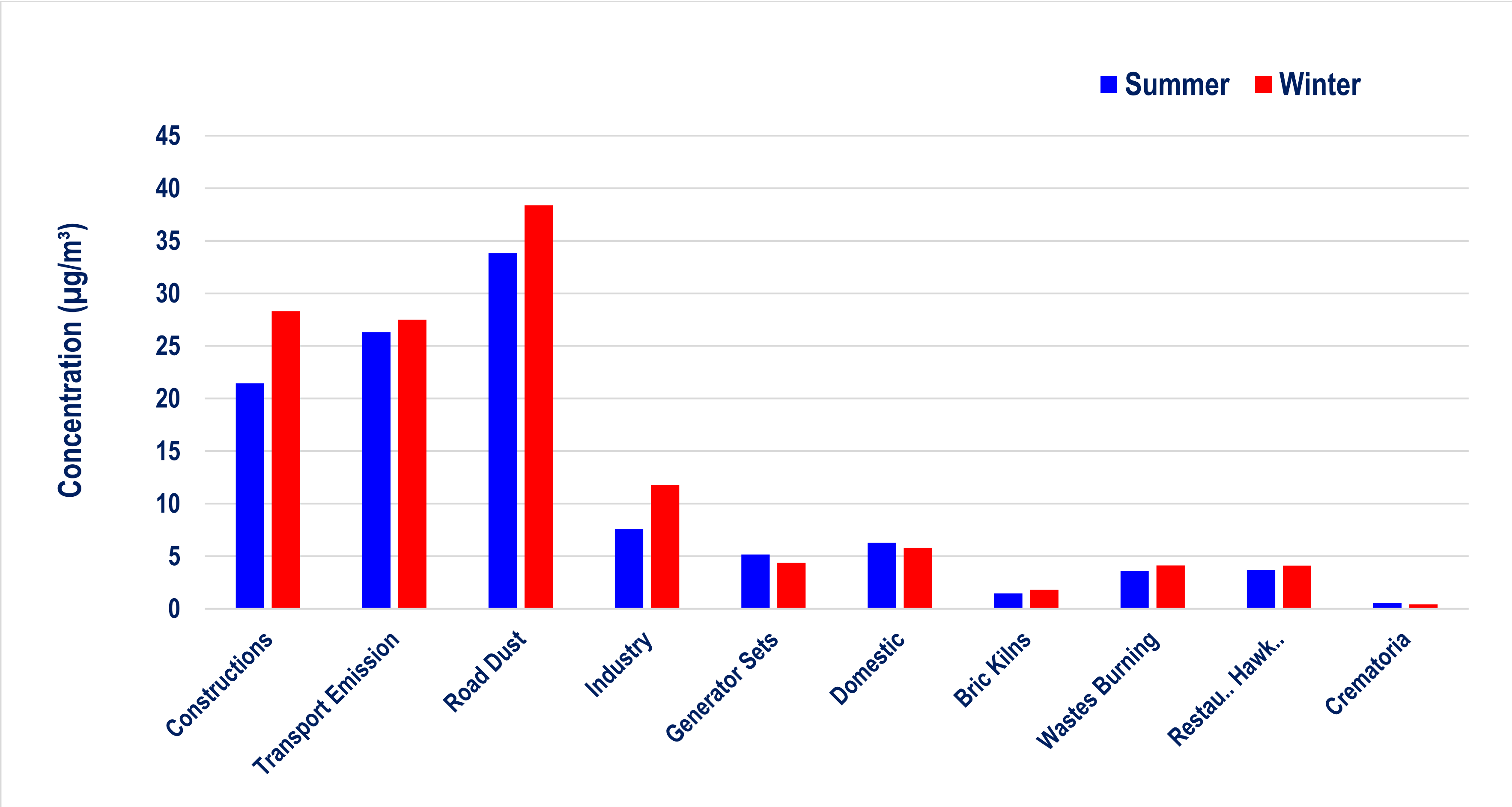


Figure 2.105: Sector wise emission variation with the change of seasons is shown graphically and separately

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 analyzed 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 analyzing 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 ^{o}C. 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 color change from blue green to reddish brown is indicated the completion of titration. Procedure for COD analysis is shown in Figure 3.1.

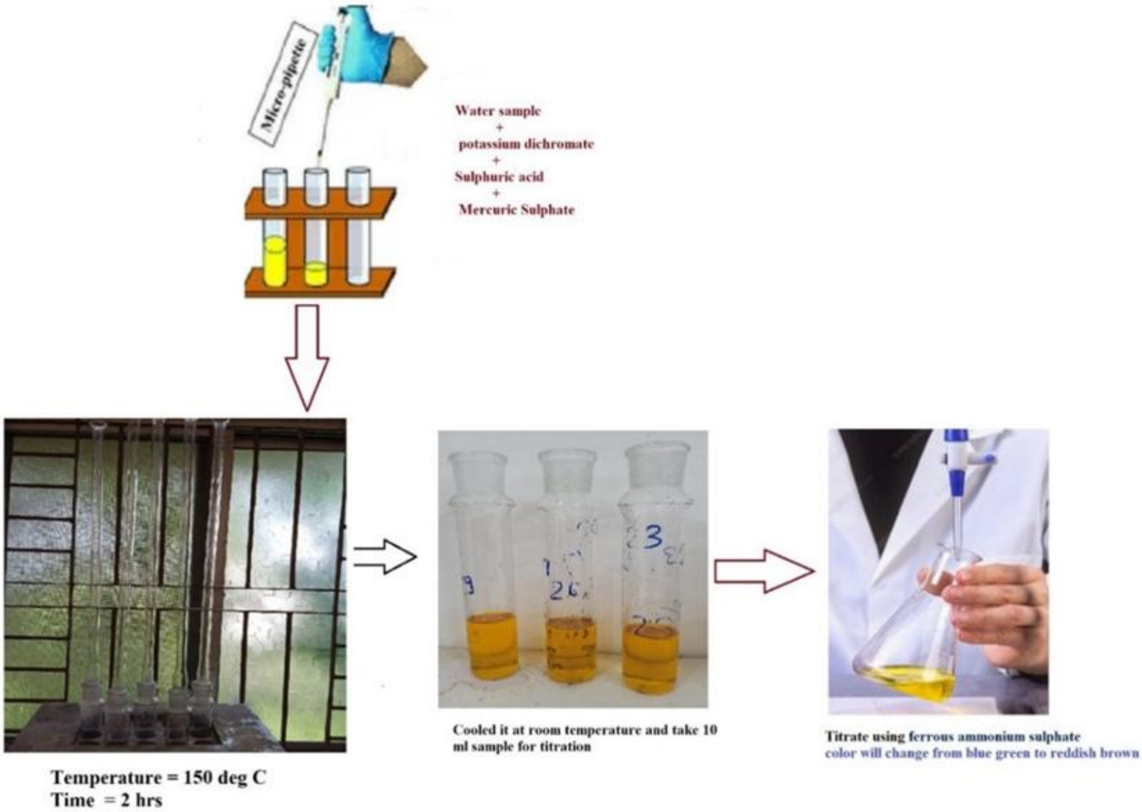


Figure 3.1: Procedure for COD analysis.

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 = Miliequivalent 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 color 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 color 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 2.23, 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 color changes to blue.
5. A color change from wine red to blue indicated the completion of titration.

B. Calcium Hardness

As shown in Figure 2.24, 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.

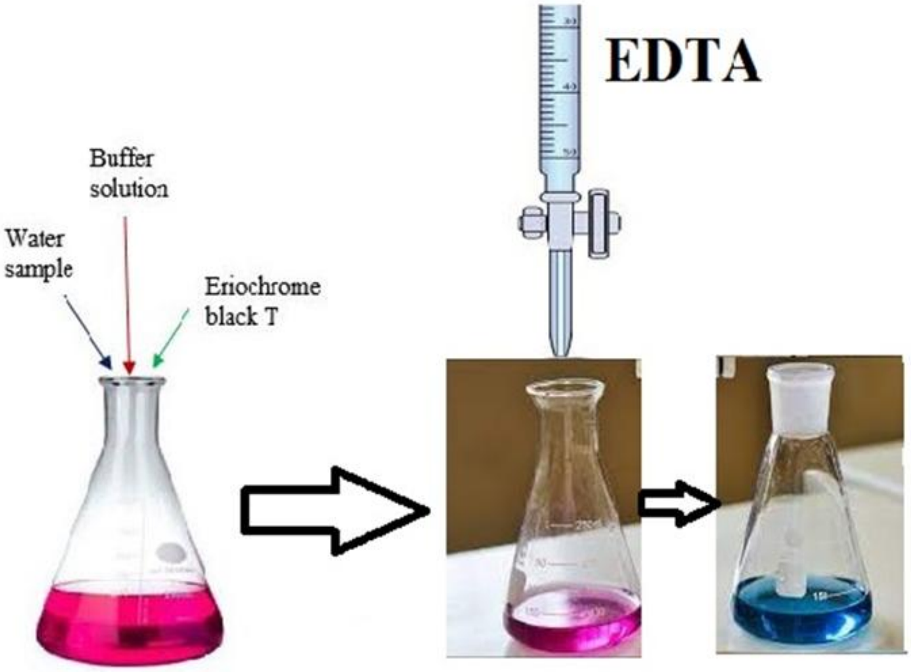


Figure 3.2: Procedure for total hardness analysis.

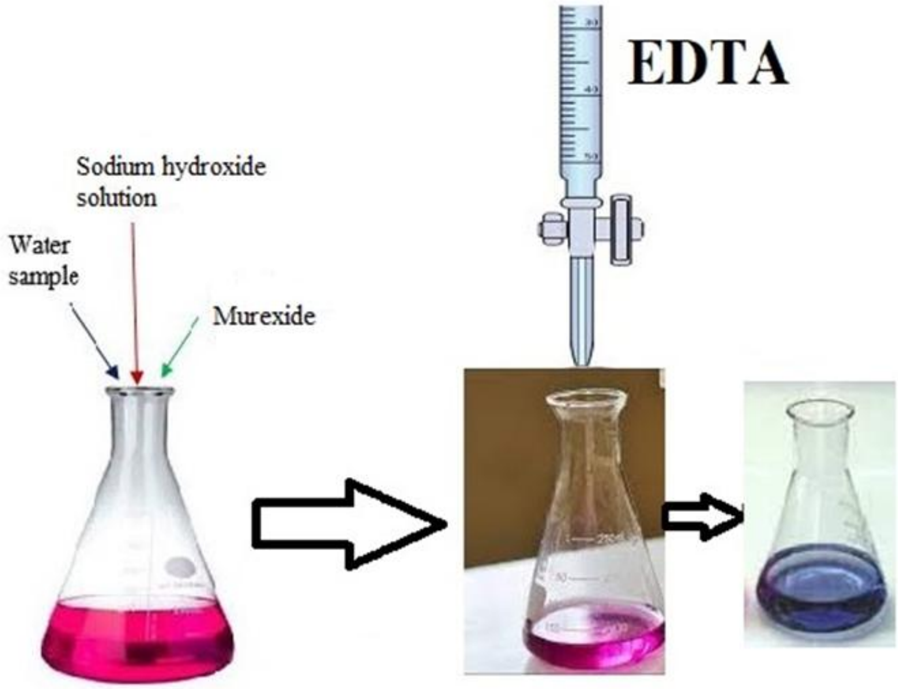


Figure 3.3: Procedure for calcium hardness analysis.

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 color 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 3.4, 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 titrate 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).

Table 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.

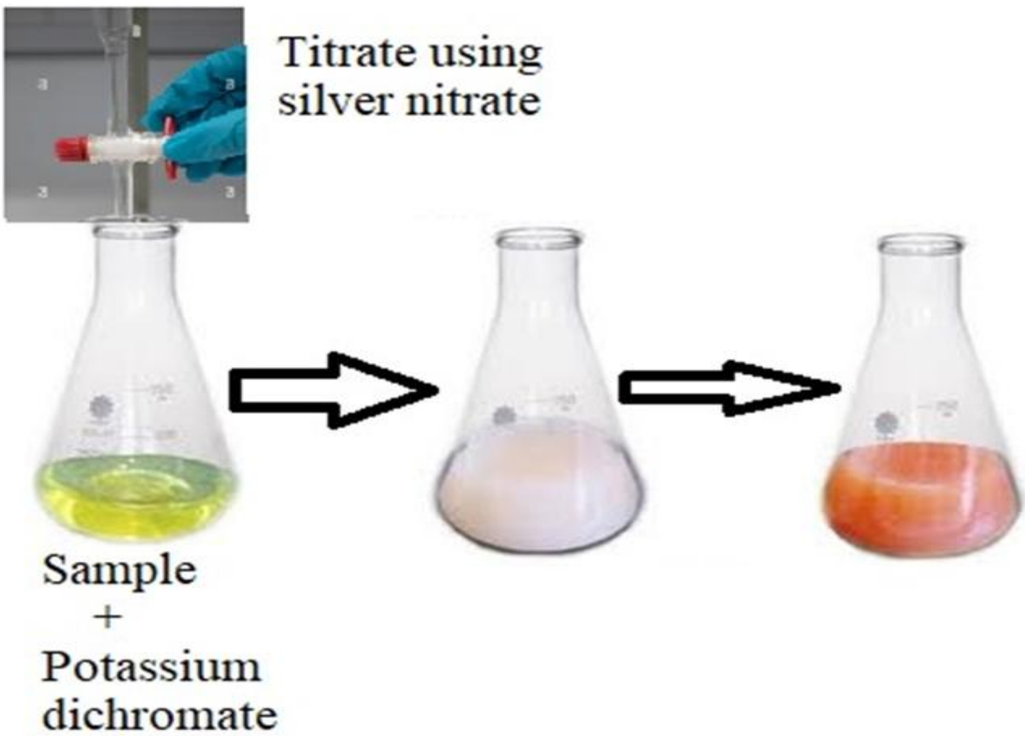


Figure 3.5: Procedure for chloride analysis.

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.

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

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

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

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

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

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

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

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.

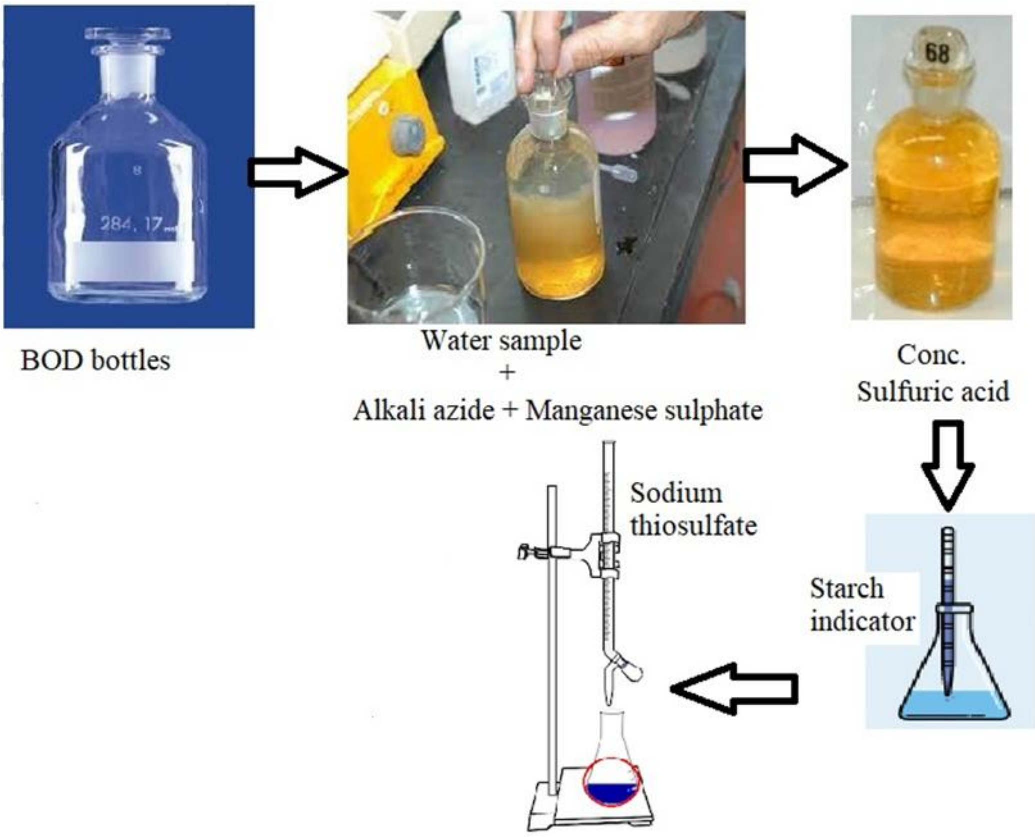


Figure 3.6: Procedure to calculate dissolved oxygen in water sample.

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 pretreatment 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, 0.025N**

   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 analyzes 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 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. 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

$$\text{BOD as } O_2 \text{ mg/L} = \{(D_1 - D_2) \times 100\} / \% \text{ dilution} \quad (2.30)$$

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 Working Method

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**)	%

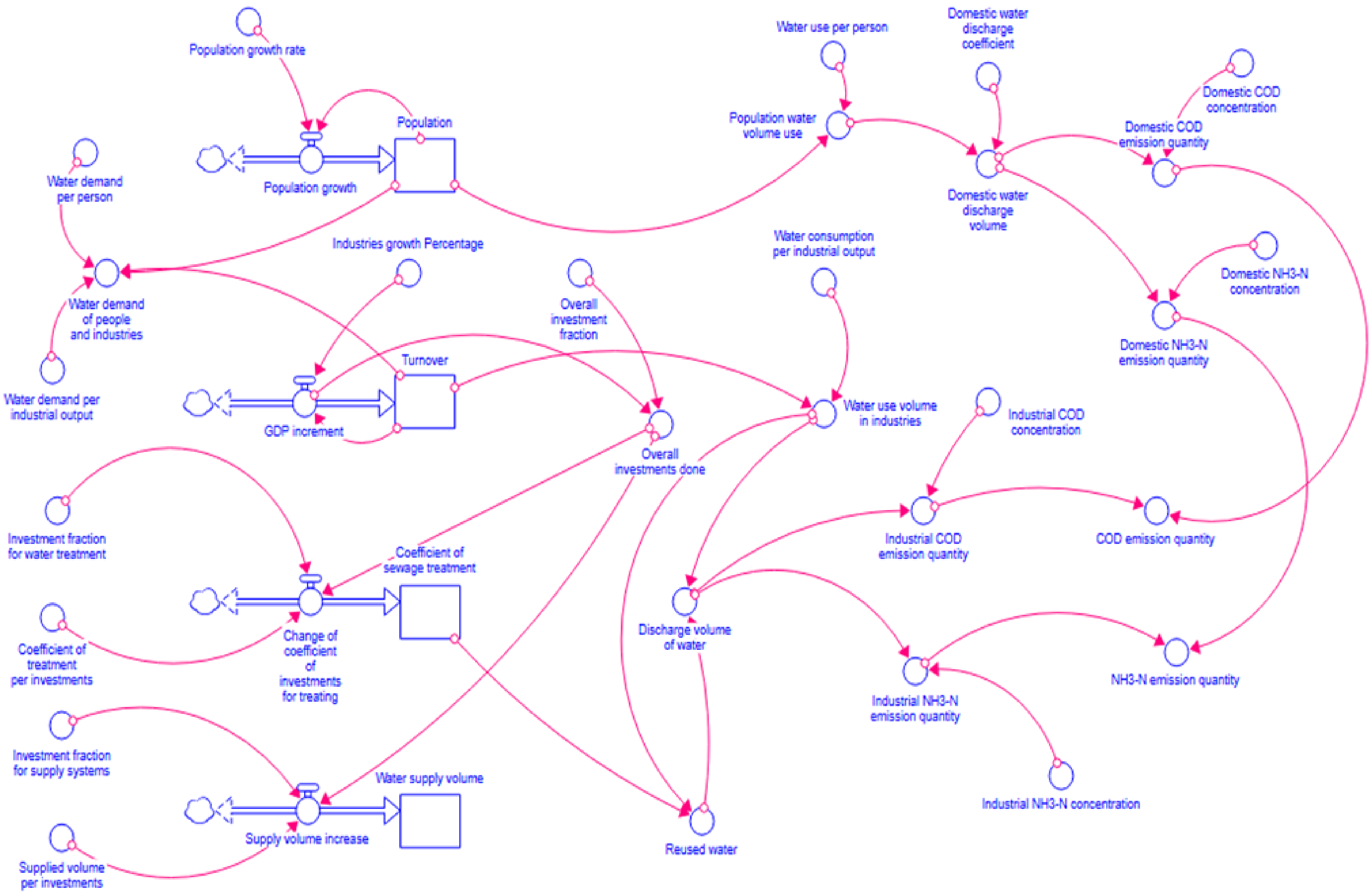


Figure 3.9: Development of water carrying capacity model by STELLA software.

