FINAL TECHNICAL REPORT
ON
POLLUTION LOAD CARRYING CAPACITY STUDY IN OPA BHILAI - DURG

Submitted to

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

By

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CERTIFICATE

This is to certify that the content of the final technical report entitled " Pollution Load Carrying Capacity and Source Apportionment Studies in OPA Bhilai - Durg" 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, Bhilai industrial cluster in Chhattisgarh State is identified as the research area where pollution is an important issue. Bhilai industrial cluster refers to the Industrial estate, Light industrial area, Heavy industrial area, Hathkhoj and Engineering Park, Hathkhoj in the Durg district. Durg district is one of the densely populated districts of Chhattisgarh. As per Census 2011, the population of the district is 1721726. Out of which 617184 is rural population and 1104542 is urban population. It is situated on the Howrah-Mumbai main line of the South-Eastern Railway. National Highway No. 6 also passes through the district. The area of District Durg is 2238.36 Sq. Km. Durg district lies between 20’54 and 21’32 North latitude, and 81’10 and 81’36 East Longitude.The Administrative Setup of the District is decentralized into 3 Sub Divisions, 3 Tehsils, 3 Blocks, 9 Urban Local Bodies and 297 Gram Panchayats.The district is bounded by Bemetara district in the north, Rajnandgaon district in the west, Balod district in the south and Bhilai and Dhamtri district in the east. Bhilai industrial cluster is placed in the category of Other Polluted Area. Shivnath River is a tributary of the Mahanadi River. Shivnath is the main river of the district. Shivnath River originates from Mountain at height of 625 meters at Panabaras situated in the southwestern parts of Rajnandgaon and flows towards north east direction. Kharun River flows in eastern parts of the district starting from Petechua in Balod District. This river flows towards the north and joins (meet) Shivnath River at Somnath. This river

determines the boundary of Bhilai and Durg district. The length of this river is about 120 KM. This district has high-quality rich deposits of limestone. The quarrying of limestone is ongoing at Nandini, Semariya, Khundani, Pithaura, Sahgaon, Deurjhaal, Ahiwara, Achcholi, Matragota, Ghotwani and Medesara. Limestone thus derived is utilized mainly by ACC for cement production and BSP for steel production.The climate of Durg district is of tropical type. Summer is a little bit hotter. Rise of temperature begins from the month of March to May. May is the hottest amongst others. Durg district's annual average rainfall is 1052 MM. During the year, most rainfall occurs during the monsoon months June to September. July is the month of the highest rainfall.

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; 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. Receptor models represent the statistical evaluation of ambient measurements at different times and locations.

Study Area:

A Central Indian state named Chhattishgarh is heavily forested state, with co-ordinates 21.25º N to 81.60º E. Our study areas of Bhilai of Chhatishgarh.

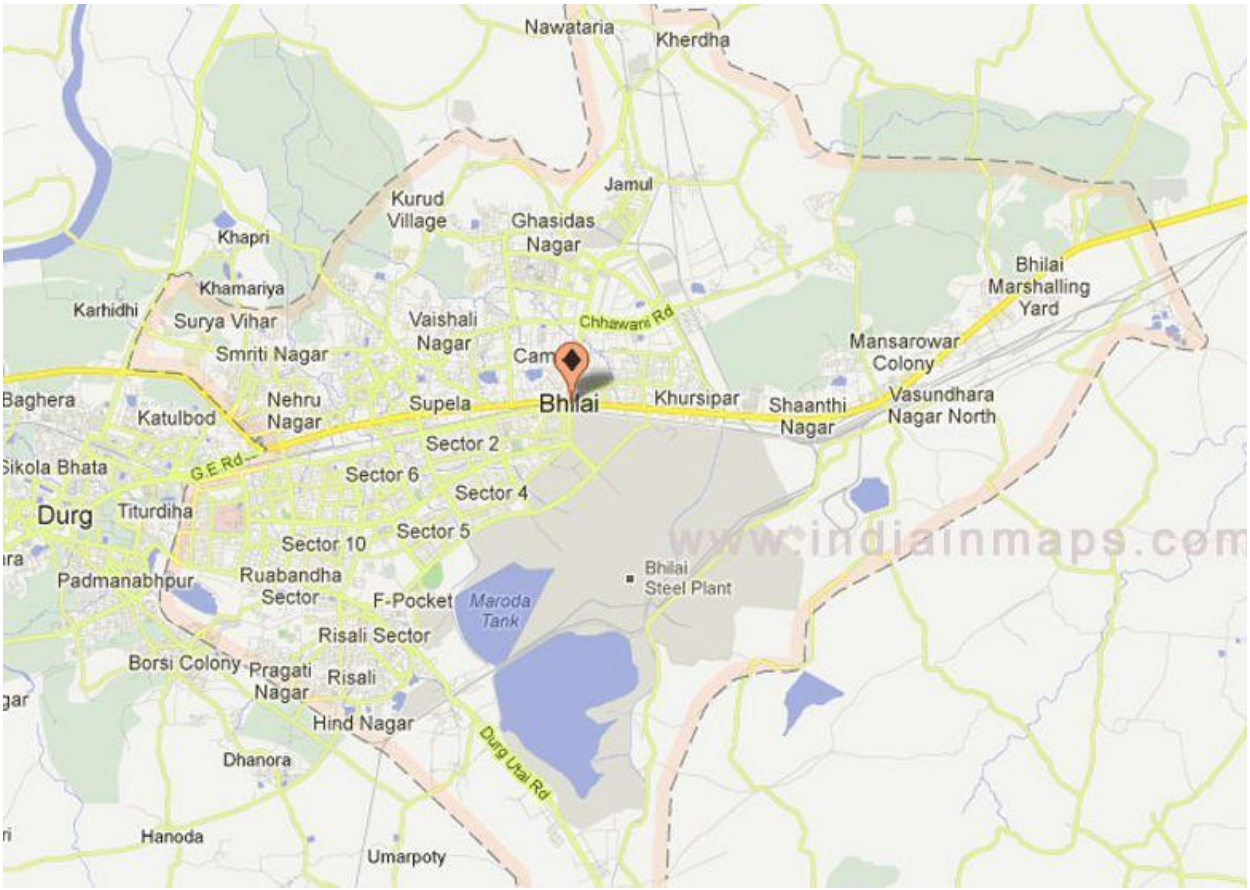


Figure 1.1: Bhilai area of study (*Source: www.Google.com).

1.2 Objectives

The aim of the project is to conduct the carrying capacity study with respect to air, water, noise, land pollution for OPA Bhilai for a radius of 15 km from the center of the study area..

1.3 Scope of Work

The major component of the study will be the assessment 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 modelling.
[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 16 air quality monitoring stations in Bhilai.
- 16 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 Bhilai-Durg are presented in Table 1.1 and their geographic location in Topo map is shown in Figure 1.2.

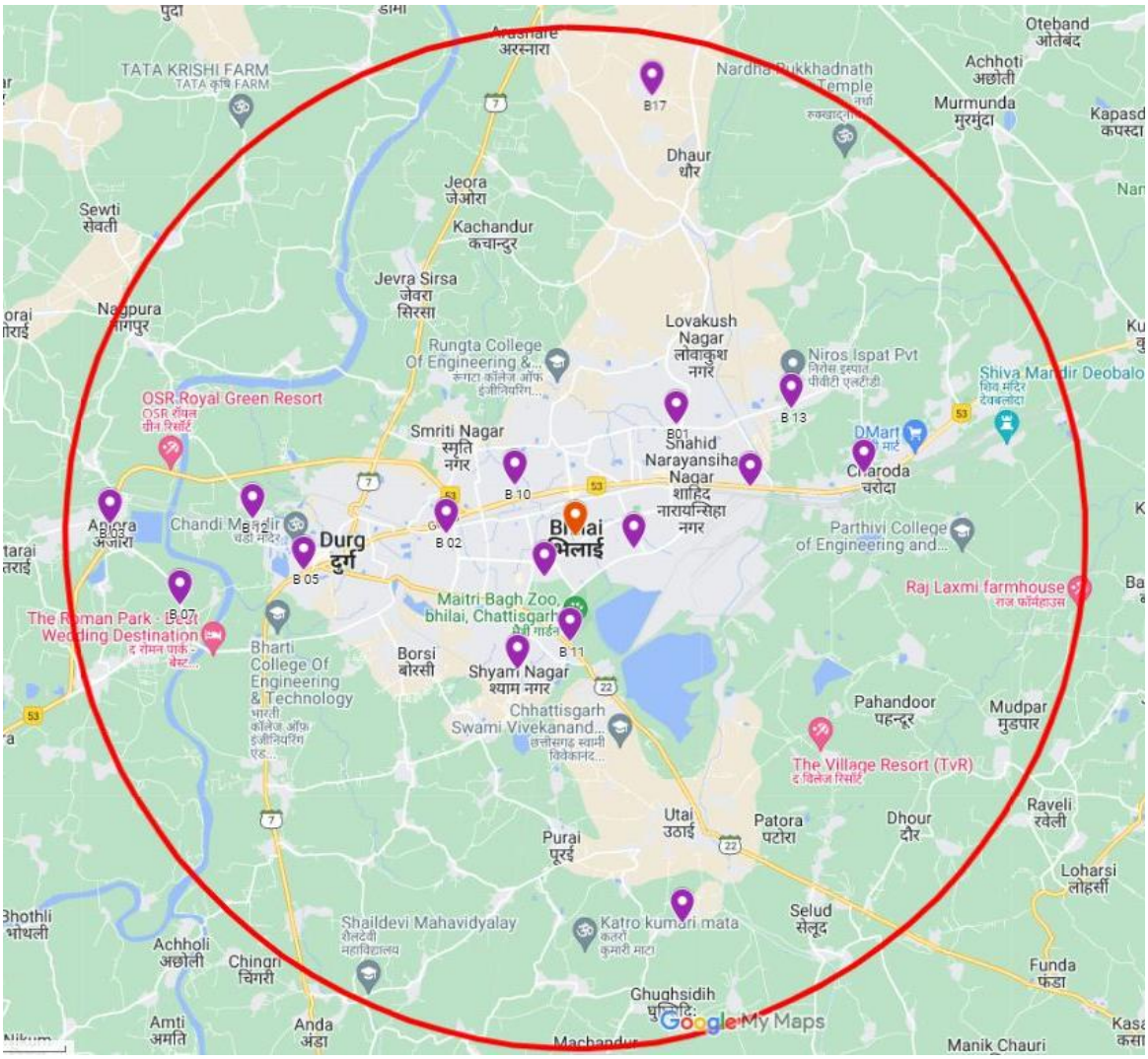


Figure 1.2: Geographical representation of different air sampling stations in Bhilai.

Table 1.1: Air Quality Monitoring Stations (16 different places) and type of stations in Bhilai are presented in tabular form.

Station Name	Code	Type
CSIDC	B01	Commercial
R O Office	B02	Residential
CSIDC (Borai)	B03	Commercial
Bokaro Boys Hostel	B04	Commercial
Kotwali Police Station	B05	Residential
Nagar nigam	B06	Commercial
Jayshree Grain Processing Pvt Ltd	B07	Agriculture
Choroda Nagar Nigam	B08	Residential
Risali Nagar Nigam	B09	Residential
Kosanagar High School	B10	Commercial
Maroda Govt. High School	B11	Residential
Bhagera High school	B12	Agriculture
CSIDC Market complex engineering park	B13	Commercial
Housing Board	B14	Commercial
Khapali govt. High School	B15	Agriculture
Nursery	B16	Agriculture

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.

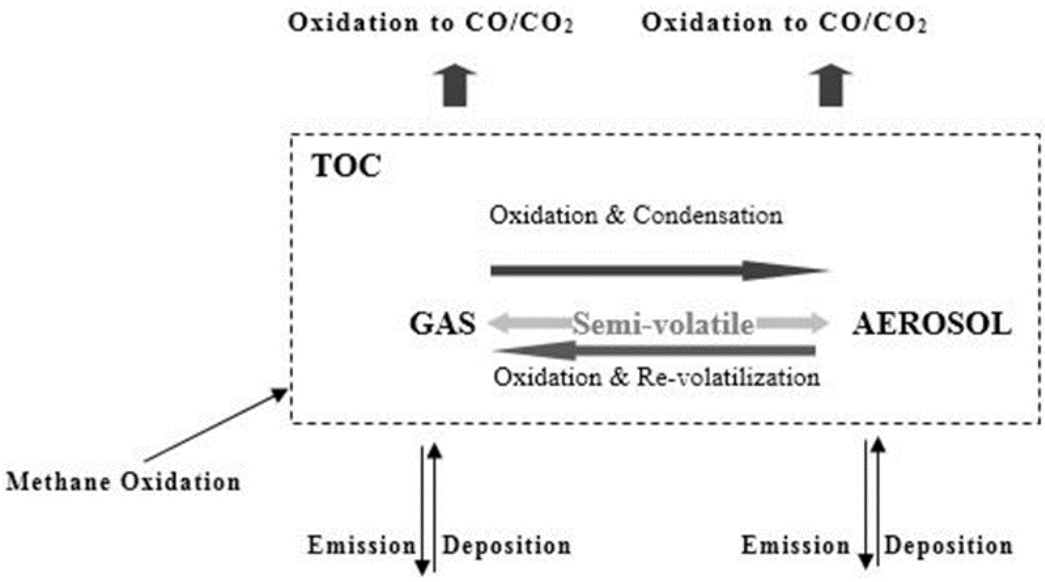


Figure 1.3: Framework for conversion of total organic carbon (TOC) into carbon monoxide (CO) and carbon dioxide (CO_2).

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

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

1.4.5.2 Volatile Organic Carbons (VOCs)

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

The atmosphere contains a variety of organic carbons, including volatile organic compounds (VOCs) such as hydrocarbons, alcohols, carbonyl, aromatics, ethers, etc. as well as low-volatile compounds and aerosols. Many VOCs are reactive and affect the atmospheric oxidative capacity, while

organic aerosols are important for air quality, human respiratory health and cloud formation. Volatile organic carbons (VOCs) are mainly four compounds: benzene, ethyl-benzene, xylene and toluene. Gaseous pollutants include ozone (O_3), nitrogen oxides (NOx), carbon monoxide (CO), sulfer dioxide (SO_2), volatile organic compounds and various toxic air pollutants. Ozone generates in ambient air as a result of a chemical reaction between nitrogen oxides and volatile organic compounds in the presence of sunlight (hλ, where 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 μg/m^3. The district Bhilai 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 2.1.7).

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 compound is benzo(a)pyrene [B(a)P] which vary widely in different industrial activities, ranging from 0.1 to 48000 ng/m^3. Levels in water may range from 0 to 13 µg/L B(a)P. Aerosols associated with transportation, coal combustion and wood burning have higher benzo(a) pyrene concentrations. In contrast, oil combustion is not a major source of PAHs. PAHs are adsorbed onto many types of solid aerosols, including black carbon and road dust, and when they reach the lungs, PAHs can be activated; showing cytotoxic effects and generating DNA adducts. Pollution of air by PAHs is mainly due to the incomplete combustion of wood or fuel used for residential heating and industrial or motor vehicle exhaust.

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

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

1.4.5.4 Presence of Heavy Metals in Particulate Matters

Sources of heavy metals in the ambient air may include industrial production (chemical industry, oil refineries, petrochemical plants, pesticide production, etc.), mining, untreated sewage sludge, and

heavy traffic as well as combustion by-products from coal-burning power stations. So chance of emission of heavy metals in ambient air or biosphere is also high. Thus particulate matters with different size are easily coming in open air and local peoples are subjected to it. Control of heavy metals in the mining sector is very difficult but in industrial or ore processing center it is mandatory. Industries are seriously installing different filters and checking their efficiency in regular basis.

1.4.6 Ambient Air Quality Sampling Schedule

Sampling of ambient PM_{10}, $PM_{2.5}$, SO_2, NO_2, Ammonia and Ozone was carried out with various samplers as per the guidelines of Central Pollution Control Board. PTFE and quartz filters were used. A 6-digit microbalance was used for initial and final gravimetric estimation of the filters. We have collected sample from 16 site location i.e. B01 to B16. 30 samples each were collected for SO_2, NO_2, NH_3 and O_3 and 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 16 stations in pre/post monsoon season in 2021 and 2022. Air sampling for post monsoon season was collected in October and November months of 2021 and 2022. Pre monsoon sample collected from 15th may to June.

1.4.6.2 Ambient Air Quality: Winter

Ambient air quality was monitored at 16 stations in winter 2021and 2022. Air sampling for winter season was started from December 2021 to February 2022 for another year sample collected from December 2022 to February 2023. (Winter stayed till last February so we took data for two extra month that is January and February).

1.4.6.3 Ambient Air Quality: Summer

Ambient air quality was monitored at 16 stations in summer 2022. Air sampling for summer season was started from 1st Mar 2022 (at least 30 days monitoring with 24 hours frequency, three sites at a time), continued till second week of May and completed before onset of pre monsoon.

CHAPTER-II

AIR ENVIRONMENT

2.1 Introduction

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

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

2.2 Materials and Methods

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

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

2.2.1.1 Principle

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

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

2.2.1.2 Sampling

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

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

Figure 2.1: Respiratory dust sampler.

2.2.1.3 Wrking 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.

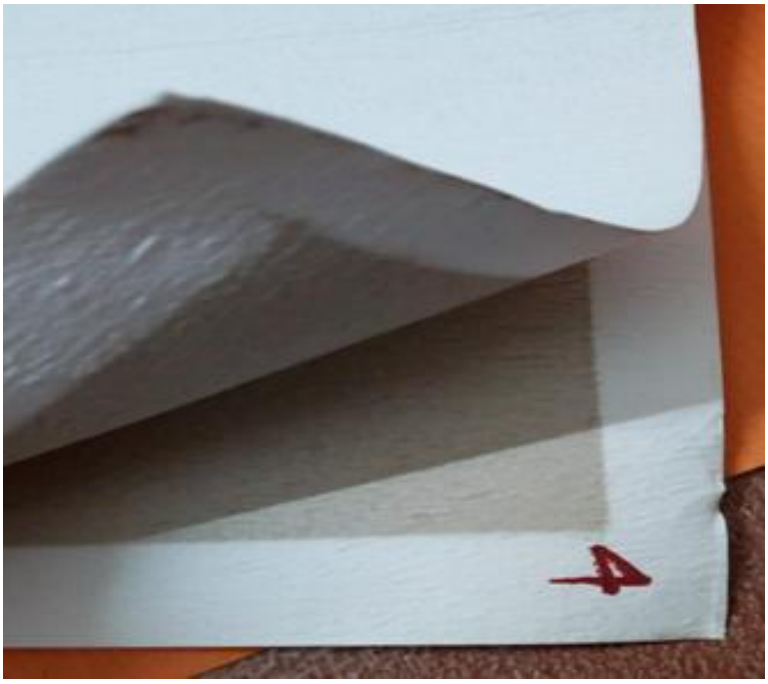


Figure 2.2: Photograph of filter paper of size 25.4 cm × 20.3 cm.

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 gm

W_i = Initial weight of filter in gm

10^6 = Conversion of g to µg

V = Volume of air sampled, m^3

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

Method: Gravimetric Method

2.2.2.1 Principle

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

2.2.2.2 Sampling

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

Filter Media:

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

Figure 2.3: Fine particulate sampler.

2.2.2.3 Working Method

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

2.2.2.4 Analysis

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

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 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 tetrachloromercurate (TCM) of potassium sulphur dioxide absorbed in it to from a dichlorosulphitomercurate complex.

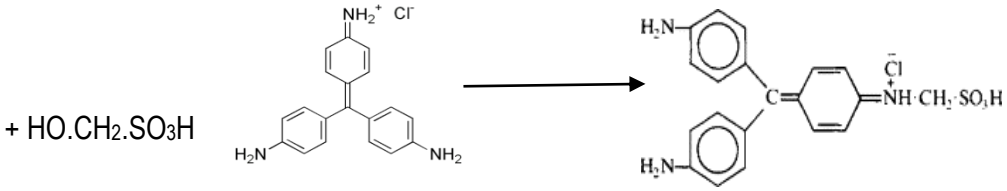
$$HgCl_4^{--} + SO_2 + H_2O \rightarrow HgCl_2.SO_3^{--} + 2Cl^- + 2H^+$$

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

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

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

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



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

2.2.3.2 Calibration

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

2.2.3.3 Preparation of Reagents

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

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

   Working Iodine Solution (0.01N)

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

2) **Starch Indicator**

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

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

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

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

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

5) **Stock Sulphite Solution:**

0.30 gm Sodium metabisulphite is disintegrated in 500 ml distilled water

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

a. Mercuric chloride 10.86 gm

b. EDTA 0.066 gm

c. Potassium chloride 6.0 gm

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

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

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

8) **Formaldehyde (0.2%)**

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

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

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

10) **Pararosaniline Working Solution**

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

2.2.3.4 Working Method

I) Standardization of Sodium thiosulphate

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

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

Where,

W = Weight of Potassium Iodate, gm = 1.97 gm

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

35.37 = Equivalent wt. of Potassium iodate.

N = Normality of Sodium thiosulphate.

II) Working Sodium Thiosulphate Solution (0.01N)

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

Where,

N_1 = Normality stock Sodium thiosulphate Solution = 0.1249N

V_1 = Volume of stock Sodium thiosulphate solution

N_2 = Normality of working Sodium thiosulphate (0.01N)

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

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

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

Table 2.1: Determination of sulphite strength.

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

Blank iodine flask (V_A) = 40.7 ml

Sample iodine flask (V_B) =12.4 ml

III) Strength of Stock Sulphite Solution

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

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 concentration is given in Table 2.2 and 2.3 respectively. Calibration curve and pictorial view of sample prepared for SO_2 is presented in Figure 2.4 and 2.5 respectively.

Table 2.2: Data for SO_2 calibration curve.

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

Table 2.3: Absorbance measurement at 560 nm.

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

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

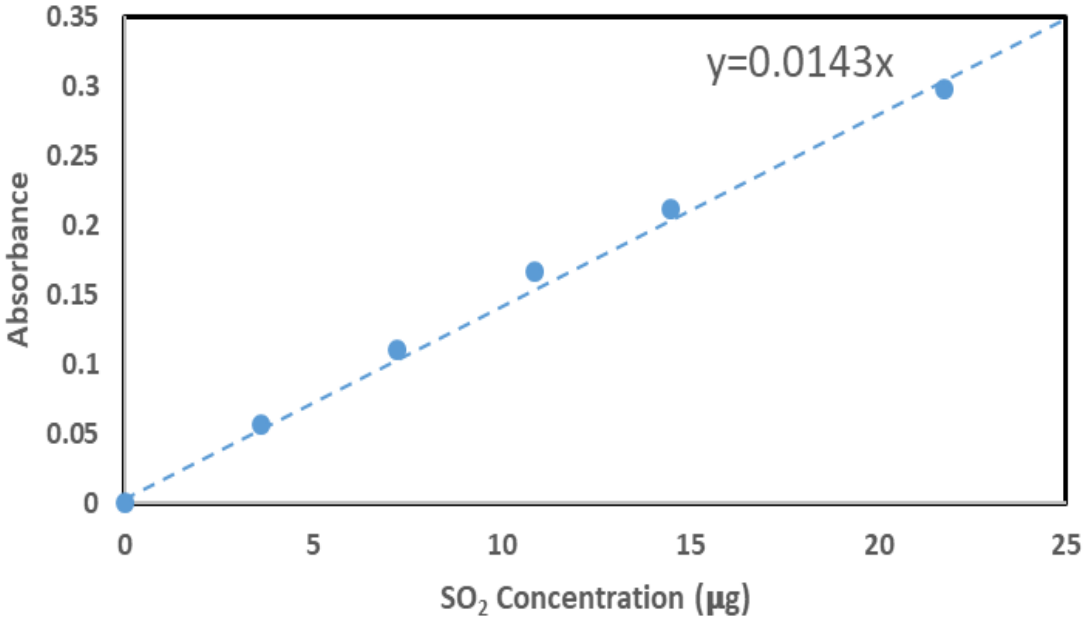


Figure 2.4: Calibration curve of SO_2.

Figure 2.5: Samples of SO_2.

VI) Sampling

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

10.86 gm of Mercuric chloride, 0.066 gm of EDTA

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

VII) Procedure

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

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

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

Figure 2.6: Photograph of Impinger used for gas samples collection

VIII) Analysis

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

Preparation of Solutions:

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

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

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

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

4. **Pararosaniline Working Solution**

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

IX) Working Method

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

X) Calculation

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

Where,

C_{SO_2} = Amount of Sulphur dioxide in air, $\mu g/m^3$

A_s = A for sample

A_b = A for reagent blank

CF = Calibration factor = 69.93

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

V_s = Sampling volume= 30 ml

V_t = Sample taken for analysis = 10 ml

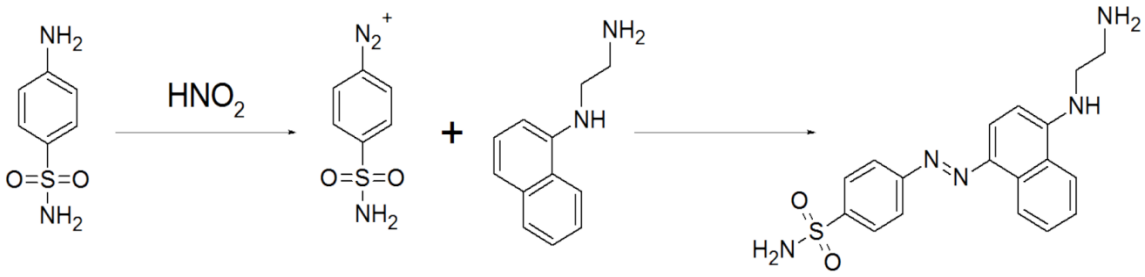
2.2.4 Determination of Nitrogen Dioxide Concentration in Air

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

2.2.4.1 Principle

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

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



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

2.2.4.2 Calibration

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

2.2.4.3 Preparation of Reagents

The following reagents are used for analysis.

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

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

B. Working Sodium Nitrite Standard Solution

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

C. Hydrogen Peroxide Solution

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

D. Sulphanilamide Solution

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

E. NEDA Solution

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

2.2.4.4 Calibration Curve

The preparation steps and absorbance at various concentrations is given in Table 2.4 and 2.5, respectively. Calibration curve and pictorial view of sample prepared for NO_2 is presented in Figure 2.7 and 2.8 respectively.

