FINAL TECHNICAL REPORT

ON

POLLUTION LOAD CARRYING CAPACITY AND SOURCE APPORTIONMENT STUDIES IN OPA KORBA

Submitted to

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

By

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CERTIFICATE

This is to certify that the content of the final technical report entitled " Pollution Load Carrying Capacity and Source Apportionment Studies in OPA Korba" 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, Korba industrial cluster in Chhattisgarh State is identified as the research area where pollution is an important issue. Korba industrial cluster refers to Kharmora industrial area, SECL coal mines area, CSEB and BALCO area, NTPC and CSEB area, ACB group and Washery area, and industrial area in Korba district. Initially 15 sample stations were chosen for air monitoring in the Korba city and the sample code for those station are K01 to K15. Korba industrial cluster is placed in the category of Other Polluted Area (OPA). Korba is the power capital of Chhattisgarh State. It has more than 10 coal-fired thermal power plants producing 6000MWof electricity. It also holds world's second largest open cast coal mines Gevra and other major open cast coal mines such as Kusmunda mines and Dipka mines. It was designated as a full-fledged revenue district from May 25, 1998.The district is part of the Bilaspur Division and is primarily inhabited by tribals, including the protected tribe Korwas. Korba district is situated (between 22.3595° N, 82.7501° E) in the northern half of the Chhattisgarh State and is surrounded by the districts Korea, Surguja, Bilaspur, Janjgir-Champa. The total area of the district is 7145.44 sq. km out of which 2834.97 sq. km is forest land. The mean height of korba district from sea level is 304.8 meter. Main river flowing through Korba is Hasdeo river and its tributaries are Gagechorai, Tan and Ahiran. Coal is the major mineral in the district, which led to the establishment of profit-making South-Eastern Coal Fields Ltd. (SECL)

under the Coal India Ltd. The district is divided in to 2 subdivisions, 5 tehsils, 188 patwari circles, 5 panchayat samitis and 352 Gram Panchayats. Korba District falls under the hot temperate climate zone and hence the district experiences very hot and dry. Summer season starts from April to mid-June. Rainy season due to the South-West Mansoon is from mid-June till the end of September. The average rainfall in the district is 1506.7 mm. and normal rainfall is 1287.6 mm.

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; Korba, Bhilai. So, further analysis of actions and future needs become even more important in view of revised air quality standards.

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

Air Quality Management (AQM) is the regulation of source emissions in the ambient air in order to achieve specified National Ambient Air Quality Standards (NAAQS). A well-structured Air Quality Management Strategy (AQMS) is an efficient tool which integrates a multiple data sets like; source density, emission intensity, meteorology, geography and receptor information. Over the past few years, several Governmental agencies or administrators, legislators and the general people have shown stark increase in interest in transgressing air quality. Such a response is essential for the management of urban environment and the factors influencing its agglomeration. This forced the Government to bring forward laws for protecting the environment from emission sources. Air Pollution

Act, 1988 (Preservation and Control of Pollution), the Motor Vehicles Act, 1988 and Central Motor Vehicle Rules, 1989 are most important implementation among them. Also implementation of NAAQS and emission standards are made to control air pollution in India. However, fast urbanization, lack in effective public transport system and traffic congestion led decline of local ambient air quality, predominantly near traffic intersections, at busy urban centres and around the industrial areas.

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

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

Initially, CMB has been proposed for both the identification and quantification of source contributors. This model is robust and relatively easy to apply, based on the mass conservation of individual chemical species or markers viz. Organic compounds, elements and ions. These concentrations and compositions at 'receptor' are expressed in linear sum of products of source profile abundances and their contributions. The proportions must be different for each of the source emissions and changes between source and receptor proportions are negligible or can be approximated. Here, we are discussing about the Source Apportionment scenario among 15 different sampling stations of Korba by using CMB Model.

Study Area:

A Central Indian state named Chhattishgarh is heavily forested state, with co-ordinates 21.25º N to 81.60º E. Our study area Korba is often referred as the Industrial Hub of Chhattisgarh.

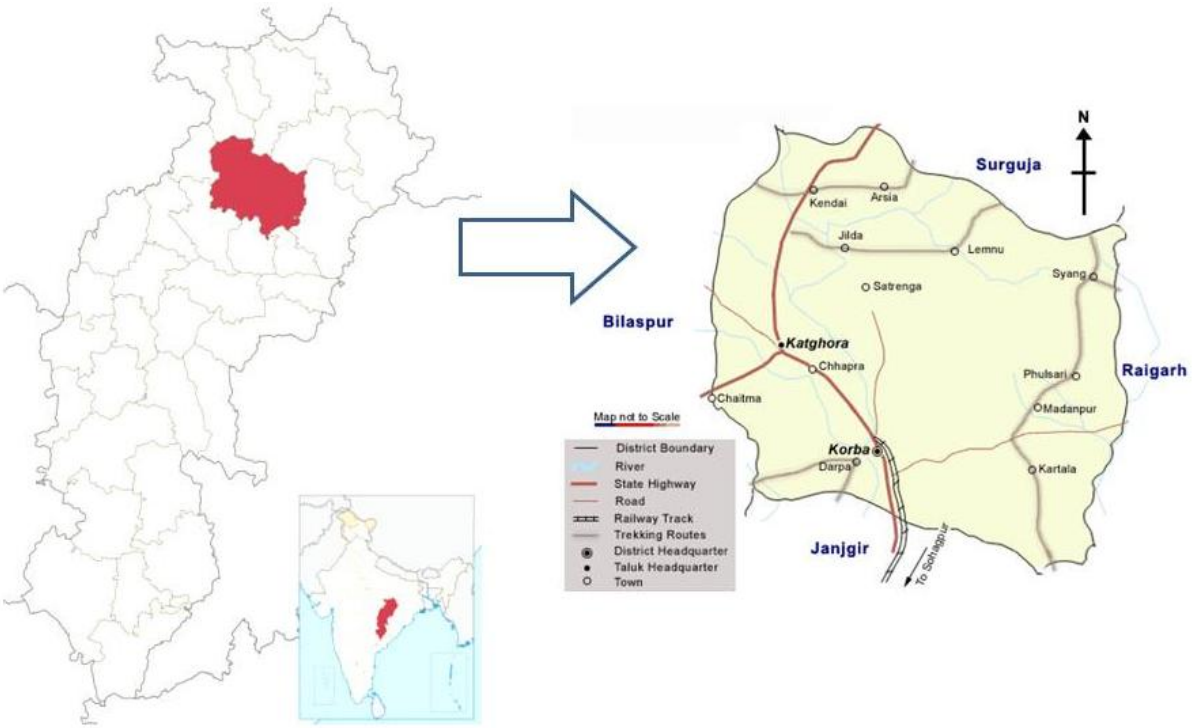


Figure 1.1: Korba district in Chhattisgarh, India (Source: www.Google.com).

1.2 Objectives

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

1.3 Scope of Work

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

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

The main components of work in estimating assimilative capacity are:

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

1.4 Work Plan

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

1.4.1 Air Pollution

Air pollution is one of the leading causes of damages to human health in the world. Air pollutants are released into the atmosphere from a number of sources that alter the composition of the atmosphere

and impact the biotic environment. Sources of air pollution are vehicles, industry, residential, and natural sources. The concentration of air pollutants is determined not only by the amount of pollution emitted by pollution sources, but also by the capacity of the atmosphere to absorb or disperse these emissions. Because of variations in meteorological and topographical conditions, air pollution concentrations change geographically and temporally, leading the air pollution pattern to shift with various places and times. For the prevention, control and abatement of air pollution, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981, which has been further emphasized under the Environment (Protection) Act, 1987. In India, air quality monitoring programs have been carried out under National Air Quality Monitoring Programme (NAMP). The work plan for air quality monitoring in this project is as follows:

- The emission inventory is the first step toward understanding the sources and their strength. Thus, the inventory of point, line, and area sources have been prepared.
- The number of monitoring stations should be as per IS 5182 (Part 14) 2000 "Method for measurement of Air pollution (Part 14 Guidelines for planning the sampling of Atmosphere)". We have collected air samples from 15 air quality monitoring stations in Korba.
- 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 Korba are presented in Table 1.1 and their geographic location in Topo map is shown in Figure 1.2.

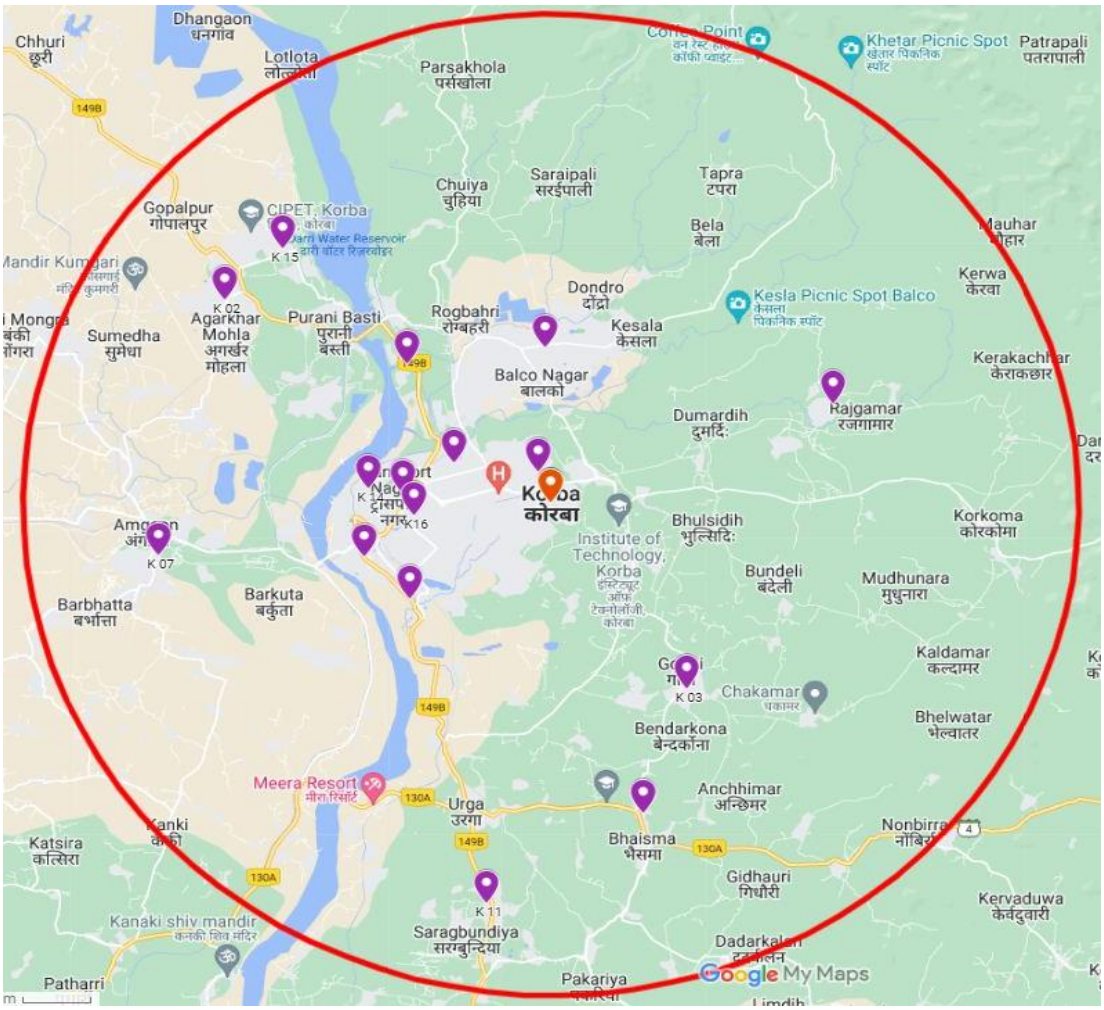


Figure 1.2: Geographical representation of different air sampling stations in Korba.

Table 1.1: Air Quality Monitoring Stations (15 different places) and type of stations in Korba are represented in tabular form.

Station Name	Code	Type
R O Office Kosawadi	K01	Commercial
NTPC Jamnipali KV	K02	Silent
Godhi HS School	K03	Agricultural
Bhaisma HS School	K04	Agricultural
Rajgamar Hs School	K05	Agricultural
S S Mandir Railway Station	K06	Commercial
Kusmunda CMPDI	K07	Commercial
D S P M Thermal Power	K08	Industrial
Balco Get Hostel	K09	Mixed
Municipality Office Purani Basti	K10	Traffic
LANCO Power Plant	K11	Industrial
Kohariya Sub Station Charpara	K12	Industrial
Gov. Girls school T P Nagar	K13	Mixed
Tulshi Nagar PHC	K14	Silent
HTPS Darri	K15	Mixed

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 has a significant influence on the quality and quantity of water in our country. The problem necessitates immediate action by way of drastically enhanced water resources and water quality management systems. For prevention, control, and abatement of water pollution and the maintenance or restoration of the water, Govt. of India has enacted the Water (Prevention and Control of Pollution) Act in 1974. The sampling and analysis of surface and groundwater will be carried out as per the IS 3025 (Part I): 1987 “Methods of sampling and test (Physical and Chemical) for water and wastewater: Part 1 sampling (First Revision)” and CPCB guidelines/norms. The work plan for water quality monitoring in the current research is as follows:

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

1.4.3 Land Pollution

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

- The existing land use pattern has been assessed using satellite imagery and field surveys.

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

1.4.4 Noise Pollution

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

- The present noise levels in the research area have been assessed owing to diverse activities, workplaces, residential areas, state/national roads, changing commercial centres, hospitals, schools, and other factors.
- The number and placement of monitoring stations have been determined.

- Prediction and evaluation of impacts due to noise generation by existing and proposed development activities, including transportation has been carried out.
- High-noise-level zones that require mitigating measures have been identified.
- The cumulative effects of all noise pollution sources have been predicted using proper mathematical models.
- These management plans have divided into short and long-term categories, with a focus on low-cost, high-benefit measures.

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

1.4.5.1 Impact of Carbon on Living Ecosystem

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

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

The totals organic carbon is the summation of gaseous organic carbons and particle-phase organic carbon. The large emissions of non-methane organic carbon relative to their relatively modest atmospheric burden imply rapid turnover of these compounds. Atmospheric organics are terminally removed by conversion to carbon monoxide (CO) and carbon dioxide (CO_2), or wet and dry deposition to the surface as aerosols or gases. Organic carbon plays a significant role in natural and

anthropogenic emissions, atmospheric reactivity (mainly with OH radicals), and the formation of secondary pollutants, e.g., ozone and secondary organic aerosols. Nascent organic carbon is present mainly in the gas phase, highly reactive in nature, can undergo multi-generation oxidation reactions to form increasingly oxygenated, lower-volatility compounds, some of which will partition into the particle phase to form secondary organic aerosols.

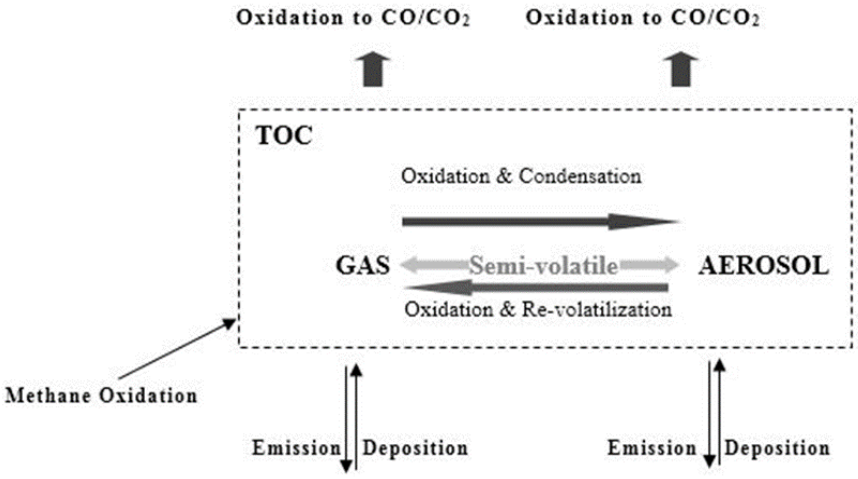


Figure 1.3: Framework for conversion of total organic carbon (TOC) into carbon monoxide (CO) and carbon dioxide (CO_2).

Carbon dioxide (CO_2) is dominated form of the inorganic carbon and methane is the dominated form of organic carbon in the troposphere. Methane is an important greenhouse gas and has a lifetime about 10 years. Organic carbon in the atmosphere, excluding methane, has a much smaller reservoir. However, they can play as a climate forcing agent. Recent studies suggest that organic carbon may undergo chemically mediated phase changes under ambient conditions (Figure 1.3). Higher is the organic carbon burden in the atmosphere higher is the carbon dioxide concentration in the ambient air reveals harmful near living ecosystems. The primary concern with carbon dioxide pollution is it exacerbates the greenhouse effect. By increasing temperature and humidity, carbon dioxide emissions increase the formation of smog (photo-chemical smog), which has adverse effects on human respiratory health. As the average global temperature rises due greenhouse effect, the polar ice melts. This raises the overall sea level and can cause flooding in coastal areas. Global temperature change helps in the formation of major weather events like, hurricanes, storms. The changing sea temperature also impacts aquatic life and fish populations migrate to colder regions for better natural life, which disturbs local fishermen's economy.

Total carbon (TC), is the sum of all organic carbon (OC) and inorganic or elemental carbon (IC/EC) fractions, are measured by TOR/TOT method after the acid leaching as described in the

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

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

1.4.5.2 Volatile Organic Carbons (VOCs)

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

The atmosphere contains a variety of organic carbons, including volatile organic compounds (VOCs) such as hydrocarbons, alcohols, carbonyl, aromatics, ethers, etc. as well as low-volatile compounds and aerosols. Many VOCs are reactive and affect the atmospheric oxidative capacity, while organic aerosols are important for air quality, human respiratory health and cloud formation. Volatile organic carbons (VOCs) are mainly four compounds: benzene, ethyl-benzene, xylene and toluene.

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

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

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

The appearance of humans has gradually changed the natural balance. The amount of waste material released by man-made activities has increased to such a point that inevitable side-effects are now felt. The numerous accidents that are occurred revealed the lack of knowledge on the fundamental processes responsible for the dispersion and deposition of gases and aerosols, and the factors influencing meteorology. A group of scientists has been charged with studying the meteorology of the low troposphere and dispersion of gas and aerosols in air. Global estimates indicate that approximately 235 metric tons per year of VOCs are released into the atmosphere by man-made sources. An additional input of approximately 153 million tons per year of methane comes from man-controlled emissions.

The uncertainty concerning global estimates illustrates well the intrinsic difficulties associated with the evaluation of VOC emission. Modelling studies performed in different scenarios provide emission data and facilitate selection of the best control or abatement strategies for local, religion or global scales. The ideal situation would be real-time knowledge of the amount of each organic component released in a given parcel of air by any existing source. In practice this is virtually

impossible because of: (1) The number and type of sources emitting VOCs; (2) The large differences in chemical composition of VOCs; and (3) The possibility that changes in emission occur in space and time. To give an idea of the difficulties have encountered in evaluating VOC emission, it should be recalled that more than 200 different organic compounds can be present in some sources, and their identification and accurate quantification is not even for dedicated laboratories with sophisticated analytical techniques and skilled personnel. Consequently, continuous and accurate knowledge of the amount of each component present in VOC emission sources applies only a limited number of existing sources. For this reason, continuous and semi-continuous instrumentation for evaluating the total or non-methane VOC content in air and emission sources has been developed and used in last two decades (see section 2.2.7).

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

1.4.5.3 Effect of Polycyclic Aromatic or Aliphatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs), a class of compounds that consist of two or more fused aromatic rings, are well known class of carcinogens found in the atmosphere, and they have been intensively studied over the past few years. PAHs are a group of organic chemicals characterized by chemical stability, low volatility, and low solubility in water. PAHs belong to the group of persistent organic pollutants (POPs). These are organic contaminants that are resistant in spontaneous or natural degradation. Some of them are susceptible to dispersion on a global scale because in addition to having environmental persistence, they are “semi-volatile”, i.e. under environmental conditions they move between the atmosphere and the Earth’s surface in repeated, temperature driven cycles of deposition and volatilisation. POPs are truly multimedia contaminants which occur in all parts of the environment: atmosphere, inland, sea waters, sediments, soils and vegetation. They are mainly of anthropogenic origin and have no significant natural sources.

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

Gaseous and particle-bound PAHs can be transported or travelled over long distances before deposition, and may accumulate in vegetation. This may indirectly cause human exposure to PAHs through respiration, food consumption, and thus may pose a human health threat. Health damage associated with PAHs exposure has been evaluated repeatedly by different health and environmental protection agencies, such as the International Agency for Research on Cancer (IARC), the Environmental Protection Agency (EPA), the National Toxicology Program (NTP), and the Agency for Toxic Substances and Disease Registry (ATSDR). The main sources of human exposure to PAHS are occupation, passive and active smoking, food and water, and water pollution. The total intake of carcinogenic PAHs in the general population has been estimated to be 3 µg/day. One of the most abundant PAH compounds is benzo(a)pyrene [B(a)P] which vary widely in different industrial activities, ranging from 0.1 to 48000 ng/m^3. Levels in water may range from 0 to 13 µg/L B(a)P. Aerosols associated with transportation, coal combustion and wood burning have higher benzo(a)pyrene concentrations. In contrast, oil combustion is not a major source of PAHs. PAHs are adsorbed onto many types of solid aerosols, including black carbon and road dust, and when they reach the lungs, PAHs can be activated; showing cytotoxic effects and generating DNA adducts. Pollution of air by PAHs is mainly due to the incomplete combustion of wood or fuel used for residential heating and industrial or motor vehicle exhaust.

PAHs entering the atmosphere derived from the combustion and from volatilization. They are present in the ambient air as vapours or adsorbed into airborne particulate matter. Gas to particle

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

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

1.4.5.4 Presence of Heavy Metals in Particulate Matters

Sources of heavy metals in the ambient air may include industrial production (chemical industry, oil refineries, petrochemical plants, pesticide production, etc.), mining, untreated sewage sludge, and heavy traffic as well as combustion by-products from coal-burning power stations. So chance of emission of heavy metals in ambient air or biosphere is also high. Thus particulate matters with different

size are easily coming in open air and local peoples are subjected to it. Control of heavy metals in the mining sector is very difficult but in industrial or ore processing centre it is mandatory. Industries are seriously installing different filters and checking their efficiency in regular basis.

1.4.6 Ambient Air Quality Sampling Schedule

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

1.4.6.1 Ambient Air Quality: Pre/Post Monsoon

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

1.4.6.2 Ambient Air Quality: Winter

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

1.4.6.3 Ambient Air Quality: Summer

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

CHAPTER-II

AIR ENVIRONMENT

2.1 Introduction

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

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

2.2 Materials and Methods

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

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

2.2.1.1 Principle

Air particles which have in diameter beneath cut-point of conduit are gathered using filter media. Particle weight is enumerated measuring contrast of avoirdupois of filter paper before and after sampling. The concentration of PM_{10} is deliberated from division of the avoirdupois achieved in filter by air volume.

2.2.1.2 Sampling

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

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

Figure 2.1: Respiratory dust sampler.

2.2.1.3 Working Method

The filter paper is placed in desiccators for 24 hrs to remove moisture and Initial weight is taken before placing it in the jacket. Then faceplate wing nuts are loosened for confiscation of faceplate. Filter is taken out of integument to place on the sustain display. The plate is placed at its slot and the wing

screws are tightened to secure the rubber washer against the filter brim. Now RDS instrument is connected to electric supply to run. Immediately initial time and flow rate is measured and noted. After specific time of running [generally 8 hrs] again final time and flow rate is measured from the time meter and flow rate meter and immediately the system is stopped. Now the filter paper as shown in Figure 2.2 is taken out and placed in desiccators to remove moisture and then final weight is taken.

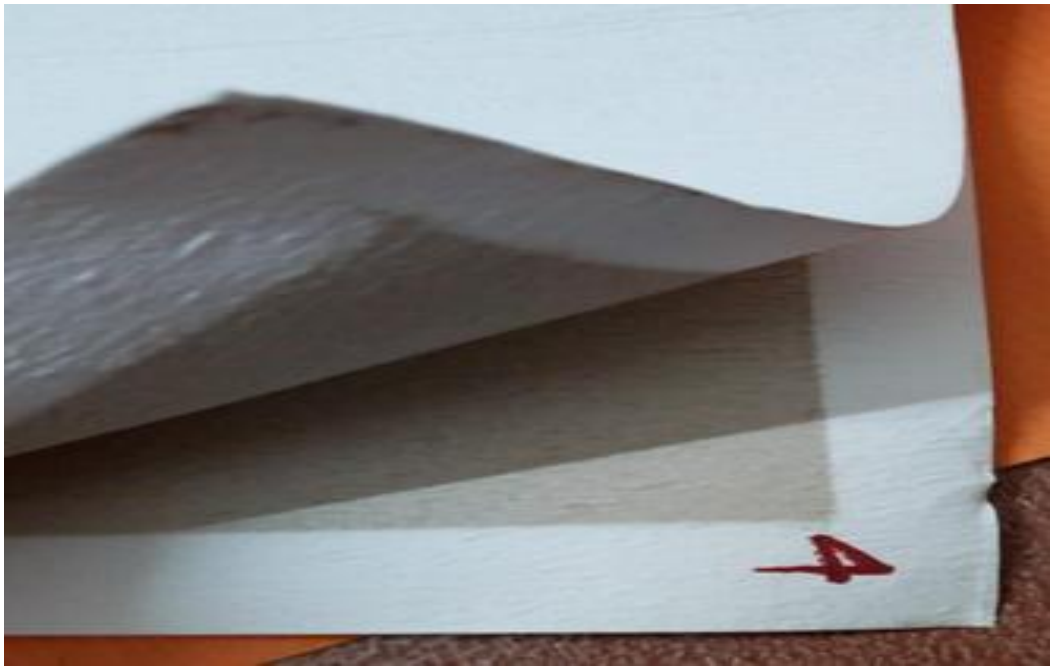


Figure 2.2: Photograph of filter paper of size 25.4 cm × 20.3 cm.

2.1.1.4 Analysis

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

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

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

Where,

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

W_f = Initial weight of filter in g

W_i = Initial weight of filter in g

10^6 = Conversion of g to µg

V = Volume of air sampled, m^3

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

Method: Gravimetric Method

2.2.2.1 Principle

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

2.2.2.2 Sampling

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

Filter Media:

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

Figure 2.3: Fine particulate sampler.

2.2.2.3 Working Method

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

2.2.2.4 Analysis

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

Where,

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

W_f = Initial weight of filter in g

W_i = Initial weight of filter in g

10^6 = Conversion of g to µg

V = Volume of air sampled, m^3

2.2.3 Determination of Sulfur Dioxide (SO_2) Concentration in Air

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

2.2.3.1 Principle

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

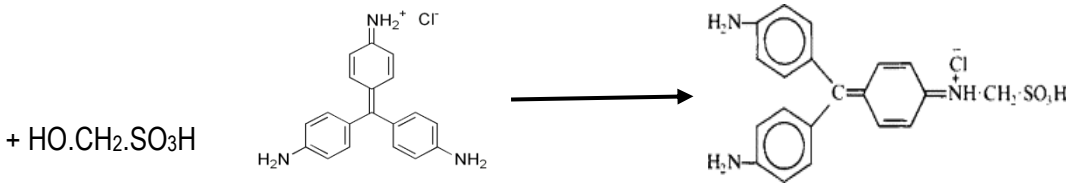
$$HgCl_4^{--} + SO_2 + H_2O \quad \rightarrow \quad HgCl_2.SO_3^{--} + 2Cl^- + 2H^+$$

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

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

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

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



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

2.2.3.2 Calibration

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

2.2.3.3 Preparation of Reagents

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

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

   Working Iodine Solution (0.01N)

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

2) **Starch Indicator**

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

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

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

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

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

5) **Stock Sulphite Solution:**

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

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

a. Mercuric chloride 10.86 gm.

b. EDTA 0.066 gm.

c. Potassium chloride 6.0 gm.

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

7) **Sulphamic Acid (0.6%)**

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

8) **Formaldehyde (0.2%)**

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

9) **Purified Pararosaniline Stock Solution (0.2% Nominal)**

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

10) **Pararosaniline Working Solution**

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

2.2.3.4 Working Method

I) Standardization of Sodium Thiosulphate

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

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

Where,

W = Weight of Potassium Iodate, gm = 1.97 gm

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

35.37 = Equivalent wt. of Potassium iodate.

N = Normality of Sodium thiosulphate.

II) Working Sodium thiosulphate Solution (0.01N)

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

Where,

N_1 = Normality stock Sodium thiosulphate Solution = 0.1249N

V_1 = Volume of stock Sodium thiosulphate solution

N_2 = Normality of working Sodium thiosulphate (0.01N)

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

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

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

Table 2.1: Determination of sulphite strength.

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

Blank iodine flask (V_A) = 40.7 ml

Sample iodine flask (V_B) =12.4 ml

III) Strength of Stock Sulphite Solution

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

Where,

C = Concentration of SO_2 (µg/ml)

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

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

N = Strength of Sodium thiosulphate solution

K = 32000 Miliequivalent wt. of SO_2/µg

V = Sulphite volume (25 ml)

IV) Working Sulphite Solution

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

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

1 ml of this solution = 7.25 µg SO_2/ml

V) Calibration Curve

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

Table 2.2: Data for SO_2 calibration curve.

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

Table 2.3: Absorbance measurement at 560 nm.

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

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

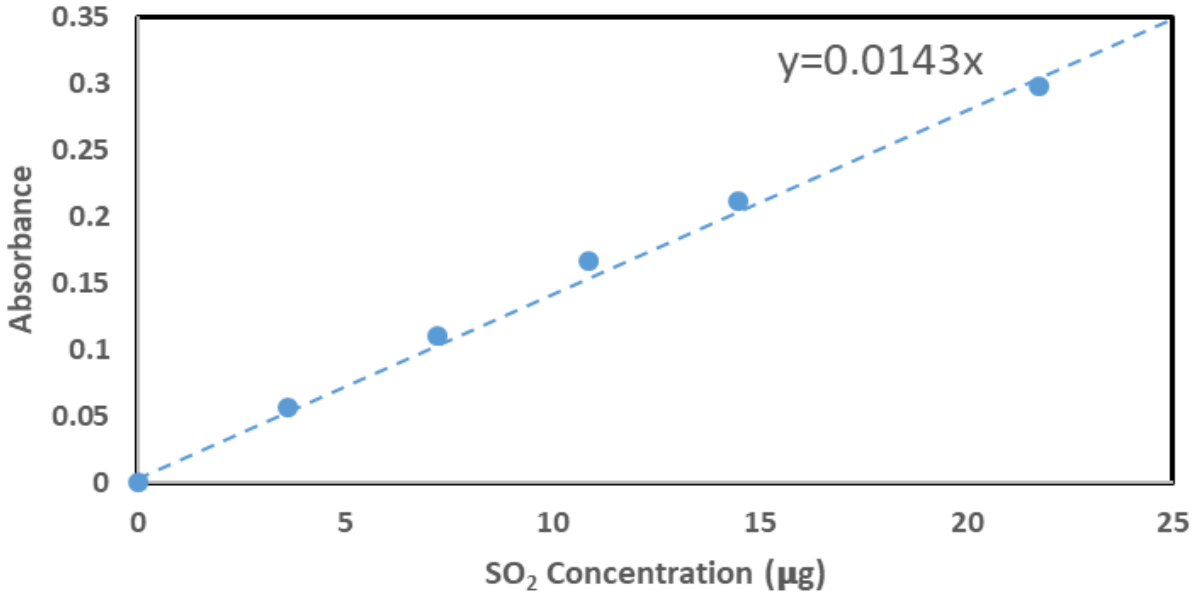


Figure 2.4: Calibration curve of SO_2.

Figure 2.5: Samples of SO_2.

VI) Sampling

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

10.86 gm of Mercuric chloride, 0.066 gm of EDTA

10.86 gm of Potassium chloride, 6.0 gm of sodium chloride are dissolved in water and volume is made to the mark in a 1 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 gm. Sulphamic acid is dissolved in 50 ml distilled water.
    b. Prepared freshly

2. **Formaldehyde (0.2%)**

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

3. Purified Pararosaniline Stock Solution (0.2% Nominal)

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

Pararosaniline Working Solution

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

IX) Working Method

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

X) Calculation

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

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

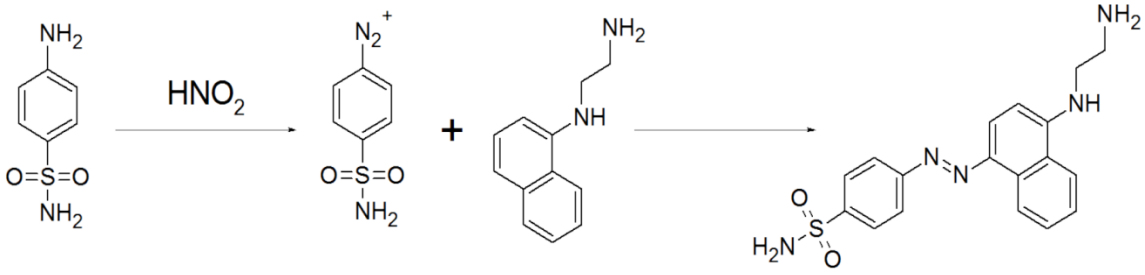
2.2.4 Determination of Nitrogen Dioxide (NO_2) Concentration in Air

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

2.2.4.1 Principle

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

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



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

2.2.4.2 Calibration

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

2.1.4.3 Preparation of Reagents

The following reagents are used for analysis.

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

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

B. Working Sodium Nitrite Standard Solution

- **Solution A (10.0 µg NO_2/ml):** 1 ml stock Nitrite is watered to 100 ml by distilled water.

- **Solution B (1.0 µg NO_2/ml):** 25 ml Solution A is diluted to 250 ml with absorbing Solution. It is prepared freshly.

C. Hydrogen Peroxide Solution

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

D. Sulphanilamide Solution

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

E. NEDA Solution

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

2.2.4.4 Calibration Curve

The preparation steps and absorbance at various concentration 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: Data for NO_2 calibration curve.

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

Table 2.5: Absorbance measurement at 540 nm.

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

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

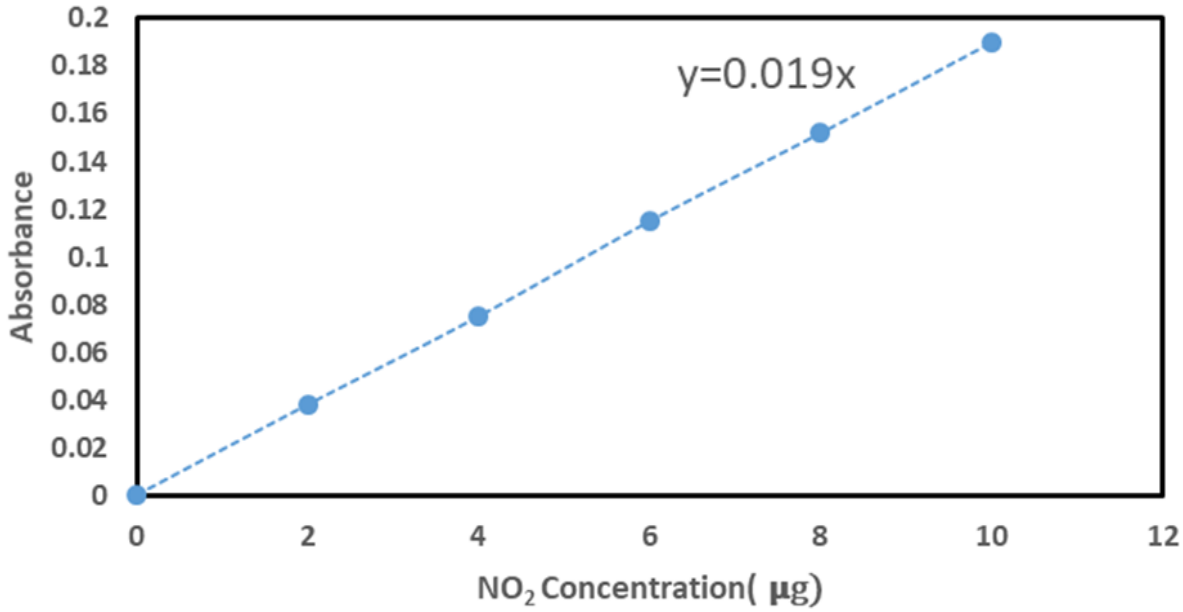


Figure 2.7: Calibration curve of NO_2.

Figure 2.8: Sample of NO_2 for calibration.

2.2.4.5 Sampling

Absorbing solution required for sampling of Nitrogen Dioxide is

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

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

2.1.4.6 Procedure

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

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

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

2.2.4.7 Analysis

The following reagents are used for analysis.

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

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

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

2.2.4.8 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.

2.1.4.9 Calculation

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

Where,

C_{NO_2} = Amount of NO_2, µg/m^3

A_s = Absorbance for sample

A_b = Absorbance for reagent blank

CF = Calibration factor = 52.63

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

V_s = Sampling volume = 30 ml

V_t = Sample taken in analysis = 10 ml

0.82 = Sampling efficiency

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

2.2.5.1 Principle

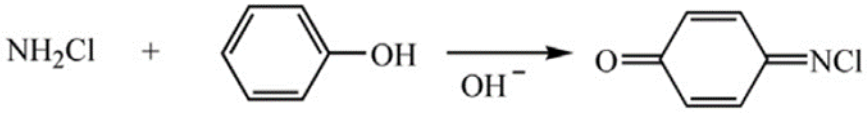
A. When air passes through dilute solution of H_2SO_4, the NH_3 in the air is converted to ammonium sulphate

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

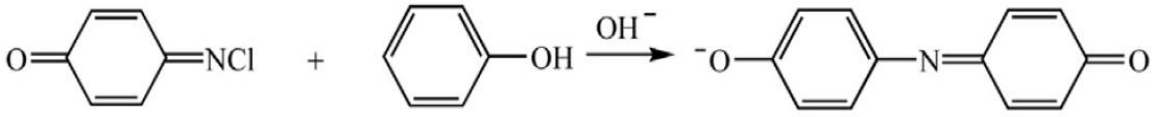
B. The ammonium ion reacts with hypochlorite ion to produce monochloroamine

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

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



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



2.2.5.2 Calibration

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

2.2.5.3 Preparation of Reagents

A. Sodium nitroprusside

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

B. 6.75 M Sodium hydroxide

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

C. Sodium hypochlorite solution (0.1N)

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

D. Buffer Solution

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

E. Working Phenol Solution

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

F. Working hypochlorite solution

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

G. Absorbing Solution [0.1N Sulphuric Acid]

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

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

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

I. Working Ammonia (10.0µg NH_3/ml)

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

2.2.5.4 Calibration Curve

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

Table 2.6: Data for NH_3 calibration curve.

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

Table 2.7: Absorbance measurement at 630 nm.

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

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

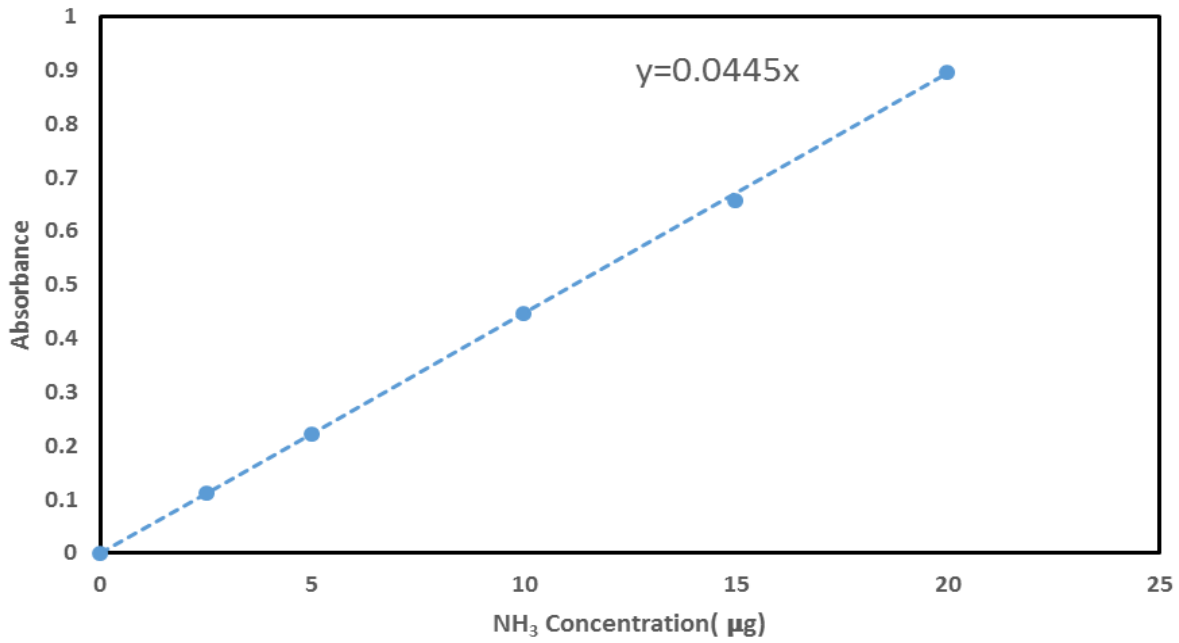


Figure 2.9: Calibration curve of NH_3.

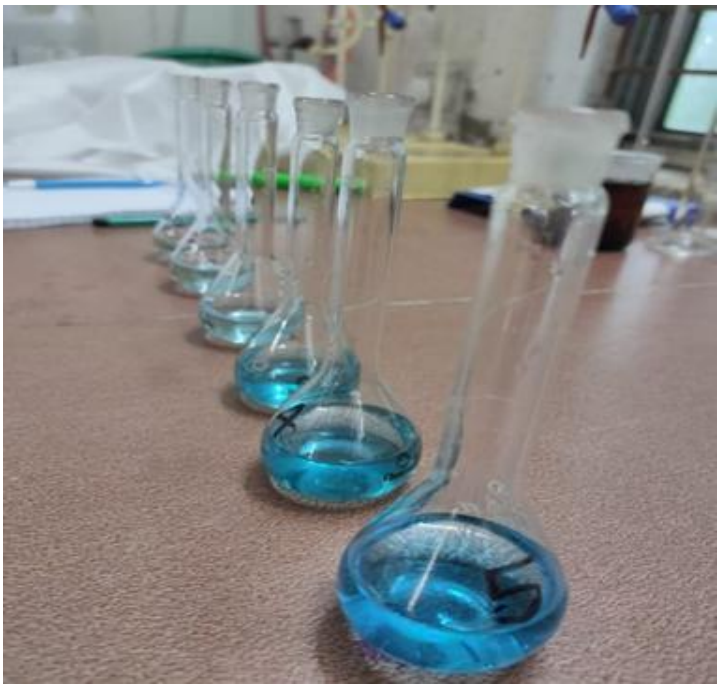


Figure 2.10: Sample of NH_3 for calibration.

2.1.5.5 Sampling

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

2.1.5.6 Procedure

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

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

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

2.2.5.7 Analysis

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

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

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

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

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

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

2.2.5.8 Working Method

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

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

2.2.5.9 Calculation

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

Where,

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

A_s = Absorbance for sample

A_b = Absorbance for reagent blank

CF = Calibration factor = 22.47

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

V_s = Sampling volume = 30 ml

V_t = Sample taken for analysis = 10 ml

2.2.6 Determination of Ozone (O_3) Concentration in Air

Method: Chemical method

2.1.6.1 Principle

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

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

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

2.2.6.2 Calibration

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

2.2.6.3 Preparation of Reagents

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

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

B. Standard Iodine Solution (0.002 N I_2)

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

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

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

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

KH_2PO_4 13.6 g

Na_2HPO_4 14.2 g

Or $Na_2HPO_4.12\ H_2O$ 35.8 g

KI 10.0 g

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

2.1.6.4 Calibration Curve

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

Table 2.8: O_3 calibration data

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

Table 2.9: Absorbance measurement at 352 nm.

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

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

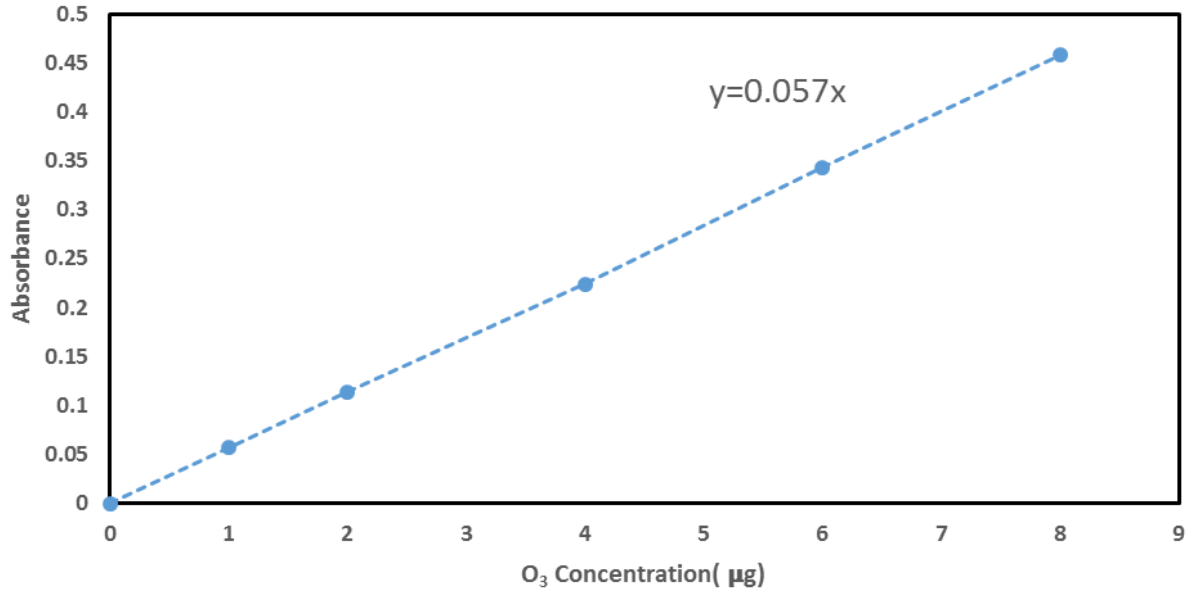


Figure 2.11: Calibration curve of O_3.

2.2.6.5 Sampling

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

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

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

2.2.6.6. Procedure

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

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

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

2.2.6.7 Analysis

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

2.1.6.8 Calculation

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

Where,

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

A_s = Absorbance for sample

A_b = Absorbance for reagent blank

CF = Calibration factor = 17.54

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

V_s = Sampling volume = 30 ml

V_t = Sample taken for analysis = 10 ml

1.962 = Conversion factor, µl to µg

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

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

2.2.7.1 Working Method

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

2.1.7.2 Sampling

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

Figure 2.12: VOC sampler.

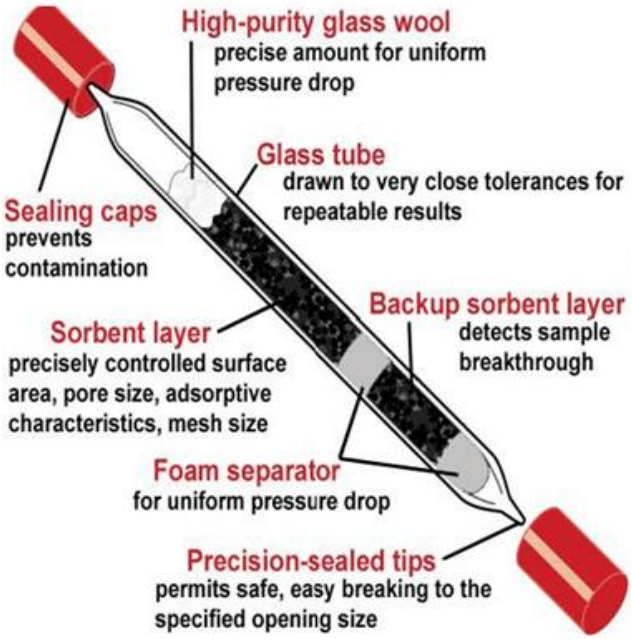


Figure 2.13: Adsorption tube used in VOC sampler.

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

2.2.7.3 Calibration of GC

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

2.2.7.4 Sample Analysis

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

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

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

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

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

2.2.8.1 Working Method

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

2.2.8.2 Calibration of GC

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

2.2.8.3 Sample Analysis

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

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

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

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

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

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

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

Methods:

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

2.2.9.1 Working Method

The method is based on active sampling using PM_{10} High Volume Sampler. A part (1" × 8") of exposed Glass Fiber Filter Paper (EPM – 2000; Sized: 8" × 10") was covered with the extraction solution (3% HNO_3 and 8% HCl) and extraction was carried out by Hot-plate procedure for 30 min. After cooling down, extracted solution was filtered and transferred into a 100 mL volumetric flask. Make the volume with deionized water and shake. This solution was analysed by Atomic Absorption Spectrophotometer (AAS) and Inductively Coupled Plasma–Mass Spectrophotometer (ICP-MS). Atomic Absorption Spectrophotometer used in measuring heavy metals in ambient air sample is shown in Figure 2.16.

2.2.9.2 Calibration of AAS and ICP-MS

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

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

2.2.9.3 Calculation

Sample air volume was calculated by using the following formula:

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

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

Then metal concentrations were calculated as:

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

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

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

2.2.10.1 Working Method

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

2.2.10.2 Calibration of IC

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

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

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

The separation between organic carbons (OC) and elemental carbons (EC) as well as the correction for the pyrolyzed carbons (Pyrol-C) is carried out by both the Thermal-Optical Reflectance (TOR) and Thermal-Optical Transmittance (TOT) methods. A 0.6 cm^2 sized PM_{10} quartz-filter paper sample is placed inside the quartz oven. The oven is then purged with pure helium gas (He) to remove air and a simultaneous stepped temperature increases to 580 ºC to desorb the organic and carbonate carbons.

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

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

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

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 pilot tube is used to sense the draft velocity in the stack and the differential pressure produced is measured on a digital manometer. A thermocouple and Digital pyrometer have been provided to measure the stack gas temperature.

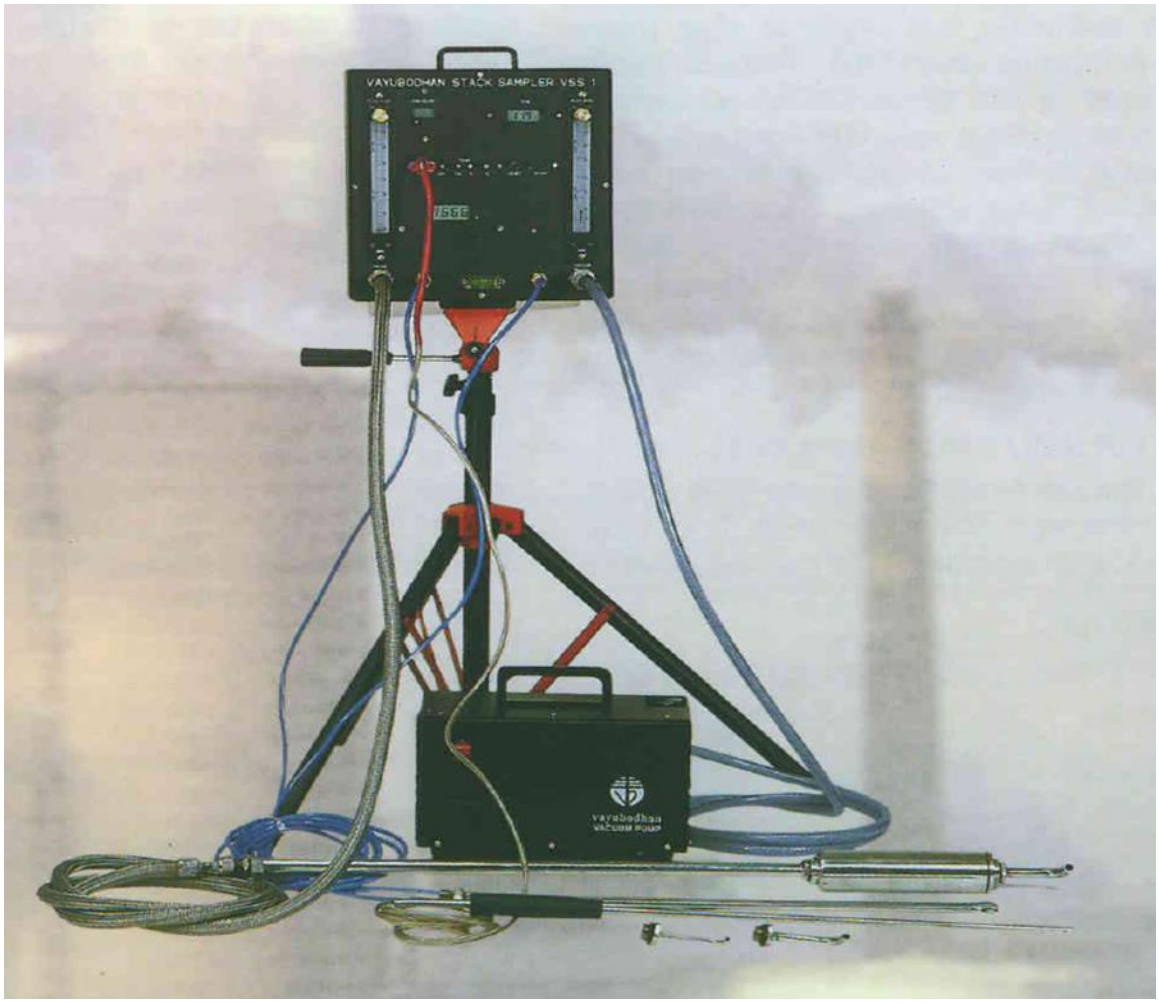


Figure 2.18: Vayubodhan stack sampler.

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

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

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

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

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

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

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

Substituting in Equation (2.1) we have:

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

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

Taking 'h' in millimeters.

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

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

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

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

Aerodynamic drag along the stack wall, damper vanes, right angle bends, and side entry ducts etc. cause the flow rate across the cross-section of the duct/chimney to vary. Hence air velocity measurements must be averaged out by determining the velocity at different points across the cross-section.

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

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

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

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

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

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

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

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

Where;

Q_m = Actual flow rate in LPM

Q'_s = Sampling rate from stack

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

P_m = Average mean pressure at the metering point.

P'_m = Barometric pressure at the metering point.

T_s = Stack gas temperature (K)

T'_a = Temperature at metering point (K)

Note: The pressure unit must be consistent.

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

2.2.13 Real Time Air Monitoring

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

Methodology:

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

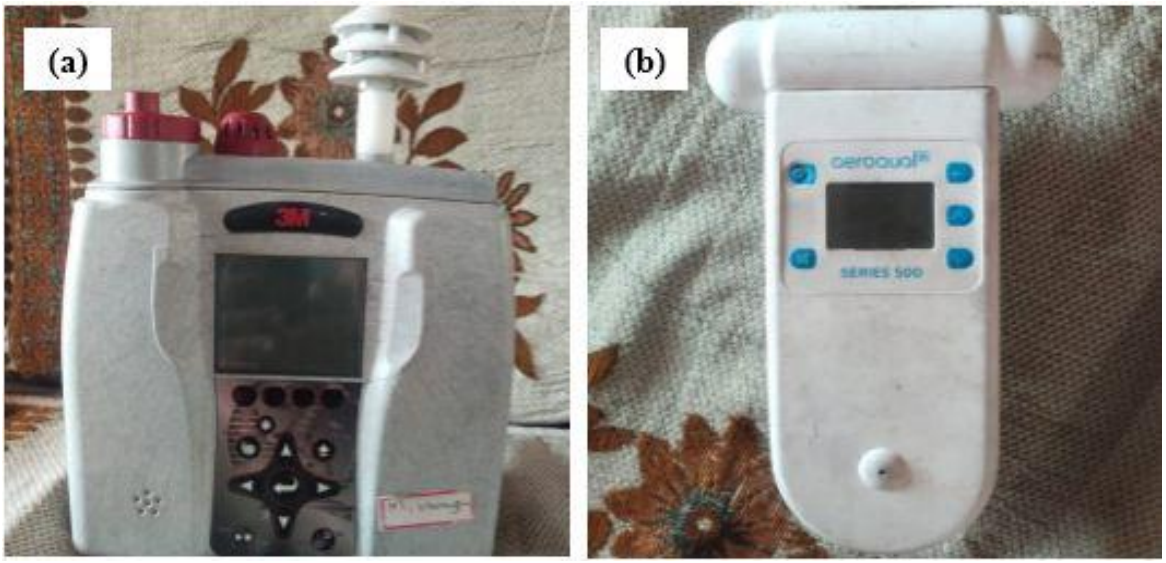


Figure 2.19: Real time air monitoring devices (a) 3M Instrument (b) Aeroqual series 500.

2.2.14 Molecular Markers

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

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

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

2.2.15 Air Quality Management Plan

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

- Sampling of PM_{10} and $PM_{2.5}$ on selected filter papers (made of PTFE / Quartz) by using specific samplers, RDS and others at 15 -17 sampling sites in 5 cities mentioned above. Details of site selection have been given in study area section.
- Sampling (for 24 hrs.) for at least 10 days in each season.
- Calculation of PM emission load for different sampling stations based on primary surveys.
- Analyses of collected samples in PM sampling filter papers (PTFE / Quartz) were undertaken in the following methods described in CPCB methods, 2011.

2.2.16 Air Quality Modelling

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

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

2.2.16.1 Dispersion Modelling

A set of mathematical equations called dispersion modelling is used to mimic the emission and dispersion of air contaminants within the environment. Another way to put it is that it is a mathematical

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

2.2.16.2 Gaussian Plume Dispersion Model

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

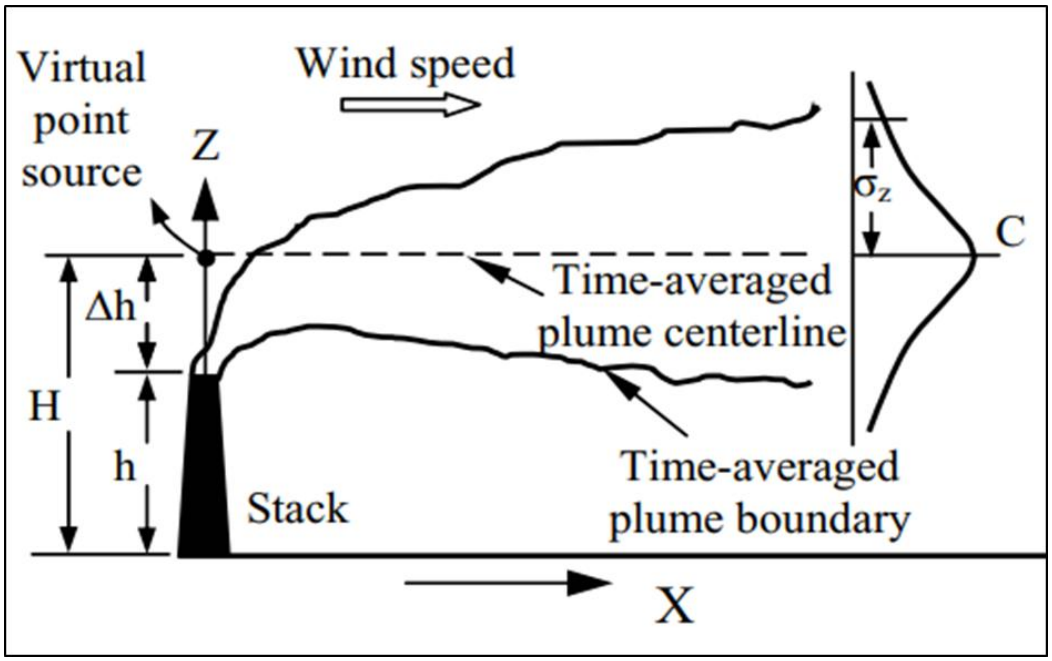


Figure 2.20: Schematic diagram of plume dispersion.

2.2.16.3 Derivation of Gaussian Plume Dispersion Model

The important crucial assumptions include the following:

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

Consider the mass transport within a small volume for derivation of an equation describing the distribution of mass within the plume. The average horizontal wind affects mass transport in the X-direction. The turbulent motions affect the Y and Z-directional mass transport. On solving the differential equation obtained after applying the mass balance, gives the concentration correlation shown in Equation 2.25.

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

Where;

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

x = downwind distance [m]

y = crosswind distance [m]

z = vertical distance above ground [m]

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

σ_x = lateral dispersion coefficient function [m]

σ_y = vertical dispersion coefficient function [m]

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

H = effective stack height [m]

Concentration at ground level (z = 0)

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

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

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

Source at ground level (h = 0)

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

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

Maximum ground level centreline concentration from elevated sources

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

2.2.16.4 Software for Air Dispersion Modelling

Different software for air dispersion modelling:

A) Model Selection

ISC 3

AERMOD – most recent version for Dispersion modelling

SEC3 – Specify reasons for use

B) Dispersion Coefficient

Urban

Rural

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

C) Coordinate System

UTM Coordinates

Local Coordinates

Other

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

2.2.16.5 AERMOD - Air Dispersion Model

In this dispersion model, AERMOD utilizes both a Gaussian and a bi-Gaussian method (USEPA, 2002). A standard Gaussian model is not AERMOD. It operates several algorithms depending on the prominent meteorological features of the region where the predictions are to be produced. AERMOD produces ambient air pollution concentrations on a daily, monthly, and annual basis. The model can handle a variety of contaminants in both urban and rural environments, as well as on level and difficult terrain.

The software consists of 3 components extensively:

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

2.2.16.6 Procedure for Dispersion Modelling

A. AERMET View: Pre-processing of meteorological data

Pre-processor AERMET View transforms unprocessed meteorological data into the format needed by AERMOD (version 10.2.1). Chhattisgarh Environment Conservation Board (CECB) provided the raw meteorological data from January 2022 to December 2022. AERMET View imports a datasheet providing meteorological parameters for one hour on average for the given

period, including temperature, cloud coverage, velocity of wind, relative humidity, direction of wind. This file is converted to Samson format, and the software generates surface properties for an area with deciduous forests/cultivated region, including albedo, the Bowen ratio, and surface roughness. The upper air estimator of AERMET (for UTC +5 Islamabad time zone) generates upper air data by using input meteorological characteristics, including temperature, humidity, wind, and cloud cover. These characteristics help determine sensible heat flux, which is then utilized to calculate the shear stress caused by wind speed and turbulence. Surface shear stress is used to compute the night time boundary layer, whereas sensible heat flux is used to calculate the mixing height. Two output files surface meteorological file (*.sfc format file) and profile meteorological file (*.pfl format file) are generated once the AERMET model has been assembled.

B. AERMAP: Terrain pre-processing

Irregular elevations are a part of complex terrain modelling. Therefore, pre-processing is carried out for terrain that is raised and flat. Shuttle Radar Topography Mission (SRTM), National Elevation Dataset (NED) and Digital Elevation Model (DEM) are just a few of the convenient terrain data sources offered by Web GIS. Terrain data used for the present modelling process is obtained from SRTM 30. The Source output file and the receptor output file, which are utilized as input for the Source and Receptor pathways, respectively, are provided by AERMAP in a similar way to that of AERMET. As a result, a correlation between plume rise and terrain characteristics is created. After running AERMAP, the topographic map is obtained and superimposed on the model's base map.

C. Compiling AERMOD

The following dispersion modelling procedure is used for the Korba 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 the ongoing study.

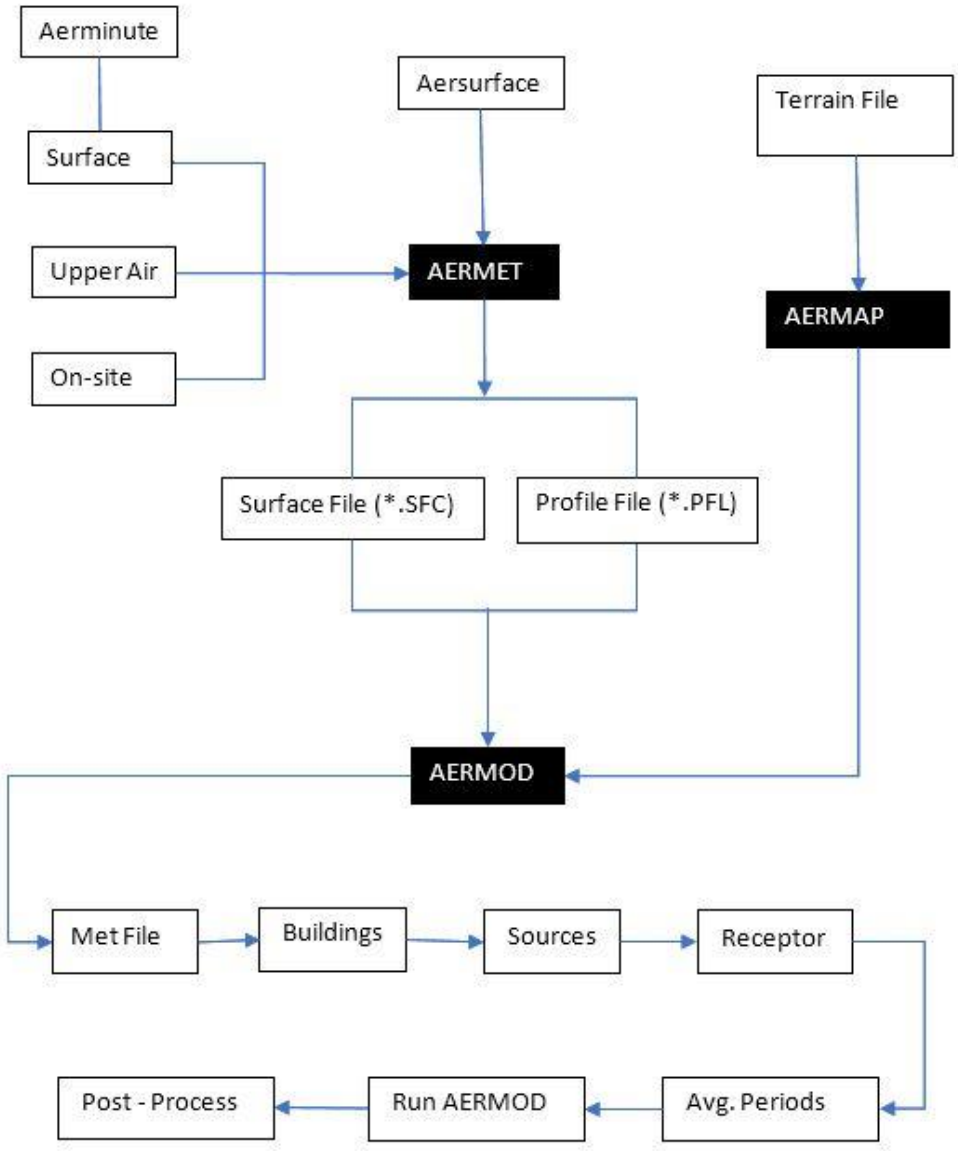


Figure 2.21: Flowchart for input parameters for AERMOD.

2.2.17 Receptor Modelling and Source Apportionment Analysis

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

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

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

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

There are some assumptions for CMB model:

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

Following approach has been used for CMB modelling:

a) Identification of the contributing sources to the monitoring sites.
b) Selection of chemical species to be included in the calculation. Following species are analysed from the PM_{10} and $PM_{2.5}$ samples collected at respective sites in the summer and winter seasons.

    1. Carbon fractions based on temperature (Organic Carbon and Elemental Carbon) using Thermal Optical Reflectance (TOR) Carbon Analyser,
    2. Ions (Anions – fluoride, chloride, bromide, sulphate, nitrate and Cations – sodium, ammonium, potassium) using Ion-chromatography.
    3. Elements (Cu, Fe, Ni, Zn, Cd, Pb and As) using Atomic Absorption Spectrophotometer (AAS) and Inductively Coupled Plasma – Mass Spectrophotometer (ICP-MS).
    4. A few study-specific analyses like the presence of heavy metals in both the soil as well as water has been carried out by using X-ray Fluorescence Spectrometer and Atomic Absorption Spectrophotometer (AAS) or Inductively Coupled Plasma – Mass Spectrophotometer (ICP-MS), respectively.

c) Estimation of both the ambient concentrations and uncertainty of selected chemical species from the particulate matter has been collected at respective sites.
d) Solution of the chemical mass balance equations has obtained through CMB-8.2 receptor model by using the chemical composition results of 24 hr daily samples collected at all sites and sources profiles of applicable sources at respective sites as an input.
e) Contributing sources has been identified by averaging the contribution from sources observed based on daily samples across the monitoring period.

Different air pollutants, which are described above, are quantified and arranged in a tabular form for CMB modelling. 15 sampling stations of Korba 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:

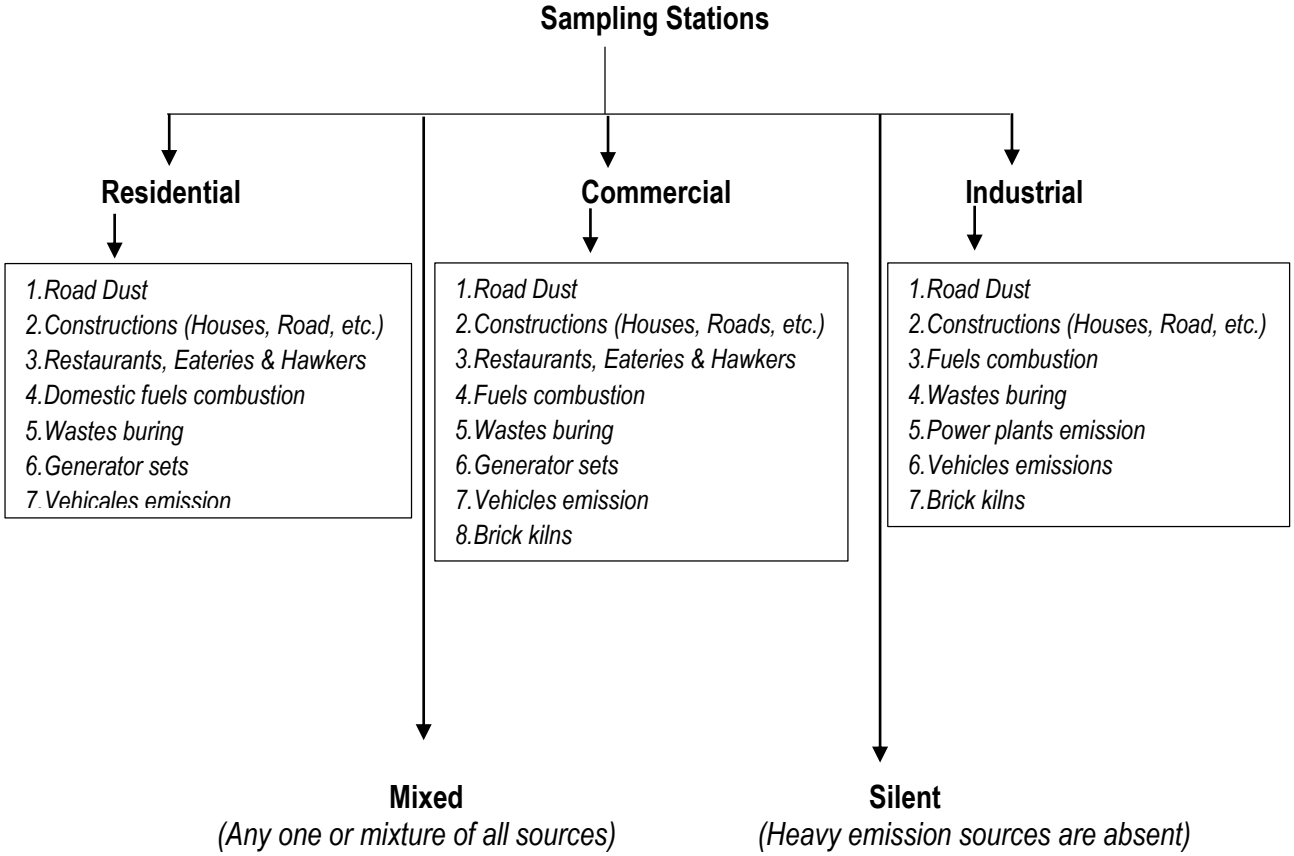


Figure 2.22: Types of different sampling stations and different sources of pollution may present there.