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

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

Negative Indicator

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

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:

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

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

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:

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

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 Discussions

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

Table 3.5: Water sample collection location in Raipur

Location ID	Location name	Latitude (°N)	Longitude (°E)
RAW 001	Dangania Talab	21.233	81.602
RAW 002	Aamnaka Talab	21.238	81.605
RAW 003	Dumar Talab	21.253	81.754
RAW 004	Dumar Talab	21.250	81.592
RAW 005	Ispat Power Plant	21.314	81.601
RAW 006	Mahadev Ghat Road Talab	21.223	81.594
RAW 007	Mahadev Ghar (Kharoon River)	21.216	81.589
RAW 008	Jhara Talab	21.226	81.597
RAW 009	Bhagobat Talab	21.528	81.591
RAW 010	Bhaya Talab	21.221	81.625
RAW 011	Maharajbend Talab	21.224	81.627
RAW 012	Chakuli Talab	21.227	81.626
RAW 013	Kilabala Talab	21.229	81.631
RAW 014	Budha Talab	21.230	81.635
RAW 015	M.D. Talab	21.242	81.625
RAW 016	Handi Talab	21.242	81.626
RAW 017	Dhubhi Talab	21.244	81.622
RAW 018	Ama Talab	21.244	81.623
RAW 019	Ghoroi Talab	21.246	81.621
RAW 020	Sitila Talab	21.245	81.619
RAW 021	Marine Drive Talab	21.240	81.661
RAW 022	Dori Talab	21.187	81.657
RAW 023	Gajaraj Talab	21.191	81.646
RAW 024	Jayjagata Talab	21.208	81.556
RAW 025	Bhomo Nagar Ranf Maa H.P	21.209	81.640
RAW 026	Kharor Mura River	21.190	81.607
RAW 027	Achi Talab	21.208	81.616
RAW 028	Sahu Para Talab	21.268	81.639
RAW 029	Sitala Talab	21.275	81.635
RAW 030	Chatua Talab	21.275	81.635
RAW031	Dari Talab	21.290	81.641
RAW032	Chhtwa Talab	21.290	81.641
RAW033	Bandhwa Talab	21.291	81.644
RAW034	Rameswar Nagar Hand Pump 1	21.293	81.642
RAW035	Rameswar Nagar Hand Pump 2	21.292	81.642
RAW036	Chiraj Talab 1	21.223	81.631
RAW037	Chiraj Talab 2	21.222	81.631
RAW038	Tabri Talab	21.228	81.633
RAW039	Bankoli Talab	21.236	81.628
RAW040	Mahan Talab	21.256	81.595
RAW041	Mangal Bhawan (Kota) Well	21.260	81.604

RAW042	Naya Talab Kota	21.261	81.604
RAW043	Sitala Talab	21.262	81.597
RAW044	Thakur Basti (H.P)	21.261	81.600
RAW045	Mohan Talab 2	21.258	81.595
RAW046	Ambleshwar Talab	21.209	81.580
RAW047	Kumbhakar Para Talab	21.205	81.581
RAW048	Amleswar - 3	21.202	81.588
RAW049	Amleswar Durga Nagar (H.P)	21.203	81.583
RAW050	Nouwa Talab	21.302	81.569
RAW051	Bendri Road Talab	21.314	81.602
RAW052	Urla Water Plant (H.P)	21.312	81.603
RAW053	Ashram Talab	21.329	81.644
RAW054	Daburi Talab	21.152	81.556
RAW055	Bora Talab (Mohadi)	21.162	81.565
RAW056	Mana Gram Panchayat (H.P)	21.169	81.725
RAW057	Ashirbad Talab	21.307	81.169
RAW058	Kara Middle School H.P.	21.332	81.576
RAW059	Kharun River Kara Ghat	21.333	81.576
RAW 060	Ashram Bore Well	21.329	81.643
RAW 061	Jahrana (Hizapur)	21.275	81.580
RAW 062	Dabra Talab(Guma-2)	21.304	81.571
RAW 063	Kharun River (Akola)	21.309	81.550
RAW 064	Gomachi Bhatpara(H.P.)	21.298	81.545
RAW 065	Gomachi Raipur Talab(Village)	21.294	81.538
RAW 066	Aaama Talab(Guma-2 (Village)	21.309	81.566
RAW 067	Uchala Taria Talab(Guma-2)	21.233	81.566
RAW 068	Kara(H.P.) Village	21.329	81.578
RAW 069	Tatibandh Talab - 01	21.264997	81.571576
RAW 070	Tatibandh Talab - 02	21.263937	81.572032
RAW 071	Sandongri Talab	21.279079	81.593222
RAW 072	Phanari Para Talab	21.277338	81.597721
RAW 073	Gogaon Talab	21.267523	81.572032
RAW 074	Bhunia Talab	21.267523	81.387459
RAW 075	Nareshwar Talab	21.227979	81.640691
RAW 076	Nalka Talab	21.216985	81.630052
RAW 077	Terna Talab	21.270105	81.577101
RAW 078	Boratariya Talab	21.273426	81.573395
RAW 079	Bandha Talab	21.276764	81.566482
RAW 080	Tendua Bosti(H.P.)	21.292872	81.562200
RAW 081	Gorin Talab	21.299203	81.566327
RAW 082	Bora Talab	21.290198	81.567065
RAW 083	Banarasi Talab-01	21.178569	81.727218
RAW 084	Banarasi Talab-02	21.181386	81.725470
RAW 085	Banarasi Talab (H.P.)-01	21.183072	81.724331
RAW 086	Banarasi Talab (H.P.)-02	21.184256	81.724299
RAW 087	Jora Village (H.P.)(Vatapara)	21.240822	81.713136
RAW 088	Vatapara Talab	21.241022	81.713136

RAW 089	Sita Monoir Talab(Serikhedi)-01	21.232177	81.735306
RAW 090	Sita Monoir Talab(Serikhedi)-02	21.233372	81.735193
RAW 091	Serikedi(H.P.)	21.232210	81.735112
RAW 092	Naha Kenal(Sankari)	21.280793	81.740803
RAW 093	Colon Talab	21.280697	81.740720
RAW 094	Chhattvd(H.P.)	21.336664	81.794028
RAW 095	Mauli Talab(Chhattud)	21.338369	81.794107
RAW 096	Sivsankha Talab(Chhattud)	21.343313	81.791588
RAW 097	Daburi Talab (Chhattud)	21.342937	81.792228
RAW 098	Chhattvd(H.P.)01	21.342940	81.791631
RAW 099	Dungia Talab	21.189313	81.562574
RAW 100	Sankar (H.P.)	21.188554	81.559635
RAW 101	Khandan Talab	21.188787	81.558584
RAW 102	Motipur	21.174789	81.539857
RAW 103	Moti Talab	21.172286	81.539297
RAW 104	Pankhatia Talab	21.170816	81.542319
RAW 105	Motipur (Well)	21.170279	81.541870
RAW 106	Sitala Talab	21.168554	81.545345
RAW 107	Morum Talab(Kapsi)	21.157697	81.547861
RAW 108	Kandawaria Talab(Jheet)	21.149125	81.551331
RAW 109	Bandatwaria Talab	21.147360	81.551007
RAW 110	Macchi Taria Talab	21.264446	81.631293
RAW 111	Pandri Talab	21.258933	81.653047
RAW 112	Raja Talab	21.248322	81.653832
RAW 113	Mana (Borai Para)(H.P.)	21.167621	81.724025
RAW 114	Bhatagon-01	21.171025	81.713670
RAW 115	Mana Basti	21.168822	81.725337
RAW 116	Banarasi(H.P.)	21.176889	81.724169
RAW 117	Borsi Talab-01	21.183890	81.720045
RAW 118	Borsi Talab-02	21.181076	81.711513
RAW 119	Borsi Talab -03	21.184149	81.726608
RAW 120	Devpuri Talab	21.207092	81.699197
RAW 121	Shrii Ram Chawk	21.202096	81.704756
RAW 122	Fundhar Talab	21.214243	81.691518
RAW 123	Sitalamata Mandir Talab	21.214181	81.691383
RAW 124	Amidn Mondir	21.22487	81.676154
RAW 125	Purana Talab	21.234466	81.671391
RAW 126	Devri Talab	21.233826	81.671478
RAW 127	Pangania Talab	21.238354	81.605104
RAW 128	Dhanalaxmi Talab	21.249474	81.592029
RAW 129	Sitalamata Dumar Talab	21.253568	81.585176
RAW 130	Mukha Dhara Talab	21.255205	81.594968
RAW 131	Mahant Talab	21.258182	81.596140
RAW 132	Karbala Talab	21.244526	81.613281
RAW 133	Ramkumar Talab	21.242759	81.620786
RAW 134	Ama Talab	21.245568	81.621211

RAW 135	Yougbodh Talab	21.243456	81.622243
RAW 136	Kali Talab	21.242344	81.625001
RAW 137	Handi Talab	21.241733	81.625930
RAW 138	Kakri Talab	21.254763	81.626698
RAW 139	Macchi Taria Talab	21.263872	81.629963
RAW 140	Khoko Talab	21.232713	81.620260
RAW 141	Radhakrishna Talab	21.232087	81.619965
RAW 142	Sai Talab	21.234113	81.620005
RAW 143	Maisaraj Talab	21.227280	81.620972
RAW 144	Bhaya Talab	21.221260	81.624944
RAW 145	Mahara Band	21.225291	81.627315
RAW 146	Dabara Para Talab (Sarora)	21.244722	81.578322
RAW 147	Mondir Talab(Sarowa)	21.241034	81.574708
RAW 148	Sarora Village(H.P.)	21.245260	81.575970
RAW 149	Sarora School(H.P.)	21.246676	81.574710
RAW 150	Pachri Talab	21.246853	81.575537
RAW 151	Charmri Talab	21.254414	81.572339
RAW 152	Viyas Talab 2	21.304323	81.635948
RAW 153	Dhab Talab	21.309505	81.632697
RAW 154	Boritariya Talab	21.342290	81.655011
RAW 155	Dhaneli (H.P.)	21.337412	81.653172
RAW 156	Totra Talab	21.333258	81.658358
RAW 157	Puria Bhanda Talab	21.330335	81.678874
RAW 158	Dongia Talab	21.334800	81.679201
RAW 159	Mandir Talab	21.339134	81.677955
RAW 160	Patharidihi Chowk 1	21.340040	81.595735
RAW 161	Patharidihi Chowk (H.P.) 2	21.341258	81.595368
RAW 162	Patharidihi Chowk Kharun River	21.349419	81.587232
RAW 163	Dhari Talab	21.289631	81.641175
RAW 164	Chatwa Talab	21.287043	81.641593
RAW 165	Bandwa Talab	21.289709	81.642722

3.3.1 Heavy Metals in Water

Percentage of heavy metals present in different water samples are presented in Figure 3.10. Water samples were from Raipur areas, acidified with concentrated nitric acid (Conc. HNO_3) and filtered. Each collected samples were analyzed by AAS and ICP-MS, respectively. Everywhere we found higher percentage (almost 83%) of iron (Fe) and Nickel (Ni, almost 7%), but under human toxic level. Other micro-elements like; Cu, Ni, Zn, Cr, Cd are also present in detectable but low (in ppm) amount. We also found As and Pb as detectable as well as very low amount (in ppb level), in almost every sample. Though, in-every water-sample metal ion concentrations are in human tolerance level. Among these collected water samples from Raipur areas Fe percentage exceeded over 95% in sample collected from RAW 2, 22 and 47. Iron is one of the earth's most plentiful resources. Rainwater as it infiltrates the soil and underlying geologic formations dissolves iron, causing it to seep into aquifers that serve as sources of groundwater. Although present in drinking water, iron is seldom found at concentrations greater than 10 ppm. Moreover, iron is not hazardous to health and considered a secondary or aesthetic contaminant. Essential for good health, iron helps transport oxygen in the blood.

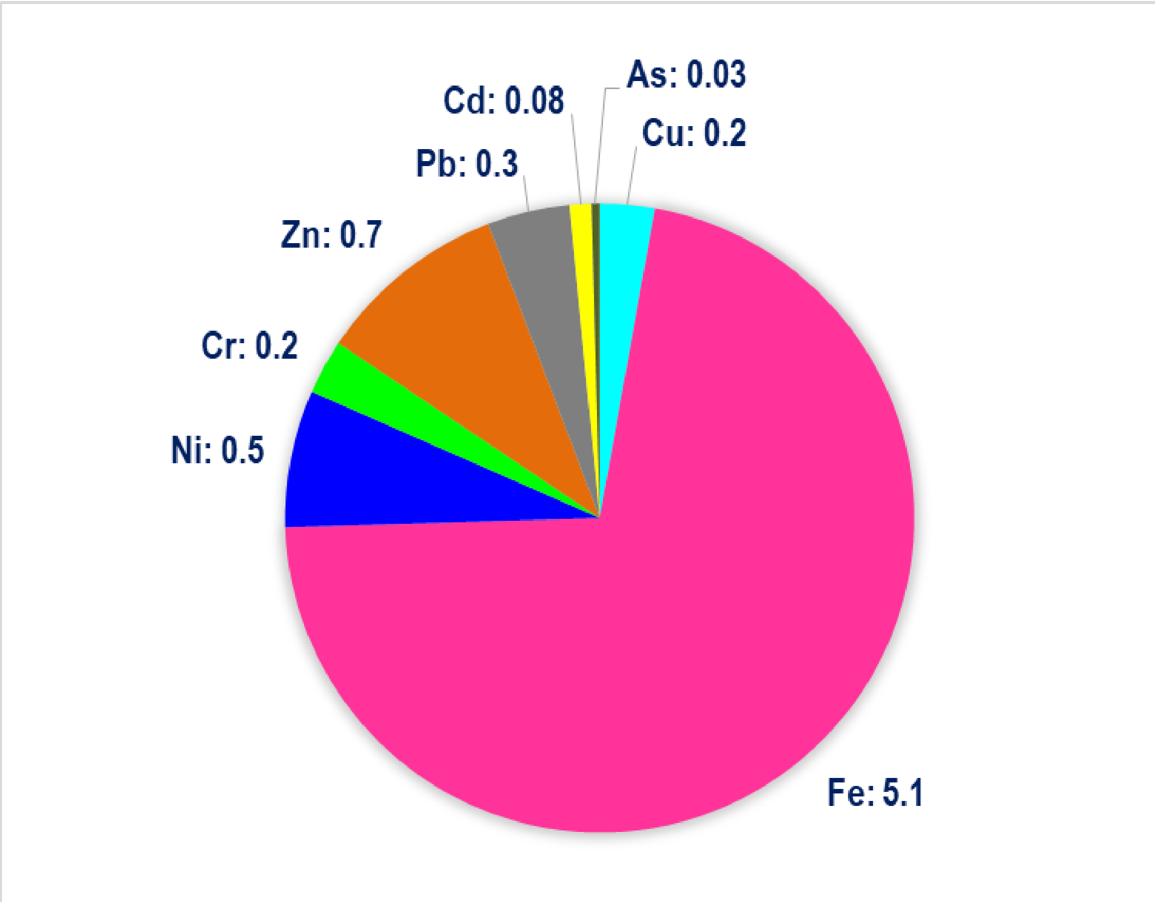


Figure 3.10: Average metal concentration (ppm) in the water samples from Raipur.

3.3.2 Physical and Chemical Analysis of Water Samples

Water sample collected from different location in Raipur in all season. Five parameter i.e. Temperature, 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 experiment was done to calculate the COD, DO, Alkalinity, chloride, hardness of the water. From the Figure 3.11 we found that hardness in all the sample is within the limit except these four sample i.e. RAW 12, 41, 45, 49, where 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 300 mg/l. However high alkalinity is good for health but within 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. More details are given below in statistical analysis.

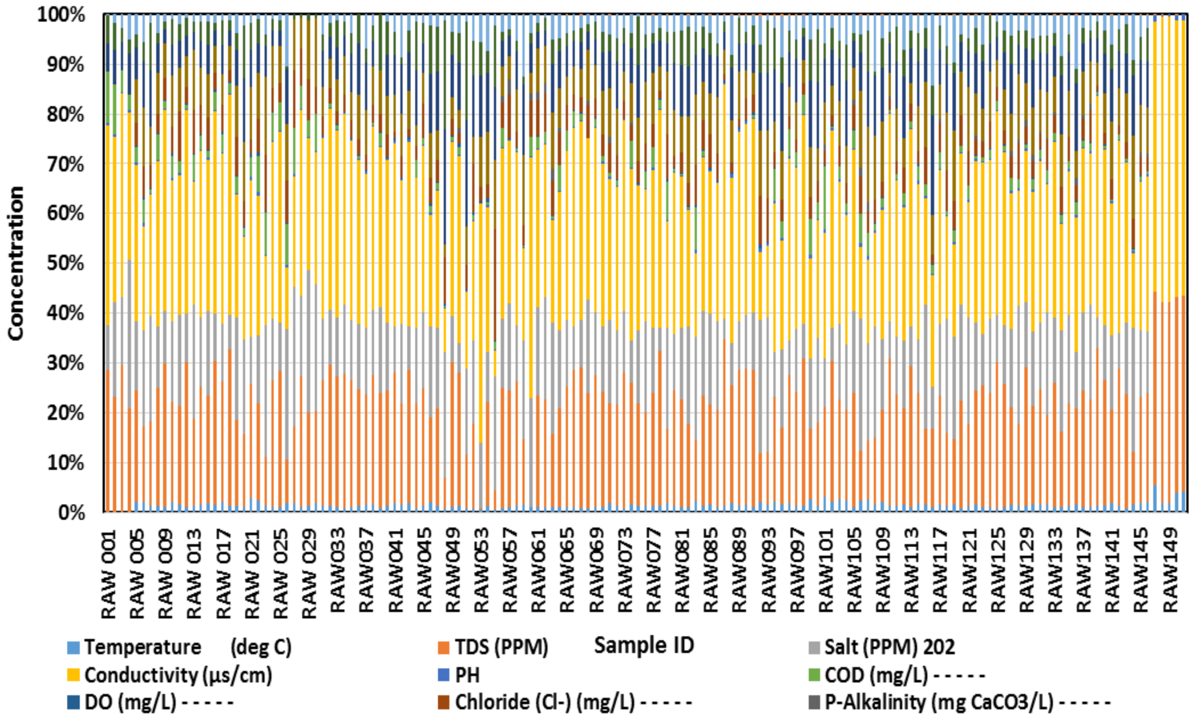


Figure 3.11: Different parameter percentile plot of different water samples collected from Raipur (Marked as RAW).