Table 2.4: 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, Calibration Factor = 0.019^{-1} = 52.63

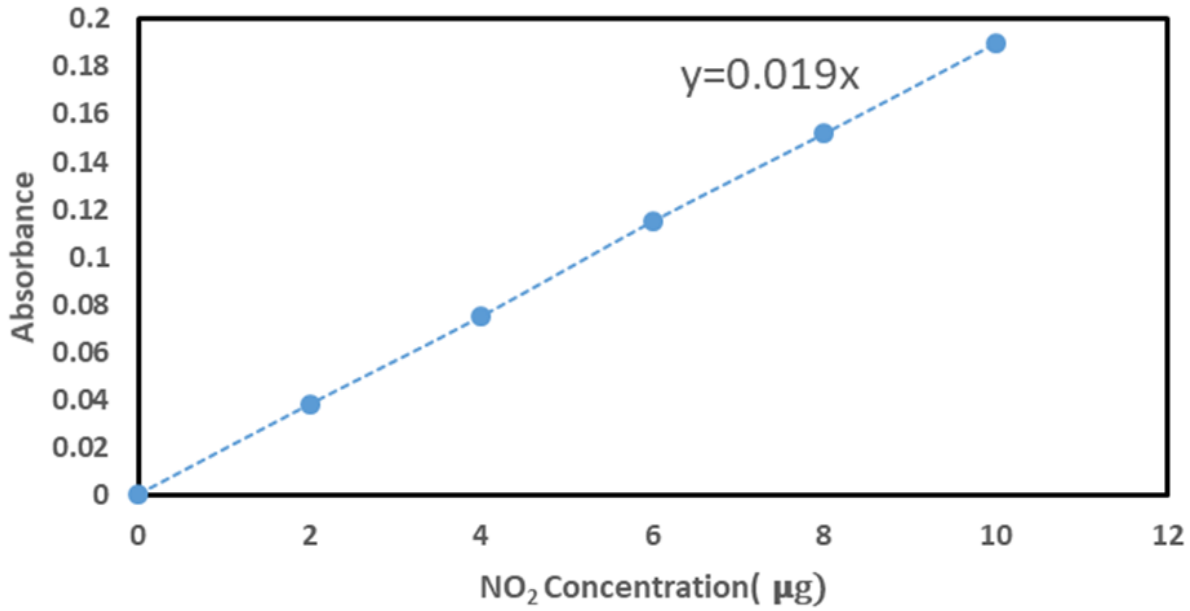


Figure 2.7: Calibration curve of NO_2.

Figure 2.8: Sample of NO_2 for calibration.

2.2.4.5 Sampling

Absorbing solution required for sampling of Nitrogen Dioxide is

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

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

2.2.4.6 Procedure

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

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

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

2.2.4.7 Analysis

The following reagents are used for analysis.

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

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

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

2.2.4.8 Working Method

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

2.2.4.9 Calculation

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

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 Concentration in Air (Indophenols Method)

2.2.5.1 Principle

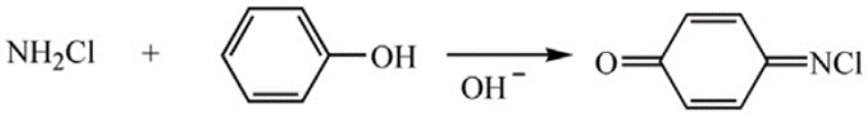
A. When air passes through dilute solution of H_2SO_4, the NH_3 in the air is converted to ammonium sulphate

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

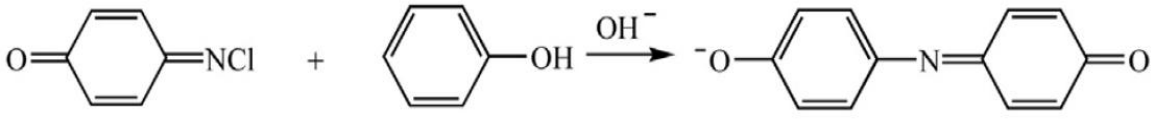
B. The ammonium ion reacts with hypochlorite ion to produce monochloroamine

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

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



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



2.2.5.2 Calibration

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

2.2.5.3 Preparation of Reagents

A. Sodium nitroprusside

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

B. 6.75 M Sodium hydroxide

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

C. Sodium hypochlorite solution (0.1N)

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

D. Buffer Solution

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

E. Working Phenol Solution

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

F. Working hypochlorite solution

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

G. Absorbing Solution [0.1N Sulphuric Acid]

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

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

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

I. Working Ammonia (10.0µg NH_3/ml)

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

2.2.5.4 Calibration Curve

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

Table 2.6: 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

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

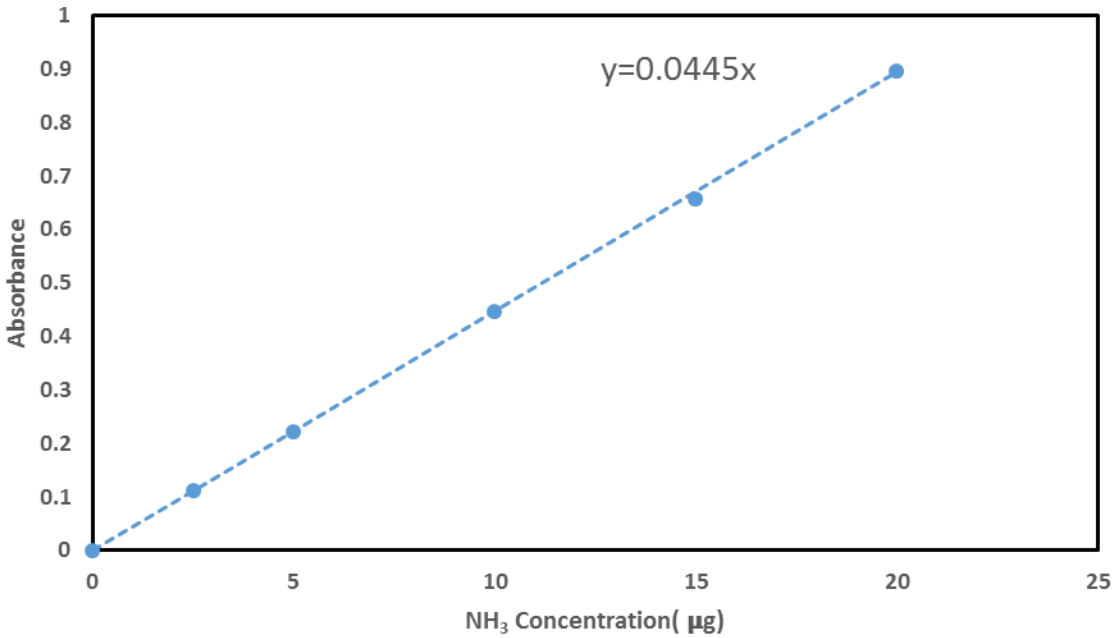


Figure 2.9: Calibration curve of NH_3.

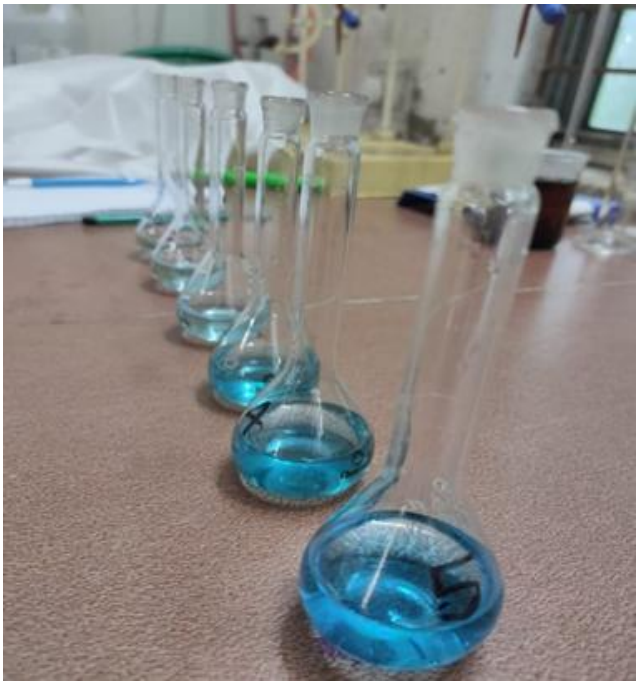


Figure 2.10: Sample of NH_3 for calibration.

2.2.5.5 Sampling

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

2.1.5.6 Procedure

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

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

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

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 Concentration in Air

Method: Chemical method

2.1.6.1 Principle

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

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

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

2.2.6.2 Calibration

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

2.2.6.3 Preparation of Reagents

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

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

B. Standard Iodine Solution (0.002 N I_2)

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

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

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

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

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

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

2.2.6.4 Calibration Curve

The preparation steps and absorbance at various concentration 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: Data for O_3 calibration curve.

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

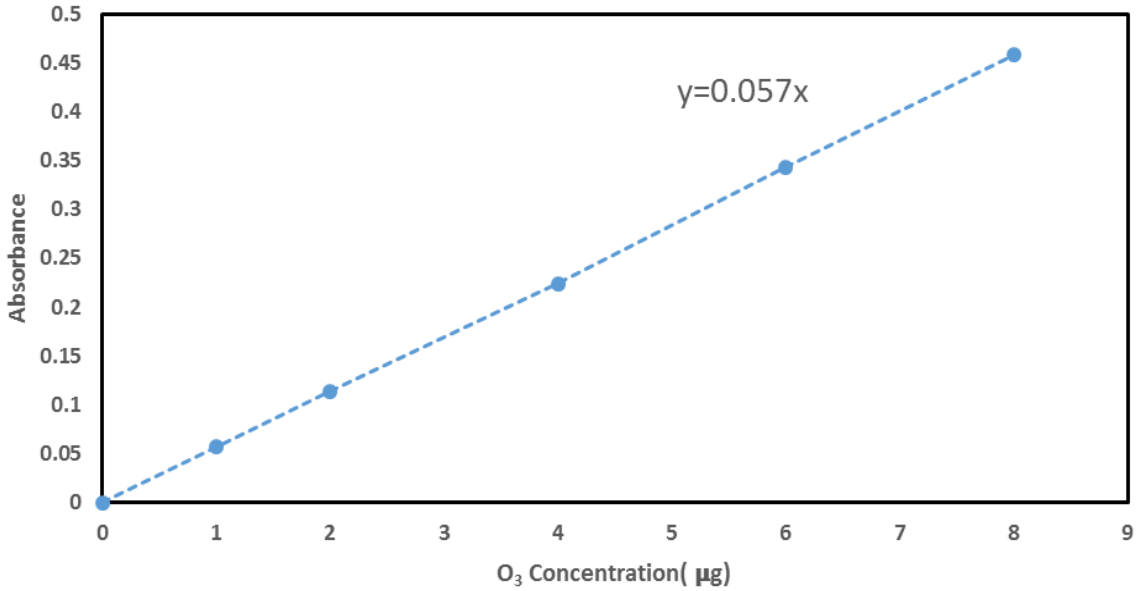


Figure 2.11: Calibration curve of O_3

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.

2.2.6.8 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 analyzed by capillary gas chromatography (GC). Any suitable gas chromatography with flame ionization detector (FID) with fused silica capillary column (Capillary 624 column) used for analysis, while quantification is performed using the internal/external standard.

2.2.7.2 Sampling

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

Figure 2.12: VOC sampler.

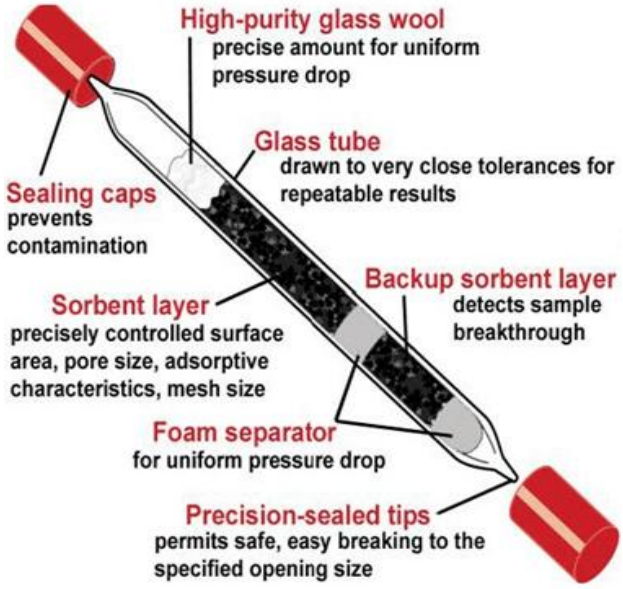


Figure 2.13: Adsorption tube used in VOC sampler.

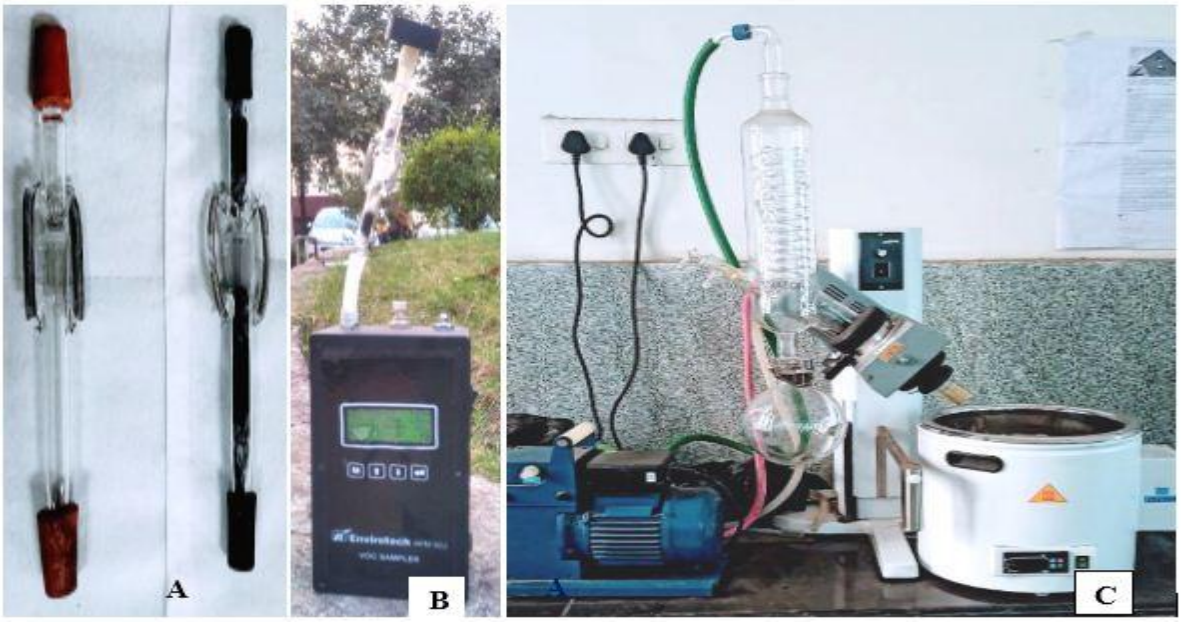


Figure 2.14: [A] Charcoal tube or VOCs sampling tube. Both empty [L.H.S.] and activated charcoal filled [R.H.S.] tubes are shown side by side; [B] VOC sampler and [C] Rotary vacuum evaporator to concentrate the VOC extract in CS_2 solution.

2.2.7.3 Calibration of GC

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

2.1.7.4 Sample Analysis

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

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

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

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

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

2.2.8.1 Working Method

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

2.2.8.2 Calibration of GC

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

2.2.8.3 Sample Analysis

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

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

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

2.2.9.2 Calibration of AAS and ICP-MS

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

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

2.2.9.3 Calculation

Sample air volume was calculated by using the following formula:

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

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

Then metal concentrations were calculated as:

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

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

2.2.10 Measurement of Poly-Atomic Ions in Ambient Air Sample (Water Extraction and Ion Chromatography Method)

2.2.10.1 Working Method

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

2.2.10.2 Calibration of IC

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

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

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

The separation between organic carbons (OC) and elemental carbons (EC) as well as the correction for the pyrolyzed carbons (Pyrol-C) is carried out by both the Thermal-Optical Reflectance (TOR) and Thermal-Optical Transmittance (TOT) methods. A 0.6 cm^2 sized PM_{10} quartz-filter paper sample is placed inside the quartz oven. The oven is then purged with pure helium gas (He) to remove air and a simultaneous stepped temperature increases to 580 ºC to desorb the organic and carbonate carbons. After initial cooling down, an oxidizing carrier gas (He with 10% O_2) is passed at 500 ºC. In this stage,

the EC (elemental carbon) and Pyrol-C (pyrolyzed organic carbon) are oxidized. All types of carbons are then oxidized to CO_2 in a manganese dioxide (MnO_2) oxidizing oven immediately downstream from the desorption oven. Finally, the produced CO_2 is then reduced to CH_4 in a methanator oven and is analyzed by a flame ionization detector (FID).

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

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

2.2.12 Principles of Operation of Stack Monitor

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

The basic properties of various gaseous pollutants are used to absorb them in suitable chemical reagents. A filtered sample of flue gas is bubbled through an impinger train at a metered flow rate. The

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

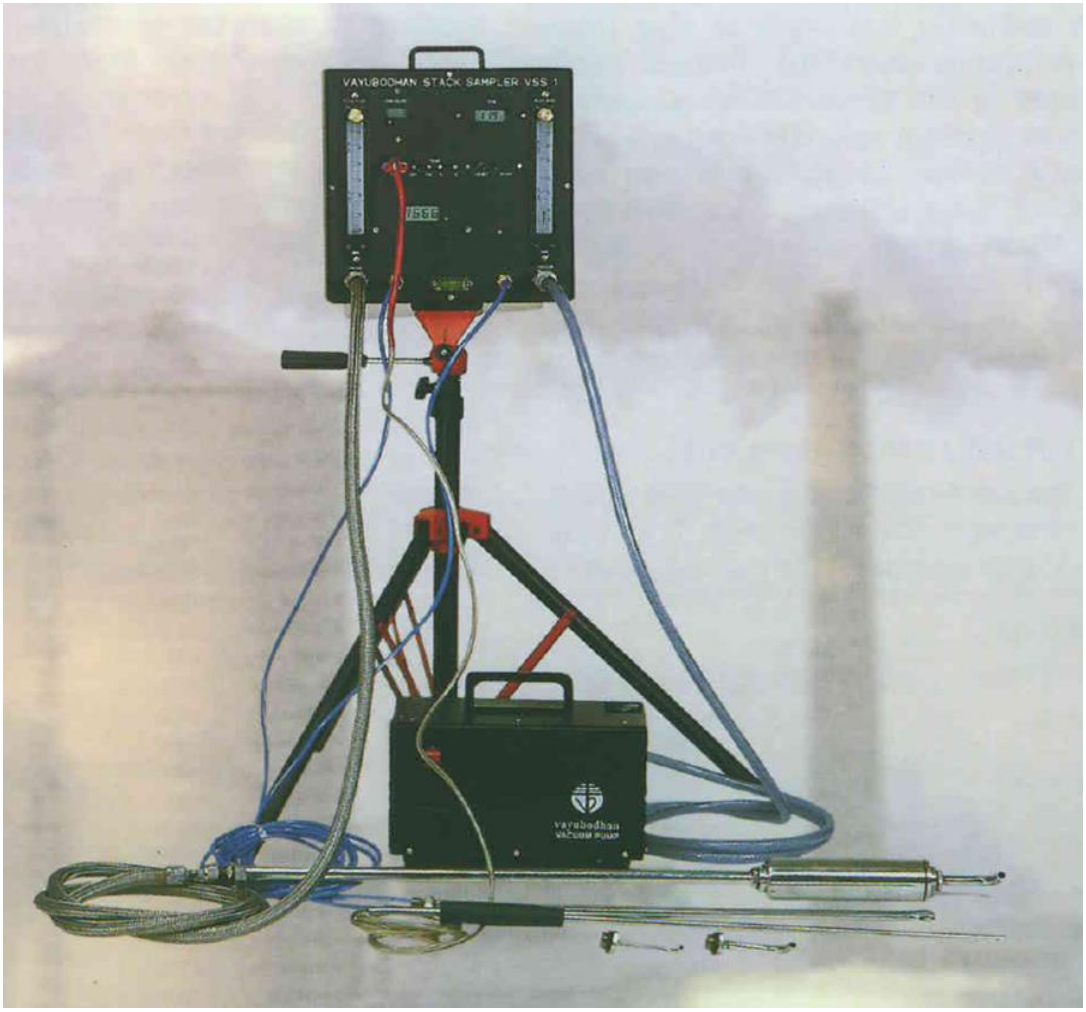


Figure 2.18: Vayubodhan stack sampler.

The stack gas velocity can be determined by using the Equation (2.19). It gives the relation that can be used to determine the stack gas velocity (V) in meter per second. '**S**' type 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.

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

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.

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

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:

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

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

Taking 'h' in millimeters.

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

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

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 $= 0.1900\ \sqrt{(\mathrm{h\ x\ T_s})}$

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

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

$$\mathrm{Qs} = \mathrm{V\ x\ A_n\ x\ 60\ x\ 1000} \tag{2.22}$$

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

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

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

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

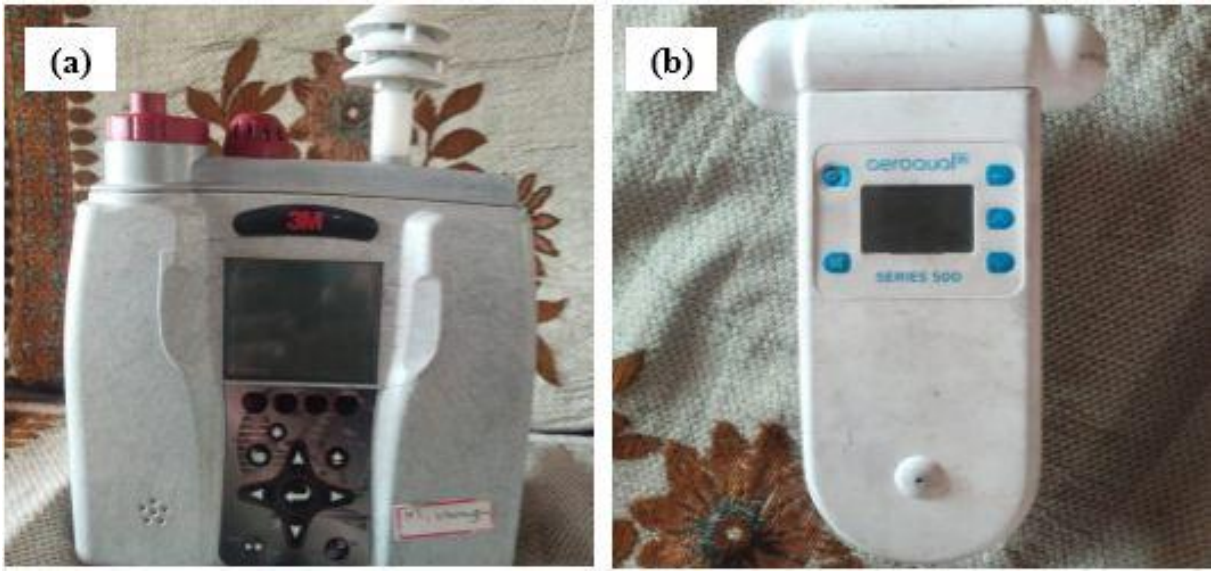


Figure 2.19: Real time air monitoring devices (a) 3M Instrument (b) Aeroqual series 500.

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 ($C_{35}H_{72}$)		
Hopans: 22,29,30 – Trisnorneohopane, 17α(H), 21β(H)-29 Norhopane, 17α(H), 21β(H) norhopane		
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 ($C_6H_{10}O_5$)		
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 16 sampling sites in Bhilai-Durg. Details of site selection have been given in study area section.
- Sampling (for 24 hrs.) for at least 20 days in each season.
- Calculation of PM emission load for different sampling stations based on primary surveys.
- Analysis of collected samples in PM sampling filter papers (PTFE / Quartz) were undertaken in the following methods described in CPCB methods, 2011.

2.2.16 Air Quality Modeling

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

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

2.2.16.1 Dispersion Modeling

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

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

2.2.16.2 Gaussian Plume Dispersion Model

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

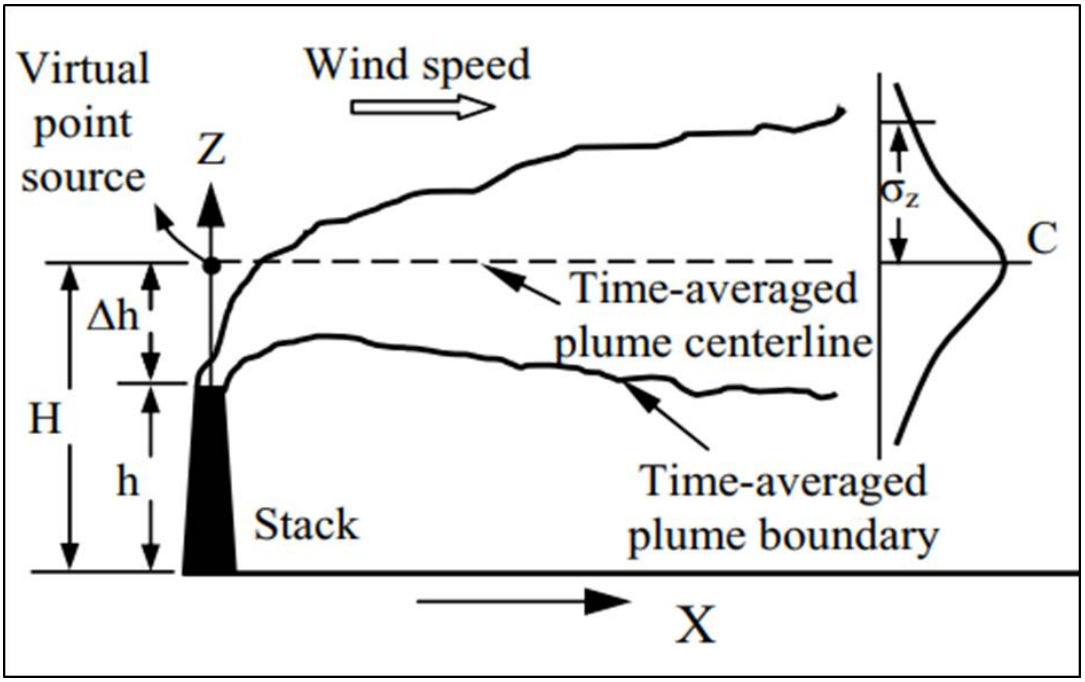


Figure 2.20: Schematic diagram of plume dispersion.