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

2.3. Results and Discussion

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

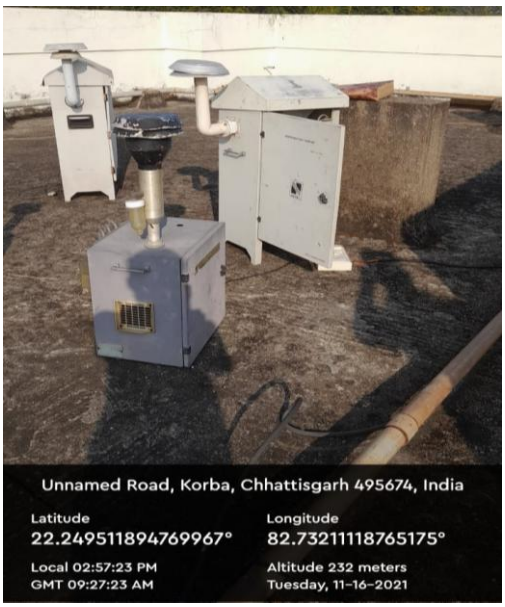
Following 15 sampling stations has been identified in Korba industrial cluster for air sampling.

Table 2.11: Air sampling stations at Korba.

Location ID	Location Name	Latitude (°N) and Longitude (°E)	Station View
K01	R.O. Office Kosawadi	22.368236, 82.746753	
K02	NTPC Jamnipali KV	22.415414, 82.659604	

K03	Godhi H.S. School	22.30834091, 82.78760584	
K04	Bhaisma H.S. School	22.274273, 82.775331	
K05	Rajgamar H.S. School	22.38700088, 82.828017594	

K06	S.S. Mandir Railway Station	22.333270995, 82.7110222354	
K07	Kusmunda CMPDI	22.3449450, 82.6415130	
K08	D.S.P.M. Thermal Power	22.370850965, 82.723441282	

K09	BALCO GET Hostel	22.402199, 82.748487	
K10	Municipality Office Purani Basti	22.344704, 82.698539	
K11	LANCO Power Plant	22.249511894, 82.732111187	

K12	Kohariya Sub Station Charpara	22.397721, 82.710368	
K13	Gov. Girls School T.P. Nagar	22.361996, 82.709176	

K14	Tulshi Nagar P.H.C.	22.363449, 82.699713	
K15	H.T.P.S. Darri	22.42942659, 82.6758718	

2.3.2 Ambient Air Monitoring Stations Details

Table 2.12: Observed sources near sampling site.

Location ID	Location Name	Coordinates	Station Classification	Observed Sources
K01	R.O. Office Kosawadi	22.368236 82.746753	Commercial	Restaurants, Dairy shop, Food stalls, Petrol pump, Electronic repair shop, Pond
K02	N.T.P.C. Jamnipali K.V.	22.415414 82.659604	Silent	NTPC Hospital, Vehicle Sales and Crevice centre, Hardware Shops, Electronics shops, Food stalls, Petrol pump

K03	Godhi H.S. School	22.30834091 82.78760584	Agricultural	School, Poultry farm, Restaurant, Gas godown
K04	Bhaisma H.S. School	22.274273 82.775331	Agricultural	School, Hotel, Rice mill, Petrol pump, Ashok Leyland sales and crevice centre
K05	Rajgamar H.S. School	22.38700088 82.8280175942	Agricultural	School, Food stalls, BALCO, Petrol pump
K06	S.S. Mandir Railway Station	22.333270995 82.7110222354	Commercial	Railway station, Restaurants, Coal mine, Auto service
K07	Kusmunda CMPDI	22.3449450 82.6415130	Commercial	Café, Auto parts service, Medical shop
K08	D S P M Thermal Power	22.3708509653 82.72344128228	Industrial	CSEB Hospital , Thermal power plant
K09	BALCO GET Hostel		Mixed	BALCO, Electronic repair shops, Tea stalls, Gas godown, Traffic
K10	Municipality Office Purani Basti	22.344704 82.698539	Traffic	Traffic, Offices, Clinic, Flour mill, Petrol pump, Hotels
K11	LANCO Power Plant	22.249511894 82.7321111876	Industrial	Power plant, Iron & steel industries, Petrol pump
K12	Kohariya Sub Station Charpara	22.397721 82.710368	Industrial	Vehicle service, Restaurant, Tyre works, BALCO Aluminum plant, Petrol pump
K13	Gov. Girls school T P Nagar	22.361996 82.709176	Mixed	School, Hospital, Gas agency, Book and stationary shops, Xerox centre, Food stalls
K14	Tulshi Nagar PHC	22.363449 82.699713	Silent	PHC, Offices, Flour mill, Restaurant
K15	HTPS Darri	22.42942659, 82.6758718	Mixed	Flour mill, NTPC Hospital, Clinics, Medical shops, Pathological laboratories

2.3.3 Graphical Representation Ambient Air Monitoring Data

2.3.3.1 PM_{10} Variation in Different Season

Air sample collected from 15 stations and the highest PM level were found in K10, K13 and K154 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

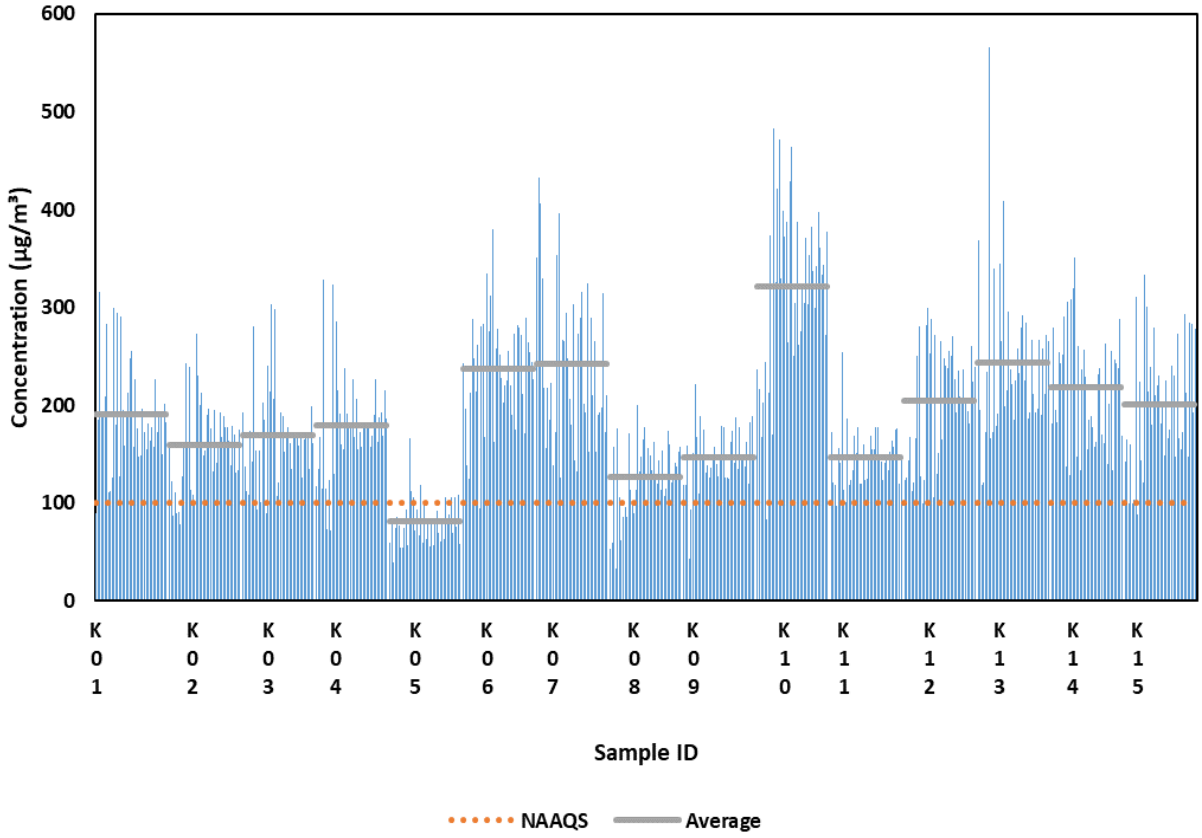


Figure 2.23: Concentration of PM_{10} in winter season.

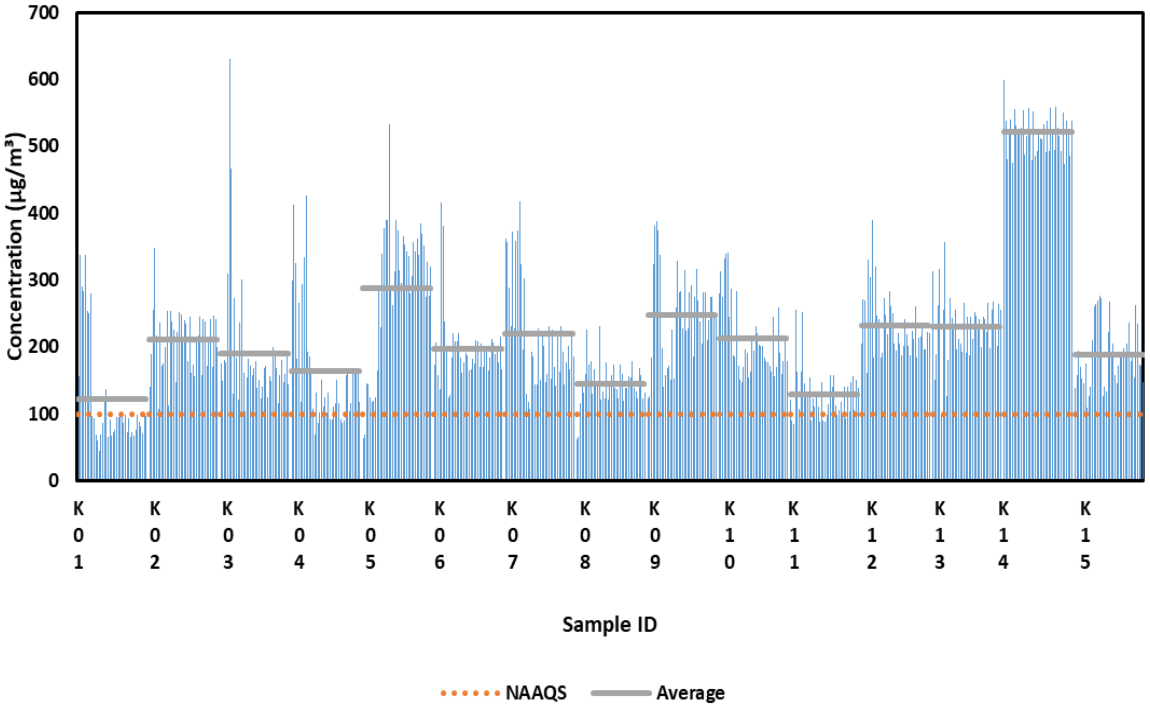


Figure 2.24: Concentration of PM_{10} in summer season.

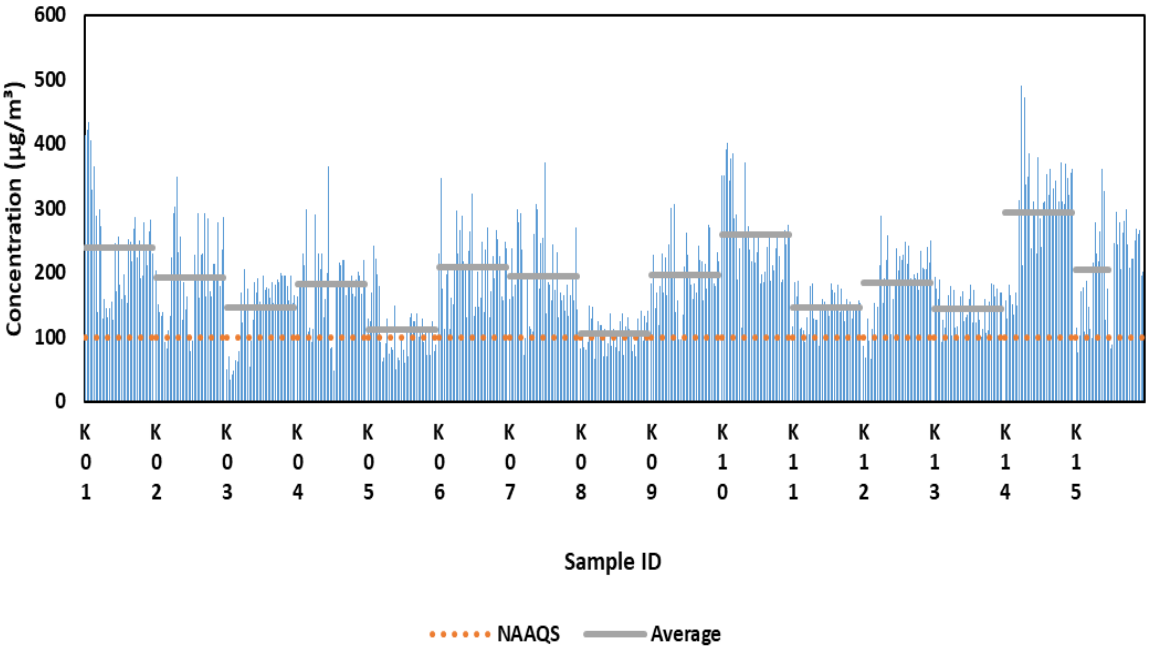


Figure 2.25: Concentration of PM_{10} in pre/post-monsoon season.

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

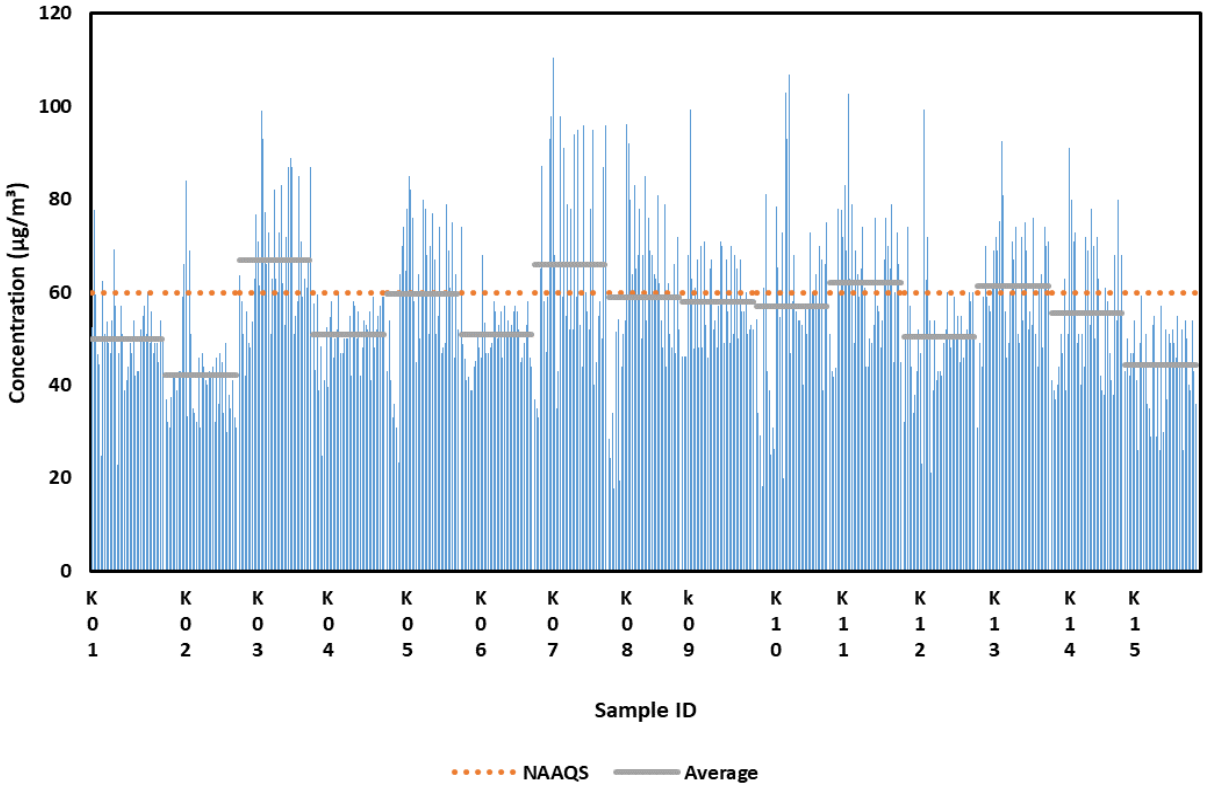


Figure 2.26: Concentration of $PM_{2.5}$ in winter season.

Air sample collected from 15 stations and in the summer season highest $PM_{2.5}$ level were found in K06, K13, and K14 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.

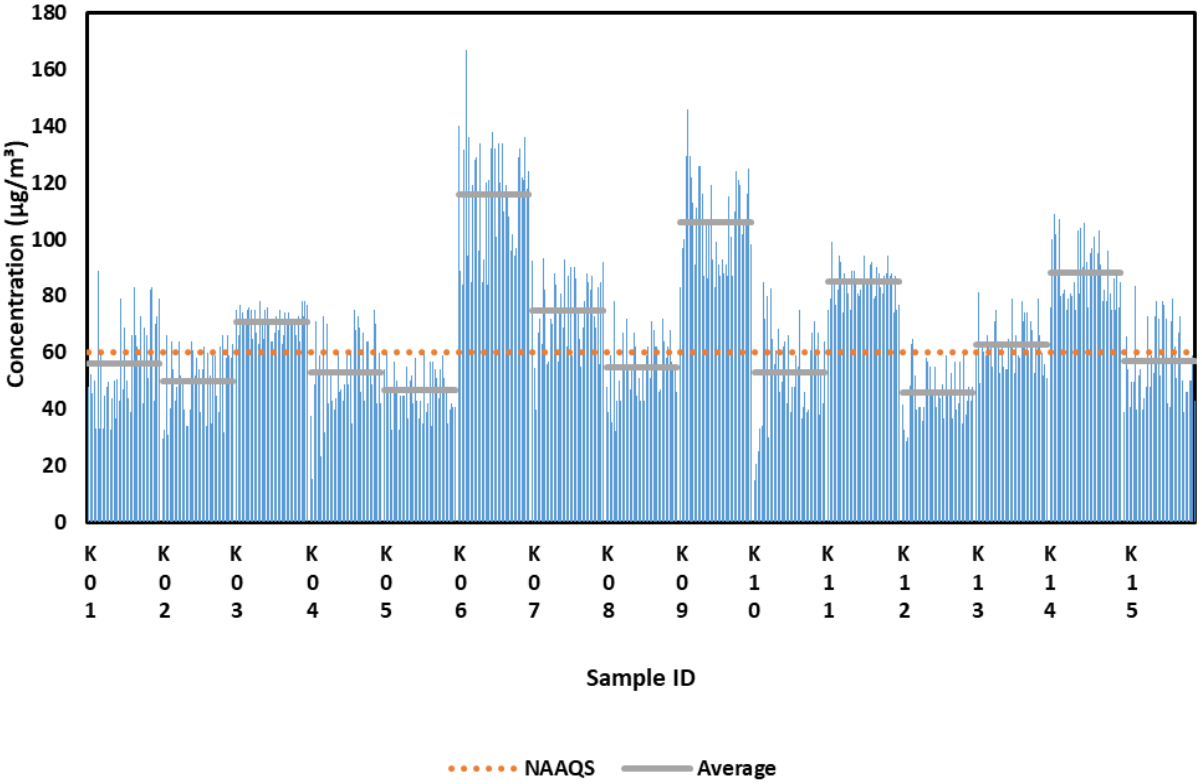


Figure 2.27: Concentration of $PM_{2.5}$ in summer season.

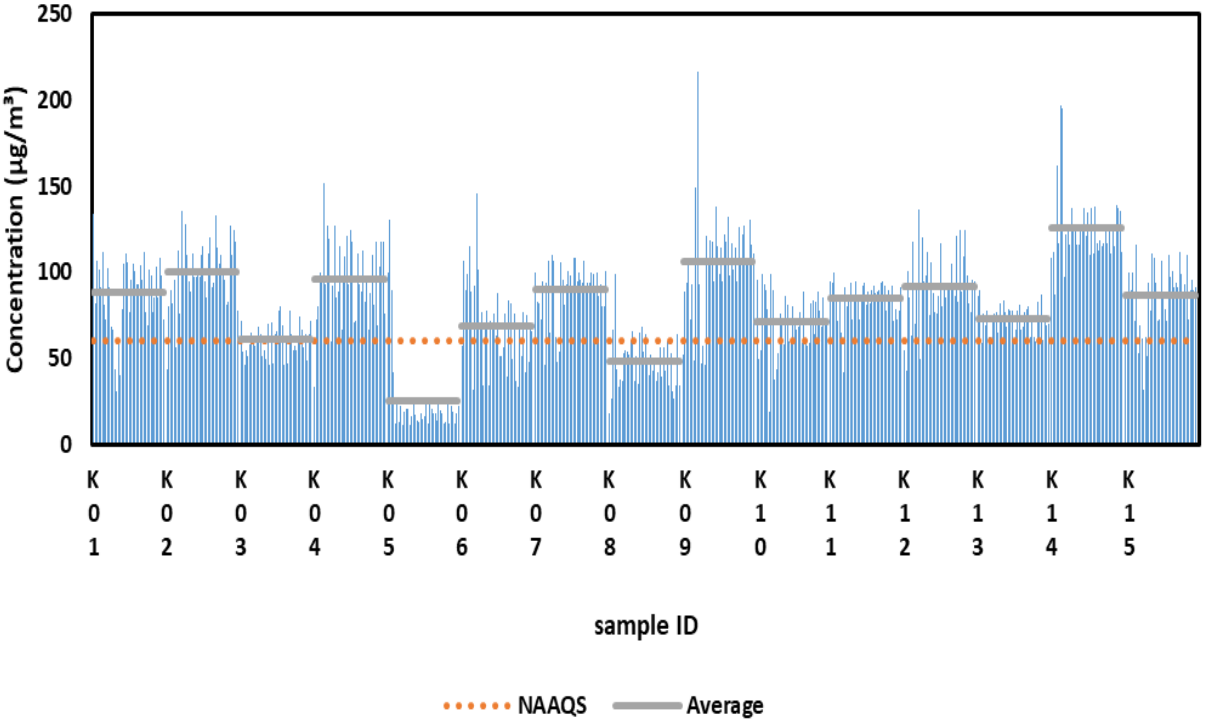


Figure 2.28: Concentration of $PM_{2.5}$ in pre/post monsoon season.

2.3.3.3 SO_2 Variation in Different Season

Air sample collected from different season in Korba for SO_2 as shown in Figure 2.29 to 2.31 .as we can see all SO_2 values are within the limit that is 80 µg/m³ but station shows the high value of SO_2 which are K06 and K13 that is mainly because of wood industry and other industries. As we know the main reason for SO_2 high concentration is due to the burning of fossil fuel and also other industrial facilities. High concentration of SO_2 in air can cause a lot of problem to our skin like irritation and rashes and also it is very dangerous for our respiratory system. In the monsoon season we know that most of the dirt wiped out but in post monsoon season still we can see the value of SO_2 which again are in limit but the same station are showing highest peak and the reason are due to industries nearby or by ongoing construction taking at that moment. In winter it contribute more SO_2 generation as we know it has lowest temperature so people burn many more wood or coal and more tea stall and food stall use often use these coal for selling their food item .so more the burning of these fossil fuels more generation of SO_2 in figure also we can see the highest values are found in winter season as compare to the others.

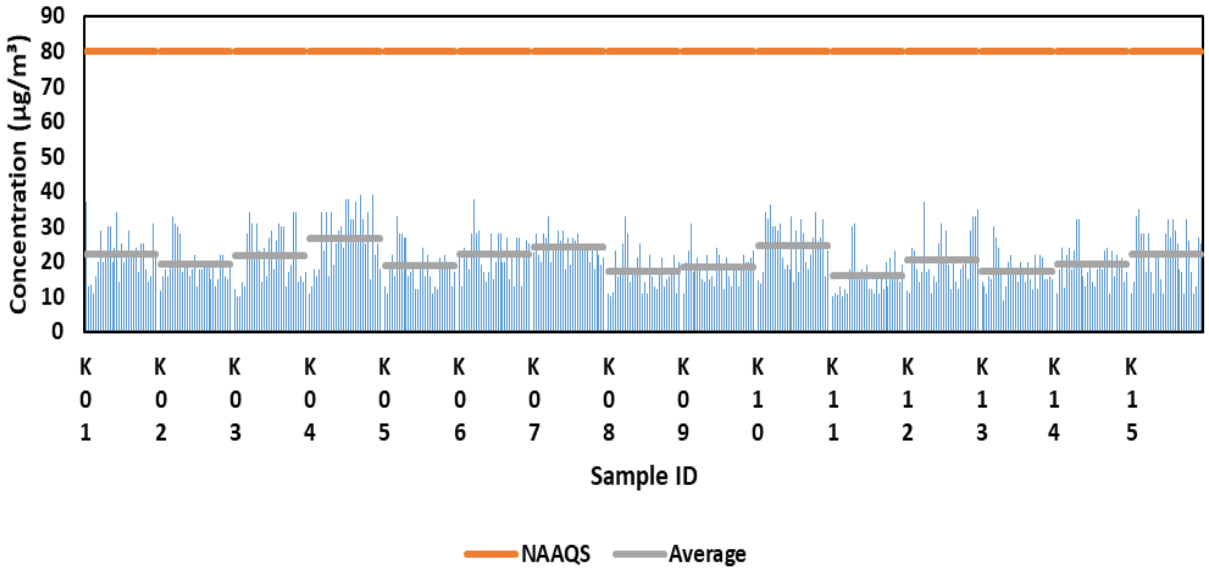


Figure 2.29: Concentration of SO_2 in winter season.

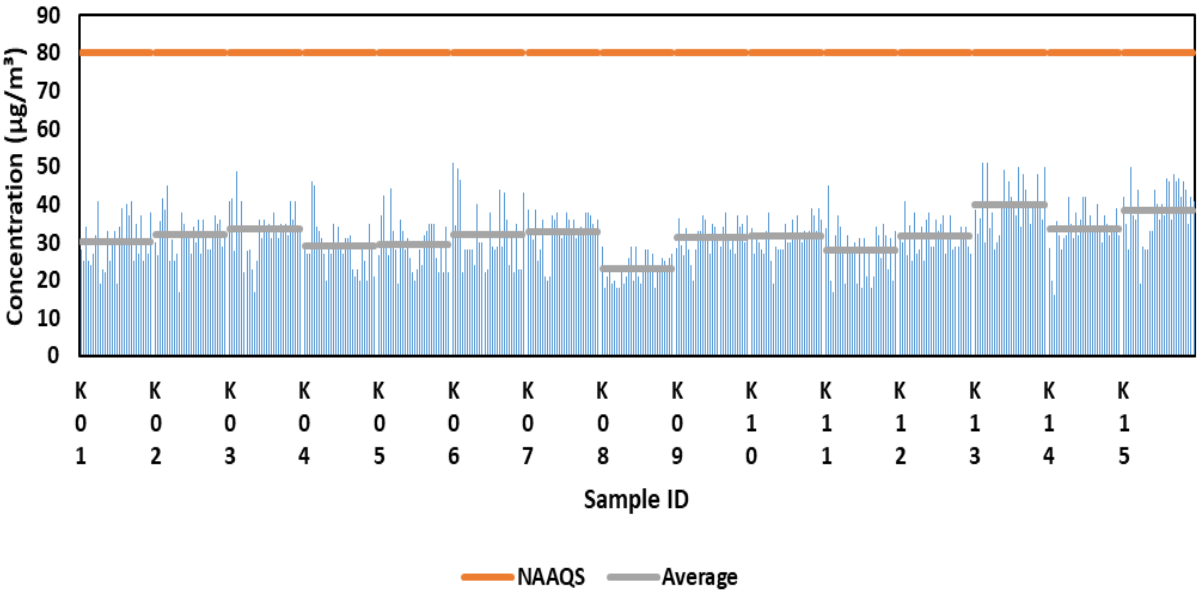


Figure 2.30: Concentration of SO_2 in summer season.

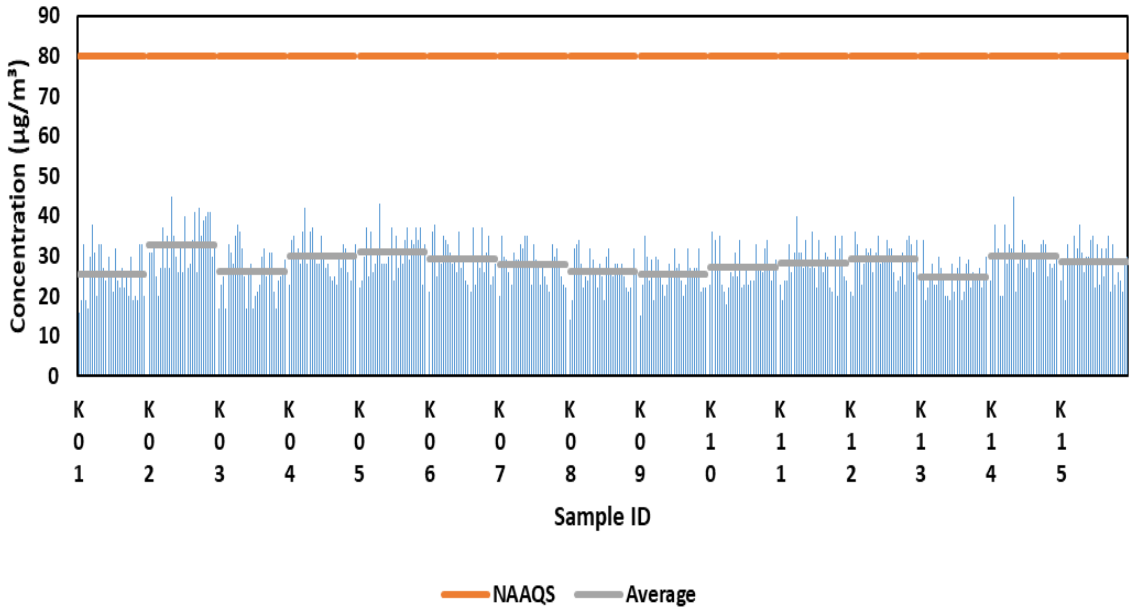


Figure 2.31: Concentration of SO_2 in pre/post-monsoon season.

2.3.3.4 NO_2 Variation in Different Season

Air sample collected from 16 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 K06 K04, and K13 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 vehicles, power plant and industrial emission etc. The high value of NO_2 can cause asthma and respiratory problem. From the fig we can easily see the highest concentration were found in K07 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. In the monsoon season we know that most of the dirt wiped out but in post monsoon season but still here we can see the value of NO_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.

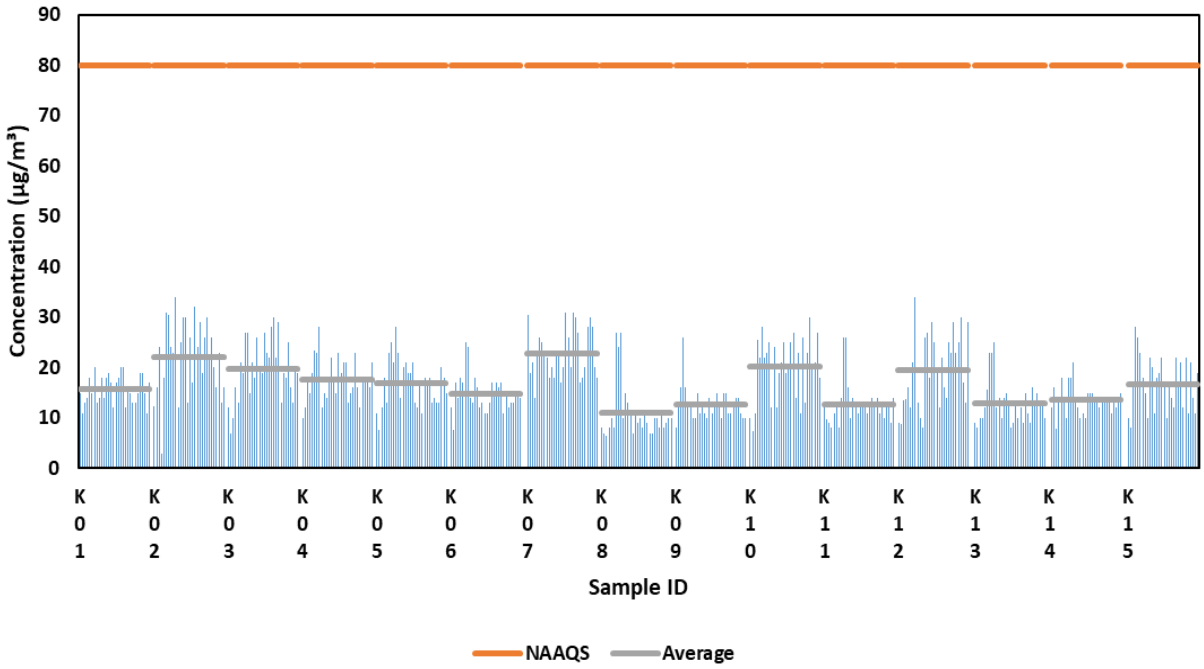


Figure 2.32: Concentration of NO_2 in winter season.

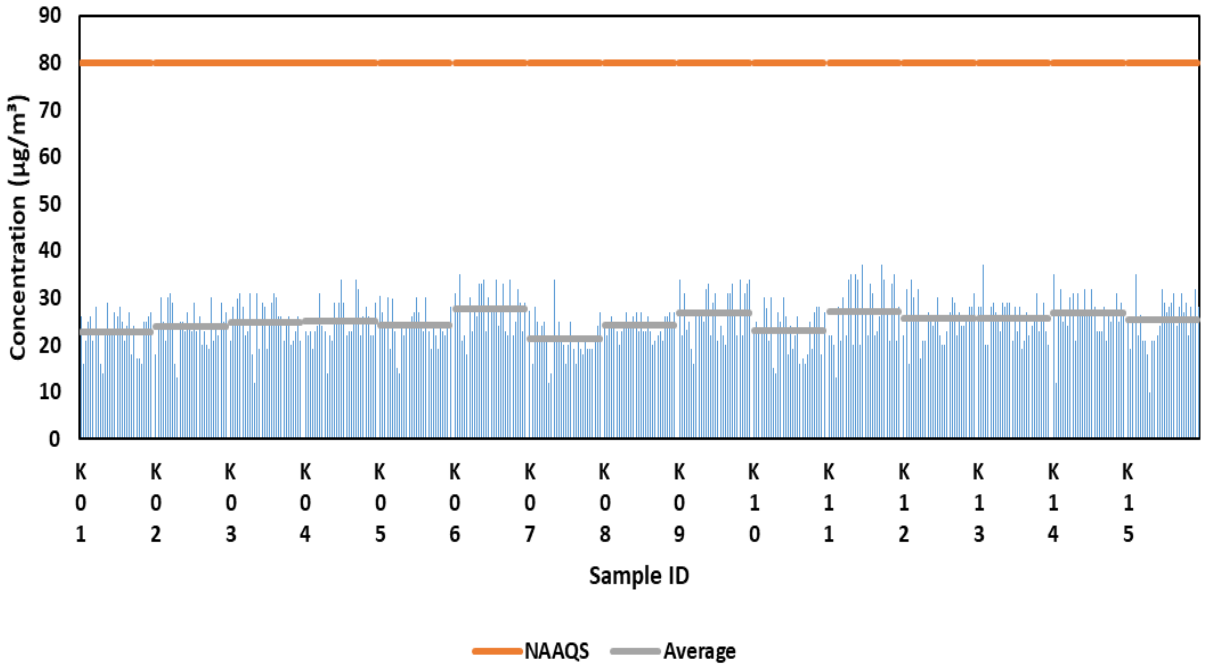


Figure 2.33: Concentration of NO_2 in summer season.

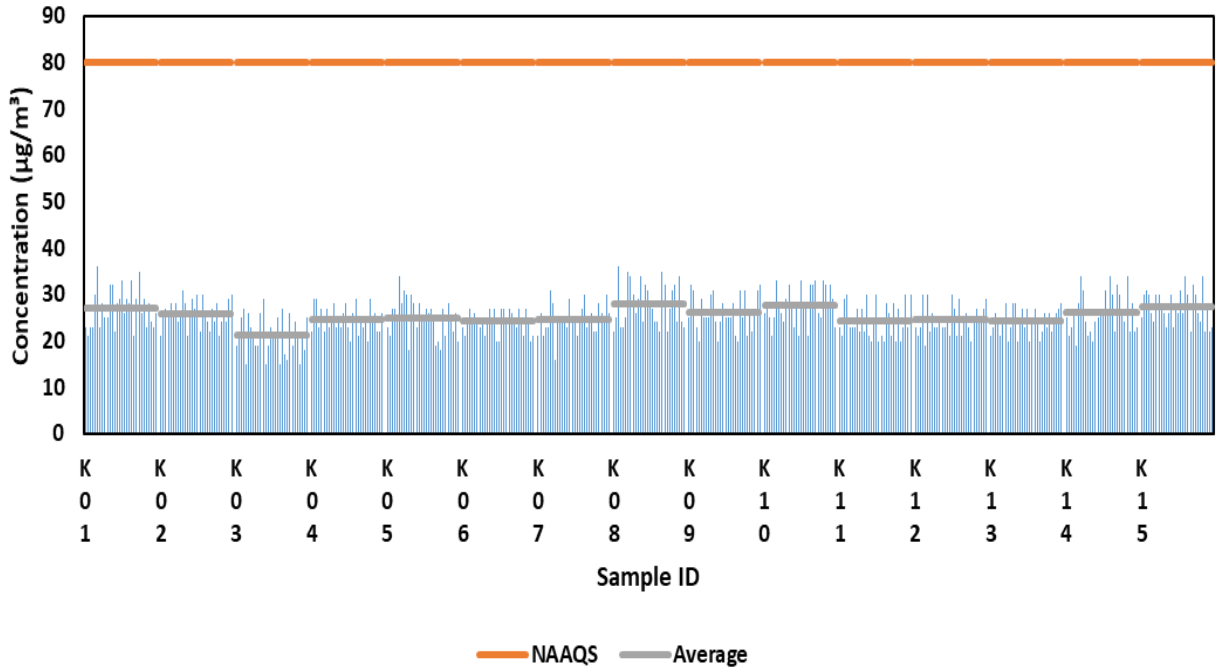


Figure 2.34: Concentration of NO_2 in pre/post monsoon season.

2.3.3.5 NH_3 Variation in Different Season

Air sample collected from 15 stations and as we can see fig highest concentration were found in K01, K03, K15 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 by-product of agriculture and industry. High concentration of ammonia can cause burning of nose throat and it is also effect the respiratory system. The highest concentration of ammonia in winter were found in K03, K12, K13 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 results in generation of ammonia. from the above fig we can note that the highest concentration was found in K01, K11 it's mainly because of nearby sources that is nearby site of industries and as it produces by-products which result in generation of ammonia.

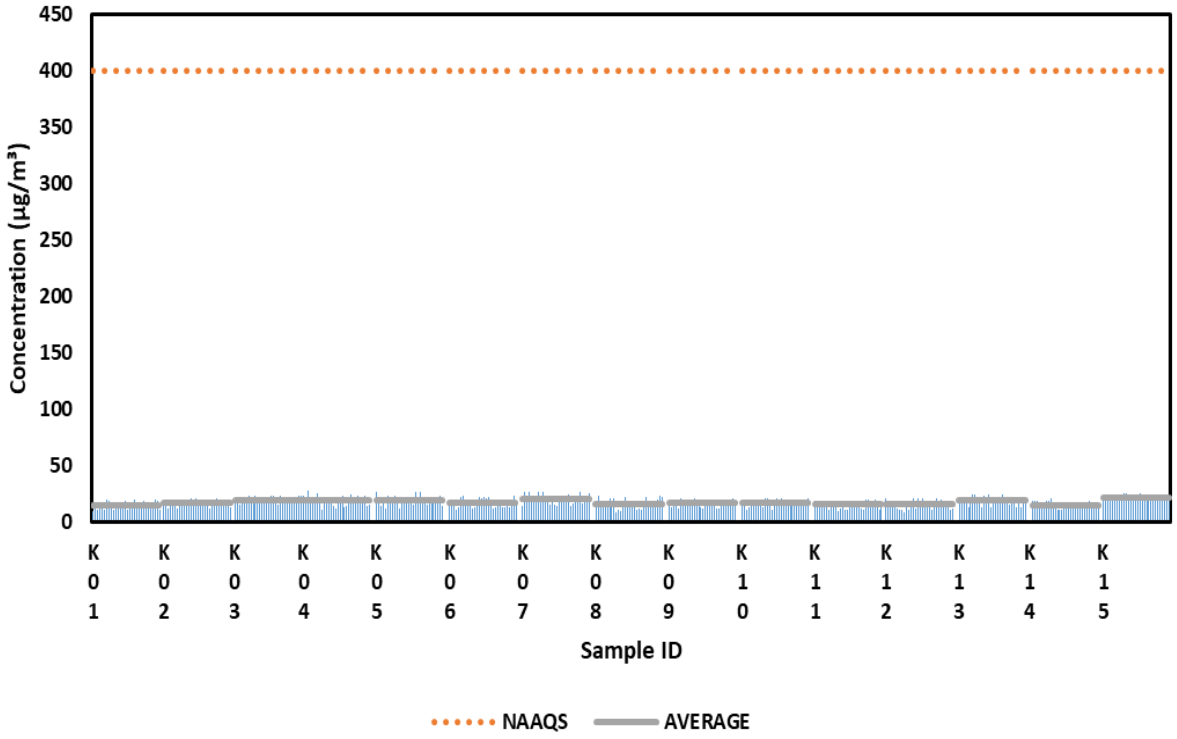


Figure 2.35: Concentration of NH_3 in winter season

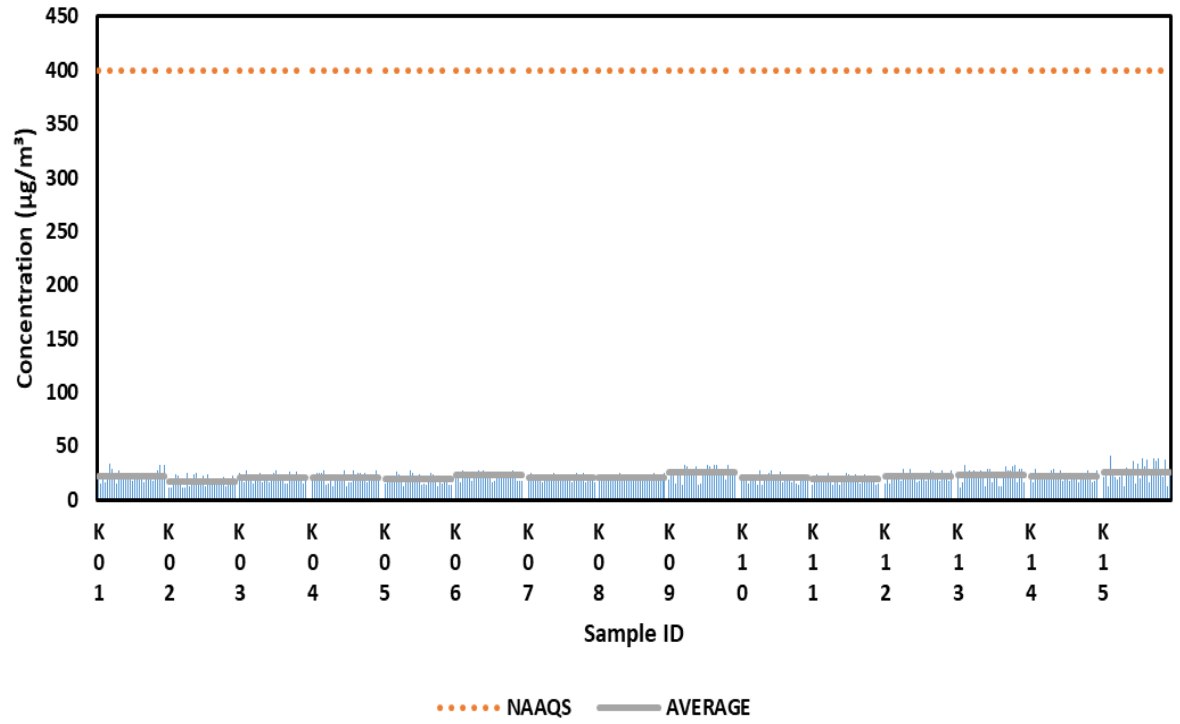


Figure 2.36: Concentration of NH_3 in summer season.

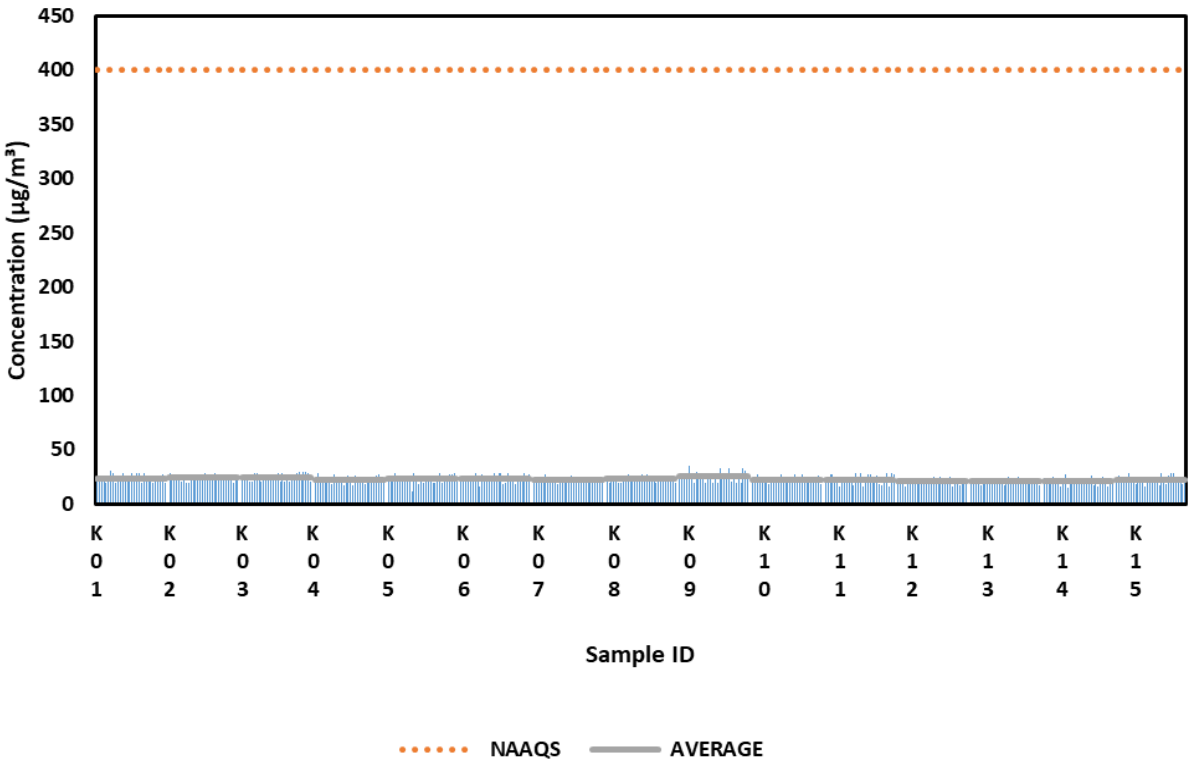


Figure 2.37: Concentration of NH3 in pre/post monsoon season

2.3.3.6 O_3 Variation in Different Season

Air sample collected from 15 stations in Korba in which some shows high concentration of ozone K03, K06, K15 and the main reason could be nearby industries and the heavy traffic in those areas as the generation of ozone is mainly because of car, power plant, refineries, chemical plant. High concentration of ozone can cause irritation in eyes, respiratory and heart problem. And also shortness of breath, chest pain, wheezing. High concentration of ozone in winter were found in K07, K11 and K14 the reason could be heavy 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. Post monsoon air sample collected from 10 stations as the other two stations are stopped at that time. The values in post monsoon season are less as compare to the summer season. That is due the rain has already wiped out the pollutant and the temperature is also low. The highest concentration was found in K05, K06 the reason could be the traffic and nearby industrial areas.

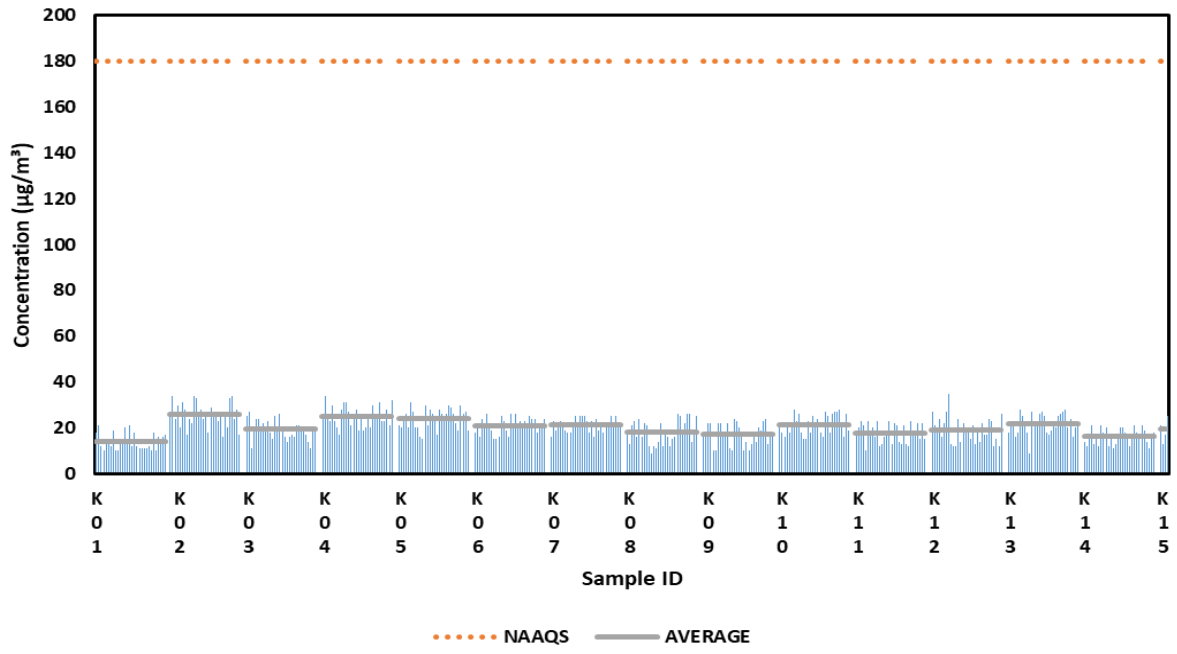


Figure 2.38: Concentration of O_3 in winter season.

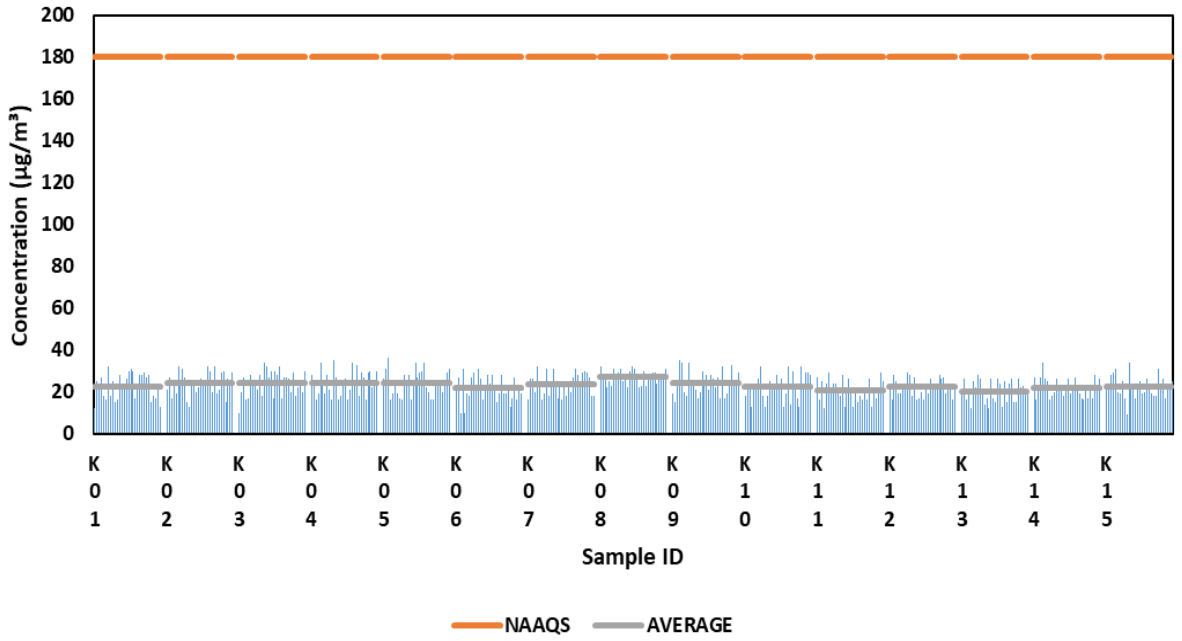


Figure 2.39: Concentration of O_3 in summer season.

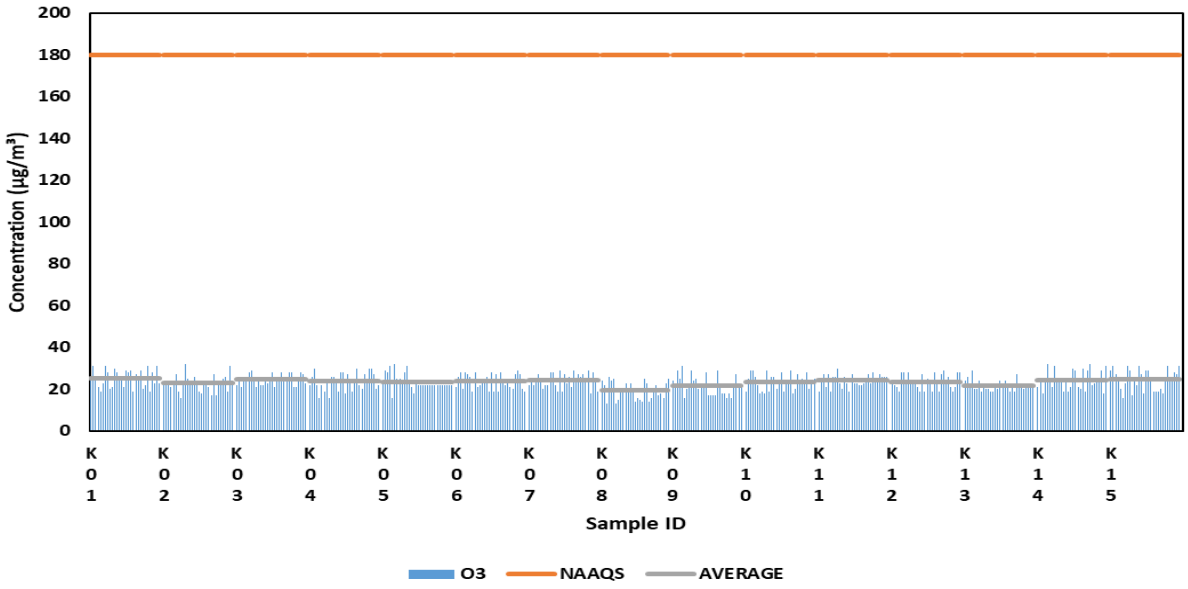


Figure 2.40: Concentration of O_3 in pre/post monsoon season.

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 $\mu g/m^3$ and this was used for estimating the **Total Assimilative Capacity**, by multiplying with the volume of air available for dispersion in each grid. The difference between the maximum permissible concentration/load of PM_{10} i.e. Total Assimilative Capacity and the existing average PM_{10} concentration/ load i.e. Existing Pollution Load gives an indication of the **Supportive Carrying Capacity** of an area available for sustaining the operation of additional air polluting activities. The positive values shows the capacity to accommodate additional pollution load and the negative values indicate that the pollution load is in excess of the assimilative capacity of the area i.e. no additional pollution load can be accommodated and measures are required to bring the pollution load within the assimilative capacity.

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

Total area of Korba district: a $(km)^2$
Average Atmospheric Mixing Height during a particular month: b (km)
Total Volume of Air in Korba district during a particular month: a x b = c $(km)^3$
Average PM_{10} concentration of Ambient Air in Korba district for a particular month = d (kg/km^3)
Therefore, Total estimated load of particulate matter (PM_{10}) in ambient air of Korba district during a particular month (x): c x d = e (kg)

There is continuous/manual ambient air quality monitoring station operational in Korba district. So, the ambient air quality data has been taken from Korba 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

Korba and as per the CPCB guideline we have excluded the monsoon month (July, Aug., Sep.). Estimated total existing PM_{10} Load in Korba during different months of year 2021 and 2022 is given at Table 2.13.

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

Sl. No.	Month	Estimated load (PM_{10}) (kg)
1	October 2021	226724.19
2	November 2021	290746.09
3	December 2021	257400.05
4	January 2022	202596.47
5	February 2022	225154.33
6	March 2022	248843.62
7	April 2022	251742.91
8	May 2022	260652.91
9	June 2022	233686.01
10	Oct-22	186668.78
11	Nov-22	259281.05
12	Dec-22	444085.8
13	Jan-23	361703.64

[Area of Korba District adopted from District Korba website https://Korba.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 Korba 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 $\mu g/m^3$ i.e. 100 Kg /km^3 (Ref: Air Quality Index/NAAQ Std.)

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

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

Table 2.14: Assimilative carrying capacity in Korba.

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
10	Oct-22	120214.31
11	Nov-22	127285.74
12	Dec-22	141428.6
13	Jan-23	106071.45

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

Month wise supportive carrying capacity of Korba 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 Korba.

Sl. No.	Month	Supportive Carrying Capacity (Kg)
1	October 2021	-106509.88
2	November 2021	-163460.35
3	December 2021	-115971.45
4	January 2022	-96525.02
5	February 2022	-112011.45
6	March 2022	-128629.31
7	April 2022	-110314.31
8	May 2022	-126295.74
9	June 2022	-127614.56
10	Oct-22	-66454.47
11	Nov-22	-131998.31
12	Dec-22	-302657.2
13	Jan-23	-255632.19

Table 2.16: Carrying capacity assessment of Korba 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	188.6	579.7	120214.31	226724.19	-106509.88
2	Nov-21	706.86	1800	1.8	228.42	613.8	127285.74	290746.09	-163460.35
3	Dec-21	706.86	2000	2.0	182	682.0	141428.6	257400.05	-115971.45
4	Jan-22	706.86	1500	1.5	191	511.5	106071.45	202596.47	-96525.02
5	Feb-22	706.86	1600	1.6	199	545.6	113142.88	225154.33	-112011.45
6	Mar-22	706.86	1700	1.7	207	579.7	120214.31	248843.62	-128629.31
7	Apr-22	706.86	2000	2.0	178	682.0	141428.6	251742.91	-110314.31
8	May-22	706.86	1900	1.9	194	647.9	134357.17	260652.91	-126295.74
9	Jun-22	706.86	1500	1.5	220.31	511.5	106071.45	233686.01	-127614.56
10	Oct-22	706.86	1700	1.7	155.28	579.7	120214.31	186668.78	-66454.47
11	Nov-22	706.86	1800	1.8	203.70	613.8	127285.74	259281.05	-131998.31
12	Dec-22	706.86	2000	2.0	314	682.0	141428.6	444085.8	-302657.2
13	Jan-23	706.86	1500	1.5	341	511.5	106071.45	361703.64	-255632.19

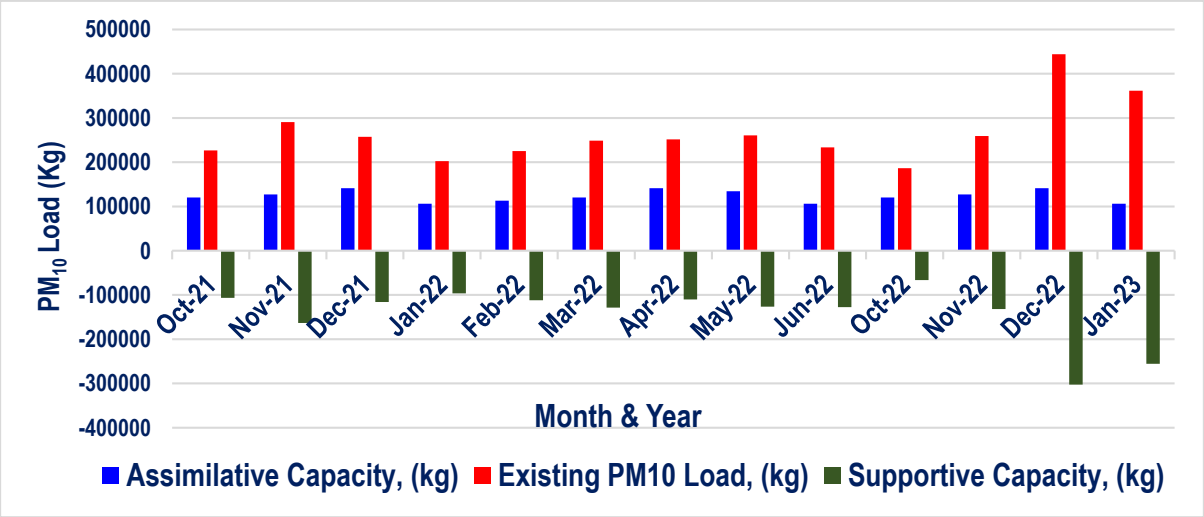


Figure 2.41: Month wise load capacity of PM_{10}.

The final outcome of the assessment with regard to the range of Supportive Carrying Capacity of the ambient air environment in Korba is summarized in the Table 2.16. 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 Korba with respect to $PM_{2.5}$.

Sr. No.	Month & Year	Area (km^2)	Mixing height, (m)	Mixing height, (km)	Avg. $PM_{2.5}$ Conc. ($\mu g/m^3$)	Volume of Ambient Air, (km^3)	Assimilative Capacity, (kg)	Existing $PM_{2.5}$ Load (kg)	Supportive Capacity, (kg)
1	Oct-21	706.86	1700	1.7	66	579.7	72128.59	79341.44	-7212.85
2	Nov-21	706.86	1800	1.8	65	613.8	76371.44	82735.73	-6364.29
3	Dec-21	706.86	2000	2	54	682	84857.16	76371.44	8485.72
4	Jan-22	706.86	1500	1.5	55	511.5	63642.87	58339.3	5303.57
5	Feb-22	706.86	1600	1.6	62	545.6	67885.73	70148.59	-2262.86
6	Mar-22	706.86	1700	1.7	54	579.7	72128.59	64915.73	7212.85
7	Apr-22	706.86	2000	2	71	682	84857.16	100414.31	-15557.15
8	May-22	706.86	1900	1.9	67	647.9	80614.3	90019.3	-9404.99
9	Jun-22	706.86	1500	1.5	63	511.5	63642.87	66825.01	-3182.14
10	Oct-22	706.86	1700	1.7	82	579.7	72128.59	98575.73	-26447.14
11	Nov-22	706.86	1800	1.8	106	613.8	76371.44	134922.88	-58551.44

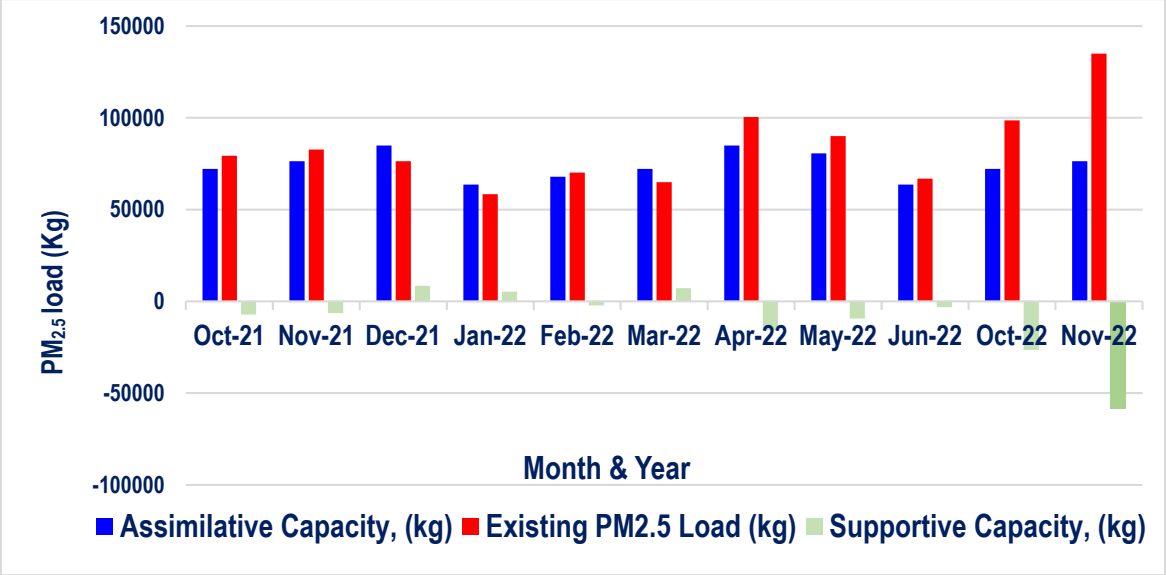


Figure 2.42: Month wise load capacity of $PM_{2.5}$.

The final outcome of the assessment with regard to the range of Supportive Carrying Capacity of the ambient air environment in Korba, 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 2.10.

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

Korba	$PM_{2.5}$			PM_{10}		
	Pre and post monsoon	Summer	Winter	Pre and post monsoon	Summer	Winter
Max	217	166.66	110.43	491	630.13	566
Min	11	15	17.82	34	43.77	32
Average	81	68	56	187	219	191
STDV	31	25	16	78	112	80
mean	81.18	68.00	55.63	186.92	219.49	191
CV	0.38	0.36	0.28	0.42	0.51	0.42

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

Korba	SO_2			NO_2		
	Pre and post monsoon	**Summer**	**Winter**	**Pre and post monsoon**	**Summer**	**Winter**
Max	45	51.206	39	36	37	34
Min	14	16	9	15	10	3
Average	28	32	21	25	25	17
STDV	5	7	7	4	5	6
mean	28.118	31.838	21	25.409	24.935	17
CV	0.20	0.22	0.33	0.15	0.19	0.37

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

Korba	NH_3			O_3		
	Pre and post monsoon	**Summer**	**Winter**	**Pre and post monsoon**	**Summer**	**Winter**
Max	35	40.985	28	32	36	35
Min	12	11.059	8	13	9	9
Average	22.971	23.255	17.380	23.469	23.107	20.1
STDV	3.443	5.668	3.986	3.965	5.484	5.316
mean	22.971	23.255	17.380	23.469	23.107	20.1
CV	0.149	0.244	0.229	0.169	0.237	0.264

2.3.6 Carbon impact on environment in Korba

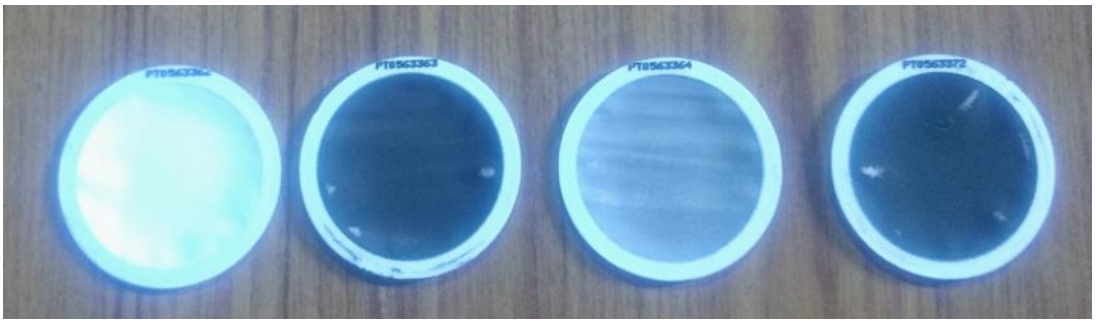


Figure 2.43: Collected $PM_{2.5}$ samples from Korba sampling stations.

Korba is a meaningful mining area and exerts significant role on Indian economy. We have selected 16 air quality monitoring stations within the geographical circumstances of Korba. All those stations are situated within human dwelling areas so that, we can properly study the effects of mining, coal as well as fuel burning, improper agricultural activities, industrial and traffic hazardous on Korba population. All these 16 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 analysed according to CPCB predicted protocols (TOR / TOT method, see section 2.2.11). We have found OC values ranges from 0.32 µg/m³ to 0.77 µg/m³ among all air quality monitoring stations. Similarly, we have found TC values ranging from 0.38 µg/m³ to 0.89 µg/m³ among all air quality monitoring stations. Carbonaceous compounds are mainly organic or house hold type in Korba non-industrial as well as non-traffic stations.

2.3.7 Seasonal VOCs Variation

We have selected 15 sampling stations in Korba district of Chhattisgarh. Out of those 15 sampling stations only 3 stations are agricultural and 2 stations are silent. So these stations should be free from any type of pollution. Other stations are industrial, traffic and mixed type. We have collected ambient air sample through activated charcoal tube fitted with VOC-sampler and then they are analysed in dissolved organic form through GC (detailed procedure has been mentioned in the method section). We have collected air samples in winter and summer seasons. VOCs values are increasing in summer than found in winter. VOCs values are under limit at the sampling stations K01 to K07 and K14 but values are high in the industrial and traffic areas (sampling stations K08 to K13 and K15). Maximum resultant

VOCs value has been found at station no. K11 (28 µg/m^3) in summer season and K10-sampling station constantly bears high VOCs in every season.

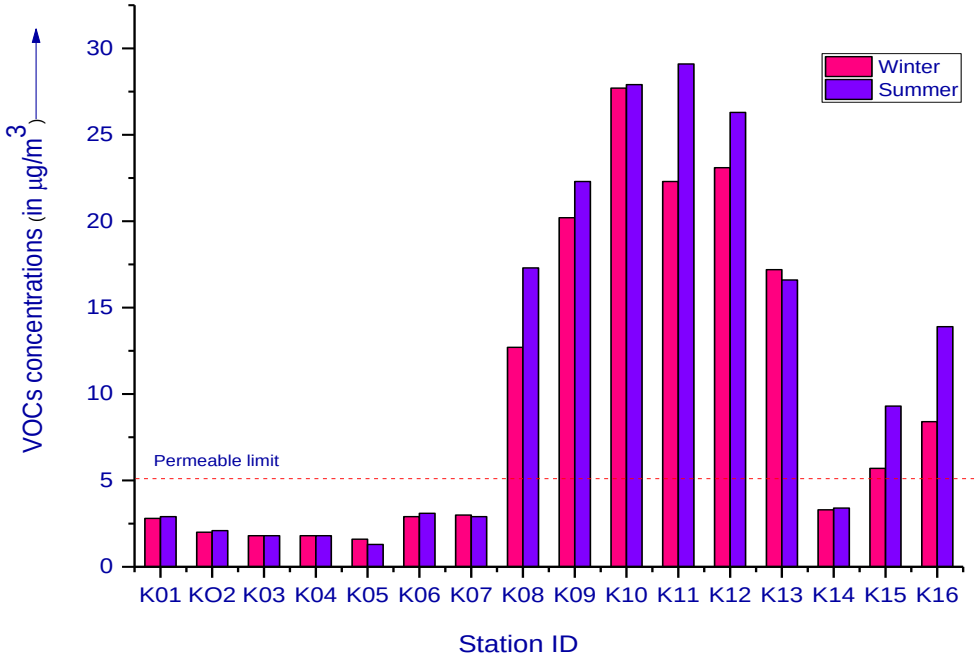


Figure 2.44: Seasonal variation of VOCs values in ambient air of Korba.