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 Raipur during study period

	Temperature (° C)	TDS (PPM)	Salt (PPM)	Conductivity (µs/cm)	pH	COD (mg/L)	DO (mg/L)
Max	33.10	979	815	1601	9.31	180	15
Min	20.80	1.01	88.60	179.40	5.76	1.00	0.80
Average	28.43	449.14	320.46	651.04	7.16	51.37	4.23
STDV	2.50	199.22	148.36	288.41	0.773	41.61	2.97
Mean	28.43	449.14	320.46	651.04	7.16	51.37	4.23
CV	0.088	0.443	0.462	0.442	0.107	0.810	0.702
	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	800	80	500	646	610	354	7.3
Min	19	0	54	54	10	2	0.1
Average	104.22	5.63	178.34	169.19	94.20	74.54	1.67
STDV	79.71	13.38	69.05	94.55	86.72	51.36	1.88
Mean	104.22	5.63	178.34	169.19	94.20	74.54	1.67
CV	0.764	2.37	0.387	0.558	0.920	0.689	1.12

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	1702000	20000	3500000	2.47	282
2022	0.802	1745086	20282	3524672	2.50	286
2023	0.805	1789263	20568	3549692	2.54	290

2024	0.808	1834559	20858	3575065	2.57	294
2025	0.810	1881001	21152	3600796	2.61	298
2026	0.813	1928619	21450	3626889	2.65	302
2027	0.815	1977442	21753	3653351	2.68	307
2028	0.818	2027501	22059	3680185	2.72	311
2029	0.821	2078827	22370	3707398	2.76	315
2030	0.823	2131453	22686	3734994	2.80	320
2031	0.826	2185411	23005	3762979	2.84	324
2032	0.829	2240735	23330	3791359	2.88	329
2033	0.832	2297460	23659	3820139	2.92	334
2034	0.835	2355620	23992	3849325	2.96	338
2035	0.838	2415253	24331	3878922	3.00	343
2036	0.841	2476395	24674	3908937	3.04	348
2037	0.844	2539086	25021	3939374	3.09	353
2038	0.847	2603363	25374	3970241	3.13	358
2039	0.850	2669267	25732	4001543	3.17	363
2040	0.853	2736840	26095	4033286	3.22	368
2041	0.857	2806124	26463	4065477	3.26	373
2042	0.860	2877161	26836	4098122	3.31	378
2043	0.863	2949997	27214	4131227	3.36	384
2044	0.866	3024676	27598	4164798	3.40	389
2045	0.870	3101246	27987	4198843	3.45	395
2046	0.873	3179755	28381	4233368	3.50	400
2047	0.877	3260250	28781	4268380	3.55	406
2048	0.880	3342784	29187	4303885	3.60	411
2049	0.884	3427407	29599	4339891	3.65	417
2050	0.888	3514172	30016	4376404	3.70	423
2051	0.891	3603134	30439	4413433	3.75	4.30

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)
43086	17080	18340	0.0005	45	0.052	180000
43086	24672	17906	0.0005	50	0.2	200000
44177	25020	17980	0.0005	50	0.2	200318
45295	25373	18049	0.0005	50	0.2	200569
46442	25731	18115	0.0005	50	0.2	200750
47618	26093	18175	0.0005	50	0.2	200859
48823	26461	18231	0.0005	50	0.2	200893
50059	26834	18282	0.0005	50	0.2	200847
51326	27213	18328	0.0005	50	0.2	200719
52626	27596	18369	0.0005	50	0.2	200505

53958	27985	18403	0.0005	50	0.2	200202
55324	28380	18432	0.0005	50	0.2	199805
56724	28780	18455	0.0005	50	0.2	199311
58160	29186	18471	0.0005	50	0.2	198717
59633	29597	18480	0.0005	50	0.2	198017
61142	30015	18482	0.0005	50	0.2	197208
62690	30438	18476	0.0005	50	0.2	196286
64277	30867	18463	0.0005	50	0.2	195245
65904	31302	18442	0.0005	50	0.2	194082
67573	31743	18413	0.0005	50	0.2	192791
69283	32191	18375	0.0005	50	0.2	191367
71037	32645	18327	0.0005	50	0.2	189806
72836	33105	18271	0.0005	50	0.2	188102
74680	33572	18204	0.0005	50	0.2	186249
76570	34045	18127	0.0005	50	0.2	184242
78508	34525	18039	0.0005	50	0.2	182076
80496	35012	17941	0.0005	50	0.2	179744
82534	35505	17831	0.0005	50	0.2	177239
84623	36006	17708	0.0005	50	0.2	174557
86765	36513	17574	0.0005	50	0.2	171689
88962	37028	17426	0.0005	50	0.2	168630
		17265	0.0005	50	0.2	165371

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	340	0.8	68080	0.003	204
0.007	1906	0.8	272320	0.004	1089
0.007	1954	0.8	279214	0.004	1117
0.007	2004	0.8	286282	0.004	1145
0.007	2055	0.8	293529	0.004	1174
0.007	2107	0.8	300960	0.004	1204
0.007	2160	0.8	308579	0.004	1234
0.007	2215	0.8	316391	0.004	1266
0.007	2271	0.8	324400	0.004	1298
0.007	2328	0.8	332612	0.004	1330
0.007	2387	0.8	341033	0.004	1364

0.007	2448	0.8	349666	0.004	1399
0.007	2510	0.8	358518	0.004	1434
0.007	2573	0.8	367594	0.004	1470
0.007	2638	0.8	376899	0.004	1508
0.007	2705	0.8	386440	0.004	1546
0.007	2774	0.8	396223	0.004	1585
0.007	2844	0.8	406254	0.004	1625
0.007	2916	0.8	416538	0.004	1666
0.007	2990	0.8	427083	0.004	1708
0.007	3065	0.8	437894	0.004	1752
0.007	3143	0.8	448980	0.004	1796
0.007	3222	0.8	460346	0.004	1841
0.007	3304	0.8	471999	0.004	1888
0.007	3388	0.8	483948	0.004	1936
0.007	3473	0.8	496199	0.004	1985
0.007	3561	0.8	508761	0.004	2035
0.007	3651	0.8	521640	0.004	2087
0.007	3744	0.8	534845	0.004	2139
0.007	3839	0.8	548385	0.004	2194
0.007	3936	0.8	562268	0.004	2249
0.007	4036	0.8	576501	0.004	2306

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	0.025	0.1	18000	0.085	15300
0.014	0.025	0.08	16000	0.065	13000
0.014	0.025	0.08	16025	0.065	13021
0.014	0.025	0.08	16046	0.065	13037
0.014	0.025	0.08	16060	0.065	13049
0.014	0.025	0.08	16069	0.065	13056
0.014	0.025	0.08	16071	0.065	13058
0.014	0.025	0.08	16068	0.065	13055
0.014	0.025	0.08	16058	0.065	13047
0.014	0.025	0.08	16040	0.065	13033
0.014	0.025	0.08	16016	0.065	13013
0.014	0.025	0.08	15984	0.065	12987

0.014	0.025	0.08	15945	0.065	12955
0.014	0.025	0.08	15897	0.065	12917
0.014	0.025	0.08	15841	0.065	12871
0.014	0.025	0.08	15777	0.065	12819
0.014	0.025	0.08	15703	0.065	12759
0.014	0.025	0.08	15620	0.065	12691
0.014	0.025	0.08	15527	0.065	12615
0.014	0.025	0.08	15423	0.065	12531
0.014	0.025	0.08	15309	0.065	12439
0.014	0.025	0.08	15184	0.065	12337
0.014	0.025	0.08	15048	0.065	12227
0.014	0.025	0.08	14900	0.065	12106
0.014	0.025	0.08	14739	0.065	11976
0.014	0.025	0.08	14566	0.065	11835
0.014	0.025	0.08	14379	0.065	11683
0.014	0.025	0.08	14179	0.065	11521
0.014	0.025	0.08	13965	0.065	11346
0.014	0.025	0.08	13735	0.065	11160
0.014	0.025	0.08	13490	0.065	10961
0.014	0.025	0.08	13230	0.065	10749

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	7.520	15504	85100
0.035	0.5	0.5	9.800	14089	340400
0.035	0.5	0.5	9.938	14138	349017
0.035	0.5	0.5	10.078	14182	357853
0.035	0.5	0.5	10.220	14223	366912
0.035	0.5	0.5	10.364	14260	376200
0.035	0.5	0.5	10.511	14292	385724
0.035	0.5	0.5	10.659	14321	395488
0.035	0.5	0.5	10.809	14344	405500
0.035	0.5	0.5	10.961	14363	415765
0.035	0.5	0.5	11.116	14377	426291
0.035	0.5	0.5	11.273	14386	437082
0.035	0.5	0.5	11.432	14389	448147
0.035	0.5	0.5	11.593	14387	459492
0.035	0.5	0.5	11.756	14379	471124

0.035	0.5	0.5	11.922	14364	483051
0.035	0.5	0.5	12.090	14343	495279
0.035	0.5	0.5	12.260	14316	507817
0.035	0.5	0.5	12.433	14281	520673
0.035	0.5	0.5	12.609	14240	533853
0.035	0.5	0.5	12.786	14190	547368
0.035	0.5	0.5	12.967	14133	561225
0.035	0.5	0.5	13.149	14068	575432
0.035	0.5	0.5	13.335	13994	589999
0.035	0.5	0.5	13.523	13912	604935
0.035	0.5	0.5	13.714	13820	620249
0.035	0.5	0.5	13.907	13718	635951
0.035	0.5	0.5	14.103	13607	652050
0.035	0.5	0.5	14.302	13486	668557
0.035	0.5	0.5	14.503	13353	685481
0.035	0.5	0.5	14.708	13210	702834
0.035	0.5	0.5	14.915	13055	720627

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)
800000	5000	50	1340400	0.2	1000000
813781	5000	50	1363116	0.2	1014098
827827	5000	50	1386248	0.2	1028396
842144	5000	50	1409806	0.2	1042894
856738	5000	50	1433798	0.2	1057598
871616	5000	50	1458232	0.2	1072508
886782	5000	50	1483117	0.2	1087629
902244	5000	50	1508463	0.2	1102963
918008	5000	50	1534278	0.2	1118513
934081	5000	50	1560573	0.2	1134282
950469	5000	50	1587356	0.2	1150274
967179	5000	50	1614638	0.2	1166491
984220	5000	50	1642429	0.2	1182937
1001597	5000	50	1670738	0.2	1199614
1019318	5000	50	1699577	0.2	1216527
1037392	5000	50	1728957	0.2	1233678
1055826	5000	50	1758888	0.2	1251071
1074627	5000	50	1789382	0.2	1268709

1093805	5000	50	1820450	0.2	1286596
1113368	5000	50	1852103	0.2	1304735
1133324	5000	50	1884355	0.2	1323130
1153682	5000	50	1917216	0.2	1341784
1174452	5000	50	1950700	0.2	1360701
1195642	5000	50	1984820	0.2	1379885
1217263	5000	50	2019588	0.2	1399339
1239324	5000	50	2055018	0.2	1419068
1261835	5000	50	2091124	0.2	1439074
1284806	5000	50	2127920	0.2	1459363
1308249	5000	50	2165419	0.2	1479938
1332173	5000	50	2203637	0.2	1500803
1356590	5000	50	2242588	0.2	1521962

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 3.19. 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	0.917	0.775	0.800	1.011	9.000	0.492	0.520
2021	0.895	0.704	0.800	2.611	10.000	0.253	0.249
2022	0.886	0.697	0.802	2.586	9.877	0.250	0.246
2023	0.878	0.690	0.805	2.561	9.752	0.247	0.243
2024	0.868	0.682	0.808	2.536	9.625	0.244	0.240
2025	0.859	0.674	0.810	2.511	9.496	0.241	0.237
2026	0.850	0.666	0.813	2.487	9.366	0.239	0.234
2027	0.840	0.658	0.815	2.463	9.233	0.236	0.231
2028	0.831	0.650	0.818	2.440	9.099	0.233	0.228
2029	0.821	0.642	0.821	2.416	8.963	0.230	0.225
2030	0.811	0.634	0.823	2.393	8.825	0.227	0.221
2031	0.801	0.625	0.826	2.371	8.685	0.224	0.218
2032	0.791	0.617	0.829	2.348	8.543	0.221	0.215
2033	0.781	0.608	0.832	2.326	8.399	0.217	0.212
2034	0.770	0.599	0.835	2.304	8.253	0.214	0.208
2035	0.760	0.590	0.838	2.282	8.105	0.211	0.205
2036	0.749	0.581	0.841	2.261	7.955	0.208	0.202
2037	0.738	0.572	0.844	2.240	7.803	0.205	0.198
2038	0.727	0.563	0.847	2.219	7.649	0.201	0.195
2039	0.716	0.553	0.850	2.198	7.492	0.198	0.191
2040	0.704	0.544	0.853	2.178	7.334	0.195	0.188
2041	0.693	0.534	0.857	2.157	7.173	0.191	0.184
2042	0.681	0.524	0.860	2.138	7.009	0.188	0.181
2043	0.669	0.514	0.863	2.118	6.844	0.184	0.177
2044	0.657	0.504	0.866	2.098	6.676	0.181	0.173
2045	0.645	0.494	0.870	2.079	6.506	0.177	0.170
2046	0.632	0.483	0.873	2.060	6.333	0.174	0.166
2047	0.620	0.473	0.877	2.041	6.158	0.170	0.162
2048	0.607	0.462	0.880	2.023	5.981	0.166	0.158
2049	0.594	0.451	0.884	2.004	5.801	0.163	0.155
2050	0.581	0.440	0.888	1.986	5.618	0.159	0.151
2051	0.567	0.429	0.891	1.968	5.433	0.155	0.147

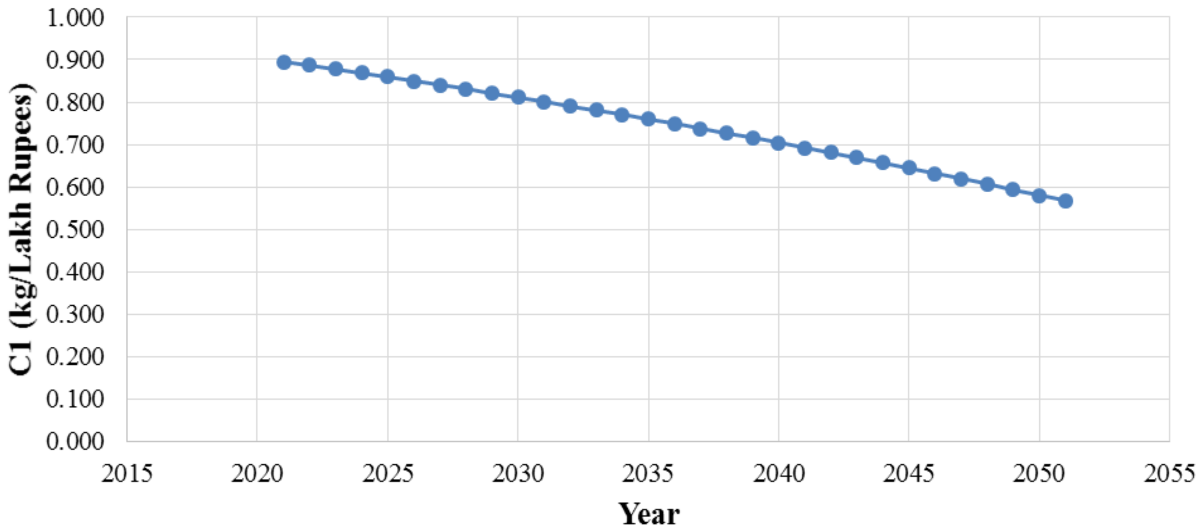


Figure 3.12: Predicted annual variation of indicator C1 for the next 10 years.

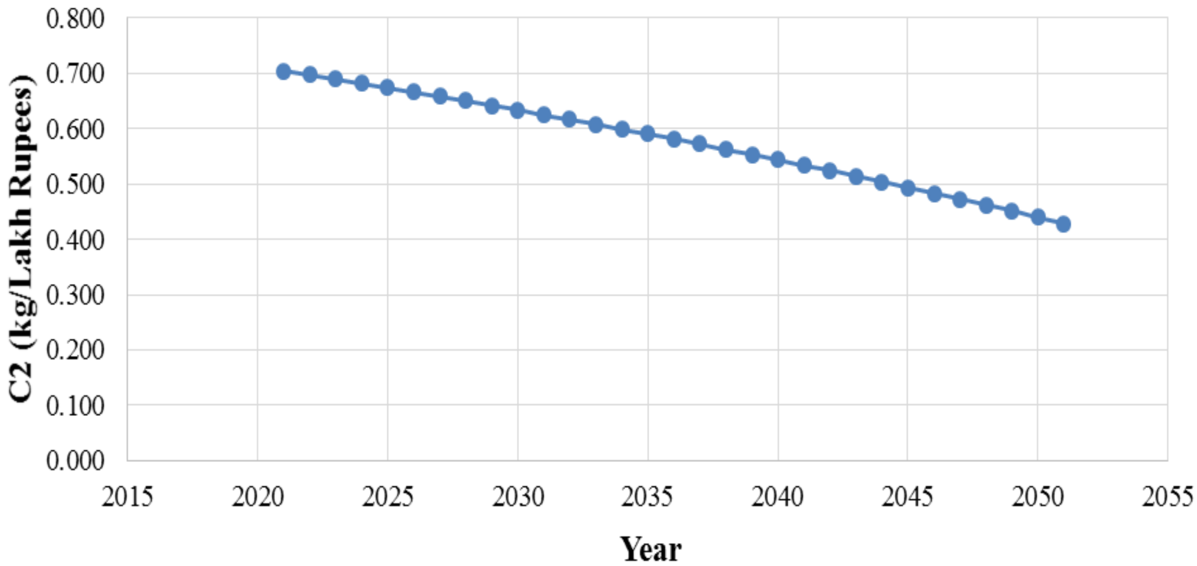


Figure 3.13: Predicted annual variation of indicator C2 for the next 10 years.

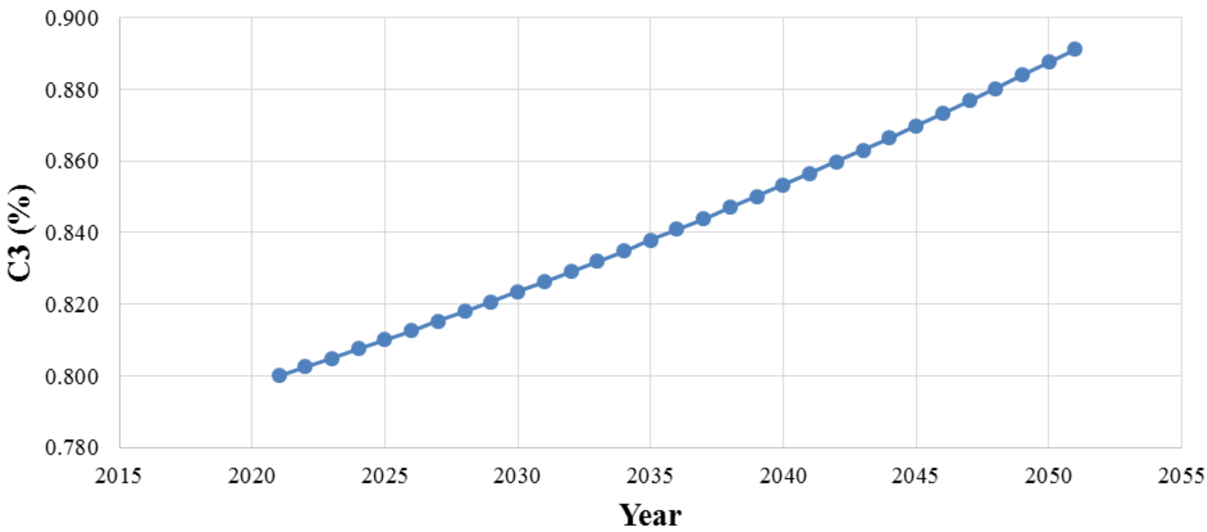


Figure 3.14: Predicted annual variation of indicator C3 for the next 10 years.

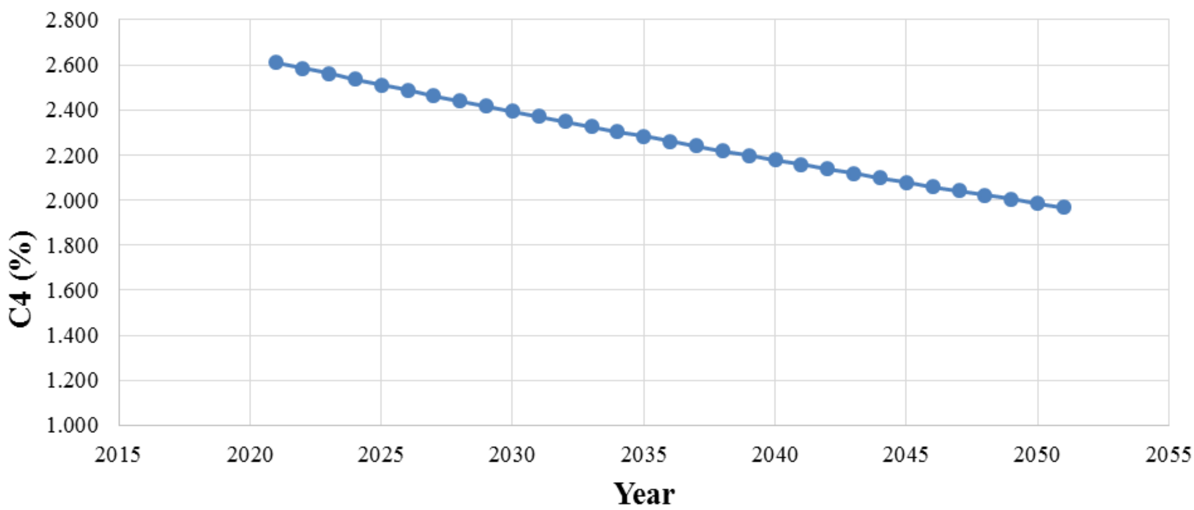


Figure 3.15: Predicted annual variation of indicator C4 for the next 10 years.