2.2.16.3 Derivation of Gaussian Plume Dispersion Model

The important crucial assumptions include the following:

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

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

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

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 Modeling

Different software for air dispersion modeling:

A) Model Selection

ISC 3

AERMOD – most recent version for Dispersion modeling

SEC3 – Specify reasons for use

B) Dispersion Coefficient

Urban

Rural

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

C) Coordinate System

UTM Coordinates

Local Coordinates

Other

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

2.2.16.5 AERMOD - Air Dispersion Model

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

The software consists of 3 components extensively:

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

2.2.16.6 Procedure for Dispersion Modeling

A. AERMET View: Pre-processing of meteorological data

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

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

B. AERMAP: Terrain pre-processing

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

C. Compiling AERMOD

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

a. Tile maps from the Lakes satellite have been used to import the map of the study region.
b. The base map imported from the Lakes satellite covers a specific region in the present modelling.
c. Control paths are chosen for non-default regulatory alternatives without gas deposition, exponential decay, or growing downwash. Pollutant has been chosen for the modelling with time weighted average utilized to calculate the concentration of pollutant.

d. Point source is located in the given area by using function in the left bar of AERMOD interface.
e. Also, modelling is only carried out using consistent polar grid receptors covering the full map region. The AERMAP receptor output file is used to import the receptor elevations.
f. Finally, AERMET results are imported into the meteorological system. Options for default wind speed are selected.
g. Following the input of all the data, AERMOD is constructed.

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

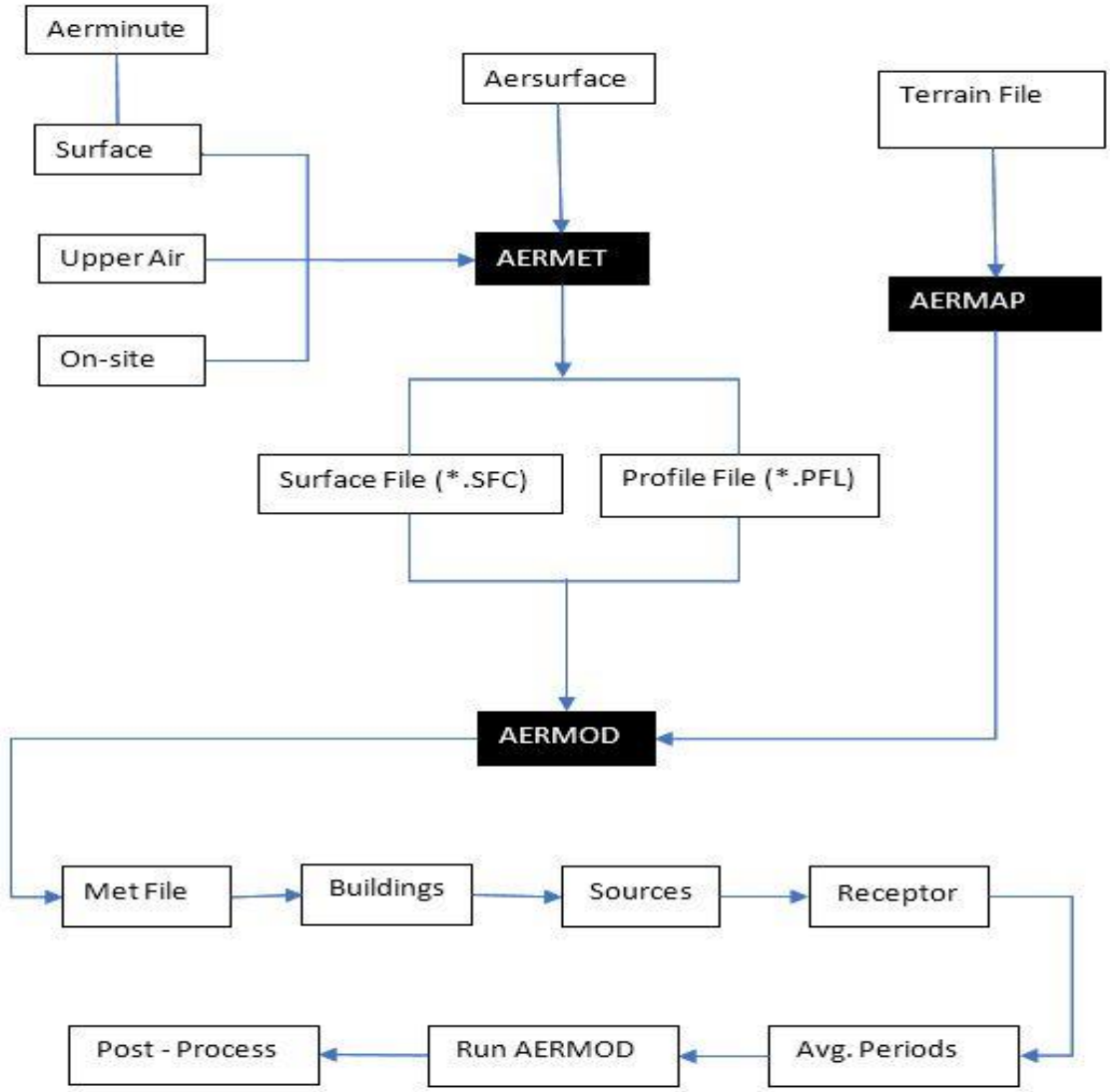


Figure 2.21: Flowchart for input parameters for AERMOD.

2.3. Results and Discussion

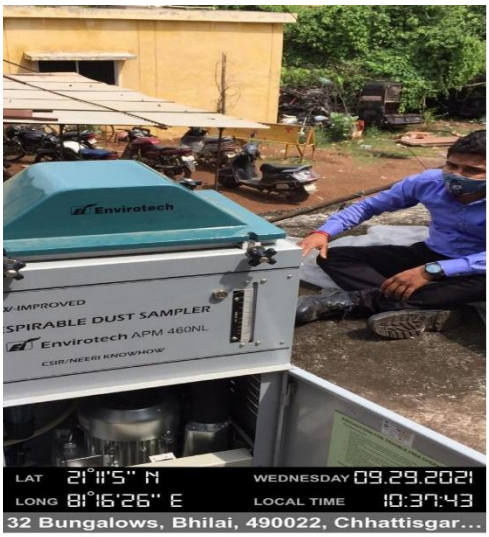
2.3.1 Assembling of Air Quality Monitoring Stations for Measurement of Air Pollution

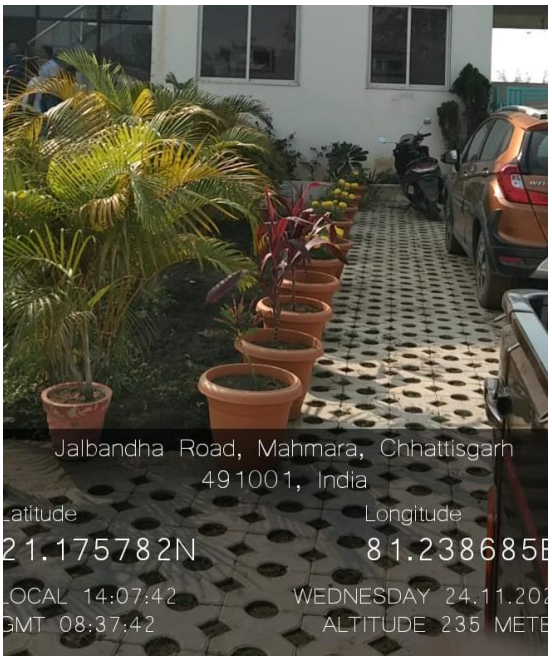
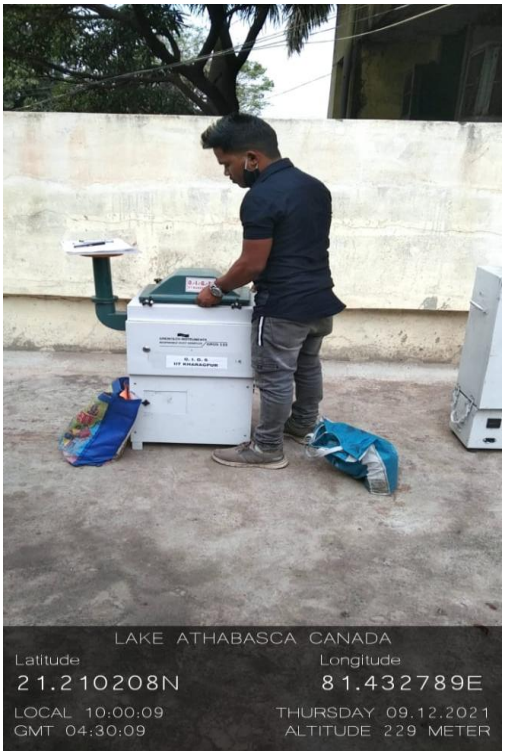
Following 16 sampling stations has been identified in Bhilai with diffrent cluster for air sampling

Table 2.11: Air sampling stations at Bhilai.

Location ID	Latitude (°N) Longitude (°E)	Location Name	Zone	Station View
B 01	21°13'23"N, 81°22'46"E	CSIDC (Power House)	Commercial	
B 02	21°11'41"N, 81°18'52"E	R O Office	Residential	

B 03	21°11'49"N 81°13'8"E	CSIDC (Borai)	commercial	
B 04	21°11'26"N, 81°22'3"E	Bokaro Boys Hostel	Commercial	

B 05	21°11'5"N, 81°16'26"E	Khatauli Police Station	Residential	
B 06	21.20670484, 81.40054573	Nagar Nigam	Commercial	

B 07	21.175782, 81.238685	Jayshree Grain Processing Pvt. Ltd.	Agricultural	
B08	21.210208, 81.432789	Choroda Nagar Nigam	Residential	

B09	21.158521, 81.334413	Risali Nagar Nigam	Residential	
B10	21.20747365, 81.3339592	Kosanagar High School	Commercial	

B11	21.16574566, 81.34937923	Maroda Govt. High School	Residential	
B12	21.19842544, 81.2595086	Bhagera High school	Agricultural	

B13	21.2274942, 81.41223157	CSIDC Market Complex Engineering Park	Commercial	
B14	21.18326897, 81.34210597	Housing Board	Commercial	

B15	21.09159699, 81.38134882	Khapali Govt. High School	Agricultural	
B16	21.31003656, 81.37278087	Nursery	Agricultural	

2.3.1.1 Ambient Air Monitoring Station Details

Table 2.12: Observed sources near sampling site.

Location ID	Location Name	Latitude (°N) Longitude (°E).	Station	Observed Sources
B01	CSIDC	21.223056 81.399444	Commercial	Traffic area, Industries (Vishv Chemicals, Simplex Engineering Foundary Works), Hospital, Tea shops
B02	R O Office	21.194722 81.314444	Residential	Offices, Market, Hospital, Talab, Electronic repair shop, Petrol pump, Bus stand, Tea stalls, Pathological laboratories
B03	CSIDC (Borai)	21.196944 81.21889	Commercial	Talab, Medical shop, Railway station, Market, Petrol pump, Dairy
B04	Bokaro Boys Hostel	21.190556 81.3675	Commercial	Manufacturing units, Talab, Shopping mall, Motor bike repair centre, Petrol pump, Food stalls
B05	Kotwali Police Station	21.184722 81.273889	Residential	Offices, Tyre shop, Tea stalls, Hospital, Electronic shop, Furniture shop, Hotel
B06	Nagar Nigam	21.20670484 81.40054573	Commercial	SAIL Bhilai, Tyre shop, Hospital, Hardware, Furniture store, Food stalls
B07	Jayshree Grain Processing Pvt. Ltd.	21.175782 81.238685	Agricultural	Petrol pump, Poultary farm, Auto workshop, Food industry, Restaurants, Nursery
B08	Choroda Nagar Nigam	21.210208 81.432789	Residential	Dairy shop, Tiffin stall, Pathological laboratories, Petrol pump, Talab
B09	Risali Nagar Nigam	21.158521	Residential	Auto parts shops, Restaurant, Clinic, Food stall, Atta chakki, Market

		81.334413		
B10	Kosanagar High School	21.20747365 81.3339592	Commercial	School, Clinics, Dairy farm, Electronic repair shop, Petrol pump, Hotel
B11	Maroda Govt. High School	21.16574566 81.34937923	Residential	School, Water Treatment Plant, Restaurant
B12	Bhagera High School	21.19842544 81.2595086	Agricultural	School, Medical shop, Rice mill, Market, Restaurant
B13	CSIDC Market Complex Engineering Park	21.2274942 81.41223157	Commercial	Metal tech. company, Electronic work shop, Chemical store, Petrol pump, Power Plant
B14	Housing Board	21.18326897 81.34210597	Commercial	Steel plant, Restaurant, Farm house, Ash pond, Petrol pump, Traffic
B15	Khapali govt. High School	21.09159699 81.38134882	Agricultural	School, Restaurant, Pond, Poeltry farm, Village area
B16	Nursery	21.31003656 81.37278087	Agricultural	Nursey, Computer repair shop, Petrol pump, Hotel, Auto parts shop, Talab

2.3.1.2 Graphical Representation of Ambient Air Monitoring Data

2.3.1.2.1 PM_{10} Variation in Different Season

Air sample collected from 16 stations and the highest PM level were found in B03 and B08 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 2.22 to 2.24.

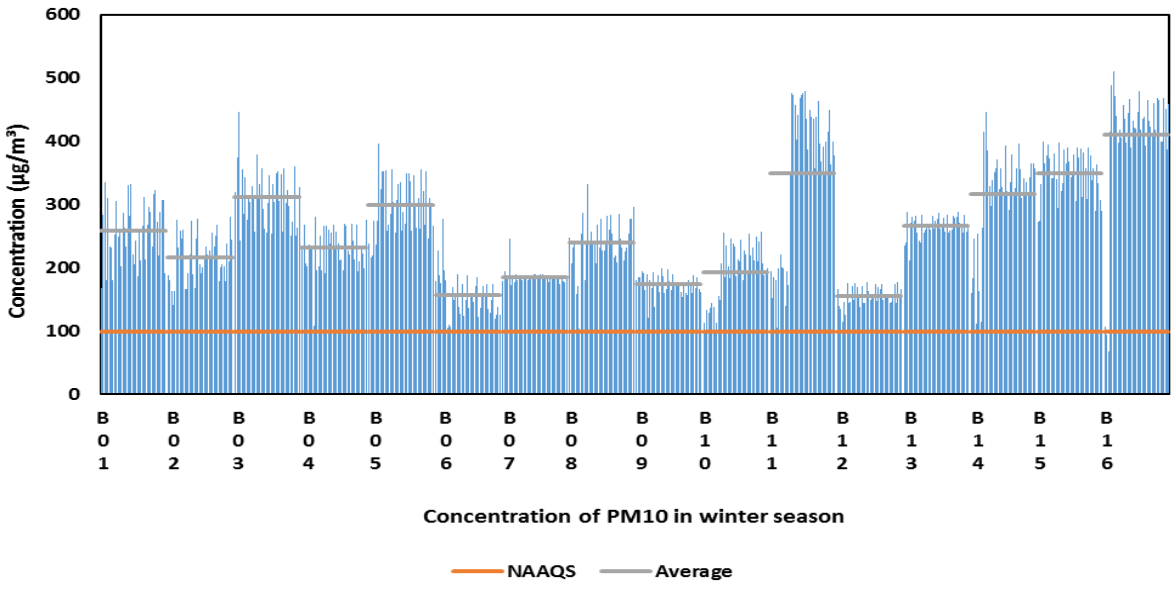


Figure 2.22: Concentration of PM_{10} in winter season.

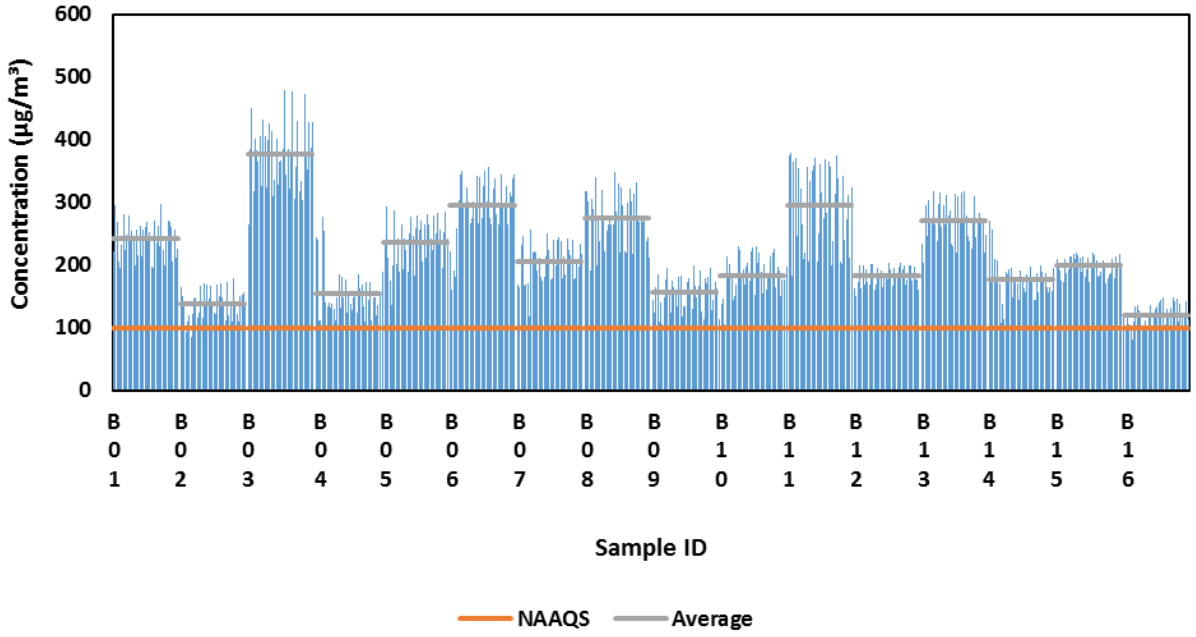


Figure 2.23: Concentration of PM_{10} in summer season.

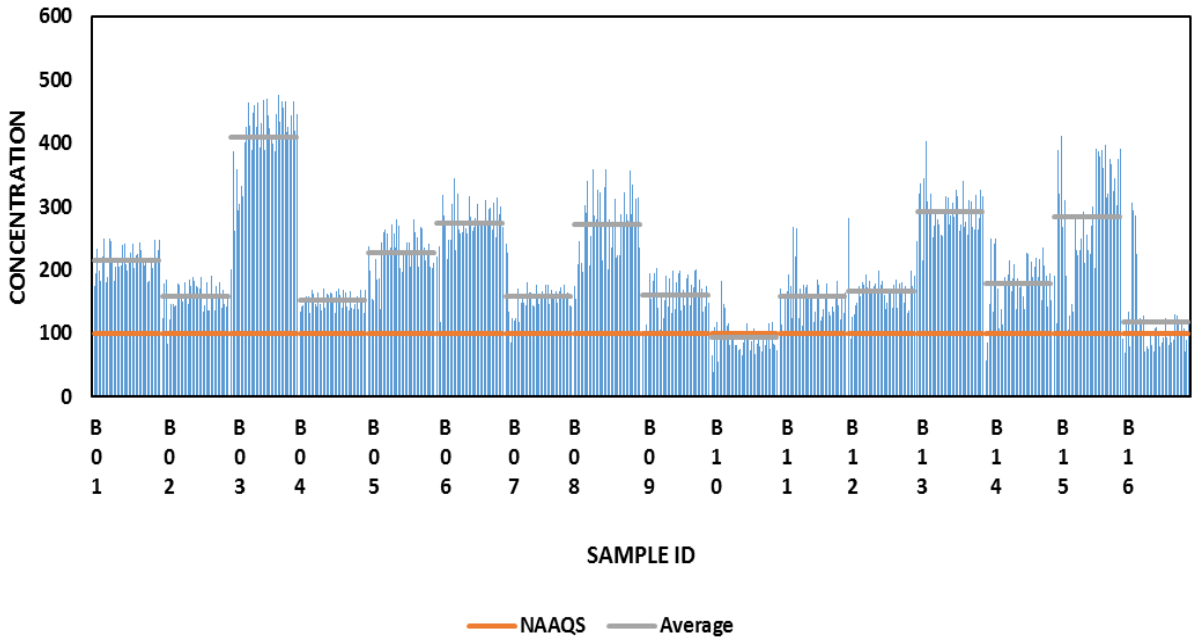


Figure 2.24: Concentration of PM_{10} in pre/post-monsoon season.

2.3.1.2.2 $PM_{2.5}$ Variation in Different Season

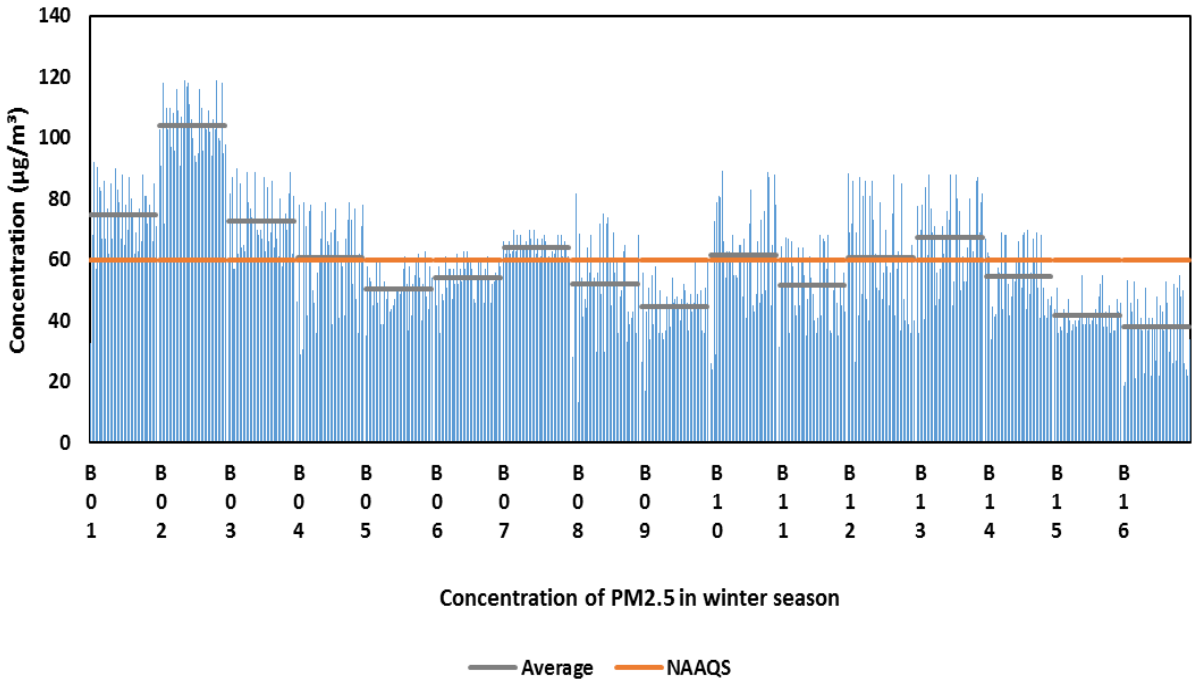


Figure 2.25: Concentration of $PM_{2.5}$ in winter season.

Air sample collected from 16 stations and the highest PM 2.5 level were found in B01, B02, B03 as it is very heavily traffic area an 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 2.25 to 2.27.

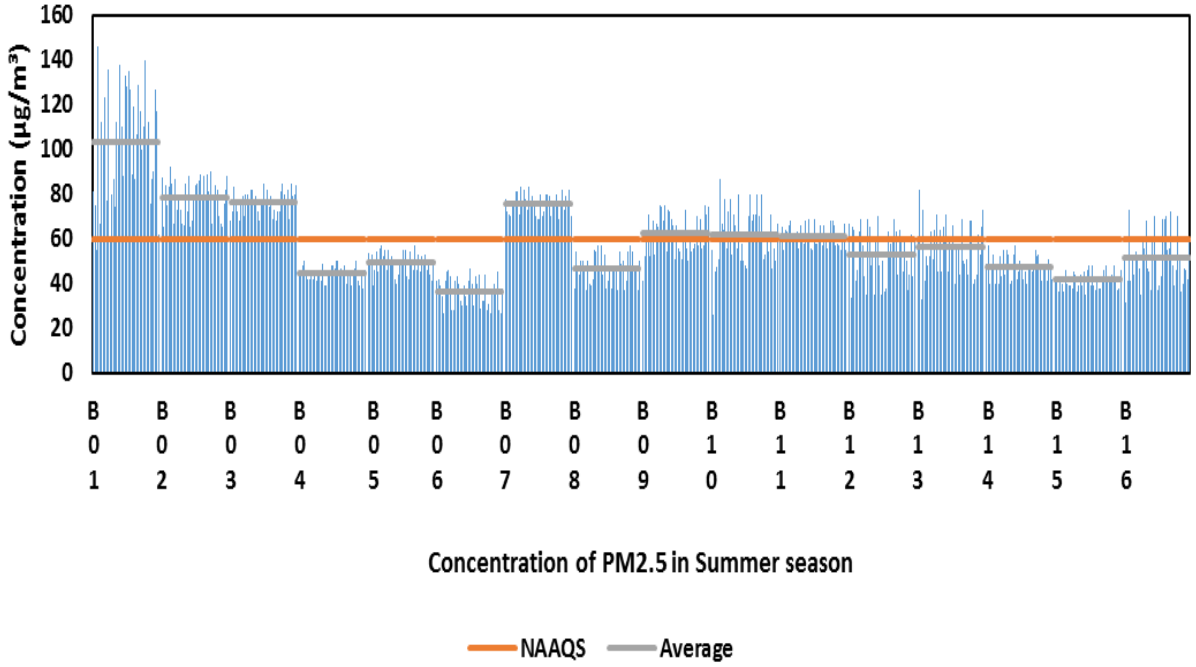


Figure 2.26: Concentration of $PM_{2.5}$ in summer season.