2.3.8 Quantification and Variation of PAHs in Ambient Air

We have prepared a Standard mixture solution (100ppb) of different markers (denoted by CPCB, India) with all following 16 components – naphthalene, acenapthylene, fluorene, phenantherene, anthracene, fluoranthene, phenylenepyrene, benzo(a) anthracene, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo (a) pyrene, benzo (e) pyrene, indeno (1,2,3-cd) pyrene, indeno (1,2,3-cd) fluoranthene, picene and diben (a,b) anthracene, respectively [Figure 2.45]. 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 are also screened through GC as above but we didn't find any compound in any sampling stations in Korba surroundings.

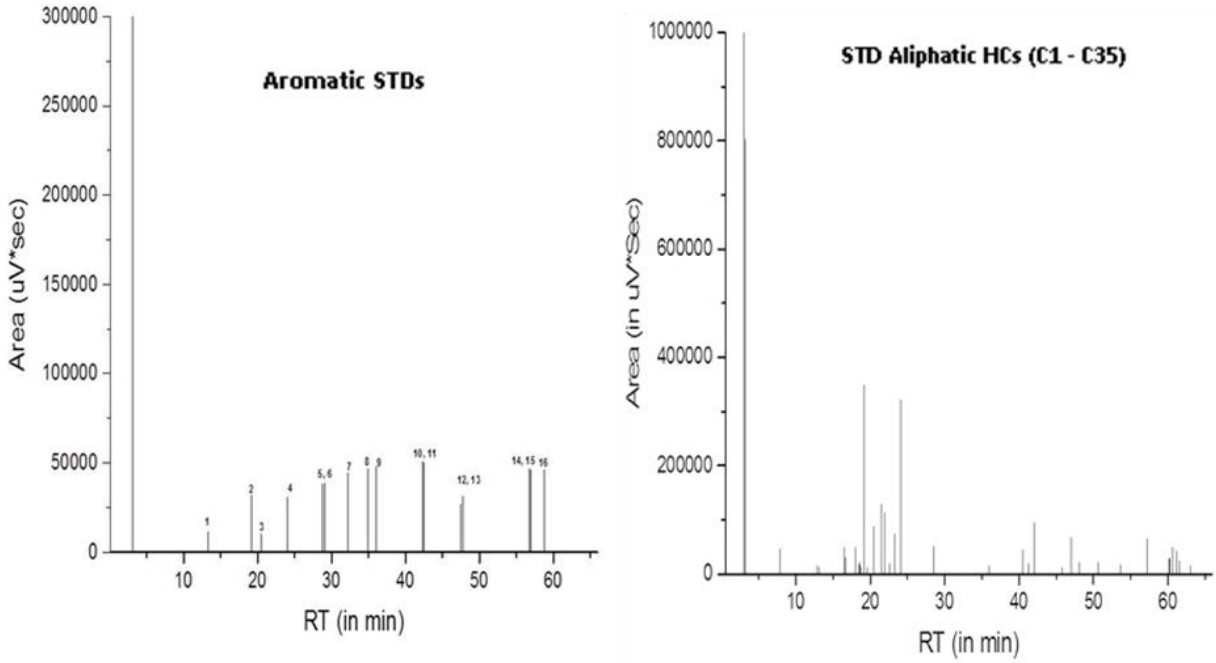


Figure 2.45: GC analysis of PAHs assay of different aliphatic (C1 to C35) and aromatic (16 selected compounds) standards hydrocarbons.

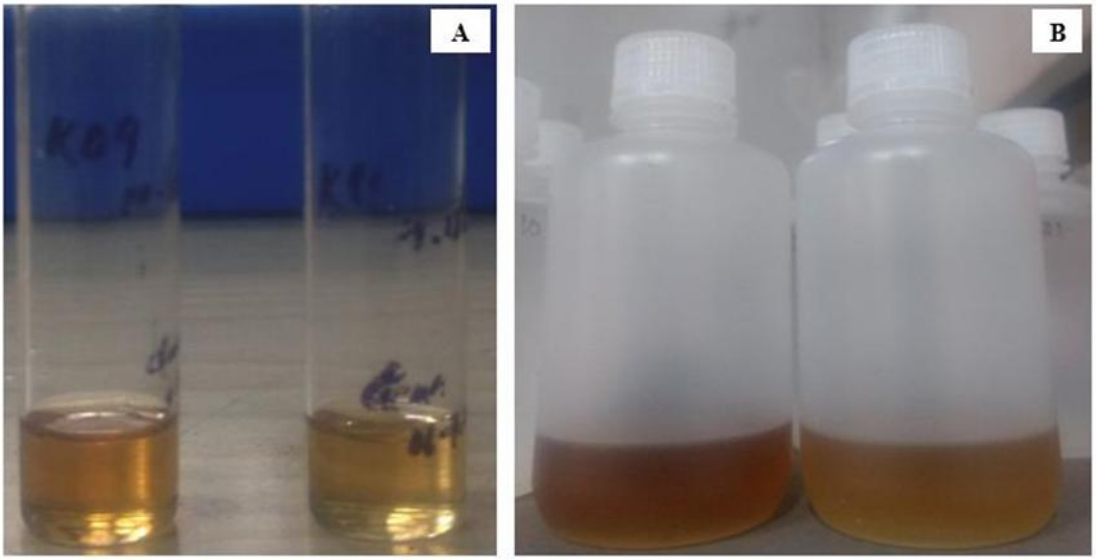


Figure 2.46: [**A**] Presence of PAHs in ambient air samples with their brownish appearance, [**B**] Concentration gradient with place variation in different air samples (PM_{10}).

Here in Figure 2.45, we have shown both standard aromatic and aliphatic hydrocarbons separately. All pure compounds were found with single separate peak as well as respective retention time. They all found with increasing molecular weight and thus increasing boiling point and time in chromatogram. All pure compounds found with certain area under the peak with same retention time (RT in min). Here, in Korba, we cannot identify any toxic or high-chain PAH, in rainy season. We have found only Fluorene, Fluoranthene, Benzo (a) pyerene and Indeno (1,2,3-cd) fluoranthene from every sampling stations, in very low concentration, during winter. Though amount of identified PAHs are beyond human toxic level (in 'ppt') but amount are increasing day by day. All extracted samples have left huge unidentified peaks and sometimes we have found Napthalene, Acenathene, Acenapthylene, Benzo(a)anthracene, Diben(a,b)anthracene as well. Here in Figure 2.47, we have figure out two cases of K09 and K11-sampling stations in Korba. Alkanes, alkenes and alkynes are combinedly known as aliphatic hydrocarbons (AHCs). AHCs trend in Korba and surrounding areas are generally non-harmful and maintained same components in every season except monsoon. Everywhere we have found Alkanes with carbon numbers like C1, C3, C8, C14, C16-C18 and C20 in very negligible amount (in 'ppt' level). In the sampling station K11, we have found 'n- Tritriacontane' ($C_{33}H_{68}$) [CPCB declared it as toxic component] and estimated concentration has been found 22.85 µg/m^3.

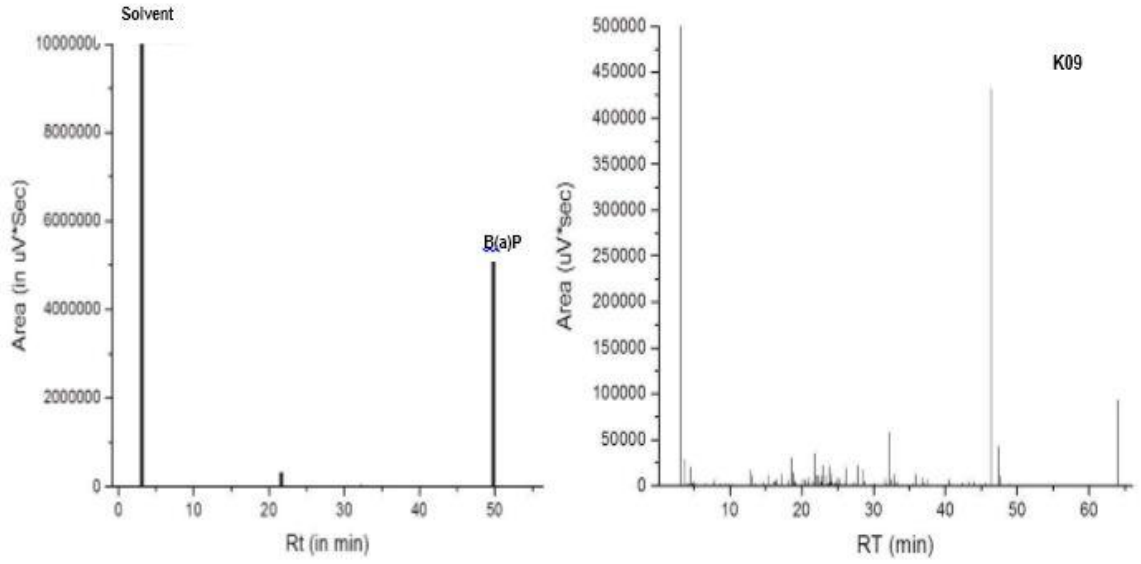


Figure 2.47: GC chromatograms have been found for standard B(a)P and air sample collected from K09 sampling station

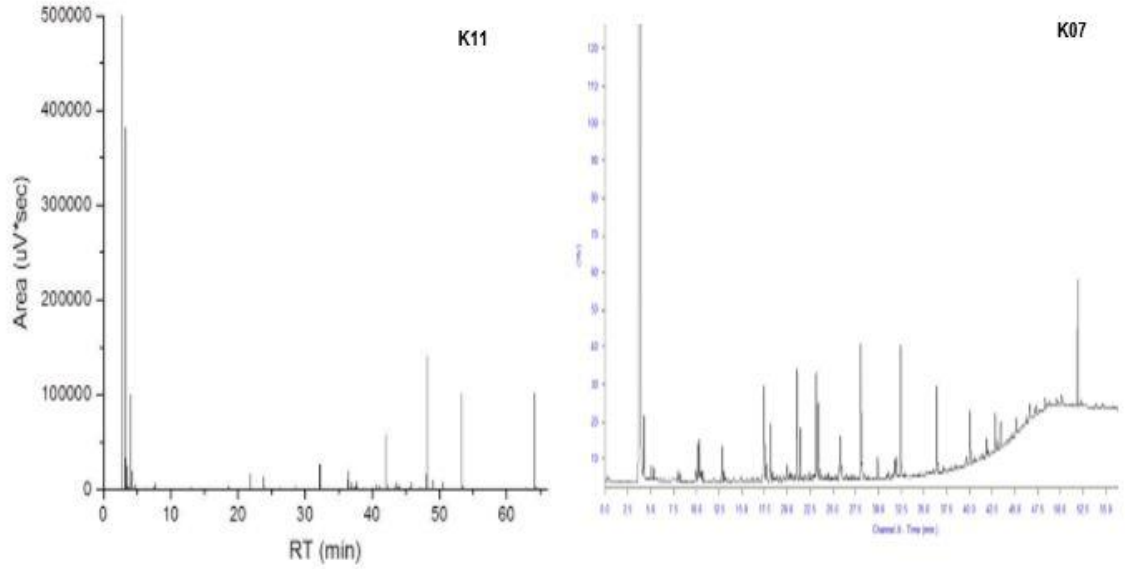


Figure 2.48: Different GC chromatogram found during GC analysis of PAHs assay

2.3.9 Metal Particulate Matters in the Ambient Air

In the ambient air samples collected from different sampling stations of Korba, we have found 'Cu', 'Cr', 'Cd', 'Fe', and 'As' in low amount and are below the limit but they are increasing day by day with change of seasons. 'Ni' has been found beyond the limit line and 'Pd' is about to cross the limit line. Toxic metal 'Hg' has not been found in the ambient air of Korba. Ambient air of Korba stations contain iron (Fe) and zinc (Zn) in high amount (Figure 2.49). Most important matter is that, every time and in every sampling station in Korba, we have found 'Pb' and 'As'. Though 'As' concentration is below limit as prescribed by CPCB, India (6ng/m^3) but sometimes 'Pb' goes beyond the limit and has reached maximum 1.476 µg/m^3 at station KO1 in summer.

Among all detectable metals, there is some randomness in particulate matters' concentration. Any time they are increasing and decreasing. There is no such trend or systematic way. The sampling stations like; K09, K11, K12 and K13 are in danger for high particulate metal concentrations. 'Ni' and 'Pb' metals concentrations are always high in every season and in every station. Abundance of iron and zinc in the ambient air don't affect much on living ecosystem but 'Pb' and 'Ni' do. Nickel, is a transitional element and concentration in atmosphere may increase for unscientific, unplanned mining process and use of liquid as well as solid fuels. Mitochondrial dysfunction, oxidative stress, genotoxicity, carcinogenicity and various metabolic abnormalities are reported as 'Ni' and 'Pb' related toxicity.

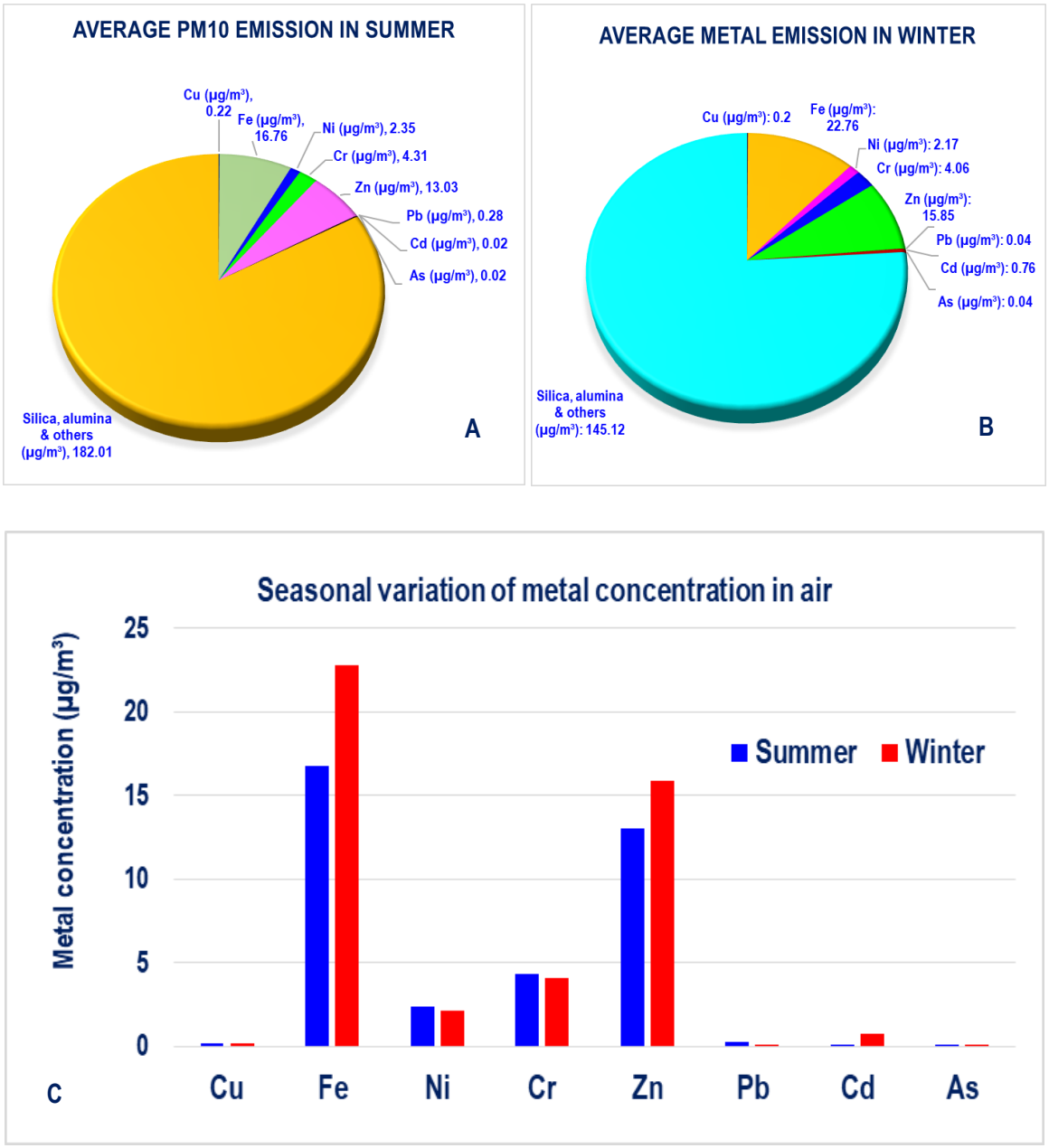


Figure 2.49: [A], [B] Mean metals concentrations (µg/m³) in the ambient air samples of Korba and [C] their individual concentration (µg/m³) variation with seasons.

2.2.10 Polyatomic Ions in Ambient Air

Polydentate anions are important in view of chemistry. These compounds can react with the heavy metal ions and make them stable or non-reactive form. But the higher concentration of poly-atomic ions may lead to toxic effect for local people and ecosystem. Sulphate ion is responsible for acidification and may cause acid rain to damage local ecosystem. In Figure 2.50, mean percentile plot represents the actual environmental condition at Korba. Sulphate anion concentration reaches to 41%, nitrate

concentration reaches to 20% and chloride percentage reaches to 38% in winter. Mainly these three anions occupied whole section and Korba is under chloride toxicity. In summer, sulphate ion concentration in ambient air increases to 49%, nitrate anion concentration increases by 1% and chloride ion concentration decreases by 8%.

Korba is a mining area and chlorine may also evolve as underground gas. So there must be some precaution or steps to prevent such underground gas emission. Chlorine is a micronutrient, essential for plant growth. However, too much chlorine can accumulate in leaf tissue, resulting in leaves with a scorched or burned appearance. Leaves may become smaller than usual and may be yellow and dropped early. Chlorine toxicity can result from air pollution, in the form of chlorine gas, or from excess chloride in the soil and soil becomes dry. High chlorine gas or chloride ion may damage 'ozone layer' which protects earth from harmful ultra-violet radiation.

Inhalation of high chlorine gas can cause severe health problems and sometime death. Chloride levels can be reduced or controlled with the use of gypsum. Incorporate gypsum into the soil at a rate of about 50 lbs. per 1000 square feet, in loam soils. Less gypsum is needed in sandy soils, more in heavy clay soils. Water spry may reduce the toxic levels of chlorine from soil. But from human body toxicity relief may not possible after certain age.

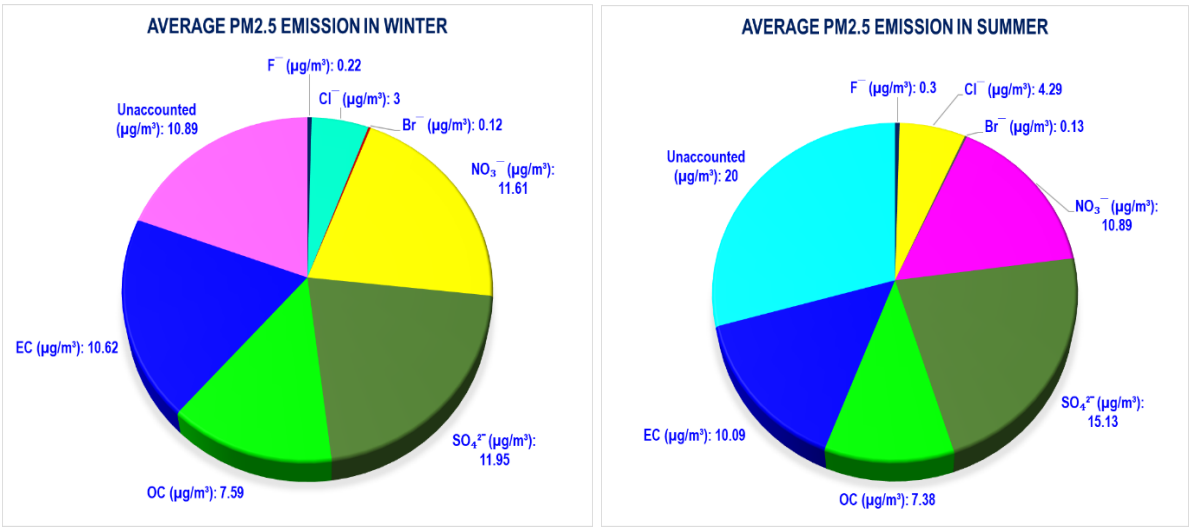


Figure 2.50: Polydentate ligands present (µg/m³) in ambient air sample of Korba surrounding areas.

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 Korba.

Sl. No.	Name of the Company	DATE	Location	Lat long.	Flow rate LPM	Time (Min)	SPM (µg/m^3)
1	BALCO		Unit3 1200Mw		24.70	30	27.67
			Unit I & II 1200 Mw		16.70	30	30.94
2	DSPM or CSPGCL(E)		CPP 540 Mw		17.13	30	24.91
			Unit II 250Mw		22.04	30	22.77
			Unit I		19.90	30	50.75
			Unit I B		19.00	30	44.39
3	LANCO		Unit I A 300 Mw		29.50	30	30.84
			Unit I B		18.12	30	39.73
			Unit II		16.99	30	34.53
4	HTPs KORBA	8.04.2022	Stack-II 210 MW(3&4)	22.4117976 82.6883849	19.00	30	29.82
		8.04.2022	Stack III 500 MW pass-3	22.4104889 82.6859490	27.00	30	66.66

2.3.12 Real Time Monitoring Data

HCHO level in all the station are within the upper limit of HCHO is 0.1 ppm above that limit human can many difficulties like burning sensation, watery eyes etc. High concentration of H_2S gas is also hazardous it is extremely poisonous to human corrosive and very flammable. Here H_2S level is low in all the station and is found below detectable level of instrument. From the Figure 2.51 we can clearly note that the highest CO_2 levels were found in KO2, KO6, KO9 and K11. 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.

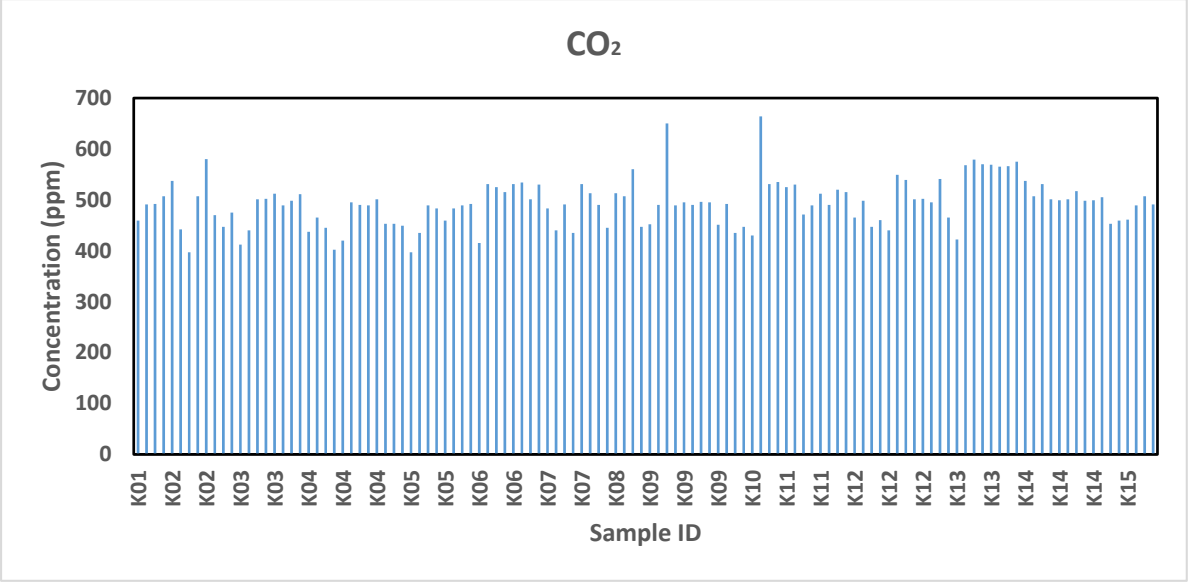


Figure 2.51: CO_2 concentration (ppm) found using online monitoring system in Korba.

2.3.13 Air Quality Modelling

2.3.13.1 Windrose Plot

It can be observed in Figure 2.52 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 Korba 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. The output files surface met data and profile met data are directly imported into the AERMOD to compile the model. These files included data of all the surface and upper-air parameters of the year 2022.

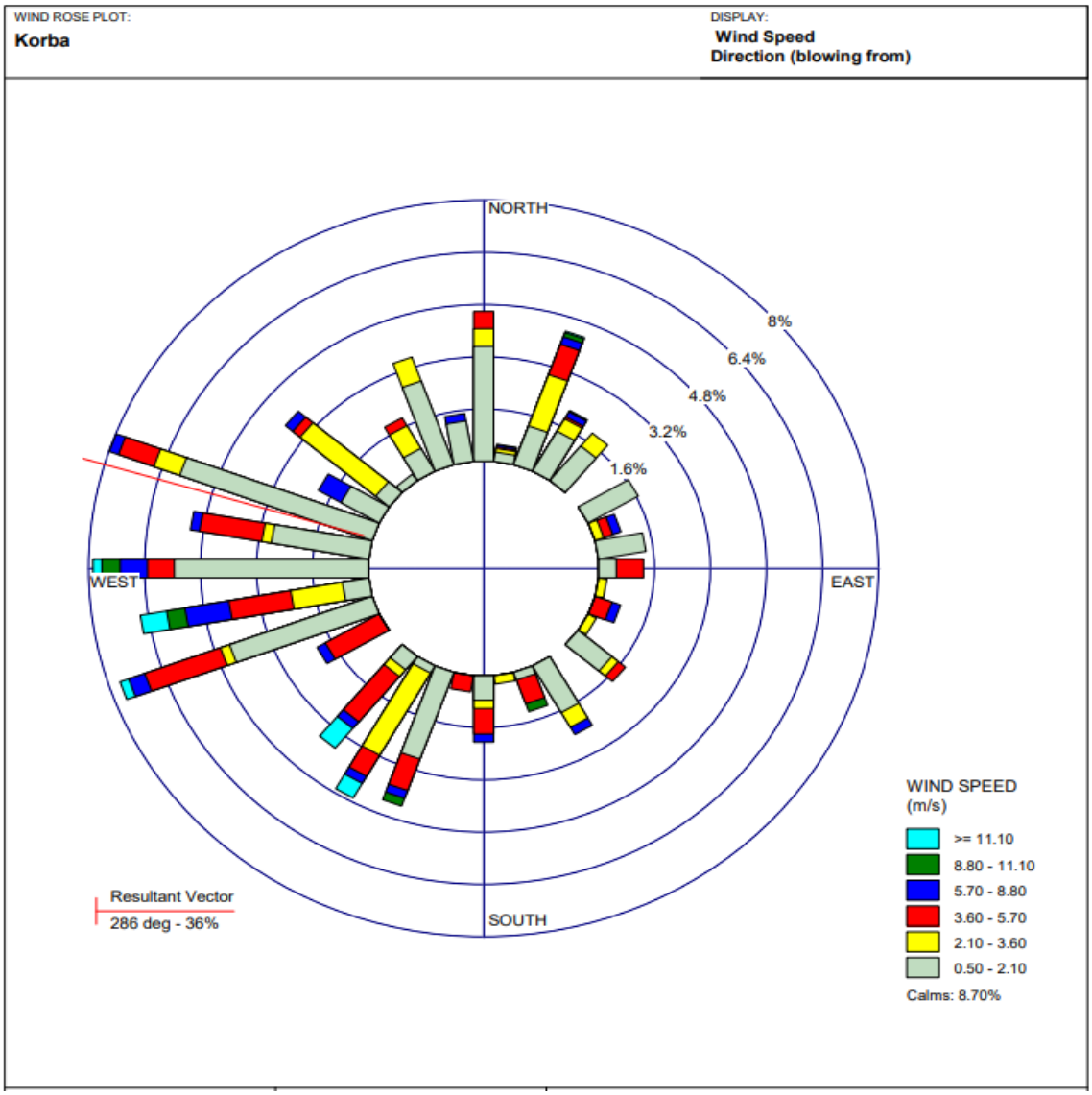


Figure 2.52: Windrose diagram for Korba.

2.3.13.2 Concentration Dispersion Isopleths

AERMOD air quality dispersion model was performed to predict the concentration of SO_2, NOx, SPM, CO, and HC surrounding the industrial area of Korba, Chhattisgarh. 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 5 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 Korba monitoring station for the period Jan 2022 – Dec 2022. The industries and plants are classified into different types namely Hasdeo Thermal Power, DSPM thermal Power Stations, Aluminium company. 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 Bharat Aluminium Company Ltd. zone (North latitude 22˚ 23' 13.978'', East longitude 82˚ 44' 13.876'') with maximum concentration 24-h obtained as 125.79 µg/m3. SO_2 hotspot are obtained as Ajgar Bahar and Santrenga (North latitude 22˚ 23' 46.861'', East longitude 82˚ 44' 7.4'') zone with maximum concentration 24-h obtained 50.767 µg/m3. NOx hotspot found to be Bharat Aluminium Company Ltd. zone (North latitude 22˚ 23' 40.608'', East longitude 82˚ 44' 25.032'') with maximum concentration 24-h of 49.487 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 22.17 µg/m^3 with hotspot nearby Transport Nagar (North latitude 22˚ 21' 33.598'', East longitude 82˚ 42' 26.893''). Carbon monoxide (CO) hotspot found to Transport Nagar and Marapara (North latitude 22˚ 20' 57.419'', East longitude 82˚ 42' 7.117'') with maximum concentration 8-h of 1400.05 µg/m^3. NOx maximum concentration 24-h obtained as 48.49 µg/m^3 with hotspot at Transport Nagar Zone (North latitude 22˚ 21' 32.042'', East longitude 82˚ 42' 29.81''). Korba East Thermal Power Station (North latitude 22˚ 23' 2.168'', East longitude 82˚ 42' 59.893'') is hotspot due to hydrocarbon (HC) with concentration 24-h of 45.21 µg/m^3.

For **the area source modelling**, we have considered different garbage coal mining areas, South Eastern Coal fields, ash dykes, ash ponds in the Korba city. Here hotspot is found to be HS Rajgomar coal mines (North latitude 22˚ 23' 51.531'', East longitude 82˚ 49' 50.547'') with SPM concentration 24-h of 178.24 µg/m^3.

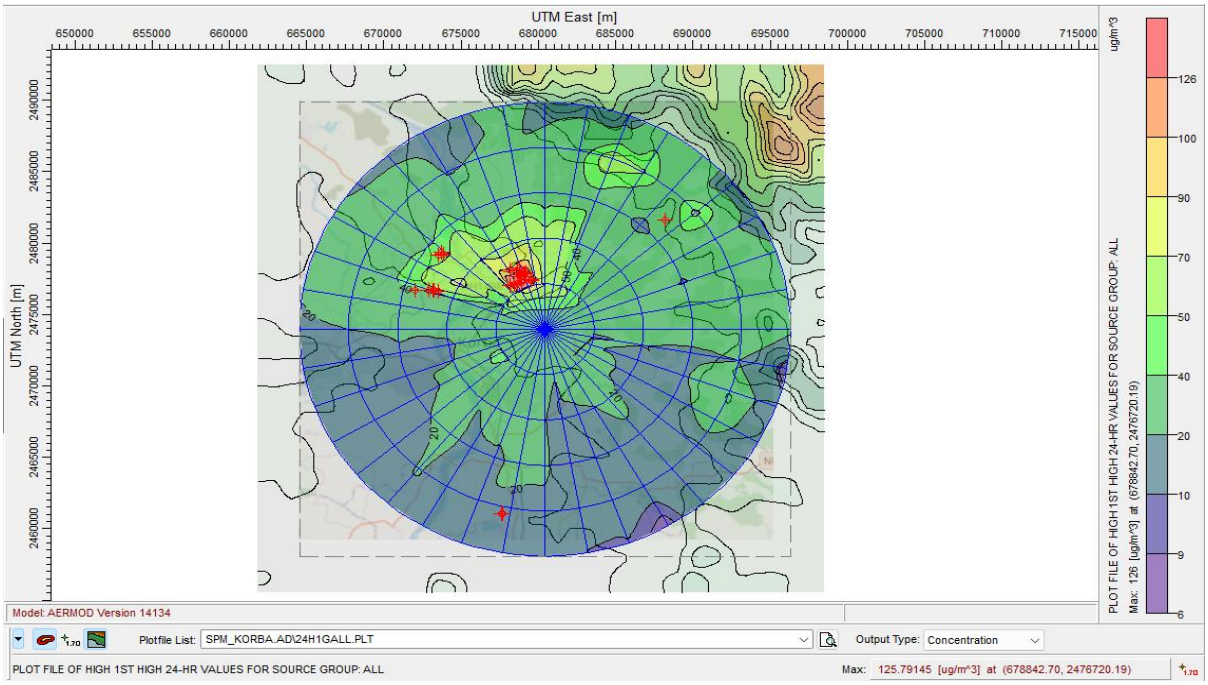


Figure 2.53: Point source isopleths of SPM for 24 hr at Korba 15 km radius region.

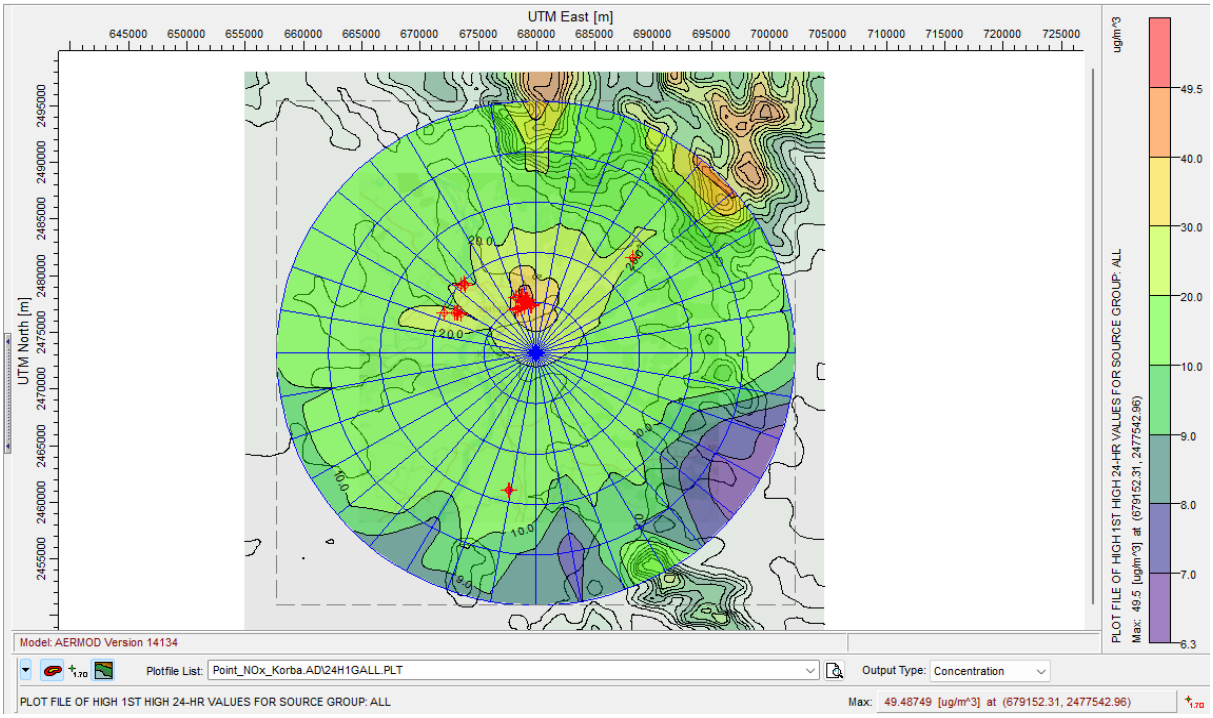


Figure 2.54: Point source isopleths of SO_2 for 24 hr at Korba 15 km radius region.

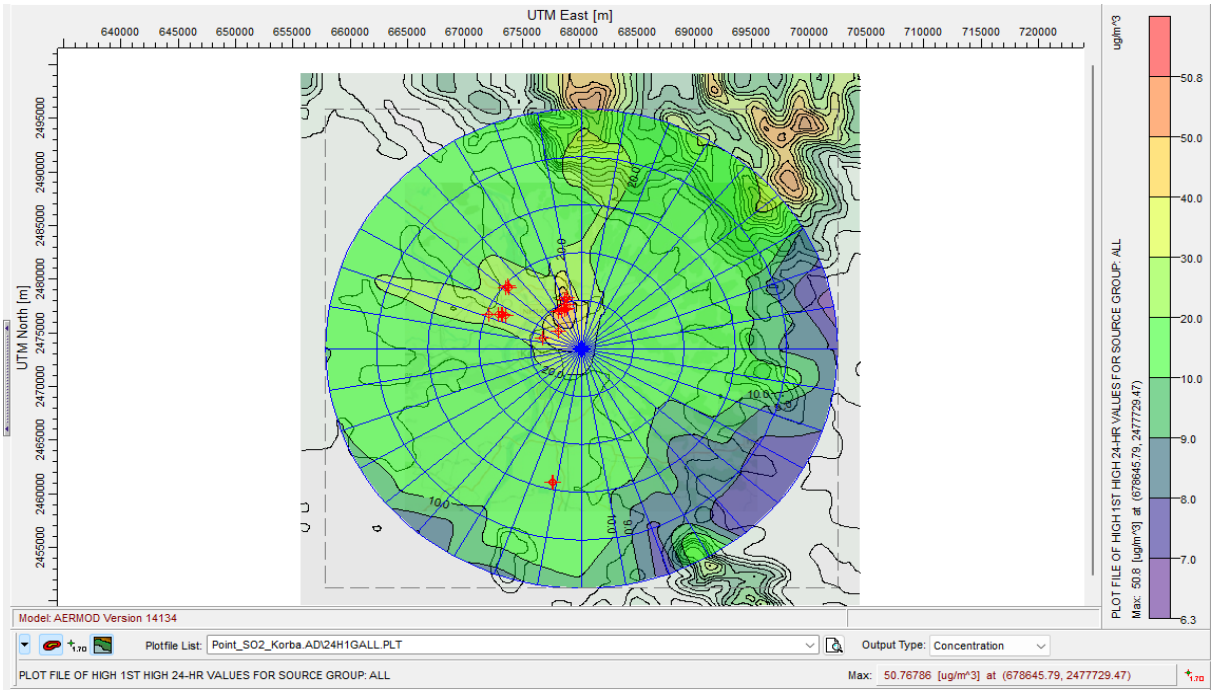


Figure 2.55: Point source isopleths of NO_x for 24 hr at Korba 15 km radius region.

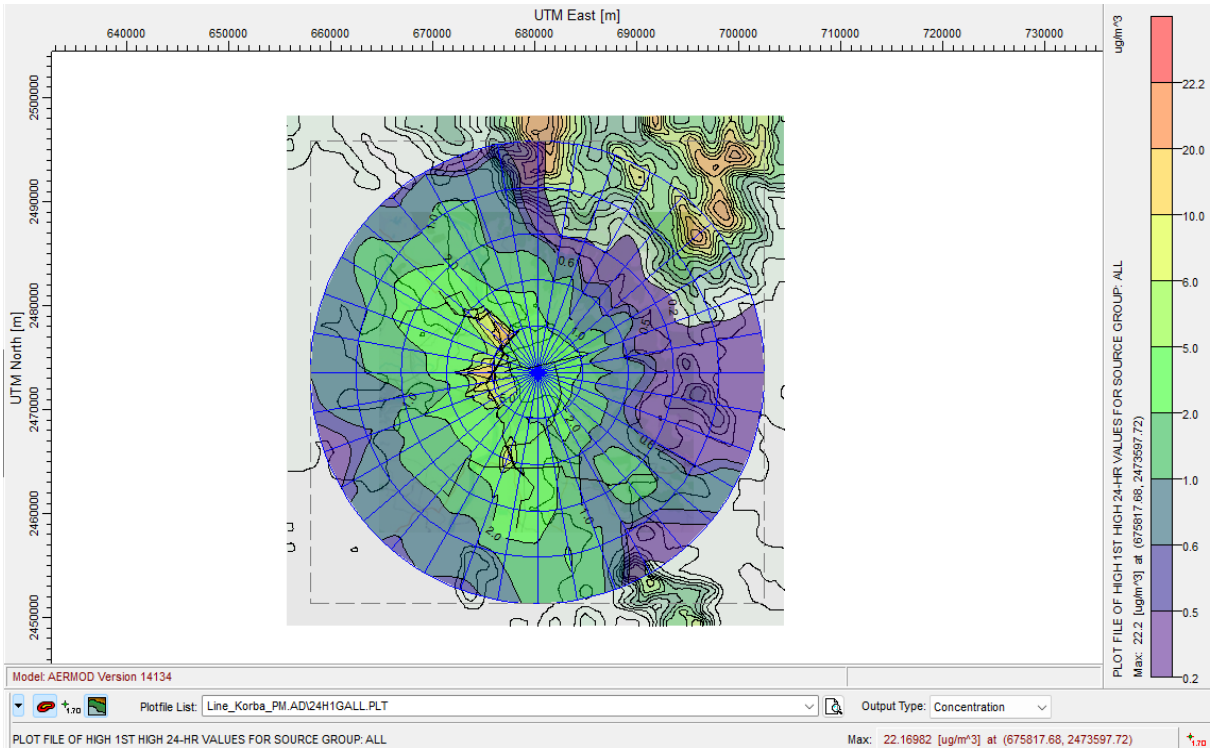


Figure 2.56: Line source isopleths of SPM for 24 hr at Korba 15 km radius region.

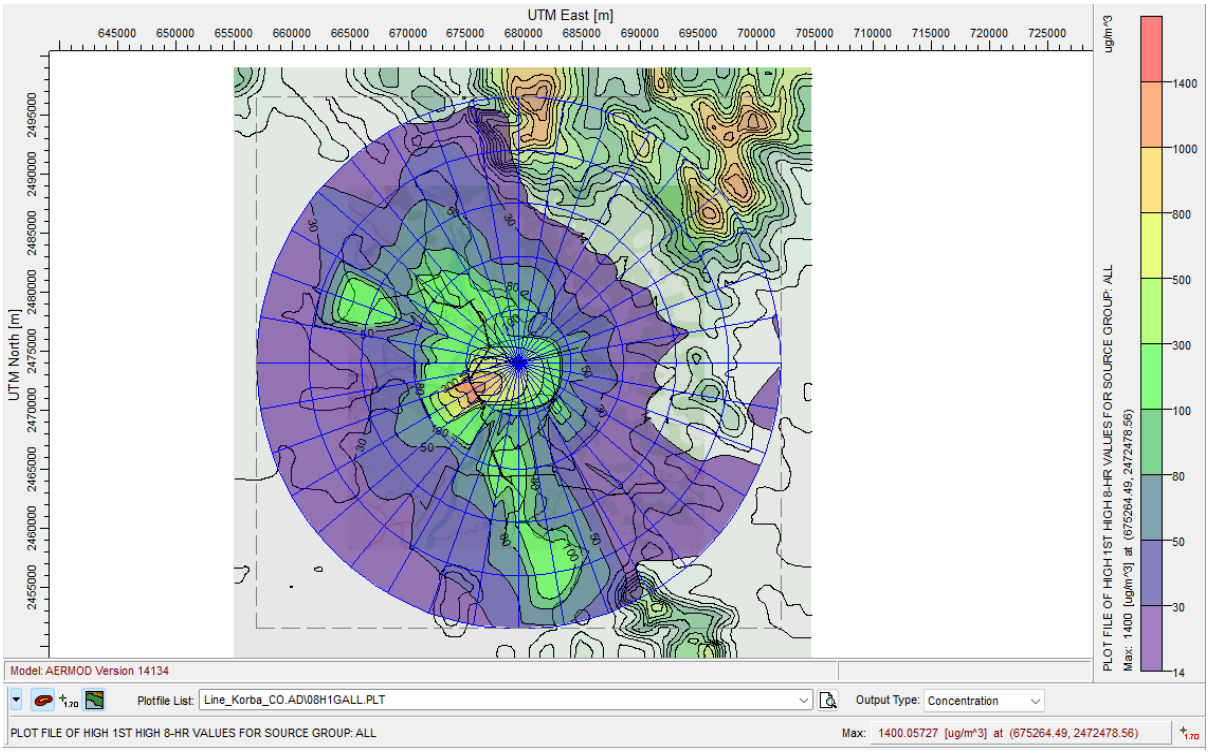


Figure 2.57: Line source isopleths of CO for 8 hr at Korba 15 km radius region.

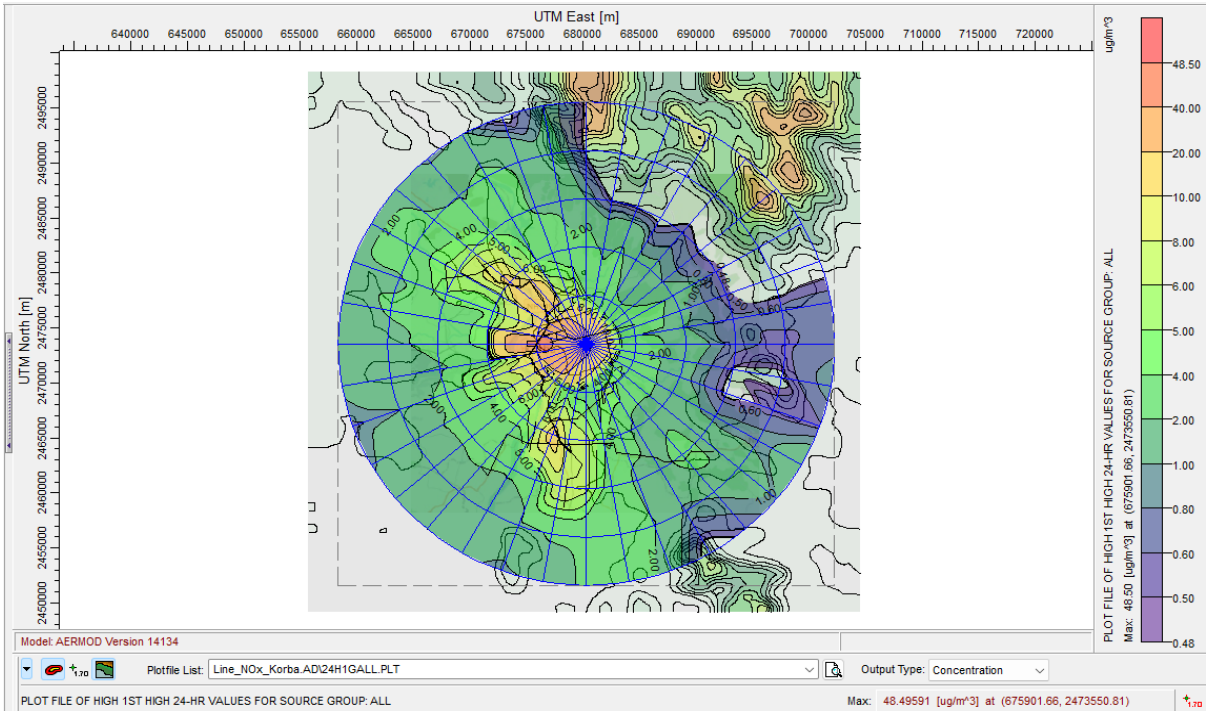


Figure 2.58: Line source isopleths of NO_x for 24 hr at Korba 15 km radius region.

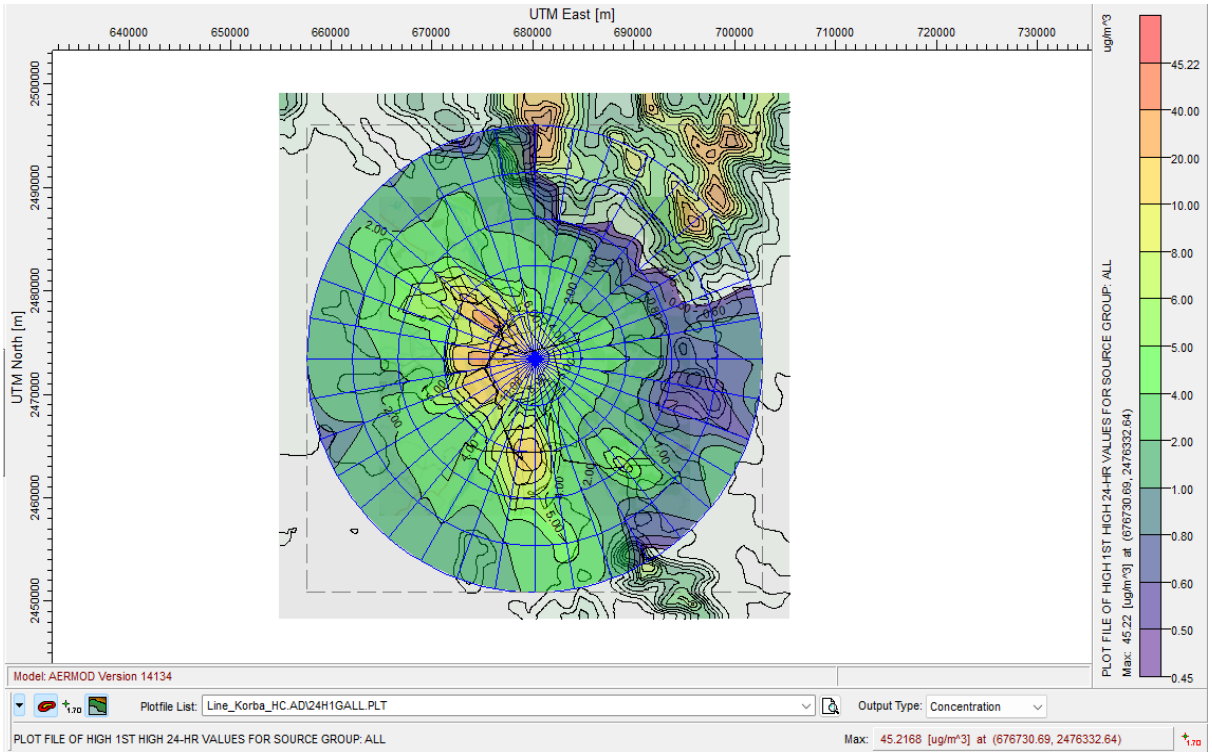


Figure 2.59: Line source isopleths of HC for 24 hr at Korba 15 km radius region.

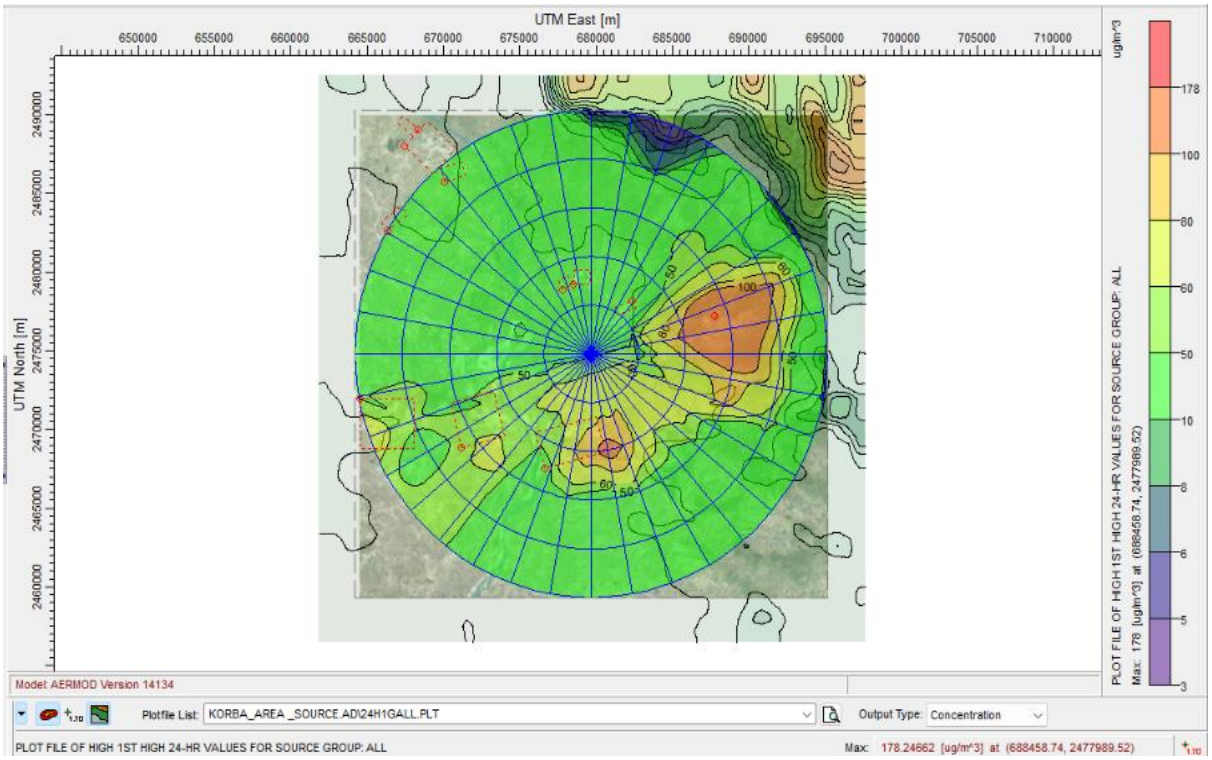


Figure 2.60: Area source isopleths of SPM for 24 hr at Korba 15 km radius of region.

2.4 Emission Inventory

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

Table 2.22: Various identified sources and sectors in Korba.

S. No.	Name of Source	Importance/ Weightage	Source of identification	Justification for weightage/ other remarks
1.	Vehicles	High	Source identified from general information, previous reports, RTO and research papers	There are lakhs of registered vehicles in Korba
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 Korba
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 Korba 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 Korba 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 Korba
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 Korba for road laying and repairing; Many other mobile ones are used whenever and wherever needed through private contractors and sub-contractors
7	Wastes burning	Low	Source identified from primary survey, newspaper reports and public interviews	Open burning of MSW (Municipal solid waste) and other waste does exist as an unorganized activity; Smouldering fire is reported from dumpsites at Karun river near sarona and sakri is outside RMC limit but can Significantly contribute to city pollution). But, no estimate is available on amount of waste on fire
8	Power Plants	High	Previous works and Power plant company website database	There are various operating power plant and hence this source is considered major in terms of presence
9	Restaurants/ Hotel kitchens/ Mobile food vendors	Low	Source identified from reconnaissance, and research papers	Restaurants and hotels, guest houses and commercial establishments having kitchens, roadside eateries, bhujiawalas and tea shops are commonly found all over Korba. 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 Korba
11	Ironing vendors	Low	Source identified from primary survey	According to initial investigation done by our group there are a few ironing vendors in Korba who use electricity and also coal for warming the ironing machines

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 Korba 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 Korba to record types of vehicles running in the city, their average mileage within KMC, 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 Korba.

Figure 2.61: Use of coal / char coal by roadside eateries and ironing vendors.

Figure 2.62: Petrol pump survey in the study area.

Figure 2.63: Open burning witnessed in the study area.

2.4.2 Secondary Data Sources

Secondary data on fuel and energy usage in industrial sector was extracted from filed-in consent to operate forms accessed through online database maintained by CECB (http://enviscecb.org/)., list of registered businesses in Korba 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	KMC database, CGPCB, Primary Survey by our team
Construction	KMC database, other data sources
Road dust	Primary Survey; Laboratory analysis, KMC 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	KMC database, Online resources
Ironing vendors	Primary Survey
Wastes burning	Primary Survey, KMC 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 Korba in last 5 years), number of restaurants/eateries, types and number on industries, number of bodies burnt in crematoria etc. are important information required to develop the emission inventory. For emission inventory estimates, along with reliable activity data, relevant emission factors or emission coefficients that represent emission per unit fuel, production, number of product, vehicle mile ran and so on is required. The calculation methodology for emission estimates is summarized in Table 2.24.

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

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

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

Domestic	Fuels (LPG, wood, coal, etc.) consumption per unit household per year; Number of households; KMC/HMC population	$E = \sum_{i=1}^{n} F_i \times EF_i \times No.of\ households$ Where, E = Total city emission (kg/y) F_i = Av. Consumption of i^{th} fuel (e.g. LPG/coal/wood) in city per household (MT/y) EF= Relevant emission factor for i^{th} fuel (e.g. kg/MT)
Crematoria	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 Plant in Korba.	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)

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 KMC 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 KMC 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 Korba.

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 KMC database on registered businesses in KMC 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 KMC. Therefore, a total of 17185 eateries are considered to be present within KMC.
Construction	KMC data on land base area (acre) under residential construction (i.e. dug up land) in 2021 was used for KMC area (271 acres). Construction land area under commercial sector was not available for KMC, 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 KMC area was arrived at by dividing KMC 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 KMC 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 KMC area (excl. vendors using electricity), which was based on extrapolation of their numbers found in sample study areas. Annual working days are about 315, taking 4 Sunday-offs per month as found during survey

During the primary survey of eateries and restaurants in Korba 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 KMC areas were provided by KMC.

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

Canal Road Korba HO	Transport Nagar
Power House Road	Banki Mongra
Indira Commercial Complex	Indira Commercial Chowk

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

Sl. No.	Vehicle Class	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	Tractor (Commercial)	446	816	547	550	391	738	981	704	896	659
2	Tractor Trolley	84	79	65	71	157	80	75	87	128	108
3	Motor Car	1976	1948	1973	2203	1813	1026	2793	2425	2839	2785
4	Ambulance	14	3	8	5	8	16	16	51	1	4
5	Omni Bus	185	185	185	185	185	185	185	185	185	185
6	Three Wheeler (Passenger)	112	145	166	44	78	113	310	84	14	39
7	Camper Van/Trailer	5	3	1	1	0	0	0	0	0	0
8	Construction Equipment Vehicle	35	23	5	2	4	26	36	16	12	15
9	Tower Wagon										
10	Camper Van/Trailer	5	3	1	1	0	0	0	0	0	0
11	e-Rickshaw with Cart (P)	0	0	0	0	1	24	18	4	7	67
12	Crane Mounted Vehicle	27	42	54	33	1	38	12	10	24	22
13	Earth Moving Equipment	3	3	4	1	3	22	15	4	68	1
14	Bus	39	14	58	62	51	65	38	10	4	24
15	E-Eickshaw(P)	0	0	0	0	1	24	18	4	7	67
16	Goods Carrier	985	695	1266	1378	1923	2416	1473	925	1181	2064
17	Haevester	2	0	0	0	0	0	0	0	0	0
18	Maxi Cab	13	12	6	7	40	53	36	15	25	1
19	Passenger Bus	5	0	0	0	0	0	0	0	0	0
20	M-Cycle/Scooter	17522	17702	17067	17449	12157	23721	18996	16849	16860	16984
21	Moped	865	850	872	2203	770	3089	459	370	417	529
22	Motor Cab	62	33	40	33	65		125	101	139	5
23	Motor Car	1976	1948	1973	2203	1813	1026	2793	2425	2839	2785

24	Three Wheeler(Goods)	9	70	122	85	59	25	57	35	37	43
25	Three Wheeler(Passenger)	112	145	166	44	78	133	310	84	14	39
26	M-Cycle/Scooter										
27	Jeep	10	0	0	2	0	0	0	0	0	0
28	Private Service Vehicles	16	11	22	13	4	0	14	10	0	0
29	Fire Tender	0	0	0	0	0	0	0	0	0	0
30	Compressor Fitted Vehicls	1	0	0	0	6	0	0	0	1	3
31	Invalide Carriage	1	0	1	4	2	6	0	0	0	0
	Total	22431	22843	22636	24510	17748	31807	25667	21747	22670	23435

Table 2.28 Summary of registered vehicle in last 10 years.

Sr. No.	Vehicle Class	Total
1	Tractor	6728
2	Tractor Trally	934
3	Ambulance	126
4	Omni Bus	1852
5	Camper Van/Trailer	10
6	Construction Equipment Vehicle	174
7	Crane Mounted Vehicle	263
8	Earth Moving Equipment	124
9	Bus	365
10	E-Eickshaw(P)	121
11	Excavator(Nt)	367
12	Goods Carrier	14306
13	Haevester	2
14	Maxi Cab	208
15	Passenger Bus	5
16	M-Cycle/Scooter	175307
17	Moped	10424
18	Motor Cab	603
19	Motor Car	21781
20	Three Wheeler(Goods)	542
21	Three Wheeler(Passenger)	1125
22	Jeep	12
23	Private Service Vehicles	90
24	Fire Tender	0
25	Compressor Fitted Vehicles	11
26	Invalid Carriage	14
	Total	**235494**

Total registered vehicle in last 10 year is **235494** and these data collected from Transport Department, Korba RTO, and Chhattisgarh. Emission from various type of vehicles at different years is shown in Table 2.29 (**Source:** ARAI Emission Factor Report, January 2008)

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

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

Buses (Diesel)	1991-1995	2.013
	1996-2000	1.213
	2001-2005	1.075
	2006-2010	0.3

2.4.5 Emission Estimates

Emission estimate has been prepared for important sectors in Korba. Table 2.30 presents emission estimates from Korba in decreasing order of PM_{10} from sectors viz. Road, Household, Transport, Industry, Construction, Hot Mix Plants, Open Burning, Restaurants and eateries, Thermal Power, Ironing Vendors, and Crematoria (Table 2.30). The share of various sectors in PM_{10} and $PM_{2.5}$ emissions is presented in Figure 2.64 and 2.65.

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

Sector	**Emission (MT/y)**	
	$PM_{2.5}$	**PM_{10}**
Constructions	77.77	337.71
Transport Emission	100.1	252.39
Road Dust	160.99	549.05
Industry	550.17	1911.79
Generator Sets	25.55	36.69
Domestic	24.44	43.02
Mining Activities	109.76	410.08
Wastes Burning	21.12	36.36
Restaurants, Eateries and Hawkers	10.01	18.09
Crematoria	1.69	3.61
Total	**1111.6**	**3598.79**

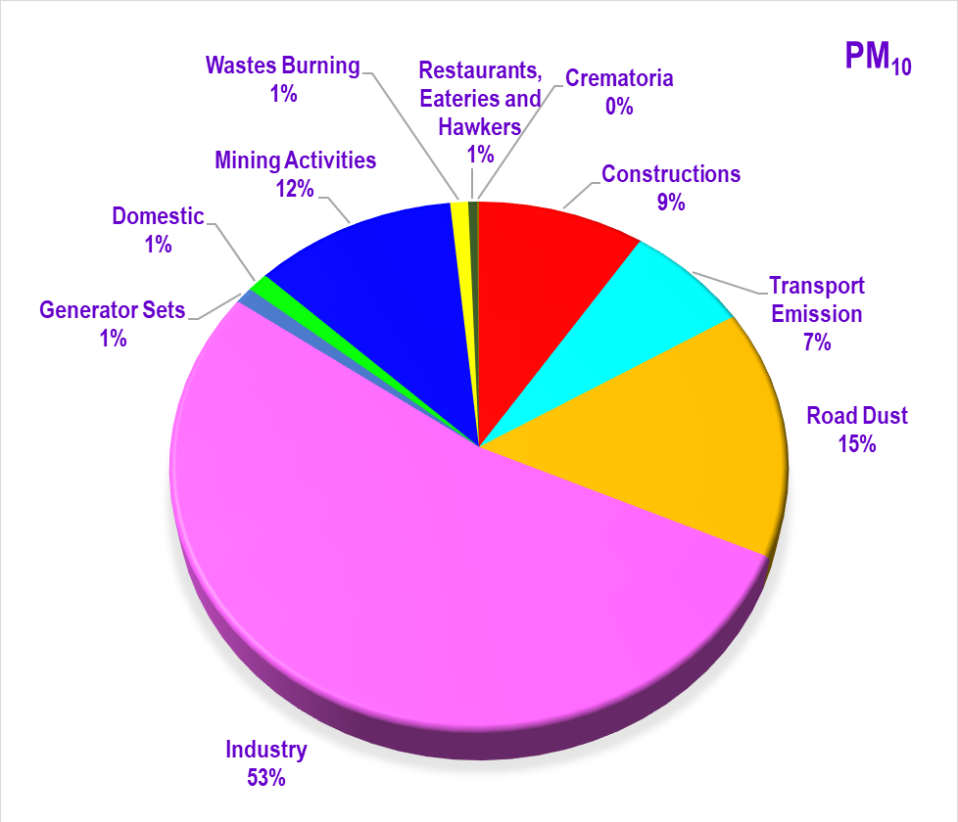


Figure 2.64: PM_{10} emission estimates (% share) from various sectors in Korba.

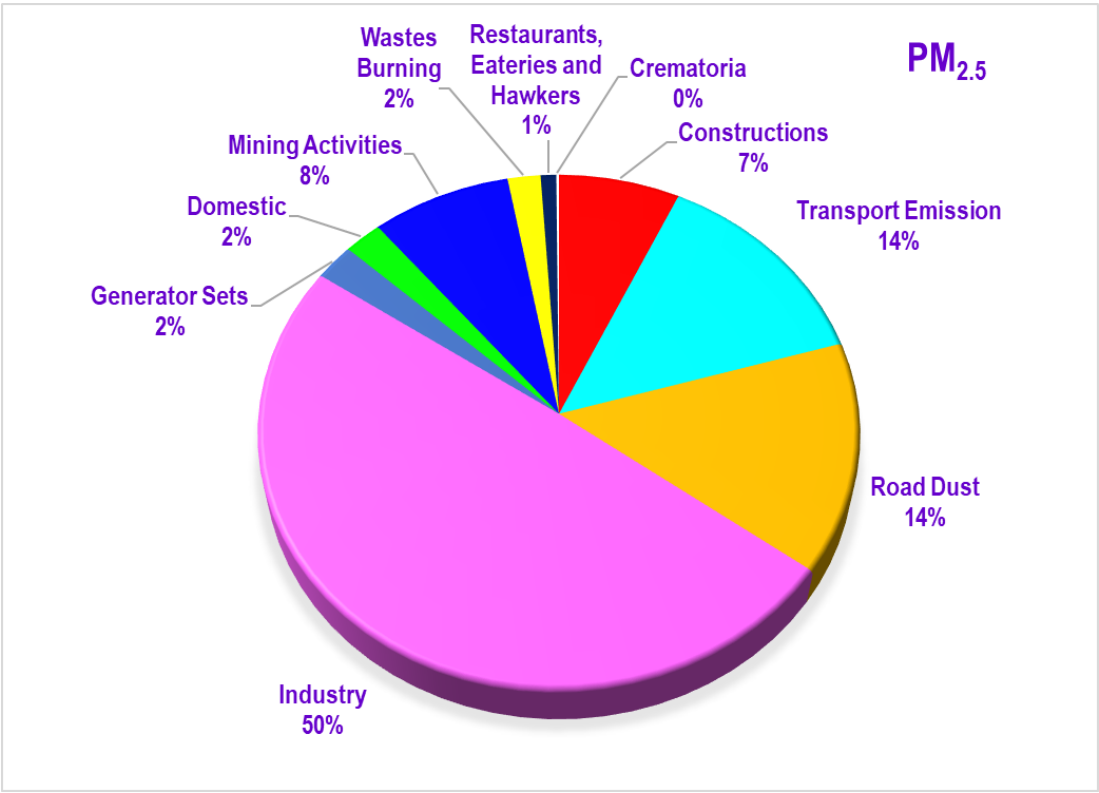


Figure 2.65: $PM_{2.5}$ emission estimates (% share) from various sectors in Korba.

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

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

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.

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

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 2.30) to identify the major contributors to PM_{10} and $PM_{2.5}$ pollution in Korba. This involved statistical methods and spatial analysis techniques to determine the relative contributions of various pollution sources.

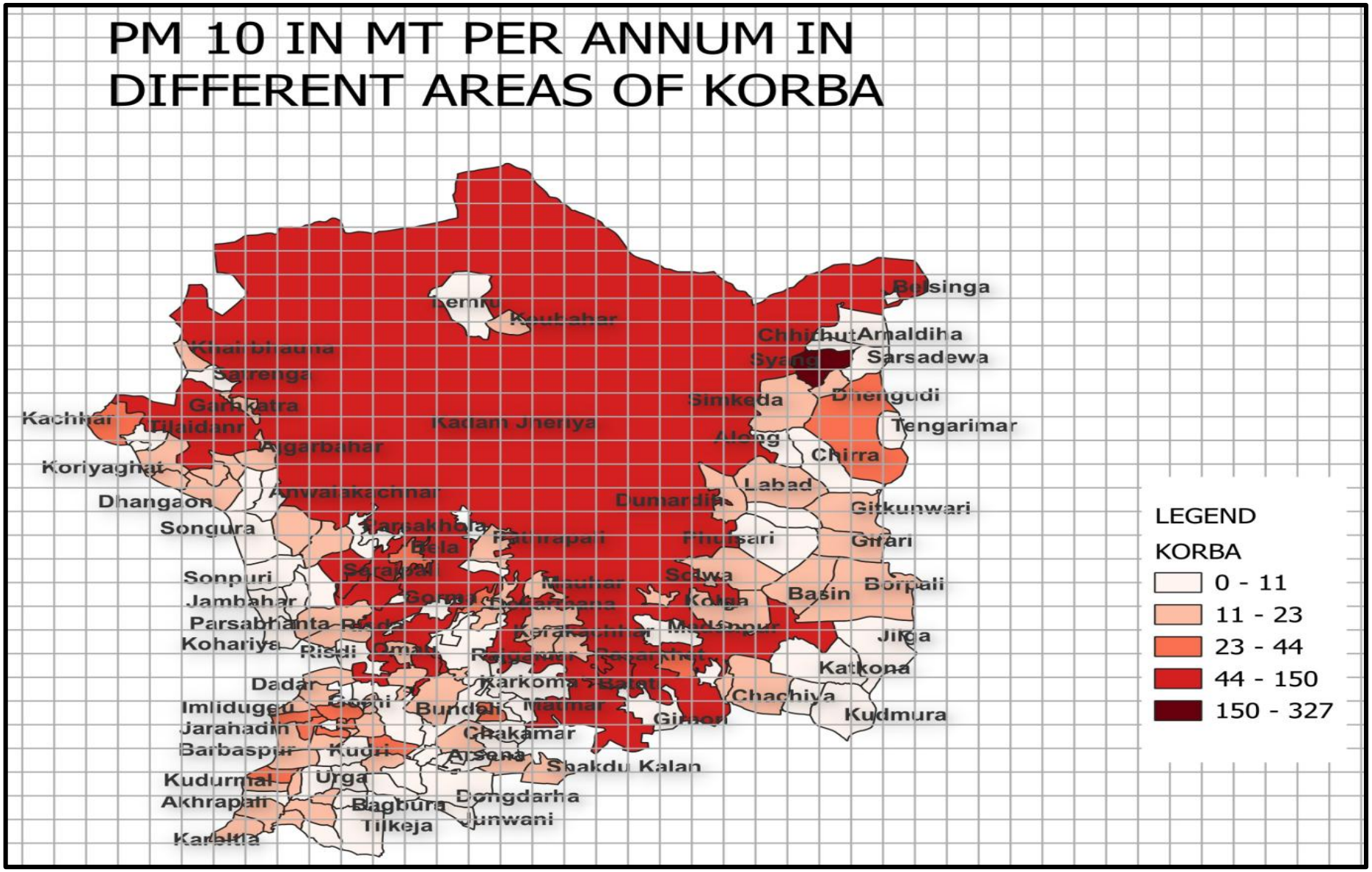


Figure 2.66: 2×2 sq. km gridded spatial distribution of PM_{10} generated from QGIS software for different areas of Korba.