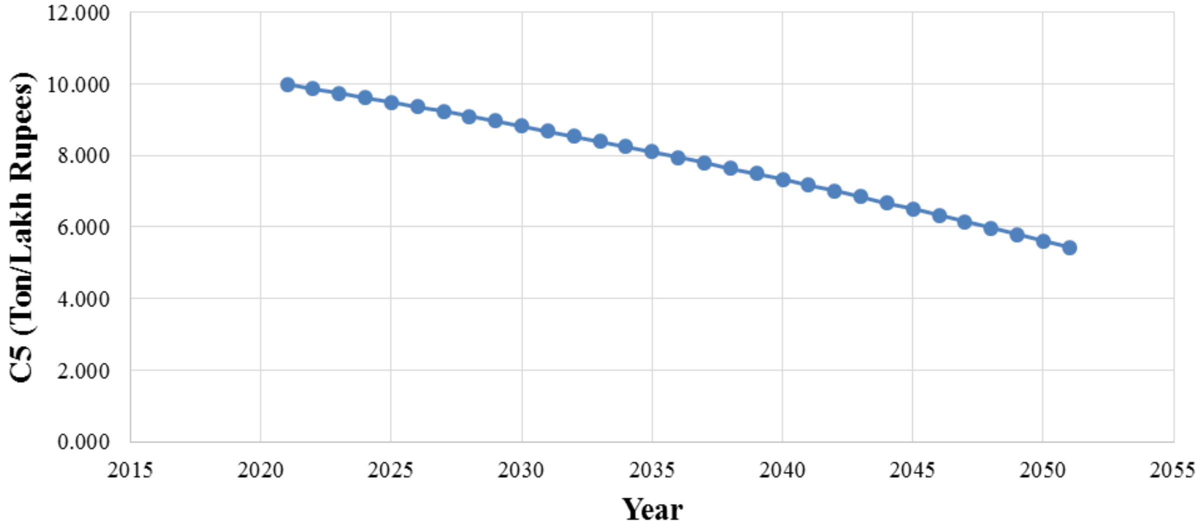


Figure 3.16: Predicted annual variation of indicator C5 for the next 10 years.

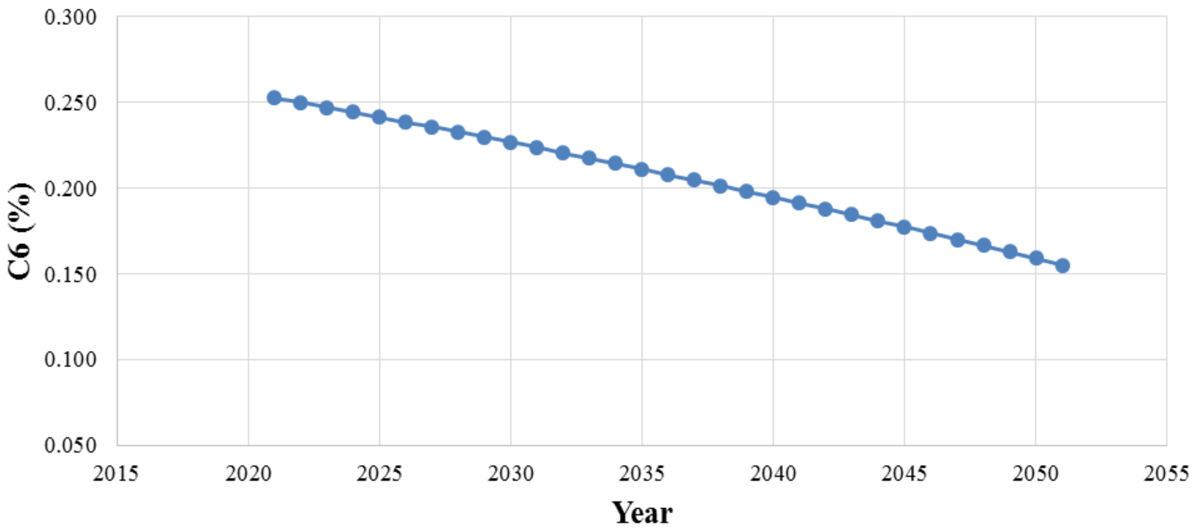


Figure 3.17: Predicted annual variation of indicator C6 for the next 10 years.

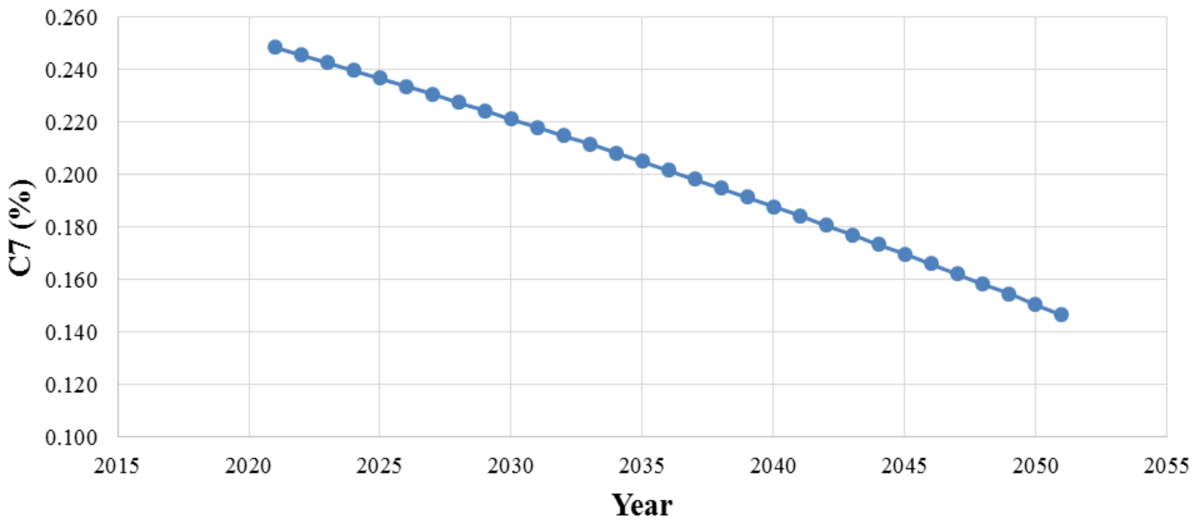


Figure 3.18: Predicted annual variation of indicator C7 for the next 10 years.

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

	C1	C2	C3	C4	C5	C6	C7
Weight	0.036	0.049	0.002	0.011	0.042	0.350	0.510

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

	C1	C2	C3	C4	C5	C6	C7
Entropy	0.996	0.995	1.000	0.999	0.995	0.961	0.944

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

Year	Comprehensive Value
2021	0.523
2021	0.592
2022	0.583
2023	0.574
2024	0.565
2025	0.556
2026	0.547
2027	0.538
2028	0.529
2029	0.519
2030	0.510
2031	0.500
2032	0.490
2033	0.480
2034	0.470
2035	0.460
2036	0.450
2037	0.439
2038	0.429
2039	0.418
2040	0.407
2041	0.396
2042	0.385
2043	0.374
2044	0.362
2045	0.351
2046	0.339
2047	0.327
2048	0.315
2049	0.303
2050	0.290
2051	0.278

Predicted values of the weight and entropy change of each indicator for water carrying capacity at Raipur is shown in Table 3.10 and 3.12. Moreover, the obtained values for the comprehensive environmental water carrying capacity at Raipur for the next 30 year i.e. up to 2051 is presented in Table 4.19 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.

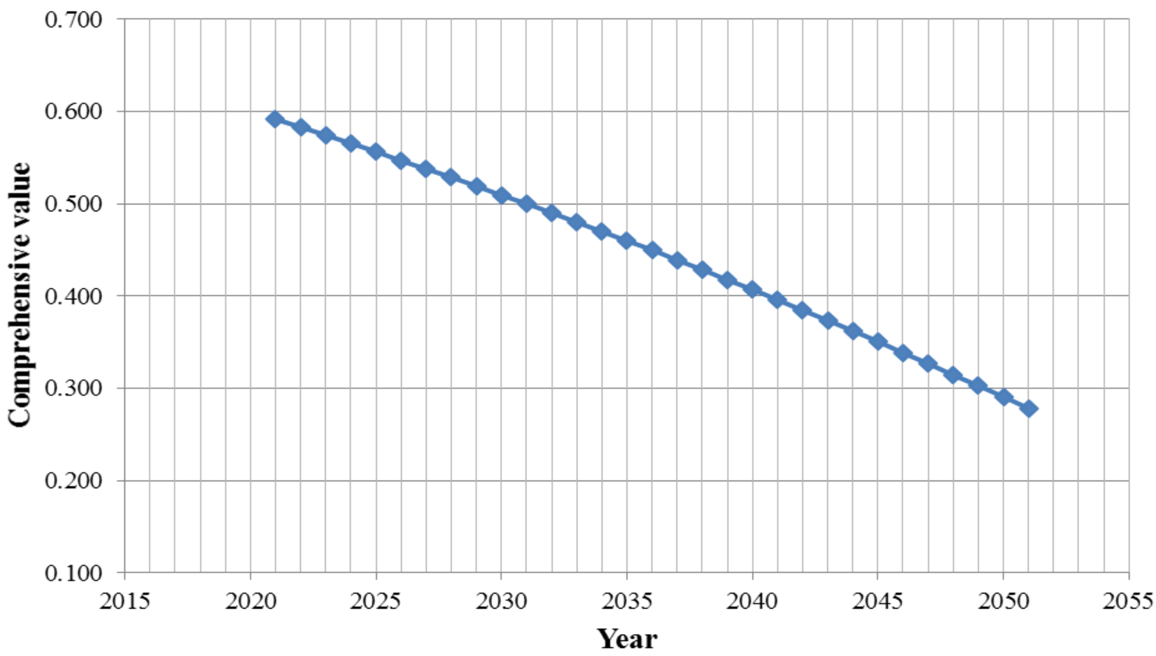


Figure 3.19: Predicted comprehensive environmental water carrying capacity of Raipur for the next 10 years.

From Table 3.12 we can see the comprehensive value is 0.592 in 2021, it falls to 0.480 in 2033. At 2040 it reaches the value of 0.407 after that it crosses the normal comprehensive value and goes to the poor comprehensive value. Overall the value ranges from 0.6 to 0.4, which is in normal level till 2040. But 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 need 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 Raipur. The appropriate action plan should be taken after the review of report as applicable.

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 productions of wastes remain 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?

4.2. Methodology

4.2.1 Land Pollution and Wastes in Raipur

6463 /km^2 is the population density of Raipur city and produces about 600 tones waste every day from different sources as of 2020. Currently, the urban solid wastes coming from houses, small scale industries and market in Raipur are dumped nearby a village in Sarona in the vicinity of Kharun River. Point to note is that this site is overloaded (capacity) and simple landfilling 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 Raipur, 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 bioenergy 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 Raipur 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 Raipur 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. In Raipur, 74.79% land is unsuitable for disposing (as they are (will be) land in use, 20.93% are least suitable (environmental, societal, financial considerations), 3.25% is moderately suitable and 1.03% is most suitable. 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.

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/ landfilling/ 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 used for soil analysis.

4.3 Results and Discussions

4.3.1 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 Raipur is shown in Table 4.1.

Table 4.1: Land use distribution in Raipur

AREA/ YEAR	1976	2011	2021
Residential (%)	34.9	55.3	50.55
Industrial (%)	16.4	11.6	9.07
Commercial (%)	2.2	4.8	8.56
Public/ Semi-public (%)	32.4	12.1	9.41
Recreational (%)	2.2	2.7	10.06
Transportation (%)	11.9	13.5	12.35

4.3.2 LULC Pattern in Raipur

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 Raipur 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 Raipur, 74.79% land is unsuitable for disposing (as they are (will be) land in use, 20.93% are least suitable (environmental, societal, financial considerations), 3.25% is moderately suitable and 1.03% is most suitable. Currently 0.085 sq km of area is being utilized for waste disposal in Sarona Raipur in front of 226 sq km land area. 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 Raipur city.

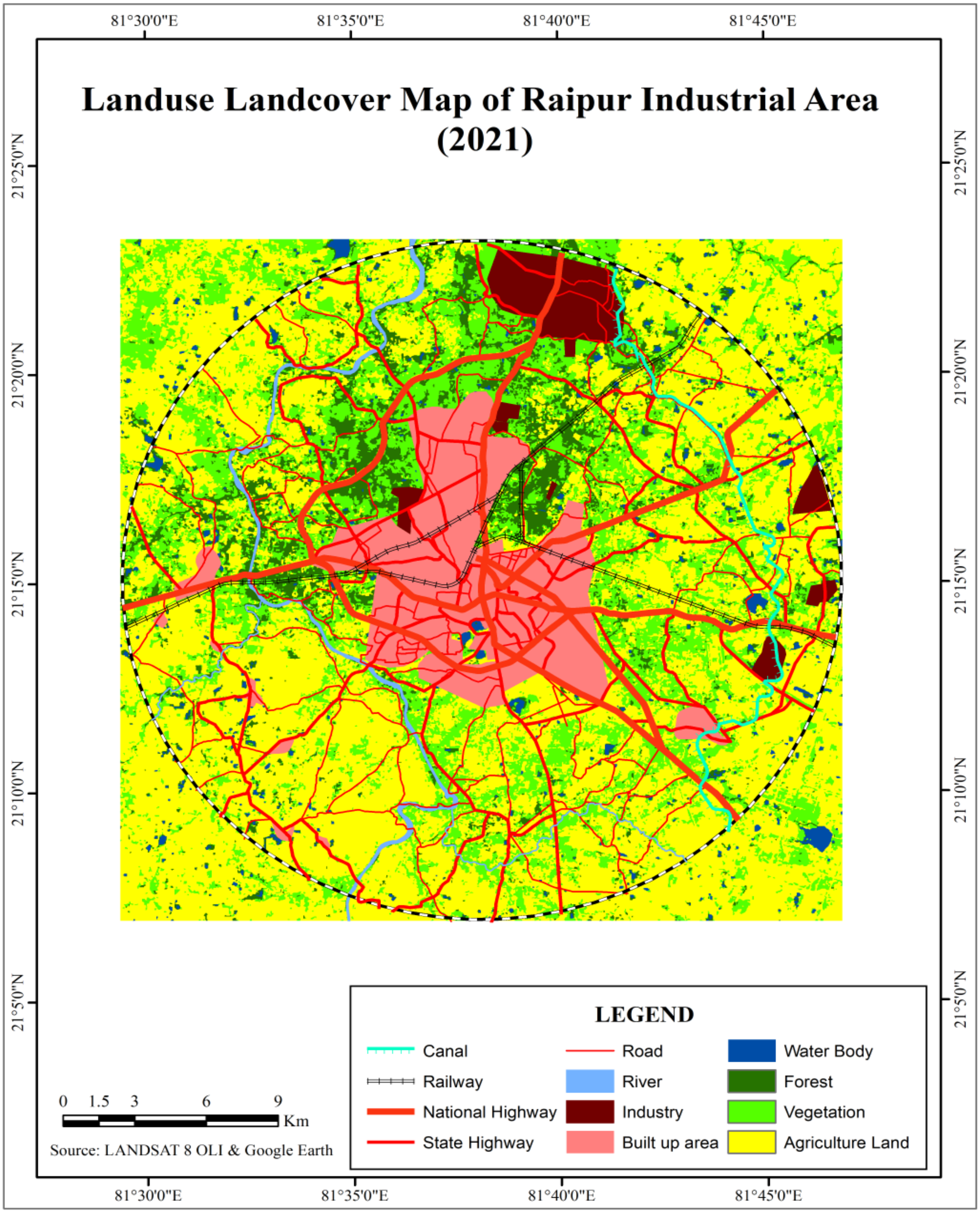


Figure 4.2: LULC map of the Raipur industrial area for the year 2021.

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 4.20, with increasing population and shifting of people from rural areas to urban city like Raipur, land use for residential purpose is rising.
- **Commercial/ Market Area:** Raipur 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 Raipur 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.

4.3.3 Current Waste Disposal/ Management Practice in Raipur

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 Raipur 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 Raipur. 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 land filling 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 Raipur city. 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 Raipur.

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

Sl. 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

4.3.4 Proposed Model being implemented in Raipur for Disposal

Since 11/06/2020 Integrated Solid Waste Processing Facility for disposal by sanitary landfilling has been started in Raipur 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 Raipur. RMC in association with company- Kivar Environ Private Limited of Bangalore and RWMPL for integrated City Sanitation and Municipal solid waste management in Raipur 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 Raipur 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 Raipur 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.

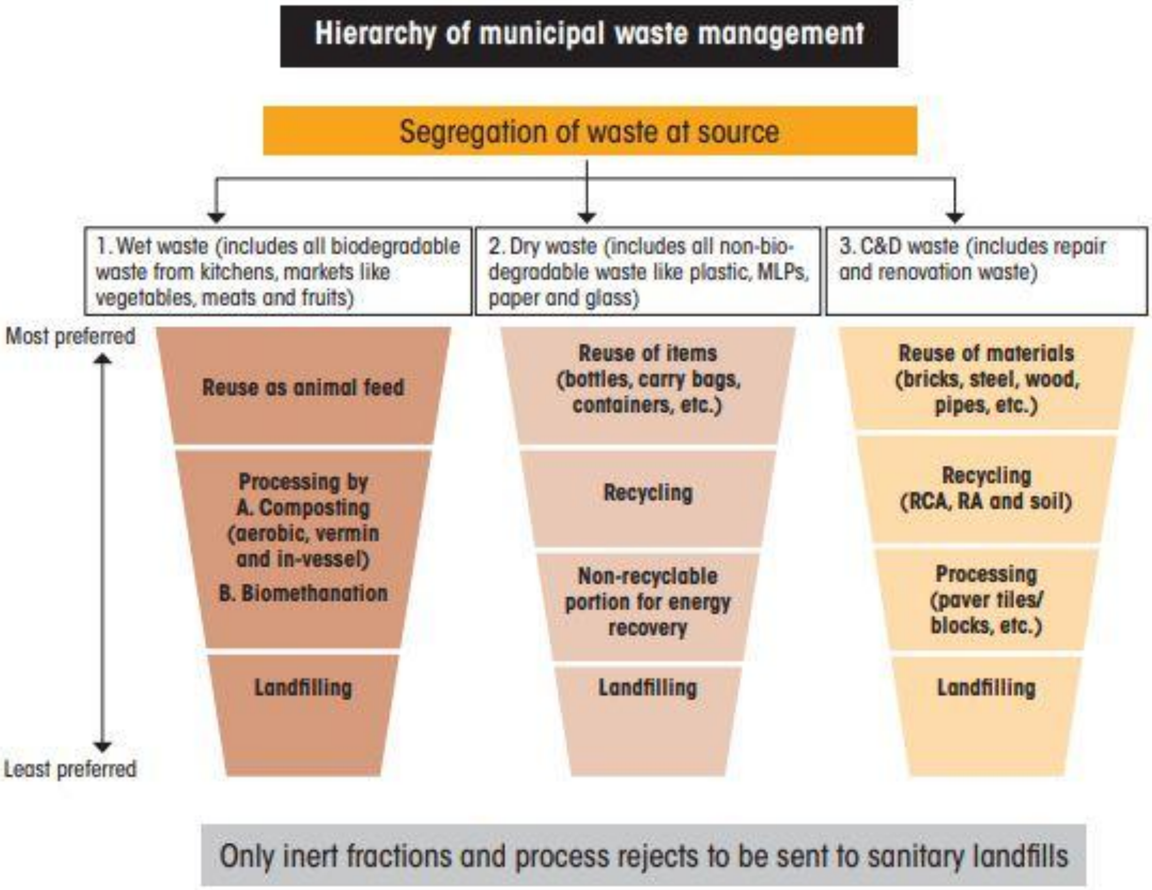


Figure 4.5: The hierarchy of Municipal waste management

4.3.5 Management Plan for Hazardous Wastes

Wastes that are dangerous to humans, environments and pose threat to life because of their toxic nature are classified as hazardous waste. Mostly generated from Industries, hospitals, chemical laboratories, etc. sources. The damage/ harm from such waste can be caused at any stage, may it be storage, transport, treatment or disposal. Thus, efficient and careful actions are necessary. Spent acids, residue, sludge and ash from reactive and hazardous processes and reaction waste, used/ waste oil, toxic metal effluents, etc. along with bio-medical wastes, pesticides, etc. The salient features of hazardous wastes are: 1. Corrosive 2. Reactive 3. Flammable 4. Toxic 5. Radioactive 6. Infectious (at any stage of their life cycle)

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.

4.3.6 E-Wastes Management

Electrical and Electronics wastes (whole/ broken/ in parts) have increased drastically since past two decades because of inventions, improvement and growth of Technology and digitalization. E-Waste Management is necessary because of impacts it may leave on the land, air and water bodies in the form of pollutant when thrown openly in the ambient atmosphere. Majorly acid formation and release, toxic elements spread in the environment, bio- magnification as a result of heavy metals and allied substances present in them. In worst cases they are carcinogenic too (long term exposure) and many more are harmful consequences of E-Waste. Wastes like that of damaged laptops, PCs, Televisions, Refrigerator, Washing Machine, Hard disk, Pen drive, Mobile phones, etc. kind of electrical and electronic species may it be household or commercial are all categorized as e-waste.

Short Term Plan:

1. Collection from dumping sites after segregation and directly from such electronic and electrical waste generating factories, repair shops.
2. Selling to the concerned recyclers or dismantlers- private agencies (in case of unavailability of facility) for carrying out the necessary work of recovery and reuse.
3. Disposing off useless waste along with other waste after crushing via. Landfilling and incineration.