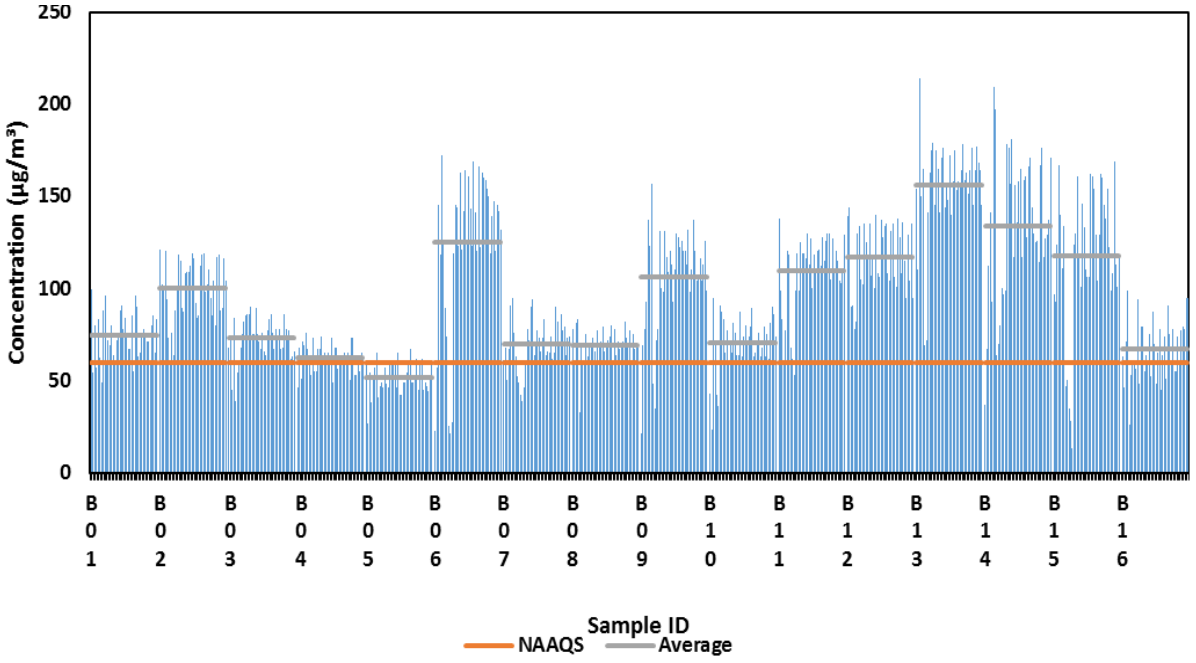


Figure 2.27: Concentration of $PM_{2.5}$ in pre/post monsoon season.

2.3.1.2.3 SO_2 Variation in Different Season

Air sample collected from different season in Bhilai-Durg for SO_2 as shown in Figure 2.28 to 2.30 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 B03, B10, B13 that is mainly bcoz of steel power plant 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.

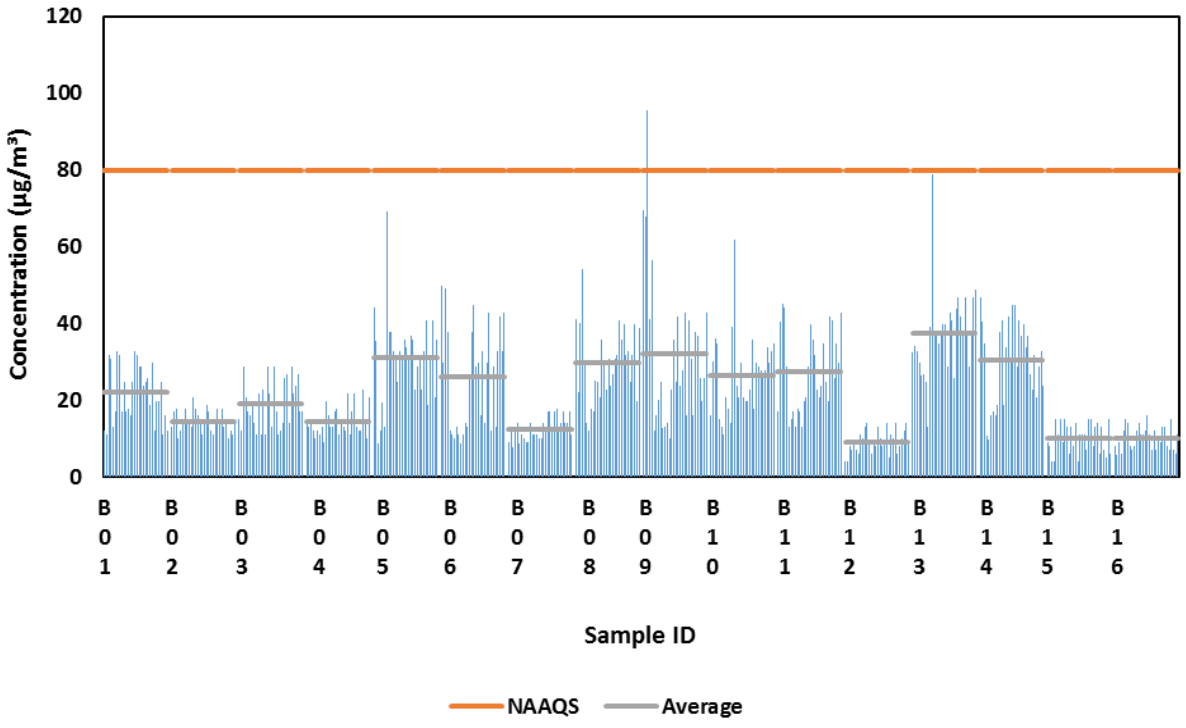


Figure 2.28: Concentration of SO_2 in winter season.

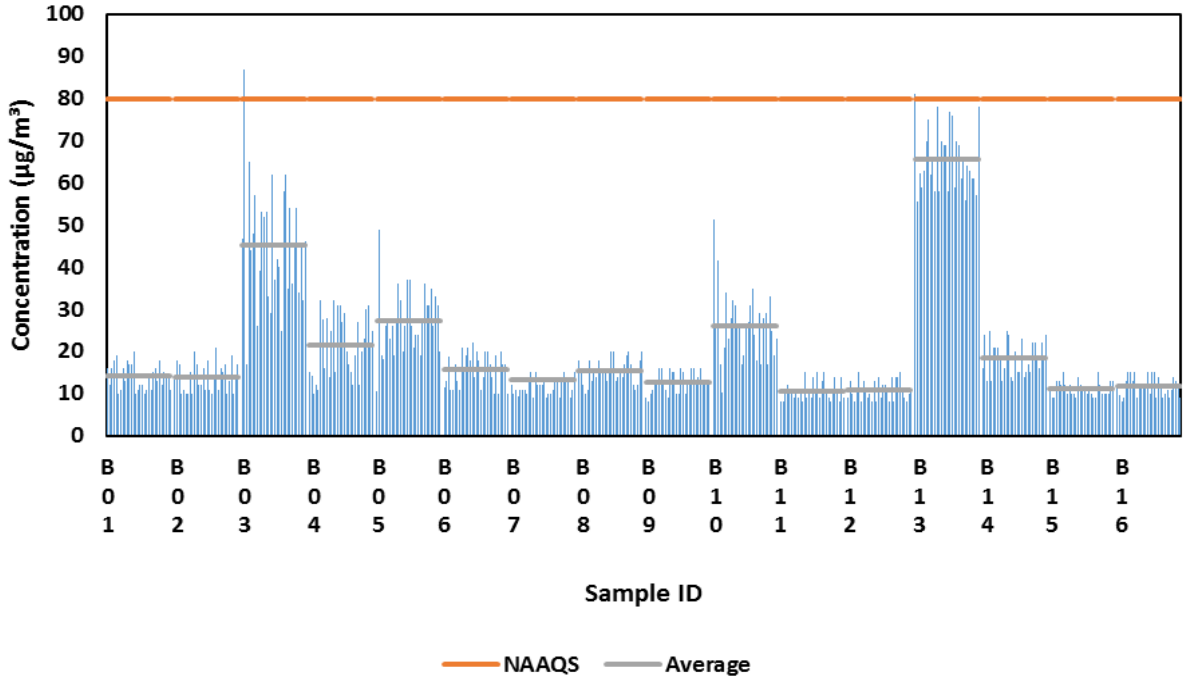


Figure 2.29: Concentration of SO_2 in summer season.

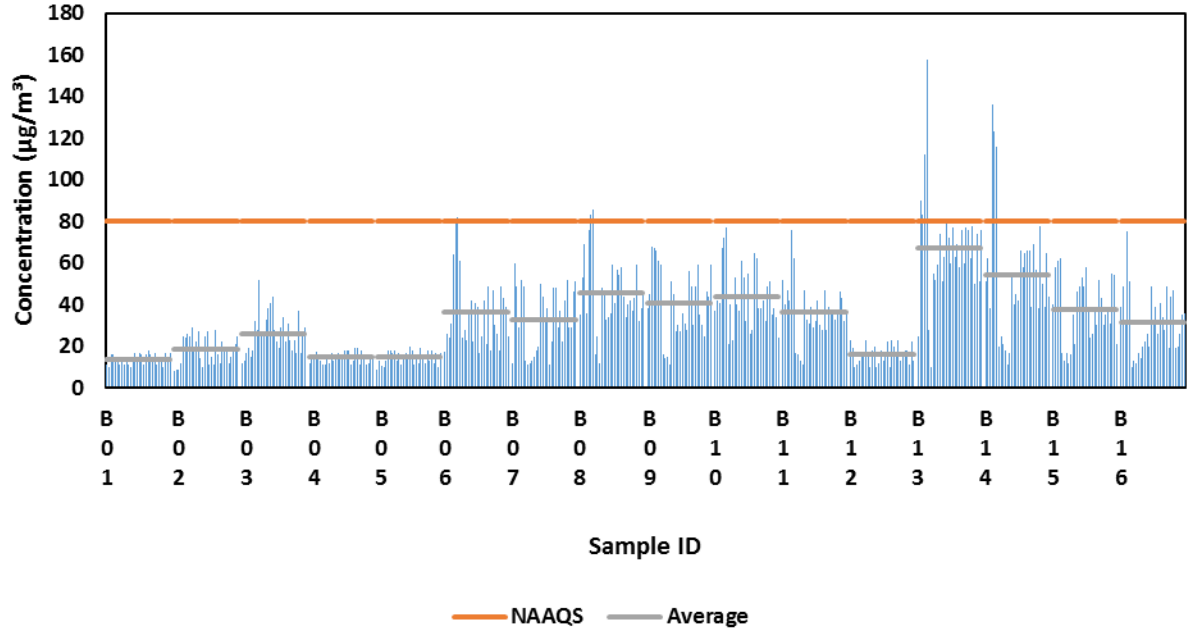


Figure 2.30: Concentration of SO_2 in pre/post-monsoon season.

2.3.1.2.4 NO_2 Variation in Different Season

Air sample collected from 16 stations as and from Figure 2.31 to 2.33 we can see that all the values are within limit that is 80 µg/m³. However high concentration was found in B03, B05 and the main reason could be the nearby industry such as wood industry and other industries as NO_2 in air is because of vehical power plant and industrial emission etc. The high value of NO_2 can cause asthma and respiratory problem. The high value of NO_2 in post monsoon were found in B04 the main cause could be is more traffic in those station and also industries and ongoing construction contributed an increase of NO_2 concentration. The highest concentration in winter were found in B03 and B12 and also the causes could be industrial emission more traffic and all the stations have high value in winter as compare to the winter mainly because of more combustion of wood and coal are taking place .

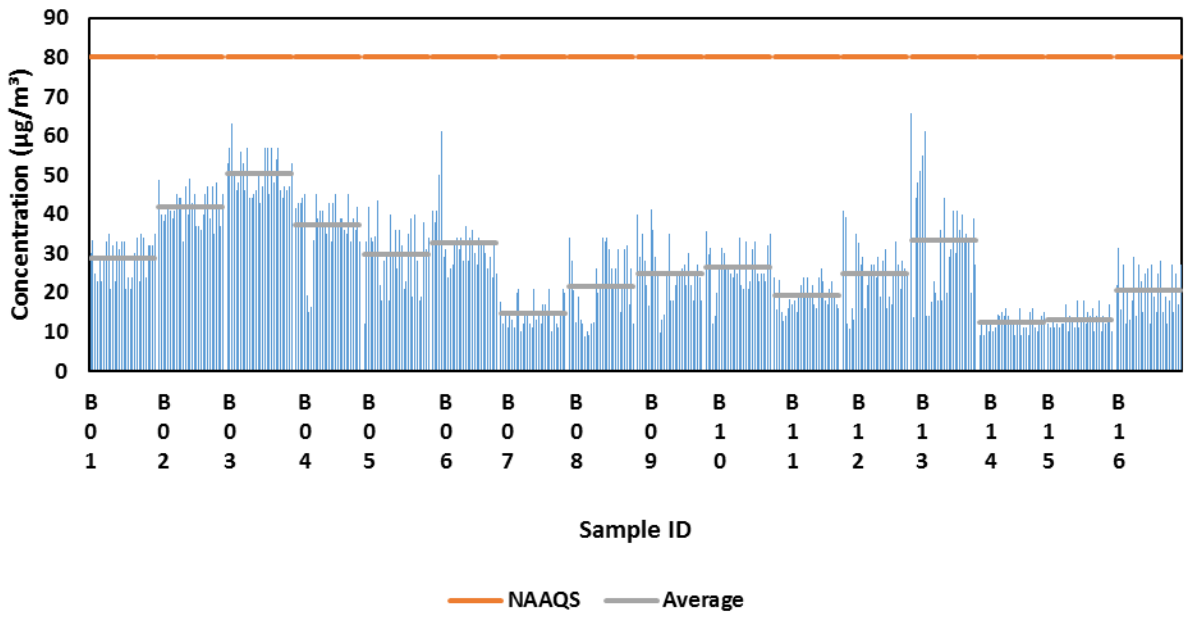


Figure 2.31: Concentration of NO_2 in winter season.

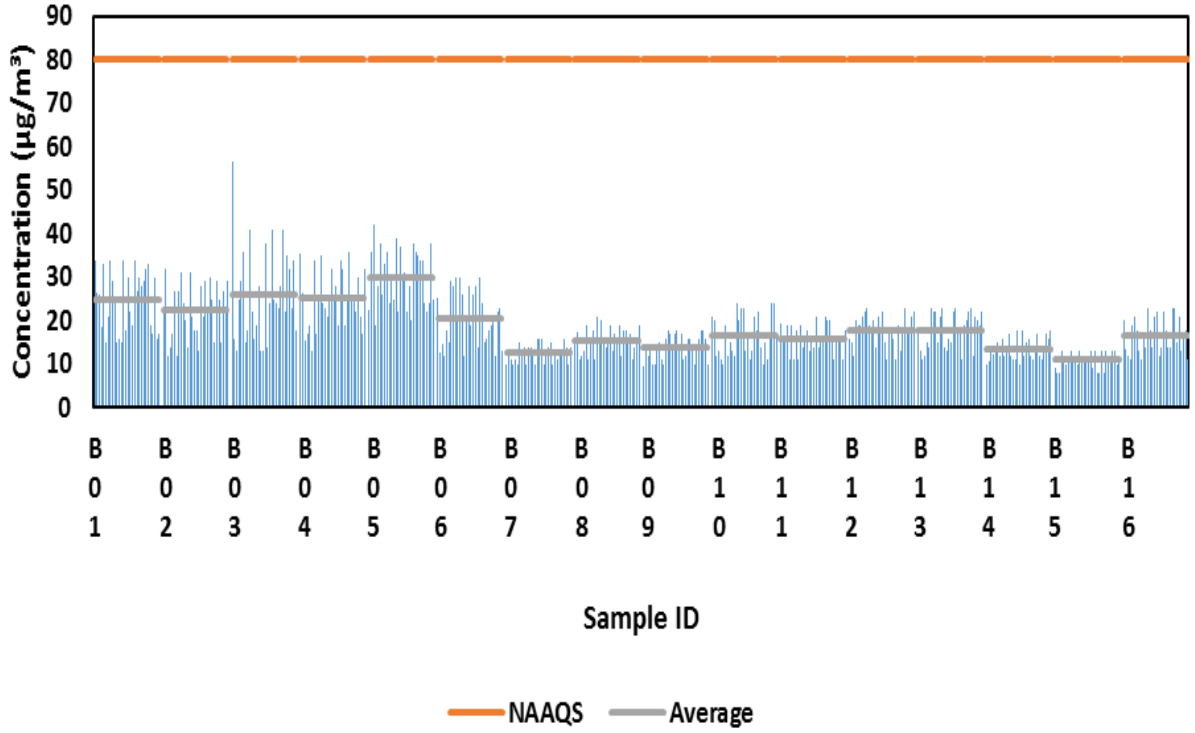


Figure 2.32: Concentration of NO_2 in summer season.

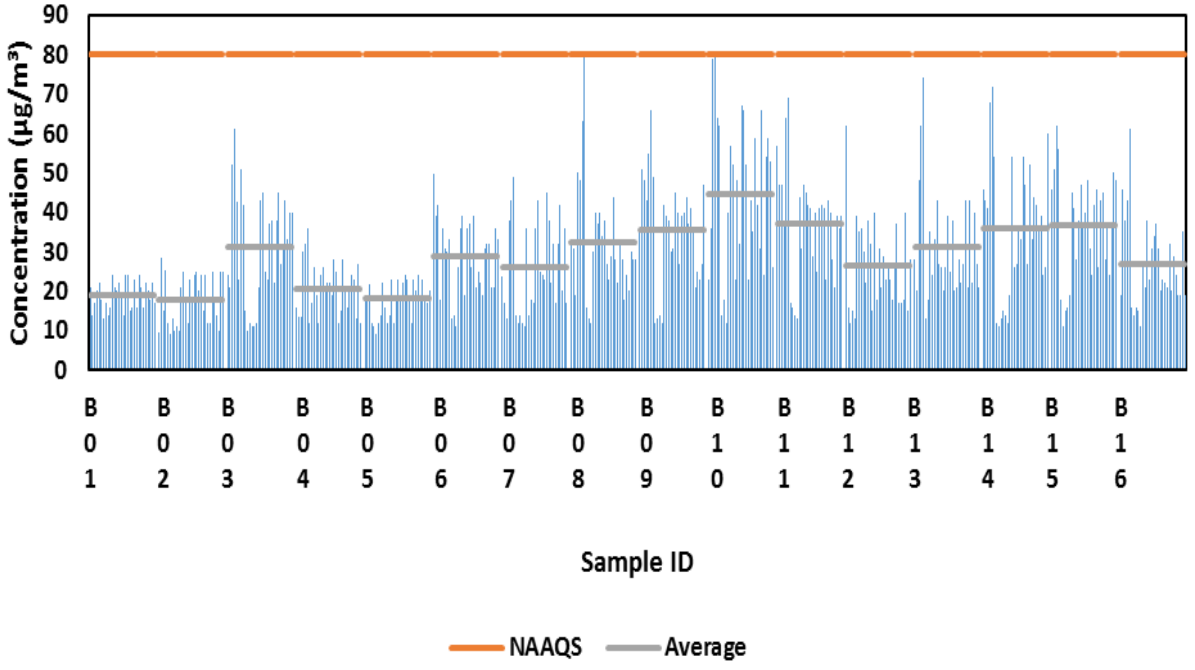


Figure 2.33: Concentration of NO_2 in pre/post monsoon season.

2.3.1.2.5 NH_3 Variation in Different Season

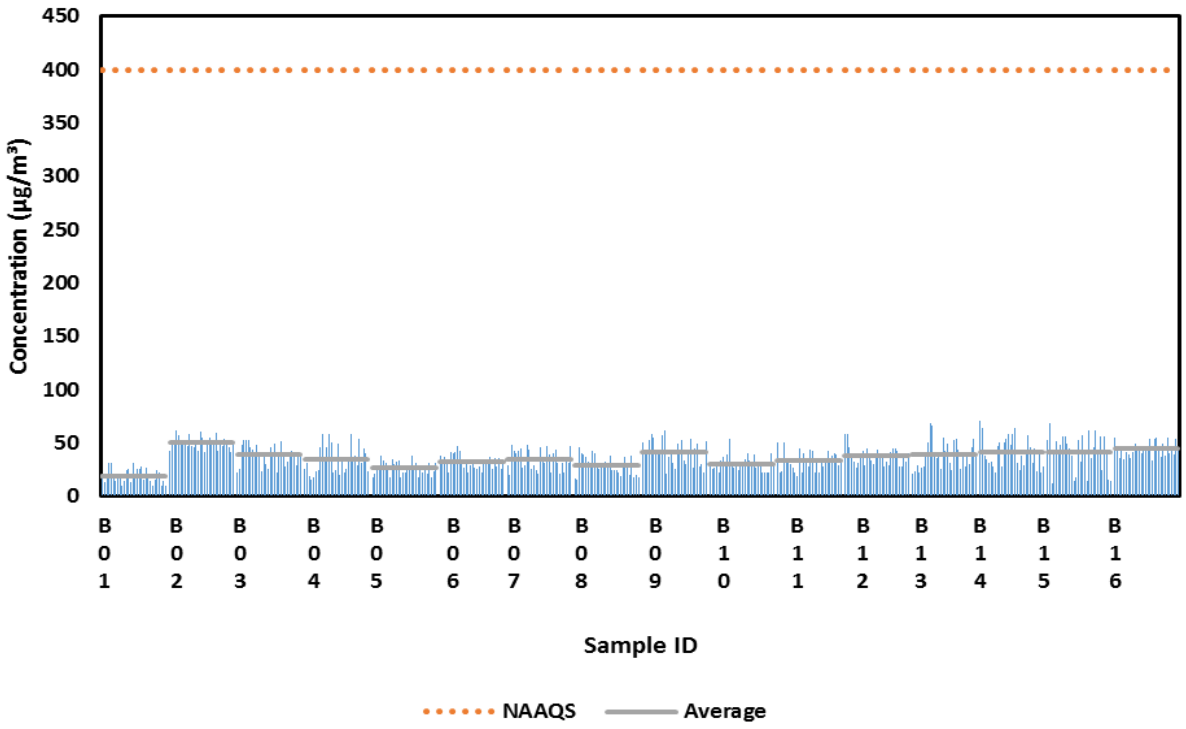


Figure 2.34: Concentration of NH_3 in winter season.

Air sample collected from 16 stations and as we can see Figure 2.34 to 2.36 highest concentration were found in B06, B07, and B09 and it is mainly because of ferro alloy industry nearby and also some other activities as the main reason for generation of ammonia in air due to decomposition of organic matter and as a byproduct of agriculture and industry. High concentration of ammonia can cause burning of nose throat and it is also effect the respiratory system. In pre/post monsoon season the highest concentration were found in B03 is mainly because of nearby sources that is nearby site of industries and as it produces byproducts which result in generation of ammonia. The highest concentration of ammonia in winter were found in B09, B15, and B16 and rest of the station has low value as compare to these stations and the reason could be the nearby restaurant and industries as it result in generation of ammonia.

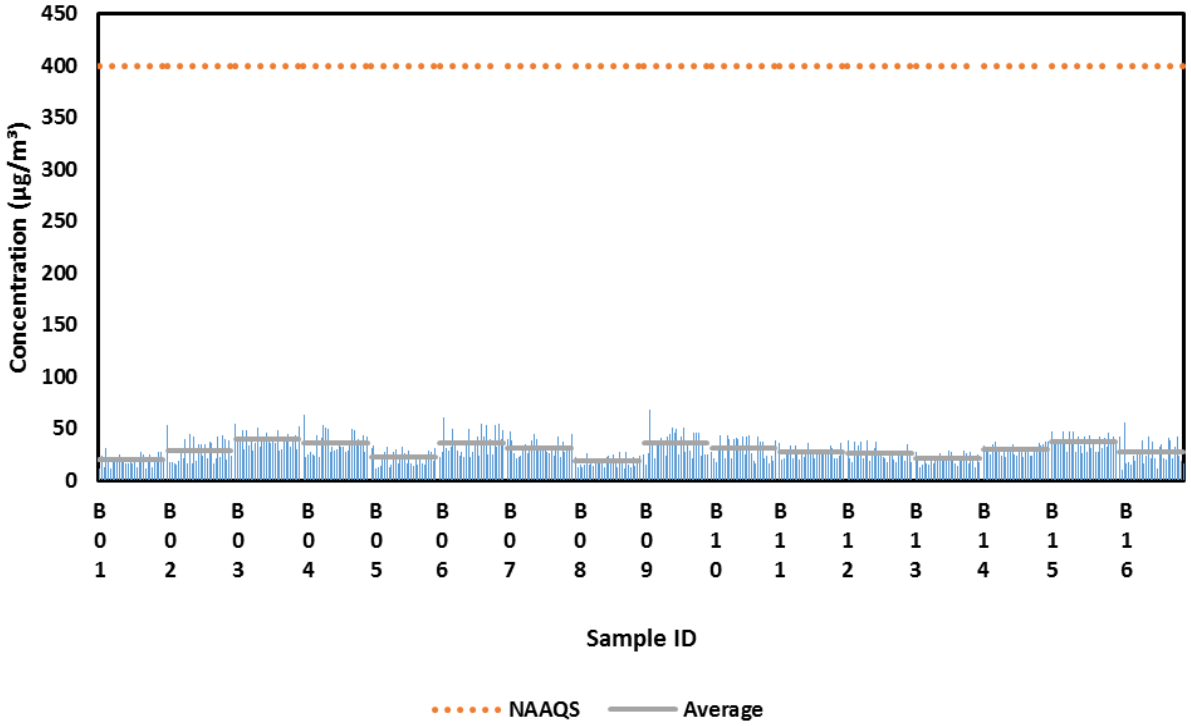


Figure 2.35: Concentration of NH_3 in summer season.