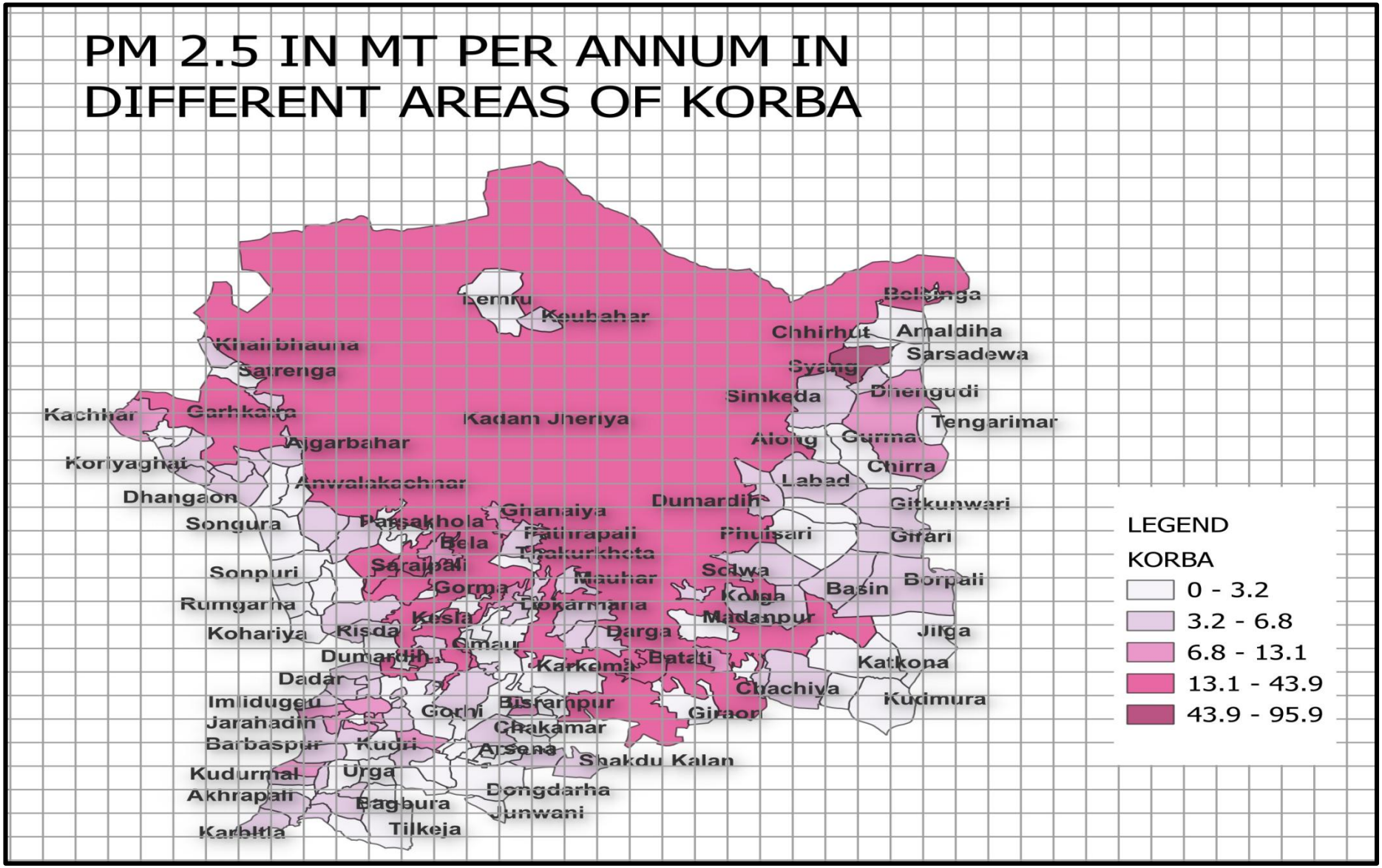


Figure 2.67: 2×2 sq. km gridded spatial distribution of $PM_{2.5}$ generated from QGIS software for different areas of Korba.

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 Korba 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 Korba. 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 through C.M.B. Model

2.4.8.1. Winter Season

We have arranged 15 air-quality monitoring stations in Korba and have collected air samples in different seasons or though-out the year. Collected air samples are processed and analysed according to the methods described above. All the analysed data are then arranged in different tabulated '.csv' files and then those files are taken for emission inventory and source apportionment study. After selecting each source 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.

Air quality monitoring station 'K01' is categorized as 'Commercial'. Emission study shows this station has largely been affected by different types of industry (52%; 55.01 µg/m^3); road dust (19%; 19.92 µg/m^3) and transports (12%, 12.28 µg/m^3). Emission from construction (9%; 9.69 µg/m^3), wastes burning (4%; 4.78 µg/m^3), restaurants/ eateries/ hawkers fuels combustion (2%; 1.99 µg/m^3) and generator sets fuel oil combustion (2%; 2.21 µg/m^3) have also effect on the ambient air of 'K01' (Figure 2.68).

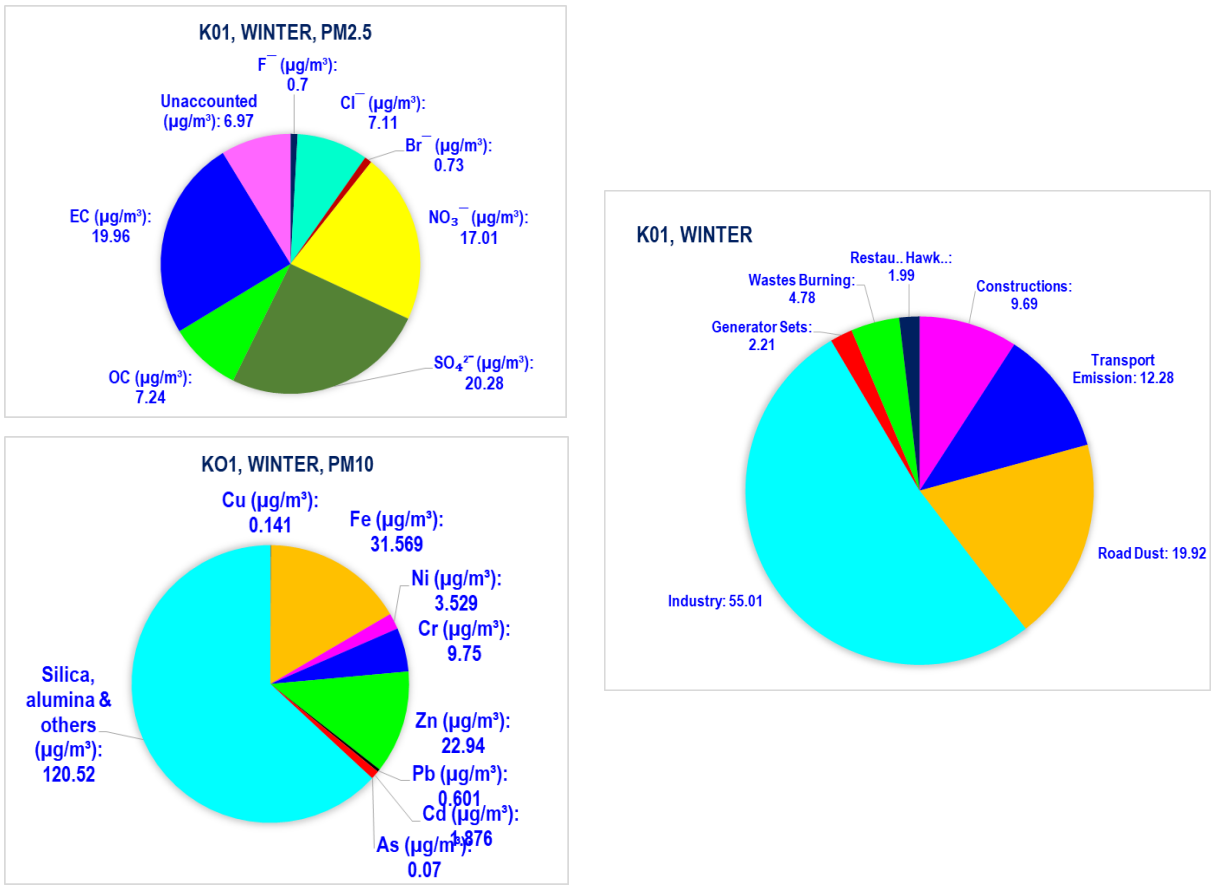


Figure 2.68: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K01' during winter.

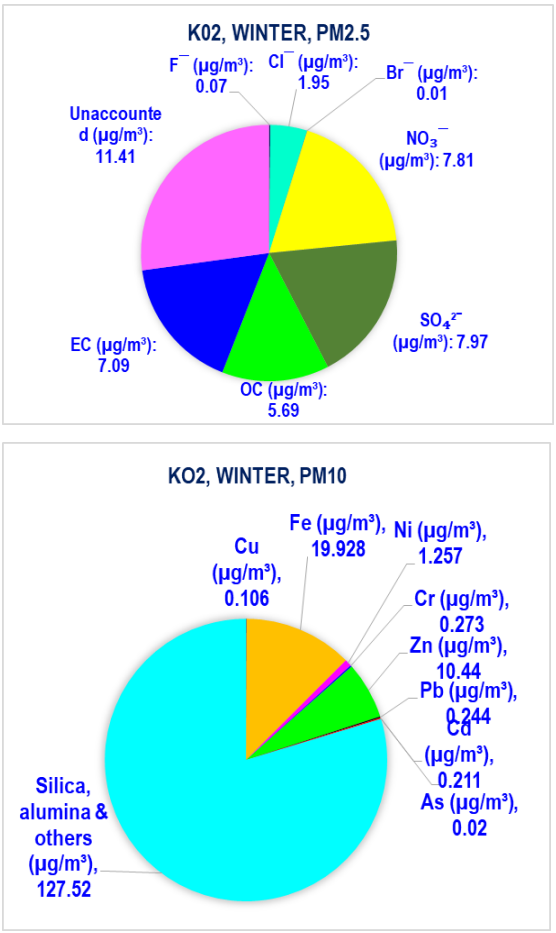


Figure 2.69: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K02' during winter.

'K02' is a 'Silent' type air-quality monitoring station. Road dust (19%; 10.22 µg/m^3), transports emission (14%; 7.21 µg/m^3), industry (52%; 27.65 µg/m^3), domestic fuels combustion (5%; 2.54 µg/m^3) and wastes burning (4%; 1.94 µg/m^3) are shared the emission plot (Figure 2.69).

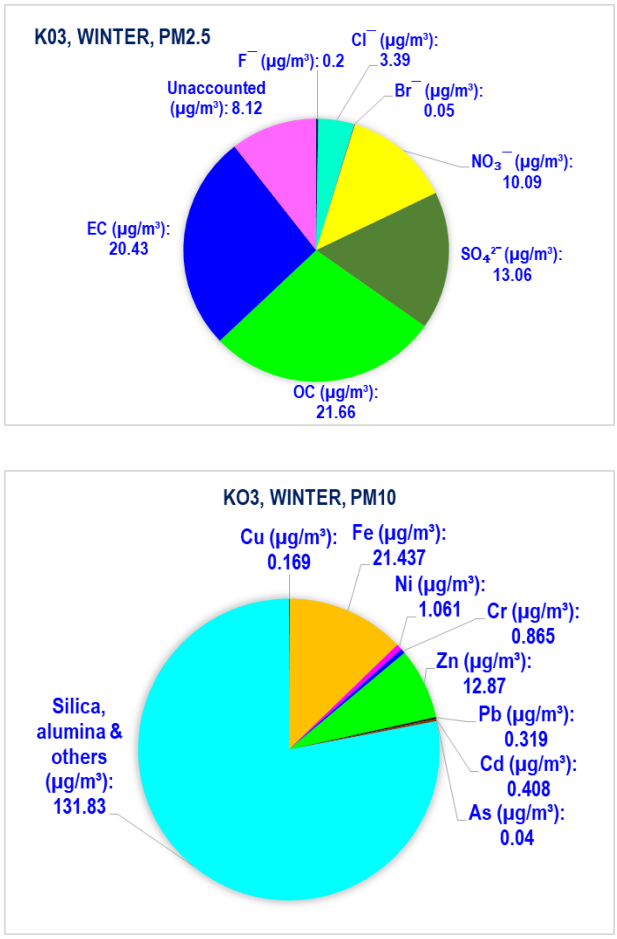


Figure 2.70: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K03' during winter.

'K03' is an 'Agricultural' type air-quality monitoring station and polluted due to industrial emission (53%; 57.04 µg/m^3). Other sources are intra-sectoral like road dust (15%; 15.69 µg/m^3), transports emission (11%; 11.99 µg/m^3), construction (4%; 4.17 µg/m^3), domestic fuels combustion (6%; 6.77 µg/m^3), generator sets fuel oil combustion (5%; 4.86 µg/m^3), wastes burning (4%; 4.18 µg/m^3) and restaurants/eateries/hawkers (2%; 2.68 µg/m^3) (Figure 2.70).

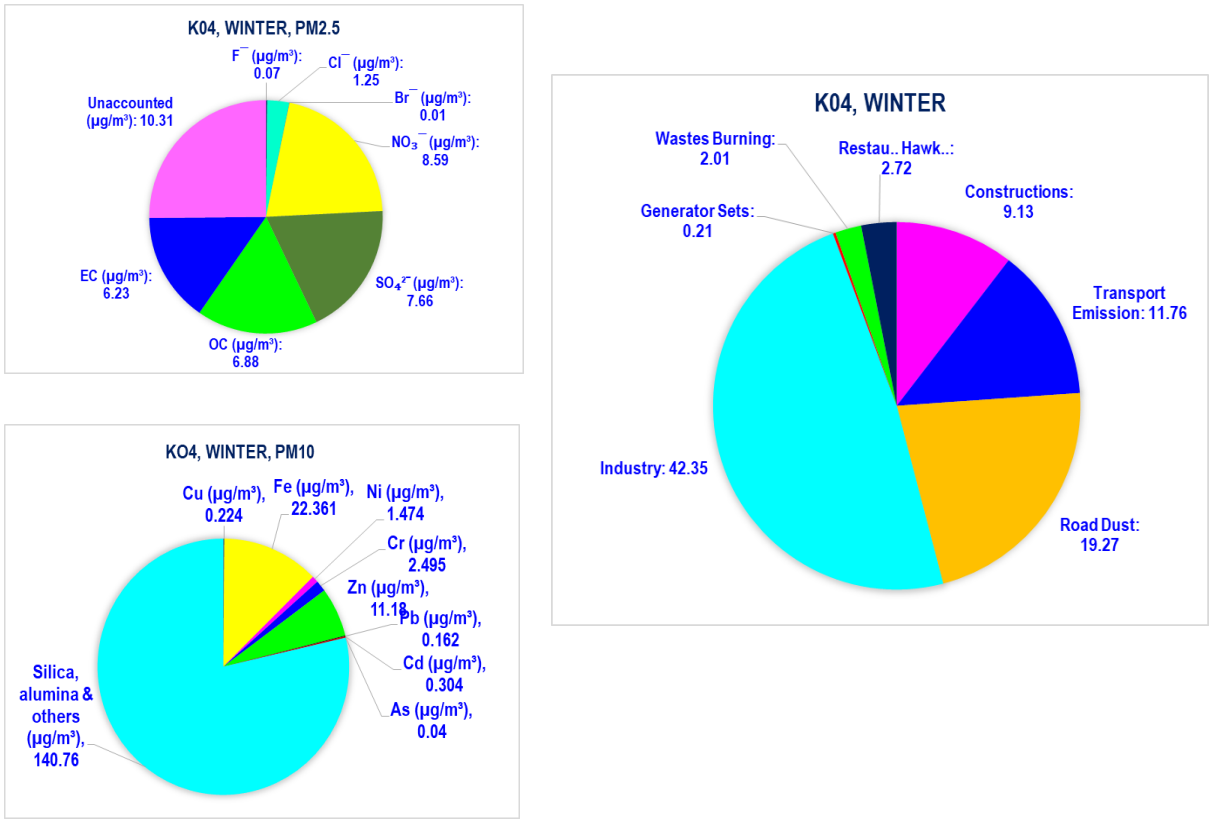


Figure 2.71: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K04' during winter.

Similarly, 'K04' is an 'Agricultural' type air-quality monitoring stations. Both stations are affected by other sectors, mainly by industrial emission (48%; 42.35 µg/m^3). Sectoral emission inventory analysis shows that ambient air contains road dust (22%; 19.27 µg/m^3), transports emission (14%; 11.76 µg/m^3), construction (11%; 9.13 µg/m^3), wastes burning (2%; 2.01 µg/m^3) and generator sets fuel oil combustion (3%; 2.72 µg/m^3) (Figure 2.71).

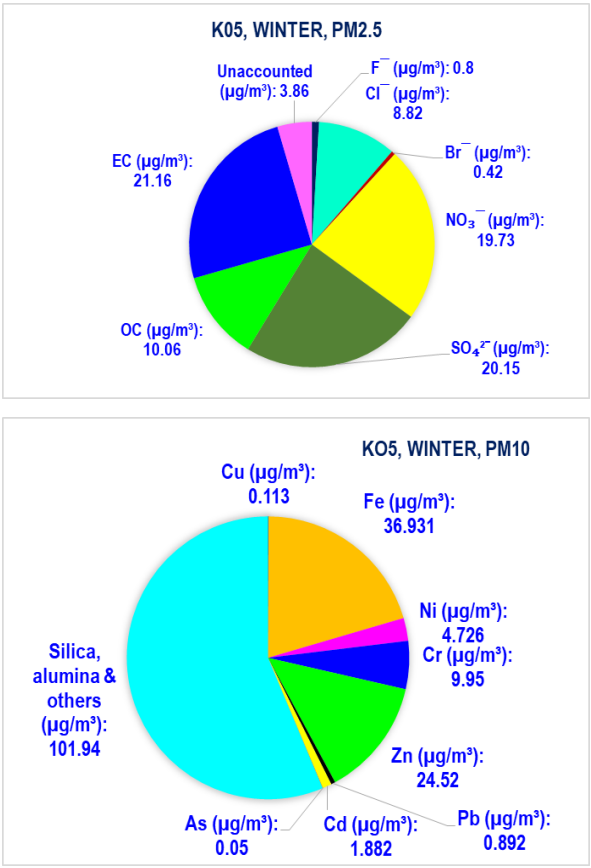


Figure 2.72: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K05' during winter.

'K05' is mainly polluted by industrial emission (57%; 77.19 µg/m^3), while it's an agricultural area. Other sources are road dust (16%; 21.05 µg/m^3), construction (7%; 10.03 µg/m^3), wastes burning (5%; 7.02 µg/m^3), transports emission (13%; 18.04 µg/m^3) and generator sets fuel oil combustion (2%; 3.19 µg/m^3) (Figure 2.72).

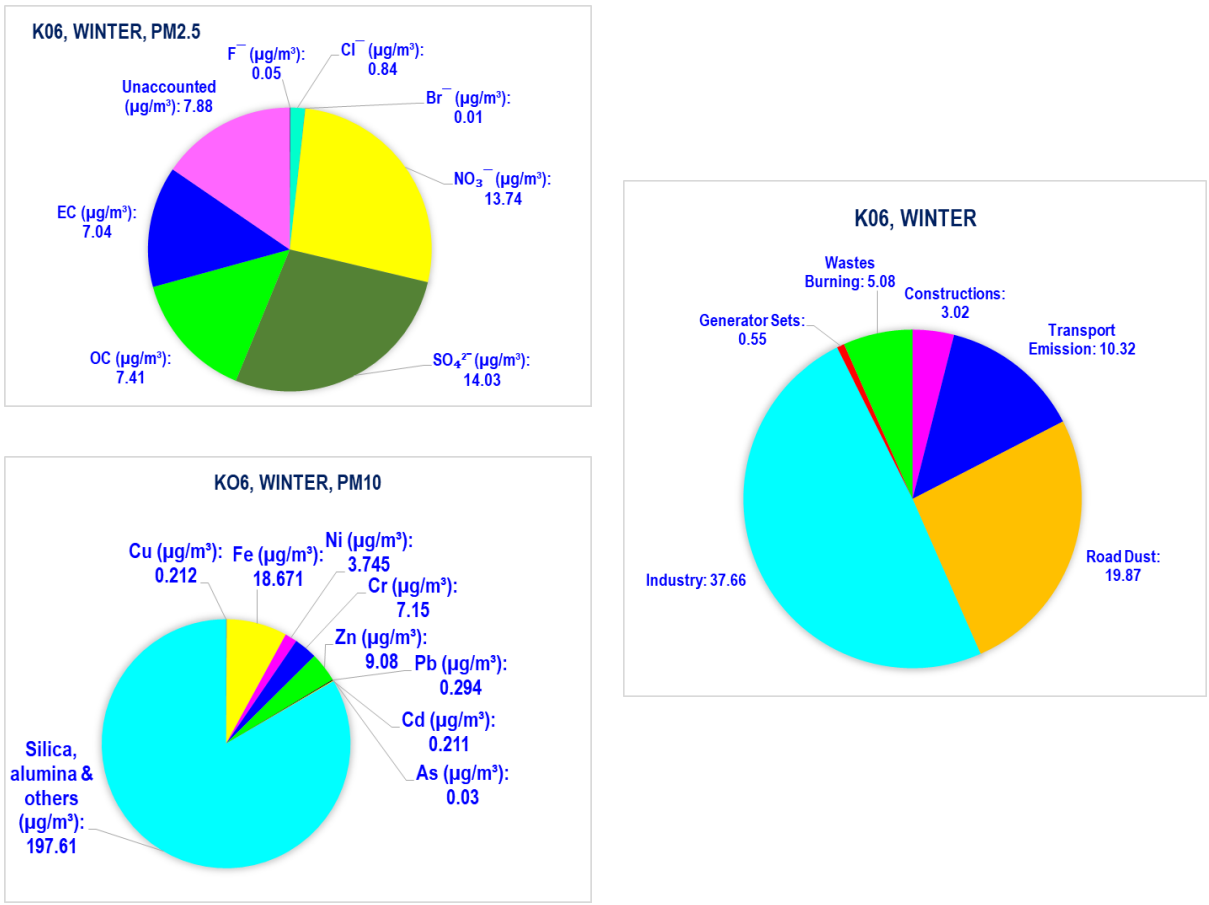
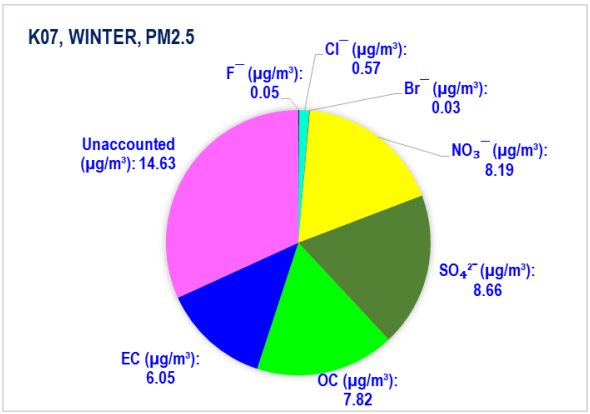
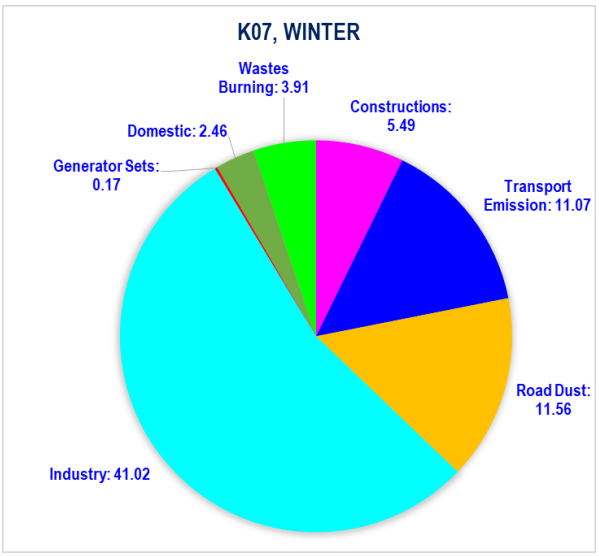


Figure 2.73: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K06' during winter.

'K06' is a 'Commercial' type sampling station. Emission inventory study shows that, sources of pollutants in 'K06' are industry (49%; 37.66 µg/m^3), road dust (26%; 19.87 µg/m^3), transports emission (13%; 10.32 µg/m^3), construction (4%; 3.02 µg/m^3), generator sets fuel oil combustion (1%; 0.55 µg/m^3) and wastes burning (7%; 5.08 µg/m^3) (Figure 2.73).





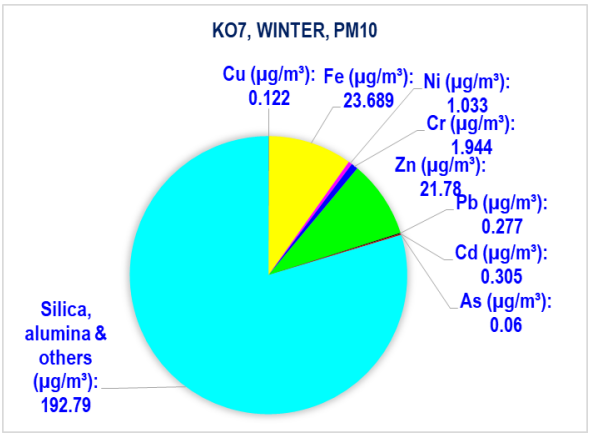


Figure 2.74: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K07' during winter.

Emission sources in the air-quality monitoring station 'K07' are industry (54%; 41.02 µg/m^3), road dust (16%; 11.56 µg/m^3), transports emission (15%; 11.07 µg/m^3), construction (7%; 5.49 µg/m^3), wastes combustion (5%; 3.91 µg/m^3) and domestic fuels combustion (3%; 2.46 µg/m^3) (Figure 2.74).

Air-quality monitoring station 'K08' is a Thermal Power Plant, named 'DSPM Thermal Power Plant'. Emission sources in the air-quality monitoring station 'K08' (Industrial) are power plant (53%; 47.61 µg/m^3), road dust (16%; 14.26 µg/m^3), transport emission (15%; 13.37 µg/m^3), constructions (4%; 4.04 µg/m^3), wastes burning (10%; 8.99 µg/m^3) and generator sets fuel oil combustion (2%; 1.92 µg/m^3) (Figure 2.75).

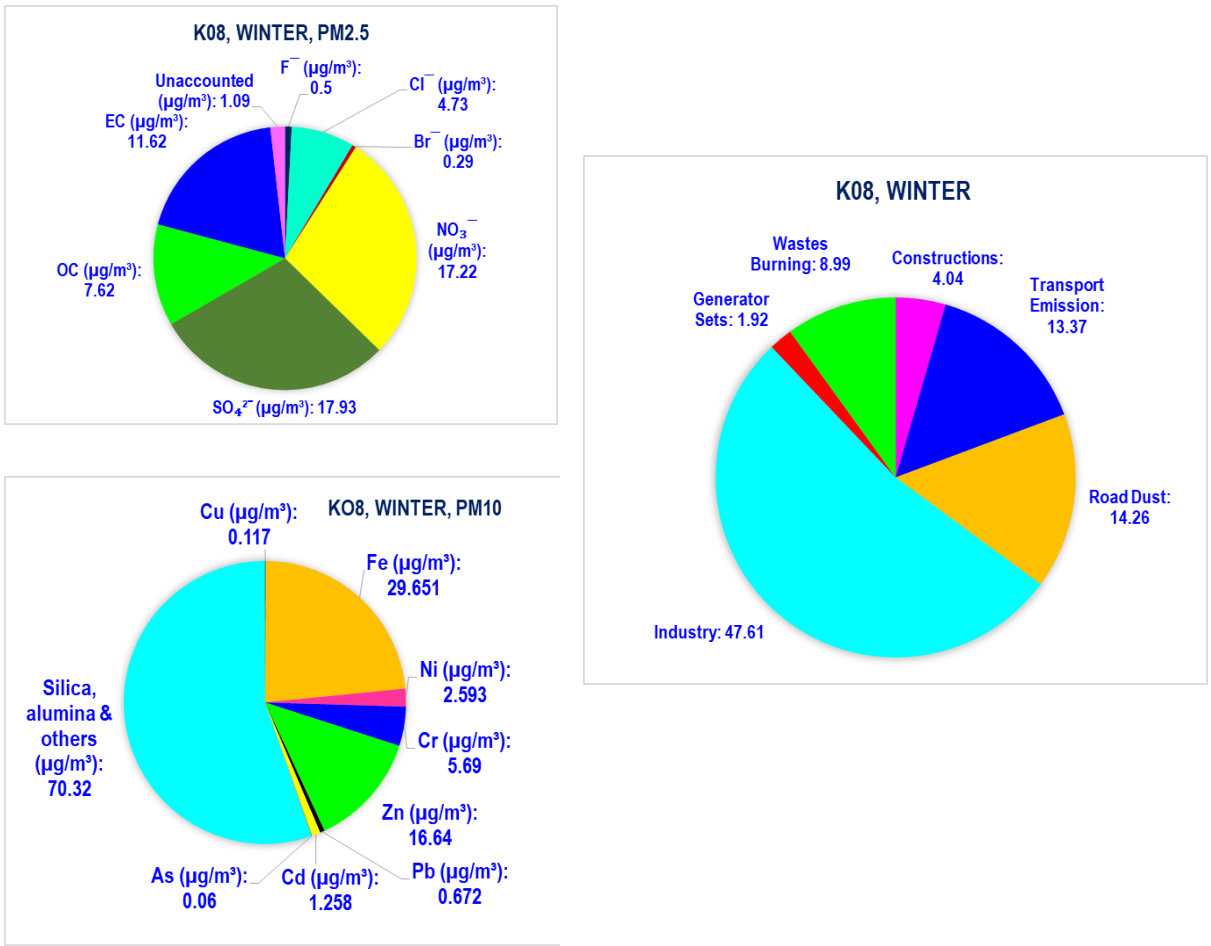


Figure 2.75: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K08' during winter.

'K09' is a 'Mixed' categorized air-quality monitoring station on 'BALCO Get House' at Korba. This is just beside the Power Plant. So, power plant or industry may play main sources of emission here. According to the emission inventory study, the sources which affect the ambient air quality are industrial emission (53%; 46.13 µg/m^3), transports emission (18%; 15.33 µg/m^3), construction (6%; 4.98 µg/m^3), road dust (17%; 14.43 µg/m^3), wastes burning (4%; 3.89 µg/m^3), generator sets fuel oil combustion (2%; 1.87 µg/m^3) (Figure 2.76).

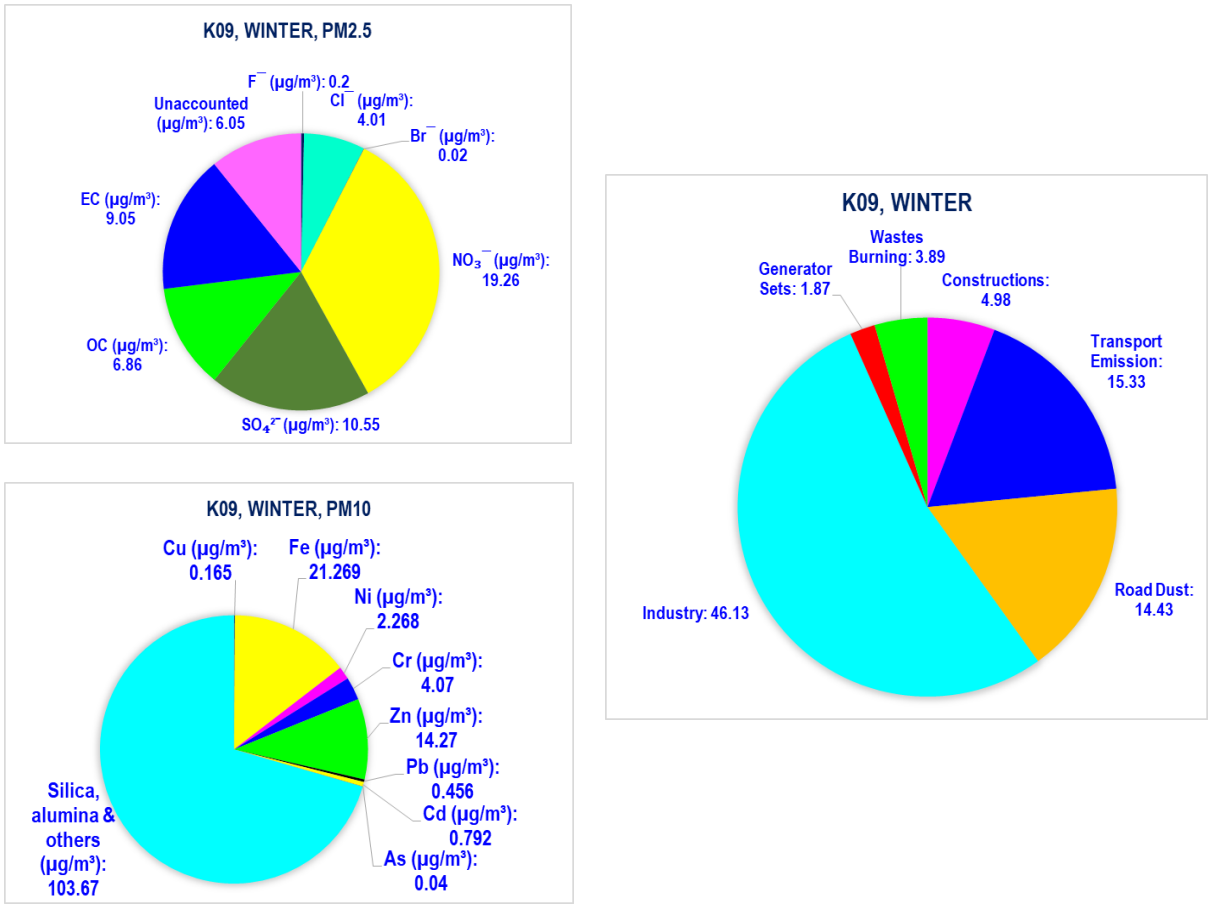


Figure 2.76: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K09' during winter.

'K10' is a 'Traffic' station. Emission inventory study shows the air-quality in this station is affected by industry (46%; 28.47 µg/m^3), road dust (21%; 13.45 µg/m^3), transport emission (17%; 10.39 µg/m^3), construction (9%; 5.66 µg/m^3), generator sets fuel oil combustion (3%; 2.11 µg/m^3) and wastes burning (4%; 2.44 µg/m^3) (Figure 2.77).

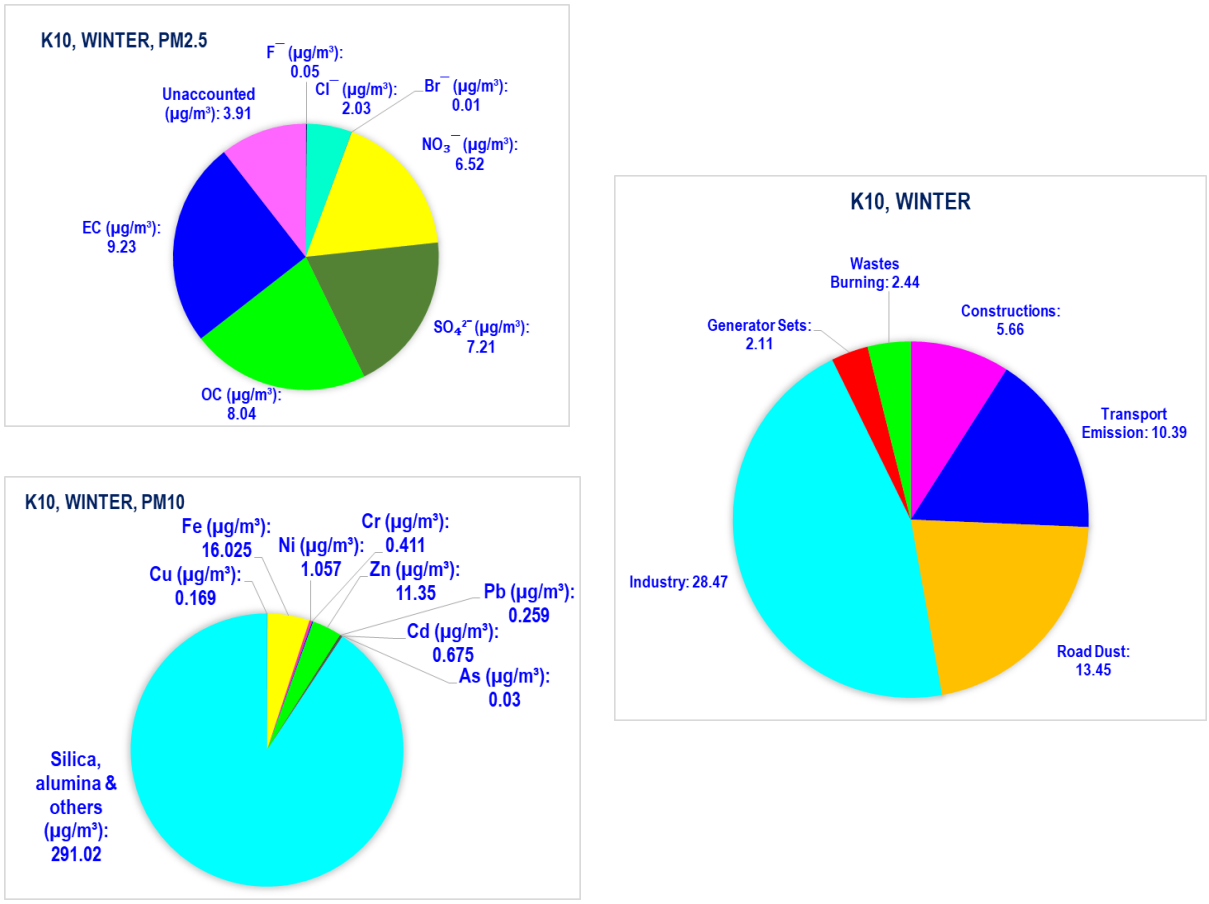


Figure 2.77: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K10' during winter.

'K11' is an 'Industrial' type air-quality monitoring station in 'LANCO Power Plant'. Emission sources are industry / power plant (56%; 66.37 µg/m^3), road dust (19%; 22.83 µg/m^3), generator sets fuel oil combustion (3%; 3.76 µg/m^3), transport emission (9%; 11.03 µg/m^3), wastes burning (8%; 9.79 µg/m^3) and construction (5%; 5.82 µg/m^3) (Figure 2.78).

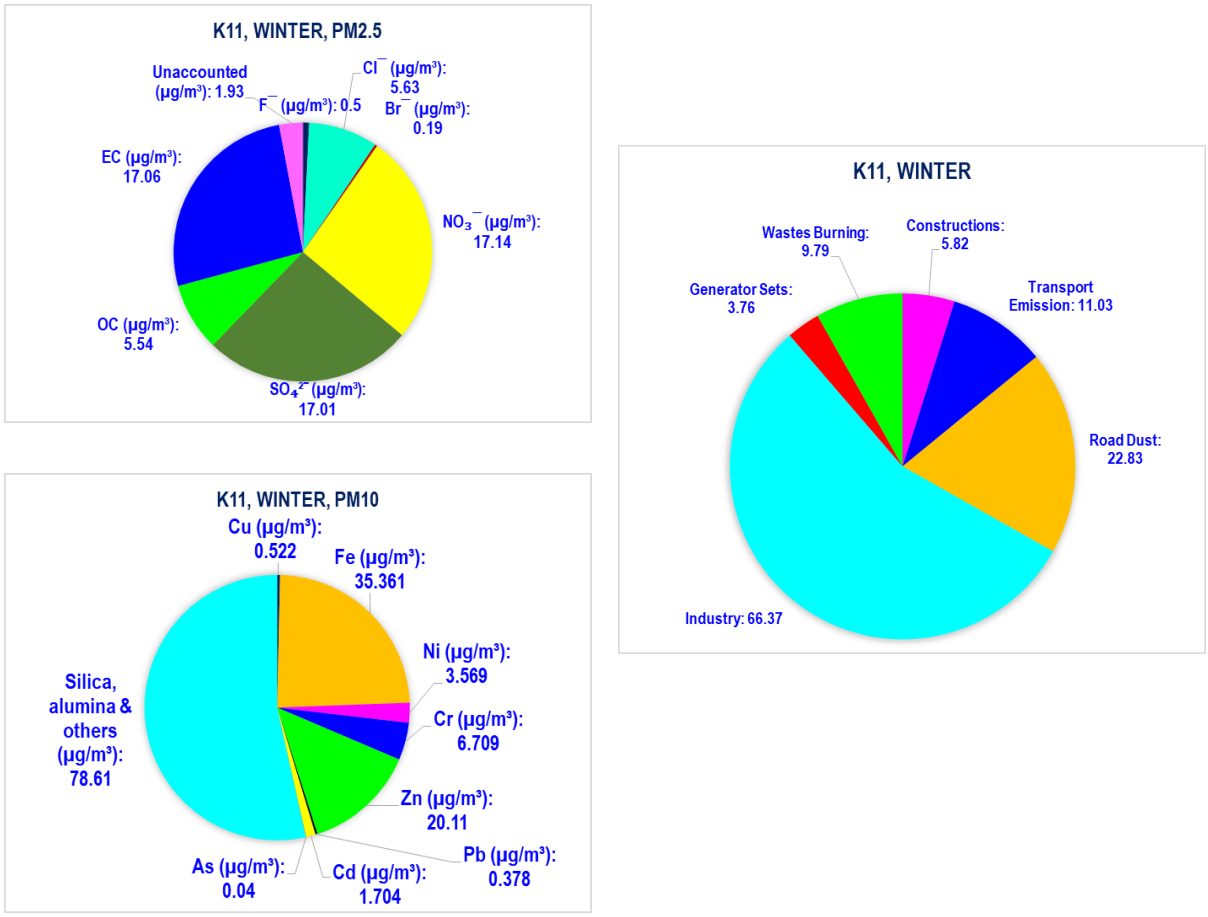


Figure 2.78: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K11' during winter.

'K12' is also an 'Industrial' type sub-station of Power Plant. Where, emission inventory study shows emission from industry (46%; 35.77µg/m^3). Other emission sources are road dust (22%; 17.02 µg/m^3), transports emission (19%; 14.27 µg/m^3), construction (7%; 5.48 µg/m^3), wastes burning (3%; 2.27 µg/m^3), generator sets fuel oil combustion (3%; 2.09 µg/m^3) (Figure 2.79).

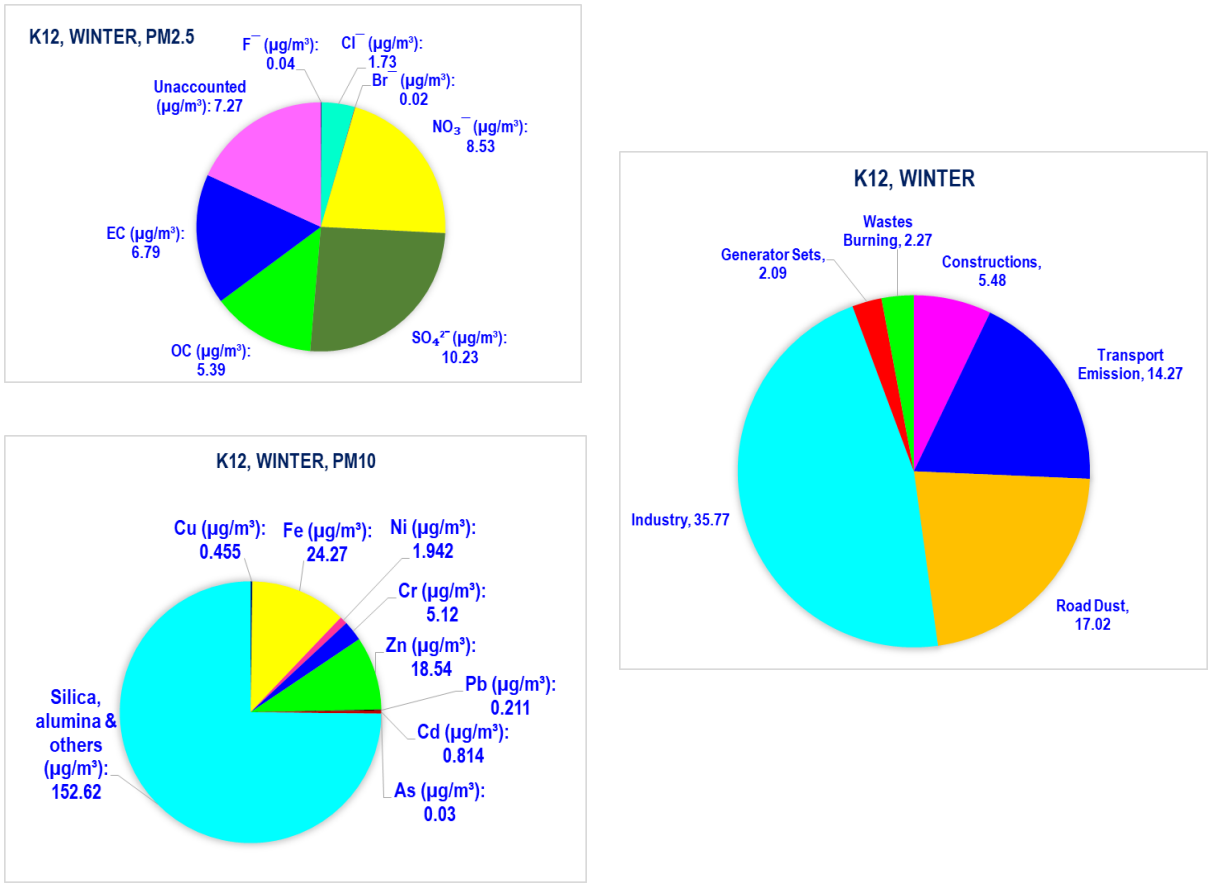


Figure 2.79: Average composition (µg/m^3) of particulate matter and their emission sources in air quality monitoring station 'K12' during winter.

'K13' is a 'Mixed' type sampling station on a Govt. High School. But all kinds of intra–sectoral effects have been found here. Emission sources are industrial emission (49%; 36.92 µg/m^3), transports emission (12%; 9.05 µg/m^3), road dust (13%; 10.07 µg/m^3), constructions (8%; 5.78 µg/m^3), domestic fuel combustion (13%; 9.97 µg/m^3), wastes burning (1%; 1.09 µg/m^3) and generator sets fuel oil combustion (4%: 2.99 µg/m^3) (Figure 2.80).

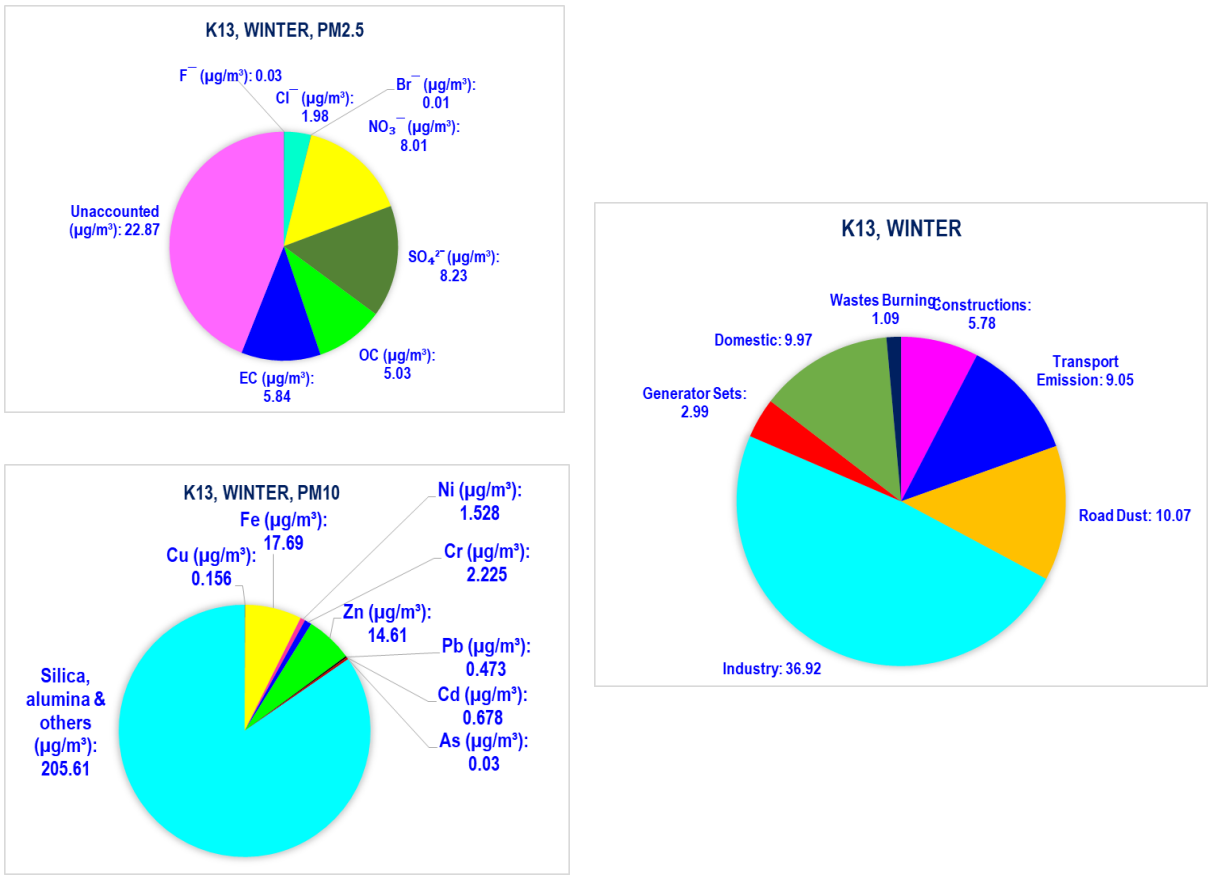


Figure 2.80: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K13' during winter.

'K14' is a P.H.C. and its' a 'Silent' type air-quality monitoring station. According to the emission inventory analysis, sources of pollutants are industry (49%; 30.06 µg/m^3), road dust (20%, 11.89 µg/m^3), constructions (8%; 5.01 µg/m^3), transports emission (15%; 9.41 µg/m^3) and resatrants/ eateries/ hawkers fuels combustion (8%; 5.07 µg/m^3) (Figure 2.81).

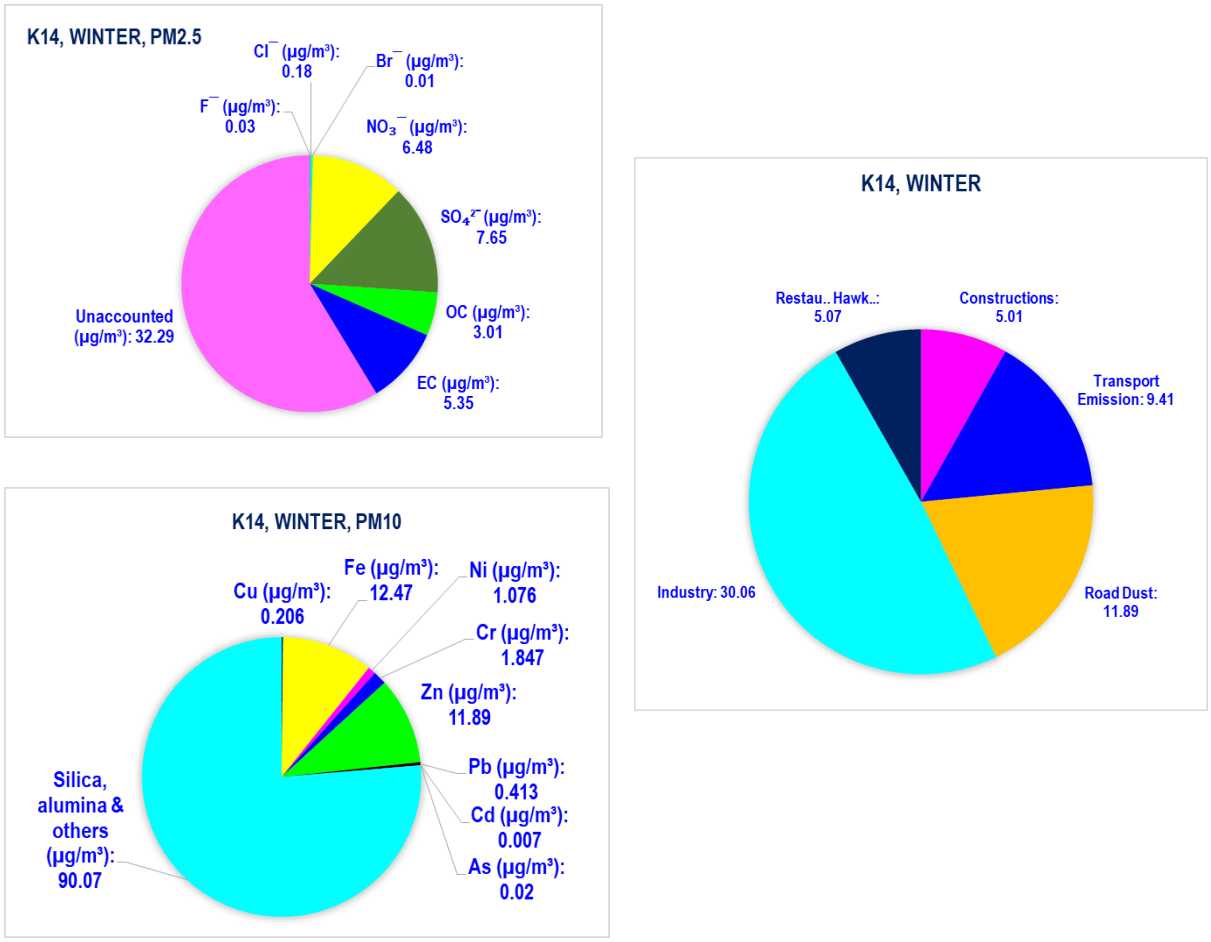


Figure 2.81: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K14' during winter.

'K15' is a 'Mixed' type and intra-sectoral contamination has been found in both stations. In 'K15' sources are road dust (16%; 10.64 µg/m^3), transports emission (12%; 8.22 µg/m^3), constructions (8%; 5.11 µg/m^3), industry (56%; 37.02 µg/m^3) and wastes combustion (8%; 4.99 µg/m^3) (Figure 2.82).

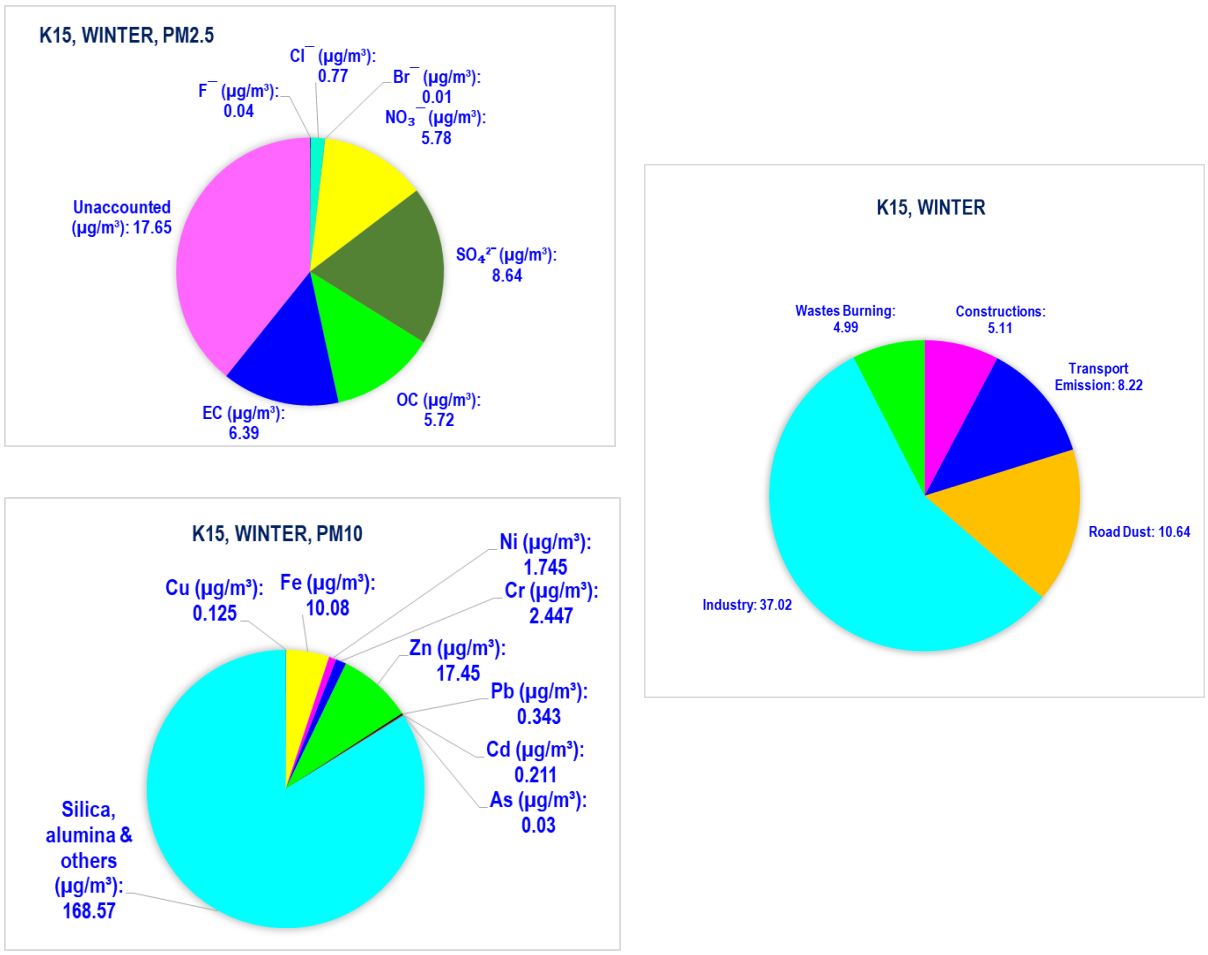


Figure 2.82: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K15' during winter.

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 Korba.

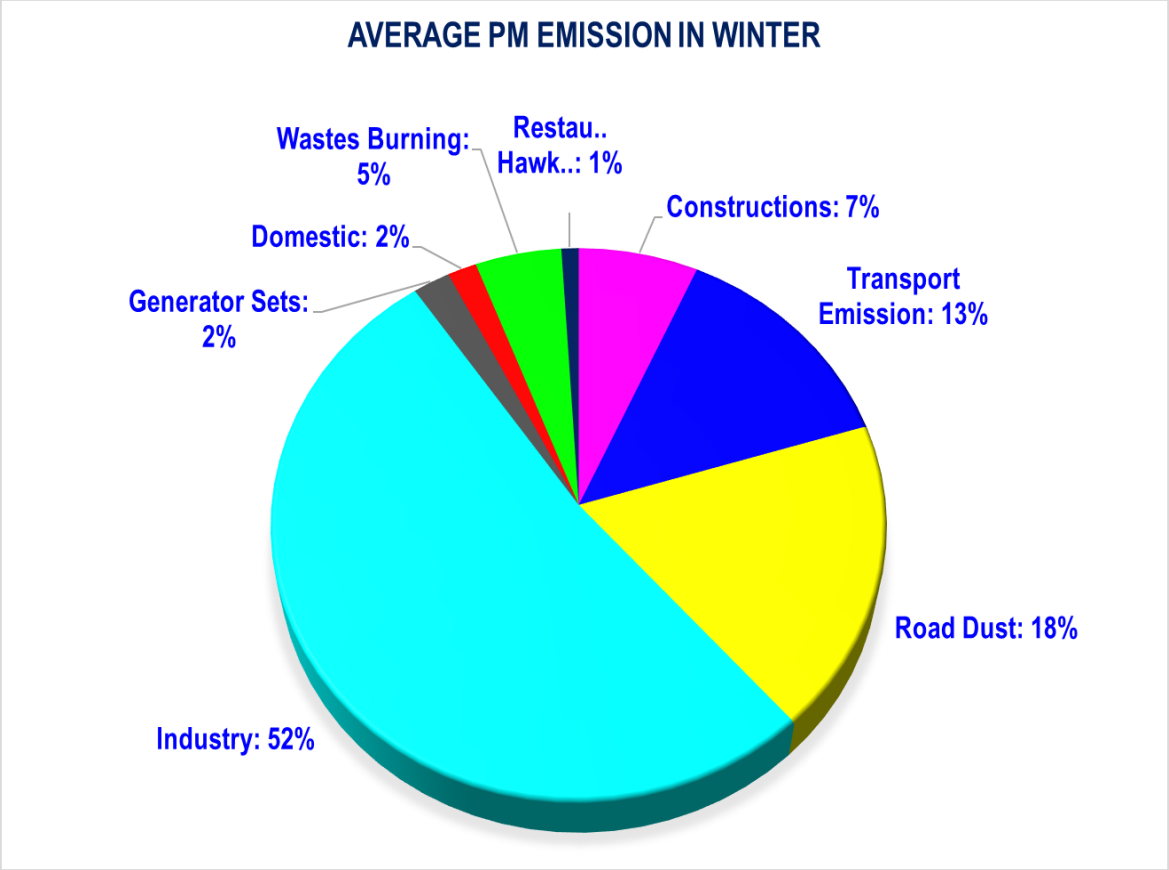


Figure 2.84: Different sources of pollutants and their percent contribution in the ambient air pollution of Korba during winter season.

Ambient air in Korba has mainly effected by its 'Power Plants' and different mining activities. Both are combinedly taken as 'industrial emission' and have 52% contribution with 44.42 µg/m^3 particulate matters emission. Similarly, the emissions from different road is 18% (15.49 µg/m^3), constructions 7% (5.76 µg/m^3), transport emission 13% (11.58 µg/m^3), wastes burning 5% (4.16 µg/m^3) have major contributions in ambient air pollution of Korba. Other emission sources of pllutants and their emission are shown in the Figure 2.84.

2.4.8.2. Summer Season

Air quality monitoring station 'K01' is categorized as 'Commercial'. Emission study shows this station has largely been affected by different types of industrial emission (51%; 44.06 µg/m^3), road dust (15%; 13.23 µg/m^3), transports emission (14%; 11.56 µg/m^3) and construction (5%; 4.18 µg/m^3). Emission from wastes burning (5%; 4.19 µg/m^3), generator sets fuel oil combustion (7%; 6.21 µg/m^3) and restaurants/ eateries/ hawkers fuels combustion (3%; 2.55 µg/m^3) have also effect the ambient air of K01 (Figure 2.85).

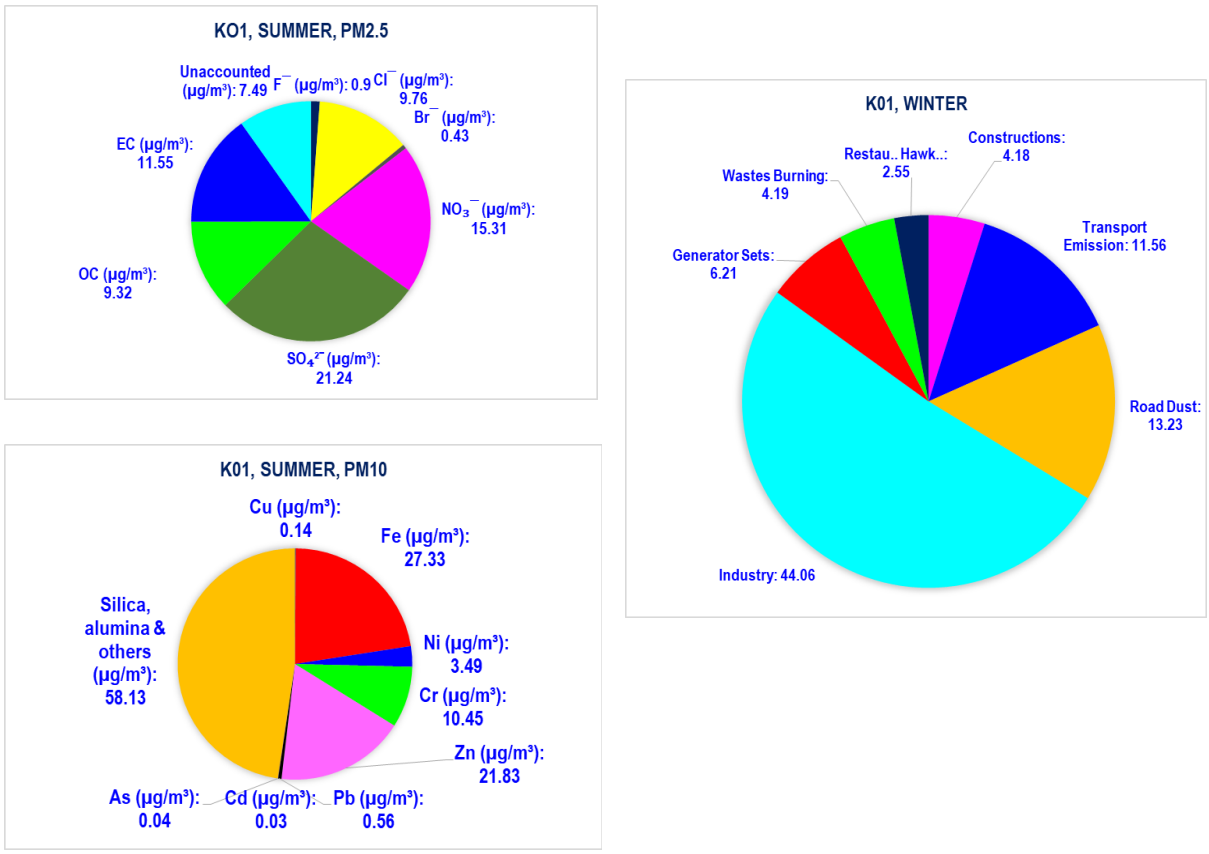


Figure 2.85: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K01' during summer.

'K02' is a 'Silent' type air-quality monitoring station. Industrial emission (45%; 23.48 µg/m^3), road dust (21%; 11.21 µg/m^3), transports emission (19%; 10.14 µg/m^3), different types of constructions (5%; 2.81 µg/m^3), wastes burning (4%; 1.86 µg/m^3), domestic fuels combustion (3%; 1.59 µg/m^3) and generator sets fuel oil combustion (3%; 1.72 µg/m^3) are shared the emission plot (Figure 2.86).

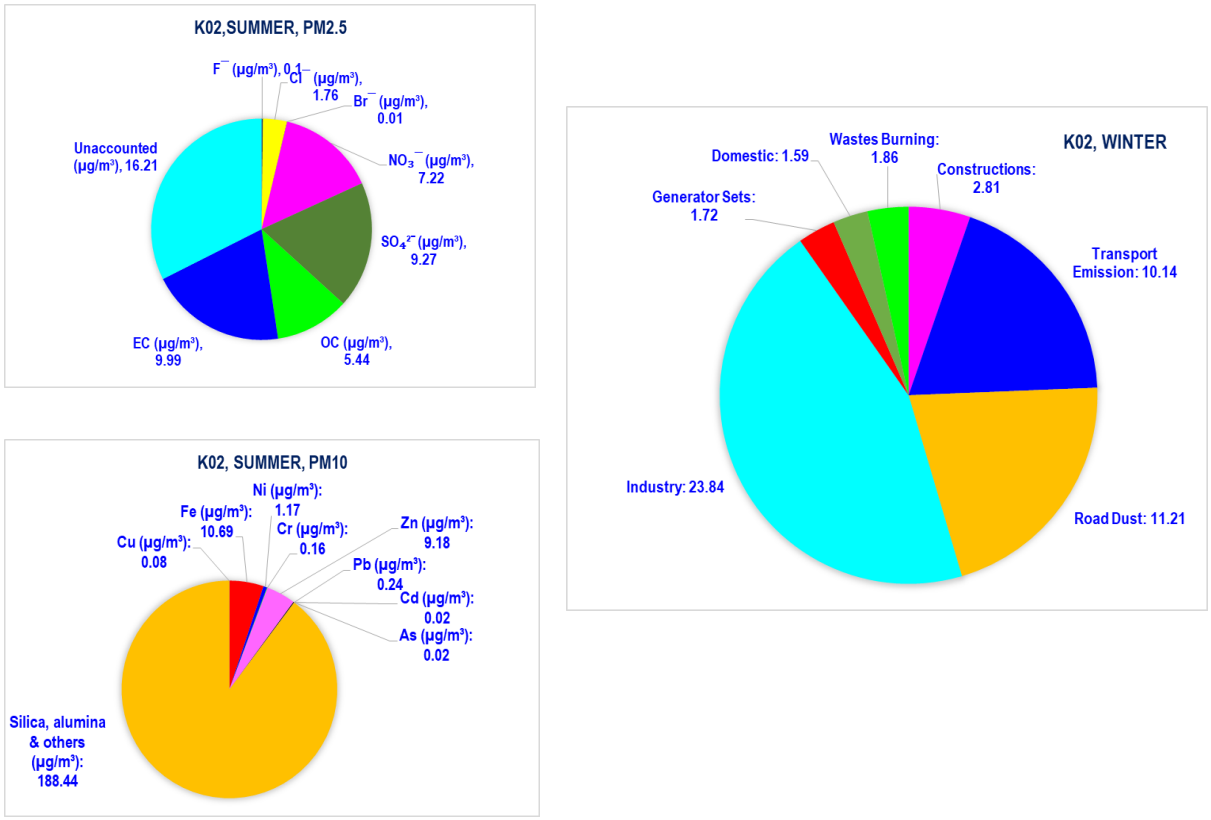


Figure 2.86: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K02' during summer.

'K03' is an 'Agricultural' type air-quality monitoring station and polluted mainly due to industry (50%; 45.19 µg/m^3), road dust (20%; 18.11 µg/m^3) and transport emission (16%; 14.28 µg/m^3). Other sources are intra-sectoral like construction (6%; 5.57 µg/m^3) and domestic fuels combustion (5%; 4.49 µg/m^3) (Figure 2.87).

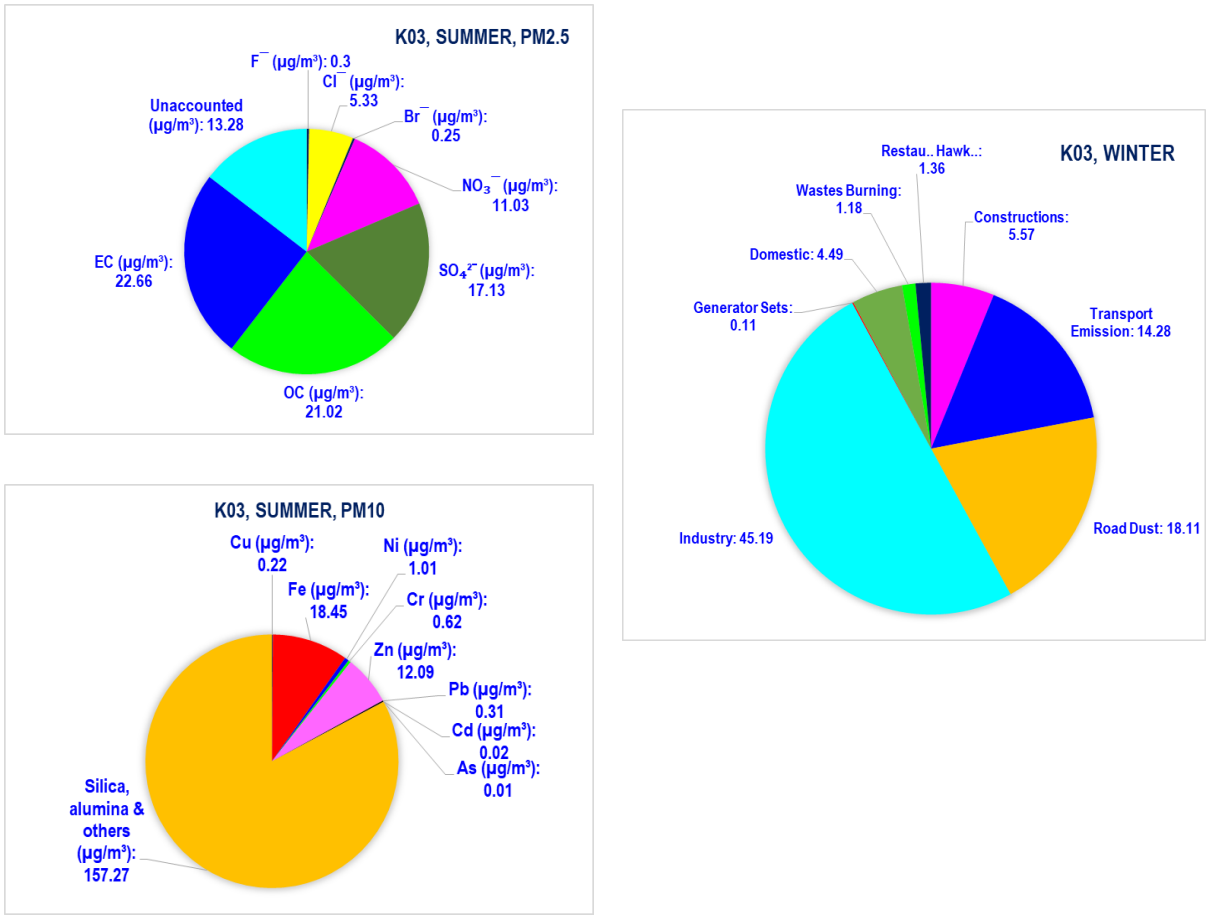


Figure 2.87: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K03' during summer.