Long Term Plan:

1. Collection
2. Segregation and Separation.
3. Transportation to e-waste recycling/ dismantling/ processing/ storing units set up.
4. Magnetic Separation.
5. Separation into metallic, non-metallic, plastic, wires, hardware, rejects, etc.
6. Mechanical Treatment (size reduction).
7. From this- magnetic material, recyclable materials are taken for further processing.
8. Shredding and breaking of useless waste.
9. Directly landfilled for disposal.
10. Monitoring, inventory maintenance and record check.
11. Awareness to dump e-waste separately.

4.3.7 Municipal Wastes Management

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 Raipur City. Thus, the ties up companies are given the responsibility to do the needful. Nearby village Sakri situated at

about 20 kilometres from Raipur 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. RWMPL will manage the waste collection and transportation within the Raipur 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 Raipur 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.
- Monitoring, record maintenance and data check.
- Awareness to common people.
- Stricter rules and policies to ensure rules are obeyed.

4.3.8 Industrial Wastes Management Plan

Some key points are as follows:

- Prevention, Minimization and Study of wastes focused on source of generation.
- Modification of equipment to enhance recovery and recycle. Moreover, ensuring lesser waste is generating.
- Optimization of reactions, methodology and raw materials used in production process for waste reduction.
- The initial investment and expenditure for pollution control and waste disposal might be high but in long term is a profitable deal and a good investment. Moreover, the operation, maintenance, running and management cost in long term is not that high in front of consequences mankind and environment will face and what solution we will be looking for at later stage.

Short Term Plan:

1. Setting norms for Pre-treatment of the wastes coming out of industry within industry.
2. Collection, segregation, transportation of the wastes to dumping sites.
3. Selling the recyclable wastes and potential wastes to the respective dealers for processing at their end.
4. Finally, incinerating and land filling rest of the wastes and wastes from processing units of dealers for final disposal.

Long Term Plan:

1. Collection & Segregation as discussed earlier.
2. Storage- temporary storage within industrial premises in case of wet/ chemical/ hazardous waste, before final storage at MSW allotted place.
3. Pre-treatment before releasing the dangerous waste from industry for disposal/ treatment/ recycle.

4. Combined Treatment Facilities: Statistics show that the Small-scale industries are the major contributor of wastes. These industries are not capable of treating their solid wastes and effluents because of limited space, monetary send technological constraints. Hence, what can be done is treating the waste generated by these industries in collective way and sharing the resources like recycled products, energy generated, etc. with each other. Combined Effluent Treatment Plants (CETP) is the best example where, sharing of the cost of between individual industries is done.
5. Disposal Methods: Mostly the industrial wastes are categorized as hazardous and non-hazardous industrial wastes and in accordance with the waste category, disposal techniques are finalized. Landfilling, Incineration, Composting is the final step of disposal after recycle, reuse, separation and treatment. Landfilling is the most widely used technique but not suitable for hazardous waste and leachate forming wastes since it causes land and water pollution. Incineration is suitable in such cases because burning takes place in a closed way and aim is volume reduction.
6. Manifest System, i.e., deciding responsibility and distributing role of generator, carrier, employ at different levels from common public, industrialists and workers to government and local bodies undertaking this work.
7. Monitoring and laboratory tests are an indispensable part of the management process.
8. Stricter rules and regulations.
9. Collaborating with industries, dealers and allied units in this field to carry out the solid waste management work smoothly.
10. Inventorization and analysis.

Cost Effective Wastes Management Plans

1. Collaboration between the manufacturing industries, institutes and governmental bodies will reduce load on government and hence would be a cost-effective methodology.
2. Environmental compensation, wherein resource-based compensation is taken instead of monetary fine for harming environment. This can be imposed on individuals, industries and bodies for violating waste/ pollution/ disposal rules. This would sort out two problems: negligence and mishap in solid waste management and an aid coming from compensation.
3. Preparation and Analysis of data, Inventory preparation can be a big asset in bringing down the cost of operation since it will help in preparing strategies.
4. Teaching people about the importance of waste disposal in correct way is the key in long term.

5. Common treatment plants and sharing of resources amongst industries and transferring/ selling useful materials from one industry to other.

4.3.9 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+ Land filling) 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 Raipur 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. Prediction of waste amounts that shall be generated in coming years in Raipur using Forecast function of excel. Data was collected for 2005, 10, 15,17,18,20 waste generated data in tonnes per day from different sources and utilized it to predict future values. The annual waste generated in TPD in Raipur along with the predicted values till 2050 is shown in Figure 4.6. The forecasted waste generation trend along with upper and lower confidence bound for the analysis is shown in Figure 4.7.

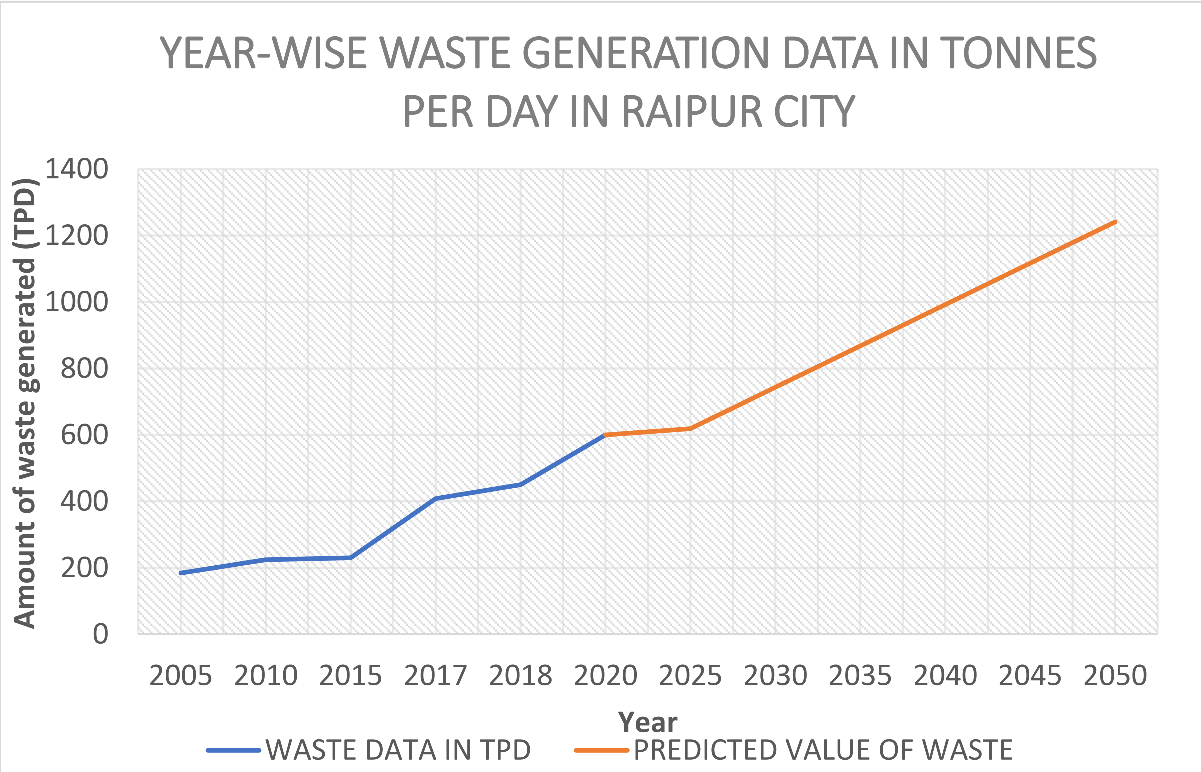


Figure 4.6: Graphical representation of annual waste generated in TPD in Raipur.

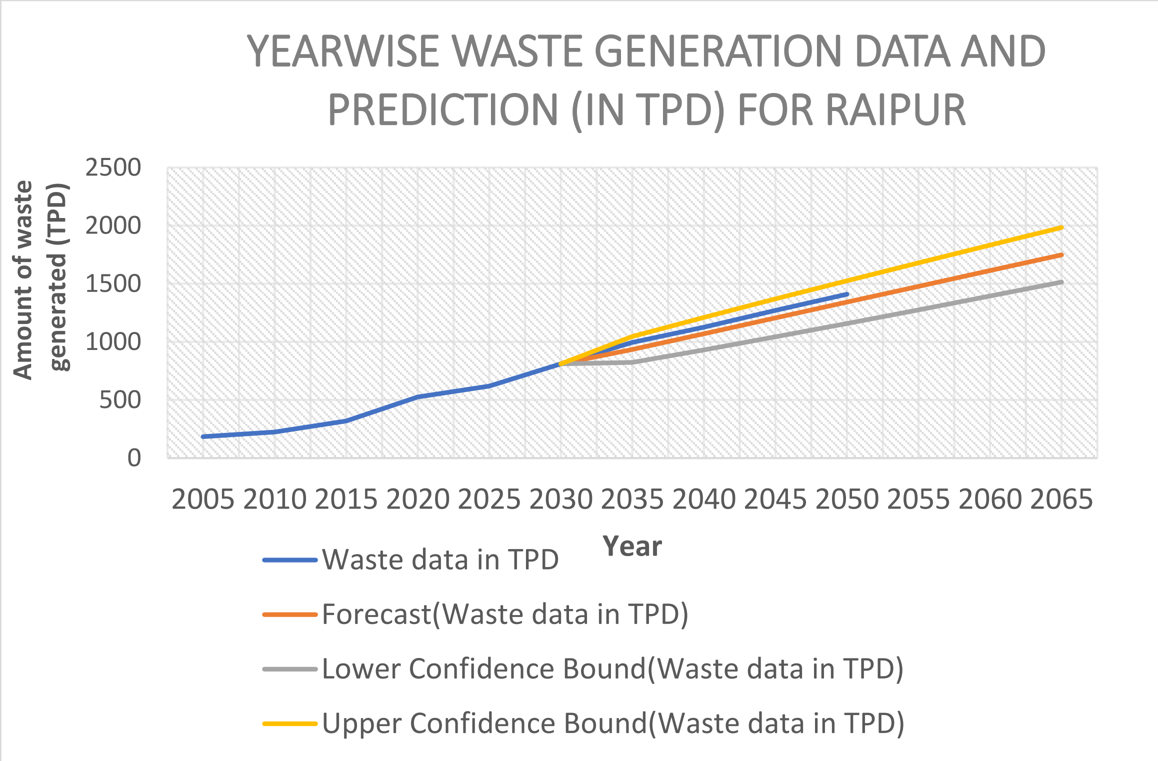


Figure 4.7: Graphical representation of annual forecast for waste generated in Raipur.

4.3.10 Assessing the Existing Pattern and Predicting the Critical Values of Wastes Generation in Accordance with Land Available

Approach 1:

- 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 [48]. Thus, implementing this mathematical approach:
- Conversion: $24000\ ft^2$ means $2229.67\ m^2$.
- 2229.67 m^2 area can store 100 tons of waste therefore, 8500 m^2 will accommodate 381.22 tons of waste approx. Hence, we are generating about 220 tonnes extra waste as of 2020 (601−381) in accordance with the land available in Sarona for waste disposal.

<u>Note</u>: In Delhi 25 meter is the permissible pile height and with time many cities have increased this height to 35 meters and even more to curb the problem of lack of land.

- In 2050 the rate is expected to be 1250 tons per day, so:

$$\frac{220}{381} = 0.577\ or\ 57.7\%$$

- Now, $1250 \times 57.7\% = 721.784 \text{ tons per day}$ 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., 867 to 1083 tons per day of waste in 2050 shall be handled with minimum complications and maximum efficiency.
- Thus, $1250 - 867 = 383$ & $1250 - 1083 = 167$ i.e., 13.36% to 30.64% decrease in the predicted value (1250 TPD) shall be disposed off in 2050 effectively.

Approach 2:

- Since, currently we have <0.1% land in use for waste disposal in Raipur city and looking at the growing population and land use and land cover trend, it can be predicted that waste amount will continue to increase however, there are plants being set up outside the city for treatment. Thus, lowering the load on environment. It is known that about 600 tons of waste is generated every day in Raipur and by 2050, this amount will double (1250 tons per day) in accordance with the trend.
- Hence, if the treatment and processing units continue working properly and a land facility of nearby 0.2% of total usable land (double) is provided in future (not necessarily at one single point/ place) for waste dumping to counter the 2x waste generation rate by 2050, then positive impacts might be observed i.e., much lesser harm to environment and livelihood.
- In Sarona, 8500 sq. meter of land is holding 520000 cu meter of wastes as of 2020 and is known that 1 ton reg points to 2.83 cubic meter accommodation.
- Therefore, $\frac{520000\, m^3\, waste}{8500\, m^2\, land} = 61.176$ m of waste is accommodated in every unit of area as of 2020. We know that 1m^2 means 1000 kg or 1 ton of accommodation, so it can be inferred that 5.2 metric tons of waste is lying in Sarona.
- $\frac{520000}{2.83 \times 8500} = 21.617 \frac{\text{tons reg waste}}{\text{cubic meter}}$ can be stored easily at present i.e., in total 183600 tons reg (21.6×8500)can be stored safely at full capacity.
- Therefore, 183600/600= 306 tons reg/ tons per day should be the generation which is almost half of today's rate.
- So, in future too we need to halve the wastes we are generating on daily basis (1250/2= 625 tons per day). But it is expected that more land area will be provided (0.2%) and improvement in

technological aspects. Thus, we can forecast that approximate range will be somewhat higher (say 1.5%) thus about 937.5 tons per day of waste (1.5% of 625) in 2050.

- $\frac{520000}{2.83\times600} = 310\ (\frac{tons\ reg}{tons\ per\ day})$ Approximately should be the current waste generation value keeping in mind the existing waste lying in sarona.
- Thus, in future waste amount is going to double approximately, but our infrastructure will be improved by than so obviously the waste storing capacity shall increase too.
- Thus, we need to keep the waste generation below 937.5 tons per day in 2050 and as if now it should be lying between 306 to 459 tons per day.

Note: 1.5% relaxation is added based on improvements that would be made.

4.3.11 Analysis of Soil in the Raipur Region

Soil monitoring data are presented in Table 4.3.

Table 4.3: Soil monitoring station in Raipur

Sampling ID	Place	Latitude (°)	Longitude (°)
RAS 001	Dunda Chock	21.186111	81.656944
RAS 002	Kamal Vihari Chock	21.193333	81.651944
RAS 003	Keshibagicha	21.198611	81.613056
RAS 004	Keshimbagicha	21.190278	81.611667
RAS 005	KeshiPura	21.182500	81.615278
RAS 006	Bhatagon 1	21.198056	81.616389
RAS 007	Bhatagon 2	21.189722	81.610278
RAS 008	Bhatagon 3	21.196111	81.610278
RAS 009	Kota colony raod	21.258801	81.607382
RAS 010	Kota colony	21.258801	81.607382
RAS 011	amleshwar	21.210953	81.580736
RAS 012	Dihi (amleshwar)	21.201904	81.578479
RAS 013	tenduya	21.308158	81.564367
RAS 014	Dhuma	21.256243	81.590007
RAS 015	Tendua village	21.286633	81.572332
RAS 016	Tendua 2	21.296401	81.570273
RAS 017	Gomachi village 2	21.304971	81.560720
RAS 018	Gomachi nandanvan	21.302363	81.554673
RAS 019	Gomachi vatapara	21.297941	81.545535
RAS 020	Bana 2 village	21.322020	81.553474
RAS 021	Horticulture	21.329538	81.555021

RAS 022	Kara village	21.332059	81.569950
RAS 023	Bana 2 road side village	21.327905	81.579467
RAS 024	Bora tariya	21.273562	81.573363
RAS 025	Bhandha village	21.276979	81.564362
RAS 026	Hatband	21.276979	81.559085
RAS 027	Motipur	21.168965	81.543450
RAS 028	Jheet village	21.150826	81.556043
RAS 029	Jheet village	21.140397	81.561871
RAS 030	Kumhari village	21.208900	81.378677
RAS 031	Kumhari nursery	21.242064	81.496808
RAS 032	Loha bazar hirapur	21.276872	81.585367
RAS 033	Kodaraka road	21.235780	81.599323
RAS 034	Kodaraka road 1	21.369295	81.585845
RAS 035	Hardi ganv	21.377902	81.586074
RAS 036	Bhimbouri road	21.422993	81.590077
RAS 037	Kusomi road	21.433196	81.589627
RAS 038	Bhata ganv	21.200678	81.611922
RAS 039	Bhata ganv 2	21.193537	81.609474
RAS 040	Bhata ganv 3	21.19328836	81.603590
RAS 041	Amleswar village	21.19823843	81.59066447
RAS 042	Amleshwar 2	21.20339611	81.57662188
RAS 043	Amleshwar 3	21.19658639	81.56956447
RAS 044	Durg village	21.18924569	81.56064314
RAS 045	Patan , sanka village	21.18430457	81.54980591
RAS 046	Patan Raipur road	21.17936685	81.54102300
RAS 047	Kapis nawa para	21.17936685	81.54533887
RAS 048	Jheet village	21.14813406	81.55768708
RAS 049	Patan kumhari road	21.14159656	81.55886559
RAS 050	Patan kumhari road	21.13108886	81.56473526
RAS 051	Mahuda village	21.1584433	81.56910502
RAS 052	Mahuda village	21.1735354	81.6112139
RAS 053	Mahuda village	21.16730654	81.5820879
RAS 054	Patan village	21.17313685	81.58868324
RAS 055	Ghughwa village	21.17927147	81.59550024
RAS 056	Khudmuda village	21.1847910	81.60358183
RAS 057	Boria kala	21.18356871	81.70885962
RAS 058	Abhanpur	21.17168291	81.72152669
RAS 059	Mana village	21.16690494	81.72216365
RAS 060	Mana village	21.15935047	81.72736594
RAS 061	Mana village	21.15787642	81.73323981
RAS 062	Parsatti 2	21.15954997	81.73577406
RAS 063	Mana village	21.16916994	81.73439807

RAS 064	Mana village	21.17272517	81.74002747
RAS 065	Sagar home Mana	21.17819553	81.74602469
RAS 066	Barasa 1	21.18012778	81.75479426
RAS 067	Devpuri	21.20700939	81.6957344
RAS 068	Changura bhata	21.21579032	81.59498648
RAS 069	Raipur 4J	21.21094433	81.60249055
RAS 070	Indraprastha colony	21.20275259	81.60716539
RAS 071	Raipur VH8	21.20633457	81.61182558
RAS 072	Raipur 3M9	21.18670803	81.61180013
RAS 073	Raipur	21.17329640	81.62128868
RAS 074	Mundara village	21.16738013	81.62682291
RAS 075	Mundara ravi (S. Pharm)	21.16076529	81.6314326
RAS 076	Mundara city road	21.15337651	81.6224339
RAS 078	Raipur 9MS	21.14556361	81.61353791
RAS 079	Rawali village	21.13875140	81.60897418
RAS080	Raweli village	21.12939100	81.618538
RAS081	Raweli village	21.134818	81.623265
RAS082	Mundara village	21.142723	81.62629
RAS083	Raweli village	21.149684	81.635841
RAS084	Datrenga	21.15742	81.637005
RAS085	Dhamdha road	21.252212	81.50959
RAS086	Rampur	21.261334	81.501964
RAS087	Pasan	21.235731	81.600937
RAS088	Rungta collage	21.282477	81.550343
RAS089	Hatband road	21.288829	81.556348
RAS090	Tendua gaon	21.296864	81.563927
RAS091	Tendua road	21.296832	81.563937
RAS092	Gomchee	21.297123	81.550516
RAS093	Nandanbon road	21.291799	81.544044
RAS094	VNR nursery gomchee	21.291799	81.544044
RAS095	Dinesh industries	21.293451	81.576951
RAS096	Tendua gaon	21.292120	81.565155
RAS097	Bana	21.316886	81.557757
RAS099	Semariya-2	21.316413	81.742343
RAS100	Semariya-2 (uatika)	21.307576	81.735175

4.3.12 Presence of Heavy Metals in Soil Samples Collected from Raipur

Soil of Raipur sampling stations are analyzed through XRF and results are represented by pie-diagram in Figure 4.8 and station wise representation of metals composition is shown in Figure 4.9. All macro- and micro- elements have been found in detectable and expectable amount. SiO_2 (Sand or Silica) is an important component for soil composition and texture. Here we also have found higher percentage of Si in its' oxide form (SiO_2) about 24%. Rather than silica, we get 20% iron. Other metals are also present in oxide form and we got 44% oxide. Plants nutrients like; Na, Ca, Mg, P, K are also present side by side as 1%, 2%, 2.18%, 0.2% and 2.76%, respectively. Other metals like; Al, Cu, S are also found in detectable amount. Most importantly, every soil sample is free from toxic metals like Pb, As and Hg. Soils samples have been collected from different sampling stations in Raipur are Laterite type. Soils are found with high percentage of Fe (20%) and metals with their oxide form (42%). Soils are red colored and found in both clay and granular form. P and K are found in low amount. Thus fertility of this soil is medium.