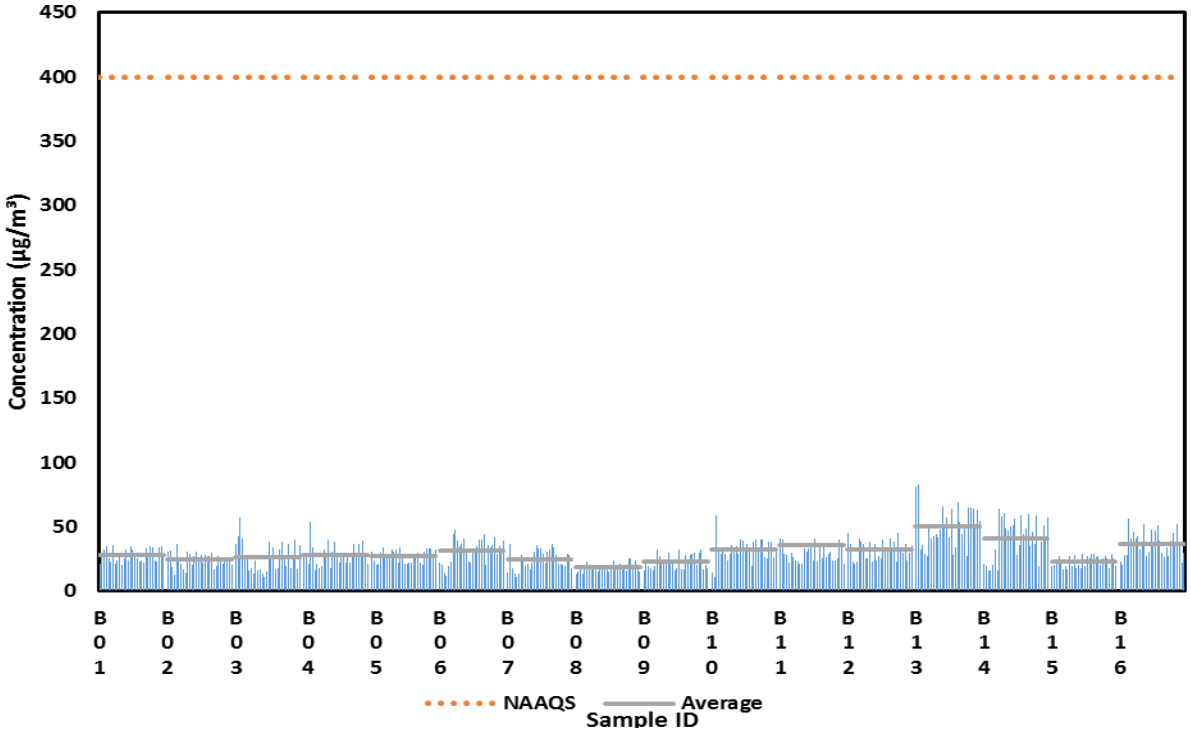


Figure 2.36: Concentration of NH_3 in pre/post monsoon season.

2.3.1.2.6 O_3 Variation in Different Season

Air sample collected from 16 stations in Bhilai in which some shows high concentration of ozone which are B01, B06, and B13 and the main reason could be nearby industries and the heavy traffic in those areas as the generation of ozone is mainly because of car, power plant, refineries, chemical plant. High concentration of ozone can cause irritation in eyes respiratory and heart problem. And also shortness of breath, chest pain, wheezing. In pre/post monsoon air sample collected from 16 stations as the other two stations are stopped at that time. The values in post monsoon season are less as compare to the summer season that is due the rain has already wiped out the pollutant and the temperature is also low the highest concentration were found in B02 the reason could be the traffic and nearby industrial areas. High concentration of ozone in winter were found in B05, B03, and B13 and the reason could be heavy traffic more traffic and all the values are high in winter as compare to the other season which is because of more combustion of wood and furniture , coal in this season as the temperature is lowest in this season.

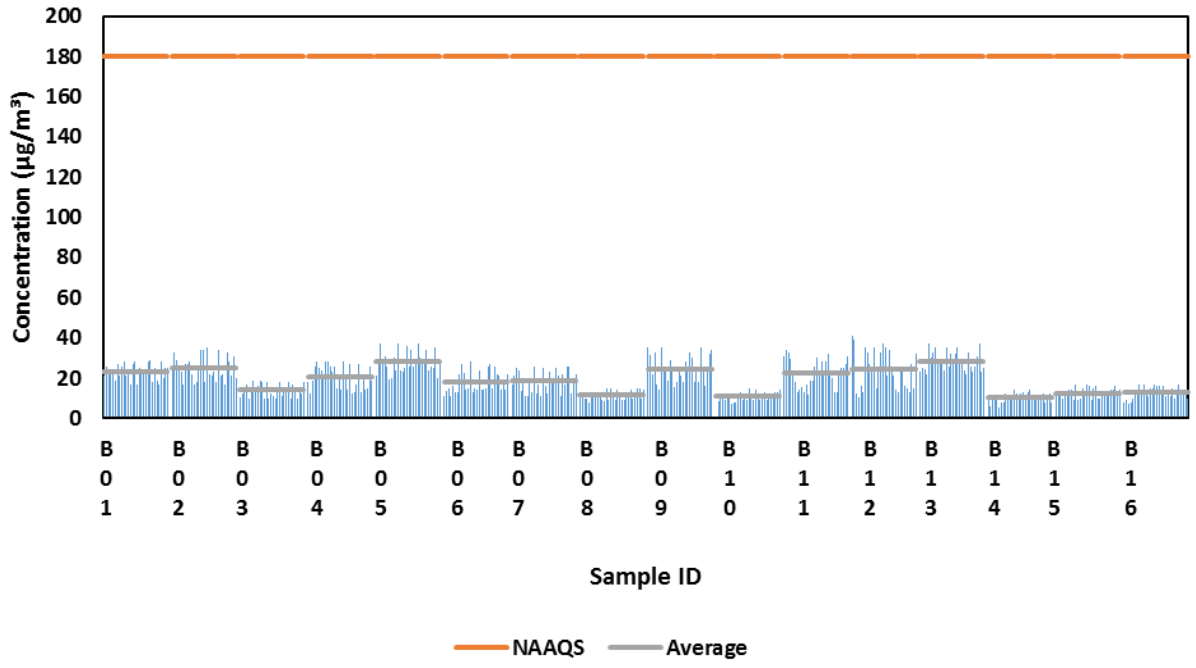


Figure 2.37: Concentration of O_3 in winter season.

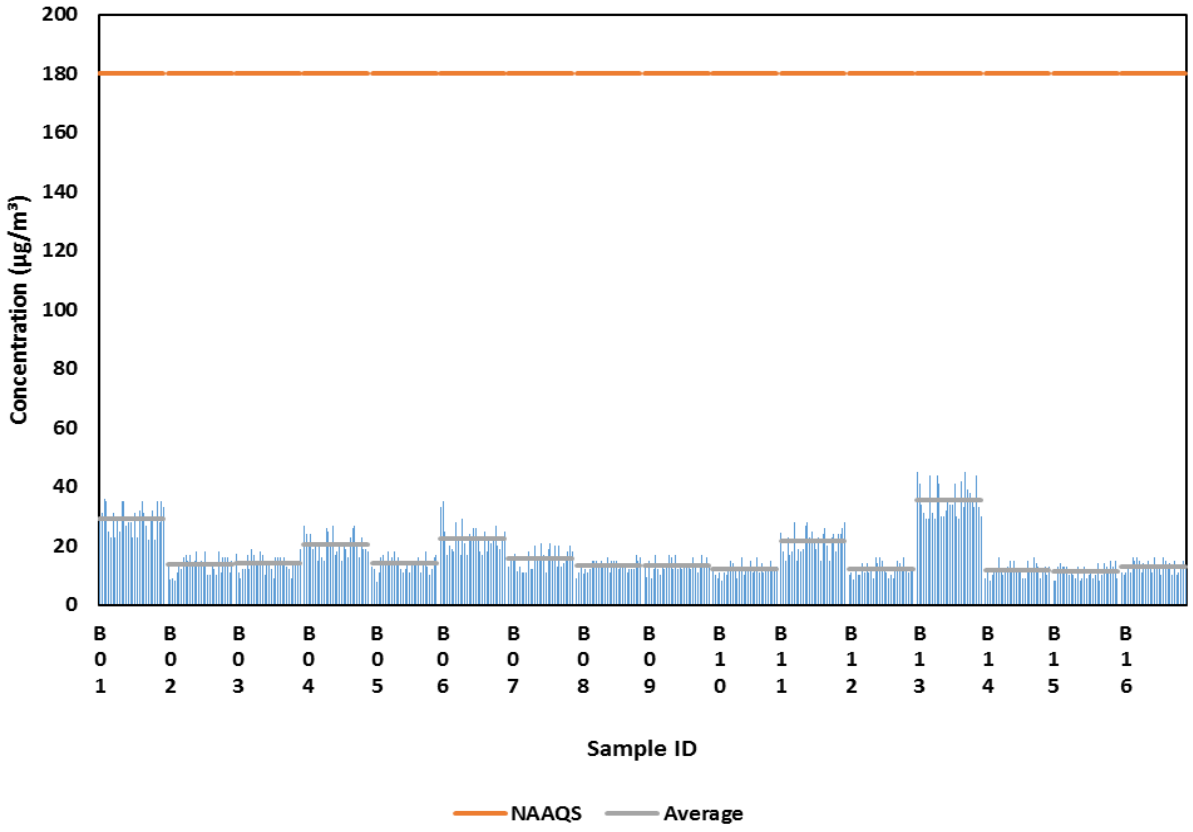


Figure 2.38: Concentration of O_3 in summer season.

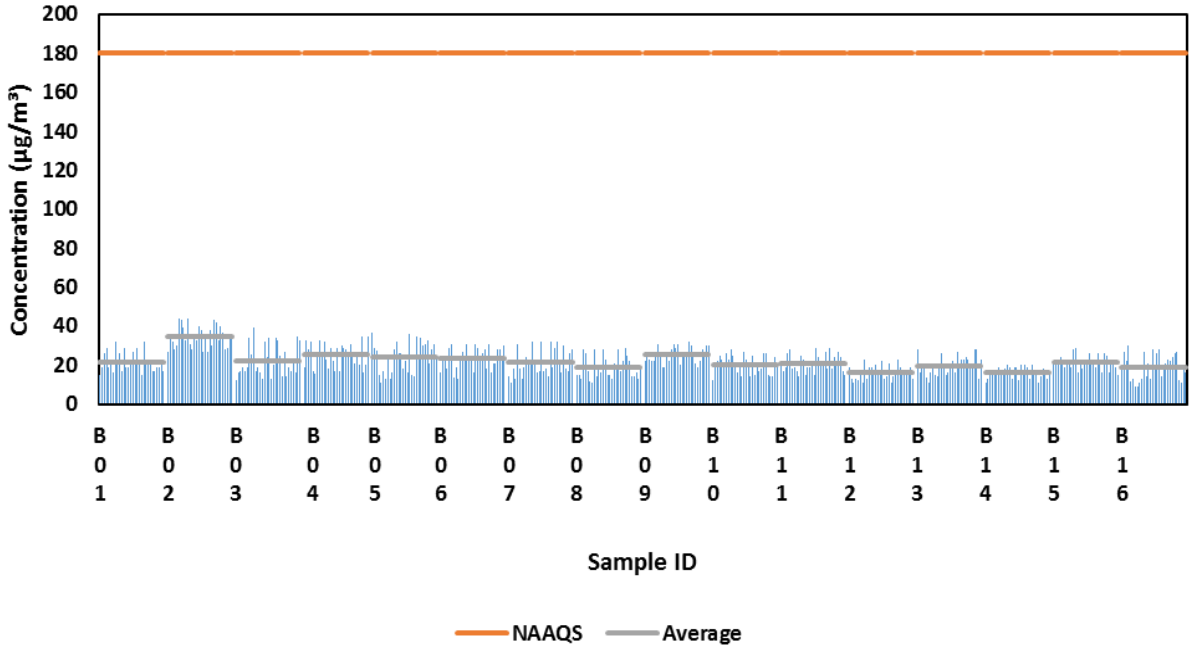


Figure 2.39: Concentration of O_3 in pre/post monsoon season.

2.3.1.3. Carrying Capacity for PM_{10} and $PM_{2.5}$

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

The Pollution load at which the maximum permissible concentration is reached is considered as the assimilative capacity. The maximum permissible concentration of PM_{10} as per National Ambient Air Quality Standard (NAAQS) of PM_{10} (24-hour average) is 100 µg/m^3 and this was used for estimating the **Total Assimilative Capacity**, by multiplying with the volume of air available for dispersion in each grid. The difference between the maximum permissible concentration/load of PM_{10} i.e. Total Assimilative Capacity and the existing average PM_{10} concentration/ load i.e. Existing Pollution Load gives an indication of the **Supportive Carrying Capacity** of an area available for sustaining the operation of additional air polluting activities. The positive values shows the capacity to accommodate additional pollution load and the negative values indicate that the pollution load is in excess of the assimilative capacity of the area i.e. no additional pollution load can be accommodated and measures are required to bring the pollution load within the assimilative capacity.

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

Total area of Bhilai: a $(km)^2$

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

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

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

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

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

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

Sr. 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	October 2022	186668.78
11	November 2022	259281.05
12	December 2022	444085.8
13	January 2023	361703.64

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

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

Table 2.14: Assimilative carrying capacity in Bhilai

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	October 2022	120214.31
11	November 2022	127285.74
12	December 2022	141428.6
13	January 2023	106071.45

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

Month wise supportive carrying capacity of Bhilai, 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 Bhilai.

Sl. No.	Month	Supportive Carrying Capacity
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	October 2022	-66454.47
11	November 2022	-131998.31
12	December 2022	-302657.2
13	January 2023	-255632.19

Table 2.16: Carrying capacity assessment of Bhilai 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	182	682	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	178	682	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	314	682	141428.6	444085.8	-302657.2
13	Jan-23	706.86	1500	1.5	341	511.5	106071.45	361703.64	-255632.19

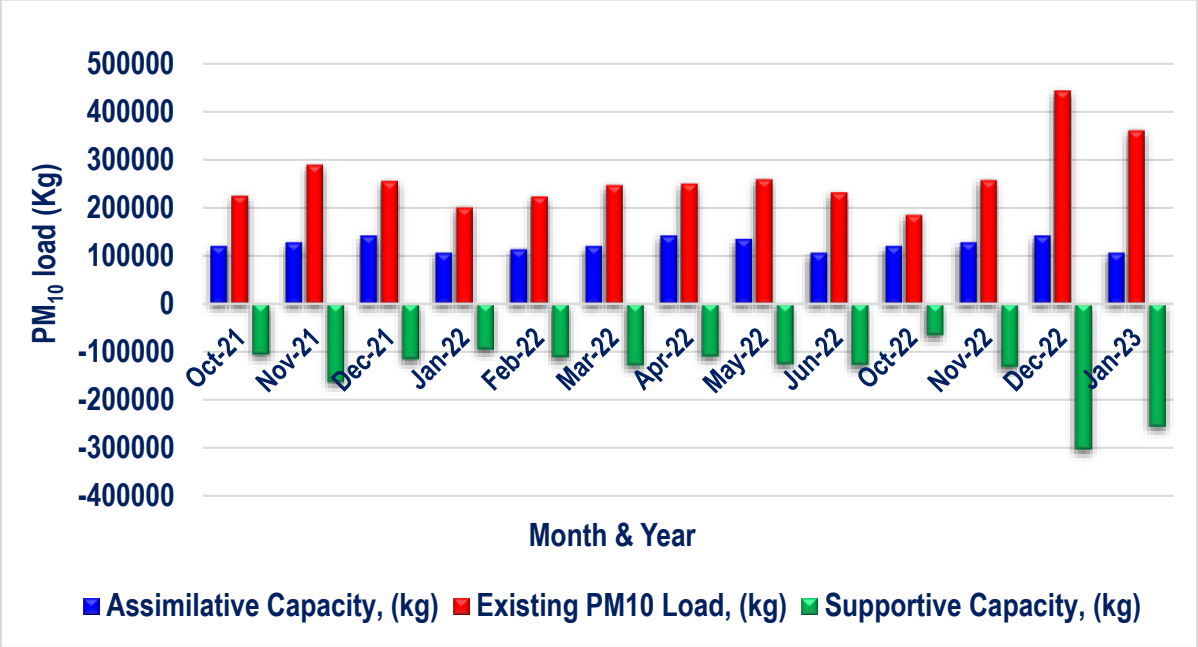


Figure 2. 40: Month wise load capacity of PM_{10}.

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

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

Sl. 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

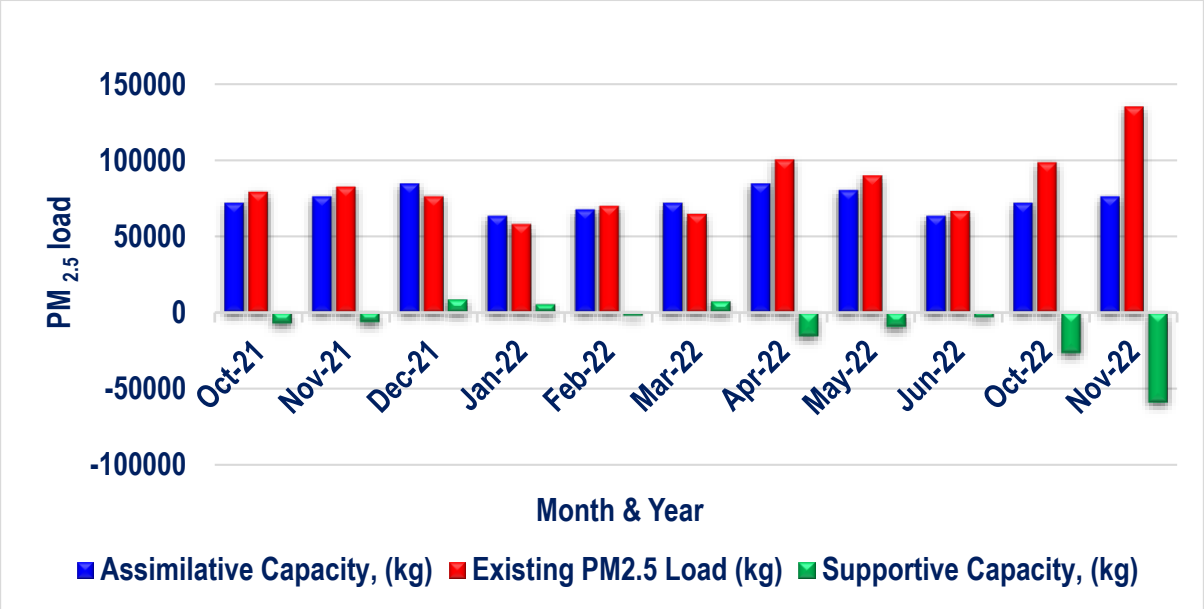


Figure 2.41: Month wise load capacity of $PM_{2.5}$.

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

2.3.1.4 Statistical Analysis

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

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

Bhilai	$PM_{2.5}$			PM_{10}		
	Pre and post monsoon	Summer	Winter	Pre and post monsoon	Summer	Winter
Max	214	146	119	477	480	510
Min	13	26	13	39	80	68
Average	94	59	60	207	219	257
STDV	37	19	19	89	76	91
mean	94	59	60	207	219	257
CV	0.40	0.33	0.32	0.43	0.35	0.35

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

Bhilai	SO_2			NO_2		
	Pre and post monsoon	Summer	Winter	Pre and post monsoon	Summer	Winter
Max	158	87	96	81	57	66
Min	8	8	4	9	8	9
Average	33	21	22	29	19	27
STDV	21	16	13	14	7	12
mean	33	21	22	30	19	27
CV	0.64	0.75	0.60	0.49	0.39	0.45

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

Bhilai	NH_3			O_3		
	Pre and post monsoon	Summer	Winter	Pre and post monsoon	Summer	Winter
Max	83	68	70	44	45	41
Min	11	10.40	10	9	7.72	5.57
Average	29.78	29.42	36.18	21.96	17.13	19.07
STDV	11.50	10.47	12.20	6.85	7.53	7.89
mean	29.78	29.42	36.18	21.96	17.13	19.07
CV	0.386	0.355	0.336	0.31	0.44	0.41

2.3.1.5 Carbon Impact on Environment of Bhilai

Bhilai is industrial zones and play significant role on Indian economy. We have selected 16 air quality monitoring stations within the geographical circumstances of Bhilai. All those stations are situated within human dwelling areas so that, we can properly study the effects of coal as well as fossil fuels burning, improper agricultural activities, industrial and traffic hazard on Bhilai's 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 analyzed according to CPCB predicted protocols (TOR / TOT method, see section 2.1.11). We have found OC values ranges from 0.75 µg/m³ to 0.83 µg/m³ among all air quality monitoring stations. Similarly, we have found TC values ranging from 1.13 µg/m³ to 1.87 µg/m³ among all air quality monitoring stations. Carbonaceous compounds are mainly organic or house hold type in Bhilai's.

2.3.1.6 Seasonal VOCs Variation

Under the provisions of the Air (Prevention & Control of Pollution) Act, 1981, the CPCB has notified fourth version of National Ambient Air Quality Standards (NAAQS) in 2009. They mentioned benzene limit in the ambient air should not be exceeding over 5 µg/m^3. In the sampling stations of the Bhilai and Durg surroundings, we have found seasonal effect on VOCs amount. Environmental temperature also effects on VOCs value. In winter, we have found benzene in the ambient air of every sampling station of Durg and Bhilai. Resultant values are found high in this area and maximum value has been touched 53.47 µg/m^3 mark at B03. In summer, benzene concentrations are also found high and in the sampling station B07, we have found value 42.54 µg/m^3 (Figure 2.42). Though in summer, benzene concentration in the ambient air of Durg and Bhilai is decreasing but values are still quite high beyond the permeable limit.

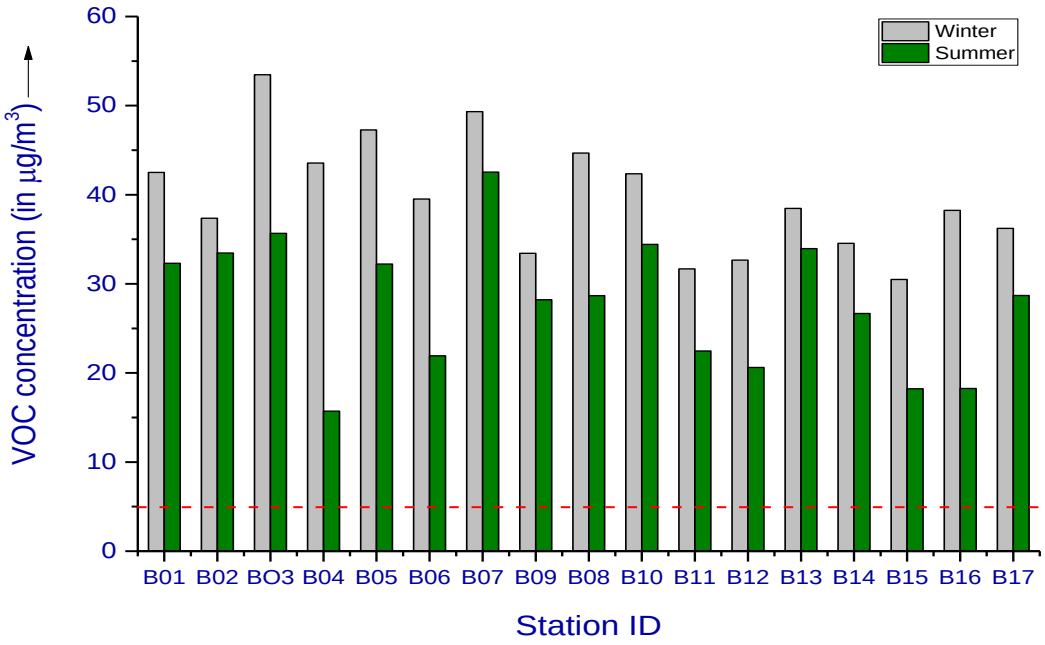


Figure 2.42: Seasonal representation of VOCs concentration in ambient air of Bhilai.

2.3.1.7 Quantification and Variation of PAHs in Ambient Air

We have prepared a Standard mixture solution (100 ppb) of different markers (denoted by CPCB, India) with all following 16 components – naphthalene, acenapthylene, fluorene, phenantherene, anthracene, fluoranthene, phenylenepyrene, benzo(a) anthracene, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo (a) pyrene, benzo (e) pyrene, indeno (1,2,3-cd) pyrene, indeno (1,2,3-cd) fluoranthene, picene and diben (a,b) anthracene, respectively [Figure 4.22]. Then run all extracted samples from PM10-filter papers and above STD mix solution separately and respectively through GC fitted with a capillary column (GB-5, Agilent Technologies, Made in USA) and FID detector. Then quantified the identified component(s) present in the extracted samples with respect to the standard solution mixtures' retention time (RT; in min) and area (in uV*Sec) under any peak. Hopens, alkanoic acids were also screened through GC as above but we didn't find any compound in any sampling stations in Bhilai surroundings. Here in Figure 2.43, 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).

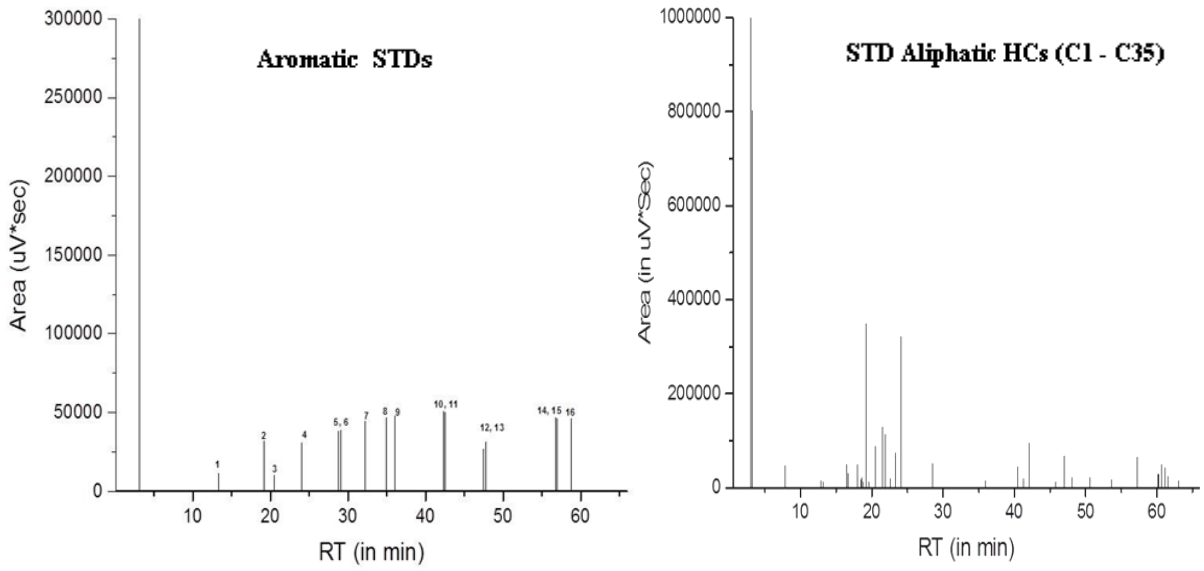


Figure 2.43: GC analysis of different aromatic standard hydrocarbons (16 selected compounds) and aliphatic standard hydrocarbons (C1 to C35) are presented side by side.