'K04' is an 'Agricultural' type air-quality monitoring stations. Sectoral emission inventory analysis shows that ambient air contains road dust (17%; 14.05 µg/m^3), construction (11%; 8.92 µg/m^3), industry (49%; 40.29 µg/m^3), transports emission (18%; 15.26 µg/m^3), wastes burning (3%; 2.31 µg/m^3), restaurants/ eateries/ hawkers fuels burning (1%; 1.17 µg/m^3) and generator sets fuel oil combustion (1%; 0.51 µg/m^3) (Figure 2.88).

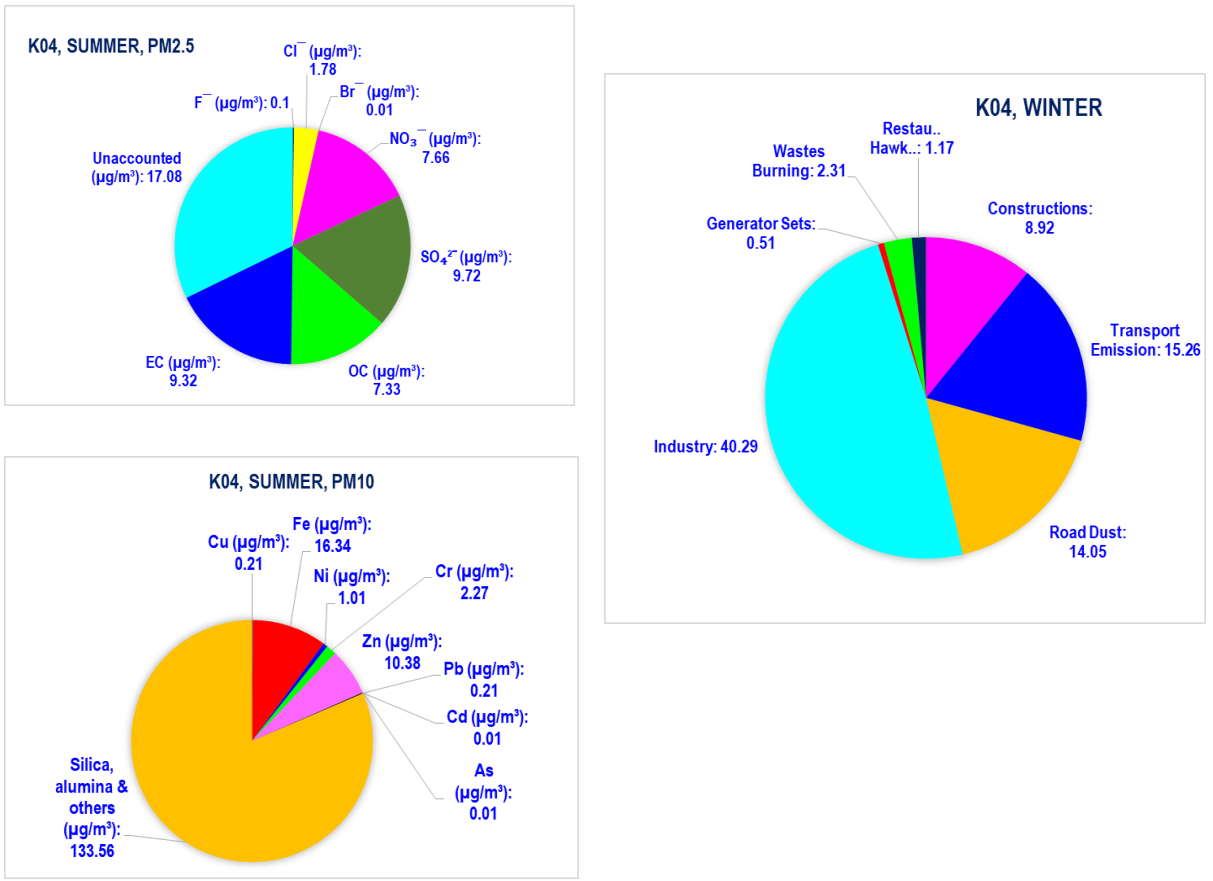
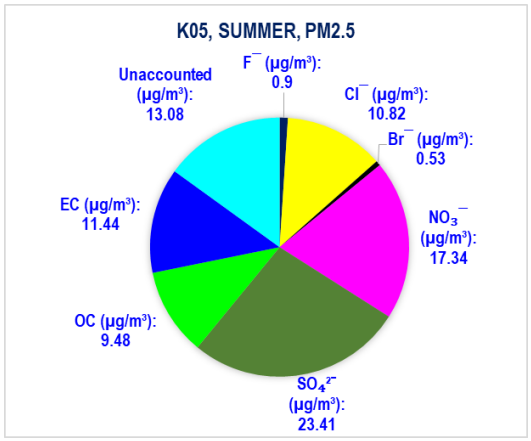
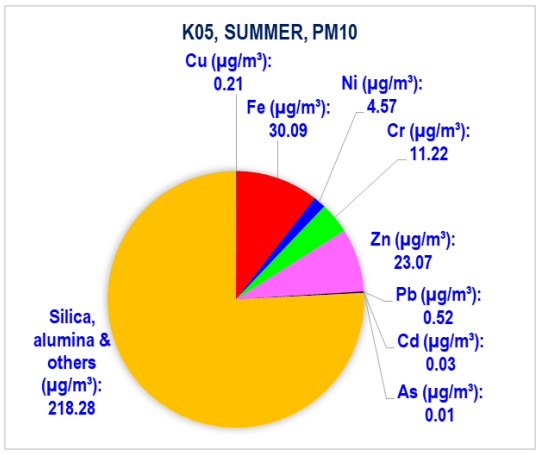


Figure 2.88: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K04' during summer.

'K05' is mainly polluted by industrial emission (48%; 54.39 µg/m^3), while it's an agricultural area. Other sectoral shares are road dust (17%; 19.61 µg/m^3), transport emission (15%; 17.13 µg/m^3), construction (10%; 11.91 µg/m^3), wastes burning (4%; 4.54 µg/m^3) and generator sets fuel oil combustion (6%; 6.39 µg/m^3) (Figure 2.89).





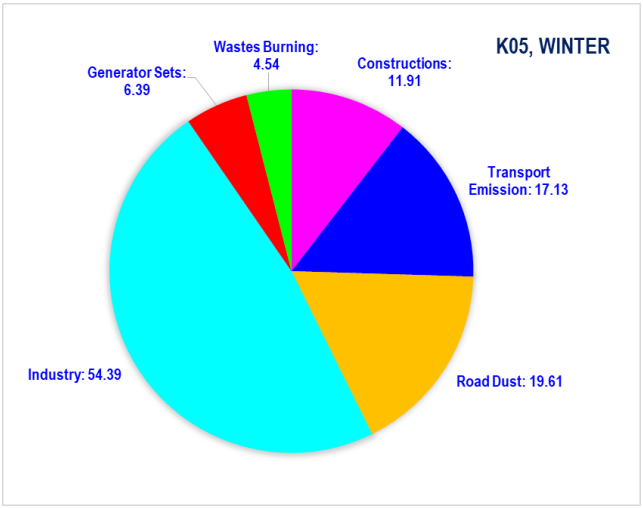
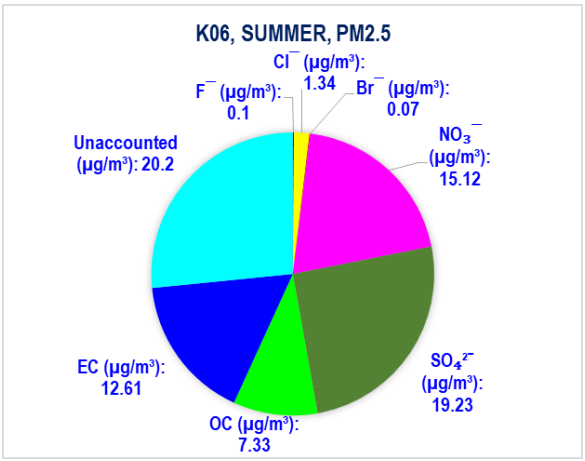
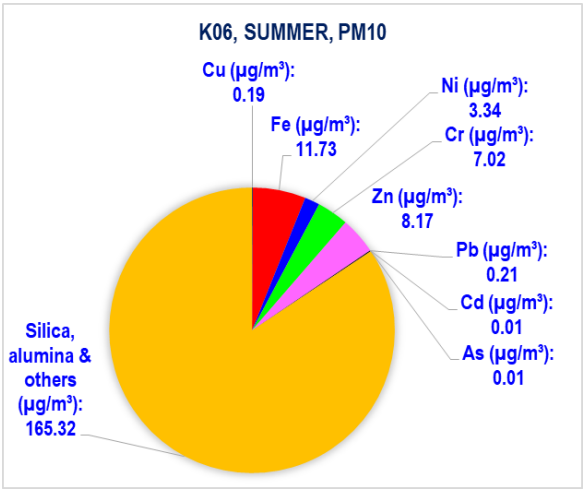


Figure 2.89: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K05' during summer.

'K06' is a 'Commercial' type sampling station. Emission inventory study by CMB shows that, sources in 'K06' are industrial emission (42%; 32.51 µg/m^3), road dust (23%; 17.62 µg/m^3), transports emission (16%; 12.92 µg/m^3), wastes burning (10%; 7.48 µg/m^3), construction (3%; 2.36 µg/m^3) and generator sets fuel oil combustion (6%; 4.85 µg/m^3) (Figure 2.90).





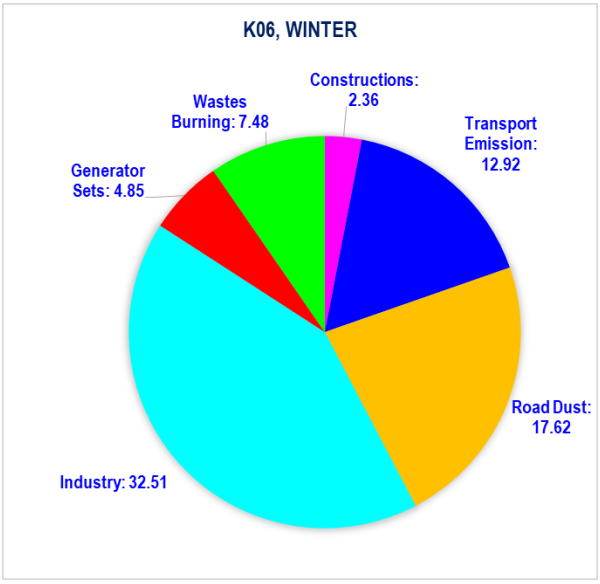


Figure 2.90: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K06' during summer.

While emission sources in the air-quality monitoring station 'K07' are industrial emission (52%; 46.79 µg/m^3), transports emission (16%; 14.54 µg/m^3), road dust (11%; 9.77 µg/m^3), wastes combustion (4%; 3.72 µg/m^3), construction (8%; 7.57 µg/m^3), domestic fuels combustion (7%; 6.51 µg/m^3) and generator sets fuel oil combustion (2%; 1.67 µg/m^3) (Figure 2.91).

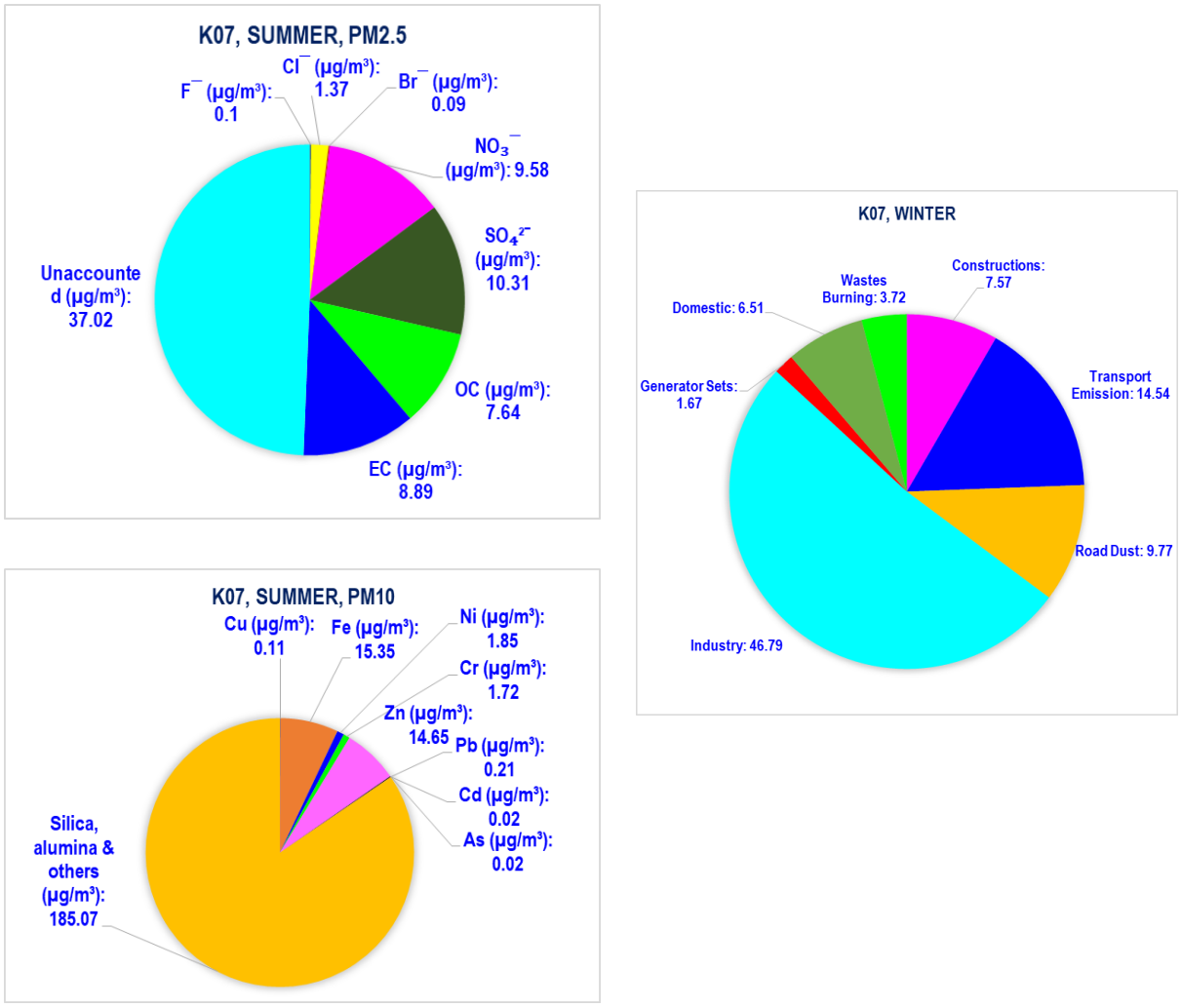


Figure 2.91: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K07' during summer.

Emission sources in the air-quality monitoring station 'K08' (Industrial) are industrial emission (51%; 40.91 µg/m^3), transports emission (15%; 12.37 µg/m^3), construction (5%; 3.64 µg/m^3), road dust (17%; 13.21 µg/m^3), wastes burning (11%; 8.98 µg/m^3) and generator sets fuel oil combustion (1%; 1.07 µg/m^3) (Figure 2.92).

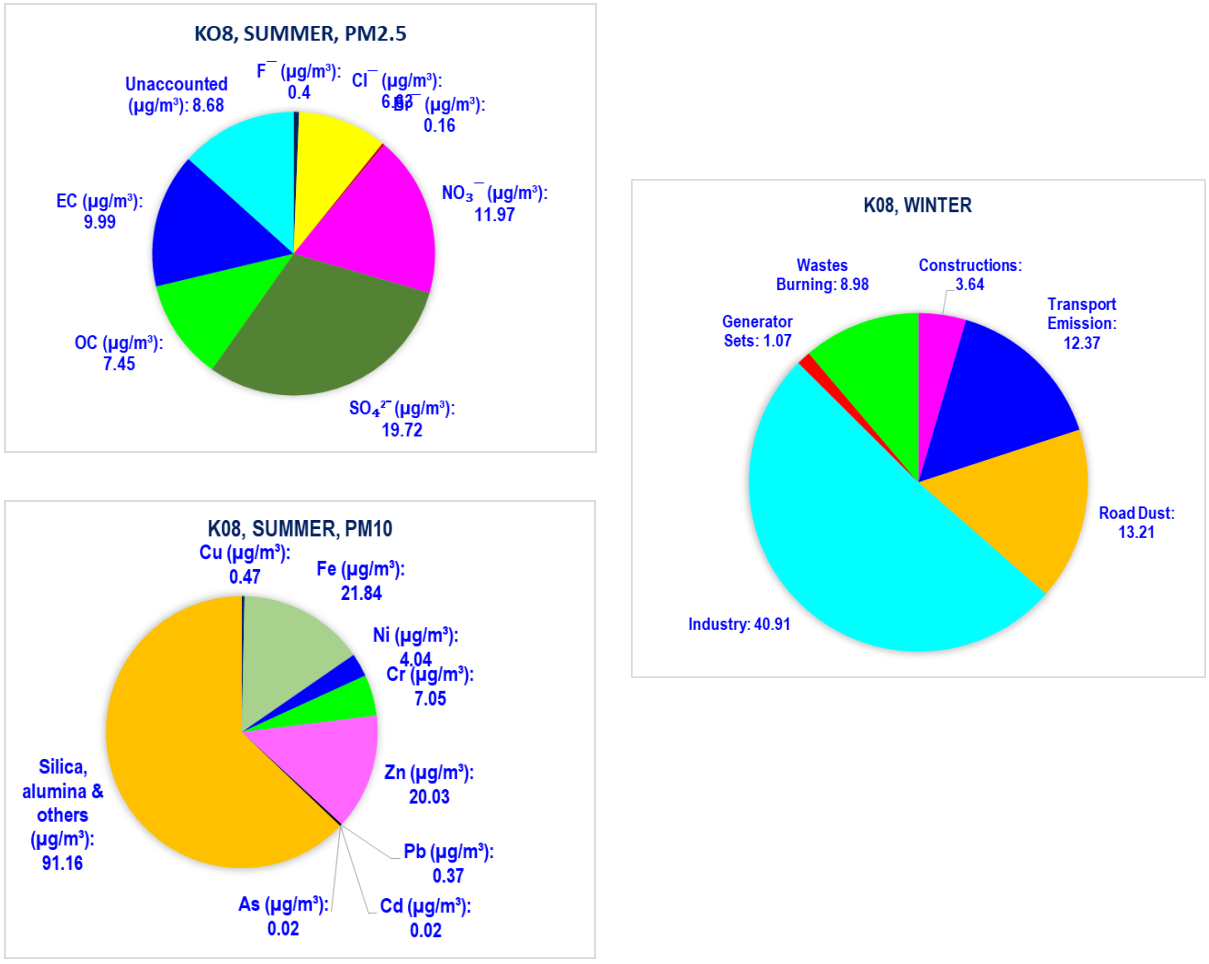


Figure 2.92: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K08' during summer.

'K09' is a 'Mixed' categorized air-quality monitoring station on 'BALCO Get House' at Korba. According to the emission inventory study, the sources which affect the ambient air quality are power plant / industrial emission (54%; 49.73 µg/m^3), road dust (18%; 16.84 µg/m^3), transports emission (20%; 17.89 µg/m^3), construction (4%; 3.31 µg/m^3), wastes burning (3%; 2.98 µg/m^3), generator sets fuel oil combustion (1%; 0.94 µg/m^3) (Figure 2.93).

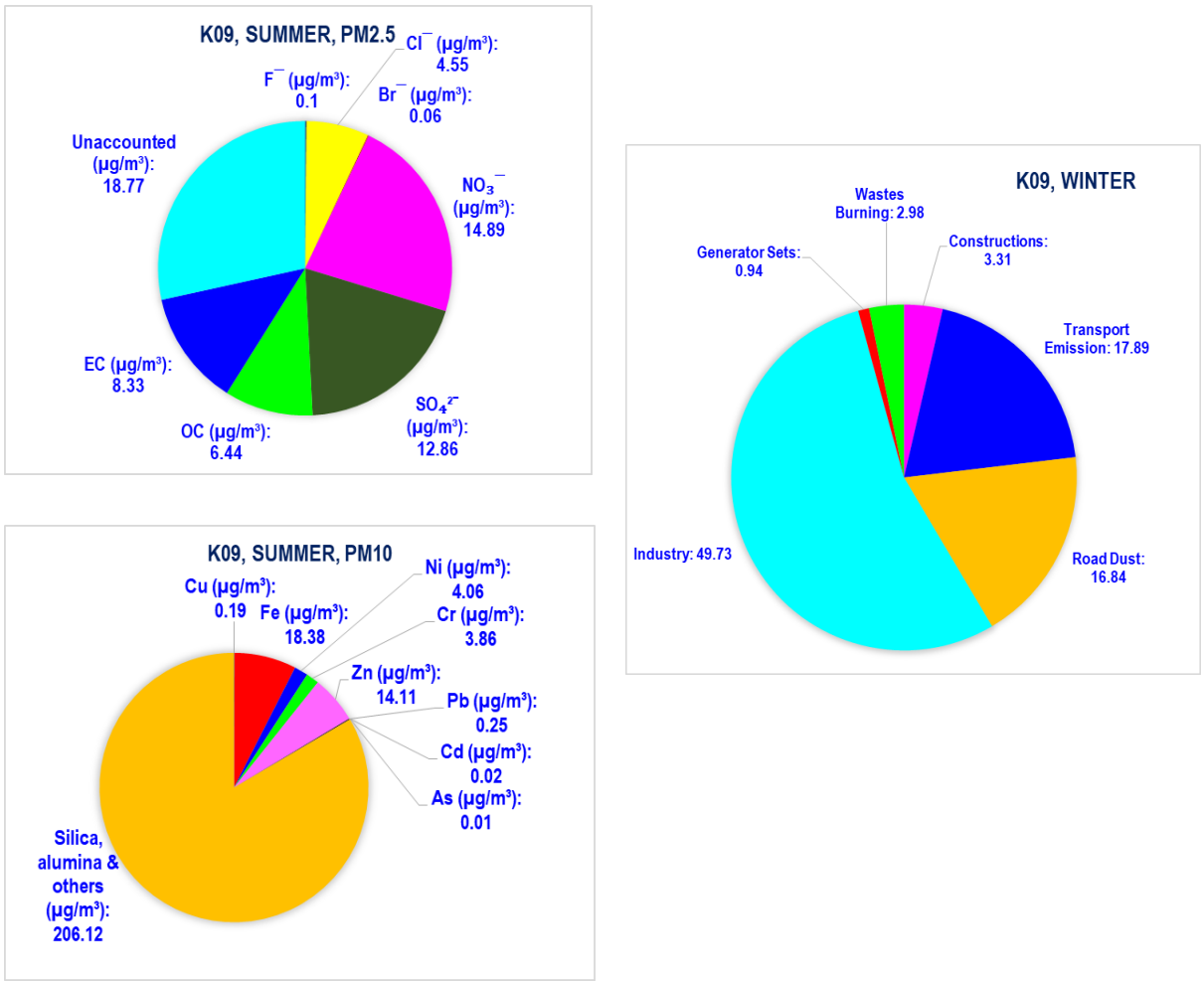


Figure 2.93: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K09' during summer.

'K10' is a 'Traffic' station. Emission inventory study shows the air-quality in this station is affected by industrial emission (39%; 27.39 µg/m^3), road dust (22%; 15.46 µg/m^3), transports emission (22%; 15.84 µg/m^3), construction (8%; 5.85 µg/m^3), generator sets fuel oil combustion (6%; 4.31 µg/m^3) and wastes burning (3%; 2.41 µg/m^3) (Figure 2.94).

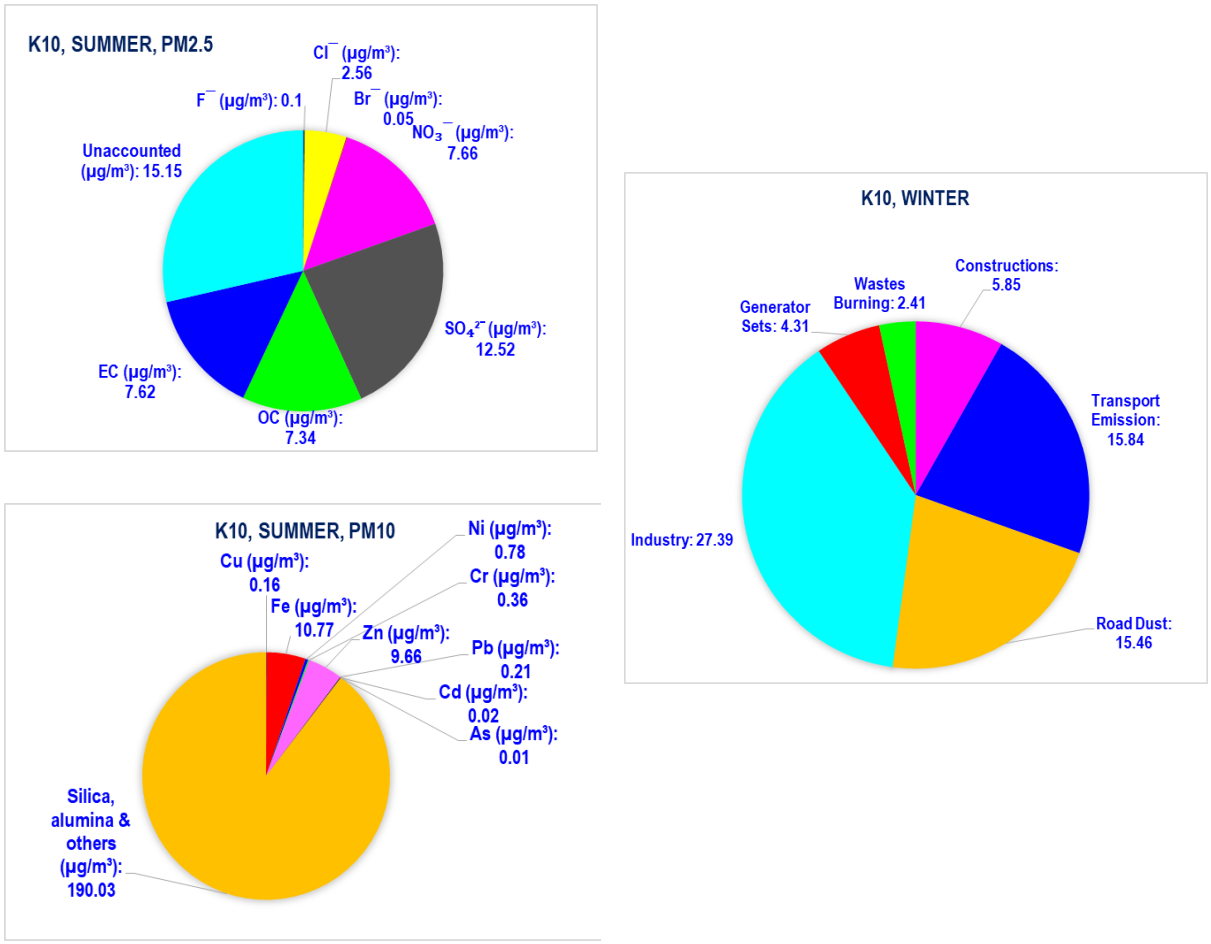


Figure 2.94: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K10' during summer.

'K11' is an 'Industrial' type air-quality monitoring station in 'LANCO Power Plant'. Emission sources are industrial or Power Plant (46%; 46.09 µg/m^3), road dust (19%; 19.22 µg/m^3), transport emission (18%; 17.43 µg/m^3), construction (5%; 5.12 µg/m^3) and wastes burning (10%; 9.47 µg/m^3) (Figure 2.95).

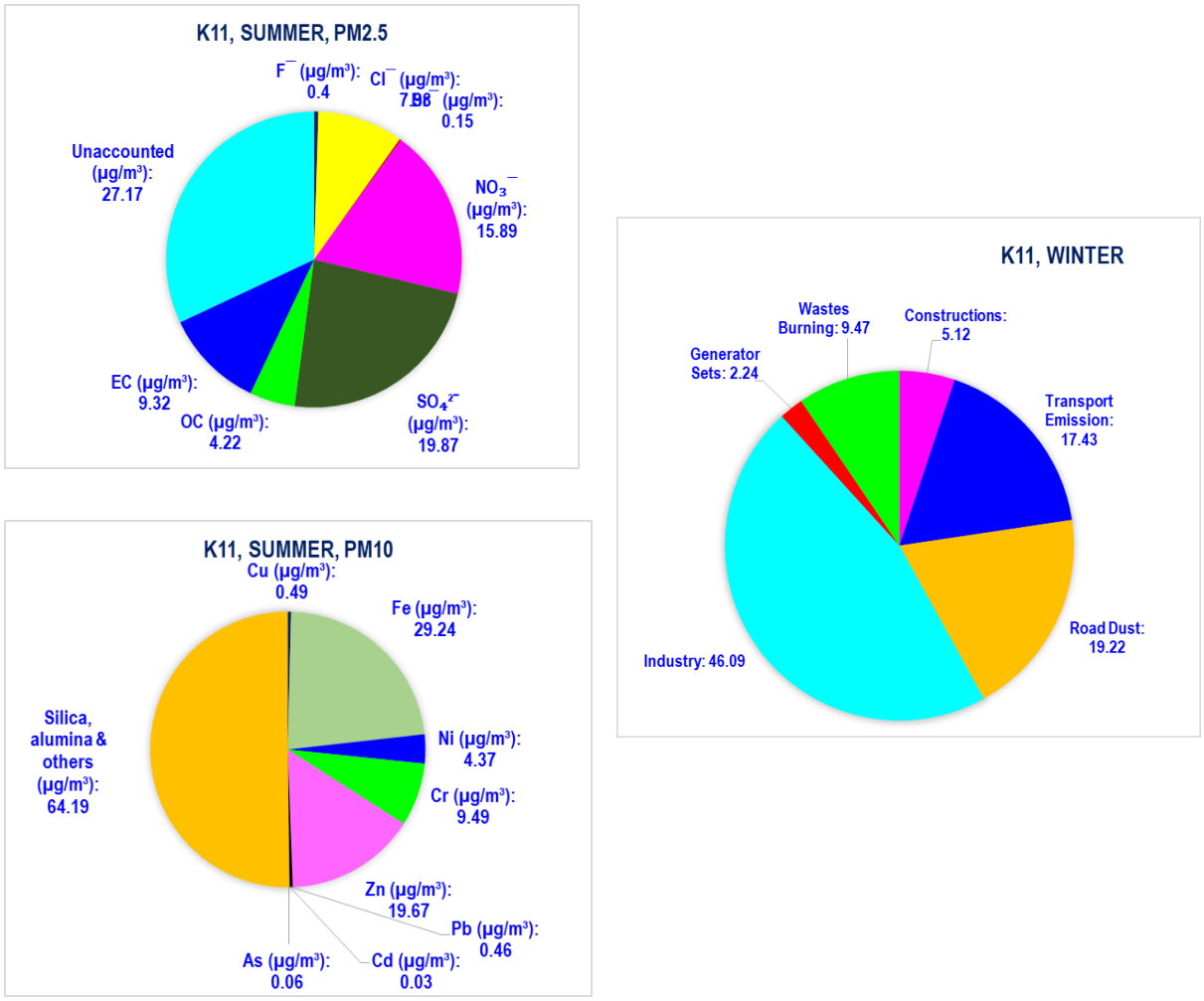


Figure 2.95: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K11' during summer.

'K12' is also an 'Industrial' type sub-station of Power Plant. Where, CMB predicts emission sources are industry / power plant (39%; 34.28 µg/m^3), road dust (24%; 21.05 µg/m^3), transport emission (21%; 19.06 µg/m^3), constructions (8%; 6.81 µg/m^3), wastes burning (1%; 1.42 µg/m^3) and generator sets fuel oil combustion (7%; 6.12 µg/m^3) (Figure 2.96).

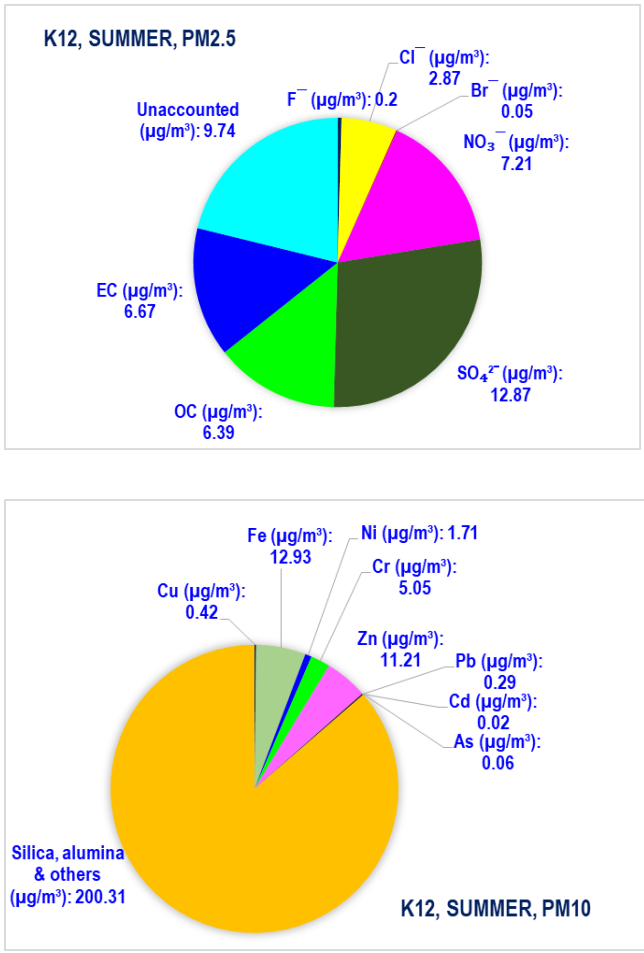


Figure 2.96: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K12' during summer.

'K13' is a 'Mixed' type sampling station on a Govt. High School. But all kinds of intra–sectoral effects have been found here. Emission sources are industrial emission (44%; 34.81 µg/m^3), transports emission (13%; 10.44 µg/m^3), road dust (16%; 12.61 µg/m^3), constructions (7%; 5.13 µg/m^3), wastes burning (3%; 1.86 µg/m^3), domestic fuels combustion (11%; 8.81 µg/m^3) and generator sets fuel oil combustion (6%; 4.99 µg/m^3) (Figure 2.97).

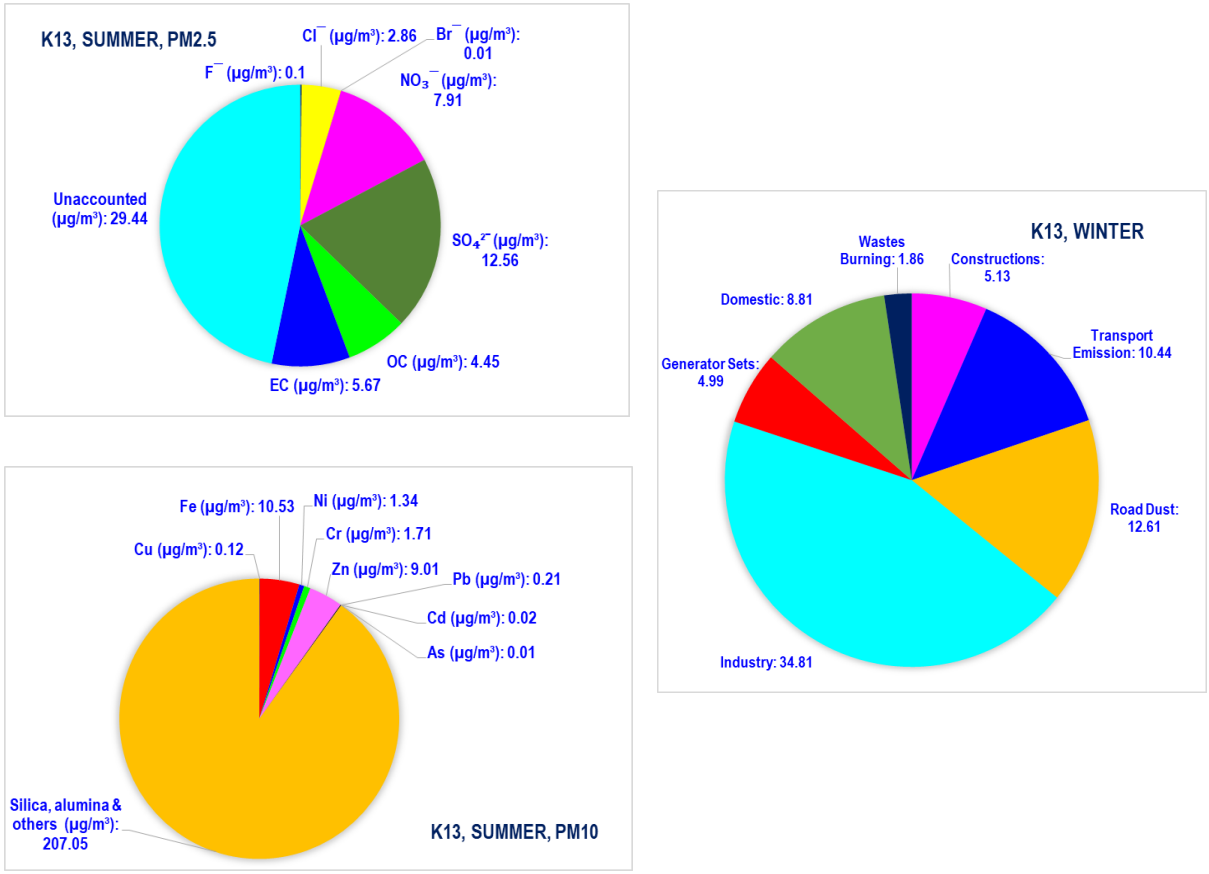


Figure 2.97: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K13' during summer.

'K14' is a P.H.C. and its' a 'Silent' type air-quality monitoring station. According to the emission inventory analysis, sources of pollutants are industry (52%; 37.94 µg/m^3), road dust (17%; 12.21 µg/m^3), constructions (7%; 5.23 µg/m^3), transports emission (16%; 11.48 µg/m^3), wastes combustion (1%; 0.94 µg/m^3), generator sets fuel oil combustion (1%; 0.51 µg/m^3) and restaurants/ eateries/ hawkers fuels combustion (6%; 4.55 µg/m^3) (Figure 2.98).

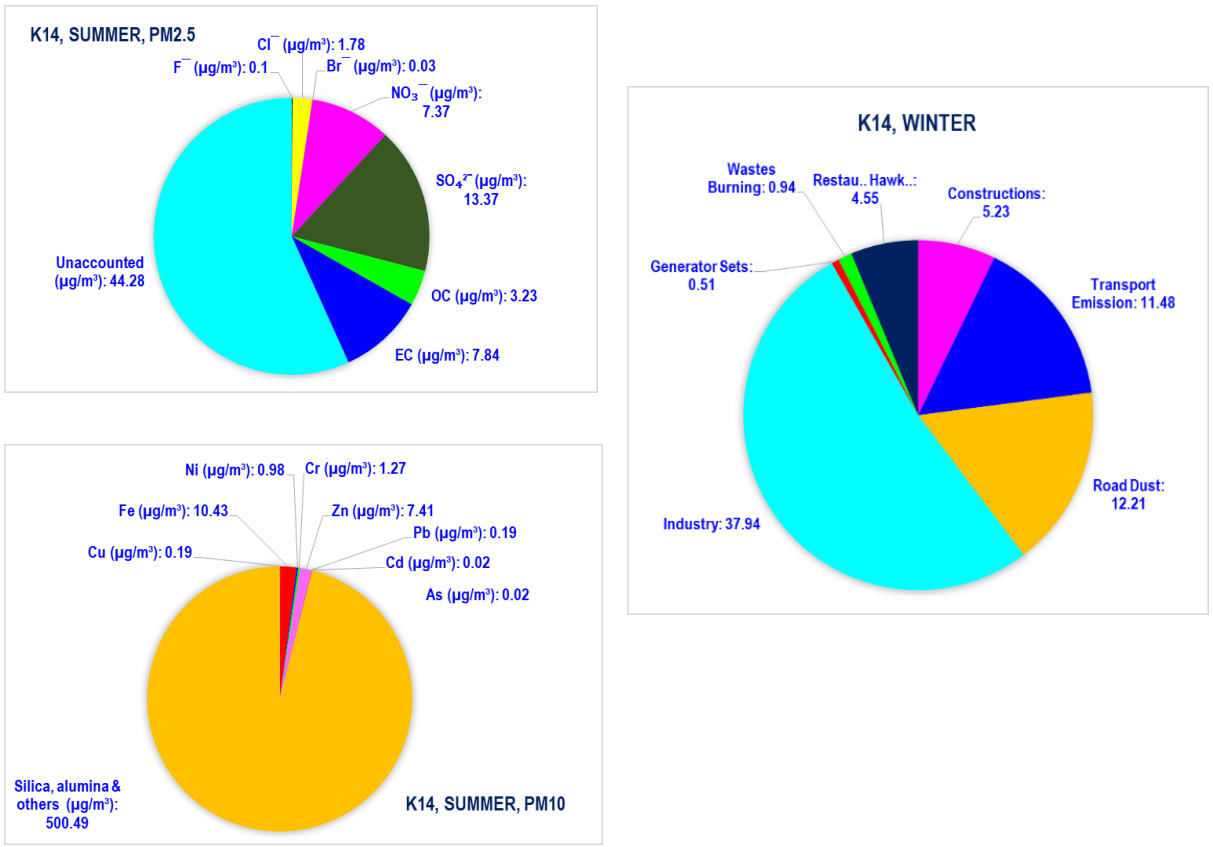


Figure 2.98: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K14' during summer.

'K15' is a 'Mixed' type and intra-sectoral contamination has been found in both stations. In 'K15' sources are road dust (16%; 13.86 µg/m^3), industrial emission (49%; 42.07 µg/m^3), constructions (9%; 7.98 µg/m^3), transports emission (14%; 11.89 µg/m^3), generator sets fuel oil combustion (4%; 3.02 µg/m^3) and wastes combustion (8%; 6.37 µg/m^3) (Figure 2.99).

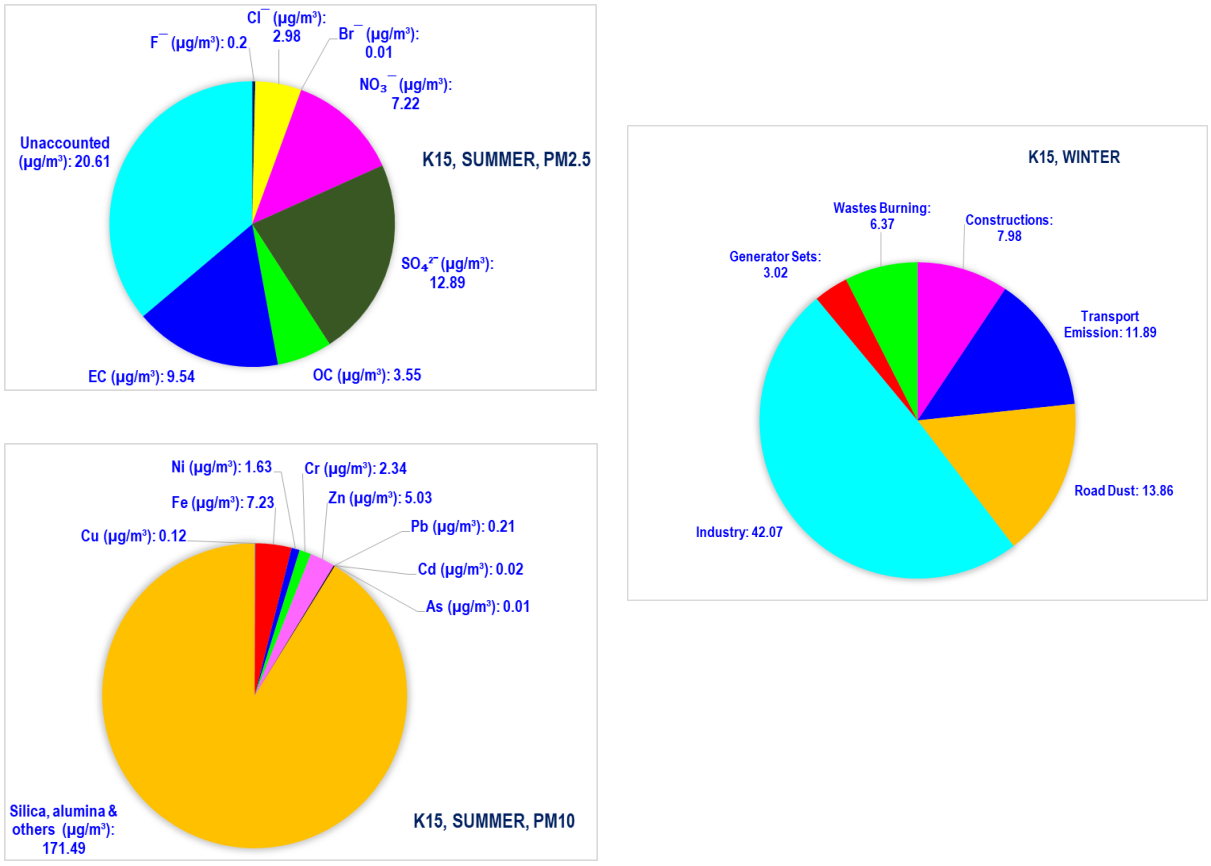


Figure 2.99: Average composition (µg/m^3) of particulate matters and their emission sources in air quality monitoring station 'K15' during summer.

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 Korba.

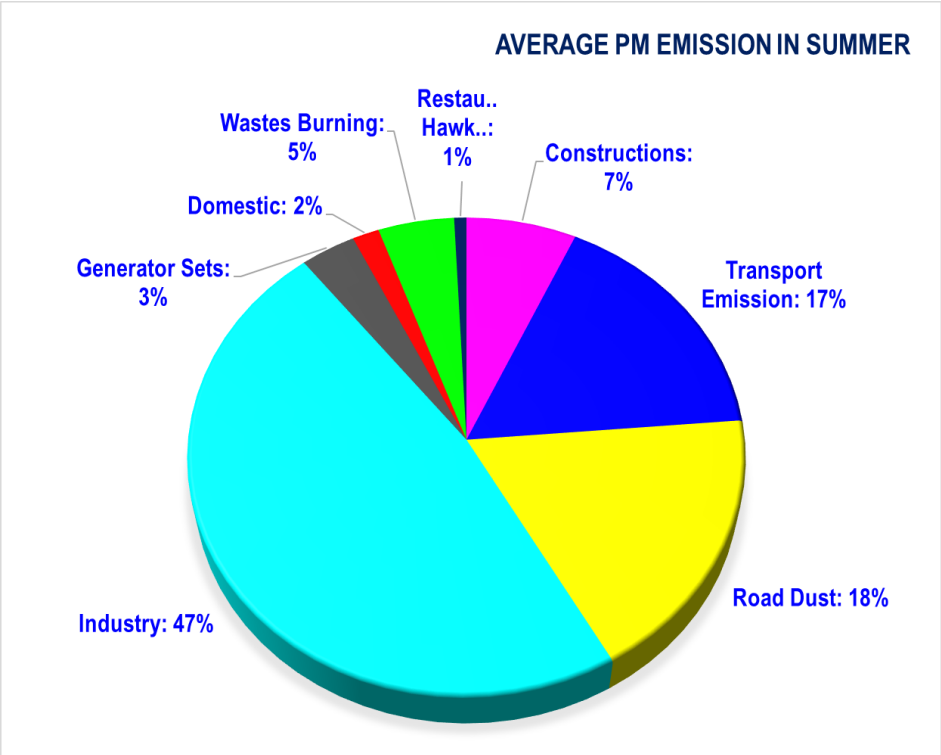
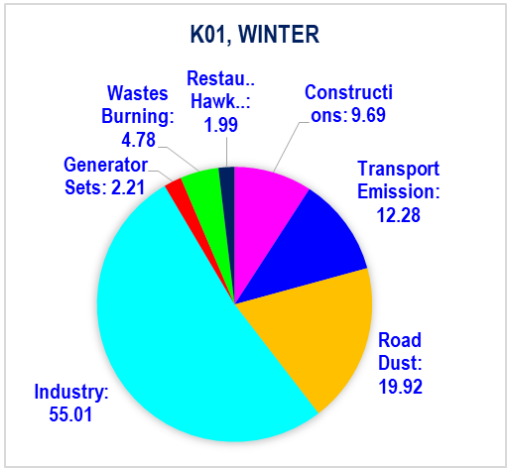


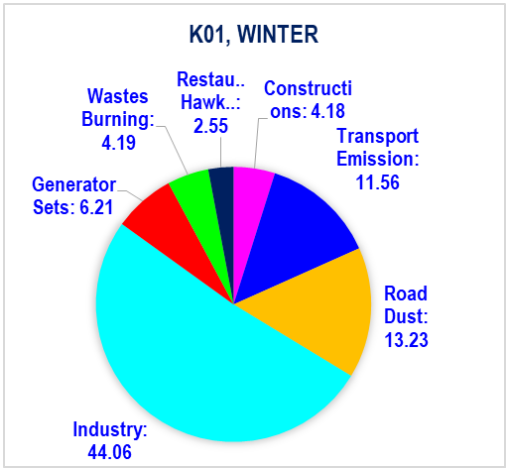
Figure 2.101: Different sources of pollutants and their percent contribution in the ambient air pollution of Korba during summer season.

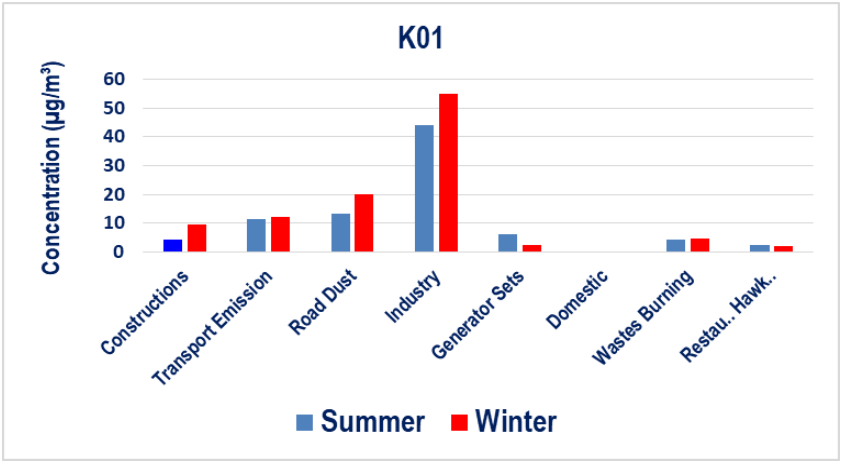
Emission inventory study shows, ambient air quality of Korba has mainly effected by its Power Plants, industries and open pit coal mining. They have 47% contribution with 40 µg/m^3 particulate matters emission rate. Similarly, the emissions from road dust has 18% (15.2 µg/m^3), transports emission 17% (14.15 µg/m^3), constructions 7% (5.76 µg/m^3), wastes burning 5% (3.98 µg/m^3), domestic fuels combustion 2% (1.4 µg/m^3), generator sets fuel oil combustion (3%; 2.9 µg/m^3) and restaurants/ eateries/ hawkers fuels burning (1%; 0.64 µg/m^3) have major contributions in ambient air pollution of Korba. Emissions and their contributions are shown in the Figure 2.101.

2.4.8.3. Seasonal Variation

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







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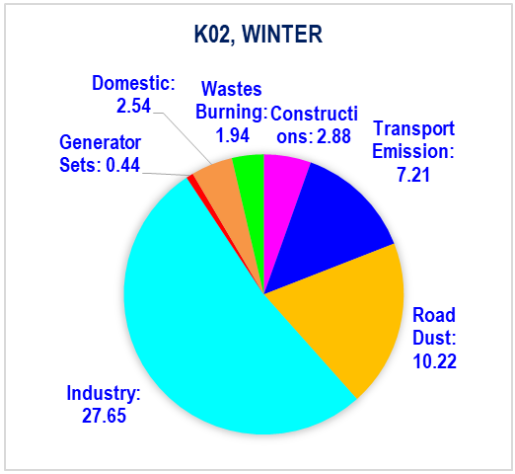
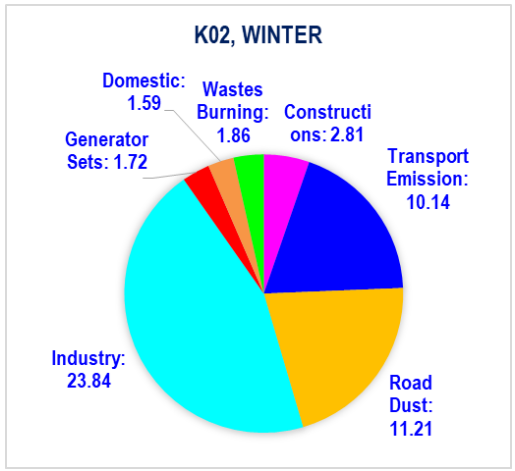
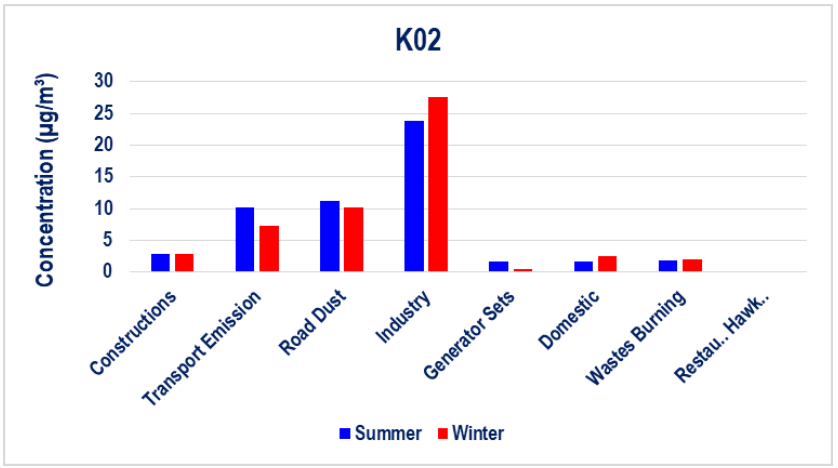
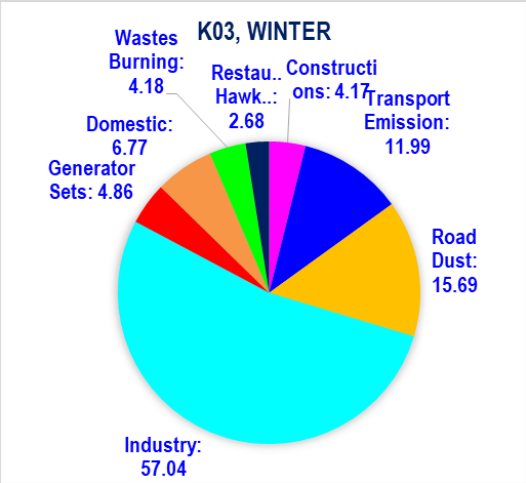




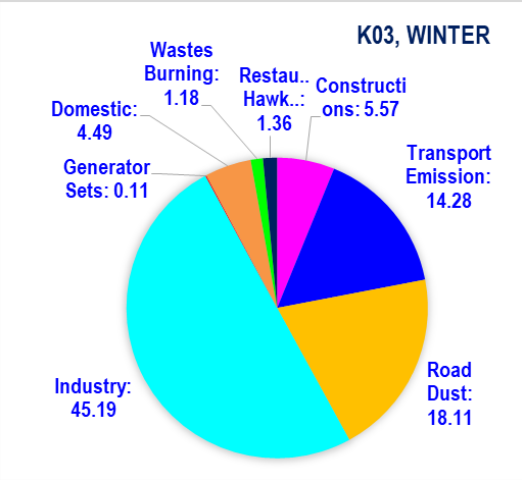


K02

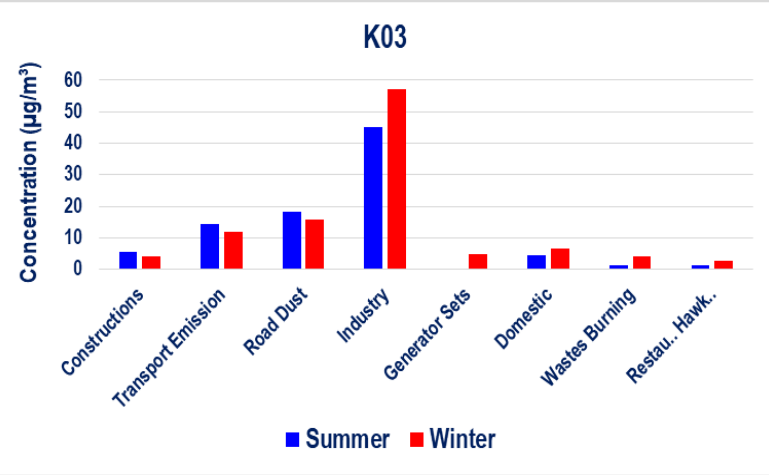
WINTER



SUMMER



SEASONAL VARIATION



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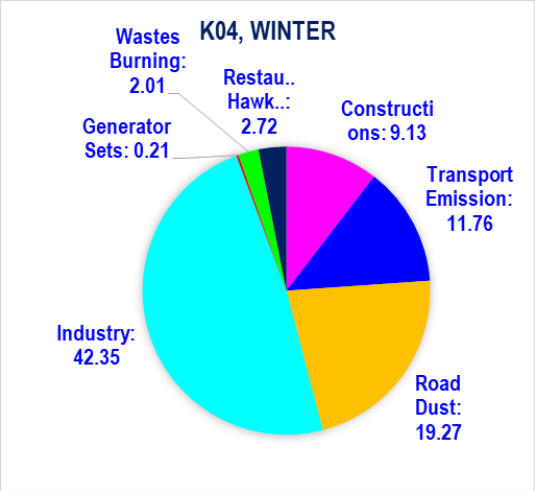
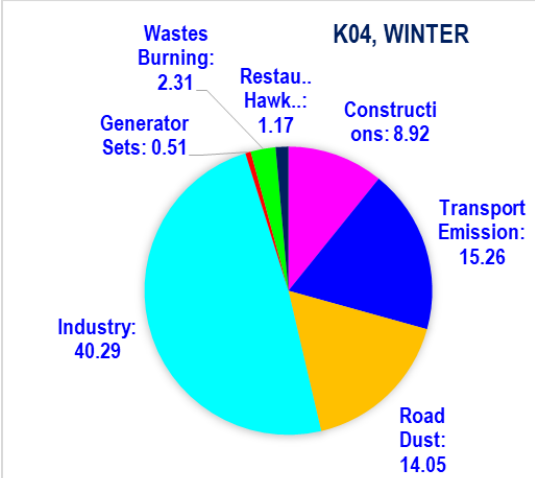
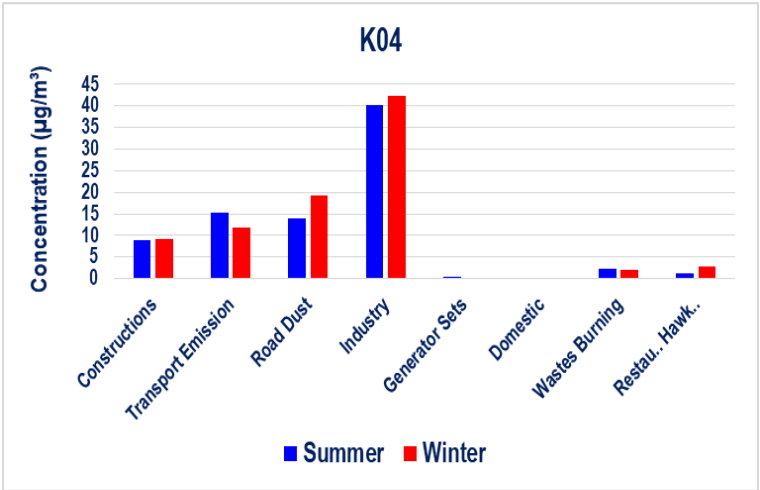




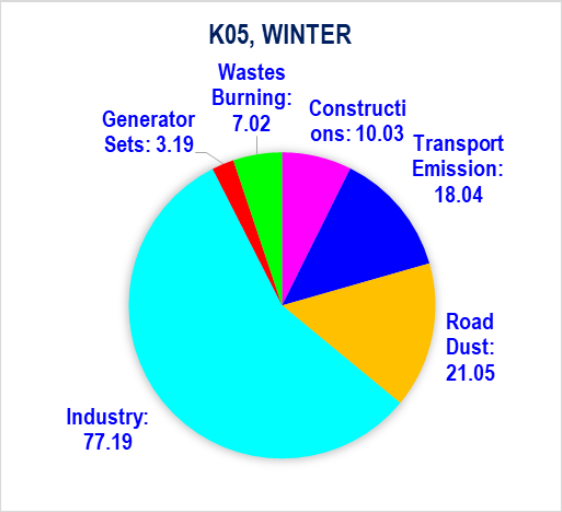


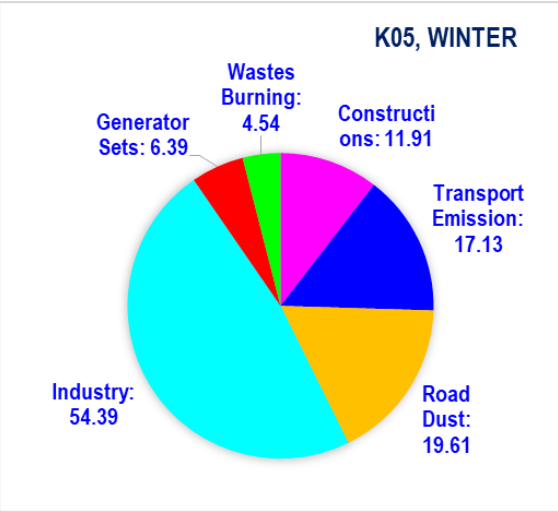
K04

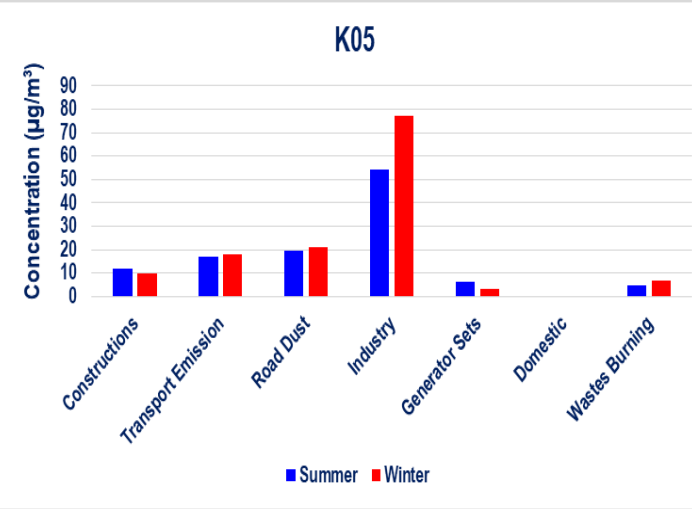
WINTER

SUMMER

SEASONAL VARIATION







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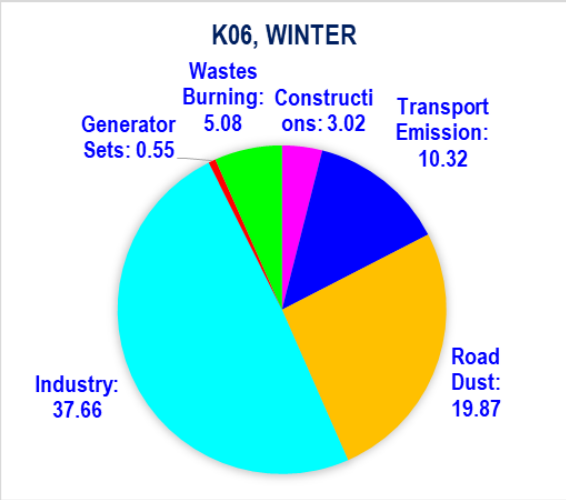

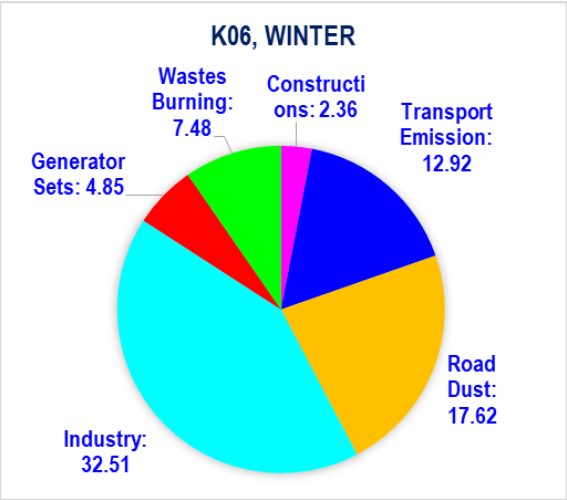

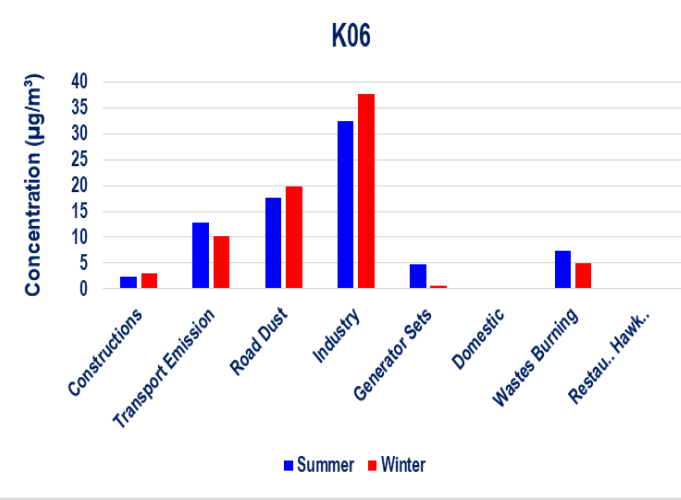

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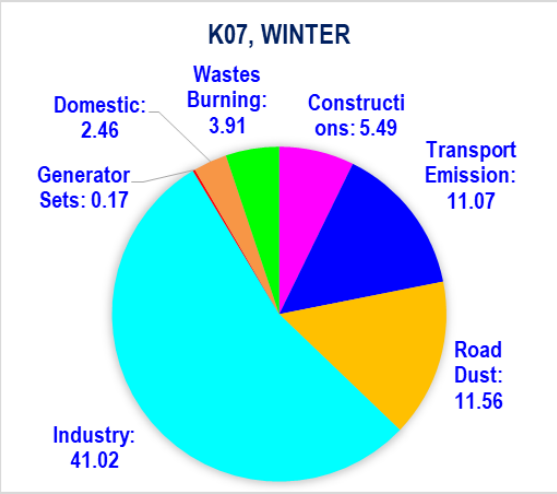

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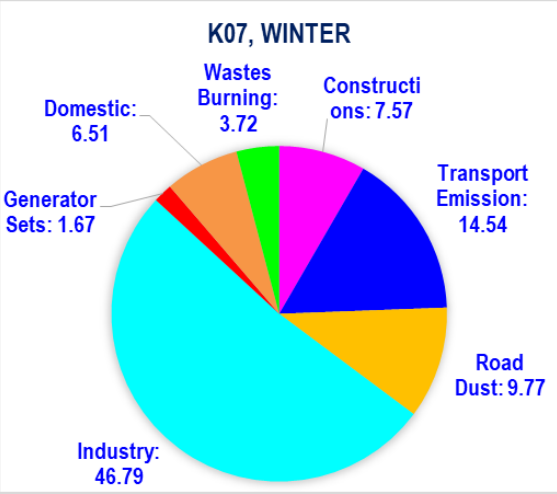

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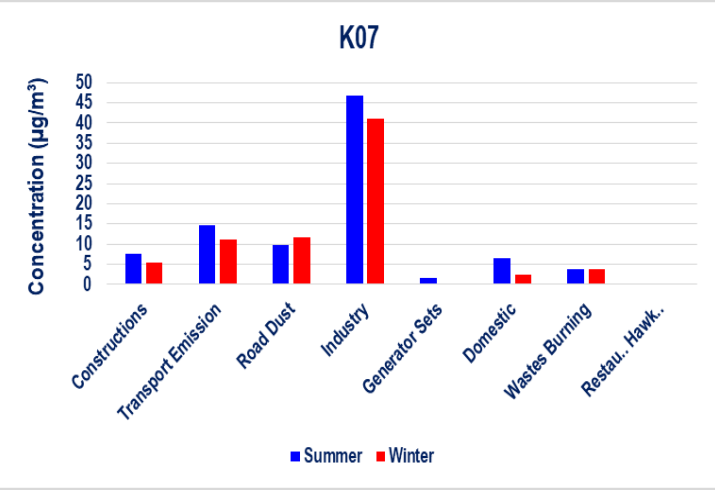

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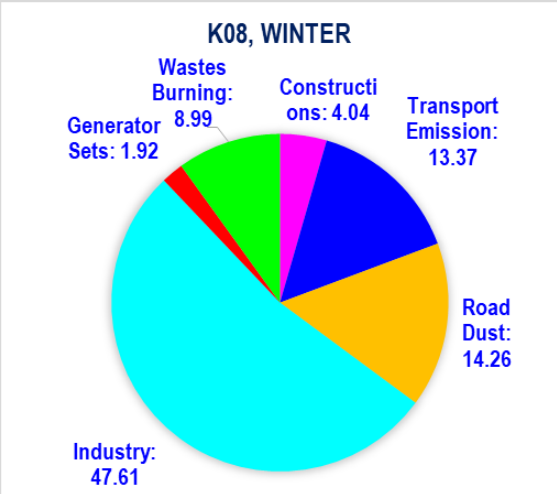