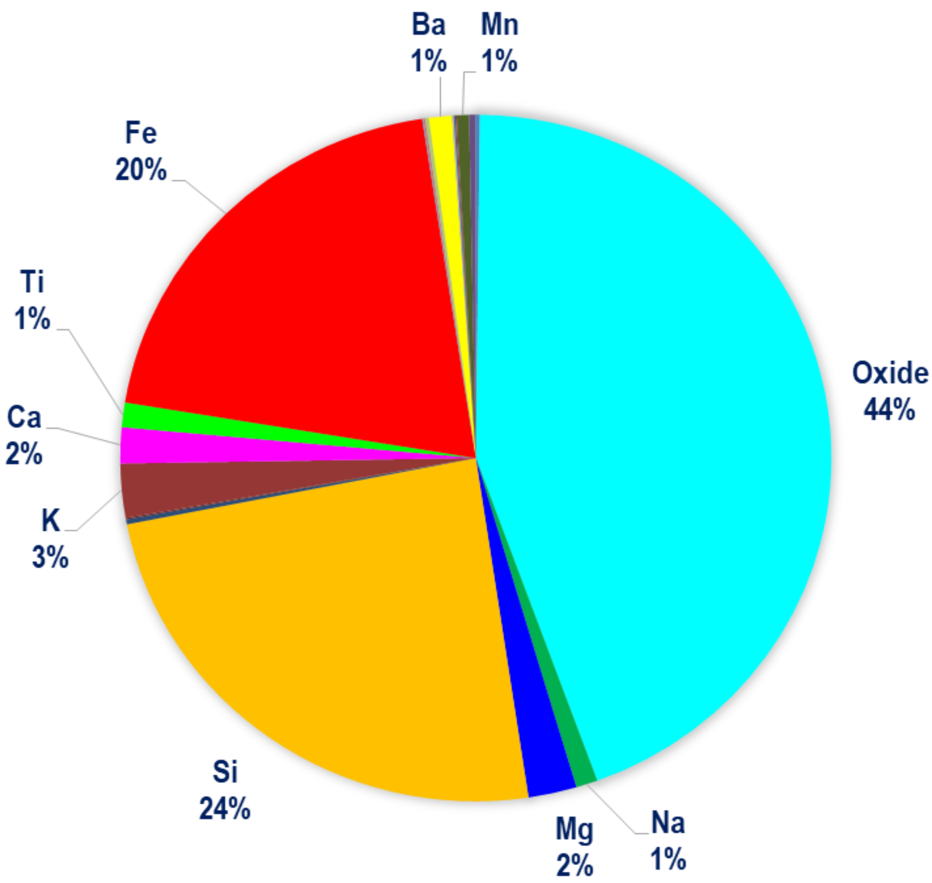


Figure 4.8: Mean metal percentile plot of metals found in Raipur soil.

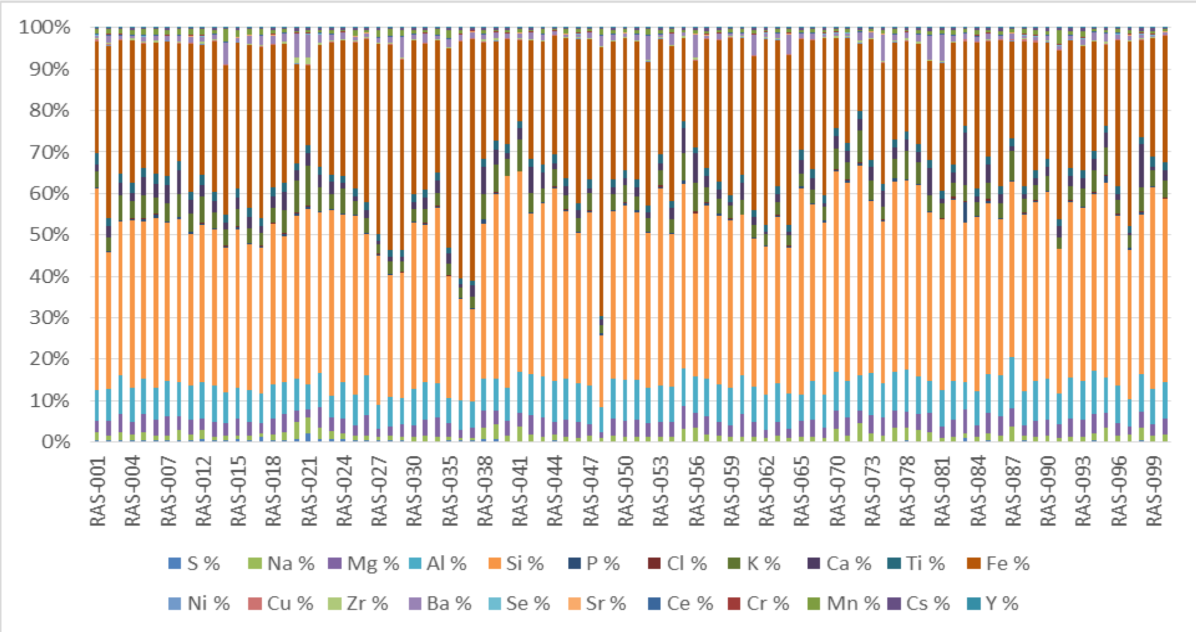


Figure 4.9: Presence of Metals (%) in the soil samples collected from Raipur

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 Bhilai city, we divided it in 7 zone Based on the Road passes through that location. For example: Bhilai chowk, Koradi chowk, Bhiali Gandhi chowk, Surya nagar chowk, Pratap chowk , Toll plaza bhilai , Bhilai Power House Rail Station PF1, Sirsa chowk , these location lies on Patan Raipur road so I take them as zone 1 as Patan Raipur road zone & similar way for other zone. Similarly, other zones were formed taking into account different monitoring stations falling under them. 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:

$$\mathrm{Leq} = \mathrm{L}_{50} + 0.01(\mathrm{L}_{10} - \mathrm{L}_{90})^2 \quad (2.31)$$

$$\mathrm{L}_{10} = 61 + \log(\mathrm{Q}) + 0.15\mathrm{P} - 11.5\log(\mathrm{d}) \quad (2.32)$$

$$L_{50} = 44.8 + 10.8\,log(Q) + 0.12P - 9.6log(d) \quad (2.33)$$

$$\mathrm{L_{90}} = 39.1 + 10.5\log(\mathrm{Q}) + 0.06\mathrm{P} - 9.3\log(\mathrm{d}) \quad (2.34)$$

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:

$$\mathrm{NPL} = \mathrm{L_{50}} + (\mathrm{L_{10}} - \mathrm{L_{90}}) + \frac{(\mathrm{L_{10}} - \mathrm{L_{90}})^2}{60} \quad (2.35)$$

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 $10\log(\mathrm{Q_{eq}})$ 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:

$$y = a \times x + k \qquad (2.39)$$

By applying the variables on the straight line equation, we get:

$$L_{eq} = a \times 10log[Q(1 + 5 \times \frac{P}{100})] \qquad (2.40)$$

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:

$$L_{eq} = 2.28 \log \left[Q \left(1 + 5 \times \frac{P}{100} \right) \right] + 70.62 \qquad (2.41)$$

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 Raipur

Sampling Id	Place	Latitude (°N)	Longitude (°E)	Noise level (dB(A))
RAN 001	Mahadev Ghat Road	21.223056	81.593333	72.0
RAN 002	Khapoon River Bridge Pass	21.216944	81.589167	72.7
RAN 003	Bhagabat Talab Road Pass	21.226944	81.591667	65.2
RAN 004	Raipura Chock	21.231111	81.584722	80.1
RAN 005	Nit Raipur	21.247778	81.603333	57.4
RAN 006	Amanaka Bus Stop	21.251944	81.598889	82.1
RAN 007	Mouhiba Bazar	21.256111	81.59	84.2
RAN 008	Tatibandha Road Pass (Near Bank of Baroda)	21.258056	81.582222	83.3
RAN 009	Nh53, Aiims Campus	21.259167	81.56889	83.1
RAN 010	Geeta Nagar (Ramkund)	21.243889	81.610278	85.2
RAN 011	Samta Colony	21.241667	81.61889	85.7
RAN 012	Samta Colony (Railway Crossing Pass)	21.24	81.624722	88.0
RAN 013	Samta Colony (Railpur-1)	21.246111	81.626111	76.1
RAN 014	Samta Colony Ramkund (Raipura)	21.24667	81.614444	86.7
RAN 015	Santoshi Chock	21.216944	81.641667	90.1
RAN 016	Pachperi Naka	21.220278	81.649167	90.2
RAN 017	Tosal Pass Chock	21.227222	81.611667	90.6
RAN 018	Panta Chock	21.216389	81.62556	81.2
RAN 019	Bajaj Colony	21.226667	81.6575	85.7
RAN 020	Jivan Bihar Teli Bandha	21.2383333	81.671944	87.8
RAN 021	Vip Chock	21.239167	81.679444	70.5
RAN 022	Agrasen Lavani Chock	21.2369444	81.683611	73.4
RAN 023	Kuburbhata	21.234722	81.584444	67.3
RAN 024	Amapara Chock	21.239722	81.625833	60.8
RAN 025	Azad Chock	21.239444	81.627222	67.1
RAN 026	Tatyapara Chock	21.240556	81.63	67.8
RAN 027	Sradha Chock	21.243333	81.633889	69.1
RAN 028	Jay Seme Chock	21.243611	81.635556	85.6
RAN 029	Ghari Chock	21.24556	81.641667	72.3

RAN 030	Collector Chock	21.244722	81.643611	71.3
RAN 031	Sarpke Chock	21.242222	81.655278	67.8
RAN 032	Ayanagarmsrinne Drive	21.241389	81.658056	67.8
RAN 033	Telibandha Chock	21.239444	81.662222	69.3
RAN 034	Dunda Chock	21.186111	81.657222	70.1
RAN 035	Kamal Vihar Gate No.3	21.193611	81.662778	63.7
RAN 036	Boriakhunadarai	21.199722	81.646111	62.4
RAN 037	Sanjaya Lal Chock	21.222778	81.640556	74.5
RAN 038	Siddharth Chock	21.22556	81.640278	71.4
RAN 039	Police Line Chock	21.23	81.639722	70.4
RAN 040	Kalibadi Chock	21.234167	81.63864	78.2
RAN 041	City Kotoali	21.237778	81.636944	79.8
RAN 042	Bijli Office Chock	21.23556	81.6375	74.6
RAN 043	Keshori Bagicha	23.19	81.611111	65.1
RAN 044	Hira Pura Ganapat Chock	21.268596	81.384457	68.7
RAN 045	Ashoke Nagar Chock	21.279734	81.605779	69.7
RAN 046	Dhaba Petrol Chock	21.28224	81.610404	76.2
RAN 047	Basti Chock	21.285879	81.617581	72.5
RAN 048	Mandi Gate	21.258587	81.654328	80.5
RAN 049	Ram Mandir	21.263611	81.653533	75.7
RAN 050	Khamira Nigam	21.261857	81.642652	95.5
RAN 051	Mandi Road	21.26155	81.637471	92.7
RAN 052	Khamtrai Bazar Chowk	21.278220	81.633517	99.3
RAN 053	Bhanpuri Chowk	21.295286	81.635917	75.7
RAN054	Mouha Chowk Bazer	21.257534	81.592079	72.1
RAN055	Jagannath Chowk	21.258509	81.60329	68.3
RAN056	Gudhiyari Bharata Mata Chowk	21.260902	81.61988	75.6
RAN057	Chota Ashok Nagar	21.263666	81.61717	78.7
RAN058	Big Ashok Nagar RDA Colony Chowk	21.267765	81.615585	69.5
RAN059	Bhanpuni Chowk	21.278734	81.620025	67.7
RAN060	Nahar Road (Chandi Chowk)	21.285828	81.617725	80.5
RAN061	Bhanpuni	21.284116	81.635745	74.2
RAN062	New Market Mandi Road	21.262042	81.643017	66.5
RAN063	Devendra Nagar	21.263491	81.653647	71.3
RAN064	Baloda Bazer Chowk	21.255154	81.651386	78.9
RAN065	Pandri Bus Stand Chowk	21.250239	81.646174	76.3
RAN066	Devendra Nagar(Pandri Road)	21.248501	81.643904	74.2
RAN067	Telibandha	21.239097	81.669018	79.2

RAN068	Telibandha	21.239491	81.663209	80.1
RAN069	Amildhi Main Road	21.224436	81.664407	87.8
RAN070	New Rajendra Nagar	21.214647	81.660108	79.3
RAN071	Baba Golaram Nagar	21.207609	81.672162	75.5
RAN072	Devpuri Road	21.204816	81.676749	67.7
RAN073	Subham Ke Mart	21.20194	81.6834	71.1
RAN074	Dumardara	21.19485	81.694619	76.9
RAN075	Mana Moda	21.194897	81.694736	77.7
RAN076	Boria Kal	21.184367	81.70771	85.7
RAN077	Mana Camp	21.194796	81.703355	73.3
RAN078	Atal Pat	21.214585	81.690194	75.5
RAN079	Govinda Nagar	21.25045	81.052338	73.3
RAN080	Jagriti Nagar	21.259257	81.636871	73.1
RAN081	Jay Road	21.256537	81.636598	77.8
RAN082	Devendar Nagar	21.254538	81.639719	76.7
RAN083	Devendar Nagar	21.257105	81.342075	87.7
RAN084	Pandri	21.253192	81.648798	74.4
RAN085	Railway Crossing	21.24369	81.714177	66.7
RAN086	Parda Chowk	21.265654	81.737505	77.6
RAN087	Bidhan Sabha Flyover	21.288785	81.716173	77.1
RAN088	Swaran Magal Chowk	21.292409	81.70683	75.7
RAN089	Giravd Chowk	21.314902	81.688681	82.3
RAN090	Giravd Road	21.32458	81.676638	81.2
RAN091	Tendua	21.290673	81.571107	67.5
RAN092	Loha Bazer (Hirapur)	21.274191	81.581209	77.4
RAN093	Road Colony Hirapur Chowk	21.208629	81.584538	75.3
RAN094	Kabir Nagar	21.272546	81.590793	73.1
RAN095	Kabir Nagar(Sbi Bank)	21.269528	81.592829	68.3
RAN096	Shankara Nagar	21.257754	81.660441	71.2
RAN097	Logipara Chowk	21.26059333	81.6573134	73.4
RAN098	Mukta Prayag (Pandri)	21.25484433	81.6512004	79.3
RAN099	Kutchery Chowk	21.24708235	81.6418580	80.4

Sound or noise monitoring done at several locations in Raipur is shown in Figure 5.2. The highest level of sound was found in RAN050, RAN051 and RAN052, which are above 90 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.

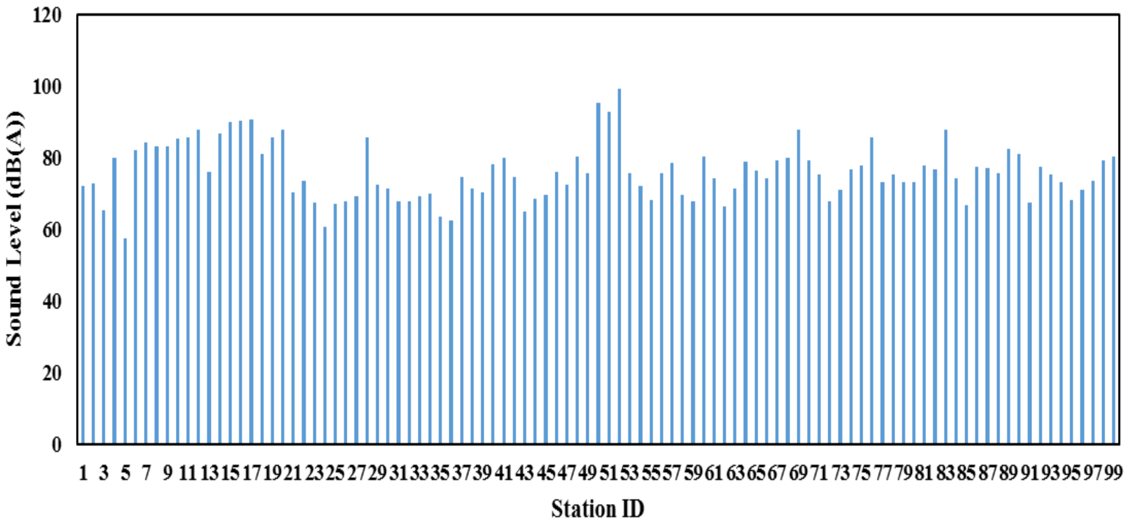


Figure 5.2: Sound level recorded at different monitoring stations at Raipur.

Moreover, to find the Equivalent noise level (L_{eq}) by using "Griffiths and Langdon Method" at various location in Raipur city. The data collected from various monitoring stations RAN001 to RAN099 is combined to form 10 zones based on the road passes through that location. For example Mahadev Ghat Road (RAN001), Khapoon River Bridge Pass (RAN002), Bhagabat Talab Road Pass (RAN003), and Raipura Chock (RAN004), these location lies on Patan Raipur road so taken them as zone 1. Similarly, other zones 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 5.3. 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 Raipur 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	Patan Raipur Road	2928	4.98	76.19	78.74
2	Great eastern Road	4184	4.87	77.70	79.09
3	Atal Path Road	2428	4.61	75.33	78.54
4	Road no 30 B (Panderi to Samariya Road)	3646	4.22	77.00	78.93
5	Ring road no 3 (mandir Hasaud to Dhaneli Road)	1126	25.39	75.53	78.38
6	NH-30 Road (Tati bandh to Bilaspur)	1394	29.41	77.11	78.68
7	Road no 30 (Raipur Bilaspur Express)	4360	14.72	79.47	79.46
8	Kolkata to Mumbai highway Road	3464	25.23	80.22	79.49
9	Ring road 2 (Tati bandh to Bhanpuri Road)	2516	26.86	79.15	79.21
10	NH-30(Sitara to Dhasriya Road)	728	6.59	70.54	77.42

The scatter plot for model validation is shown in Figure 5.4 has coefficient of determination (R^2) of the 45^0 line is 0.9617. 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 5.3, the highest Noise pollution level (NPL > 90) is observed at Zone 2, 3, 4, and 9. This consists of Great eastern Road, Atal Path Road, Panderi to Samariya Road and Tati bandh to Bhanpuri Road. Moreover, from Figure 5.4, 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.

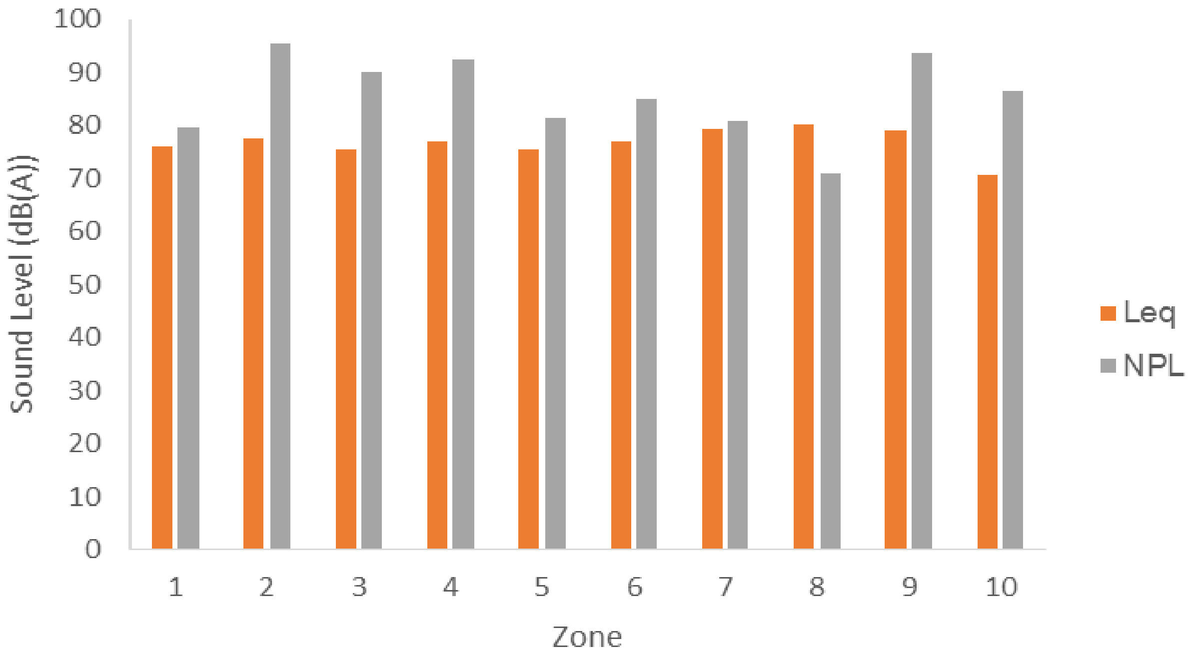


Figure 5.3: Comparison of observed L_{eq} with Noise Pollution level (NPL) of different zone in Raipur.