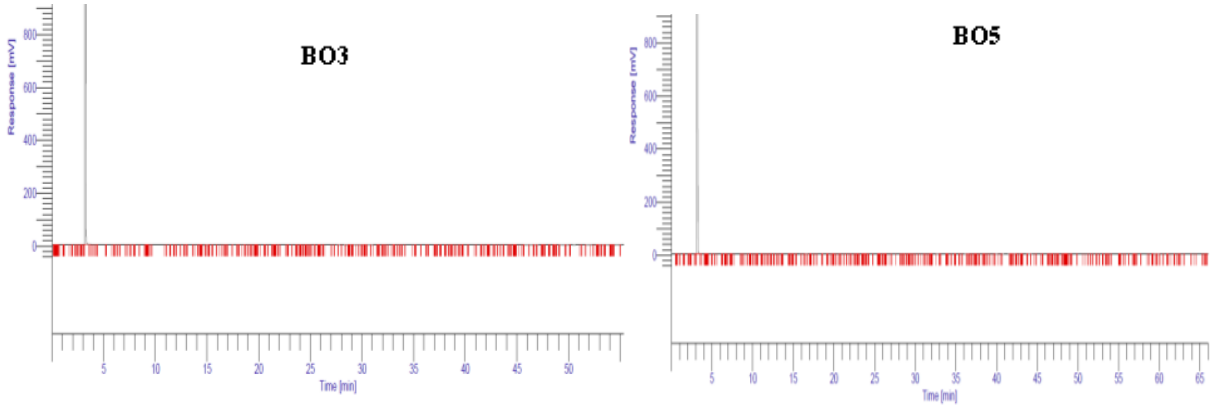


Figure 2.44: GC chromatograms of PAH samples collected from BO3 and BO5 sampling stations.

2.3.1.8 Metal Particulate Matters in the Ambient Air

Acid leached exposed PM_{10} filter paper extracts are analyzed through AAS. In every extracted samples we have found 'Cu', 'Ni', 'Fe', 'Zn', 'Cr', 'Pb', 'Cd' and 'As'. 'Fe' has been found as main metal in the ambient air samples of different sampling stations. 'Cu', 'Zn', 'Ni' and 'Cr' are also found in very low amount. Most important thing for Bhilai and Durg area, 'As'and 'Pb' have been detected from every

sampling stations beyond the limit (6 ng/m^3 as per CPCB, India) (Figure 2.45). Sampling station 'B10' area is in danger as all detected metals are present in high range.

Arsenic (As) poisoning is now a global health issue. It is a naturally occurring metalloid element with ubiquitous distribution throughout the earth's crust and groundwater. It is also found in lower levels in the air and food products. The release of arsenic into the environment propagates through weathering and mining processes. Arsenicosis occurs after the ingestion and inhalation of high levels of arsenic. Symptoms of arsenic poisoning may include red or swollen skin, abdominal pain, nausea and vomiting, diarrhoea, abnormal heart rhythm, muscle cramps, tingling of fingers and toes and so on. According to the World Health Organization, long-term symptoms tend to occur in the skin first, and can show up within five years of exposure. Cases of extreme poisoning may lead to death.

Bhilai is well known for steel manufacturing and representing India near World as steel producing nation. So iron and related ore processing factories are there and 'As' comes in air from these processing factories. In this situation, amount of arsenic level is very low but may increase day by day if they don't take any precaution. Factories have to check their filters or re-install new one to prevent 'As' emission in ambient air.

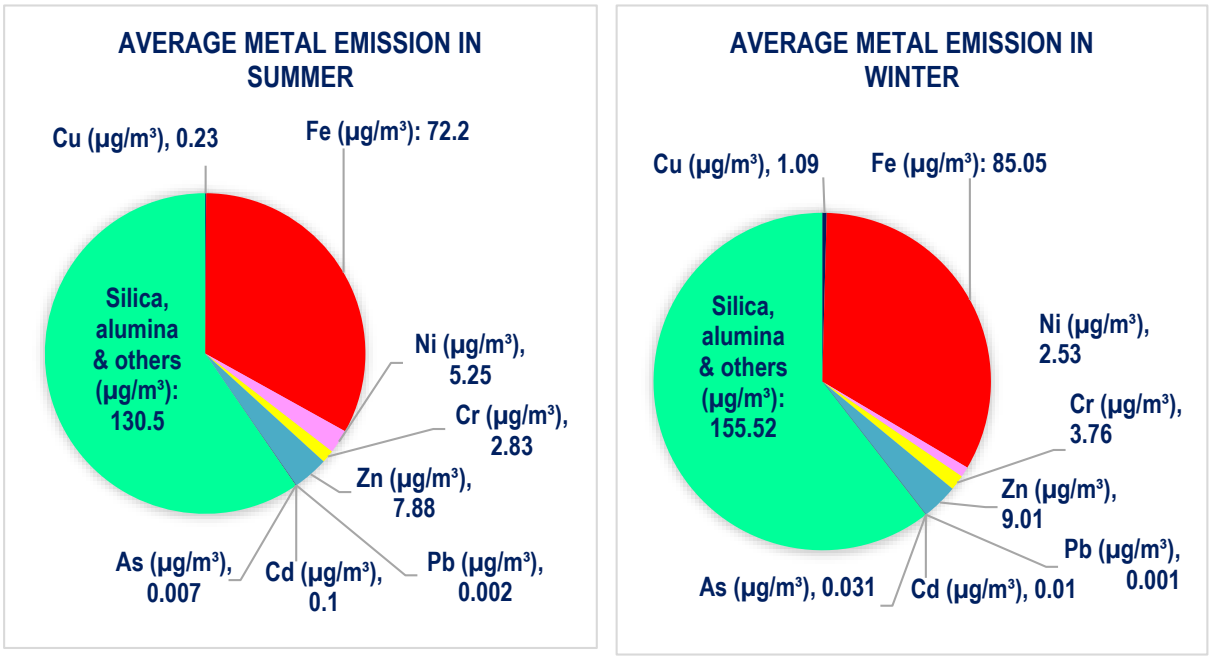


Figure 2.45 : Seasonal variation of metals concentration (µg/m^3) in the ambient air of Bhilai.

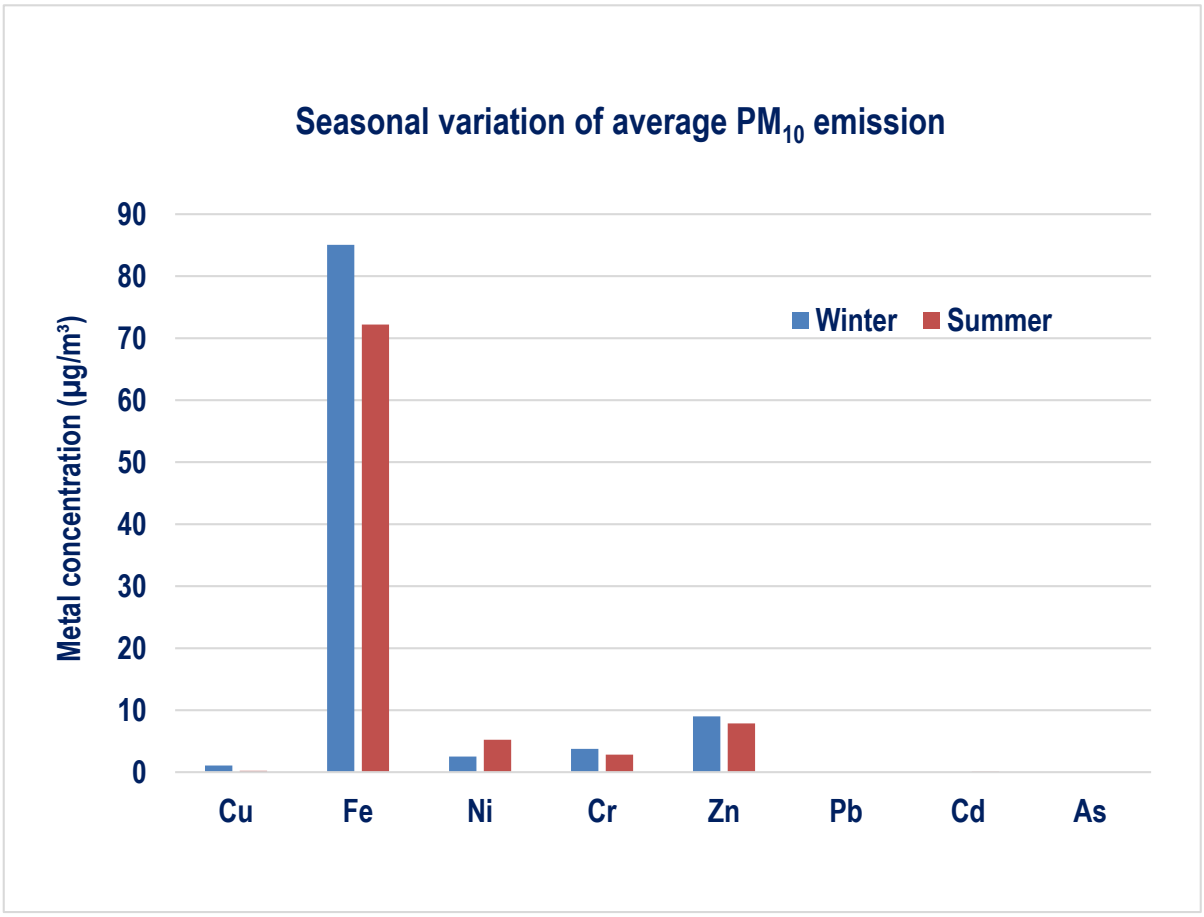


Figure 2.46: Seasonal variation of metal particulate matters (µg/m³) present in the ambient air of Bhilai.

2.3.1.9 Polyatomic Ions in Ambient Air of Bhilai

Water-extracts of exposed $PM_{2.5}$ filter papers samples, have been prepared from Bhilai sampling stations, are analyzed ion-chromatographically. Analyzed data are presented graphically in Fig.2.48. Ambient air at Durg and Bhilai surroundings contain water soluble fine respiratory particles with SO_4^{-2}, NO_3^{-1}, F^{-1}, Cl^{-1} poly-atomic anions. Among them SO_4^{2-} is percentile rich and reached up to 64% in winter. In summer, SO_4^{2-} ion concentration increases to 68% with spontaneous NO_3^{-1} and Cl^{-1} concentrations decrease.

Ambient particulate matter is a complex of inorganic and organic compounds. CPCB regulates particulate matters (PM) as a criteria pollutant and promulgates National Ambient Air Quality Standards for it. The PM indicator is based on mass concentration, chemical composition and specific size fractions. Sulfate and nitrate are significant particle mass in the atmosphere. Toxicology studies to date also suggest that secondary sulphates pose little health risk. However, the role that secondary sulphate may play in ambient PM chemistry pathways leading to potentially harmful products, such as the possible effects of secondary organic aerosols that may be the product of acid catalysis of sulfur dioxide. Sulfates can contribute to acidification of surface water and soil, and contribute to acid rain and fog that can damage the environmental ecosystem.

There are lesser data available for nitrate. But chloride ion is known as an important hazardous environmental gaseous compound that can damage ozone layer and so on. Moreover, higher amount of unwanted PM particles inhalation can cause nausea; vomiting; headache and other sever breathing problems. Higher percentage of acidic compounds may lead lung diseases and the diseases like Parkinson, Alzheimer's diseases.

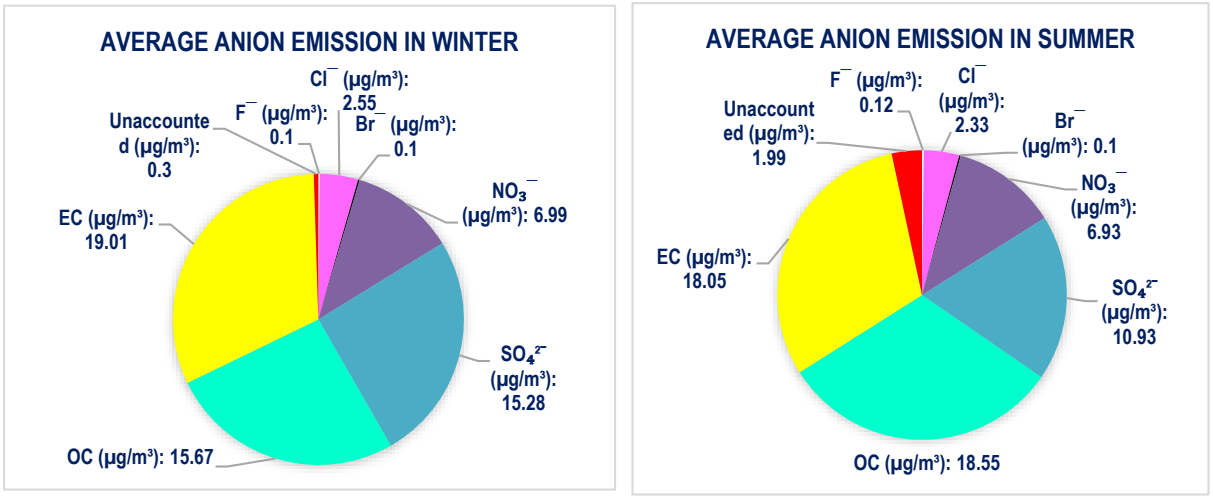


Figure 2.48: Mean $PM_{2.5}$ pollutants concentration (µg/m³) representation in the ambient air of Bhilai

2.3.1.10 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 Bhilai.

Sl.No.	Industry Name	Date	Location of Stack	Latitude (°N) Longitude (°E)	LPM	SPM mg/Nm^3
1	NIROS Ispat Pvt. Ltd.	4.04.2022	300 TPD	21.233637 81.415128	16.1	16.56
			25 TPD	21.234141 81.414715	16.5	274.74
2	ACC Cement	4.04.2022	Pre-Heater	21.240093 81.386194	18.73	26.69
			VRM	21.239672 81.384574	16.9	45.36
3	JK Laxmi Cement	5.04.2022	RABH	21.372508 81.447299	15.5	30.1
			Cooler ESP	21.372185 81.449695	16.7	25.94
4	M/S Sita Edibles Pvt. Ltd.	5.04.2022	12T Boiler	21.30247 81.33028	9.5	37
5	Aparna Carbons Pvt. Ltd.	5.04.2022	Thermo Fluid Heater	21.266333 81.307567	15.5	131.18
		6.04.2022	Battery No. 5	21.1833408 81.3875784	15.5	45.16
6	Bhailai Steel Plant	6.04.2022	Battery No. 6	21.1831015 81.3873137	14.69	37.44
		6.04.2022	LF-2	21.1792705 81.380039	14.9	20.13
		6.04.2022	Power plant Boiler-6	21.189001 81.385186	16.89	23.68
7	Jai Balaji Industries Ltd.	7.04.2022	Power plant 12.8 MW	21.1942542 81.2122642	15.6	41.66
		8.04.2022	Stack-I 210 MW (1&2)	22.41220061 82.68974083	15.3	102.39

2.3.1.11 Real Time Monitoring Data

In Bhilai HCHO, H_2S and CO concentrations are below the instruments dectection level. CO_2 concentrations in the ambient air of Bhilai are quite high. B15, B17 and B08 are found as highly concentrated stations. 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.

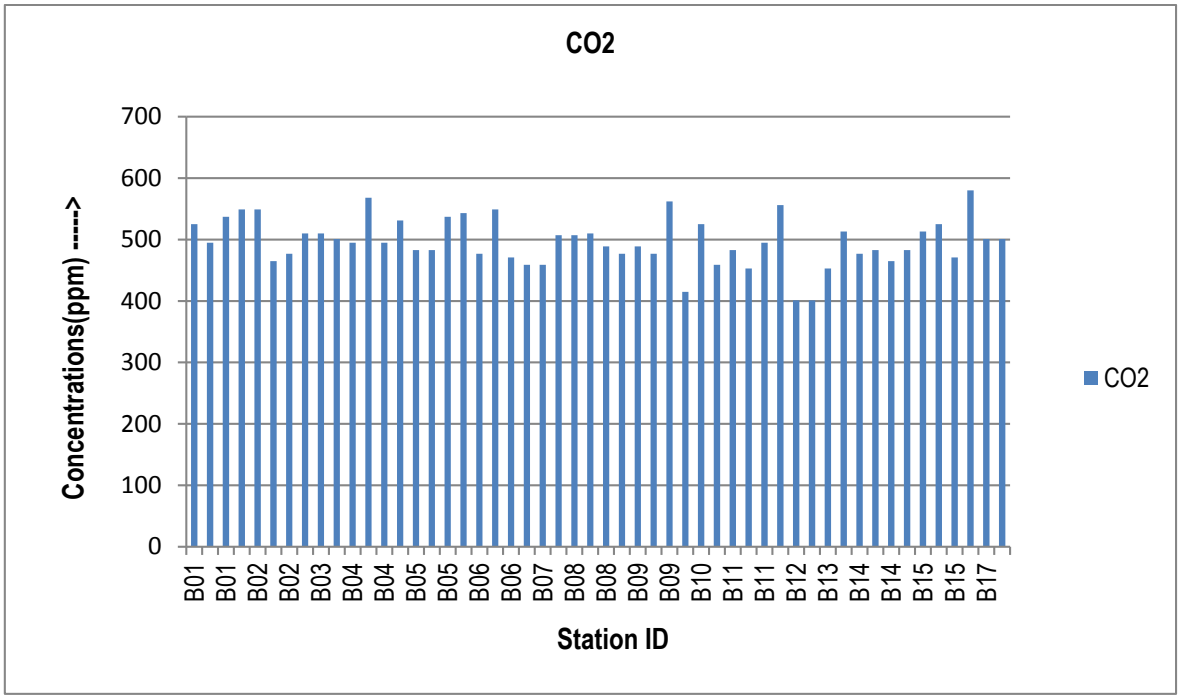


Figure2.50: CO_2 concentration (in ppm) found using online monitoring system in Bhilai.

2.3.1.12 Air Quality Modeling

2.3.1.12.1 Windrose Plot

The average angular distribution of wind directions for the period 1 Jan 2022 – 31 Dec 2022 as simulated by WRPLOT View and as observed. Windrose Plot obtained after compiling AERMET for the input meteorological data is shown in Figure 2.51. As expected, the meteorology does not change much from one location to another. It can be observed in Figure 4.29 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 Bhilai for year 2022 ranged from 0.0 m/sec to 11.1 m/sec with an annual average wind speed of 2.75 m/sec. The output files surface met data and profile met data are

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

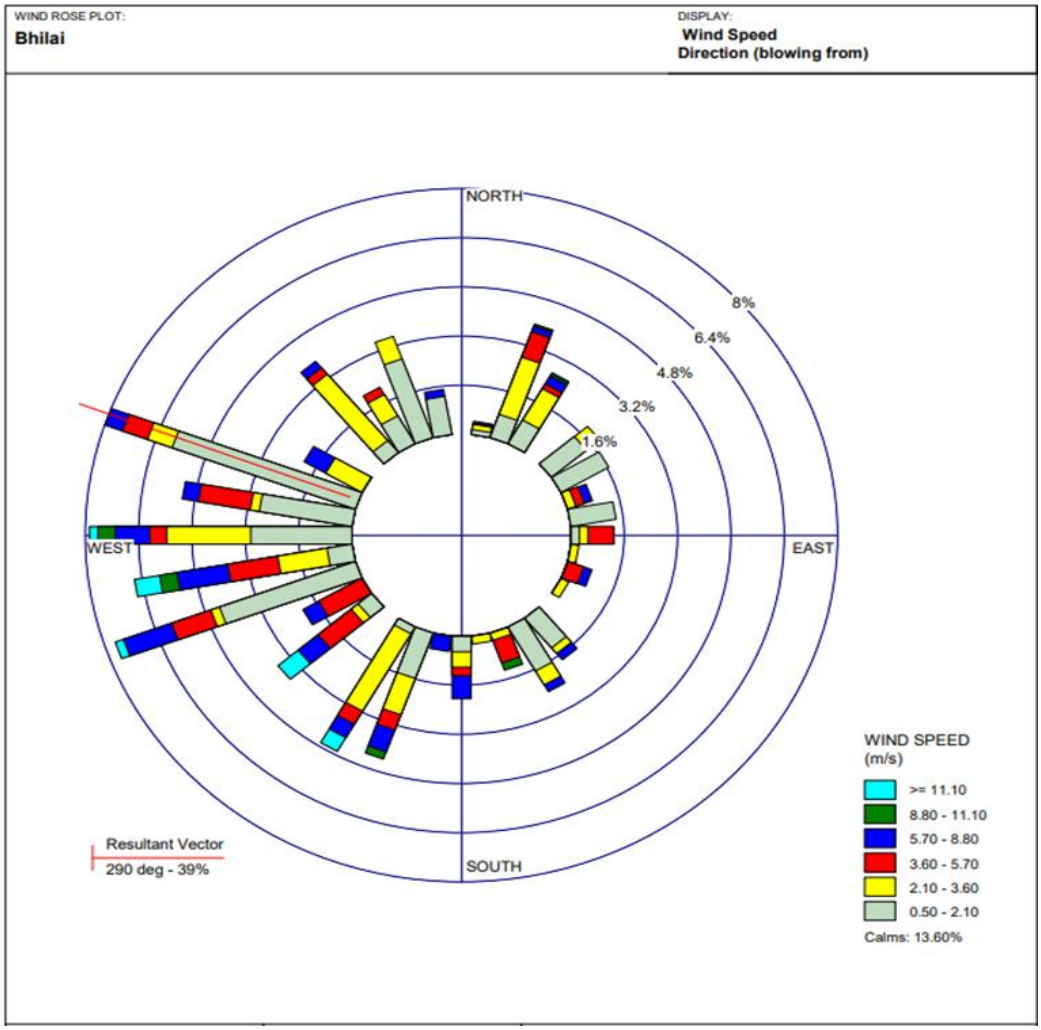


Figure 2.51: Windrose diagram for Bhilai.

2.3.1.12.2 Concentration Dispersion Isopleths

The AERMOD air quality dispersion model was performed to predict the concentration of SO_2, NO_x, SPM, CO, and HC surrounding the industrial area of Bhilai, Chhattisgarh as shown in Figure 2.52 to 2.59. 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 13 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 Bhilai monitoring station for the period Jan 2022 – Dec 2022. The industries are classified into different types namely steel, ferro alloy, sponge and power, casting and cement industries. The location of each industry is referenced to the location of one industry given **a reference point (0, 0)** which is presented as a red star in isopleths figures for **point sources**.

From the modeling **hotspots** are obtained which have high concentration of pollutants. For **point sources modeling**, SPM hotspot are found to be Mangata (North latitude 21˚ 12' 48.344'', East longitude 81˚ 12' 15.967'') and maximum concentration 24-h obtained as 72.50 µg/m^3. SO_2 hotspot are obtained as Shyam Nagar (North latitude 21˚ 9' 37.061'', East longitude 81˚ 21' 38.958'') and maximum concentration 24-h 77.31 µg/m^3. NO_x hotspot found to be Nehru Nagar (North latitude 21˚ 11' 46.288'', East longitude 81˚ 24' 47.822'') with maximum concentration 24-h of 52.41 µg/m^3.

For the **line sources modeling** 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 64.86 µg/m^3 with hotspot near by Nehru Nagar (North latitude 21˚ 12' 4.315'', East longitude 81˚ 19' 25.28''). Carbon monoxide (CO) hotspot found to be Bhilai Nagar (North latitude 21˚ 11' 52.064'', East longitude 81˚ 19' 39.45'') with maximum concentration 8-h of 363.76 µg/m^3. NO_x maximum concentration 24-h obtained as 41.899 µg/m^3 with hotspot at Ashish Nagar and Shyam Nagar (North latitude 21˚ 7' 43.71'', East longitude 81˚ 20' 19.79''). Bhilai Nagar, Belauli and Sanjay Nagar (North latitude 21˚ 11' 9.332'', East longitude 81˚ 19' 26.53'') are hotspot due to hydrocarbon (HC) with concentration 24-h of 49.60 µg/m^3.

For **the area source modeling**, we have considered different garbage dumping yard, stone crushers zones in the Bhilai city. Here hotspot is found to be Bhilai Steel Plant (North latitude 21˚ 5' 15.598'', East longitude 81˚ 24' 51.814'') with SPM concentration 24-h of 85.54 µg/m^3.

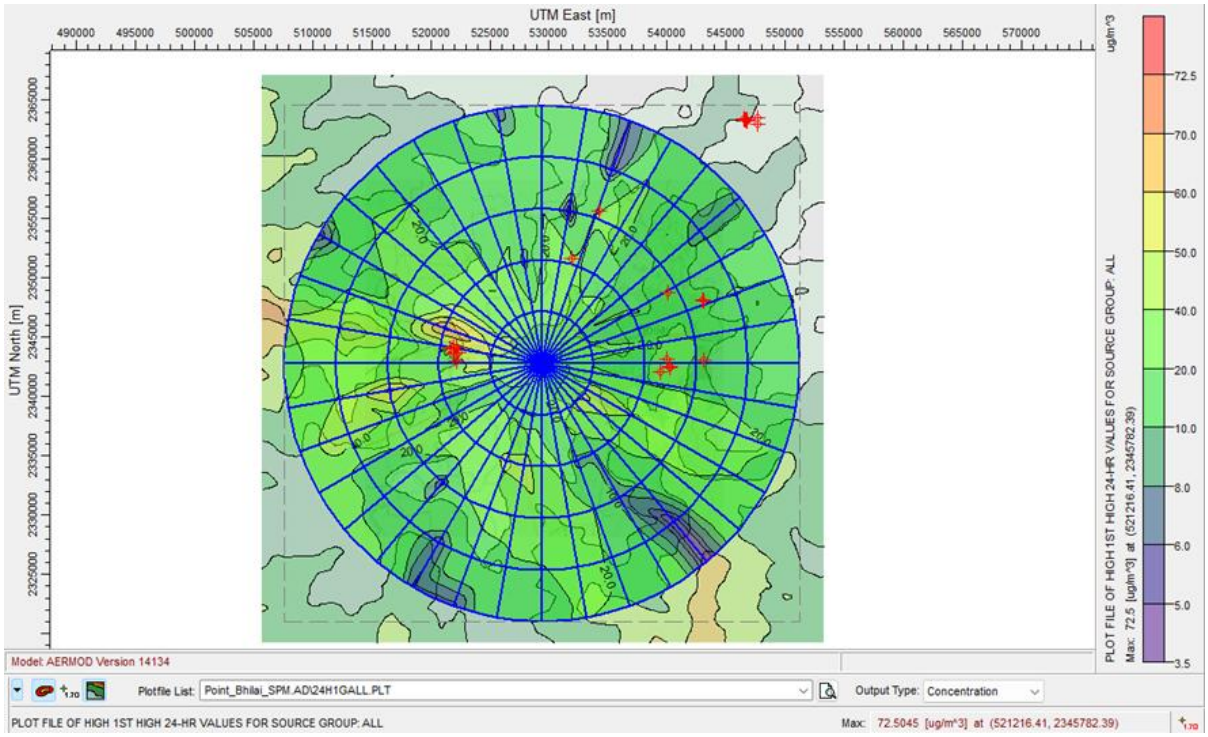


Figure2.52: Point source isopleths of SPM for 24 hr at Bhilai 15 km radius region.