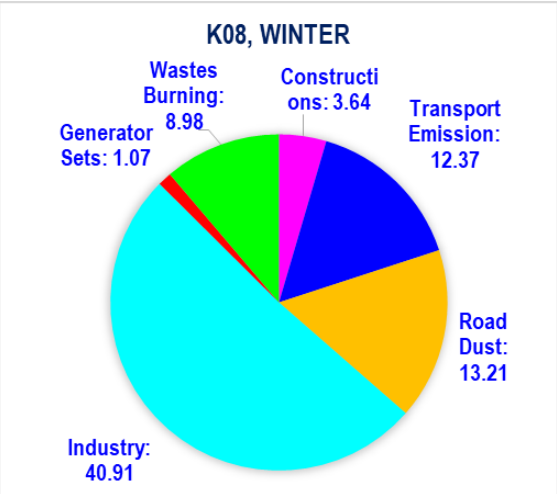

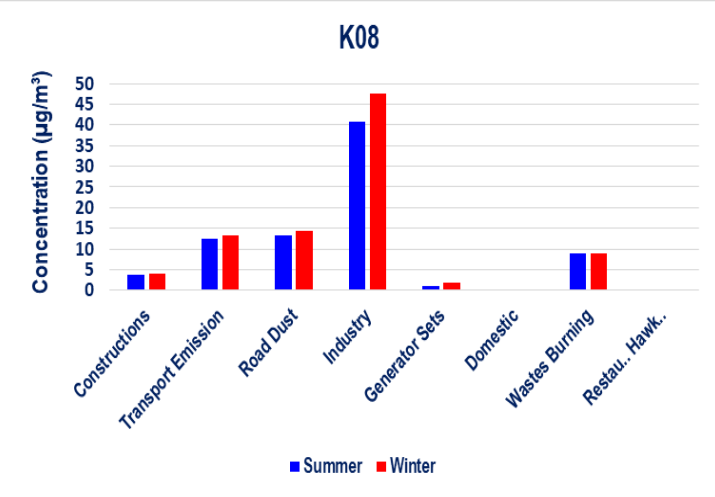

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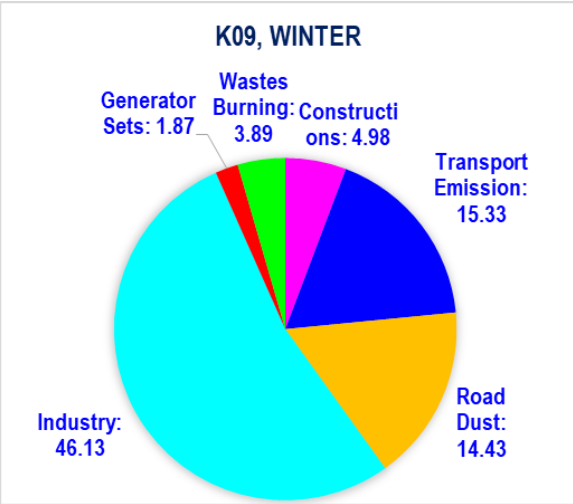

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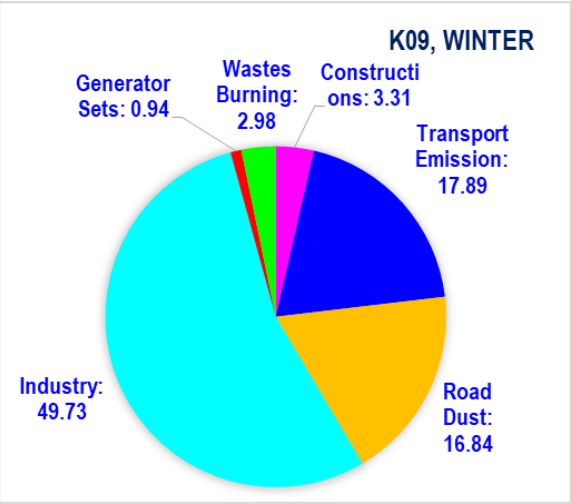

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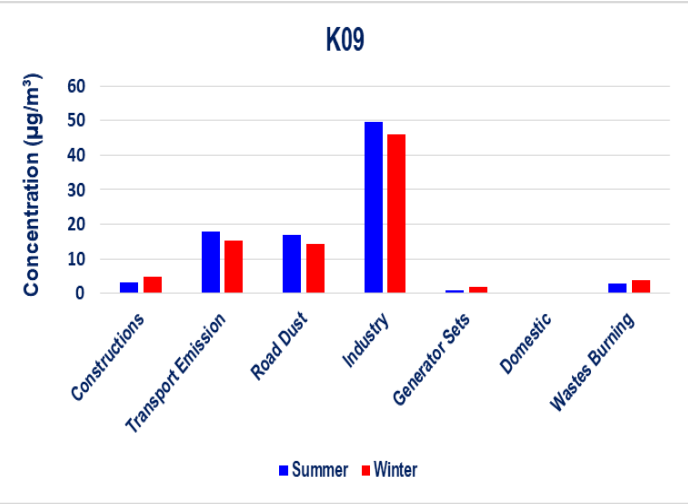
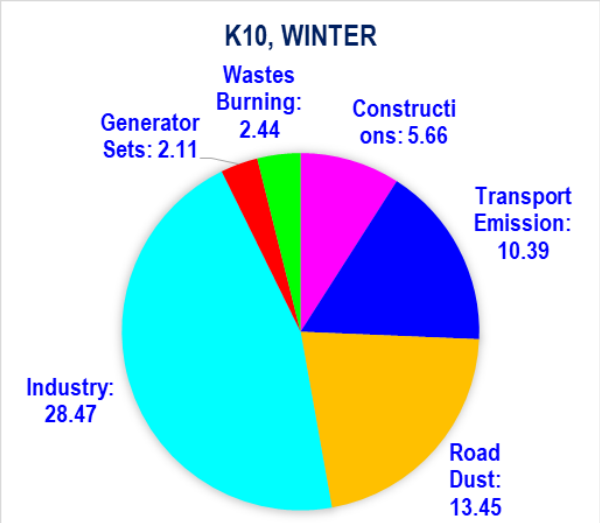
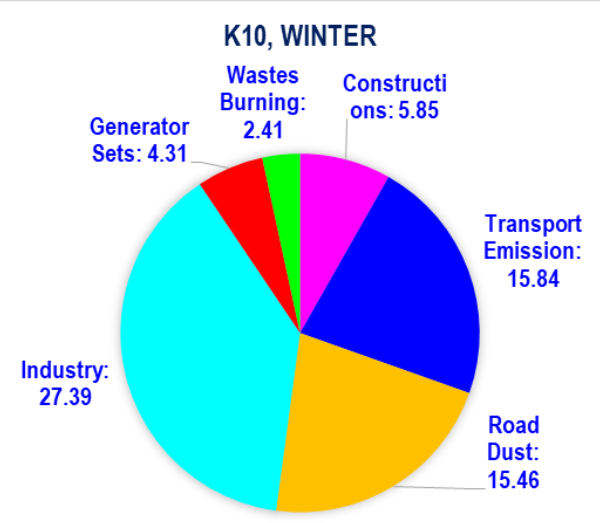
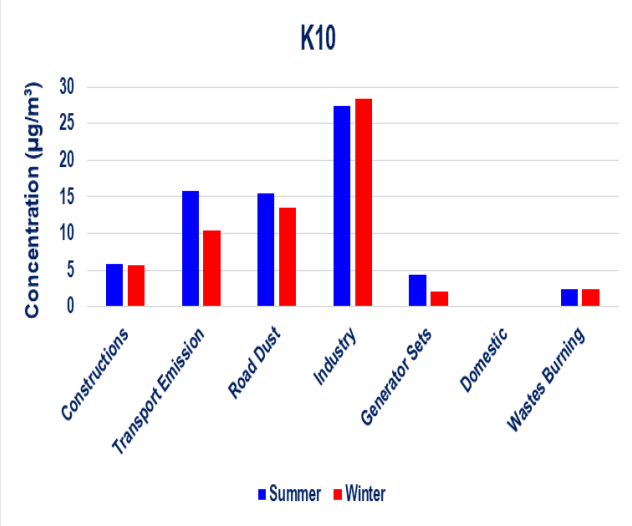


K09





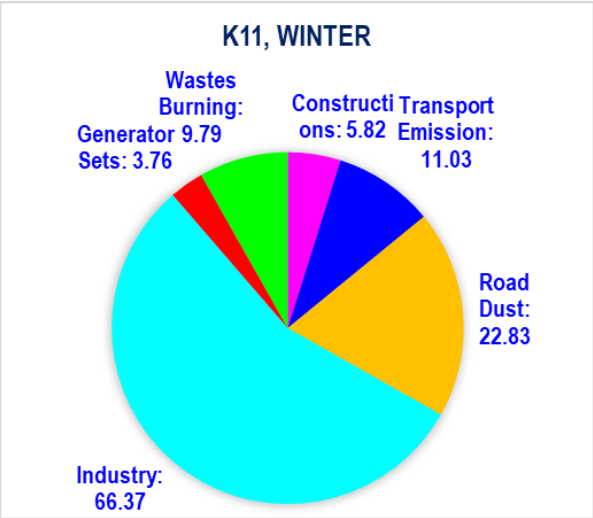


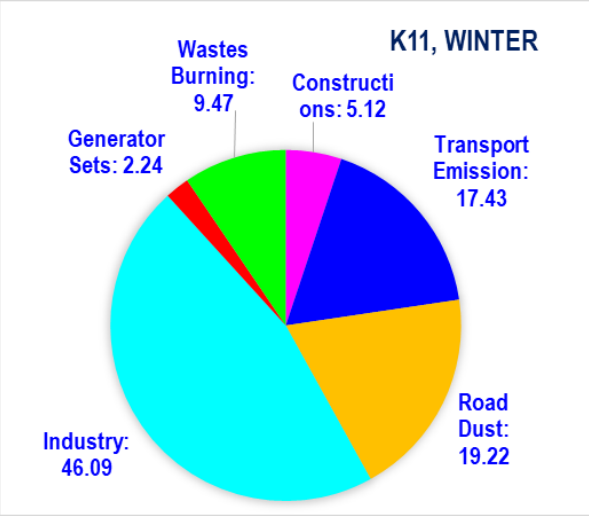
K10

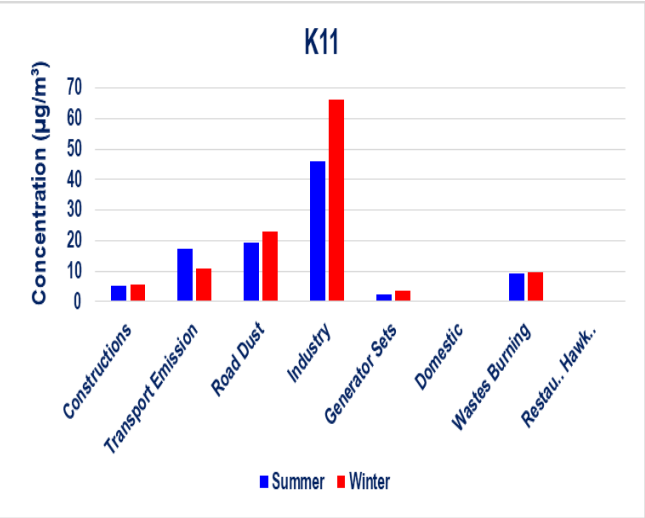
WINTER

SUMMER

SEASONAL VARIATION







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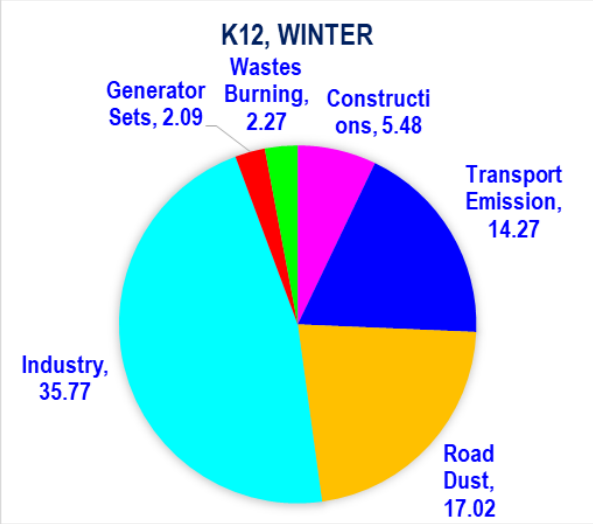
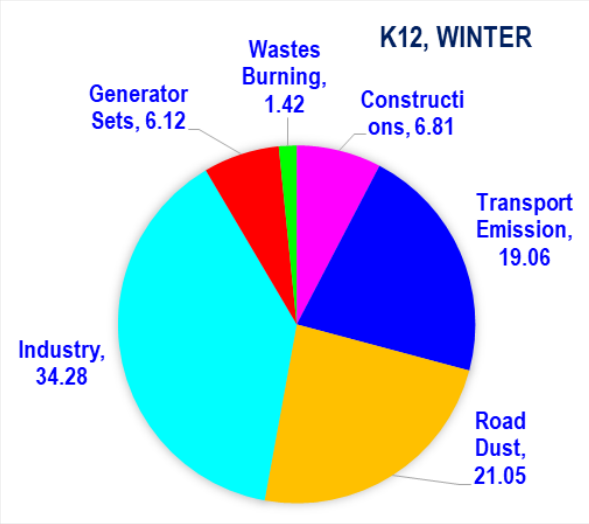
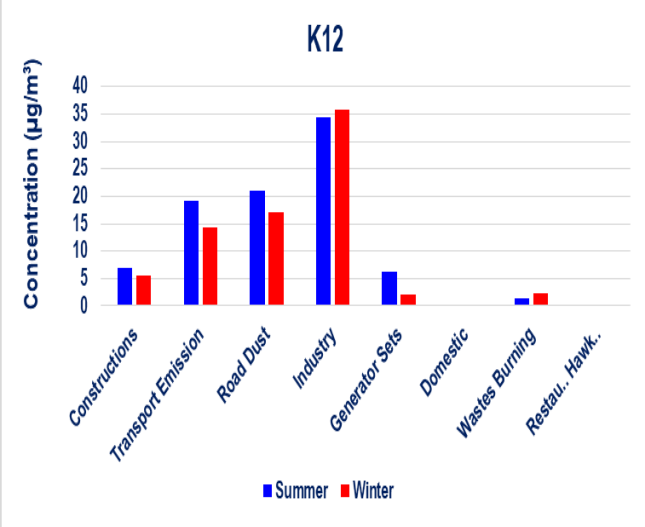
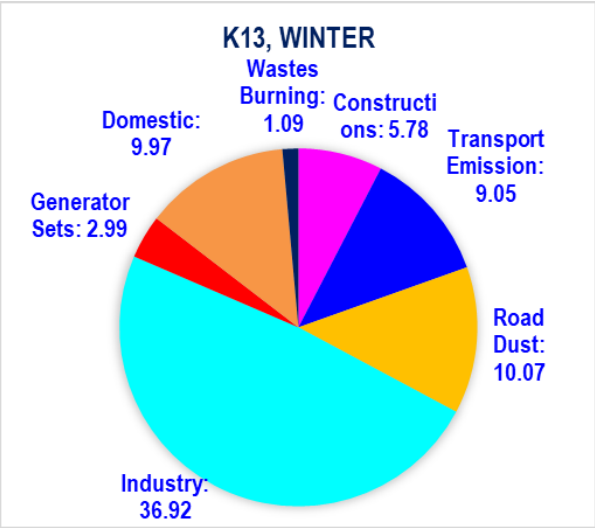






K12

WINTER



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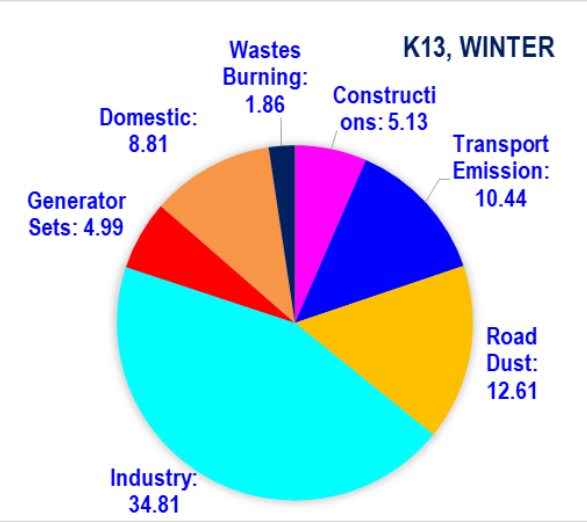

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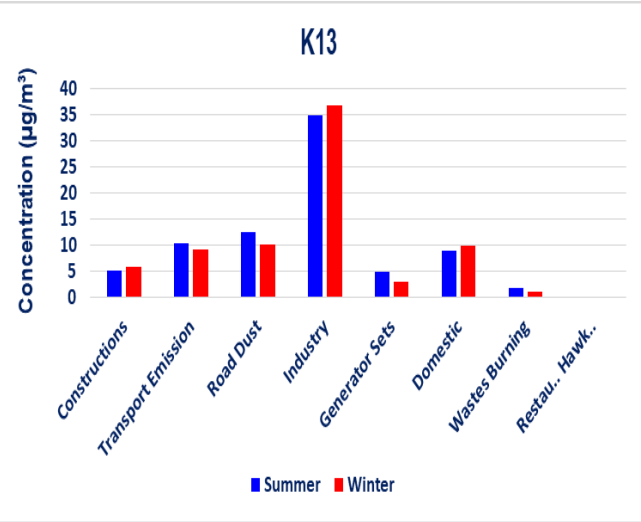

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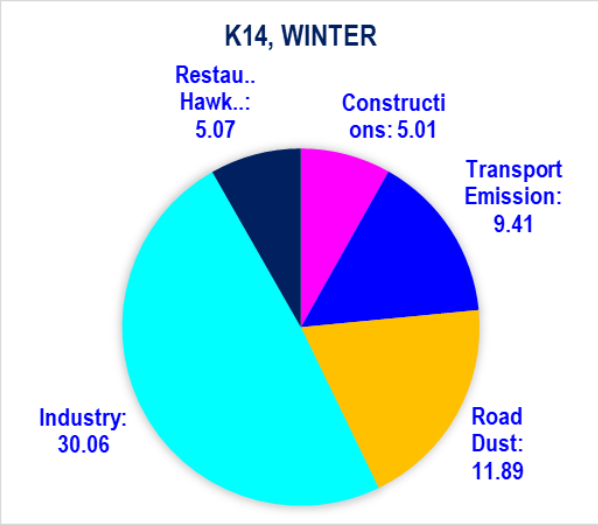
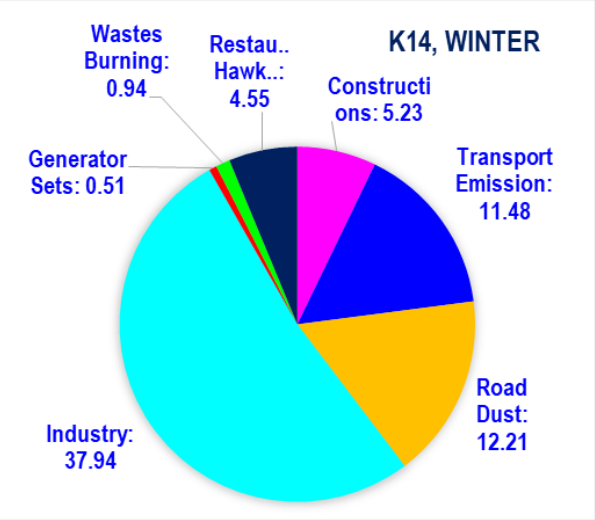
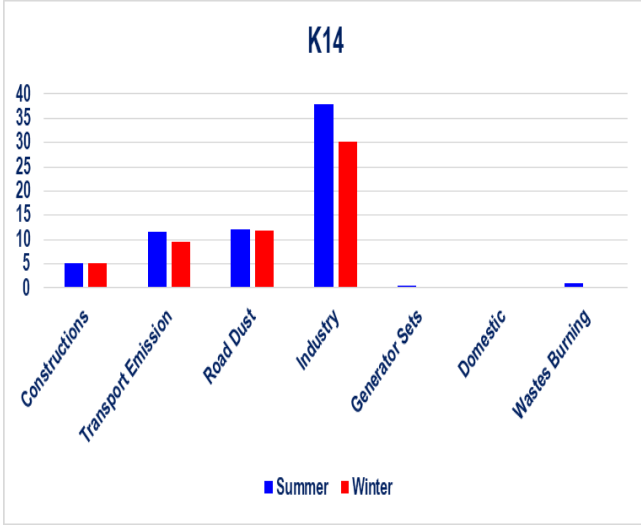
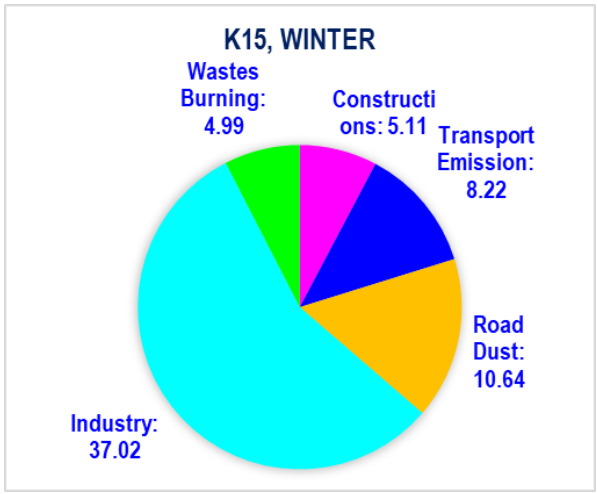






K14

WINTER



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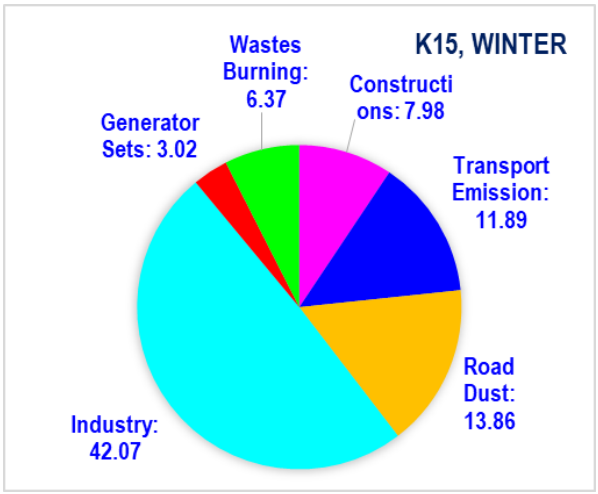
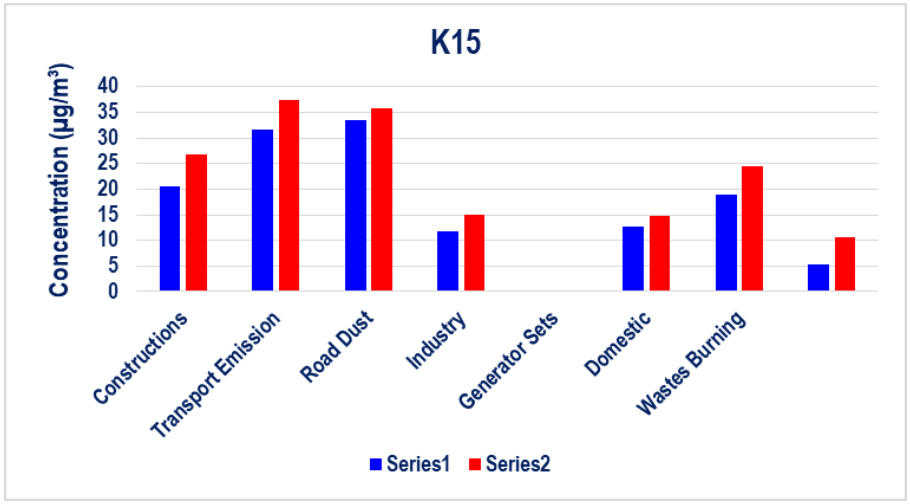


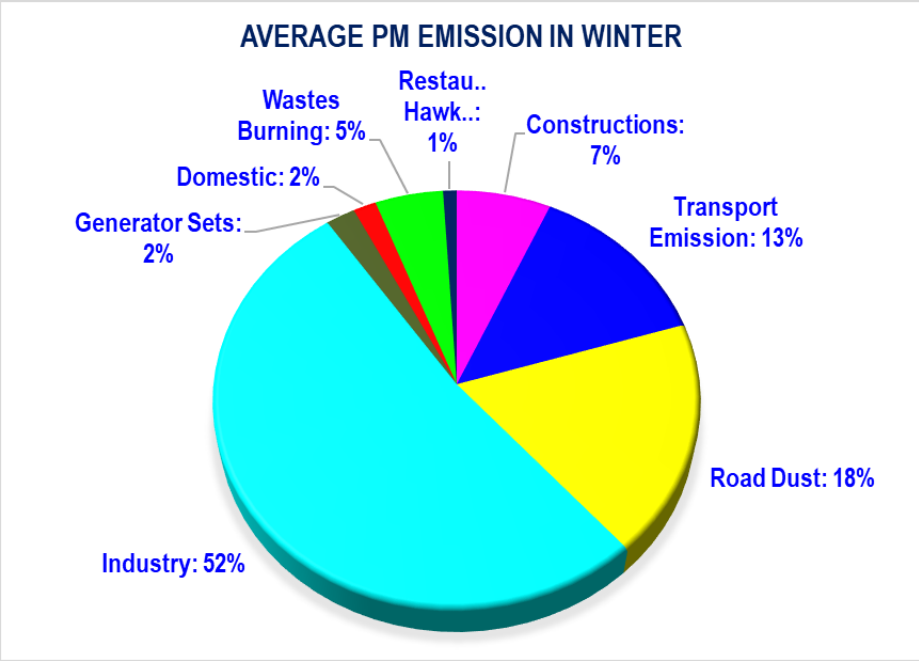
SEASONAL VARIATION



K15

Figure 2.102: Station wise emission variations of each station with the change of seasons are shown graphically and separately

WINTER



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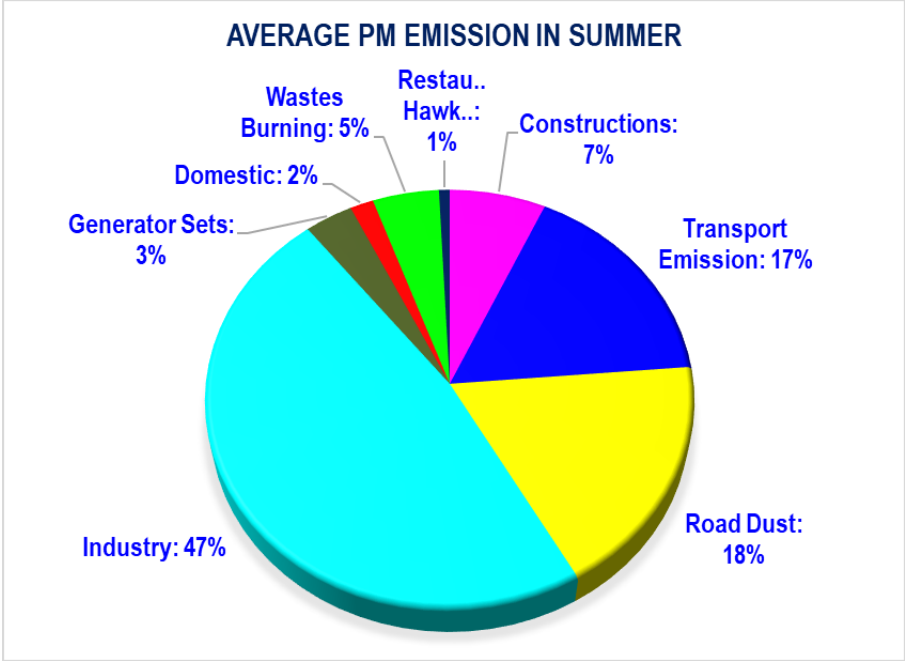

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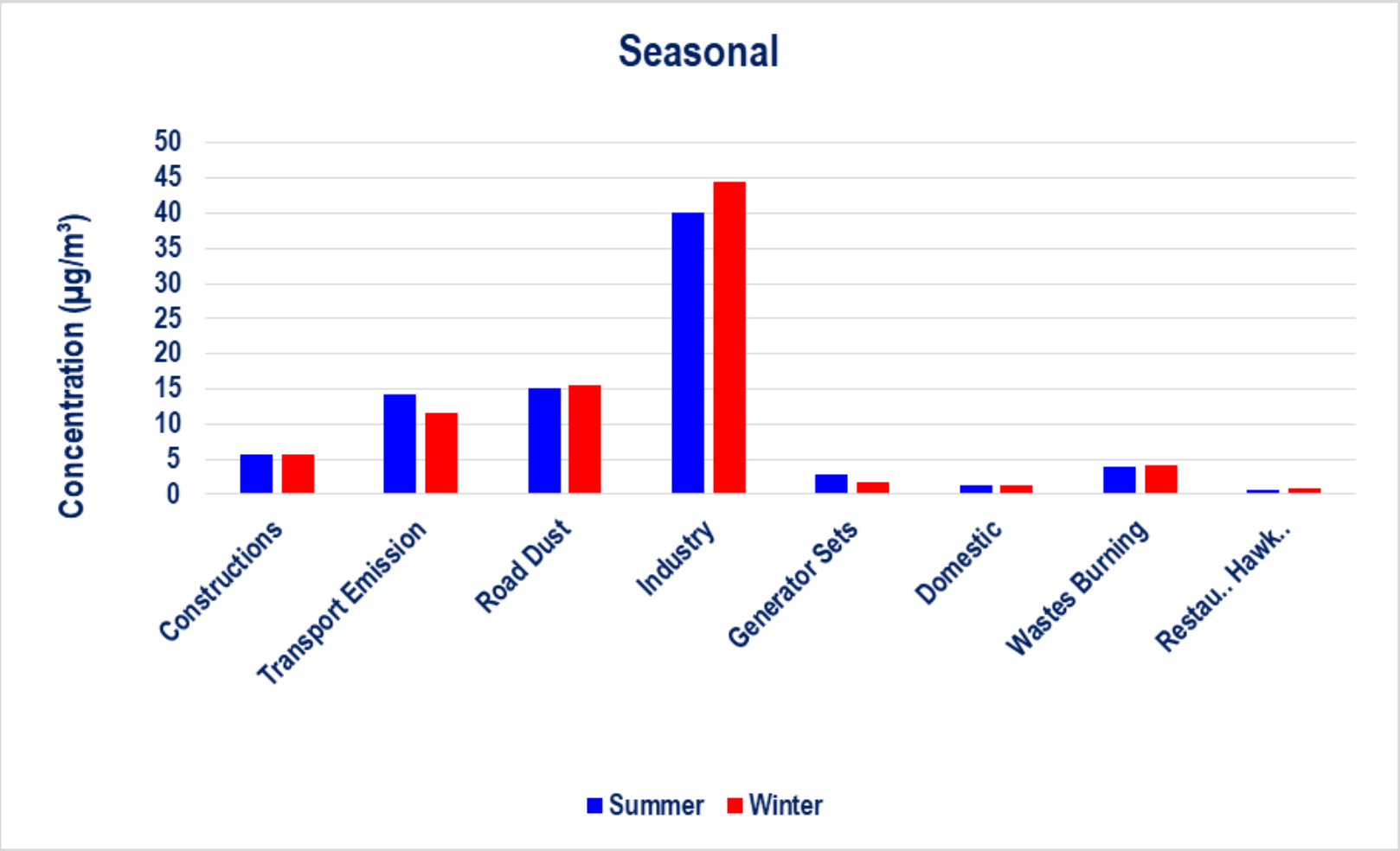


Figure 2.103: Sector wise emission variation with the change of seasons is shown graphically and separately

CHAPTER-III

WATER ENVIRONMENT

3.1 Introduction

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

3.2. Material and Methods

3.2.1 Chemical Oxygen Demand (COD)

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

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

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

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

3.2.1.1 Reagent used for analysis

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

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

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

2. Sulphuric Acid Reagent

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

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

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

4. Ferroin Indicator Solution

5. Mercuric Sulphate

3.2.1.2 Working Method

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

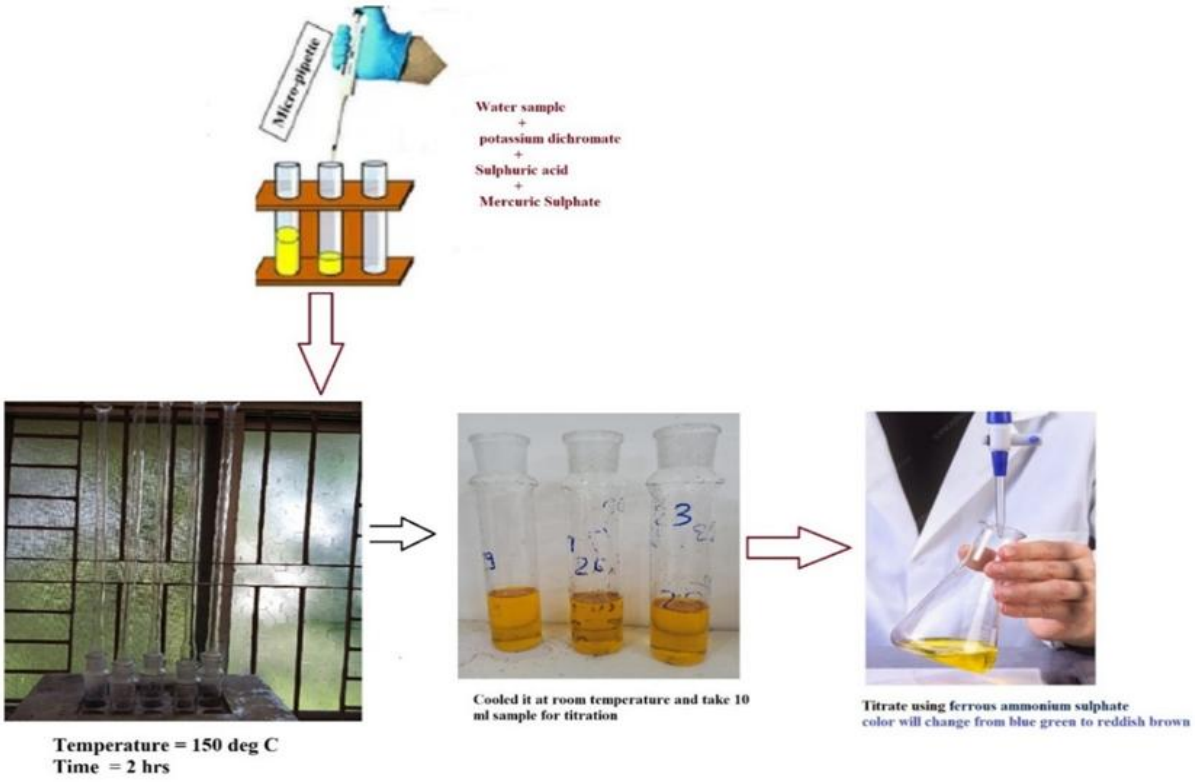


Figure 3.1: Procedure for COD analysis.

3.2.1.3 Calculation

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

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

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

b = ml of ferrous ammonium sulphate used for sample

8000 = Mili equivalent weight of oxygen * 1000

3.2.2 Hardness

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

Soft (0-60 mg/L)

Medium (60-120mg/L)

Hard (120-180mg/L)

Very hard (>180mg/L)

3.2.2.1 EDTA Titration Method

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

3.2.2.2 Reagents used for Analysis

1. Buffer Solution

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

2. Inhibitor

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

3. Eriohrome Black T Indicator

4. Murexide Indicator

5. Sodium Hydroxide 2 N

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

6. Standard EDTA Solution 0.01 M

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

7. Standard Calcium Solution

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

3.2.2.3 Procedure

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

A. Total Hardness

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

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

B. Calcium Hardness

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

1. 50 ml well mixed sample in taken into the conical flask.

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

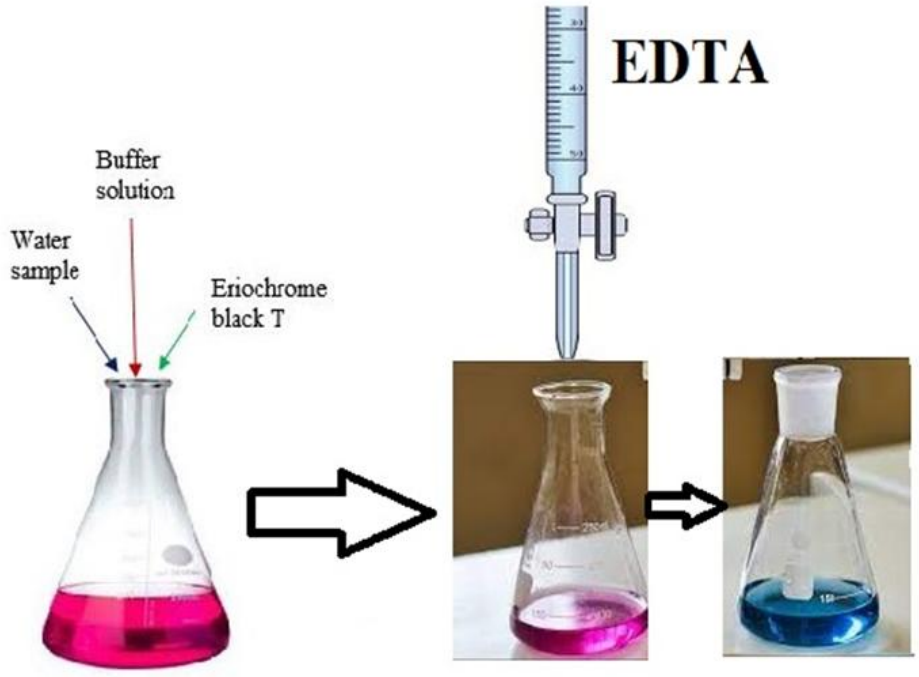


Figure 3.2: Procedure for total hardness analysis.

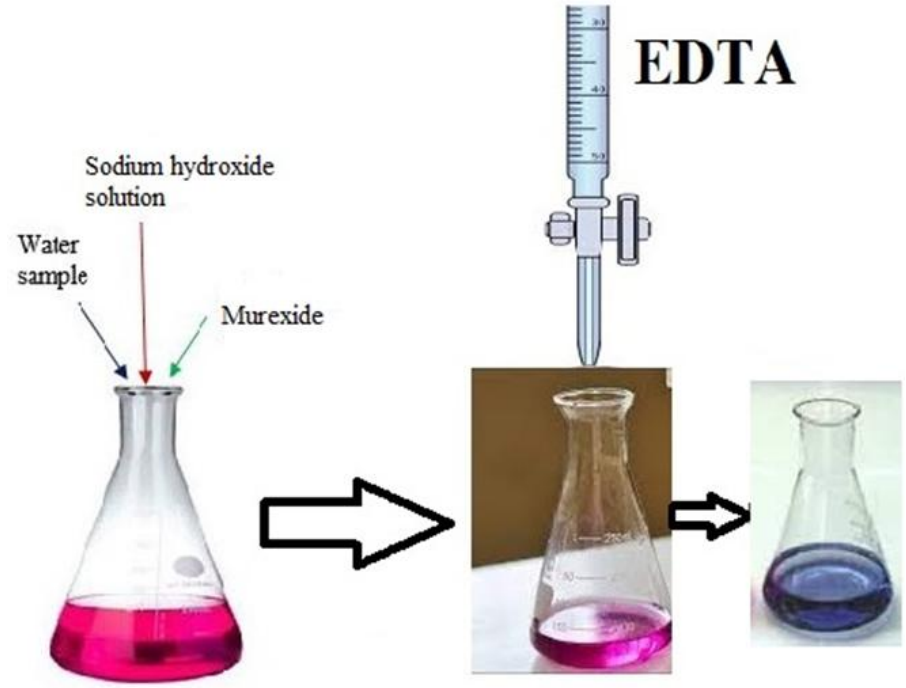


Figure 3.3: Procedure for calcium hardness analysis.

3.2.2.4 Calculation

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

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

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

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

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

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

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

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

3.2.3 Alkalinity

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

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

3.2.3.1 Reagents used for Analysis

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

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

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

2. **Phenolphthalein Indicator**

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

3. **Methyl Orange Indicator**

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

3.2.3.2 Procedure

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

1. 50 ml sample is taken in a conical flask
2. Addition of 2-3 drops of phenolphthalein indicator is carried out.
3. After addition of the above indicator if pink color develops then 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).

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

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

3.2.3.3 Calculations

Alkalinity is determined by the following equations,

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

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

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

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

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

Where,

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

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

N = normality of H_2SO_4

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

Table 3.2: Type of alkalinity.

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

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

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

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

From above, molar concentration may be obtained as follows:

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

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

3.2.4 Chloride (Cl^-)

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

3.2.4.1 Reagents used for Analysis

The reagent listed below are used for the determination of Chloride

1. **Potassium Dichromate Indicator**

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

2. **Silver Nitrate, 0.0141N**

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

3. **Sodium Chloride, 0.0141N**

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

3.2.4.2 Procedure

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

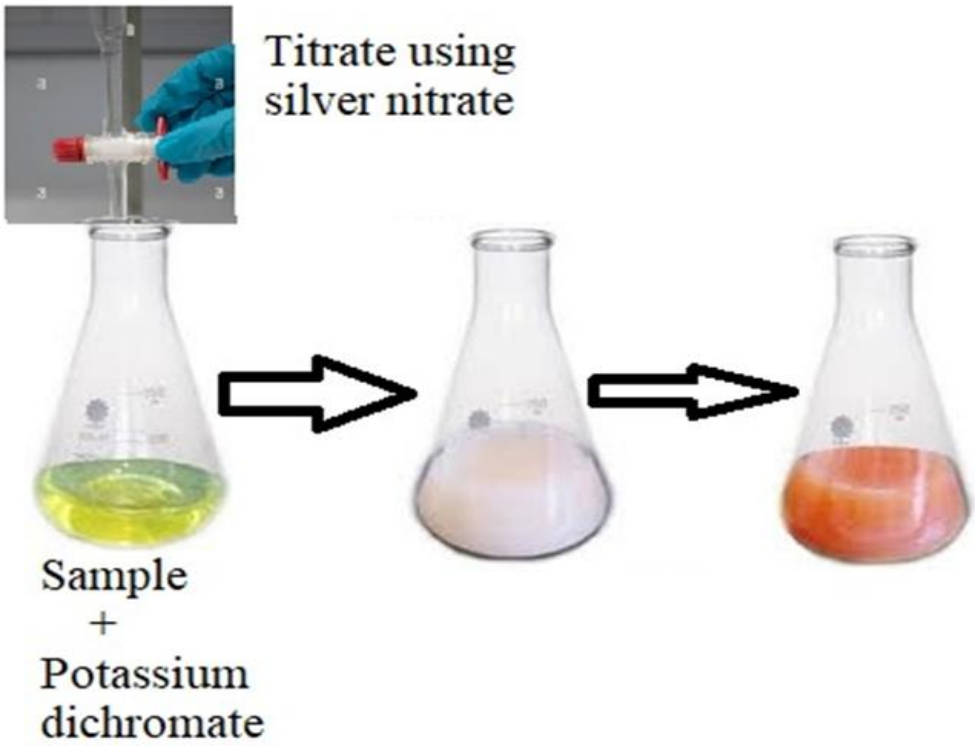


Figure 3.5: Procedure for chloride analysis.

3.2.4.3 Calculation

The following equations are utilized for determination of chloride.

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

Where,

A = mL Silver nitrate required for sample

B = mL Silver nitrate required for blank

3.2.5 Dissolved Oxygen (DO)

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

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

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

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

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

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

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

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

3.2.5.1 Reagents used for Analysis

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

1. **Manganese sulphate**

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

2. **Alkali Iodide-azide Reagent**

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

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

   b. **For supersaturated samples**

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

3. **Sulphuric acid**

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

4. **Starch indicator**

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

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

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

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

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

2.2.5.2 Procedure

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

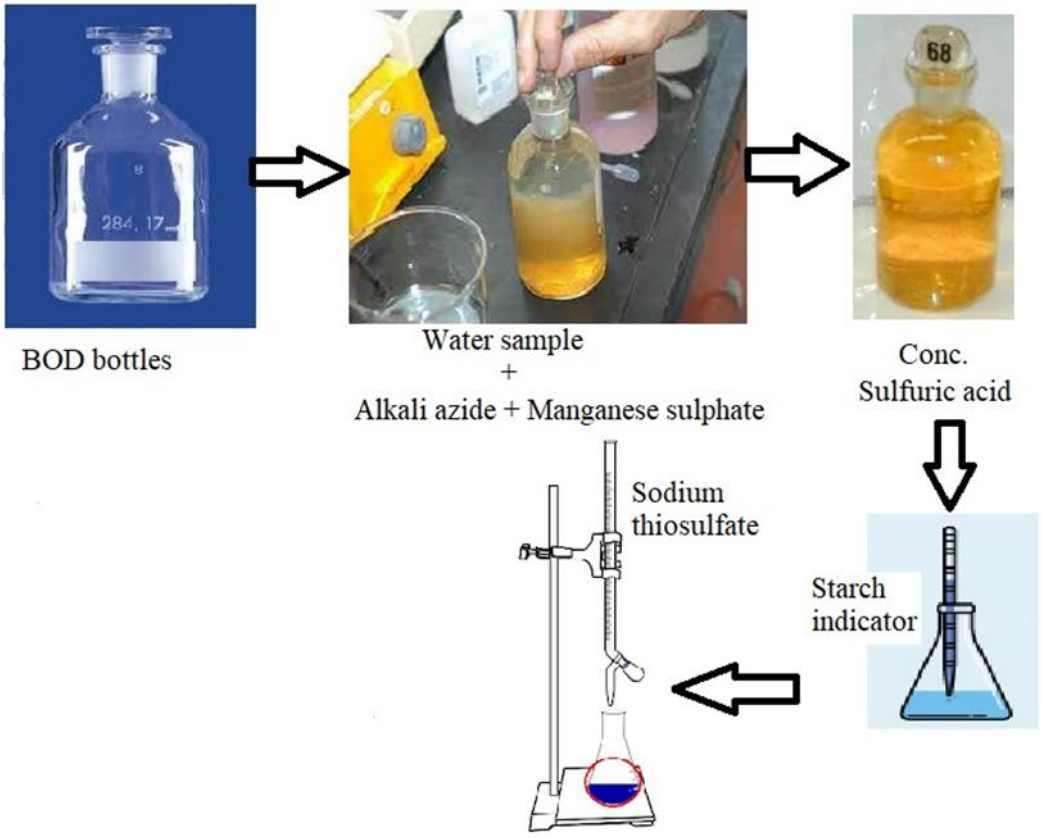


Figure 3.6: Procedure to calculate dissolved oxygen in water sample.

3.2.5.3 Calculation

The following equations are used for determination of dissolved oxygen.

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

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

3.2.6 Biochemical Oxygen Demand (BOD)

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

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

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

3.2.6.1 Reagents used for Analysis

The following reagents are used for BOD analysis:

1. **Manganese Sulphate**

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

2. **Alkali Iodide-azide Reagent**

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

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

   b. **For supersaturated samples**

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

3. **Sulphuric acid**

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

4. **Starch Indicator**

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

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

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

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

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

3.2.6.2 Method

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

Figure 3.7: BOD incubator used in analysis.

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

3.2.6.3 Calculations

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

When dilution water is not seeded

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

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

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

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

3.2.7.1 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**)	%

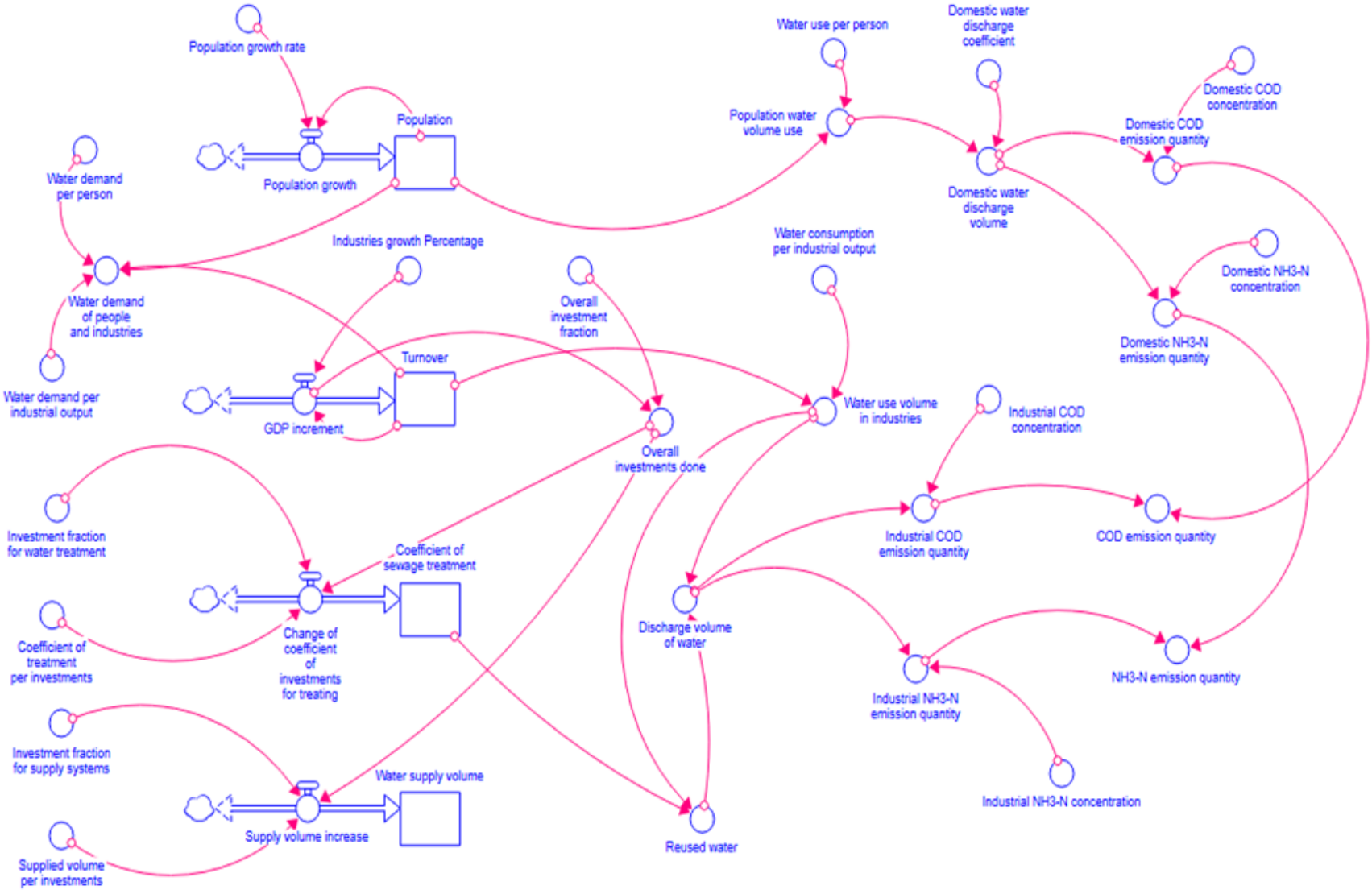


Figure 3.9: Development of water carrying capacity model by STELLA software.

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

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

Negative Indicator

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

Valuating method – Entropy Method

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

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

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

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

The entropy value of indicator j

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

Finally, we calculated the weight of each indicator:

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

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

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

3.3. Results and Discussion

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

Table 3.5: Water sample collection location in Korba.

Location ID	Location Name	Latitude (°N)	Longitude (°E)
KOW01	Sec- 6 Rd Balco (C.G) Borewell	22.402447	82.748547
KOW02	Pipeline Rd Korba River	22.332293	82.778889
KOW03	Dondro River	22.399813	82.711869
KOW04	Hati Dhara Near Rajgamar Borewell	22.380758	82.82554
KOW05	Bhaisma Pond	22.274991	82.77254
KOW06	Power house Road Canal River	22.350605	82.702529
KOW07	Hasdeo River	22.366743	82.695636
KOW08	Sitamani Tubewell	22.338677	82.705887
KOW09	Korba-Champa Road(C.G) River	22.301159	82.718834
KOW10	Urga Pond	22.276178	82.725154
KOW11	Bhulsidih Pond	22.354556	82.793902
KOW12	Bhulsidih Tubewell	22.351407	82.789762
KOW13	Karmandi River	22.284555	82.774677
KOW14	Darri Road River, Kobra	23.397750	82.71253
KOW15	T.P Nagar Pond, Korba	22.362035	82.70913
KOW16	Kusmunda Tube-Well, Korba	22.345068	82.641582
KOW17	Surakachhar Pond, Korba	22.378529	82.632867
KOW18	Water Tretment Plant, BALOC	22.392942	82.715141
KOW19	Dari Dam, Korba	22.406292	82.694898
KOW20	Rajgamar Tube-Well	22.38682	82.827844
KOW21	Sec-B Rd, BALCO, CG	22.40244	82.748547
KOW22	Pipe Line Rd Canal Korba,	22.332293	82778884
KOW23	Dondro River	22.399813	82.71186
KOW24	Hati Dhara River, Rajgamar	22.380758	82.82554
KOW25	Bhaisma Pond	22.274991	82.77254
KOW26	Power House Road Canal, Korba	22.350605	82.702529
KOW27	Hasdo River	22.366743	82.695636
KOW28	Sitamani Pond	22.338677	82.705887
KOW29	Korba-Champa Road	22.301159	82.718834
KOW30	Urga Pond	22.276178	82.725154
KOW31	Bhulsidih	22.354556	82.793902
KOW32	Bhulsidih	22.351407	82.789762
KOW33	Karmandi	22.284551	82.774677
KOW34	Risdi, Korba	22.370686	82.760734

KOW35	Surakachhar,CG	22.363039	82.633051
KOW36	Rumgara	22.410924	82.703247
KOW37	BALCO, Korba	22.385897	82.751019
KOW38	Korba	22.276401	82.769207
KOW39	Korba	22.27675	82.748396
KOW40	Nehrunagar, Korba	22.356004	82.708388
KOW41	Manas Nagar	22.375463	82.719112
KOW42	227, Manas Nagar	22.375586	82.722022
KOW43	BALCO Nagar	22.404782	82.728345
KOW44	BALCO Nagar	22.403365	82.739855
KOW45	BALCO Nagar Samsan Ghat	22.410013	82.749434
KOW46	Korba	22.331198	82.770064
KOW47	Lalpur Bango River	22.60166	82.595828
KOW48	Bango Dam	22.602198	82.591435
KOW49	Koharia Pump House, Korba	22.392942	82.715141
KOW50	B-Type Colony Hasdeo River	22.373276	82.705694
KOW51	Urga River	22.280007	82.688004
KOW52	Pahanda Pond , Korba	22.247547	82.734397
KOW53	Amraiyapara Canal , Korba	22.348428	82.702515
KOW54	Krishna Nagar Pond, Korba	22.338863	82.715484
KOW55	Balco Ring Road Canal, Korba	22.379774	82.749042
KOW56	Pump House , SH 4,Korba	22.392942	82.715141
KOW57	Pump House Canal SH 4 ,Korba	22.391087	82.714364
KOW58	Manas Nagar Canal ,Korba	22.376077	82.721675
KOW59	Hasdo River, Ratakhar, Korba	22.367048	82.695835
KOW60	Korba-Rajgamar Road	22.375466	82.791744
KOW61	Dumardih	22.379189	82.798779
KOW62	Bhulsidih	22.359777	82.7956
KOW63	Bhulsidih	22.354295	82.793839
KOW64	Bundeli Road	22.351055	82.795157
KOW65	Pipe Line Road	22.341032	82.782495
KOW66	Bendarkona	22.301658	82.781119
KOW67	Karmandi	22.28402	82.775027
KOW68	Bhaisma Pond	22.26460	82.77772
KOW69	Sharda Vihar, Korba	22.352801	82.707952
KOW70	Korba	22.341442	82.68956
KOW71	Korba	22.319944	82.700798
KOW72	Korba	22.31824	82.700355
KOW73	Khairbhawana	22.300485	82.696708
KOW74	Khairbhawana	22.299408	82.696763
KOW75	Godhi	22.314044	82.791905

KOW76	Korba	22.266408	82.795403
KOW77	Korba	22.264867	82.79582
KOW78	Korba	22.265778	82.806467
KOW79	Korba	22.264657	82.792738
KOW80	Bhaisma	22.267671	82.776943
KOW81	Bhaisma	22.276969	82.774811
KOW82	Barampur, Korba	22.348820	82.675948
KOW83	Korba	22.350750	82.65375
KOW84	Korba	22.352267	82.660069
KOW85	Korba	22.355803	82.662407
KOW86	Korba	22.356073	82.65872
KOW87	Panshabhata Pond, Korba	22.402573	82.747302
KOW88	Rogbahari Pond, Korba	22.421239	82.743558
KOW89	Pond, Korba	22.434300	82.737424
KOW90	Saraipali Tube-Well, Korba	22.443842	82.744769
KOW91	Rogbahari Tube-Well, Korba	22.421888	82.744267
KOW92	Ratakhar River, Korba	22.366483	82.695933
KOW93	Tube-Well, Korba	22.402482	82.696111
KOW94	River, Korba	22.406228	82.694874
KOW95	Bhadrapara, Korba	22.391644	82.757175
KOW96	Tube-Well New Risda, Korba	22.391433	82.754304
KOW97	Pond Bhaisma, Korba	22.266085	82.775714
KOW98	Bhaisma Pond, Korba	22.262838	82.775511
KOW99	Junwani Pond, Korba	22.260574	82.775086
KOW100	Junwani Pond, Korba	22.258794	82.776209
KOW101	Tube-Well, Korba	22.268040	82.776069
KOW102	Junwani Tube-Well, Korba	22.261090	82.776386
KOW103	Pond, Korba	22.257067	82.773693
KOW104	Korba Pond	22.248519	82.770454
KOW105	Pond, Korba	22.247060	82.772173
KOW106	Tilkeja Pond, Korba	22.241387	82.761874
KOW107	Korba Pond	22.234058	82.761692
KOW108	Tube-Well, Korba	22.234394	82.761317
KOW109	Tilkeja Pond, Korba	22.236912	82.762596
KOW110	Tilkeja Tube-Well, Korba	22.236571	82.761632
KOW111	Tilkeja Pond, Korba	22.239080	82.759002
KOW112	Tilkeja Tube-Well, Korba	22.239070	82.760009
KOW113	Tilkeja Pond, Korba	22.237310	82.759526
KOW114	Tilkeja Tube-Well, Korba	22.233698	82.760112
KOW115	Pond , Korba	22.229724	82.762298
KOW116	Sanaidih Tube-Well, Korba	22.226125	82.76219

KOW117	Tube-Well Risdi, Korba	22.366352	82.761424
KOW118	Tube-Well Balco Nagar, Korba	22.389572	82.745616
KOW119	Pond Ring Road, Korba	22.391020	82.747793
KOW120	Tube-Well Ring Road, Korba	22.390500	82.748274
KOW121	Bhadrapara Pond, Korba	22.390474	82.759886
KOW122	Bhadrapara Tube-Well, Korba	22.393974	82.756843
KOW123	Bhadrapara Pond, Korba	22.395435	82.758136
KOW124	Sadacolony Pond, Korba	22.397781	82.753956
KOW125	Sadacolony Tube-Well, Korba	22.400053	82.754515
KOW126	Tube-Well, Korba	22.403649	82.743321
KOW127	Tube-Well Nehru Nagar, Korba	22.404956	82.745091
KOW128	River, Korba	22.412125	82.749364
KOW129	Rogbahri Tube-Well, Korba	22.420167	82.738831
KOW130	Rogbahri Tube-Well, Korba	22.421442	82.738460
KOW131	Pond Rogbahri, Korba	22.425000	82.739190
KOW132	Tube-Well, Korba	22.405532	82.692480
KOW133	Ntpc Pond, Korba	22.412415	82.651929
KOW134	Pond Jaminipali, Korba	22.420910	82.655474
KOW135	Tube-Well Jaminipali, Korba	22.422330	82.657965
KOW136	Pond, Korba	22.421104	82.654943
KOW137	Jaminipali Pond, Korba	22.421292	82.656950
KOW138	Ntpc Township Tube-Well, Korba	22.422498	82.657402
KOW139	Ompur Pond, Korba	22.375533	82.820743
KOW140	Pond Korba	22.362886	82.829518
KOW141	Korba Pond	22.363290	82.822911
KOW142	Tube-Well, Korba	22.361104	82.822544
KOW143	Rajgamar Road Tube-Well, Korba	22.381195	82.807275
KOW144	River Dumardih, Korba	22.379134	82.798760
KOW145	Pond, Korba	22.370780	82.794098
KOW146	Dumardih Tube-Well, Korba	22.373588	82.793947
KOW147	Korba Pond	22.425675	82.717291
KOW148	Pond Jambahar, Korba	22.425860	82.719175
KOW149	Tube-Well Jambahar, Korba	22.423453	82.721333
KOW150	Jambahar Tube Well, Korba	22.422645	82.721908
KOW151	Tube-Well Jambahar, Korba	22.420372	82.722631
KOW152	Pond Jambahar, Korba	22.417213	82.722904
KOW153	Tube-Well Jambahar, Korba	22.418254	82.723140
KOW154	Jambahar Tube Well, Korba	22.418410	82.723230
KOW155	Devpehri Road Pond, Korba	22.426388	82.721216
KOW156	Pond Devpehri, Korba	22.429382	82.722545
KOW157	Devpehri Road Pond, Korba	22.431772	82.723613

KOW158	Sonpuri Pond, Korba	22.436322	82.720903
KOW159	Sonpuri Tube-Well, Korba	22.436502	82.719234
KOW160	Tube-Well Sonpuri, Korba	22.437080	82.717425
KOW161	Sonpuri Tube-Well, Korba	22.436931	82.716280
KOW162	Tube-Well Sonpuri, Korba	22.435326	82.713802
KOW163	Sonpuri Tube-Well, Korba	22.434395	82.712683
KOW164	Balco Nagar Tube-Well, Korba	22.416816	82.707080
KOW165	Devpehri Road Pond, Korba	22.427447	82.723517
KOW166	Jambahar Tube Well, Korba	22.424034	82.724778
KOW167	Tube-Well, Korba	22.423834	82.726192
KOW168	Korba Tube-Well	22.409562	82.707645
KOW169	Tube-Well, Korba	22.413772	82.703352
KOW170	Pond, Korba	22.403000	82.705550
KOW171	Darri-Korba Road Canal, Korba	22.397591	82.712467
KOW172	Korba Tube-Well	22.396239	82.707565
KOW173	River, Korba	22.397770	80.708760
KOW174	Tube-Well, Korba	22.402641	82.691482
KOW175	Korba Tube-Well	22.403067	82.691597
KOW176	Tube-Well, Korba	22.405565	82.692560
KOW177	Darri-Korba Rd Tube-Well, Korba	22.410630	82.694738
KOW178	Korba Tube-Well	22.403560	82.695260
KOW179	Tube-Well Risdi, Korba	22.367163	82.762352
KOW180	Tube-Well Ring Road, Korba	22.367198	82.761847
KOW181	Risdi Tube-Well, Korba	22.367347	82.760448
KOW182	Korba-Rajgamar Road Tube-Well	22.375450	82.791733
KOW183	Korba-Rajgamar Road Tube-Well	22.372828	82.791807
KOW184	Tube-Well, Korba	22.371747	82.791795
KOW185	Korba Tube-Well	22.370543	82.791514
KOW186	Tube-Well, Korba	22.369699	82.791263
KOW187	Hasdo River, Korba	22.410593	82.695139
KOW188	Hasdo River Uper Side, Korba	22.341408	82.689728
KOW189	Sitamani Canal, Korba	22.330522	82.712622
KOW190	Korba-Champa Road Canal	22.301208	82.718715
KOW191	Urga Pond, Korba	22.276214	82.725239
KOW192	Bhanbhaspur Pond, Korba	22.276204	82.720612
KOW193	Urga Pond, Korba	22.279057	82.710002
KOW194	Canal Korba	22.274024	82.699508
KOW195	Naktikhar Pond, Korba	22.350605	82.770499
KOW196	Urga-Risdi Road Pond, Korba	22.341838	82.772277
KOW197	Naktikhar Pond, Korba	22.345323	82.776770
KOW198	Pond Naktihar, Korba	22.344795	82.776990

KOW199	Pond, Korba	22.331854	82.759175
KOW200	Korba Pond	22.336656	82.756620
KOW201	Bhulsidih Pond, Korba	22.354279	82.793798
KOW202	Pipe Line Road Pond, Korba	22.341221	82.782667
KOW203	Pipe Line Road River, Korba	22.332283	82.779078
KOW204	Godhi Road Pond, Korba	22.314669	82.792661
KOW205	Godi-Bhaisma Road Pond, Korba	22.310033	82.786693
KOW206	Karmandi Pond, Korba	22.290945	82.785754
KOW207	Karmandi River, Korba	22.284038	82.774975
KOW208	Bhaisma Pond, Korba	22.264597	82.777724
KOW209	Pond Bhaisma, Korba	22.275272	82.772717
KOW210	Pond Korba	22.272885	82.752987
KOW211	Koraba Pond	22.272248	82.751341
KOW212	Semipli Pond, Korba	22.275799	82.746486
KOW213	Semipli Pond, Korba	22.274903	82.739268
KOW214	Urga Pond, Korba	22.272957	82.728398

3.3.1 Heavy Metals in Water

Groundwater is the main source of the water that is used for drinking, agriculture and domestic work purposes. Again, the groundwater source, agricultural system and irrigation systems are connected with each other. Rapid growing population and demanding industrialization are the causes of geogenic pollution helps to dissolve anthropogenic rocks, metals into water. Higher is the probability of parental rock weathering, higher is the probability of groundwater pollution. Thus, a hydrogeochemical study is very essential for clear understanding and identification of possible markers responsible for water quality change. The geochemistry may describe possible mechanism of metals dissolution from anthropogenic rock and chemometric techniques may describe and elaborate the most possible way of contamination and also the way to recover. Korba is well-known area for extensive coal mining activities.

Korba is drained by the river Hasdeo except small area in eastern part. The tributaries are Tan, Teti, Sondi, Charnoi and Aharan rivers. River Hasdeo flows north to south in the district and finally joins with the Mahanadi district. The river Mand flows through eastern boundary of Korba with Raigarh district. The drainage pattern is dendritic in the central and north western part and trellis in the eastern part of the district. The drainage density is very high n the hilly areas of the north and north-west part of the district indicating that the infiltration is low.

An irrigation project, named 'Minimata Hasdeo Bango Project' is constructed on Hasdeo River, 42 kms away from Korba. The main reservoir is spread over an area of 187 sq. Kms. and the gross catchment area of the reservoir is 6730 sq. kms. The live storage capacity of the reservoir is 3416 mcm and it caters the irrigation requirement of the districts. In all, 13 number of observation wells (National Hydrograph Network Stations) and 4 piezometers have been established in the district to monitor water levels 4 times in a year and water quality once a year. The water levels fluctuation varies from 2.5 to 9.36 m with average fluctuation of 4.4 mbgl. The ground water resources for Korba has been estimated based on the GEC 1997 methodology. The estimates indicate that the annual replenishable ground water resource for the district is 456.15 mcm. The net ground water availability is 424.83 mcm. The gross annual draft is 63.65 mcm, out of which draft for irrigation is 40.34 mcm and for domestic is 23.30 mcm. The overall stage of ground water development for Korba is 14.98%.

The ground water mainly occurs in phreatic (water table) conditions and at places under semi-confined conditions. Water samples have been collected randomly from different places of Korba like; ponds, hand pumps, well, river stream or any drinking water sources. Collected water samples are then filtered, acidified and analysed according to the method described in the method section 3.2.7. Estimated metals concentration has arranged in tabular form and then presented graphically in the Figure 3.10. Concentrations of heavy metal ions are estimated in 'ppm' or 'mg/L' unit.

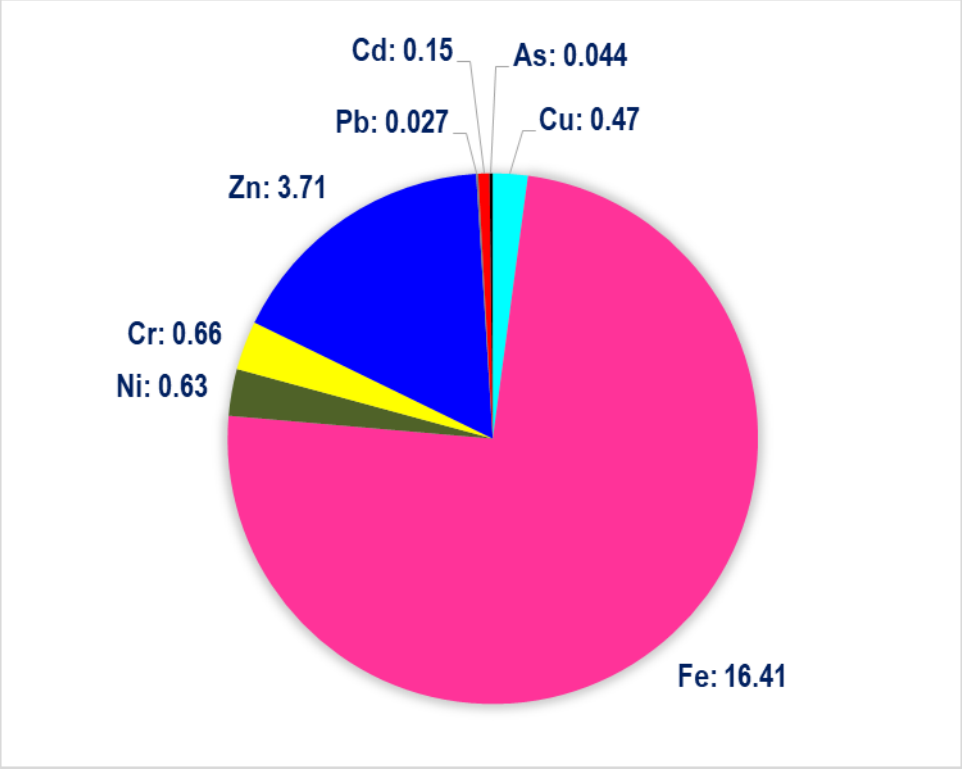


Figure 3.10: Average Heavy metals present (ppm) in collected soil samples from Korba

Though the concentration of 'Fe' in the drinking water of Korba is beyond the limit. Iron is a valuable metal, which not only plays significant role in human respiration, blood circulation and different metabolic activities but also has important role on other living ecosystems. Plant kingdom is also dependent on iron for photosynthesis and photosynthetic pigment biogenesis. Next higher concentrated metal in Korba ground water is 'Zn' and under permeable limit (5ppm). Only in samples 27, 47 and 130 have been found to have high 'Zn' but not more than 8 ppm. While 'Zn' is one of the important trace elements that play vital role in protein synthesis and is also responsible for waster taste.

The concentrations of 'Cd' and 'Pb', in the drinking water of Korba, are now alarming. All the collected water samples from Korba and its surrounding have been found highly 'Cd'-contaminated. Korba is a mining area and high concentration of heavy metals in surface water source is very natural. But when they come in ground water source, is a matter of thinking. No water sample has been found to have a trace amount of 'Hg'. 'As', in the collected water samples, is detectable in 'ppb' range and sometimes it's very high than the prescribed-permissible value. So, inhabitants of Korba may suffer from 'Cd', 'Pb' and 'As' related health syndromes.

3.3.2 Physical and Chemical Analysis of Water Samples

Water sample collected from different location in Korba 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 30 to 977.2 (µs/cm). Then experiments have been 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 beyond the limit i.e. KOW 88-186, where values are more than 200 mg/l and maximum value touches the 400mg/l mark. COD level is within the limit of 10 mg/l. DO level was found within 10 mg/l. Alkalinity range of collected water samples are found to be within 140 mg/l. Chloride values of sample are within 232 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.