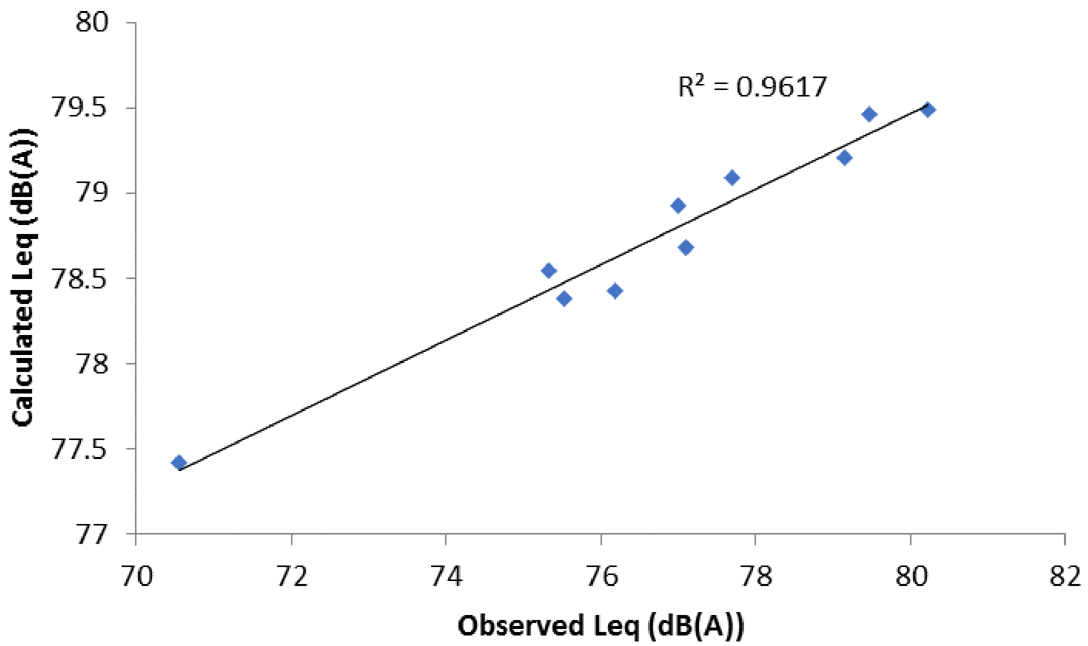


Figure 5.4: Comparison of observed L_{eq} with calculated L_{eq} sound level in the Raipur region.

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 Raipur

The floral biodiversity is complex comprising of different species including Aonla, , Neem , Imli , Harra , Bel , Baheda , Baibidang , Baichandi, Adusa, Kalihari, Safed Mulsi, Kali musli , Aloe vara , Lemon grass , Bixa orellana, Ashwagandha, Isabghol , Sarpa gandha , Malkangni , Kali haldi , Nirmali , Kuchla , Tikhur , Keokand , Kiwanch , Sarphokha Bhuai amla , Giloy , Nagar motha , Kalmegh , Satabar , Bidarikand , Ananth Mul , Brahmi , Bach , Jangli haldi , Jangli piaj , Rasna , Chitrak, Shankpuspi , Ratti, Tejraj , Bhojraj , Gokhaur , Bavachi, Bhragnraj , Salparni and senna . In Chhattisgarh 1,685 specimens of different plant species have been collected. Till now 1685 species belonging to 785 genera and 147 families have been identified and preserved in the herbarium. Ten dominant families of Chhattisgarh are *Fabaceae, Poaceae, Cyperaceae, Asteraceae, Euphorbiaceae, Acanthanaceae, Convulvulaceae, Malvaceae, Rubiacaeae,* and *Scorphulariaceae.*

The Major Medicinal plants (MPS) of Chhattisgarh region comprises about 911 genera and 196 families. These plants are belonging to 14 taxa at species level. It contains total 1525 species of vegetation including 1) Climbers - 161 sp. 2) Hebs - 808 sp. 3) Shrubs - 262 sp. 4) Trees - 294 sp. (Table 4.26). In the Chhattisgarh state utilization of Traditional knowledge (TK) of Medicinal Plants (MPS) have been practiced by the Tribal Group (TGS) inhabitating in the remote places of forest and Hills. The traditional knowledge (TK) related with the medicinal properties of the plants which occurs in the nearby vicinity of the localized natural Forests are customary and Folklore are inherent to their culture. It conserves the Biosphere traditionally & culture transmitted to the next generation which help in protection/conservation of the original/Natural form of Bio-resource. Different categories of plant found in Raipur are shown in Table 6.1.

Table 6.1: Different category of plant found in Raipur

Sl. No.	Category	Plant species variety
1.	Climbers	*Aristolochia indica, Cenopegia bulbosa, Hemidesmus indicus, Mucuna pruriens, Piper longum, Tinospora cordifolia*
2.	Herbs	*Andographis paniculata, Eulophia herbacea, Ranvolfia Serpentina, Peucedamum nagpurense.*
3.	Shrubs	*Acacia Sinuata, caesalpinia digyna, Embelia tsjerium - cottam, Gardenia gummifera, premna tomentosa*
4.	Trees	*Azardirachta indica, Madhuca longifolia, Terminalia arjuna, Boswellia serrata, pterocarpus- Marsupium, Emblica ofiicinalis, Anogeissus latifolia, Buchununia lanzan, Litsea glutinosa, Terminalia Chebula, Schleichera oleosa etc.*


Delonix regia Bojer

Figure 6.1: Different flora growing in the Raipur.


Cassia fistula l


Spathodea campanulata


Bauhinia veriegata L.

Figure 6.2: *Alianthus excelsa* and *Sesbania sesban* tree growing in the Raipur

Table 6.2: Different medicinal plant found in Raipur

Sl. No.	Name of MPS	Scientific Name of Sp. Botanical Scientific Nomenclature	Usefulness For human body Healing
1.	Brahmi	*Centella asiatica*	Brain tonic
2.	Keoti bela	*Ventiligo denticulata*	Hair tonic
3.	Nagermotha	*Cyperus rotundus*	Hypertension
4.	Lahsun	*Allium sotivum*	Headache
5.	Bhringraj	*Eclipa alba*	Hair tonic
6.	Sudarshan	*Criman asiaticum*	Ear disorders
7.	Amla	*Phyanthus emblica*	Eye tonic
8.	Sarso	*Brassica cumpestris*	cold
9.	Bhattcataiya	*Solonum xanthocopum*	Earache
10.	Mahua	*Madhuka latifalia*	Toothache
11.	Adusa	*Adhatoda zeylancia*	Cough
12.	Harra	*Termanalia chechula*	Dyspnoea
13.	Mahua	*Madhuka latifoia*	Skin disorder
14.	Tabbaco	*Nicotiana tabacum*	Body pains
15.	Arandi	*Ricinus communis*	Galactogogue
16.	Giloye	*Tinospora cordifolio*	Heart tonic
17.	Baheda	*Terminalia belevica*	Digestion
18.	Keukand	*Costus speosus*	Stomach
19.	Haldi	*Curcuma longa*	Respiratory disorder
20.	Adrack	*Zingiber officinate*	Hyperacidity
21.	Saphed Musli	*Chlorophytum boribillonum*	Debility tonic
22.	Banchaneli	*Dioscored pentaphylla*	Health tonic
23.	Ghritkumari	*Alove barbadensis*	Body skin healing

Figure 6.3: *Khair* (*Acacia catechu*) tree growing in the Raipur.

Figure 6.4: *Alianthus excelsa* and *Sesbania sesban* tree growing in the Raipur.

Figure 6.5: Different flora growing in the Raipur

The wild fauna consists of Tiger, Panther, Sambhar, Blue bull (Nilgai), Chinkara, Chital, wagtails, Munias, Blue king fisher, Jangli murgi, Red Spur fall, Phakta, Ducks, Baj, Harial, Neelkanth Kabootar, Koel, Bhura Teetar, Kala Teetar, Tree pie, Drongo, Shikara, Giddha, Bagula, Dubchick, Wild pig, Hanuman, Langoor, Rhesus monkey, Porcupine, Hare, Wild dogs, Jungle cat, Jackals, Hyena, Fox, Kobra, Python, Monitor lizards, Peacock, Barlets, Bulbulis, Minivets oriolets, Wild cat, Cheetal. Barking deer, Jackal, Sloth bear, Flying squirrel, Crocodile, Otter and Civet. Insects are the largest one and most diverse successful and dominant taxon group on the earth. Because of their diversity they play an important role in ecology and influence on agriculture, human health and natural resources. Insects are the hexapod invertebrates from class insecta, phylum *Arthropoda* and kingdom - *Animalia*. Insect biodiversity is the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems. They possess an amazing diversity in size and the ability to fly permits them to run away from the enemies and scatter to new environment as they got a protective shell or exoskeleton. There are different kinds of insects according to their habits and habitats are as follows:

- Beetles (Coleopterans) - front wings changed into a hard shell to protect back wings.
- Butterflies and moths (Lepidopteron) large often colorful wings.
- Flies (Dipterans) - have only two wings.
- Ants, bees and wasps (Hymenoptera) - mostly in large colonies, sometimes stringer.
- True Bugs (Hemipteran) have beak, a kind of - mouth like drinking straw.
- Grasshoppers (Orthopteran) - jump with their legs and eat grass.
- Odonatan, dragonflies and damselflies are predator of other insects.

The biodiversity consists of three major parts genetic diversity species diversity and ecosystem diversity. The various insect species have been collected from the study area to identify the insect species and their diversity. Among them various insect species belonging order Lepidoptera, Coleoptera, to Hemiptera, Hymenoptera, Diptera, Dermaptera, Orthoptera, Odonata, Mantodea, and Isoptera are taken. The total identified species are 603 in number from 38 families and 10 orders. In which order Diptera identified with maximum number of species with five families i.e. *Syrphidae, Trypetidae, Muscidae, Culicidae, Asilidae* in which *Trypetidae* is dominant and *Dermaptera* is with minimum number of species with *Labiduridae* family *Hymenoptera* is the second rich diverse order with five families *Vespidae, Xylocopidae, Apidae, Formicidae, Tenthredinidae* in which *Apidae* is dominat. Order *Hemiptera* is also rich in number with six families in which *Reduviidae* is dominant. *Coleoptera* is also rich diverse order with six families with species in which

Coccinellidae is dominant. Orthoptera with 66 species of three families in which *Acrididae* is dominant. Order lepidoptera identified with 55 species of six familiesin which *Arctidae* is dominant. Order Mantodea with 24 species of one family *Mantiidae*, *Isoptera* with 10 species of one family *Termitidae* and *Odonata* with species of three families i.e., *Coenagnonidae, Gomphidae* and *Aeshnidae*.

Table 6.3: Occurrence of different insect diversity with their host in Raipur

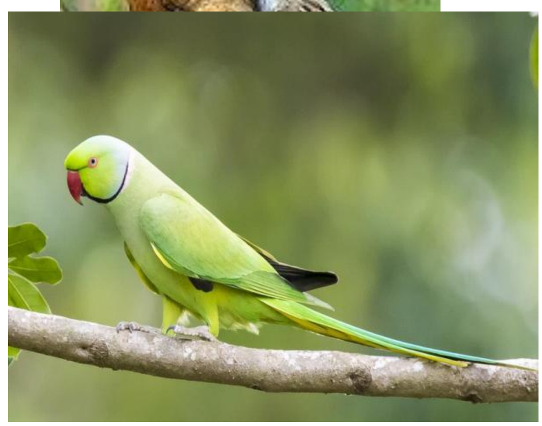
Sl.No.	Order	Family	Scientific name	Common name	Hosts
1	*Lepidoptera*	*Papilionidae*	*Papiliodemoleus*	*Swallowtail butterfly*	Sweat orange and other plant
2	*Lepidoptera*	*Dainidae*	*Danauschrysippus*	*Tigers/ milkweeds/ monarchs*	Drier, wide open areas.
3	*Lepidoptea*	*Sphingidae*	*Acherontiastyx*	*Sphingidmoth /death's headhawkmoth.*	Food plants
4	*Lepidoptea*	*Satumidae*	*Anthermeamylia*	*Tasar silk worm Nanya silk worm*	Papaya, tapioca and jetropha
5	*Lepidoptera*	*Arctidae*	*Spilosomaobliqua*	*Jute-hairy caterpillar.*	Plant leaves
6	*Lepidoptea*	*Nocturidae*	*Ergolismerioe*	*Orange butterfly.*	Soil and monocot plants
7	*Coleoptera*	*Scarabaeidae*	*Heliocoprisbucephals*	*Elephant dung beetle.*	Rose, capcicumm, guava, mango
8	*Coleoptera*	*Melolonthainae*	*Mylabrispustula*	*Hycleusbeetles*	Coffee, ginger and cinnamon.
9	*Coleoptera*	*Rutelinae*	*Anomalaruficapilla*	*Shining leaf chafersbeete.*	leaves
10	*Coleoptera*	*Dytiscidae*	*Copelatusindicus*	*Diving beetle*	Rice, Sugarcane
11	*Coleoptera*	*Coccinellide*	*Coccinellaseptuma*	*Seven spoted lay bird/beetle.*	Tecton, grindis ,Rose and brinjal

Barking Deer

Bengal Monitor Lizard (*Varanus bengalensis*)

Common Indian Flying Fox (*Pteropus giganteus*)

Indian Eagle Owl (*Bubo bengalensis*)



Common Green Shank (*Tringa nebularia*)

Rose Ringned Parakeet (*Psittacul krameri*)

Figure 6.6: Different fauna found in the Raipur.

6.1.2 Ecosystem in Raipur

Wetlands are one of the crucial natural resources. Wetlands are areas of land that are either temporarily or permanently covered by water. This means that a wetland is neither truly aquatic nor terrestrial. The wetlands of Raipur are considered as ecological important wetlands. These occupy area of more than 5 hectares and support rich food web from microscopic algae and submerged vascular plant to other organisms such as birds, reptiles and mammals. In these wetlands good population of birds are recorded. These sites will be protected for the birds in future. Ecological wetlands are among the most productive ecosystems in the world theyalso are a source of substantial biodiversity in supporting numerous species.Wetlands provide habitat for assortment of wild life species. These include Birds, mammals, reptiles etc. Healthy wetlands are essential to survive of many these species. In most of the wetlands, West Indian Lantana (*Lantana camara*) and Ipomeacarnea (*Ipomea carnea*) were the most common flowering plant. Cattle Egret (*Bubulcus ibis*) and Little Cormorant (*Phalacrocorax niger*) was the mostabundant species followed by Tufted Duck (*Aythya fuligula*), Gadwall(*Marecastrepera*), Green Sandpiper (*Tringa ochropus*), Red-crested Pochard (*Nettarufina*), Little Grebe (*Tachybaptus ruficollis*), and Asian Open-billed Stork(*Anastomus indicus*) can be seen in all the wetlands. Only one individualendangered species Egypsian Vulture (*Neophron percnopterus*) at KhanduwaDam was recorded. Almost in all the wetlands and surroundings *Ficusbengalnensis, Acacia nilotica* and *Eucylyptus globules* were observed. Wetland birds provide us with some of nature's most wonderful sights, fromenormous flocks wheeling overhead to newly hatched chicks drying in the sun. Apart from their beauty and recreational and economic importance, these birds are excellent indicators of water quality and measures of biodiversity. Khuteri Lake is one of the most prominent wetlands of Raipur City.

Figure 6.7: Egypsian Vulture (*Neophron percnopterus*) and Ipomea carnea (*Ipomea carnea*) found in the wetlands Raipur.

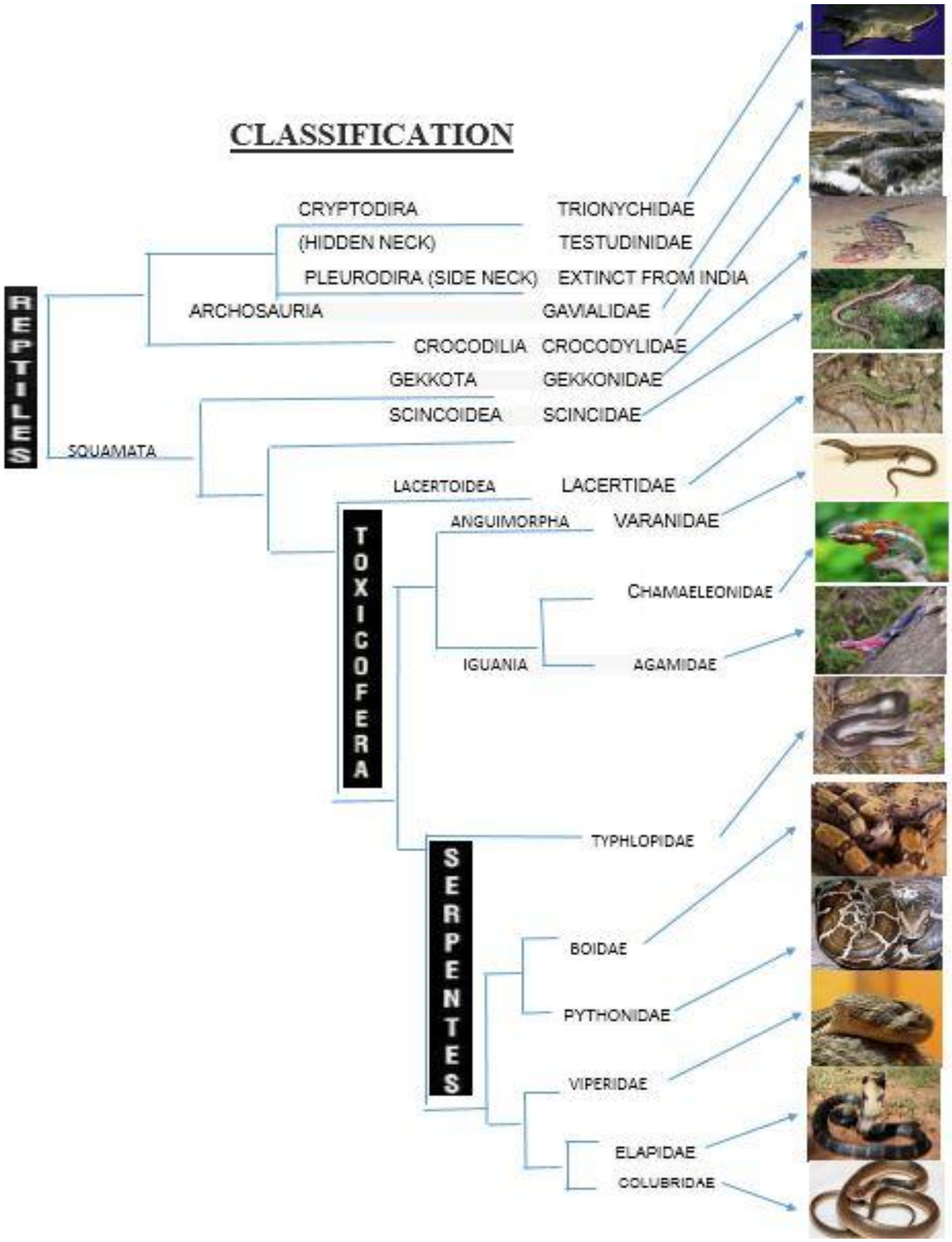


Figure 6.8: Classification of different reptiles found in the wetlands Raipur.

6.1.3 Aquatic Ecosystem of Raipur

An aquatic ecosystem is an ecosystem in a body of water. Communities of organisms that are dependent on each other and on their environment live in aquatic ecosystems. Raipur region is moving from agricultural belt to industrial belt, therefore the demand for water is on increasing mode. Mahanadi, Sheonath, Indravati, Arpa, Hasdeo, Kelo, Son, Rehar, and Kanhar are some of the main rivers of the state. Raipur city situated in the Mahandai basin of which 2903.92 sq. km 93.8 % is in Raipur district. Once Raipur accounted for around 154 small and large water bodies both natural and manmade. The “talabs” were primarily the recharging pit that protected the city from water logging and flooding during heavy rains. However, only 70 talabs have survived to the present and this has resulted in excess storm water logging in the low-lying areas of the city. Also, water quality of lakes is deteriorating due to eutrophication and the dumping of municipal solid waste, these lakes have become the breeding place for mosquito hence the residents are considering the option of land filling in thesetalabs or drying them up.

Names of few prominent water bodies of Raipur city are as follows:

- Narhareshwar Talab
- Maharaj Bandh Talab
- Kankali Talab
- Tikrapara Talab
- Handri Talab
- Kukri Talab
- Kushalpur Talab
- Burha talab
- Budhapara Lake
- Telibandha Talab

Figure 6.9: Budhapara Lake in Raipur.