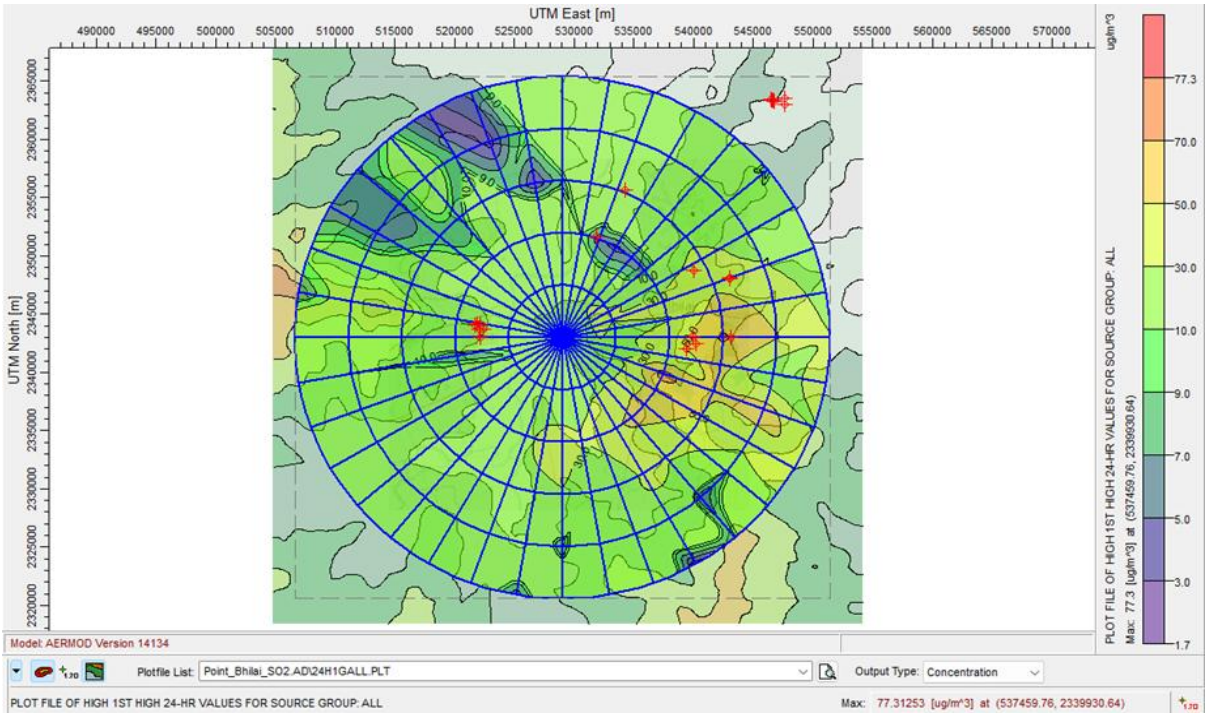


Figure 2.53: Point source isopleths of SO_2 for 24 hr at Bhilai 15 km radius region.

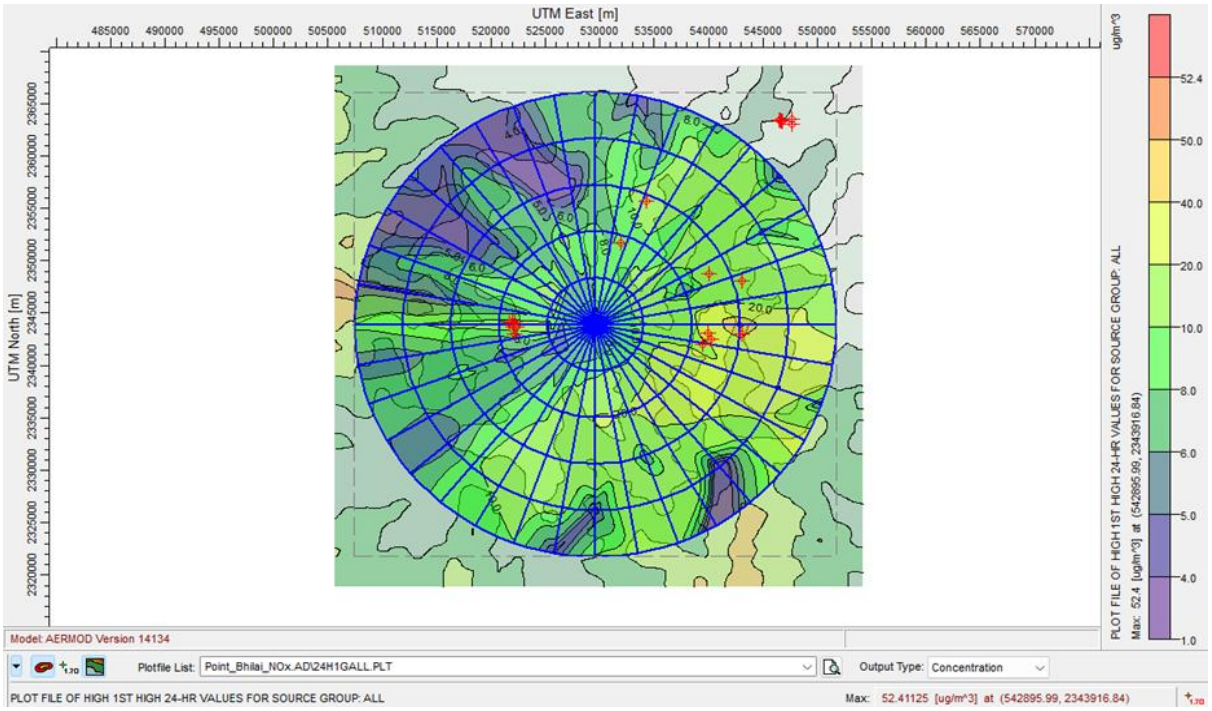


Figure 2.54: Point source isopleths of NO_x for 24 hr at Bhilai 15 km radius region.

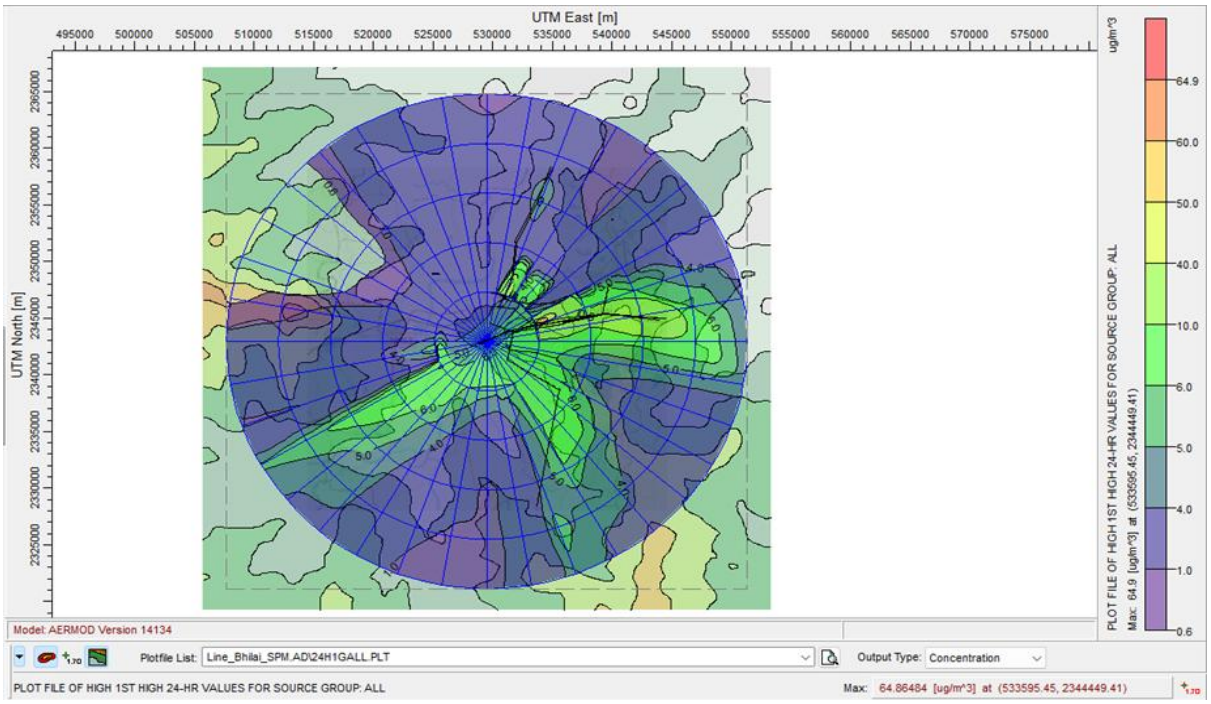


Figure 2.55: Line source isopleths of SPM for 24 hr at Bhilai 15 km radius region.

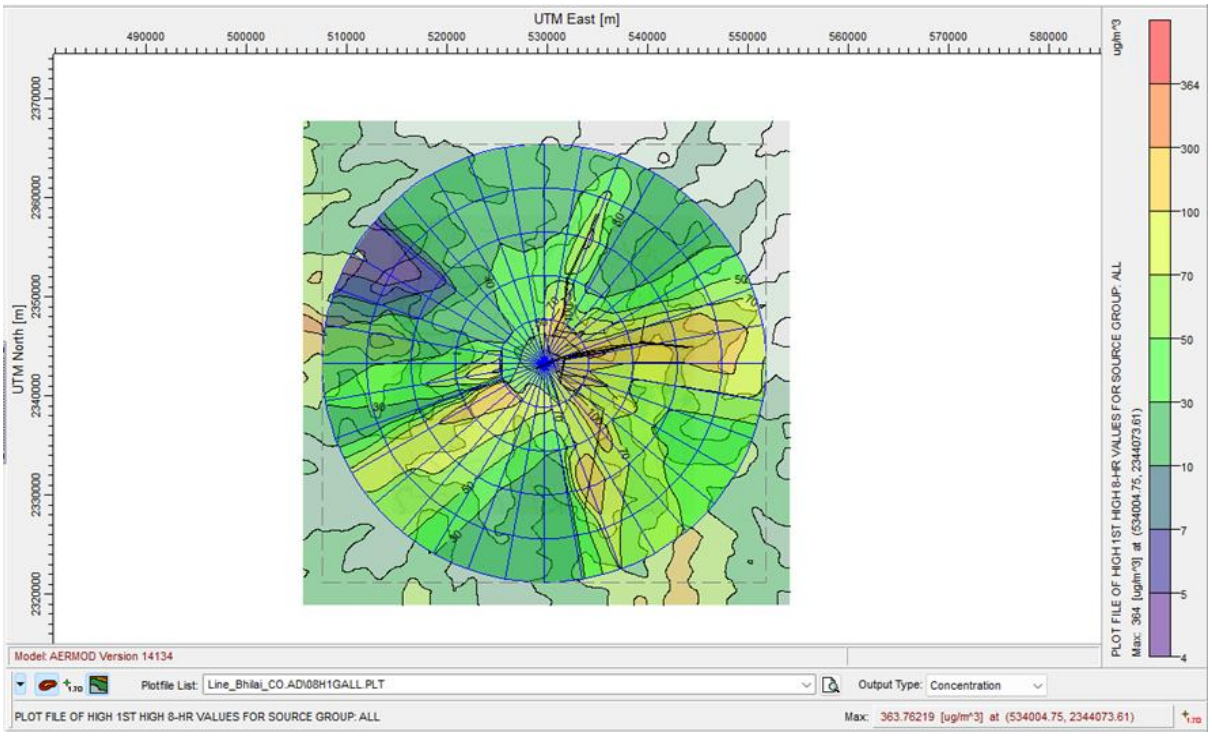


Figure 2.56: Line source isopleths of CO for 8 hr at Bhilai 15 km radius region.

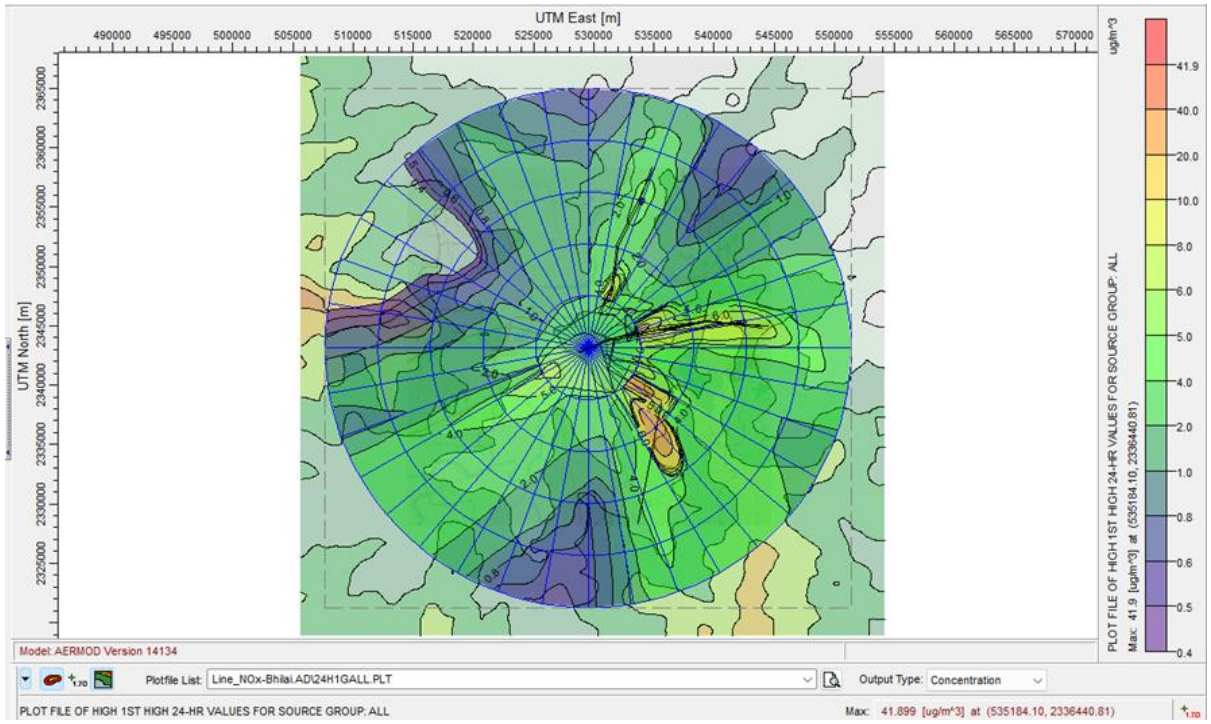


Figure 2.57: Line source isopleths of NO_x for 24 hr at Bhilai 15 km radius region.

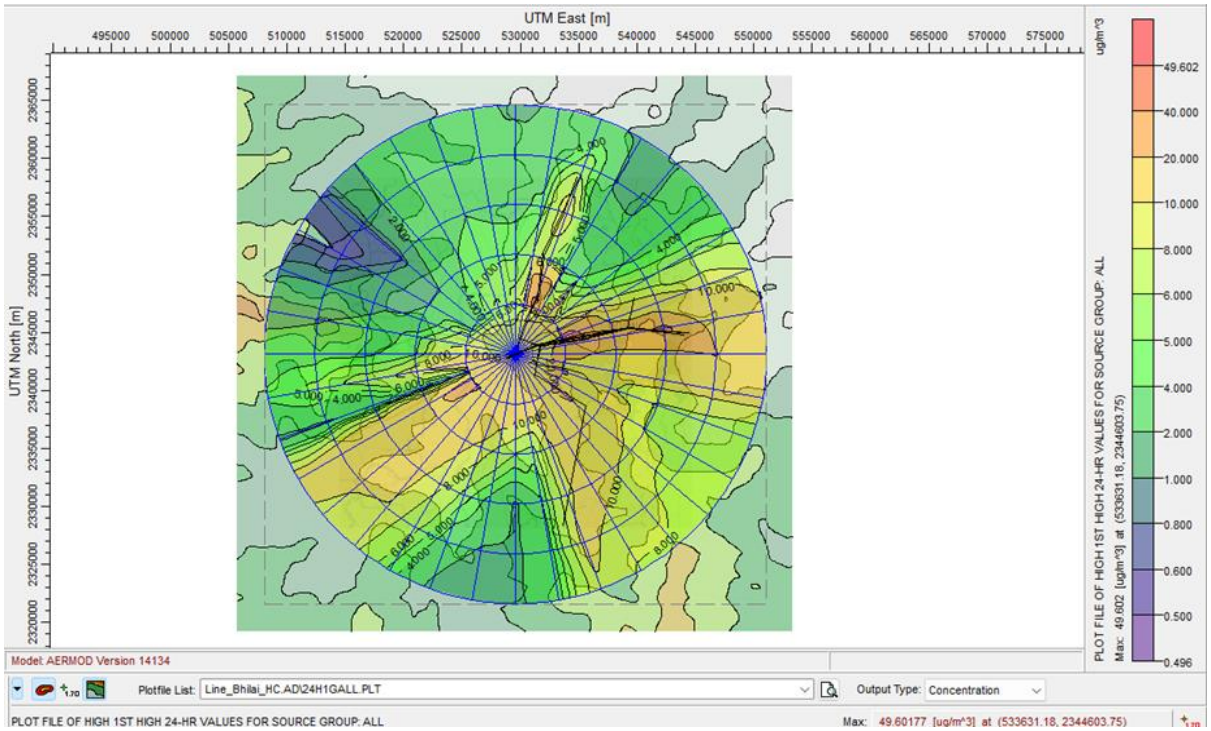


Figure 2.58: Line source isopleths of HC for 24 hr at Bhilai 15 km radius region.

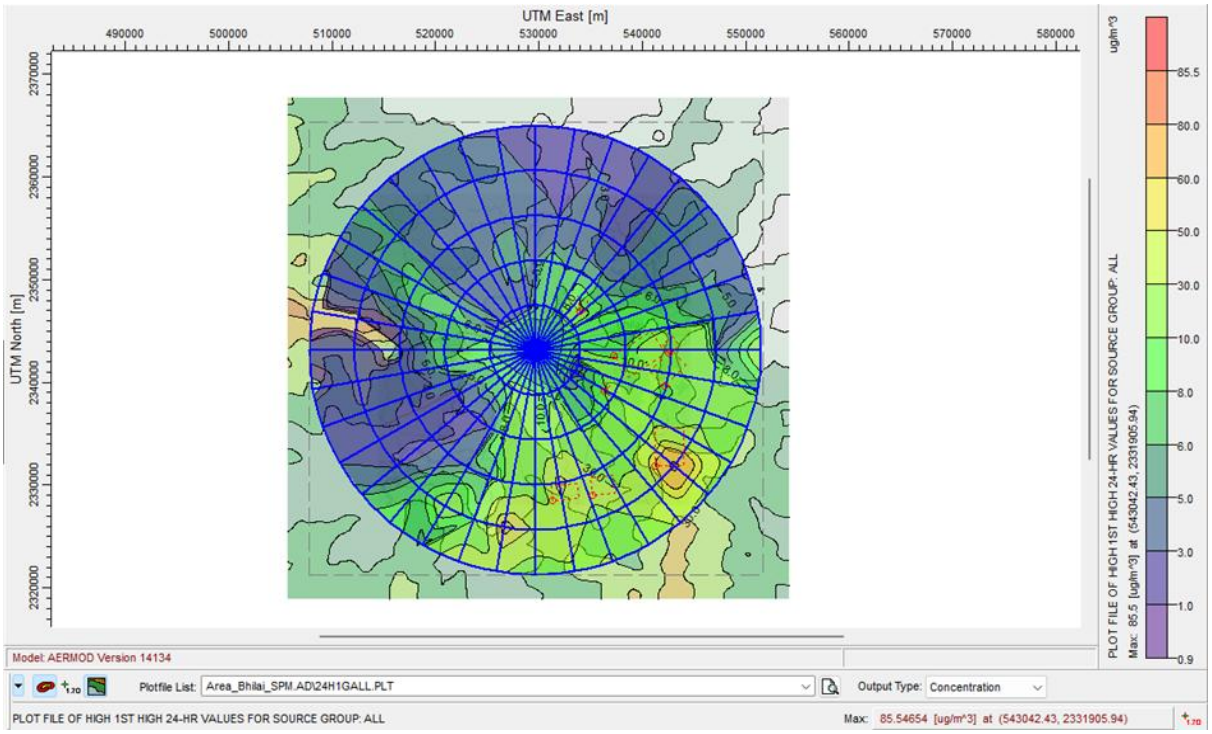


Figure 2.59: Area source isopleths of SPM for 24 hr at Bhilai 15 km radius of region.

2.4 Emission Inventory

For emission estimates, 2021 has been considered to be the base year. For transport (tailpipe emission), data available up to 2021 has been used. Detail survey/ reconnaissance of air pollution sources, activities vis a vis population and density within 2 × 2 sq. km area around the selected air quality stations in the two cities was conducted and also in many other areas that represented commercial, residential, industrial, kerb site and mixed areas. Also, various reports, research papers and map of Bhilai were consulted to understand possible types and density sources of air pollution in Bhilai. Delineation of sources was done after the initial exercise and detail activity data collection was undertaken by conducting field surveys in shortlisted areas. Also, various organizations and govt. departments were approached for collection of secondary activity data. The following major and minor sources of air pollution in Bhilai were identified and shortlisted for activity data collection (Table 2.22). Importance and weightage were 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 Bhilai.

Sl. No.	Name of Source	Importance/ Weightage	Source of identification	Justification for weightage/ other remarks
1.	Vehicle	High	Sources identified from general information, previous reports, RTO data and research papers.	There are lakhs of registered vehicles in Bhilai
2.	Industry/ Manufacturing Units	High	Sources identified from previous reports of various organizations, research papers.	There are many small and medium industrial manufacturing units in Bhilai
3.	Road Dust	High	Sources identified from previous works of various urban air pollution reports, reconnaissance and research papers.	Dust was found to be prevalent over some parts of Bhilai roads due to constant inputs from uncovered roadside soils, broken roads etc.
4.	Domestic Fuel Combustion	Low	Sources identified from reconnaissance and primary survey.	Population density in Bhilai 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	High	Sources identified from surveys, reconnaissance, previous works of morth.nic.in	Growth of construction sector including urban development activities like flyover and tunnel construction in Bhilai
6	Hot Mix Plants	Low	Sources identified from primary survey and past knowledge, Meeting with BMC officials.	Two permanent BMC controlled Hot Mix plants are operated in Bhilai 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	Sources 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 BMC 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	Sources 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 Bhilai. Many of these eateries use coal, wood, kerosene apart from LPG

10	Crematoria	Low	Sources identified from BMC websites, other web sources, and information from Stakeholders.	There are few crematoria in Bhilai.
11	Ironing vendors	Low	Source identified from primary survey.	According to initial investigation done by our group there are a few ironing vendors have been observed in Bhilai 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 Bhilai-Durg 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 Bhilai-Durg to record types of vehicles running in the city, their average mileage within BMC, 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 Bhilai.

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

Figure 2.61: Petrol pump survey in the study area.

Figure 2.62: 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 Bhilai including eateries, data on base area of construction (only for residential construction) etc. Secondary data on population was collected census database and from various other reports. The various sources of data collection are summarized in Table 2.23.

Table 2.23: Source of activity data.

Source/Sector	Source of data
Industrial/ Manufacturing units	CECB database
Transport/ Vehicular	RTO databases, Primary surveys
Restaurants/ Hotel kitchens/ Mobile food vendors	RMC database, CGPCB, Primary Survey by our team
Construction	RMC database, Other data sources
Road dust	Primary Survey, Laboratory analysis, BMC websites on roads, various reports and news
Domestic	Primary Survey, Census data on population, Data given by Food and Supplies Dept. of CG govt.
Crematoria	RMC database, Online resources
Ironing vendors	Primary Survey
Wastes burning	Primary Survey, BMC 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 2.62). 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 Bhilai 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 BMC General extent of open burning; Percent combustible in MSWs	E = F x EF Where, E = Total city emission (kg/y) F= Total waste burnt (MT/y) EF= Relevant emission factor for open burning (kg/MT)
Thermal power plant	There are Thermal Power Plants in Bhilai.	E = F x EF Where, E = Total emission (kg/y) F= Total coal burnt (MT/y) EF= Relevant emission factor for industrial boiler (kg/MT)

Brick Kilns	Previous reports mentioned present of brick kilns in Bhilai.	E = ER/F Where, E = Total emission (kg/y) F = Fuel consumption rate (kg/h) ER = Emission factor (s/h)

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

2.4.4 Collection of Activity Data

A glimpse of actual activity data use for BMC 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 (BMC)
Industry/ Manufacturing units	Fuel usage data in by industries /manufacturing units within BMC 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 Bhilai
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 BMC database on registered businesses in BMC 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 BMC. Therefore, a total of 17185 eateries are considered to be present within BMC.

Construction	BMC data on land base area (acre) under residential construction (i.e. dug up land) in 2021 was used for BMC area (271 acres). Construction land area under commercial sector was not available for BMC, 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 BMC area was arrived at by dividing BMC 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 BMC 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 BMC 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 Bhilai 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 BMC areas were provided by BMC.