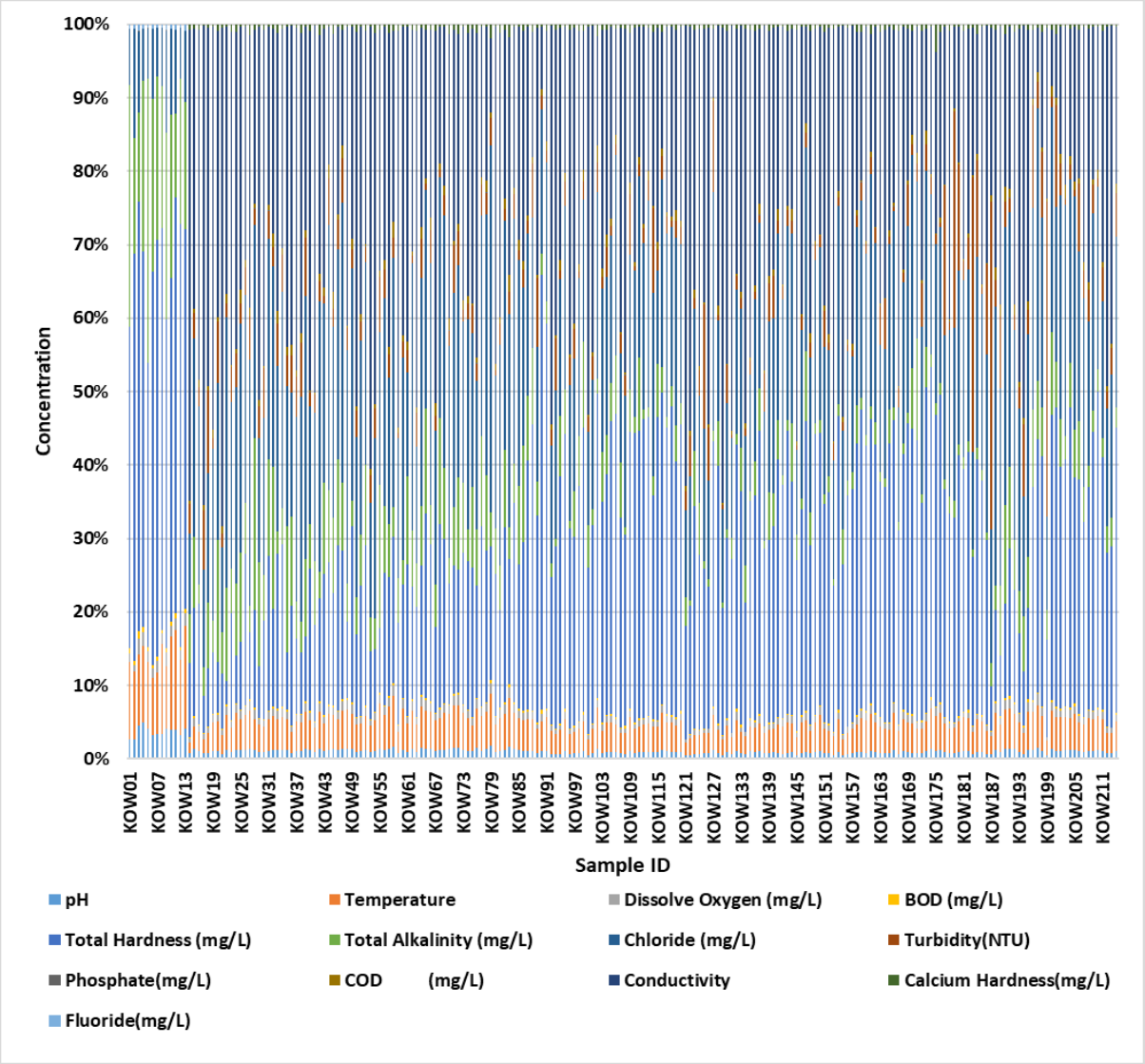


Figure 3.11: Different parameter percentile plot of different water samples collected from Korba (Marked as KOW).

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 Korba during study period.

	pH	Temperature (°C)	Dissolve Oxygen (mg/L)	BOD (mg/L)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	
Max	8.63	35	8.2	3.7	400	140	
Min	5.07	16	2.5	0.5	20	10	
Average	7.15	28.58	6.45	1.68	188.00	42.42	
STDV	0.67	2.78	1.18	0.56	86.46	28.48	
mean	7.15	28.58	6.45	1.68	188.00	42.42	
CV	0.09	0.097	0.18	0.34	0.45	0.67	
	Chloride (mg/L)	**Turbidity (NTU)**	**Phosphate(mg/L)**	**COD (mg/L)**	**Conductivity**	**Calcium Hardness (mg/L)**	**Fluoride (mg/L)**
Max	231.4	636	0.1	13.3	977.2	24	1.6
Min	12	3.17	0.1	1.3	30.25	2	1
Average	162.31	36.82	0.1	6.47	268.00	4.48	1.27
STDV	45.41	68.72	1.53E-16	3.26	169.65	2.67	0.26
mean	162.31	36.82	0.1	6.47	268.00	4.48	1.27
CV	0.27	1.86	1.53E-15	0.50	0.63	0.59	0.21

3.3.4 Water Environmental Carrying Capacity Assessment Beyond 10 years

3.3.4.1 Simulation Result of Indicated Value

The simulation result 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 co-efficient 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	1400000	50000	2000000	2.02	1010
2022	0.802	1411951	51010	2020201	2.06	1030
2023	0.804	1424003	52041	2040811	2.10	1051
2024	0.806	1436159	53092	2061837	2.15	1073
2025	0.808	1448418	54164	2083287	2.19	1094
2026	0.811	1460782	55259	2105171	2.23	1116
2027	0.813	1473252	56375	2127497	2.28	1139
2028	0.815	1485828	57514	2150274	2.32	1162
2029	0.817	1498511	58676	2173511	2.37	1185
2030	0.820	1511303	59861	2197217	2.42	1209
2031	0.822	1524204	61070	2221403	2.47	1234

2032	0.825	1537215	62304	2246077	2.52	1259
2033	0.827	1550337	63562	2271249	2.57	1284
2034	0.830	1563571	64847	2296930	2.62	1310
2035	0.832	1576918	66156	2323130	2.67	1336
2036	0.835	1590379	67493	2349859	2.73	1363
2037	0.838	1603955	68856	2377128	2.78	1391
2038	0.840	1617646	70247	2404948	2.84	1419
2039	0.843	1631455	71666	2433329	2.90	1448
2040	0.846	1645381	73114	2462285	2.95	1477
2041	0.849	1659427	74591	2491825	3.01	1507
2042	0.852	1673592	76098	2521962	3.07	1537
2043	0.855	1687878	77635	2552707	3.14	1568
2044	0.858	1702286	79204	2584074	3.20	1600
2045	0.862	1716817	80804	2616074	3.26	1632
2046	0.865	1731473	82436	2648721	3.33	1665
2047	0.868	1746253	84101	2682028	3.40	1699
2048	0.872	1761159	85800	2716007	3.47	1733
2049	0.875	1776193	87534	2750673	3.54	1768
2050	0.879	1791355	89302	2786038	3.61	1804
2051	0.882	1806646	91106	2822119	3.68	1840

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)
11951	20201	106344	0.0005	70	0.15	700000
12053	20609	107395	0.0005	70	0.15	706928
12156	21026	108422	0.0005	70	0.15	713701
12259	21451	109424	0.0005	70	0.15	720304
12364	21884	110399	0.0005	70	0.15	726723
12470	22326	111343	0.0005	70	0.15	732938
12576	22777	112254	0.0005	70	0.15	738934
12683	23237	113130	0.0005	70	0.15	744692
12792	23706	113967	0.0005	70	0.15	750192
12901	24185	114763	0.0005	70	0.15	755413
13011	24674	115513	0.0005	70	0.15	760334
13122	25172	116216	0.0005	70	0.15	764933
13234	25681	116866	0.0005	70	0.15	769186
13347	26200	117461	0.0005	70	0.15	773067
13461	26729	117996	0.0005	70	0.15	776551

13576	27269	118468	0.0005	70	0.15	779610
13692	27820	118872	0.0005	70	0.15	782216
13809	28382	119204	0.0005	70	0.15	784338
13926	28955	119458	0.0005	70	0.15	785944
14045	29540	119630	0.0005	70	0.15	787002
14165	30137	119715	0.0005	70	0.15	787477
14286	30746	119706	0.0005	70	0.15	787331
14408	31367	119600	0.0005	70	0.15	786528
14531	32000	119388	0.0005	70	0.15	785026
14655	32647	119066	0.0005	70	0.15	782784
14780	33306	118626	0.0005	70	0.15	779759
14906	33979	118062	0.0005	70	0.15	775903
15034	34666	117366	0.0005	70	0.15	771169
15162	35366	116531	0.0005	70	0.15	765507
15291	36080	115549	0.0005	70	0.15	758864

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)**
0.008	1344	0.8	168000	0.005	840
0.008	1355	0.8	169434	0.005	847
0.008	1367	0.8	170880	0.005	854
0.008	1379	0.8	172339	0.005	862
0.008	1390	0.8	173810	0.005	869
0.008	1402	0.8	175294	0.005	876
0.008	1414	0.8	176790	0.005	884
0.008	1426	0.8	178299	0.005	891
0.008	1439	0.8	179821	0.005	899
0.008	1451	0.8	181356	0.005	907
0.008	1463	0.8	182904	0.005	915
0.008	1476	0.8	184466	0.005	922
0.008	1488	0.8	186040	0.005	930
0.008	1501	0.8	187629	0.005	938
0.008	1514	0.8	189230	0.005	946
0.008	1527	0.8	190845	0.005	954
0.008	1540	0.8	192475	0.005	962

0.008	1553	0.8	194118	0.005	971
0.008	1566	0.8	195775	0.005	979
0.008	1580	0.8	197446	0.005	987
0.008	1593	0.8	199131	0.005	996
0.008	1607	0.8	200831	0.005	1004
0.008	1620	0.8	202545	0.005	1013
0.008	1634	0.8	204274	0.005	1021
0.008	1648	0.8	206018	0.005	1030
0.008	1662	0.8	207777	0.005	1039
0.008	1676	0.8	209550	0.005	1048
0.008	1691	0.8	211339	0.005	1057
0.008	1705	0.8	213143	0.005	1066
0.008	1720	0.8	214963	0.005	1075
0.008	1734	0.8	216798	0.005	1084

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)**
0.02	0.0085	0.15	105000	0.095	66500
0.02	0.0085	0.15	106039	0.095	67158
0.02	0.0085	0.15	107055	0.095	67802
0.02	0.0085	0.15	108046	0.095	68429
0.02	0.0085	0.15	109008	0.095	69039
0.02	0.0085	0.15	109941	0.095	69629
0.02	0.0085	0.15	110840	0.095	70199
0.02	0.0085	0.15	111704	0.095	70746
0.02	0.0085	0.15	112529	0.095	71268
0.02	0.0085	0.15	113312	0.095	71764
0.02	0.0085	0.15	114050	0.095	72232
0.02	0.0085	0.15	114740	0.095	72669
0.02	0.0085	0.15	115378	0.095	73073
0.02	0.0085	0.15	115960	0.095	73441
0.02	0.0085	0.15	116483	0.095	73772
0.02	0.0085	0.15	116942	0.095	74063
0.02	0.0085	0.15	117332	0.095	74311
0.02	0.0085	0.15	117651	0.095	74512
0.02	0.0085	0.15	117892	0.095	74665
0.02	0.0085	0.15	118050	0.095	74765

0.02	0.0085	0.15	118121	0.095	74810
0.02	0.0085	0.15	118100	0.095	74796
0.02	0.0085	0.15	117979	0.095	74720
0.02	0.0085	0.15	117754	0.095	74577
0.02	0.0085	0.15	117418	0.095	74365
0.02	0.0085	0.15	116964	0.095	74077
0.02	0.0085	0.15	116385	0.095	73711
0.02	0.0085	0.15	115675	0.095	73261
0.02	0.0085	0.15	114826	0.095	72723
0.02	0.0085	0.15	113830	0.095	72092
0.02	0.0085	0.15	112678	0.095	71362

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)	NH_3-N emission quantity (kg)	Population water volume use (m^3)
0.008	0.5	0.5	8.000	67340	210000
0.008	0.5	0.5	8.162	68005	211793
0.008	0.5	0.5	8.326	68656	213601
0.008	0.5	0.5	8.495	69291	215424
0.008	0.5	0.5	8.666	69908	217263
0.008	0.5	0.5	8.841	70506	219117
0.008	0.5	0.5	9.020	71083	220988
0.008	0.5	0.5	9.202	71637	222874
0.008	0.5	0.5	9.388	72167	224777
0.008	0.5	0.5	9.578	72671	226695
0.008	0.5	0.5	9.771	73146	228631
0.008	0.5	0.5	9.969	73591	230582
0.008	0.5	0.5	10.170	74003	232551
0.008	0.5	0.5	10.375	74379	234536
0.008	0.5	0.5	10.585	74718	236538
0.008	0.5	0.5	10.799	75017	238557
0.008	0.5	0.5	11.017	75273	240593
0.008	0.5	0.5	11.240	75483	242647
0.008	0.5	0.5	11.467	75644	244718
0.008	0.5	0.5	11.698	75752	246807
0.008	0.5	0.5	11.935	75806	248914
0.008	0.5	0.5	12.176	75801	251039
0.008	0.5	0.5	12.422	75733	253182
0.008	0.5	0.5	12.673	75599	255343

0.008	0.5	0.5	12.929	75395	257523
0.008	0.5	0.5	13.190	75116	259721
0.008	0.5	0.5	13.456	74759	261938
0.008	0.5	0.5	13.728	74318	264174
0.008	0.5	0.5	14.005	73789	266429
0.008	0.5	0.5	14.288	73167	268703
0.008	0.5	0.5	14.577	72446	270997

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)
2800000	5000	70	3710000	0.15	3500000
2863777	5000	70	3782497	0.15	3570705
2929137	5000	70	3856438	0.15	3642838
2996123	5000	70	3931852	0.15	3716428
3064782	5000	70	4008768	0.15	3791505
3135160	5000	70	4087216	0.15	3868098
3207304	5000	70	4167227	0.15	3946239
3281266	5000	70	4248833	0.15	4025958
3357096	5000	70	4332065	0.15	4107288
3434848	5000	70	4416956	0.15	4190261
3514575	5000	70	4503540	0.15	4274910
3596336	5000	70	4591851	0.15	4361269
3680186	5000	70	4681923	0.15	4449372
3766188	5000	70	4773791	0.15	4539255
3854403	5000	70	4867492	0.15	4630954
3944896	5000	70	4963063	0.15	4724506
4037731	5000	70	5060540	0.15	4819947
4132979	5000	70	5159964	0.15	4917317
4230709	5000	70	5261371	0.15	5016653
4330994	5000	70	5364803	0.15	5117996
4433910	5000	70	5470300	0.15	5221386
4539534	5000	70	5577904	0.15	5326865
4647948	5000	70	5687657	0.15	5434475
4759233	5000	70	5799602	0.15	5544259
4873476	5000	70	5913783	0.15	5656260
4990766	5000	70	6030245	0.15	5770524
5111194	5000	70	6149035	0.15	5887097

5234855	5000	70	6270198	0.15	6006024
5361847	5000	70	6393783	0.15	6127354
5492271	5000	70	6519838	0.15	6251135
5626232	5000	70	6648413	0.15	6377416

3.3.4.2. Predicted Value of Environmental Index for Water Carrying Capacity

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

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

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

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

Year	C1	C2	C3	C4	C5	C6	C7
2021	2.127	1.347	0.800	0.539	14.000	0.817	0.647
2022	2.105	1.333	0.802	0.534	13.859	0.817	0.647
2023	2.083	1.319	0.804	0.529	13.714	0.817	0.647
2024	2.061	1.305	0.806	0.524	13.567	0.817	0.647
2025	2.038	1.291	0.808	0.520	13.417	0.817	0.647
2026	2.015	1.276	0.811	0.515	13.264	0.817	0.647
2027	1.991	1.261	0.813	0.511	13.108	0.817	0.647
2028	1.967	1.246	0.815	0.506	12.948	0.817	0.647
2029	1.942	1.230	0.817	0.502	12.785	0.817	0.647
2030	1.917	1.214	0.820	0.497	12.619	0.817	0.646
2031	1.891	1.198	0.822	0.493	12.450	0.816	0.646
2032	1.865	1.181	0.825	0.489	12.277	0.816	0.646
2033	1.839	1.164	0.827	0.485	12.101	0.816	0.646
2034	1.811	1.147	0.830	0.481	11.921	0.815	0.645
2035	1.784	1.129	0.832	0.477	11.738	0.815	0.645
2036	1.755	1.111	0.835	0.473	11.551	0.814	0.644
2037	1.726	1.093	0.838	0.470	11.360	0.813	0.644
2038	1.697	1.075	0.840	0.466	11.165	0.812	0.643
2039	1.667	1.055	0.843	0.462	10.967	0.811	0.642
2040	1.636	1.036	0.846	0.459	10.764	0.810	0.641
2041	1.605	1.016	0.849	0.456	10.557	0.809	0.640
2042	1.573	0.996	0.852	0.452	10.346	0.808	0.639
2043	1.541	0.975	0.855	0.449	10.131	0.806	0.638
2044	1.507	0.954	0.858	0.446	9.911	0.805	0.637
2045	1.474	0.933	0.862	0.442	9.687	0.803	0.635
2046	1.439	0.911	0.865	0.439	9.459	0.801	0.634
2047	1.404	0.889	0.868	0.436	9.226	0.799	0.632
2048	1.368	0.866	0.872	0.433	8.988	0.796	0.630
2049	1.331	0.843	0.875	0.430	8.745	0.794	0.628
2050	1.294	0.819	0.879	0.427	8.498	0.791	0.626
2051	1.256	0.795	0.882	0.424	8.245	0.788	0.624

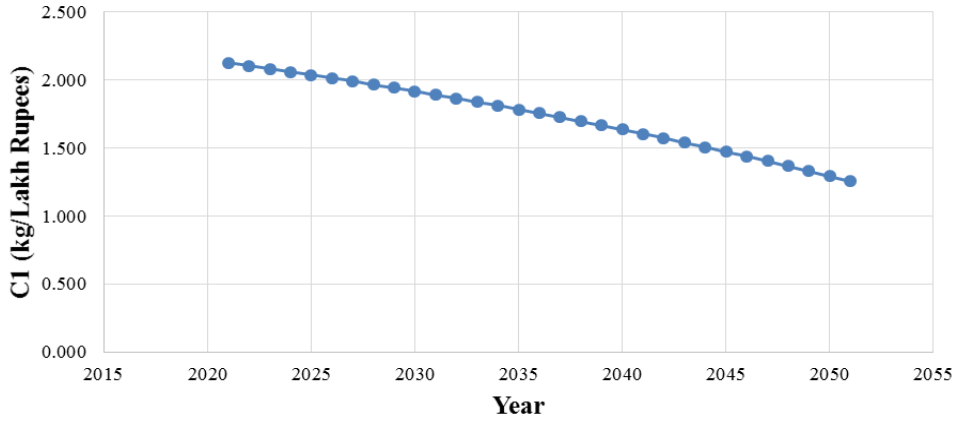


Figure 3.12: Predicted annual variation of indicator C1 for the next 10 years.

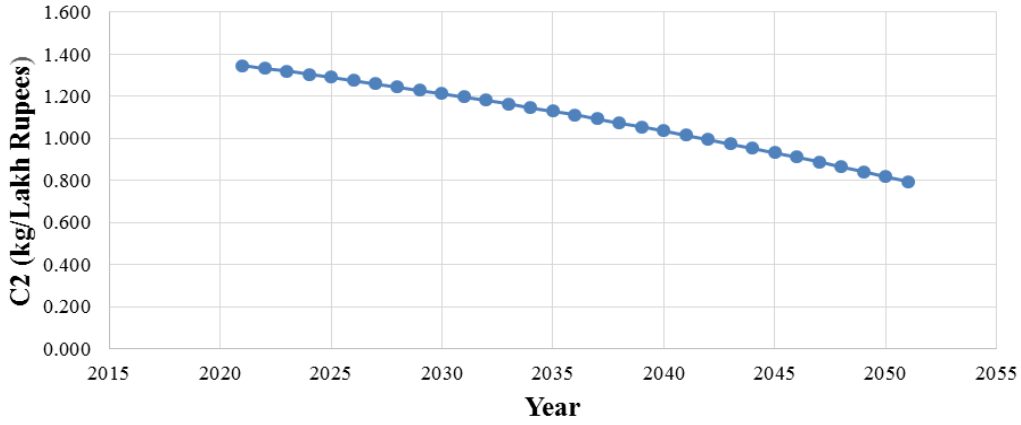


Figure 3.13: Predicted annual variation of indicator C2 for the next 10 years.

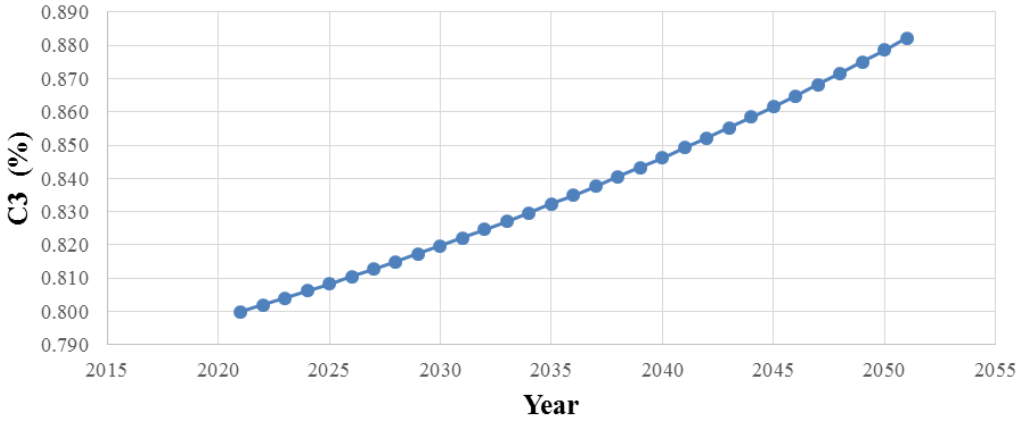


Figure 3.14: Predicted annual variation of indicator C3 for the next 10 years.

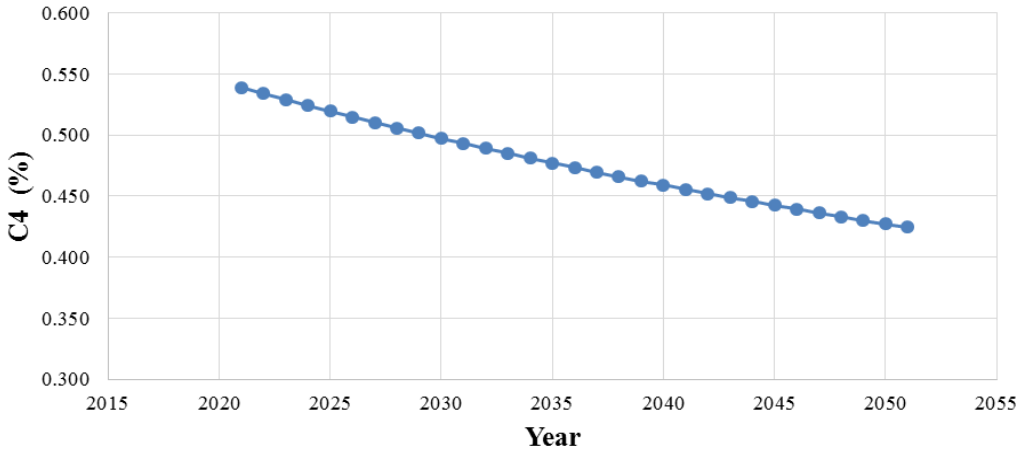


Figure 3.15: Predicted annual variation of indicator C4 for the next 10 years.

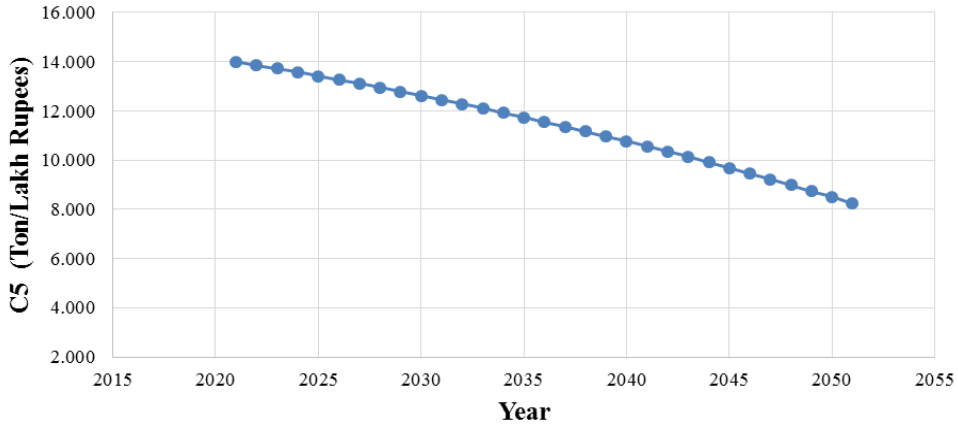


Figure 3.16: Predicted annual variation of indicator C5 for the next 10 years.

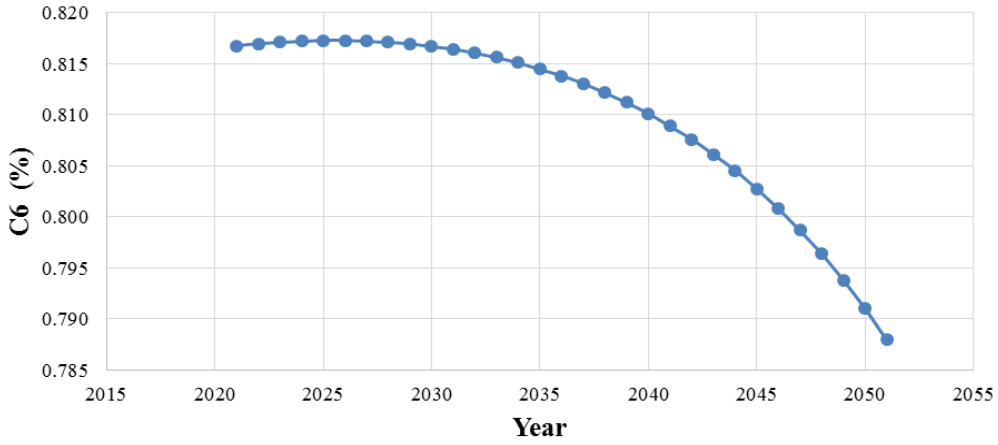


Figure 3.17: Predicted annual variation of indicator C6 for the next 10 years.

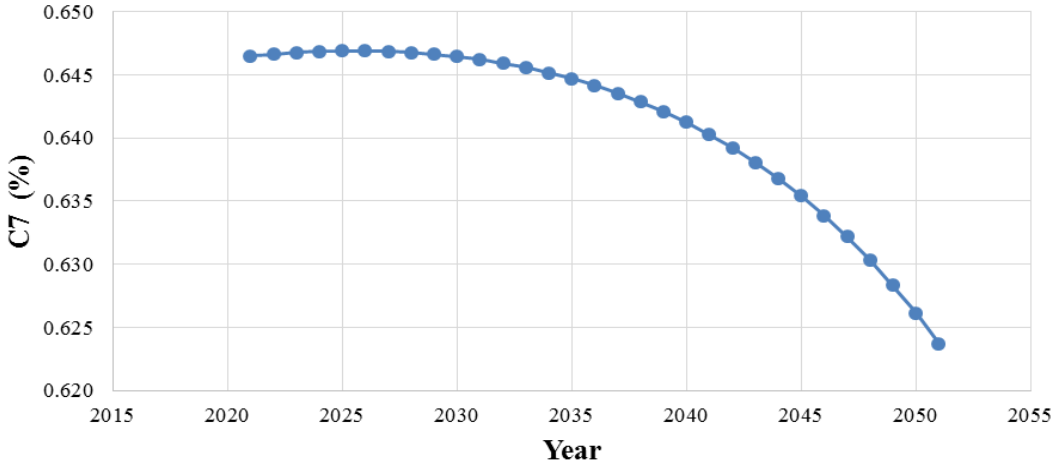


Figure 3.18: Predicted annual variation of indicator C7 for the next 10 years.

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

Indicator	C1	C2	C3	C4	C5	C6	C7
Weight	0.0645	0.0988	0.0056	0.7891	0.0397	0.0008	0.0016

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

Indicator	C1	C2	C3	C4	C5	C6	C7
Entropy	0.994	0.991	0.999	0.928	0.996	1.000	1.000

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

Year	Comprehensive Value
2021	0.613
2022	0.604
2023	0.595
2024	0.586
2025	0.577
2026	0.567
2027	0.558
2028	0.548
2029	0.539
2030	0.529
2031	0.519
2032	0.509
2033	0.499
2034	0.489
2035	0.479

2036	0.469
2037	0.458
2038	0.448
2039	0.437
2040	0.426
2041	0.415
2042	0.404
2043	0.393
2044	0.382
2045	0.370
2046	0.358
2047	0.347
2048	0.334
2049	0.322
2050	0.310
2051	0.297

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

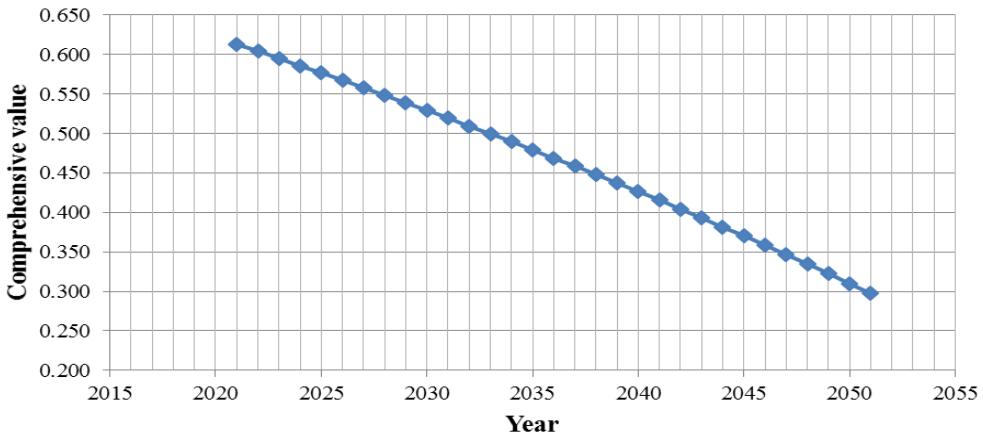


Figure 3.19: Predicted comprehensive environmental water carrying capacity of Korba for the next 10 years.

From Table 3.12 we can see the comprehensive value is 0.613 in 2021, it falls to 0.499 in 2033. At 2042 it reaches the value of 0.404 after that it crosses the normal comprehensive value and goes to the poor comprehensive value and reaches 0.297 in 2051. Therefore, we need to take appropriate steps to maintain the value in normal range or else in upcoming years it can fall to poor values. Our results indicate that the environmental water carrying capacity displays a decreasing trend. Therefore, the proper management planning is needed for long term use and further industrial developments. In this regard, a series of measures, such as water saving and water recycling, may curb the negative trend. Moreover, the pollution intensity can be further related to sectors' or plants' technological level, productivity, and capital intensity. The WRCC can significantly improve by vigorously developing energy conservation and environmental protections and promoting the construction of a conservation-oriented society. We need to ensure the harmonious development of economy, society, water resources and water environment, which is the suitable development scenario.

3.3.5 Delineation of Water Environment Management Plan

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

1. Effluent from industrial activities mainly from coal fired thermal power plant and other industries, should not be discharged directly to surface water or land, which may contaminate the water.
2. Nearby 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, and 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 is 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 national repute and enlisted third party as notified by CPCB by CECB to ensure that toxic compounds are not present in the water bodies of Korba. 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 generates wastes and the production 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 Waste in Korba

6463 /km^2 is the population density of Korba 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 Korba 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 land filling method is adopted for disposing solid wastes here. Collection, Transport and Disposing off of waste from the city is a major challenge and has several loop holes. However, even bigger challenge is to bring awareness and knowledge in society reading same. Particularly in Korba, 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 Korba 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 Korba 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 Korba, 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/ land filling/ incinerating etc.
3. Visualization and interpretation of site and how the whole city would be covered based on preliminary work carried out.
4. Then from the available regions the best ones are selected based on parameters like that of soil/ land cover, network of transport, society around, environment (humans, animals, water bodies, etc.), financial estimates, depth of ground water source, less spread of contaminants, slope or height of site and other factors are to be studied thoroughly.
5. The sites with best combination of all the factors can then be selected for disposing off wastes so that pollution can be controlled to an extent.
6. Now, collection of waste from residential houses, Industries, markets, agricultural farms and other places can be done.

7. Transportation, Clustering, Segregation, Processing, recycle, landfill, disposing off etc. can then be done with the help of different disposing techniques for different category of pollutants and wastes.
8. In addition, monitoring of the disposed wastes and subsequent steps is important.
9. 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.
10. With the help of GIS, Satellite imagery etc. technologies and Field Survey, Topography, etc. mapping is done to study the location and eliminate all the unsuitable regions for dumping/ land filling/ incinerating etc.
11. Visualization and interpretation of site and how the whole city would be covered based on preliminary work carried out.
12. 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.
13. 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.
14. Now, collection of waste from residential houses, Industries, markets, agricultural farms and other places can be done.
15. 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.
16. In addition, monitoring of the disposed wastes and subsequent steps is important.

4.2.2. Measurement of Heavy Metals in Soil

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 2.31.

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

4.3 Results and Discussion

4.3.1 Land Pollution and Waste in Korba

Korba, a city in the State of Chhattisgarh is spread over an area of 6615 sq.km. The population of Korba was 424146 in 2021, compared to 363,390 in 2011. Population growth is a major concern for increasing Municipal Solid Waste (MSW) in Korba and improper management of solid wastes leads to risks to the environment and public health. 170 Metric tons (187.4 tons) of waste is generated per day in Korba. Collection, Transport and Disposal of waste from the city is a major challenge in Korba. However, the even bigger challenge is to bring awareness and knowledge in the society. Particularly in Korba, the municipal garbage collecting vehicles visits door-to-door and collects the waste from residential areas, hotels, markets, small scale industry, public places, etc. The waste collection van is divided into two parts for separate collection of dry and wet waste, as well as each family, house, warehouse, individuals are equipped with two different bins from the state administration (green and blue). This ensures that

garbage/garbage is collected separately. This would facilitate the disposal step, as wet degradable waste is fed into pits and used to generate bioenergy, while other waste is sent to recycling and suitable waste to incineration and landfill (this was the proposed plan). Unfortunately, in Korba, waste is collected in a mixed form and in more than 90% of cases it is directly landfilled. This is one of the reasons for soil pollution in Korba, apart from other prominent ones such as dust and vehicle exhaust, open burning, human and animal excrement, hospital waste, hazardous and toxic waste, commercial, industrial, automobiles affect soil, water, soil and the entire environment adversely.

4.3.2 Major Industries in Korba

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

1. N.T.P.C. Ltd., Korba Super Thermal Power Station, Jamnipali, Korba (3x200=600 MW+3x500 = 1500 MW - Total 2100 MW)
2. Chhattisgarh State Electricity Board (CSEB), Hasdeo Thermal Power Station, Korba (West), Korba (4x21 0 = 840 MW)
3. Chhattisgarh State Electricity Board (CSEB), Korba Thermal Power Station, Korba (East), Korba (4x50=200 MW+2x120 =240 MW = Total 440 MW)
4. Chhattisgarh State Electricity Board (CSEB), Dr. Shyama Prasad Mukherjee Thermal Power Plant, Korba (East), Korba (2x250=500 MW)
5. Bharat Aluminium Co. Ltd., Balco Nagar, Korba (Aluminium Smelter Plant [Alumina-3,30,000 TPA & Hot Metal (Fabrication)-3,70,000 TPAD
6. Bharat Aluminium Co. Ltd., Balco Nagar, Korba (CPP-2) (4 x 135 = 540 MW)
7. Bharat Aluminum Company Limited (CPP-1) Balco Captive Power Plant, Jamnipali, Korba (4 x 65.5 = 270 MW)
8. Gevra Open Cast Mines, SECL, Korba (35 MTPA)
9. Dipka Open Cast Mines, SECL, Korba (25 MTPA)
10. Kusmunda Open Cast Mines, SECL, Korba (10 MTPA)
11. Lanco Amarkantak Power Private Limited, Village-Pathadi, Tehsil-Korba, Korba (2x300 MW TPP)

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

Land use mapping is the most basic and widely used methodology for assessing and observing the natural resources present in any region and gives details about the existing land use pattern too, which in turn is beneficial for predicting the better use of land in future and present. With advancements in satellite sensors and analysing techniques, the remote sensing systems have become much more realistic, efficient and attractive for implementing in research and management of natural resources and land. Land use is the activities carried out by humans on earth (land). These activities are decided by the physical, climatic, economics and social condition of region. Land cover reveals the natural and man-made structures (mountain, house, buildings, cliff, hills, commercial constructions, etc.) covering the land surface. Combination of Remote sensing and GIS techniques can serve the purpose of land use/land cover plan and map development in real time as well as for long-term monitoring of the environment. The information generated from this technique will prove to be of immense importance in the forming of action plans for pollution control and waste management. Land use distribution in Korba is shown in Table 4.1.

Table 4.1: Land use distribution in Korba.

LULC of Korba region with 15km radius		
LULC Classes	**Area (sq. km.)**	**Area (%)**
River	13.12	1.86
Forest	201.67	28.54
Agriculture land	118.85	16.82
Built up area	95.96	13.58
Vegetation	229.33	32.46
Water body	13.72	1.94
Fellow land	9.24	1.31
Industry	24.67	3.49
Total area coverage	**706.56**	**100.00**

4.3.4 Land Use Land Cover Pattern in Korba

LULC (Land use land cover) studies provides better economics and ensures 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 Korba 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 Korba, forest area constitute 28.54% with total areas of 201.67 sq. km. Furthermore, the industrial area is 24.67 sq. km with 3.49% coverage. Fellow land is 9.24 sq. km which is temporary not used for agricultural activities. Therefore, 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 Korba city.

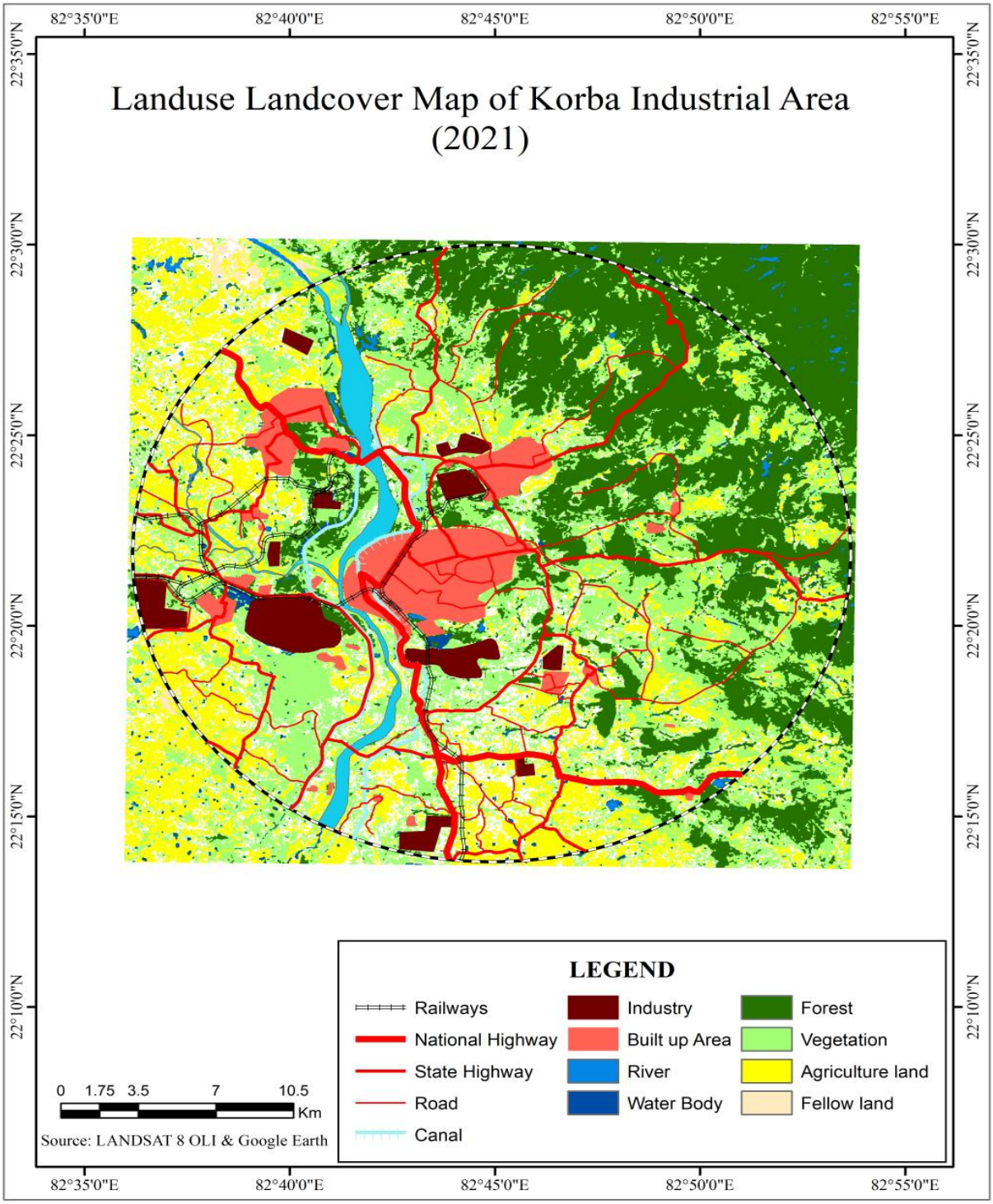


Figure 4.2: LULC map of the Korba industrial area for the year 2021.

4.3.5 Current Waste Disposal/ Management Practice in Korba

The void between the generation of waste and its disposal is the only reason for the inconsistency in the system of waste management and pollution. More than 170 metric tonnes (2011) of solid waste per day is generated in Korba district, of which municipal/domestic waste accounts for about 53%, commercial and market waste accounts for 14%. While industrial waste is the major contributor and relatively small amounts of hospital waste, biomedical waste, hazardous waste, construction debris etc. make up the rest. Figure 9 perfectly describes the solid waste management procedure in Korba.

4.3.5.1. Hazardous waste

Secured Land fill has developed by BALCO for safe storage of used pot liners. BALCO is too investigating the possibility of using used pot linings material as an alternative fuel according to MoEF guideline. Industry is also investigating the possibility of its joint processing in cement kilns. Combustible waste is sold to registered recyclers.

4.3.5.2. Bio-medical waste

The total amount of biomedical waste generated in the body is around 50 kg/day and is disposed of by deep burial method as per CPCB guidelines. Common facility at Burbuspur, Korba-Champa road, which is 15 km from Korba the township develops for the collection, segregation, transport, treatment and disposal of biomedical waste.

4.3.5.3. Solid municipal waste/Domestic waste/Sludge from ETP/CET/STP and other industry resources

Total amount of municipal solid waste/garbage produced in Korba is around 85 t/day and disposed of by bio-composting/ vermiculture method. Landfill at Burbuspur, Korba-Champa road, which is 15 km from Korba, the township is developed according to MSW rules for collection, transport and disposal.

4.3.5.4. Plastic waste.

There is no virgin or recyclable plastic production plant in Korba. Plastic used in Korba the region is made available by merchants. No survey was conducted plastic waste in the Korba region.

KMC (Korba Municipal Corporation) takes responsibility for municipal solid waste management and disposal in Korba city.

- Garbage collection from home, public places, commercial markets, hotels, government offices and organizations using mini vans, mini trucks and trucks. In addition, waste collection is carried out from various waste points and public containers located throughout the city.
- Maintaining secondary storage sites at various locations for temporary collection/storage/transportation to ensure hygiene, cleanliness and ease of handling.
- Collected municipal solid waste (MSW) is taken to disposal facilities.
- Wet wastes are buried by digging to create compost, while dry wastes like metal, plastic etc. are sold to waste recycling facilities and the remaining fractions like debris, dust, useless daily solid waste are finally dumped in SLRM (Solid Liquid Resource Management)/ Landfilling/Incineration etc.
- Extraction of existing landfilled and landfilled waste accumulated in current landfills and its transportation to relevant processing sites and waste processing and its final disposal.
- Routine maintenance and cleanliness of waste processing and disposal facilities from vehicles, machines to plants.

4.3.6 Quantification of Municipal and Industrial Solid Wastes Generation

The quantification of municipal and industrial solid waste generation can vary depending on the specific location and time period. The data is typically collected by local municipalities, waste management authorities, and environmental agencies through surveys, waste audits, and monitoring systems. Waste characterization is the first step after data collection (waste assessment data) and plays a key role. The process is exactly that: identifying the type of waste that is generated. These can further be used to determine the average rate of waste production per unit area of the region (amount (weight) per unit area of activity). The rate of waste production per unit area of the region is called the waste factor. Daily activities and increased production, population and standard of living generate much more solid waste than before, leading to environmental imbalances, pollution and serious public health problems due to poor management.

Red mud is a solid waste produced in the process of producing alumina from bauxite according to the Bayer process. Figure 4.3 shows the red mud generated. More than 4 million tons of red mud is produced annually in India alone. Fly ash and red mud are the major residues from aluminium extraction industry. One such industry is BALCO. Coal-fired power plants generate electricity by burning pulverized coal, which creates a dangerous by product called fly ash.

Figure 4.3: Red mud generated at Korba.

Table 4.2: Red Mud and Fly Ash Generation in BALCO Year Wise.

Year	Fly Ash	Red Mud
2017-18	11.52	1.69
2018-19	10.93	1.76
2019-20	10.57	2.24
2020-21	11.61	2.27
2021-22	11.45	2.51
Total	**56.08**	**10.47**

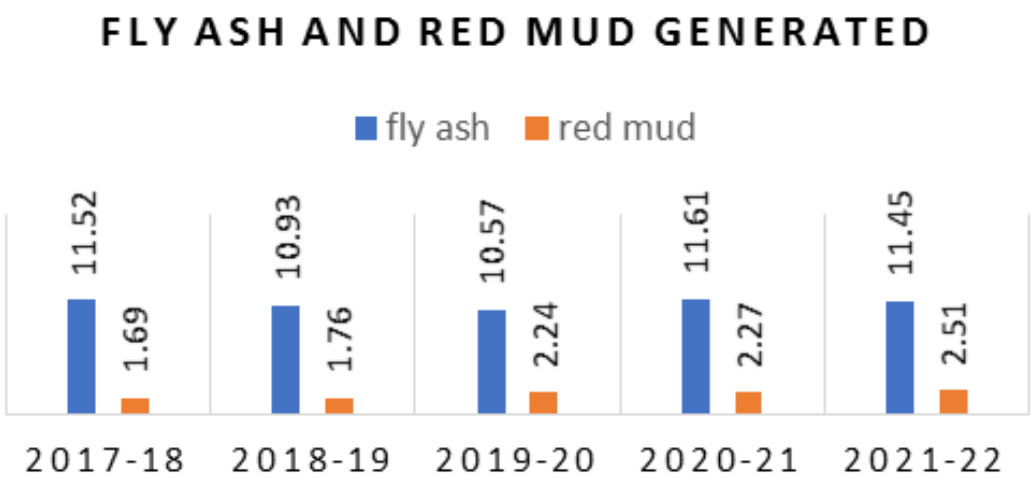


Figure 4.4: Graph showing red mud and fly ash generation in BALCO.

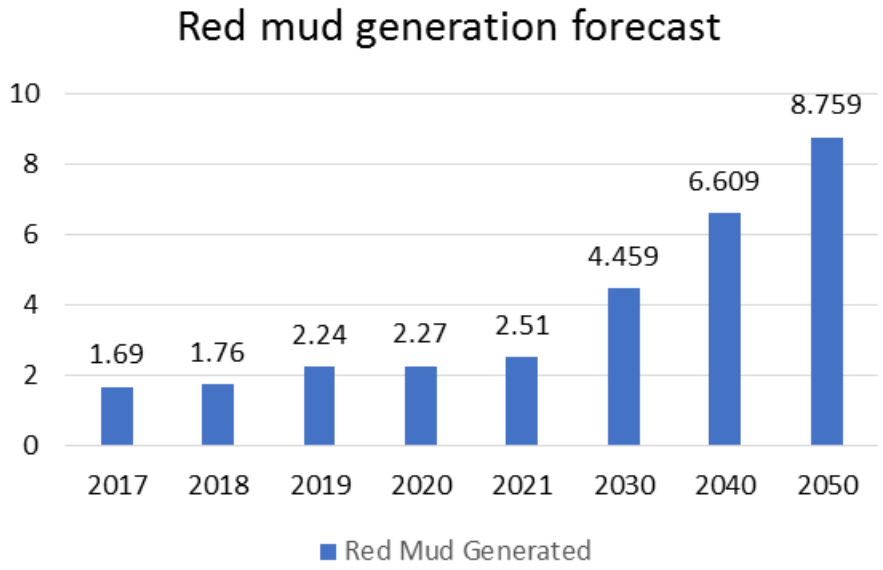


Figure 4.5: Red mud generation forecast up to year 2050.

From Table 4.2, we see the total fly ash and red mud generation from 2017-18 to 2021-22. The rate is increasing in case of red mud but for fly ash, the rate initially drops and then increases. Figure 4.5 shows the red mud generation forecast for the next thirty years, whereas Figure 4.4 sticks to a chart showing red mud and fly ash production in BALCO.

Table 4.3: Fly Ash Generation (TPD) from various industries in 2011 at Korba.

Name of Power Plant	Fly ash generation (TPD)
M/s NTPC Ltd.	20,000
M/s CSEB (West)	8,000
M/s CSEB (East)	4,200
M/s BALCO (CPP-1)	2,600
M/s BALCO (CPP-2)	5,100
M/s CSEB (expansion)	4,800
Total	**44700**

Table 4.4: Fly Ash Generation (TPD) from various industries in 2020-21 at Korba

Industry	Fly Ash (MT)
BALCO Cpp	0.92998
BALCO Tpp	2.21466
NPTC	4.7930
Shyamaprasad Thermal Power Plant	0.9705
Hasdeo Thermal Power Station	2.7495
LANCO	1.1565
Total	**12.81414**

Table 4.3 shows the industry wise fly ash generation, where Table 4.4 provides the data of 2021 whereas Table 4.3 sticks to 2011 data. This data is further used for forecasting the fly ash in TPD along the year till 2051. Figure 4.6 quite obviously depicts the future prediction of fly ash generation for consecutive 10 years and for next 20 years. Furthermore, prediction for hazardous waste generates in MTPA is shown in Figure 4.7.

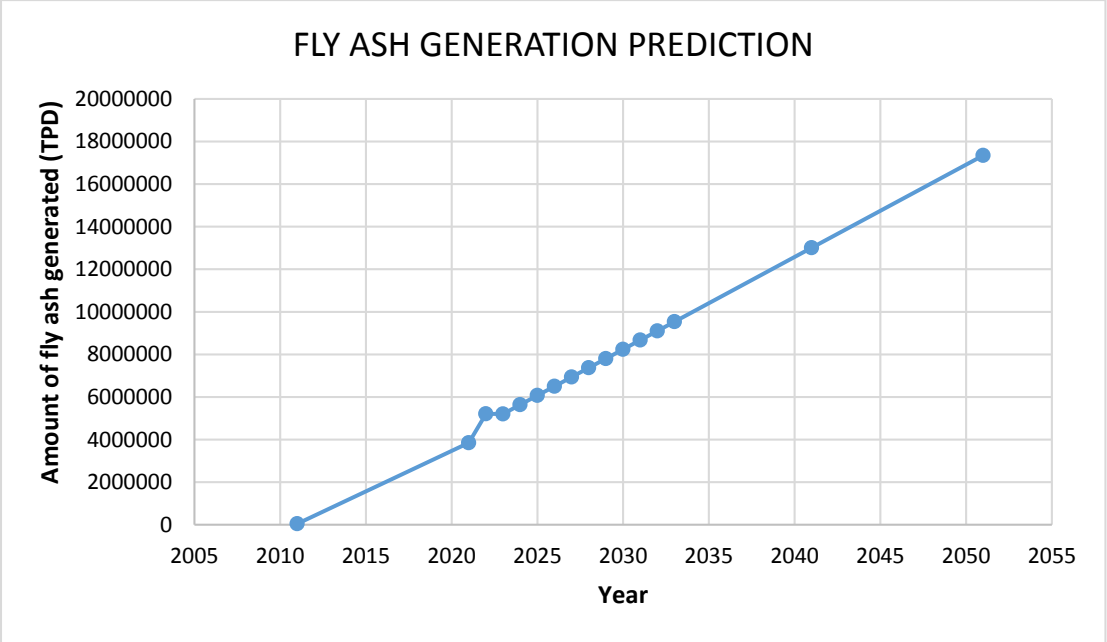


Figure 4.6: Fly ash generation forecast up to year 2050 in Korba.

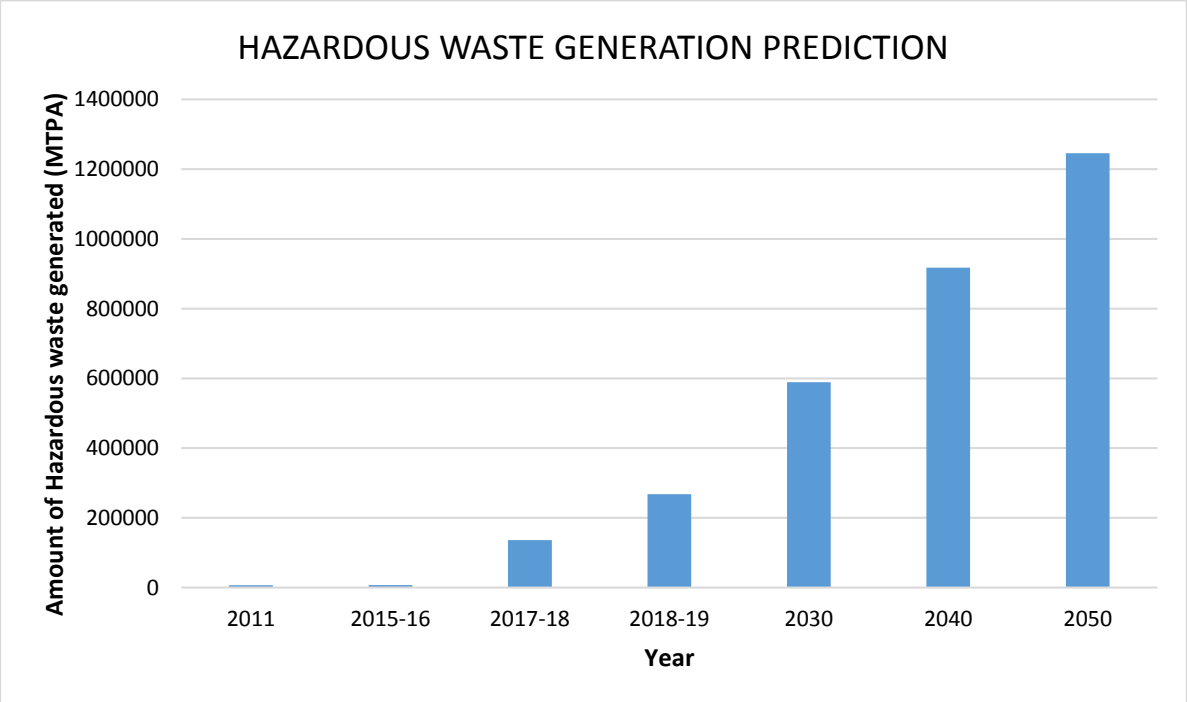


Figure 4.7: Hazardous waste generation forecast up to year 2050 in Korba.

4.3.7 Proposed Model being implemented in Korba for Disposal

Some of the disposal methods proposed by KMC for waste disposal:

- **Land filling:** Although it is not 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 Korba 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.

- **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.

- **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.

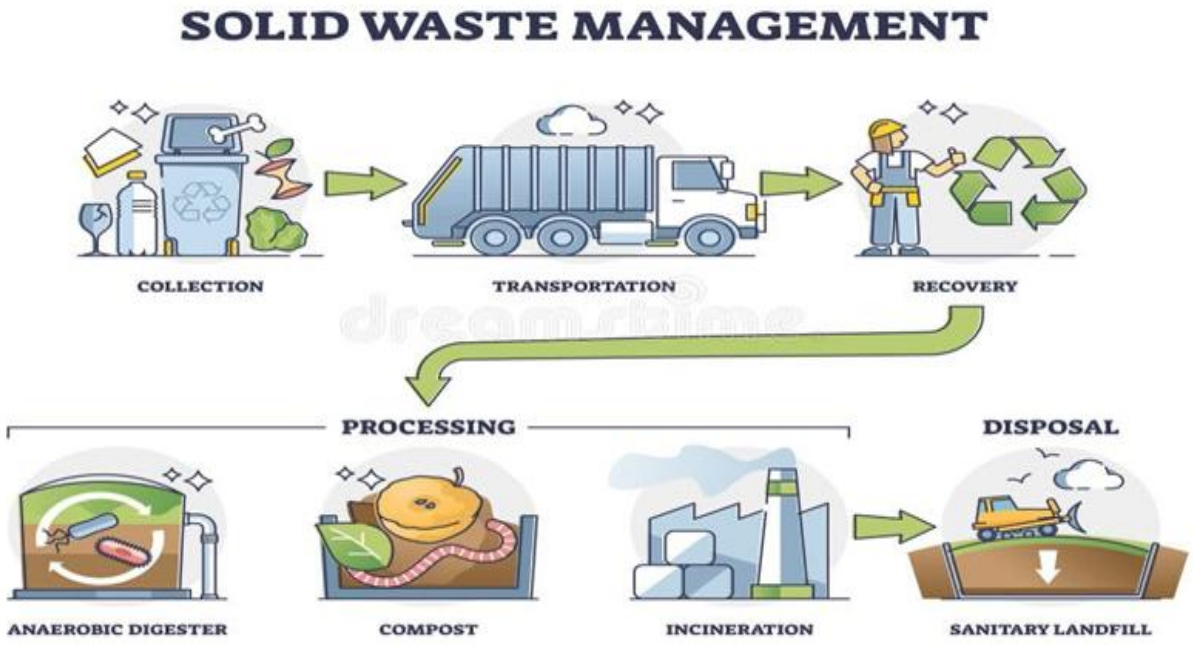


Figure 4.8: Solid waste management in Korba.

Figure 4.9: Different steps for waste management.

4.3.8 Management Plan for Solid Waste

Emphasis on the reduction of discharged waste and the development of effective methods and technologies for the disposal of inevitably generated wastes. We know that "prevention is better than cure". Measures should therefore be taken with the highest priority. A widely used strategy is integrated waste management, i.e. minimizing waste generated at the source itself, protecting the environment through proper disposal and treatment plants, and carrying out remedial/remedial works on already damaged land and environment. Newer and different points are as follows:

- Separate vehicles/containers and processing tools should be used for different types of waste.
- Monitoring: GPS enabled vehicles should collect and transport waste to ensure proper waste tracking and monitoring. Especially in the case of E-waste and hazardous waste, biomedical and industrial waste, because they are much more dangerous and pose a greater threat.
- Industries must carry out the process of storing the waste in an isolated place for several days in the industrial premises to ensure that the harmful effect does not spread.
- Using signage and boards to mark landfills, sites and vehicles, more emphasis on vehicles transporting hazardous and industrial waste and collection sites – hazard symbols can be used to mark such vehicles and sites at landfills.
- Transport in a closed manner, this can be achieved by using lids (replaceable) over the vans.
- Monitoring the process of disposal of various types of waste in accordance with assigned.
- Maintaining records of hazardous/recyclable/industrial waste etc. generated as per CPCB guidelines to facilitate monitoring and tracking.
- Validation of the assimilated information can be done from the official details of the respective organization. Interpretations and conclusions can be drawn from the collected data by graphing and analysing the past data.

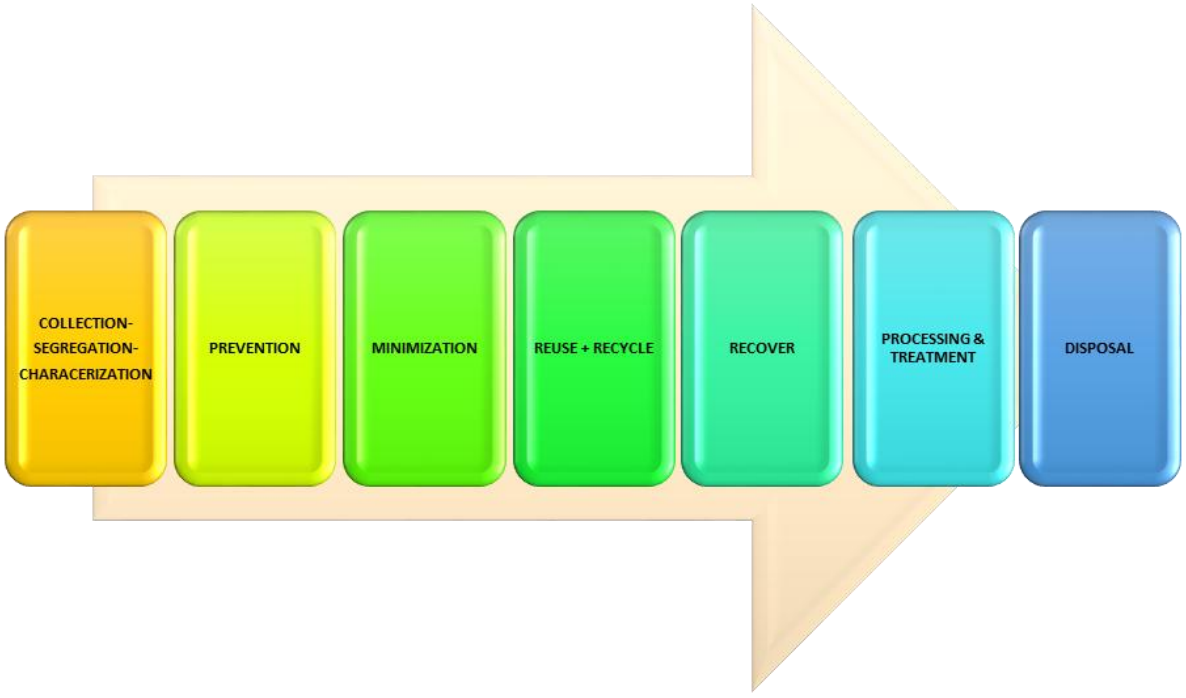


Figure 4.10: Different steps for solid waste management.

4.3.9 Hazardous Waste Management

Hazardous waste management plans encompass both short-term and long-term strategies to ensure the safe handling, treatment, and disposal of hazardous waste. Here are some considerations for both timeframes. By implementing a combination of short-term and long-term hazardous waste management plans, it is possible to mitigate the risks associated with hazardous waste, protect human health and the environment, and work towards a sustainable and safer future.

Short Term Plan:

Long Term Plan:

Figure 4.11: Some of the salient feature of Hazardous waste.

4.3.10 E-waste Management

E-waste has increased drastically since last two decades due to inventions, improvements and growth of technology and digitization. E-Waste Management is important because of the impacts it can leave on the soil, air and water in the form of pollutants if they are openly dumped into the surrounding. Mainly the formation and release of acids, the spread of toxic elements in the environment, bio-magnification due to heavy metals and related substances present in them. In the worst cases, they are also carcinogenic (long-term exposure) and many others have harmful consequences of E-waste. Waste like from damaged laptops, computers, televisions, refrigerators, pen, mobile phones etc., whether domestic or commercial, are all categorized as e-waste.

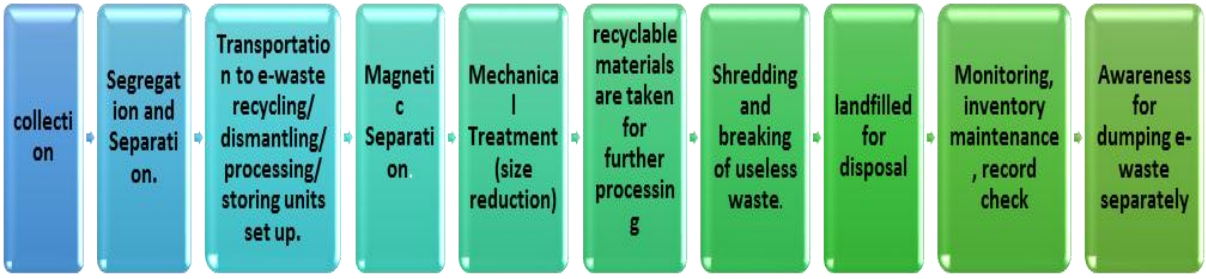


Figure 4.12: Steps to be followed in e-waste management.

4.3.11 Municipal Solid Waste Management Plans

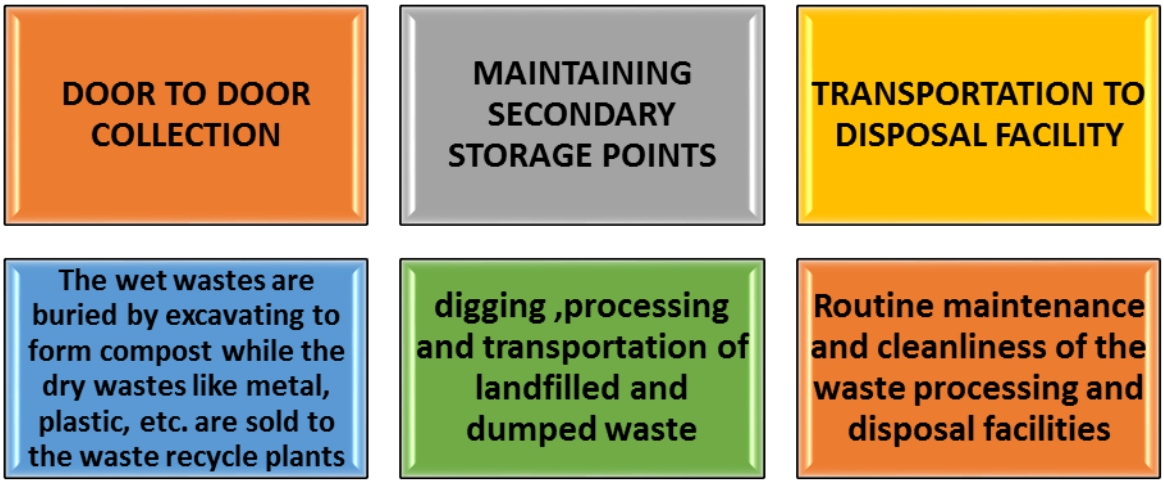
Municipal waste management plans aim to efficiently and sustainably handle the waste generated within a municipality. These plans typically involve a range of strategies and initiatives to minimize waste generation, promote recycling and resource recovery, and ensure proper waste disposal. Here are some key components of municipal waste management plans:

Waste Collection Systems: Establish an organized waste collection system that covers all areas within the municipality. This includes determining collection frequencies, routes, and appropriate collection methods for different types of waste (recyclables, organic waste, non-recyclables). Efficient waste collection helps prevent littering and ensures timely removal of waste from residential, commercial, and public areas.

Waste Segregation and Recycling: Promote waste segregation at source, encouraging residents and businesses to separate recyclable materials from non-recyclables. Provide easily accessible recycling facilities, such as recycling centres or drop-off points, where residents can deposit their recyclables. Raise awareness about the importance of recycling and the benefits of resource recovery.

Composting and Organic Waste Management: Implement programs to encourage composting of organic waste at the household and community levels. Provide education and support for residents to compost their food scraps and yard waste, reducing the amount of organic waste sent to landfills and promoting the production of nutrient-rich compost for gardening.

Short Term Plan:



Long Term Plan:

Currently, KMC doesn't have enough facility for the MSW disposal. Therefore, the tie up companies are given the responsibility to do the needful. Processing can be done by following steps:

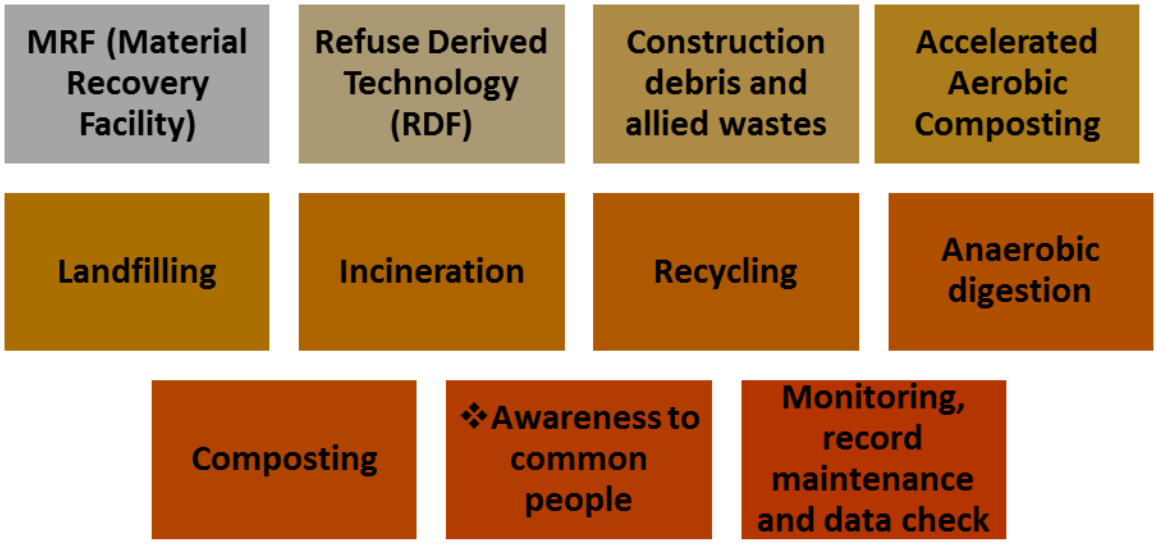


Figure 4.13: Solid waste management plans of Korba

4.3.12 Industrial Waste Management Plans

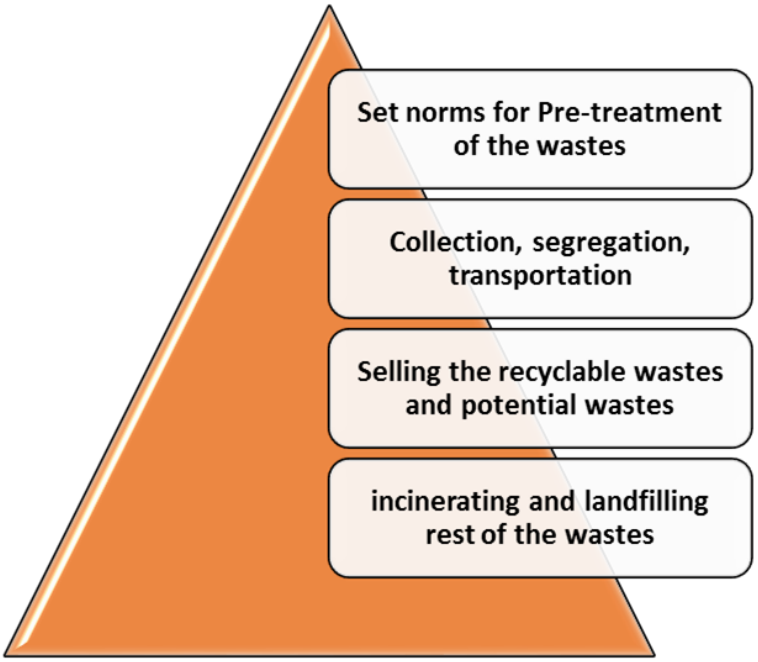
Industrial waste management plans focus on the effective handling, treatment, and disposal of waste generated by industrial processes. These plans typically involve strategies to minimize waste generation through pollution prevention and process optimization, promote waste recycling and resource recovery, implement proper storage and handling procedures to prevent spills and leaks, utilize advanced treatment technologies to treat hazardous waste, and ensure compliance with applicable regulations. The aim is to mitigate environmental impact, protect human health, and optimize the efficient use of resources within industrial operations. Some key points are as follows:

- Prevention, Minimization and Study of wastes
- Optimization of reactions, methodology and raw materials
- Modification of equipment to enhance recovery and recycle
- The initial investment and expenditure for pollution control and waste disposal might seem to be high but in long term it is a profitable deal and of course a good investment.