Figure 6.10: Telibandha Talab in Raipur

6.1.4 Threat to Agriculture Biodiversity

Many species are in various stages of threat which were available in abundance few years back. Increasing demands on the mining sector pose a serious threat to biodiversity. Northern districts of the State have witnessed installation of thermal power plants on pit heads. Resulting in thermal emissions and fly ash: serious threat to biodiversity. It has contributed to loss of forest cover and degradation of surrounding flora and fauna. Opening of new mines & mineral based industries in the recent past has led to destruction of rich habitats. Diversion of forest lands for non-for non-forestry purpose like: Mining leases, industrial estates, roads, minor and major irrigation projects and other development projects (resulting in reduction in the dense and very dense forests and about 192 sq. km and aproportionate increase in open and non-forests from 2004-09. Introduction of high yielding varieties and improved farming practices is a threat to the indigenous domestic biodiversity. Increased use of fertilizers and pesticides has led to decline in agro-biodiversity and increased chemical toxicity of soil & water. Invasive alien weeds like Parthenium, Lantana, Eupatorium poses serious hindrance in germination and growth of indigenous species and local biodiversity.

6.1.5 Threat to the Wetlands

Despite their numerous benefits and importance in socio-cultural life of people, majority of wetlands are getting degraded or lost. Wetlands are directly impacted by large scale widespread hydrological alterations. The sources and pathways of their water supply, both as surface runoff or inflow through channels, are eliminated or blocked or their water supply is greatly altered. This happens most commonly through urban expansion and land use change in their catchments. Human settlements continue to grow even today near wetlands and most often at their expense. The wetlands which come to lie within the urban limits are the most threatened for their existence. Such rapid loss of wetlands has occurred in Kashmir valley, Hyderabad, Bengaluru, Chennai, Delhi, Kolkata, and Guwahati all of which have experienced disastrous floods in recent years. Wetlands are encroached upon taking advantage of the low water levels during fry periods or by draining them and using as landfill sites. Many floodplain wetlands have been eliminated by embankments and in most cases, the flow storage and diversion structures upstream have greatly modified their flooding regimes. In lakes and other water bodies, water levels are regulated by withdrawal of water for different human uses. Wetlands are further degraded by the discharge of untreated domestic and industrial wastewaters into them. It is not readily appreciated that the upstream wastewater discharges affect the wetlands downstream. Wastewaters also facilitate siltation and alter the hydrological regime besides bringing in various pollutants. Numerous wetlands are also infested with the uncontrolled growth of exotic species, particularly water hyaci.th. In recent years, there has been little effort to remove and destroy them because of the misplaced understanding that these plants can remove pollutants and help improve water quality. It is not realized that the weeds to be effective have to be selectively removed leaving young ones to multiply. Death and decay returns the nutrients and pollutants back into water while huge quantities of un-decomposed organic matter accumulate, fill in the water body, eliminate dissolved oxygen and cause mass fish kills. The most significant factor responsible for the present state of wetlands is the absence of a clear national or state policy devoted to wetlands-natural or man-made. Wetlands receive no attention in the development plans - concerned with land use changes or the development of water resources. The economic value of the goods and services of wetlands including their contribution to livelihoods and rural economy are never accounted for in the cost-benefit analyses of various development projects.

6.1.6 Causes of Degradation in Biodiversity

The major causes of the environmental degradation are modern urbanization, industrialization, over-population growth, deforestation etc. Environmental pollution refers to the degradation of quality and quantity of natural resources. Various types of the human exercises are the fundamental reasons of environmental degradation. These have prompted condition changes that have turned out to be hurtful to every single living being. The smoke radiated by the vehicles and processing plants expands the measure of toxic gases noticeable all around. The waste items, smoke radiated by vehicles and ventures are the fundamental driver of contamination. Spontaneous urbanization and industrialization have caused water, air and sound contamination. Urbanization and industrialization help to expand contamination of the wellsprings of water. So also, the smoke discharged by vehicles and ventures like CFC, NO_2, CO and other clean particles dirty air. Neediness still remains an issue at the base of a few ecological issues such as:

- **Population:** The rapid population growth and economic development in country are degrading the environment through the uncontrolled growth of urbanization and industrialization, expansion and intensification of agriculture and the destruction of natural habitats. One of the significant reasons for environmental degradation in India could be ascribed to quick development of population which is antagonistically influencing the natural resources and condition. The developing population and the ecological weakening face the test of maintained improvement without natural harm. The presence or the nonattendance of ideal characteristic assets can encourage or hinder the procedure of economic development. Population is an important source of development, yet it is a major source of environmental degradation when it exceeds the thresh hold limits of the support systems. Unless the connection between the multiplying population and the existence emotionally supportive network can be settled, improvement programs, howsoever, imaginative are not prone to yield wanted outcomes. Population impacts on the environment primarily through the use of natural resources and production of wastes and is associated with environmental stresses like loss of biodiversity, air and water pollution and increased pressure on arable land.

- **Poverty:** It is said to be both cause and effect of biodiversity degradation. The round connection amongst poverty and environment is a to a great degree complex marvel. Imbalance may cultivate unsustainability in light of the fact that poor people, who depend on normal assets more than the rich, drain characteristic assets quicker as they have no genuine prospects of accessing different kinds of assets. As the 21st century starts, developing number of individuals and rising levels of utilization per capita are draining regular assets and corrupting the earth. The poverty-environmental damage nexus in India must be seen in the context of population growth as well. The pressures on the environment intensify every day as the population grows. The fast increment of human numbers joins with urgent poverty and rising levels of utilization are draining natural resources on which the vocation of present and future ages depends.

- **Land Degradation:** It is any change or disturbance to the land perceived to be undesirable. Land degradation can be caused by both manmade and natural reasons such as floods and forest fires. The main causes of the land degradation includes climate change, land clearance and deforestation, depletion of soil nutrients through poor farming practices, overgrazing and over grafting. In India, water erosion is the most prominent reason of land degradation. The growing trends of population and consequent demand for food, energy, and housing have considerably altered land-use practices and severely degraded environment. The growing population put immense pressure on land intensification at cost of forests and grazing lands because the demand of food could not increase substantially to population. Thus, horizontal extension of land has fewer scopes and relies mostly on vertical improvement that is supported by technical development in the field of agriculture i.e. HYV seeds, Fertilizers, Pesticides, Herbicides, and agricultural implements. All these practices are causing degradation and depletion of environment.

- **Air Pollution:** Air pollution is a serious issue with the major sources being fuel wood and biomass burning, fuel adulteration, vehicle emission and traffic congestion. Traditional fuel (fuel wood, crop residue and dung cake) dominates domestic energy use in rural India and accounts for about 90 per cent of the total. In urban areas, this traditional fuel constitutes about 24 per cent of the total. These biomass-based household stoves are also a leading source of greenhouse emissions contributing to climate change. Direct and indirect negative impacts on forest plant and animal resources, on ecological functions of the forests (including conservation of biological diversity and carbon and water cycles) are caused by poorly planned and implemented extraction of timber and non-timber products, logging and transport roads, construction of facilities for logging camps or for recreational activities in the forests, and by waste accumulation. Direct and indirect impacts on human health and on cultural and social foundations also occur in and around areas of active forest utilization. Carbon monoxide and hydrocarbon emissions are the major contributors for urban air pollution. Average CO and HC emissions of various types of petrol-driven vehicles monitored and showed that the average CO and HC emissions from the passenger cars were 4.88% and 1704 ppm, respectively, which is significantly higher than the standards prescribed for the petrol driven four-wheeler. Increasing smoke density from the vehicles pollutes the urban air and sometimes impair vision also. Vehicular emissions and air pollution due to transportation has adversely affected the health of the citizens. Acute Respiratory illness dominates the State's illness among children. In CG state, diarrhea accounts for 25% of the state's health burden. Other diseases related to poor water, sanitation and hygiene in the state include Malaria, Cholera, Tuberculosis, infectious diseases Gastroenterititis, Trachoma, Poliomyelitis and Protein-energy malnutrition. Prevalence of high incidence of respiratory illness among the urban children is an indication that air is getting polluted.

6.1.7 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).

6.1.8 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.

6.1.9 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.

6.1.10 Tree Species Suitable for Afforestation

Trees absorb key pollutants, such as CO_2, emitted by automobiles and industries before they can escape to the upper atmosphere, trap heat and contribute to global warming. Absorbed CO_2 is processed via photosynthesis, and trees are considered efficient natural carbon sinks. The planting of trees is therefore a step toward climate change mitigation. Fast-growing and long-lived tree species are ideal carbon sinks, but these attributes are usually mutually exclusive, because fast-growing trees have short lifespans, and long-lived trees typically grow slowly. Forests are major carbon sinks, but forest areas are shrinking because of deforestation for non-forestry purposes. Therefore, atmospheric pollutants and greenhouse gases are continually increasing. A total of 438 individual trees belonging to 37 species and 17 families were recorded. *Peltophorum pterocarpum* had the highest number and relative abundance of trees, followed by *Samanea saman*, *Senna siamea*, *Azadirachta indica* and *Alstonia scholaris*. The high relative abundance of these species indicated that they are the most popular trees for roadside plantations in Raipur. These tree species, except for *Azadirachta indica*, are exotic and introduced for their rapid growth and high survival rate in a wide range of soils. Therefore, these species have become abundant in wastelands, along roadsides and canal banks, and near railway lines.

Regarding indigenous trees, *Azadirachta indica* has the highest number, with a relative abundance of 6.84%. Other trees, including *Terminalia arjuna*, *Dalbergia sissoo* and *Tamarindus indica*, have relative abundances of 2.05–3.88% and are seldom found in roadside plantations. Large indigenous trees are known for their longevity and pollution mitigation potential (e.g. *Mangifera indica*, *Ficus benghalensis* and *Ficus religiosa*) have abundances of 1.82–2.51%. Because these trees grow slowly and are grazed by cattle, they are rarely chosen for roadside plantations by civic authorities. Nevertheless, these species occur between roadside plantations through seed dispersal by animals and birds or by having been planted and protected by residents on account of their religious significance. These trees efficiently filter soot and purify the air over the long term, and also act as "Green Highways" to facilitate the movement of birds, insects, and other wild animals.

Fabaceae (*Leguminoceae*) trees are the most common across all plots. Trees of this family grow fast and provide shade to pedestrians, and are therefore preferred for roadside afforestation. Moreover, these trees can survive harsh conditions, such as nutrient-deficient soil, due to the nitrogen-fixation efficiency of associated Rhizobacteria. *Fabaceae* species are used for massive afforestation initiatives across Southeast Asia. On the other hand, eight tree species that are present in single-digit numbers are indicative of their sensitivity toward high biotic pressure along the roadside.

Plantation for Arresting Dust

Trees particularly having compact branching closely arranged leaves of simple elliptical and hairy structure, shiny or waxy leaves and hairy twigs are efficient filters of dust. The following species are suggested to arrest the dusts are as follows:

- *Alstonia scholaris*
- *Bauhinia purpurea*
- *Cassia siamea*
- *Peltoferrum ferrugineum*
- *Butea monosperma*
- *Tamarindus indica*
- *Azadirachta indica*

Figure 6.11: *Butea monosperma* suitable for dust arresting in Raipur.

Plantation to Absorb SO_2 Emissions

The following plants are suggested for plantation to absorb SO_2 in the air:

- *Azadirachta indica*
- *Albizia lebbeck*
- *Alstonia scholaris*
- *Lagerstroemia flosregineae*
- *Melia azedarach*
- *Minusops elangi*
- *Poloyalthia longifloia*

Figure 6.12: *Albizia lebbeck* suitable for SO_2 absorption in Raipur.

Plantation to reduce Noise Pollution

Trees having thick and flushy leaves with petioles are suitable. Heavier branches and trunks of trees also deflect the sound waves. The following plant species are suggested to reduce noise pollution.

- *Alstonia scholaris*
- *Azadirachta indica*
- *Melia monosperma*
- *Grevillea peridifolia*
- *Tamarindus indica*

Figure 6.13: *Azadirachta indica* suitable for noise reduction in Raipur.

Plantation along the roads (Avenue plantation)

- *Alstonia scholaris*
- *Cassia fistula*
- *Bauhinia purpurea*
- *Mimusops elangi*
- *Pongamia pinnata*
- *Polyalthia longifolia*
- *Poluferrum ferrugineum*

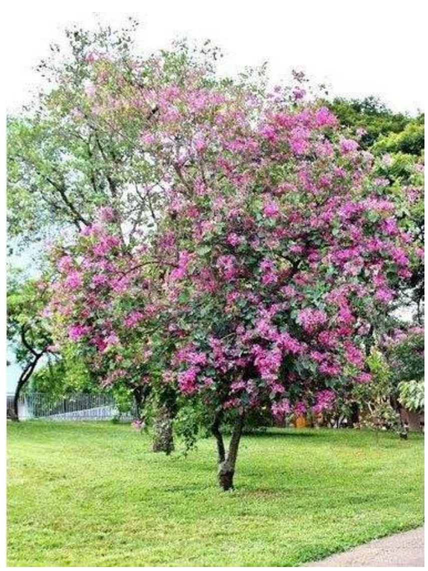


Figure 6.14: *Bauhinia purpurea* suitable for road side plantation in Raipur.

6.1.11 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 Raipur. 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.

In the Green Belt Development Plan, certain hectare of land should be proposed for the recreational use. The total amount of land that will come under the Green Belt is 35% of the total land that is because the requirement of greenery is at least 35 for the place to be healthy. Plantation on the agriculture field embankment may increase this area. Green Belt will minimize the temperature in the summer time. It will become the source of food and fodder for the rural people and raised economical condition of the people. Urbanization will not damage the natural drainage, channels, village settlement. Water management, soil conservation, organic farming this type of work will not affected and this Green Belt is also become the mean of recreation for the citizen. This plan should be considered a "living" working document. The goals and recommendations presented should be reviewed annually, and appropriate adjustments should be made for the following year.

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 Raipur. 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 18 sampling stations in the Raipur region during summer, winter, and pre/post monsoon seasons. The highest average PM_{10} concentration of 350 µg/m^3 for summer and post/pre monsoon season is found for R13 monitoring station. Moreover, the highest $PM_{2.5}$ level were found in R13 monitoring station is 260 µg/m^3 which is having high vehicular traffic and at nearby locations construction activities are also taking place. 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 Raipur, shows that there is no supportive carrying capacity and the pollution load in terms of PM_{10}, is exceeding the Assimilative Carrying Capacity. However the PM2.5 values during post-Covid time are supportive till March '22.

The SO_2 values observed at these stations are well within the NAAQS limit of 80 µg/m^3 but the stations R06, R13, and R18 shows high values mainly because of wood industry and others. Furthermore, the NO_2 variation in different seasons are within the limit of 80 µg/m^3. However, high concentration were found in R06, R08, and R09. 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 Raipur 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 0.55 µg/m^3 to 0.91 µg/m^3 among all air quality monitoring stations. Similarly, we have found TC values ranging from 0.61 µg/m^3 to 0.101 µg/m^3 among all air quality monitoring stations. Carbonaceous compounds are mainly organic or house hold type in Raipur 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 Raipur 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 pollution. VOCs (mainly benzene) are present in the ambient air of Raipur and varying with seasons.During summer, VOC s concentration in the ambient air in Raipur have been decreased and sometimes become lower than the permeable limit.

Metallic and non-metallic nanoparticles are also found in the ambient air of Raipur and are varying with season. Metallic nanoparticles are mainly Fe and Zn but under toxic level in every season. Ambient air of Raipur is sulphate rich and increases in summer. These particulate matters emission have been studies through Receptor Modelling (CMB) in every season. Sources Apportionment Assay predicts that ambient air pollution in Raipur is generally decreasing with lesser emission of PM though road dust and transports emission increase. Major emission sources are road dust and transports emission and constructions. PM emissions from these types of sources are huge and concentration in ambient air going beyond the human tolerance level. Particulate matters emission from different types of construction have been predicted by CMB as 20-22 %. Similarly, for other major emission sources are road dust (30%), transport emission (22%) during winter season. Other some sources like domestic, wastes burning and generator sets are decreasing in summer and are not alarming.

Ultimate prediction by Receptor Model (CMB) is, pollution levels are gradually decreasing in summer than winter. Only in transport section we have found some higher emission in summer but other all sections like constructions, industrial, wastes burning and domestic emission are decresing gradually. Different types of construction like, road and road-side construction, buildings (may be both domestic and industrial) construction, bridges construction has higher effect on Raipur PMs emission. 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 Raipur 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 Kumhari and maximum concentration 24-h obtained as 62.32 μg/m^3. SO_2 hotspot are obtained as Bhanpuri and maximum concentration 24-h 48.746 μg/m^3. NO_x hotspot found to be Bendari and Jarauda with maximum concentration 24-h of 49.755 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 108.91 μg/m^3 with hotspot near by Chhattisgarh Housing Board Office. For the area source modelling, we have considered different garbage dumping yard, stone crushers zones in the Raipur city. Here hotspot is found to be Birgaon with SPM concentration 24-h of 361.57 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 165 locations within Raipur city. 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 samples ranges from 300 to 1000 μs/cm. Moreover, hardness in all the samples is within the limit except for samples collected at Chakuli talab, Mangal Bhawan well, Mohan talab and Amleswar Durga Nagar hand pump where value is more than 180 mg/l. COD level is within the limit of 200 mg/l. DO level was found within 10 mg/l. Moreover, Cl^- values of samples are within the limit of 170 mg/l. Furthermore, the Fe and Ni are predominantly found heavy metal with 83 and 7% respectively but under human toxic level. Other micro-elements like Cu, Ni, Zn, Cr, Cd are also present in detectable but low in 'ppm'. However, in all the water sample metal ion concentration are within human tolerance level. 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 0.592 in 2021, it falls to 0.480 in 2033. At 2040 it reaches the value of 0.407 after that it crosses the normal comprehensive value and goes to the poor comprehensive value. Thus till 2040 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 Raipur are also analysed. Currently, the urban solid wastes coming from houses, small scale industries and market in Raipur are dumped nearby a village in Sarona in the vicinity of Kharun River. LULC mapping of Raipur has been done to calculate the best possible utilization of land present/ available for better planning and policy making. In Raipur, 74.79% land is unsuitable for disposing (as they are (will be) land in use, 20.93% are least suitable (environmental, societal, financial considerations), 3.25% is moderately suitable and 1.03% is most suitable. Currently 0.085 sq km of area is being utilized for waste disposal in Sarona Raipur in front of 226 sq km land area. 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 Raipur city. 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 800 TPD of waste will be generated by 2033. Moreover, the Soil of Raipur analyzed through XRF by collecting it from 100 sampling stations. Here it is found higher percentage of 'Si' in its' oxide form (SiO_2) about 22%. Rather than silica, we got 19% iron. Other metals are also present in oxide form and we got 43% oxide. Plants nutrients like; Na, Ca, Mg, P, K are also present side by side as 1%, 2%, 2.18%, 0.2% and 2.76%, respectively. Other metals like; Al, Cu, S are also found in detectable amount. Most importantly, every soil sample is free from toxic metals like Pb, As and Hg.

The noise pollution was measure at 99 monitoring station in Raipur. The highest level of sound was found in Khamira Nigam, Mandi Road and Khamtrai Bazar Chowk, which are above 90 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 Raipur city. The highest Noise pollution level (NPL > 90) is observed at Zone 2, 3, 4, and 9. This consists of Great eastern Road, Atal Path Road, Panderi to Samariya Road and Tati bandh 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 Raipur region was also analyzed through field survey. This shows different flora and fona in the region. There are some adverse effects 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 Raipur. Altogether, the assimilative capacity of all the component of environment namely, airs, 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 Raipur city are above the limit. Both PM_{10} and $PM_{2.5}$ carrying capacities are negative. But CMB studies predicts that only high road dust, transports emissions and construction are mainly responsible for negative air carrying capacity of this city while industrial emission is only 7 to 9%. 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 Plan

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 industrial area and making pucca / concreted drain to drain	CSIDC/ Construction companies	24 months	5 Cr	High
	Regular cleaning of road dust in the industrial and commercial cluster.	CSIDC/ CGPWD/ Urban Administration	As and when needed	10 lakhs	High

		and Development/ NHAI/ Panchayat and Rural Development Department / Construction companies			
	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 Development Department/ CECB	24 months	2 Cr	Medium
	Introduction of water fountain /water mist /fogging system at major traffic intersection	Urban Administration and	12 months	25 lakhs	Medium

		Development / CSIDC/ Construction companies / Panchayat and Rural Development Department			
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 Development Department	6 months	-	High
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	6 months	-	Medium

		Development Department			
	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 plant and ferro alloys plant.	All Industries / CECB	As and when needed	25 lakhs	High
	• 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	All Industries / CECB	3 months	-	High

	from industries in any nala/ river.				
	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 Raipur 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 may be attempted	Govt. of C.G.	96 months	100 Cr	Medium
	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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