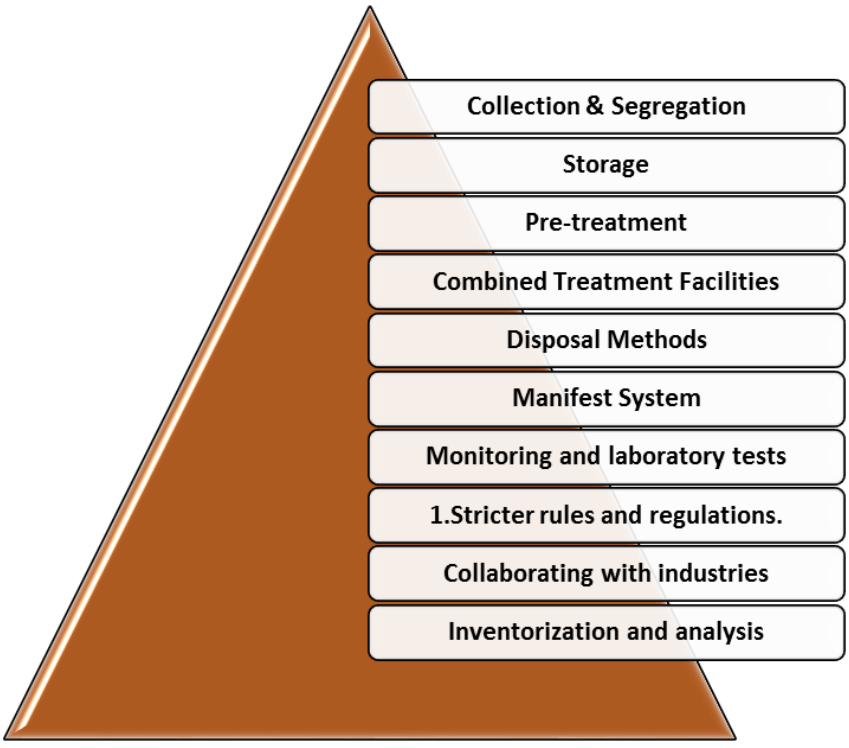
Cost Effective Plans:

1. Collaboration between the manufacturing industries
2. Environmental compensation, wherein resource-based compensation is taken instead of monetary ones.
3. Preparation and Analysis of data, Inventory preparation
4. Teaching people about the importance of waste disposal in correct way
5. Common treatment plants and sharing of resources amongst

Short Term Plan:



Long Term Plan:



7R Strategy:

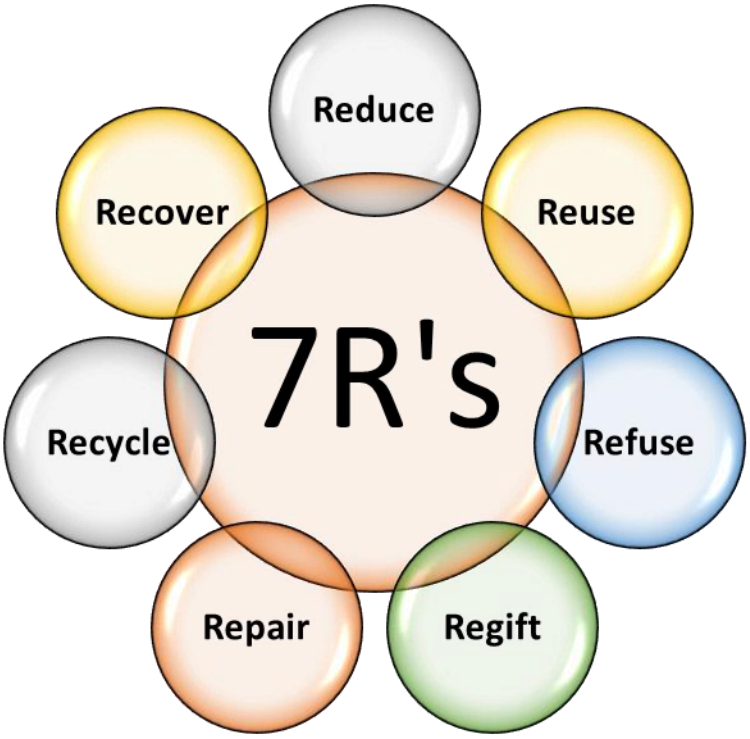


Figure 4.14: Industrial waste management plans and strategies of Korba

4.3.13 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 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/ effected. 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 Waste 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.

4.3.14 Assessing the Existing Pattern and Predicting the Critical Values of Waste Generation in Accordance with Land Available

Korba: Total Area = 66.15 km^2

Of this, barren land which can be used for landfilling = 26.53 km^2. Assume 0.1% of this barren land is actually available for landfilling. Therefore actual area for landfilling (0.1/100)*26.53 = 0.02653 km^2 = 26530 m^2

Approach 1:

According to EPA chapter 4, 2229.67 m^2 area can accommodate 100 tons of waste.

Therefore 26530 m^2 will store 1189.86 Tons waste.

We see from the data that in 2021, fly ash generation is 3.85 million ton/year. Hazardous waste is 822 TPD (approx. 300000 T per year / 365)

Fly ash generation = 3.85 million ton/year = 10548 ton/day

These are the major components of industrial waste = 10548 + 822 = 11370 ton/day

Therefore in 2021, 11370 – 1189.86 = 10180 ton/day extra waste is being generated.

In 2050, the prediction says total industrial waste/year = 17344246 + 1245629 = 18589875 tons/year = 50931 tons/day

In 2020 extra waste = (10180/1189.86)*100 = 856%

In 2050 the rate = 50931 tons/day

So the maximum possible value = 50931/9.56 = 5327.5 ton/day

However land allocation and improvement in techniques may result in 1.5 – 2 % improvement in waste management, i.e, 5407.4 TPD to 5434.05 TPD waste can be handled.

% of the predicted value that could be disposed in 2050 = (5407.4/50931) to (5439.05/50931), i.e, 10.62% to 10.67% of the predicted waste in 2050 can be disposed properly.

Approach 2:

From prediction chart for fly ash and hazardous waste, approx. in 2023 = 5500000 ton/year

Fly ash and 400000 ton/year H.W is generated, i.e, 15068.5 + 1096 = 16164.5 ton/day waste is generated.

In 2050 this is 50931 tons/day.

Considering a waste pile height of 30m, at present, available area = 26530 m^2 can accommodate 26530*30 m^3 = 795900 m^3 of waste

1ton reg = 2.83 m^3. Therefore 795900/2.83 = 281237 ton reg can be stored at full capacity

Ton reg/ sq meter = 795900/2.83*26530 = 10.6 ton reg waste /sq meter

Total storage capacity = 10.6 * 26530 = 281237 tons reg waste = 281237/16164.5 ton reg/ton/day = 17.4 ton reg/ton/day

% of present generation = (17.4/16164.5)*100 = 0.108%

So in 2050, to maintain at least the same storage facility = (0.108/100) * 50931 = 55 ton reg/TPD should be generated.

This can be relaxed by 1.5% owing to possible infrastructure development.

Therefore maximum waste generation rate in 2050 = 55*1.015 = 55.825 ton reg/TPD

Present waste generation rate must be < 17.4 ton reg/TPD

In 2050, it must be < 55.825 ton reg/TPD.

4.3.15 Analysis of Soil in the Korba Region

Soil monitoring data are presented in Table 4.5.

Table 4.5: Soil monitoring stations in Korba.

Sampling ID	Place	Latitude (°N)	Longitude (°E)
KOS01	Budhwari basti	22.365262	82.715219
KOS02	Indira complex	22.365889	82.713173
KOS03	T. P. Nagar	22.405615	82.694126
KOS04	Manikpur Korba	22.330892	82.721172
KOS05	Kailash Vihar	22.391761	82.712908
KOS06	Godhi Road	22.325772	82.782154
KOS07	Godhi Road Korba	22.319823	82.78341
KOS08	Balgi Rd Korba	22.38116	82.637424
KOS09	Surakachar CG	22.375589	82.633414
KOS10	Korba CG	22.390771	82.6552
KOS11	Rajgomar ROAD	22.376713	82.793696
KOS12	Bhaisma	22.27803	82.774983
KOS13	Godhi	22.196913	82.471039
KOS14	Korba	22.313678	82.718844
KOS15	Korba Champa Road	22.30212	82.717013
KOS16	Bharbhaspur	22.301368	82.719611
KOS17	Urga Cg	22.275357	82.733197
KOS18	Pahanda Cg	22.251129	82.734422
KOS19	Bhulsidih	22.354638	82.794081
KOS20	Pipeline Road	22.339216	82.781293
KOS21	Godhi Bhaisma Road	22.303945	82.782286
KOS22	Balgird	22.381148	82.637764
KOS23	Balgi	22.38961	82.65371
KOS24	Risdi	22.370669	82.76108
KOS25	Godhi Road	22.321914	82.781952
KOS26	Polytech Road	22.408975	82.712291
KOS27	Balgi Road	22.379212	82.633627
KOS28	Balgi Road	22.379556	82.63655
KOS29	Balgi Road	22.38169	82.638475
KOS30	Ntpc-Jamnipali	22.388515	82.653471
KOS31	Ntpc-Jannipali Road	22.394217	82.656433
KOS32	Rajnagar, Ompur	22.374218	82.823542
KOS33	Korkoma Road,Ompur	22.362234	82.834794
KOS34	Ompur	22.366278	82.847362
KOS35	Bhulsidih	22.355217	82.793953
KOS36	Pipeline Road	22.342978	82.78344
KOS37	Pipeline Road	22.336814	82.780342

KOS38	Godhi Road	22.319603	82.780342
KOS39	Godhi	22.314892	82.789863
KOS40	Ring Road,Risdi	22.377273	82.756945
KOS41	Rogbahri	22.419468	82.744504
KOS42	Rogbahri	22.422851	82.744446
KOS43	Korba	22.434552	82.73762
KOS44	Saraipali	22.439663	82.741541
KOS45	Saraipali	22.447318	82.746359
KOS46	Saraipali	22.433606	82.74902

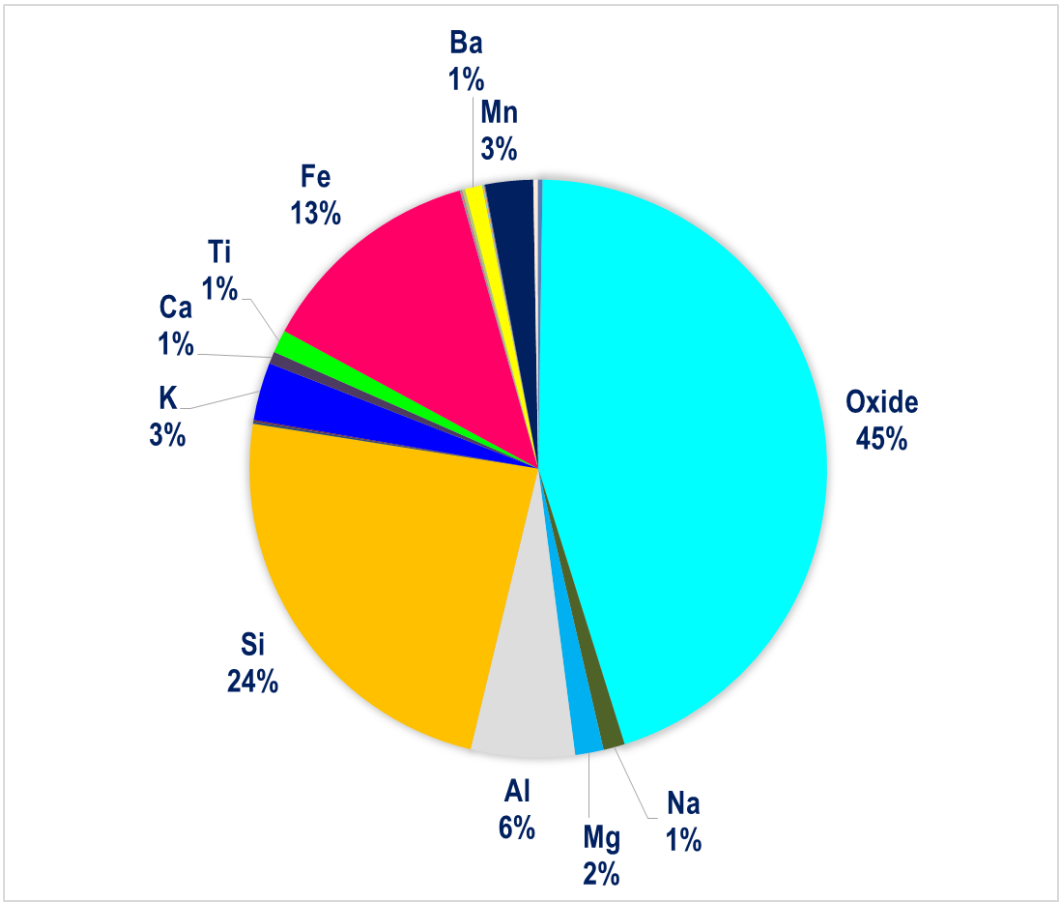
4.3.16 Presence of Heavy Metals in Soil Samples Collected from Korba

Soil is the loose surface material, originates with both inorganic and organic matters, which covers most of the land surface. It provides the structural support, water and nutrients for the plants. Soil surface acts as a major sink for gaseous and particulate pollutants. Combustion of coal in the thermal power plants produces gaseous and particulate matters like sulphur dioxide, nitrogen oxides, fly ash, etc. Particulate pollutants enter into the soil system either directly by dry deposition or precipitation scavenging or indirectly via leaf and twig fall. This leads to the change of soil pH and cause the mineral imbalance in the soil system. Fly ash contains considerable amounts of heavy metals and trace elements can alter soil metal cycle and exert toxicity to plant growth due to heavy as well as regular accumulation.

Korba is underlain mainly by three distinct geological formations ranging in age from Achaean to recent. The crystalline basement, occupy western and south-western parts of the district, comprising of granite and granitic gneiss rocks belonging to Chhota Nagpur group, severally intruded by the quartz veins and basic dykes. The major part of the district is occupied by the rocks of Gondwana of Super Group are overlying the Chhattisgarh Super group and represented by the sandstone, shale and coal seam.

The soils in the district Korba are having wide variations. About 83% of the district area is covered by yellowish to reddish Alfisols. These soils are derived from weathering of crystalline and metamorphic rocks. About 14% are of the district in north and eastern parts are covers by Ultisols in the form of Laterite. The remaining part of the district is represented by light grey and shallow black Inceptisols, covering small parts of Pondi Upreda blocks. In sedimentary formations, mainly in Barakar and Kampti sandstone, primary porosity constitutes the good aquifers. In limestone, the fractures are limited to a depth of 102-106 m.

Soil samples from Korba shows similar trend as found other parts of Chhattisgarh. Soils are rich in silica, iron and other metal oxides. In addition; 'Al', 'Mg', 'Ca', 'Na', 'Cu', 'Mn', 'Ba', 'Sr', 'Ce', 'Cr', 'Cs', 'Y' and 'Ti' are also found in little amount in the soil samples collected from Korba. They present in their different oxide forms and calculated concentrations are under control. It's good for the Korba inhabitants that, toxic heavy metals like; 'Hg', 'Pt', 'Se' and 'As' are not present in collected soil samples from Korba.



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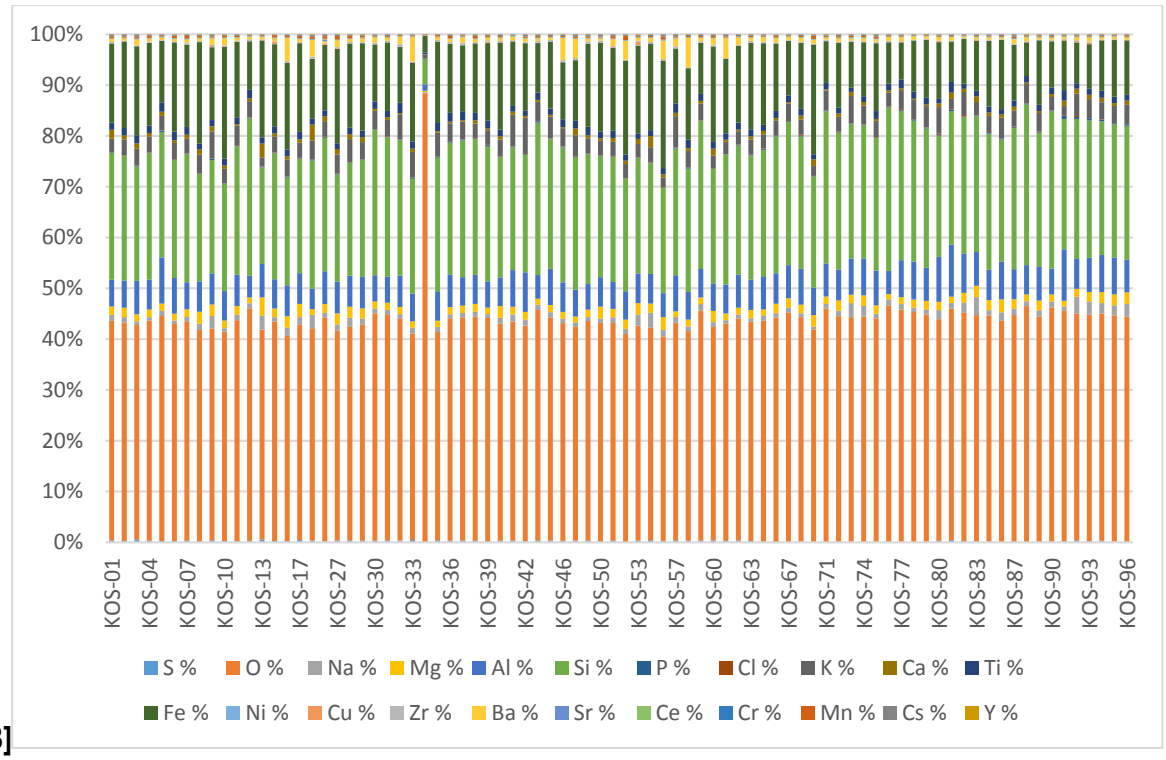


[B]

Figure 4.15: (**A**) Mean metal percentile plot of soil samples collected from different investigating stations of Korba, and (**B**) Sample-wise metals profile.

Korba soil is reach in heavy metals. Similar trend has been found in the biosphere (air, water and soil) of Korba. Fe's benevolence has found everywhere in Korba. It's important to note that Korba-soil contains little amount of aluminium (Al). All the metals concentration is calculated in percentage unit. Metals are present in soil in their different oxide form. 'As', 'Hg' and 'Pt' are not present in any form in tested Korba soil samples.

They are red in coloured, granular and dirt less Laterite soil. Character-wise, Korba soil is also rich in iron and aluminium. 'Laterization' is a prolonged process of chemical weathering, which produces a wide variety of ore mineralogy in the resulting soil. So that Korba soil is full of different ore and thus Korba is a mining area. Collected Korba soil samples are fertile in nature. Sufficient percentage of 'P' and 'K' are present in collected soils. Other plant-micronutrients like; magnesium, calcium, iron and sodium are also available in Korba soil.

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 Korba city, we divided it in 7 zone Based on the Road passes through that location. For example: T.P. Nagar , Nehru nagar, Power House,Tulsi Nagar, Manikapur, DSPM CSEB, Indira Complex, T.P. Nagar Signal Chouk, Mudapar Helipad etc . These location located on CSEB Chowk Sitamani (NH-149B). So taken them as zone 1 as CSEB chowk Sitamani (NH-149B road zone & similar way for other zone. For each sample, the following parameters were simultaneously measured:

a) The quantity of cars, motorcycles, trucks and buses that have passed by the observer during the time interval of each measurement;

b) The equivalent and statistical levels in dB(A): L_{eq}, L_{10} and L_{90}, emitted by the traffic at a distance of 10 feet from the center of the nearest road band to the observer.

5.2.1 Equivalent Level (L_{eq})

The noise levels are variable over time, going up and down continuously, making it difficult to evaluate. To make things easier the equivalent level was defined as a continuous sound level that would produce the same effect on the human ear if compared to the actual noise observed during the measurement, with all the variations. So, the L_{eq} can substitute by a single value all the variations of the noise level.

L_{10}: It is the sound level exceeded in 10% of the measurement periods.

L_{90}: It is the sound level exceeded in 90% of the measurement period.

So, this value is often surpassed, being normally considered as the background noise level. To calculate L_{eq} "Griffiths and Langdon Method" was used as per the following equations:

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

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

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

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

Where: P= Percentage of heavy vehicles

Q = Traffic volume in vehicles per hour

d = Distance from the observation point to centre of the traffic lane in feet

5.2.2 Noise Pollution Level (NPL)

The Noise pollution level (NPL) can be calculated using L10, L50 and L90 values obtained previously and is based on a following mathematical equation:

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

5.2.3 Mathematical Model for Basic Noise Emission Level

Since heavy vehicle is responsible for stronger noise than a light vehicle, a factor has been taken into account for such vehicles. In Calixto model by considering Q as real hourly vehicle flow, P as the percentage of heavy vehicles and n as weighting factor, Q_{eq} is given by following equation

$$Q_{eq} = Q\left(1 + n \times \frac{P}{100}\right) \quad (2.36)$$

And the term $10\log(Q_{eq})$ will be transformed into

$$L_{eq} = 10\log\left[Q\left(1 + n \times \frac{P}{100}\right)\right] \quad (2.37)$$

Weighting factor is calculated by using largest correlation coefficient between L_{eq} observed values and the factor given by above equation and found at n= 5

$$L_{eq} = 10\log\left[Q\left(1 + 5 \times \frac{P}{100}\right)\right] \quad (2.38)$$

Using the observed data, a new model with weighting factor n= 5 has been developed by calibrating Calixto model. Microsoft excel spread sheet has been used for estimating the values using above equation. The estimated values were then compared with observed values to get the regression equation as follows. Mathematically, this curve can be represented by:

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

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

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

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:

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

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 Korba.

Sampling ID	Place	Latitude (°N)	Longitude (°E)	Noise level (db)
KON001	Budhwari basti	22.365262	82.715219	66.9
KON002	Indira complex	22.365889	82.713173	70.2
KON003	T.p. Nagar	22.405615	82.694126	74.6
KON004	Kosawadi	22°22'4.9476"	82°44'48.559"	41.5
KON005	Dspm cseb	22°21'55.926"	82°42'54.54"	66.1
KON006	T.p. nagar	22°21'23.3748"	82°42'26.0712"	74.1
KON007	Nehru nagar	22°21'21.3624"	82°42'29.7"	64.4
KON008	T.P. Nagar signal chauk	22.356467	82.707502	81.9
KON009	Power house	22.350676	82.702236	86..2
KON010	Sitamani chauk	22.336377	82.708138	83.9
KON011	Old bus stand	22.344521	82.698518	74.8
KON012	Shree agrasen chauk	22.356064	82.695419	82.1
KON013	Ghanta ghar chauk	22.360268	82.720173	81.9
KON014	Risdi chauk	22.366757	82.76319	78.8
KON015	Urga chauk	22.276412	82.72672	68.9
KON016	Kosabadi chauk	22.363903	82.73481	83.5
KON017	Korba govt. Hospital	22.363168	82.74330	71.6
KON018	SECL gate	22.387350	82.82558	68.4
KON019	BALCO nagar gate	22.402412	82.74202	72.6
KON020	Korba railway crossing	22.349242	82.69671	83.5
KON021	Barampur	22.342425	82.68467	60.2
KON022	Korba kusmandi road	22.347189	82.67383	70.5
KON023	Surakachaar	22.366738	82.63338	55.5
KON024	Surakachar	22.366738	82.63335	55.4
KON025	Dari korba road	22.404689	82.69585	68.9
KON026	Major dhyan chand chauk	22.409132	82.70278	71.5

Sound or noise monitoring done at several locations in Korba is shown in Figure 5.2. The highest level of sound was found in KON009, KON010 and KON016, which are above 80 dB(A). And KON058, KON063, 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).

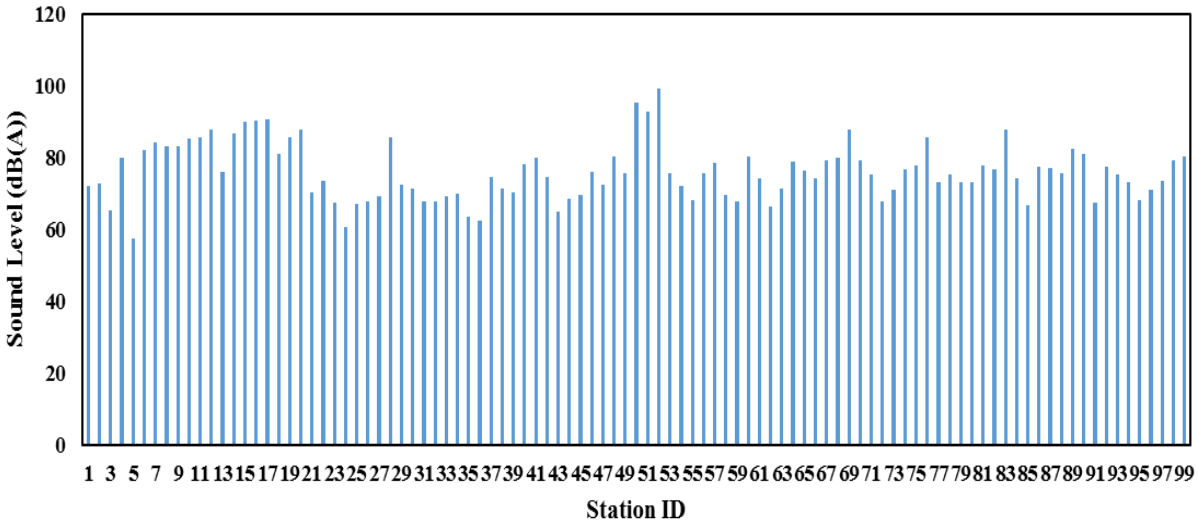


Figure 5.2: Sound level recorded at different monitoring stations at Korba.

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.

Table 5.2: Classification of different road network in Korba 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	CSEB Chowk-Sitamandi Square (NH-149B)	2816	11.93	77.18	78.59
2	Jain Mandir Chowk-ITI Chowk	1010	10.09	72.53	72.15
3	Urga-Sitamandi (NH-149B)	1470	22.31	76.16	76.58
4	Ghantaghar Chowk-CSEB Chowk	1448	7.044	72.88	73.56
5	Sarwamangla Check Post-Sunaliya Chowk (Power House Road)	1462	14.63	74.85	75.26
6	Urga-Risdi Bypass Road	556	26.61	72.84	71.46
7	ITI Chowk-Kosawadi Chowk (Collectorate Road)	798	1.25	71.07	68.39

The scatter plot for model validation is shown in Figure 5.4 has coefficient of determination (R^2) of the 45^0 line is 0.943. 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 1, 4, 5, and 7. This consist of CSEB Chowk-Sitamandi Square, Ghantaghar Chowk, Sunaliya Chowk and Kosawadi Chowk. 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.

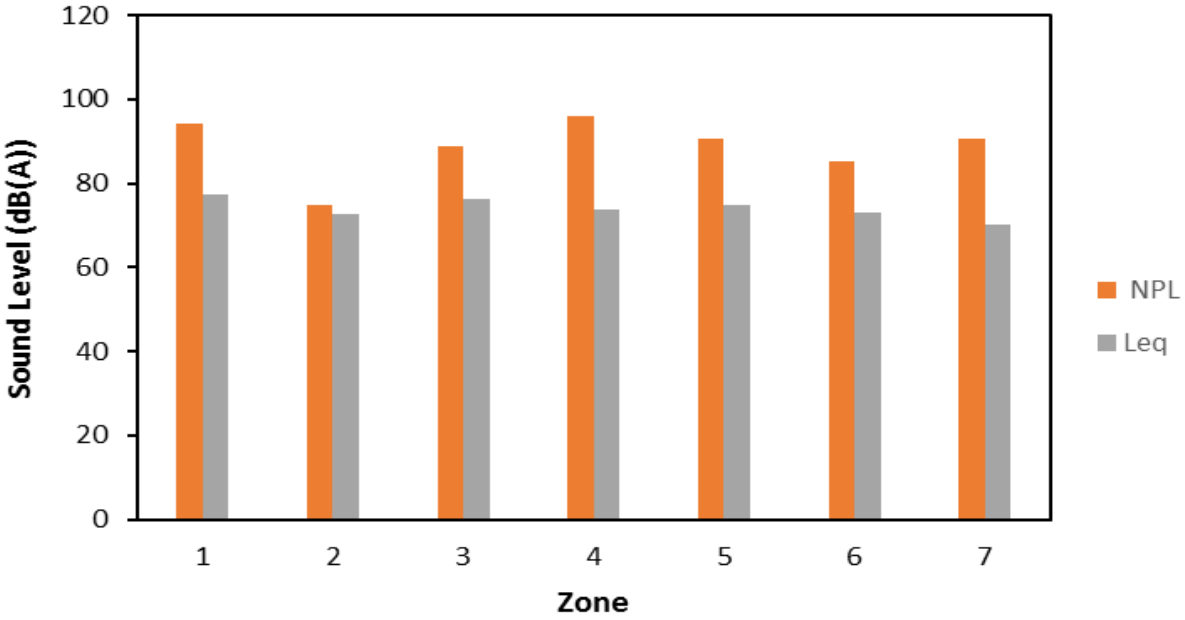


Figure 5.3: Comparison of observed L_{eq} with Noise Pollution level (NPL) of different zone in Korba.

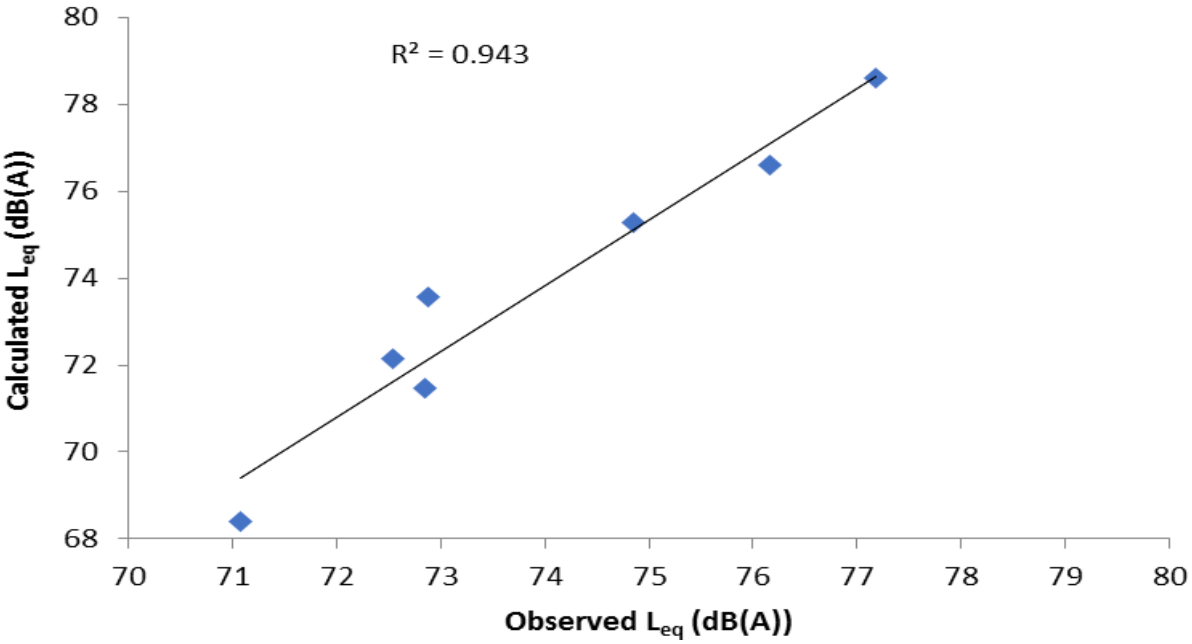


Figure 5.4: Comparison of observed L_{eq} with calculated L_{eq} sound level in the Korba region.

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 Korba

Study of biological environment is one of the important aspects in Environmental Impact Assessment in view of the need for conservation of Environmental quality. A detailed enumeration of species occurrences of flora at various locations was observed and typical plant species were noted. The visual observations of plants were recorded with a view to obtaining some idea about the relative density of certain species and their predominance. Project influence area has several floral species have been reported with some prominent tree species are Sal (*Shorea robusta*), Saja (*Terminalia tomentosa*) Arjuna (*Terminalia arjuna*) Tendu (*Diospyrox mclanoxylon*), Mahua (*Madhuca indica*), Bija (*Pterocarpus marsupium*) and Dhaura (*Anogeissus latifolia*). Sporadic growth of Bamboos occurs in the hilly areas.

The green Indian state of Chhattisgarh boasts a total of 3 National Parks and 11 Wildlife Sanctuaries known for their exceptional natural beauty and the unique and diverse flora and fauna. Wild animals like Barasinghas, Tigers, Leopards, Gaurs (Indian Bison), Nilgai, Sambar, Chausingha (four-horned Antelope), Sloth Bear, Dhole (Wild Dog), Striped Hyena, Muntjac, Wild Boar, Flying Squirrel, Porcupine, Pangolins, Monkeys and Langurs etc. The commonly found reptiles in the park are Freshwater Crocodile, Monitor Lizard, Indian Chameleon, Common Krait, Indian Rock Python, Cobra and Russell's Viper to name a few. Sighting of wild animals in the study area is quite rare. No wild animals except langurs, monkeys, hare, jungle cat and rarely a deer species are seen in the study area. Different categories of flora found in Korba are shown in Table 6.1.

Table 6.1: List of flora present in Korba.

S No.	Scientific Name (Common)	Family	Growth Forms
01.	*Diospyros melanoxylon*	*Ebenaceae*	Tree
02.	*Emblica officinalis (Amla)*	*Phyllanthaceae*	Tree
03.	*Sizygium cumini (Jamun)*	*Myrtaceae*	Tree
04.	*Tamarindus indica (Tamarind)*	*Papilionaceae*	Tree
05.	*Eucalyptus spp*	*Myrtaceae*	Tree
06.	*Shorea robusta (Sal)*	*Dipterocarpaceae*	Tree
07.	*Albizzia lebeck (Siris)*	*Mimosae*	Tree
08.	*Carica papaya (papaya)*	*Caricaceae*	Tree
09.	*Sida cordifolia*	*Malvaceae*	Tree
10.	*Vicoa indica*	*Compositae*	Tree
11.	*Prosopis juliflor (Bilati Babul)*	*Mimosae*	Tree

12.	*Pongamia pinnata (Karang)*	*Papilionaceae*	Tree
13.	*Terminalia Chebula (Harra)*	*Combretaceae*	Tree
14.	*Ficus bengalensis (Bat)*	*Moruceae*	Tree
15.	*Ficus religiosa (Asatha)*	*Moruceae*	Tree
16.	*Terminalia Belerica (Bhera)*	*Combretaceae*	Tree
17.	*Terminalia tomentosa (saja)*	*Combretaceae*	Tree
18.	*Beutia monosperma (Palash)*	*Fabaceae*	Tree
19.	*Psidium guava (Guava)*	*Myrtaceae*	Tree
20.	*Syzygium cumini (Jamun)*	*Myrtaceae*	Tree
21.	*Schleichera oleosa (kusum)*	*Sapindaceae*	Tree
22.	*Semicarpus anacardium(bhelwa)*	*Anacardiaceae*	Tree
23.	*Madhuca Indica (Mahua)*	*Sapotaceae*	Tree
24.	*Aegle marmelos*	*Rutaceae*	Tree
25.	*Azadirachta indica*	*Meliaceae*	Tree
26.	*Eragrostis japonica*	*Poaceae*	Grass
27.	*Cyanodactylon sp*	*Poaceae*	Grass
28.	*Dichanthium annulatum*	*Poaceae*	Grass
29.	*Apluda mutica*	*Poaceae*	Grass
30.	*Cenchurus ciliaris*	*Poaceae*	Grass
31.	*Themeda ciliata*	*Cyperaceae*	Grass
32..	*Sapindus trifoliatus*	*Sapindaceae*	Herb
33.	*Michelia champaca*	*Magnoliaceae*	Herb
34..	*Michelia montana*	*Magnoliaceae*	Herb
35.	*Calotropis gigantea*	*Apocynaceae*	Herb
36.	*Cocculus hirsutus*	*Menispermaceae*	Herb
37.	*Ipomoea digitata*	*Convolvulaceae*	Herb
38.	*Chlorophytum borivilianum*	*Liliaceae*	Herb
39.	*Pluchea lanceolata*	*Compositae*	Herb
40.	*Sesamum indicum*	*Pedaliaceae*	Herb
41.	*Mucuna prurita*	*Fabaceae*	Shrub
42.	*Sesbania uliginosa*	*Leguminosae*	Shrub
43.	*Sida acuta*	*Malvaceae*	Shrub

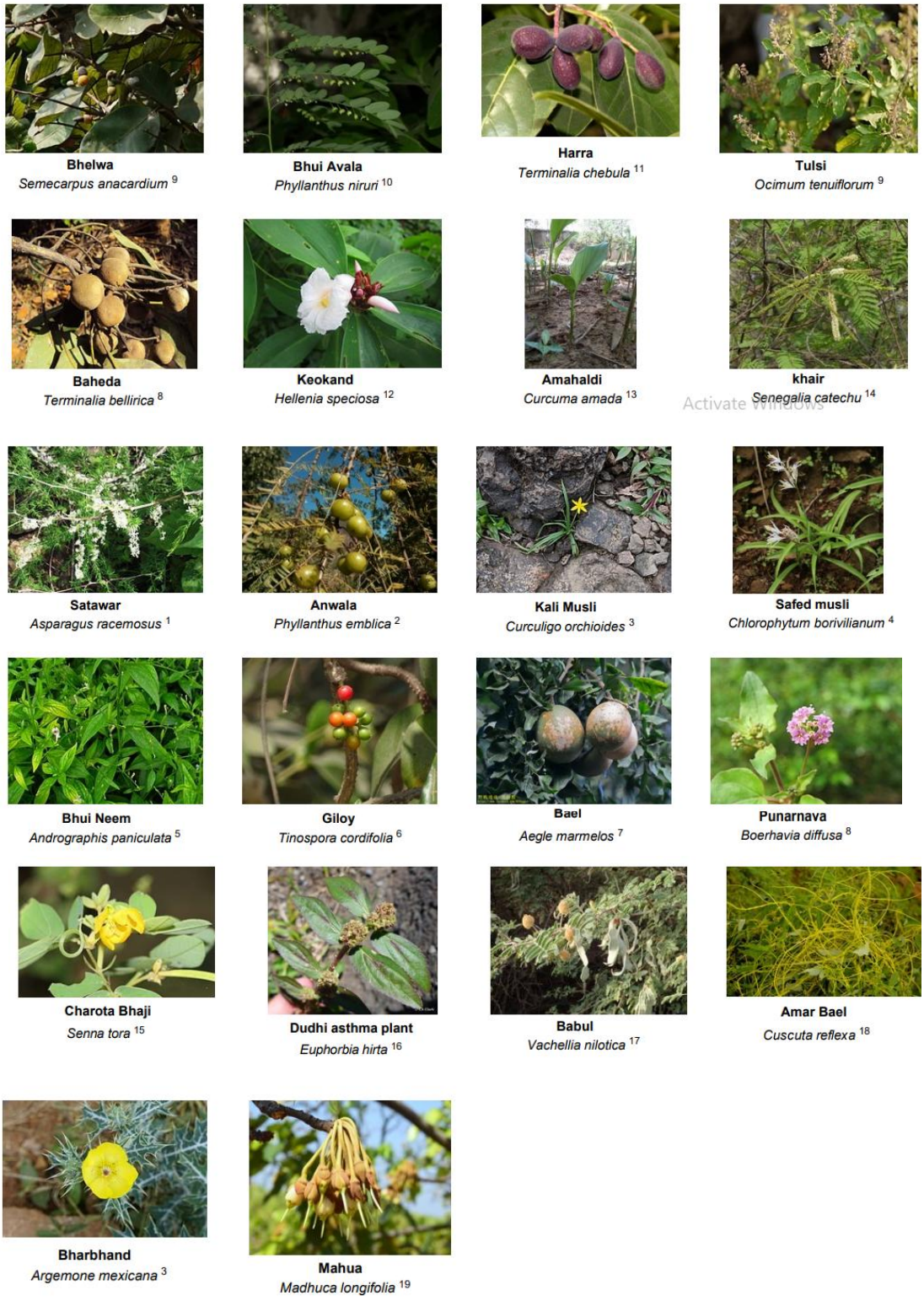


Figure 6.1: Different flora growing in the Korba.

Table 6.2: List of Domestic Fauna (animals) observed in the Korba

Sl. No.	Common Name	Zoological Name
1.	Buffalo	*Bubalus indicus*
2.	Gaur	*Bos frontalis*
3.	Sheep	*Cains familieris*
4.	Goats	*Capra hircus*
5.	Horse	*Equus caballus*
6.	Rabbits	*Oryctolagus cuniculus*
7.	Cat	*Felis catus*
8.	Sheep	*Ovis aries*
9.	Pig	*Sus scrofa domestica*

Table 6.3: List of Birds reported within the Korba

Sl. No.	Common Name	Scientific Name
1.	Treepie	*Dendrocitta vagabunda*
2.	Magpie Robin	*Copsychus Cebuensis*
3.	Lesser Whistling Teal	*Dendrocygna javanica*
4.	Pintail	*Anas bahamensis*
5.	Magpie Robin	*Copsychus saularis*
6.	Racket tailed Drongo	*Dicrurus Paradiseus*
7.	Hill Mayna	*Gracula religiosa*
8.	White eyed Buzzard	*Butustur teesa*
9.	Red headed Falcon	*Falco chiquerra.*
10.	Pond Heron	*Ardeola grayii*
11.	Cattle Egert	*Babuluus ibis*
12.	Little Egert	*Egretta garzetta*
18.	Red headed Vulture	*Sarcigypus calvia.*
13.	Painted Spurfowl	*Galloperdix houdata.*
14.	Plumheaded parakeet	*Psittiacula cynocephla*
15.	Indian Robin	*Saxicoloidesfulicata.*
16.	Teetar	*Francolinus pondicerianus*
17.	Coppersmith	*Megalaima Haemacephala*
18.	Pheasant	*Phasianus colchicus*
19.	Parrot	*Psittacula Krameri*
20.	Bulbul	*Pycnonotous atriceps.*
21.	Peafowl	*Pavo cristatus*
22.	Lesser kestrel	*Falco naumanni*
23.	Green munia	*Amandava formosa*
24.	Long billed Vulture	*Gyps indicus*
25.	Oriental white backed vulture	*Gyps bengalensis*

Peafowl

Treepie

Hill mayna

Magpie Robin

Red headed vulture

Figure 6.2: Various Birds reported within the Korba

Table 6.4: List of Wild animals reported within the Korba

Sl.No.	Common Name	Scientific Name
1.	Sloth Bear	*Melursus ursinus*
2.	Tiger	*Panthera tigris*
3.	Flying squirrel	*Glaucomys volans*
4.	Jackal	*Canis aureus*
5.	Four-horned Antelopes	*Tetracerus quadricornis*
6.	Leopards	*Panthera pardus*
7.	Chinkara	*Gazella bennettii*
8.	Blackbuck	*Antilope cevricapra*
9.	Jungle Cat	*Felis chaus*
10.	Barking Deer	*Muntiacus* muntjak
11.	Porcupine	*Erythizondorsatum*
12.	Monkey	*Catrol Vancliechin*
13.	Bison	*Bison bison*
14.	Striped Hyena	*Hyaena hyaena*
15.	Wild Dogs	*Lycaon pictus*
16.	Chital	*Axis axis*
17.	Sambar	*Cervus unicolor*
18.	Nilgai	*Boselaphus tragocamelus*
19.	Gaur	*Bos gaurus*
20.	Wild Boar	*Sus scrofa*
21.	Rhesus Macaque	*Macaca mulatta*
22.	Langurs	*Presbytis entellus*

Four-horned Antelopes

Tiger

Leopards

Barking Deer

Monkeys

Figure 6.3: Wild animals reported within the Korba

Table 6.5: List of Reptiles, Amphibians and Rodents reported within the Korba.

Sl. No.	Common Name	Scientific Name
1	Bengal cobra	*Naja kaouthia*
2	Common kukri snake	*Oligodon arnensis*
3	Checkered keelback watersnake	*Amphiesma stolata*
4	Common krait	*Bungarus caeruleus*
5	King cobra	*Ophiophagus hannah*
6	Rock python	*Python molurus*
7	Russell's viper	*Vipera russellii*
8	Reticulated python	*python reticulatus*
9	Rat snake	*Ptyas mucosus*
10	Monitor Lizard	*Varanus Indicus*
11	Grayish-brown gecko	*Hemidactylus garnotii*
12	Common Bengal monitor	*Varanus bengalensis*
13	Common Indian skink	*Mabuya carinata*
14	Dotted garden skink	*Lygosoma punctata*
15	Indian water monitor	*Varanus salvator*
16	Garden lizard	*Calotes sp*
17	Ticticky house gecko	*Hemidactylus frenatus*
18	Frog	*Rana cynophlyctis*
19	Bandicoot rat	*Bandicota indica*
20	Mouse	*Mus muscatus*
21	House rat	*Ratus ratus*
22	Squirrel	*Ratufa indica*

Dotted garden skink

Rat snake

Bandicoot rat

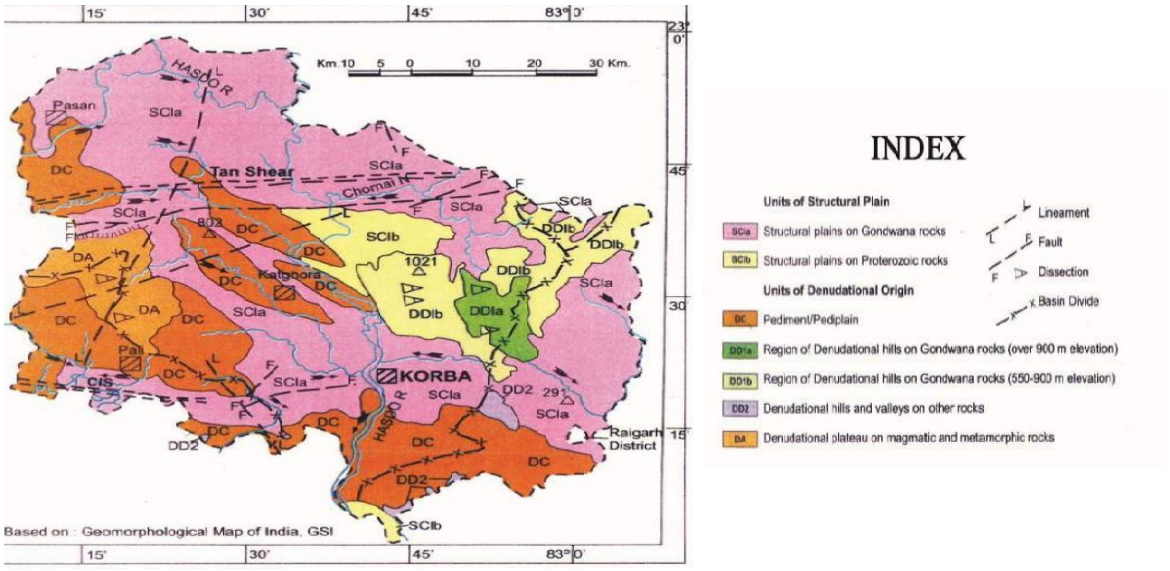
Squirrel

Figure 6.4: Reptiles, Amphibians and Rodents reported within the Korba

6.1.2 Terrestrial and Aquatic Ecosystems in Korba

KORBA district is situated in the northern parts of the state. Most of the land which has plateau from the maikal ranges of the Satpura hills, is high and low and open. The biggest area of this open land is spread near Pasan. Hasdeo is the main River which flows through this district, it has five tributaries i.e Gaj, Ahiran, Jatashankar, Chornai and Tan. On the bank of the rivers are thin forest area and villages. The area's most important hill is Karela hill with a height of 3,253 feet (992m). To the North of Katghora, the slope of the valleys of the Hasdeo and Gaj river is very less and joins the Surguja district in the north. The Tan and Chornai rivers joins the River Hasdeo from opposite directions- from the east and the west. Towards the Northen Banks are the Gurudwari Hill, Janta Hill, Matin and Dhajag hills. There is no presence of ecologically sensitive areas or buildings/ monuments of historical or religious importance.

Figure 6.5: Aquatic areas of Korba



6.1.3 Some Threatened Medicinal Plant Species in Korba

- *Rauwolfia serpentina* (L.) Benth. ex Kurz. *Rauvolfia serpentina* (*Apocynaceae* family), commonly known as Indian snakeroot, Sarpagandha, Chandrabagha, Chotachand, Chandrika and Harkaya, is a species of flowering plant native to the Indian subcontinent and East Asia.

  Low vegetative propagation rate, over exploitation and loss of habitat coupled with limited cultivation are the major causes of decline of this species from its natural habitat. This plant has been designated as threatened with extinction, endangered and threatened, critically endangered in India.

- *Acorus calamus* (*Acoraceae* family), commonly known as Sweet flag, Calamus, Calamus root, Myrtle grass, Myrtle root, Bacch, Vaj etc, is distributed throughout the tropics and subtropics, especially in India and Sri Lanka.

  Main threats to this species are because of harvest for medicine, loss of habitat, trade, fire, drought and climate change and plant reduction rate is 50-80% in Chhattisgarh.
- *Clerodendrum serratum* (L.) Moon *Clerodendrum serratum* (l.) Moon. (*Verbenaceae* family) commonly known as Blue glory, Beetle killer, Bharangi etc is a shrub and an important medicinal plant that grows in tropical and warm temperate regions like Africa, South Asia, Malaysia and throughout in forests of India and Sri Lanka.

The illegal overharvesting combined with habitat destruction resulted in a drastic reduction of its populations and has brought these plants to the verge of extinction.

Figure 6.6: (a) *Rauwolfia serpentina*, (b) *Acorus calamus*, and (c) *Clerodendrum serratum*

6.1.4 Identification of Suitable Native Tree Species for Afforestation

Sl. No.	Tree name	Description	Picture
1.	Neem Tree	These trees are found in the topical as well as non-tropical areas. Neem can be really beneficial and holds too many medicinal properties. Neem is used on a large scale in order to deal with poxviruses and control pests. It is also the biggest ingredient in some shampoos as well as soaps, so it is economically profitable. It's too healthy for our skin.	
2.	Banyan Tree	The banyan tree is found to be the best shade-giving tree in India. These trees have the biggest canopy coverage. Also the banyan tree is considered to be the national tree of India.	

3.	Arjuna Tree	These trees are found around the river beds. These tree exhibit yellow flowers during the months of March to June. One will find a woody fibrous fruit during the months of September to November.	
4.	Peepal Tree	This tree falls in the category of semi-evergreen or dry-season deciduous tree.It releases oxygen both during the day as well as night.	
5.	Sal Tree	This tree is the biggest deciduous tree in the entire country. This tree is native to the sub-Indian continent. This tree provides high-quality timber. Mostly, Hindus, as well as Buddhists, worship this tree.	
6.	Curry Tree	It's a tropical to the sub-tropical tree. It's famous and is native in the countries of Sri Lanka and India. The leaves of the curry tree is famous in South Indian dishes. The reason behind it is the strong aroma of the leaves of the Curry trees.	

7.	Gulmohar Tree	The pretty and mesmerizing flowers of the Gulmohar tree are a sight within themselves. The flowering season of the Gulmohar tree in India is between the months of April & June. This tree is known to grow in the tropical as well as dry conditions	
8.	Ashoka Tree	It's a rain-forest tree. These trees are easy to find in Deccan plateau's central area. This tree is found to be evergreen. It's popular for fragrant and foliage flowers.The leaves of this tree are found to be dark green, and they grow in bunches.	

Figure 6.7: Trees found in the roadside of Korba and suitable for afforestation

6.1.5 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 pollute 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 dominate 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 Gastro enteritis's, 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.

6.1.6 Measures for Protection and Conservation of Biodiversity

Flora

a) Introduction of Grass species since they are drought tolerant and can colonize fast in low nutrient soil due to the presence of fibrous roots.
b) Plant more native plants.
c) Long term plans like Forest fire protection plan.
d) Development of Wetland habitat.
e) Monitoring of conservation and management action plans and continued updation whenever required.

Fauna including Wildlife

a) To collect and survey all the information about wildlife, especially, their number and growth.
b) To protect habitat by protecting forests.
c) To delimit the areas of their natural habitat.
d) To protect wildlife from pollution and from natural hazards.
e) To impose complete restriction on hunting and capturing of wildlife.
f) To impose restrictions on export and import of wildlife products and severe punishment to be given to those who indulge in this activity.
g) To make special arrangements to protect those species whose number is very limited.

Migratory Avi-fauna

a) Fostering bird-friendly farmland.
b) Reduce your plastic food print.
c) Protect birds from cats.
d) Keep your woods wild.
e) Making renewable energy bird-safe.
f) Ending illegal bird killing by changing attitudes.

Rare and Endangered Species

a) Learn about endangered species in this area.
b) Create a backyard wildlife habitat. Put bird feeders and other wildlife attractants, such as bird houses and baths.
c) Minimize use of herbicides and pesticides.
d) Do not buy plastic products.

e) Don't litter and destroy sensitive habitats, which may be home to native/visiting species that are endangered or threatened.
f) Never purchase products made from endangered species.

Medicinal Plants

***In-situ* conservation**

a) Conservation of a given species in its natural habitat or in the area where it grows naturally is known as in-situ conservation.
b) It includes Gene bank / Gene sanction, Biosphere reserves, national parks, sacred sites, Sacred grooves etc.
c) It is only in nature that plant diversity at the genetic, species and eco-system level can be conserved on long-term basis.
d) It is necessary to conserve in distinct, representative biogeographic zones inter and intra-specific genetic variation.

***Ex-situ* conservation**

Conservation of medicinal plants can be accomplished by the ex-situ i.e., outside natural habitat by cultivating and maintaining plants in botanic gardens, parks, other suitable sites, and through long term preservation of plant propagules in gene banks (seed bank, pollen bank, DNA libraries, etc.) and in plant tissue culture repositories and by cryopreservation).

6.1.7 Green Belt Development

The green belts serve an important role in controlling the micro-climate, reducing dust and leading to a much higher number of birds, squirrels and butterflies as compared to other cities. Green belts act as carbon sinks, especially relevant as the vehicular and industrial emissions increase. They also play an important role in reducing the "heat island" effect associated with concrete and built environments. These green spaces in the city provide year-round refuge, food and nesting spots to around 150 species of birds that are resident or local migrants and have ample resources for another 110-migrant species. The abundance of green spaces with significant protection has led to a thriving population of birds such as Chandigarh's state bird, Indian grey hornbill, Shikra, black ibis, common babbler, barbets and purple sunbirds.

6.1.8 Mitigation Measures to Compensate the Loss of Forest Cover/ Green Cover

Some measures taken by Government of India -

1. **National Forest Policy:**

In this policy Joint Forest management and local villages worked together to manage forest. For this local villages were credited with 25% of the income of that particular forest area.

2. **Conservation of Reserve forest:**

Reserve forests are mainly located in Himalayan, Eastern Ghats and Western Ghats together with national parks and sanctuaries. In all these areas, commercial exploitation should be banned.

3. **Local People Involvement:**

Common people can play an important role for forest conservation. But the need is that there should be awareness among peoples. Public support must be generated to achieve the goal of forest production. One of the movements was Chipko Movement (1972).

4**. Adopting afforestation Scheme:**

Forest serves as a source of raw material for commercial sector of the country. So to fulfill this need for forest based industries for longer time, plantation should be promoted in the barren or fallow land.

5. **Increasing Forest Productivity:**

The productivity of forest can be enhanced by:

(a) Proper Forest Management

(b) Supplying proper nutritional demand to the plants by inorganic and organic fertilizer.

(c) Controlling disease, pests and weed by adequate insecticides, pesticides and weedicides.

(d) Use of advanced technique for forest tree breeding and tissue culture method.

During the same period, the tree cover increased from eight sq km in 2003 to 10 sq km in 2017 to 25 sq km in 2019. Overall, the green cover has increased from 26% in 2001 to 46% in 2019, a significant statistic in a country struggling to preserve its green cover.

These are few mitigation measures taken by Government of Chhattisgarh

1. <u>Controlling micro-climate</u>

   An annual assessment as part of the government's Greening Chandigarh Action Plan suggests that annually more than 1,60,000 trees have been planted over the last 14 years (2007-'21) leading to a significant increase in greenery.

2. Eucalyptus plantations have been discontinued and medicinal as well as indigenous species are being nurtured over the past decade or so with herbal gardens being set up in schools and colleges.
3. Increasing green spaces

   The continuous creation of new green spaces such as the lush Nagar Van spread over 247 acres. Designed as a city forest – a concept finding increasing global acceptance, Nagar Van adds valuable space to the Sukhna ecological complex.

   The newly established 176-acre large Botanical Garden developed at the administrative tri-junction of Sarangpur, Lahora and Dhanas villages is a cushion against urban development beyond Chandigarh's boundaries. These green spaces supplement the existing larger forest patches that require constant protection such as the Sukhna Wildlife Sanctuary (26.11 sq km), City Bird Sanctuary in Sector 21 (0.03 sq km), Lake reserved forest (1.06 sq km), Sukhna Choe reserved forest (3.87 sq km), Patiala-ki-Rao forest (1.36 sq km) and Brick kiln at Manimajra (0.06 sq km).

4. In addition to the development of new forest parks and protecting existing green spaces, innovative approaches are being adopted such as declaring 31 trees over a hundred years each as "Heritage Trees of Chandigarh", as notified by the Administrator of the Union Territory in 2017.

6.1.9 Delineation of Appropriate Environment Management Plan (For development of greenbelt/green cover in the study region classified into short and long-term with due priority to low cost measures that give maximum benefits)

Some points are as follows :

- While selecting the species for plantation in urban areas one should consider whether the species comes under the evergreen species, is wind resistant, drought hardy, fast growing, has aesthetic value and the capacity to tolerate water logging among other factors.
- While planting a tree, one should ensure that the ball of earth bearing the seedling is rested on the hard bottom of the pit. The sides around the ball should be furrowed for easy spread of new roots and the refilled earth should be a mixture of about 70% of the original soil and 30% compost.

- Urban forest carbon sequestration and air pollution removal along with other environmental impacts of urban forests (e.g.water quality improvement, reduced ultraviolet radiation loads etc.) need to be incorporated within the urban development planning efforts to improve environmental quality and enhance the quality of urban life.
- The best time to plant saplings, suggests R. Madhavan of Environmental Society of Mandavelli, is between August and September, right in time for the monsoon. "It is extremely important that they are regularly watered, especially during the next summer, and then twice a week for a year."
- A tree guard, a fence of a certain height, around them is good but it must be removed after two years, so that the branches do not get caught in the iron rings.

Right sapling is also decided keeping in view the birds and animals around. For example, wide roads, it is better to have fast-growing varieties including *Beltaforus vaghai*, while for the smaller roads with electric cables, we need more of Punnai and Magizham that take time to grow.

6.1.10 Environmental Management Plan for Biodiversity

We can create 'micro-doses' or pockets of nature by planting saplings or trees/plants in hospitals, school, housing society and complexes. Green entrances to buildings, will allow visitors to experience some nature, as well as cleaning and cooling the air that enters the building. To create a beautiful nature's view, we have to implement urban greening. Incorporate green views from within buildings, as this is found to reduce stress and increase focus. We have to bring nature nearby by providing small green spaces throughout communities where people can relax near plants. We can retain the mature trees in landscape design. Older trees provide greater aesthetic appeal and emotional benefits, as well as exponentially higher ecosystem services like air filtering, cooling and CO_2 removal, in comparison to smaller trees. We should plant a diverse range of tree species, allowing greater resilience to changes in climate, as well as pets and disease to generate plant diversity. We can design continuous shaded pathways of trees to promote physical activity. Lastly, we need to optimize green infrastructure by incorporating green permeable surfaces to allow storm water runoff to escape.

Protecting local green spaces, designing eco-friendly buildings and creating urban networks of green space can help to minimize the impacts of urban heat in our cities and towns. With the support of government organizations, we can help the locals take control by organizing public awareness events/ campaigns and plantation drive. People must take the initiative to conserve nature without waiting for the government to act. The green cover in every school premises should get increased to the maximum

possible extent. The district should set a model to others by increasing the green shade in schools with the participation of the students, which will tremendously improve the environment of the educational institutions. The action plan for this starts identifying the schools with sprawling space, where the pits will be dug to get it cooled for a while so as to ensure smooth growth of the saplings once they are planted. We can establish tree helpline to report illegal felling of trees. Natural forests should be increased — both area wise and density wise as it will not only increase the green cover but also increase the biodiversity, including flora and fauna. The allocation of huge parcels of land, rich in biodiversity, for the purpose of mining by the government to large corporations should be strongly condemned. Majority of these mines have severe impact on the quality of water, air and land. Due to mining, the water sources get contaminated leading to reduction in the availability of clean drinking water. It also affects air and land. The destruction of these habitats can lead to many endangered species of flora and fauna getting extinct.

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 Korba. 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 15 sampling stations in the Korba region during summer, winter, and pre/post monsoon seasons. The highest PM level were found in K10, K13 and K154 as the main reason could be the nearby industries and transport sources. Moreover, the highest $PM_{2.5}$ level were found in K06, K13, and K14 as it is very heavily traffic area and there nearby locations constructions are also going on. The PM_{10} and $PM_{2.5}$ can be originated from anthropogenic sources mainly from industry, natural and transport sources. PM_{10} sources are classified as mechanically generated aerosol originated from windblown dust, emission, volcanoes, plant pollen, rock blasting in mining zone etc. while $PM_{2.5}$ are complex particulate matters because of size and nature of formation. The $PM_{2.5}$ particles can grow in size because of chemical conversion of gases to low volatility vapors over primary particles. Monsoon rains are the major factor for low concentration of particulate matter during July to September as rain shower washes out them efficiently. The enormous biomass burning especially during night time in winter days due to the use of combustible goods like wooden blocks, fire wood and cow dung cake as bonfire in the open space by the people to keep themselves warm in winter season, resulting in significant quantities of ashes in the atmosphere. So the highest PM levels were found in winter followed by summer and lowest in monsoon. The final outcome of the assessment with regard to the range of Supportive Carrying Capacity of the ambient air environment in Korba, shows that there is no supportive carrying capacity and the pollution load in terms of PM_{10}, is exceeding the Assimilative Carrying Capacity.

The SO_2 values observed at these stations are well within the NAAQS limit of 80 $\mu g/m^3$ but the stations K06 and K13 that is mainly because of wood industry and other industries. Furthermore, the NO_2 variations in different seasons are within the limit of 80 $\mu g/m^3$. However, high concentration were found in K06, K04, and K13 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. In Korba 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 0.32 $\mu g/m^3$ to 0.77 $\mu g/m^3$ among all air quality monitoring stations. Similarly, we have found TC values ranging from 0.38

µg/m³ to 0.89 µg/m³ among all air quality monitoring stations. Carbonaceous compounds are mainly organic or house hold type in Korba 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 Korba 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. VOCs (mainly benzene) are present in the ambient air of Korba and varying with seasons. During summer, VOCs concentration in the ambient air in Korba have been decreased and sometimes become lower than the permeable limit.

Metallic and non-metallic nanoparticles are also found in the ambient air of Korba and are varying with season. Metallic nanoparticles are mainly 'Cu', 'Cr', 'Cd', 'Fe', and 'As' in low amount and are below the limit but they are increasing day by day with change of seasons. 'Ni' has been found beyond the limit line and 'Pd' is about to cross the limit line. Toxic metal 'Hg' has not been found in the ambient air of Korba. Ambient air of Korba stations contain iron (Fe) and zinc (Zn) in high amount. Most important matter is that, every time and in every sampling station in Korba, we have found 'Pb' and 'As'.

Ultimate prediction by Receptor Model (CMB) is, pollution levels are gradually decreasing in summer than winter. Only in traffic section we have found some higher emission in summer but other all sections like constructions, industrial resources, open burning and domestic emission are decreasing 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 Korba 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 and HC from main industrial point sources, line sources and area sources of Korba has been 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 Bharat Aluminium Company Ltd. zone with maximum concentration 24-h obtained as 125.79 µg/m^3. SO_2 hotspot are obtained as Ajgar Bahar and Santrenga zone with maximum concentration 24-h obtained 50.767 µg/m^3. NOx hotspot found to be Bharat Aluminium Company Ltd. zone with maximum concentration 24-h of 49.487 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 22.17 µg/m^3 with hotspot near by Transport Nagar. For the area source modelling, we have considered different garbage coal mining areas, South Eastern Coal fields, ash dykes, ash ponds in the Korba city. Here hotspot is found to be HS Rajgomar coal mines with SPM concentration 24-h of 178.24 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 214 locations within Korba 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 30 to 977.2 µs/cm. Moreover, hardness in all the samples is very high, where average value is more than 188 mg /l, highest value reaches to 400 mg/l. COD level is within the limit of 10 mg/l. DO level was found within 10 mg/l. Moreover, Cl^- values of samples are beyond the limit of 170 mg/l. Furthermore, the 'Cu' in every water samples, ranging from 0 to 0.204 ppm with a mean value 0.046

ppm, which are much below the limit (1.5 ppm). The concentrations of 'Cd' and 'Pb', in the drinking water of Korba, are now alarming. All the collected water samples from Korba and its surrounding have been found highly Cd-contaminated. 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 0.613 in 2021, it falls to 0.499 in 2033. At 2042 it reaches the value of 0.404 after that it crosses the normal comprehensive value and goes to the poor comprehensive value and reaches 0.297 in 2051. 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 Korba are also analysed. Currently, the urban solid wastes coming from houses, small scale industries and market in Korba are dumped nearby open lands. LULC mapping of Korba has been done to calculate the best possible utilization of land present/ available for better planning and policy making. In Korba, forest area constitute 28.54% with total areas of 201.67 sq. km. Furthermore, the industrial area is 24.67 sq. km with 3.49% coverage. Fellow land is 9.24 sq. km which is temporary not used for agricultural activities. Therefore, 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 Korba city. Subsequently, the short and long term plan for hazardous, e-waste, municipal, and industrial waste have been proposed and discussed. Moreover, the Soil of Korba analyzed through XRF by collecting from different sampling stations. The soils in the district Korba are having wide variations. About 83% of the district area is covered by yellowish to reddish Alfisols. These soils are derived from weathering of crystalline and metamorphic rocks. About 14% are of the district in north and eastern parts are covers by Ultisols in the form of Laterite. The remaining part of the district is represented by light grey and shallow black Inceptisols, covering small parts of Pondi Upreda blocks. Soil samples from Korba shows similar trend as found other parts of Chhattisgarh. Soils are rich in silica, iron and other metal oxides. In addition; 'Al', 'Mg', 'Ca', 'Na', 'Cu', 'Mn', 'Ba', 'Sr', 'Ce', 'Cr', 'Cs', 'Y' and 'Ti' are also found in little amount in the soil samples collected from Korba. They present in their different oxide forms and calculated concentrations are under control. It's good for the Korba inhabitants that, toxic heavy metals like; 'Hg', 'Pt', 'Se' and 'As' are not present in collected soil samples from Korba.

The noise pollution was measure at 26 monitoring station in Korba. The highest level of sound was found in Power house, Sitamani chauk and Kosabadi chauk, 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 Korba city. The highest Noise pollution level (NPL > 90) is observed at Zone 1, 4, 5, and 7. This consists of CSEB Chowk-Sitamandi Square, Ghantaghar Chowk, Sunaliya Chowk and Kosawadi Chowk. Moreover, it can be seen that for most of the locations the noise readings are within the prescribed limits of 75 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 Korba region was also analyzed through field survey. This shows different flora and fauna 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 measure which are needed to conserve the biodiversity of Korba. Altogether, the assimilative capacity of all the component of environment namely, airs, water, land, noise, biological and socio-economic is 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 Korba industrial area are above the limit. Both PM_{10} and $PM_{2.5}$ carrying capacities are negative. But CMB studies predicts that industrial, road dust and transports emissions are mainly responsible for negative air carrying capacity of this city. Therefore, there are scopes for setting up new industries, provided State Government take appropriate plan to reduce other sources like; road dust and transports emission.

7.2 Delineation of Environmental Management Plans (EMP)

On the basis of baseline data of different environmental components, identification, prediction and evaluation of impact, appropriate strategies needs to be formulated for each environmental components for minimization of adverse impact. The following are the components and appropriate management plans.

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 Korba 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 and Development/NHAI/ Panchayat and Rural Development Department /	As and when needed	10 lakhs	High

		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
	Plantation /green belt development in open areas of Korba industrial area	CSIDC/ Industrial Units/ Sponge Iron Association / Construction companies	12 months	-	Medium
	Introduction of water fountain /water mist /fogging system at major traffic intersection	Urban Administration and Development / CSIDC/ Construction companies / Panchayat and Rural Development Department	12 months	25 lakhs	Medium
Construction activities	Covering of construction site	Urban Administration and Development/ Town and Country Planning Department / CSIDC	As and when needed	-	High

	Transportation of construction materials like sand ,soil, stone chips etc. in covered system	Transport Department and Police Department	As and when needed	-	High
	Restriction on storage of construction material along the road	Urban Administration and Development / Town and Country Planning Department / CSIDC/ Panchayat and Rural 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 Development Department	6 months	-	Medium
	Ensuring promotion and use of cleaner fuel for commercial purposes like local dhabas/ eateries.	District Administration / Oil Companies	6 months	12 lakhs	Medium
	Attempt may be done for generation of electricity by mechanized digester system and separation of other recyclable materials	Municipalities and PHE	48 months	20 Cr.	Low
Industries	Ensuring installation and effective operation of pollution control devices, ensuring emission standards in industries and taking stringent action against violating industries	CECB	12 months	-	High
	Control of fugitive dust emission from industries • Assessment of installed bag filters by third party and up-gradation /	All Industries / CECB	As and when needed	25 lakhs	High

	modification of bag filter as per requirement in sponge iron plant, power plant and ferro alloys plant.				
	• Minimizing the height of raw materials/ coal/ solid wastes drop to the stockpile and ensuring water spray system	All Industries / CECB	6 months	10 lakhs	Medium
	• Use of water spray system/ dust suppression system/ chemical fog system/ rain guns in crusher, coal crusher, ground hopper/ screen, raw materials, fuel, solid wastes storage areas and yards and handling / conveying system	All Industries / CECB	12 months	50 lakhs	Medium
	• Storage of solid wastes from pollution control system like bag filter/ scrubber in pucca and covered area and ensuring environmentally safe disposal of these wastes through transportation in covered vehicles.	All Industries / CECB	6 months	-	Medium
	• Ensuring transportation of iron ore, sponge iron, coal, fly ash, washed coal / reject coal in covered vehicle.	All Industries / CECB	6 months	-	Medium

	• Ensuring short time storage of solid waste within premises and regular disposal in environmentally safe manner.	All Industries / CECB	12 months	-	Medium
	• Ensuring properly maintained pucca internal roads. Ensuring regular cleaning of dust and water sprinkling on internal roads through fixed sprinklers/ water tankers.	All Industries / CECB	As and when needed	10 Cr	High
	• Use of mechanized sweeping machine at integrated steel plants sponge iron plant and power plants.	All Industries / CECB	As and when needed	50 kakhs	Medium
	Increasing the height of all stacks attached to emission sources such as auxiliary process equipment/ bag filter/ scrubber to minimum 30 meter.	All Industries / CECB	6 months	50 lakhs	Medium
	Ensuring use of all treated effluent within plant premises and no discharged outside the premises of any effluent. Ensuring no mixing of any treated / untreated effluent from industries in any nala/ r Hasdeo iver.	All Industries / CECB	3 months	-	High
	Provision of wind breaking wall, installation of rain gun, wheel washing arrangement, treatment of wash water and arrangement of CCTV cameras at coal / washed coal/ reject coal handling and storage areas, entrance and exit gates in all coal washeries.	All Coal Washeries / CECB	12 months	25 lakhs	Medium

	Ensuring proper collection and disposal of municipal solid waste as per MSW Rules, 2016 generated from industries through Local Bodies.	Urban Administration and Development / All industries / CECB	12 months	-	Low
	Prohibition of storage of solid wastes (such as Char, dolochar, ESP dust, fly ash etc.) storage area established and operating in and nearby Korba 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 Hasdeo 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	Agriculture Department	12 months		Medium

	irrigation etc. should be promoted.				
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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