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

Mini Market	Gurudwara Road
Civic Center	Chhawani Road
Civic Centre Road Street	Chawni Basti
Junwani Road	Indira Palace Road
Zonal Market Road	G.E Road
Durgpara	Risali
Nehru Nagar	
Supela Main Road	

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

Sl. No.	Vehicle Class	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	Tractor (Commercial)	136	65	33	14	23	21	15	12	119	112
2	Mobile Clinic				0	0	0	0	0	1	
3	Motor Car	8964	8797	8928	9827	1055	1197	1305	1061	1323	1509
4	Tow Truck	0							1		1
5	Vehicle Fitted With Rig	7	2	5	5	5		1	2	2	
6	Three Wheeler (Passenger)	211	254	111	274	273	110	145	44	199	448
7	M-Cycle/Scooter-With Side Car	1						2			8
8	Cash Van	0					0		6	44	73
9	Tower Wagon								2		
10	Trailer (Commercial)	3	4	15	12	21	7	6	13	28	57
11	e-Rickshaw with Cart (G)						0	1	6	122	251
12	Fire Fighting Vehicle	0	0	1			0	0	2		3
13	Trailer (Agricultural)	24	9	26	20	7	74	125	8	653	826
14	Harvester	99	73	62	67	51	38	153	85	165	84
15	Hearses						1				5
16	Excavator (NT)	341	250	222	102	113	176	248	172	206	233

17	Goods Carrier	1658	2479	2928	2784	3407	4948	3634	1738	3072	6217
18	Camper Van / Trailer	1				3	3	0	1	2	1
19	Agricultural Tractor	2641	2110	1835	1934	1726	1659	2332	2074	2025	1611
20	Three Wheeler (Goods)	9	59	71	60	73	70	61	30	140	165
21	Three Wheeler (Personal)	2	1	3	1		3		5	4	28
22	Bus	129	74	89	89	55	56	43	38	17	55
23	Vehicle Fitted With Compressor							7	3	1	
24	Maxi Cab	8	22	12	17	43	75	150	31	52	91
25	Crane Mounted Vehicle	66	51	38	67	95	125	110	64	87	74
26	M-Cycle/Scooter	7395	7759	7607	7334	8192	8130	8034	5251	5088	5963
27	Motorised Cycle (CC > 25cc)						1	3		1	1
28	Articulated Vehicle	2	5	13	145	519	469	250	176	77	672
29	Adapted Vehicle	12	18	16	21	28	33		1	13	11
30	Road Roller		2	1	1	2	4	5	3	7	
31	Moped	5821	5552	5087	6562	5884	4321	2712	1934	2324	3743
32	Animal Ambulance	0	0			1		0			
33	Educational Institution Bus	68	73	112	140	113	127	111	49	6	116
34	Armoured/Specialised Vehicle					37					20
35	Construction Equipment Vehicle	8	9	17	12		71	65	60	168	237
36	Ambulance	162	8	26	75	73	20	33	362	187	2335
37	Earth Moving Equipment	1	1	2	3	32	29	11	7	7	7
38	Fire Tenders							1			1
39	e-Rickshaw (P)				7	100	54	42	21	488	2670
40	Motor Cab	55	41	55	115	211	157	201	124	169	360

41	Private Service Vehicle	2	6	4	5	4	5	5	4	8	18
42	Dumper		0			0	1	1		6	
43	Omni Bus (Private Use)	593	1054	1141	1170	1085	760	747	361	213	164
	Total	94975	98610	96926	96869	106459	106705	104620	70572	74735	95426

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

Sl. No.	Vehicle Class	Total
1	Tractor (Commercial)	550
2	Mobile Clinic	1
3	Motor Car	111047
4	Tow Truck	2
5	Vehicle Fitted With Rig	29
6	Three Wheeler (Passenger)	2069
7	M-Cycle/Scooter-With Side Car	11
8	Cash Van	123
9	Tower Wagon	2
10	Trailer (Commercial)	166
11	e-Rickshaw with Cart (G)	380
12	Fire Fighting Vehicle	6
13	Trailer (Agricultural)	1772
14	Harvester	877
15	Hearses	6
16	Excavator (NT)	2063
17	Goods Carrier	32865
18	Camper Van / Trailer	11
19	Agricultural Tractor	19947
20	Three Wheeler (Goods)	738
21	Three Wheeler (Personal)	47
22	Bus	645
23	Vehicle Fitted With Compressor	11
24	Maxi Cab	501
25	Crane Mounted Vehicle	777
26	M-Cycle/Scooter	707569
27	Motorised Cycle (CC > 25cc)	6
28	Articulated Vehicle	2328
29	Adapted Vehicle	153
30	Road Roller	25
31	Moped	43940
32	Animal Ambulance	1
33	Educational Institution Bus	915
34	Armoured/Specialised Vehicle	57

35	Construction Equipment Vehicle	647
36	Ambulance	3281
37	Earth Moving Equipment	100
38	Fire Tenders	2
39	e-Rickshaw(P)	3382
40	Motor Cab	1488
41	Private Service Vehicle	61
42	Dumper	8
43	Omni Bus (Private Use)	7288
	Total	**50000**

Total registered vehicle in last 10 year is **50000** and these data collected from Transport Department, Bhilai RTO. Emission from various types of vehicles at different years is shown in Table 2.29 (**Source:** ARAI Emission Factor Report, January 2008)

Table 2.29 Emission from various types of vehicle 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 Bhilai. Table 2.29 presents emission estimates from Bhilai 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 2.63 and 2.64.

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

Sector	Emission (MT/y)	
	PM_{10}	**$PM_{2.5}$**
Industry	1401.58	339.2
Transport Emission	665.75	289.25
Constructions	525.59	166.87
Road Dust	484.95	104.57
Generator Sets	73.58	62.29
Wastes Burning	70.08	43.39
Brick Kilns	150.67	54.51
Domestic	101.61	38.94
Restaurants, Eateries and Hawkers	24.88	12.23
Crematoria	5.26	2.22
Total	**3503.95**	**1113.47**

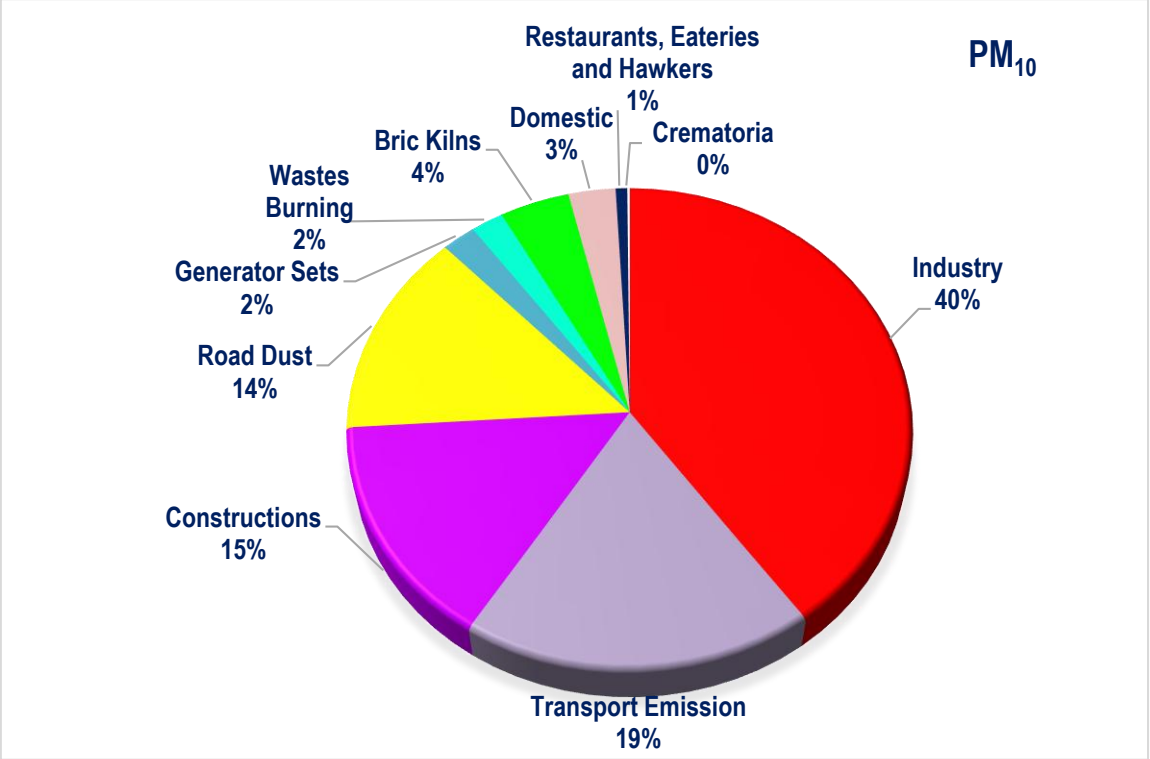


Figure 2.63: PM_{10} emission estimates (% share) from various sectors in Bhilai.

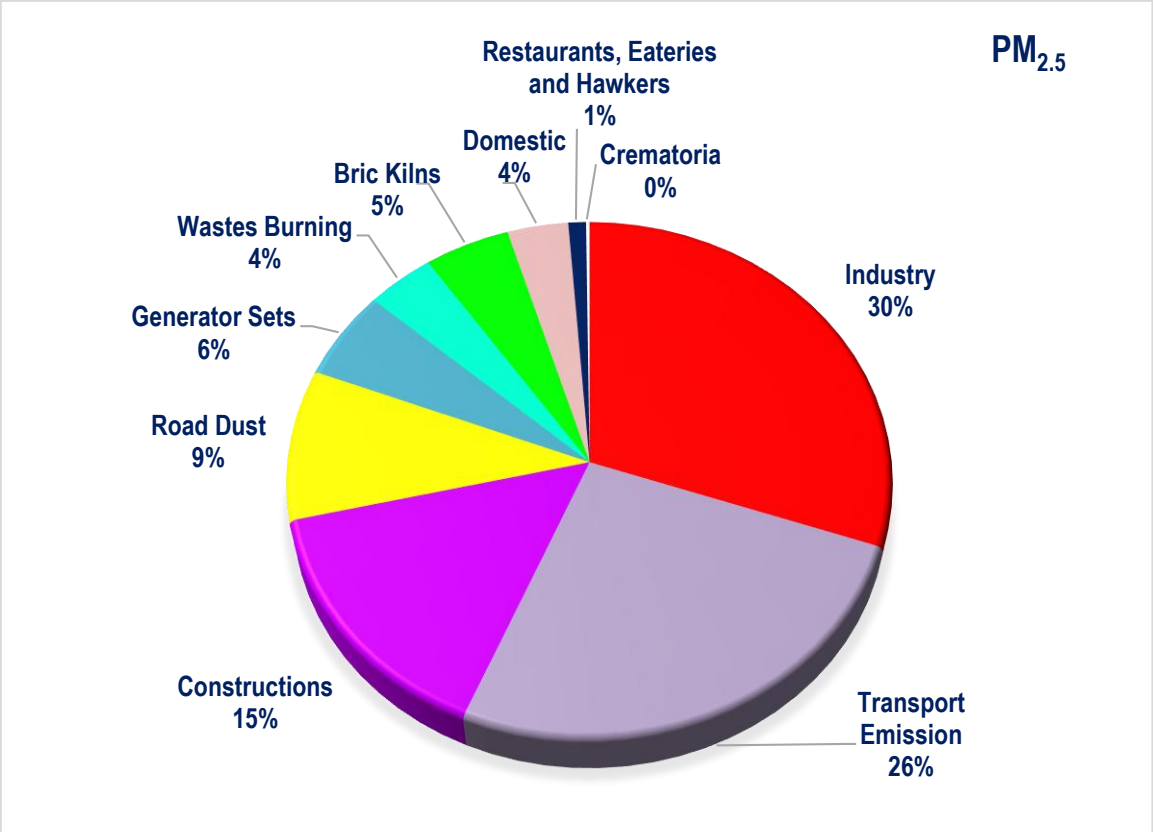


Figure 2.64: $PM_{2.5}$ emission estimates (% share) from various sectors in Bhilai.

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

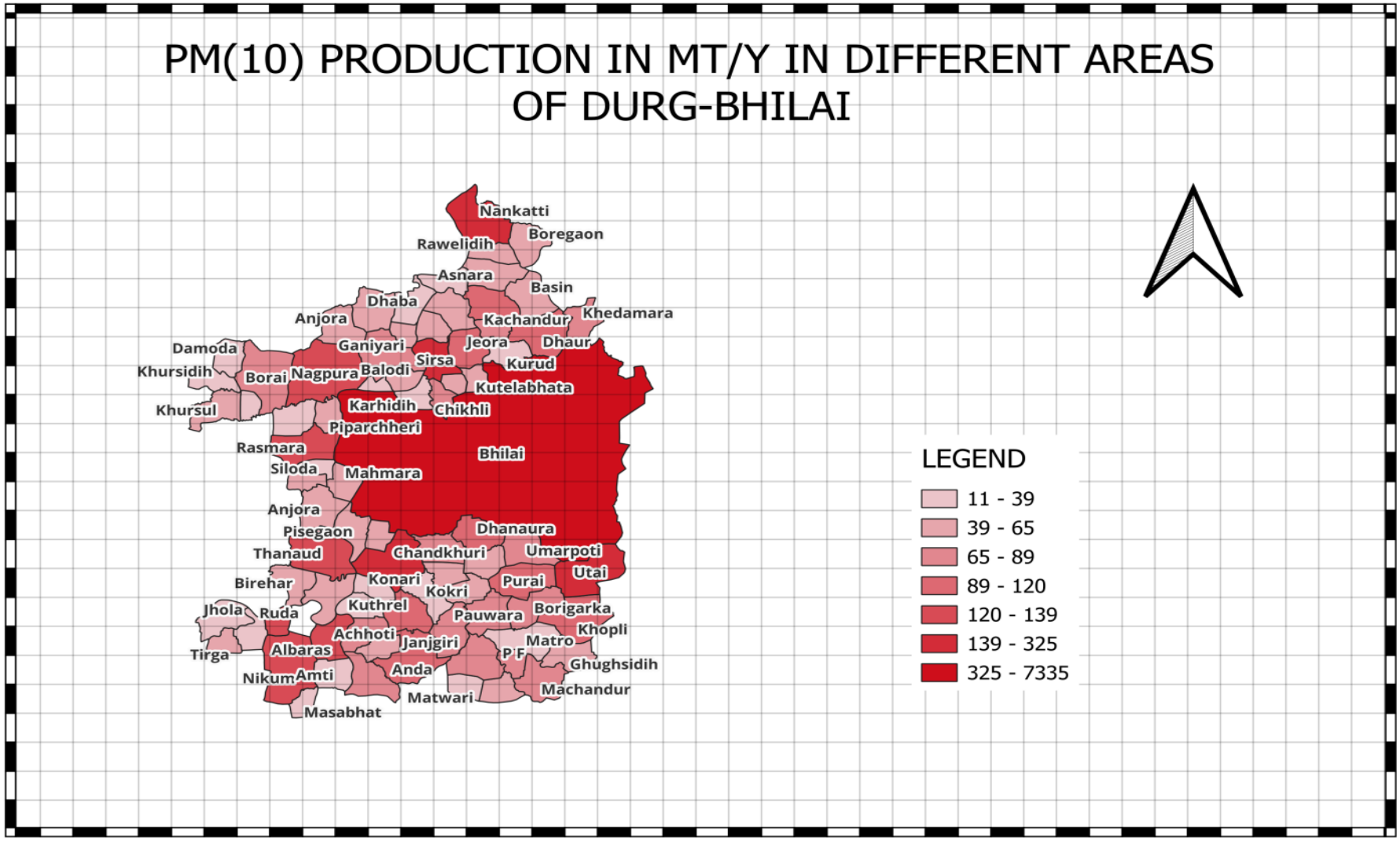


Figure 2.65: 2×2 sq. km gridded spatial distribution of PM_{10} generated from QGIS software for different areas of Bhilai.

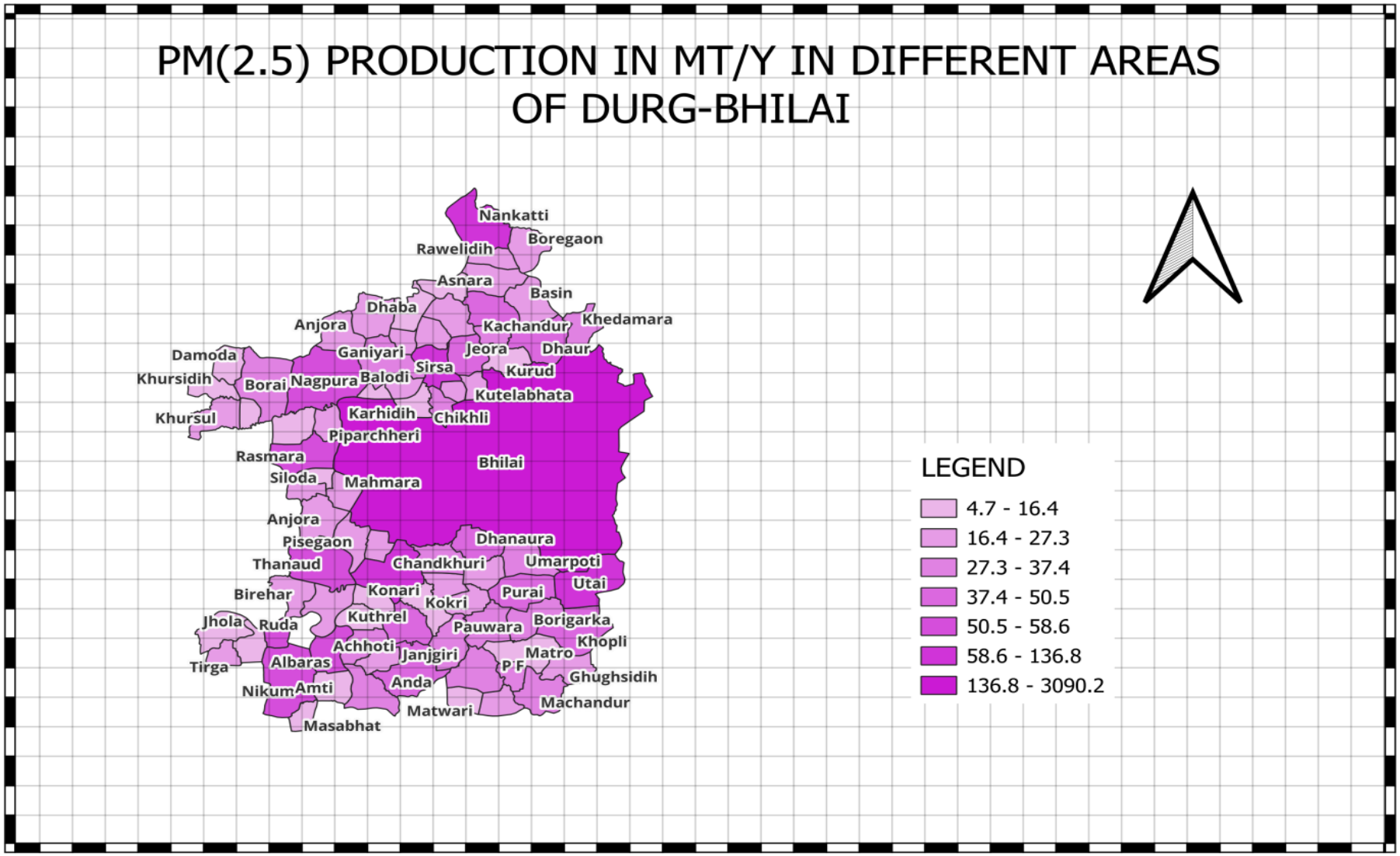


Figure 2.66: 2×2 sq. km gridded spatial distribution of $PM_{2.5}$ generated from QGIS software for different areas of Bhilai.

The air pollutant modeling showcased the concentrations of PM_{10} and $PM_{2.5}$ across the study area are presented in Figure 2.65 and 2.66 respectively. The each grid of 2×2 sq.km was prepared to divide the total Bhilai region. The interpolated maps provided insights into the spatial patterns of pollution, enabling the identification of high-risk areas. Some of the areas shows very high (> 325 MT per annum) emission which are taken as the hot spots. Moreover, for $PM_{2.5}$ this value is around 137 MT per annum. However, the hotspot distribution for both PM_{10} and $PM_{2.5}$ in Bhilai region is almost identical. Source apportionment analysis identified major pollution sources, assisting in the development of targeted control measures. The findings of this study contribute to evidence-based decision-making for air pollution control in Bhilai. Based on the study results, it is recommended to Identify and address the major sources of PM_{10} and $PM_{2.5}$ pollution through targeted control measures, including stricter emission standards, industrial regulations, and pollution control technologies.

2.4.7 Future Emission Scenarios

If the number of motorized vehicle will increase in the future than it is expected that PM emissions from transport sector could also increase in spite of advent better engines with lower emissions. It is therefore, necessary to have robust future planning on tailpipe emission control programme as well as better and clean roads to minimize road dust emissions. Numbers of highly emitting vehicular fleet like Goods Carriers are definitely on a conspicuous increasing trend apart other vehicles like commercial and private motor cars and 2-wheelers that take major share in total transport emissions. Possibility on increasing road length within Bhilai-Durg 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 Bhilai. 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.

CHAPTER-III

WATER ENVIRONMENT

3.1 Introduction

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

3.2. Materials 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 color change from blue green to reddish brown is indicated the completion of titration. Procedure for COD analysis is shown in Figure 3.1.

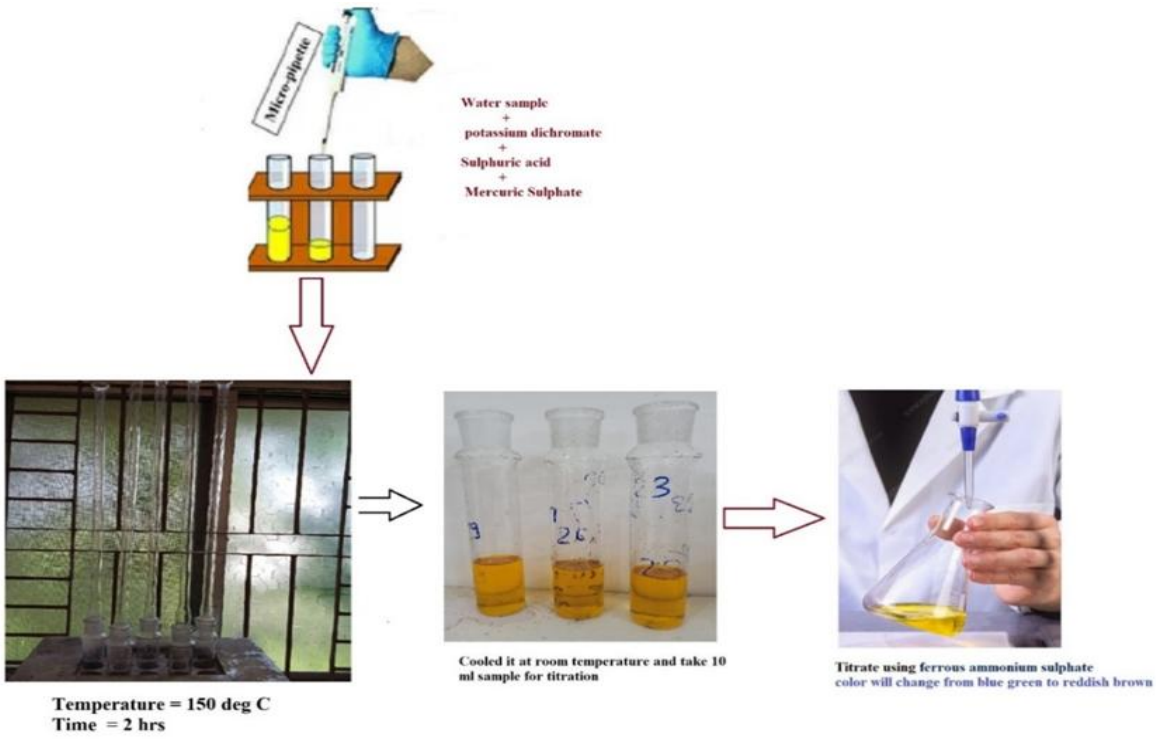


Figure 3.1: Procedure for COD analysis.

3.2.1.3 Calculation

The following are the equations which 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 = Miliequivalent weight of oxygen * 1000

3.2.2 Hardness

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

Soft (0-60 mg/L)

Medium (60-120mg/L)

Hard (120-180mg/L)

Very hard (>180mg/L)

3.2.2.1 EDTA Titration Method

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

3.2.2.2 Reagents used for Analysis

1. Buffer Solution

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

2. Inhibitor

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

3. Eriohrome Black T Indicator

4. Murexide Indicator

5. Sodium Hydroxide 2 N

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

6. Standard EDTA Solution 0.01 M

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

7. Standard Calcium Solution

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

3.2.2.3 Procedure

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

A. Total Hardness

As shown in Figure 2.23, following steps are required for the analysis of Total hardness

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

B. Calcium Hardness

As shown in Figure 2.24, following steps are required for the analysis of calcium hardness

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

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

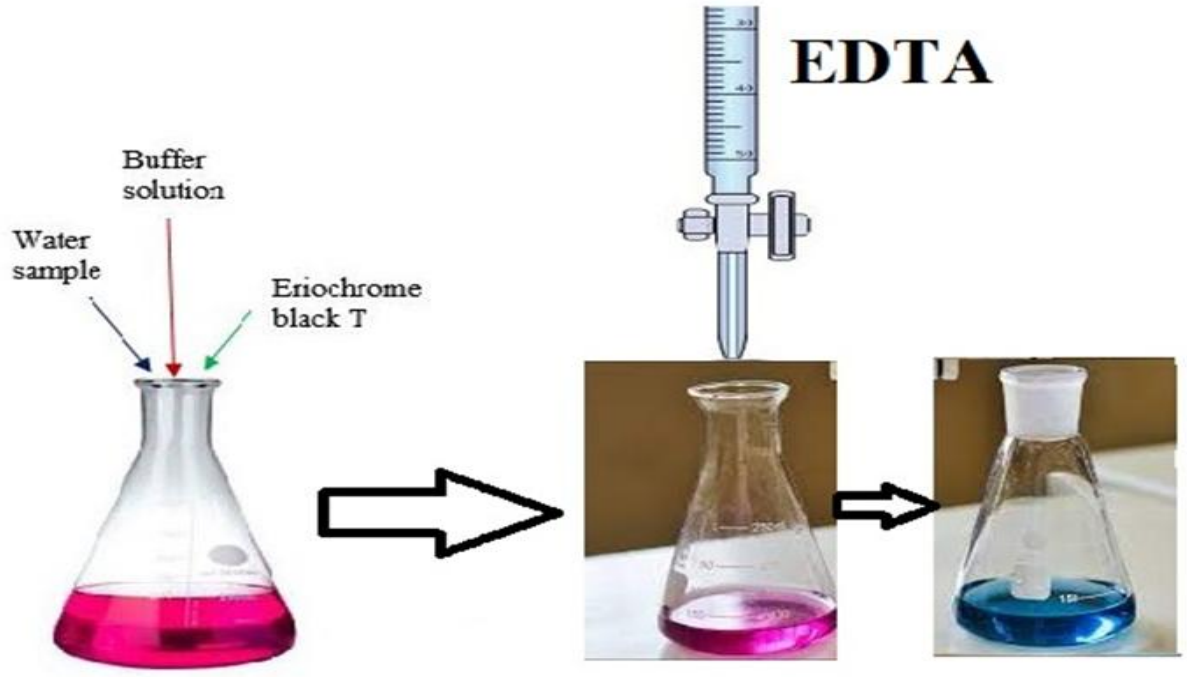


Figure 3.2: Procedure for total hardness analysis.

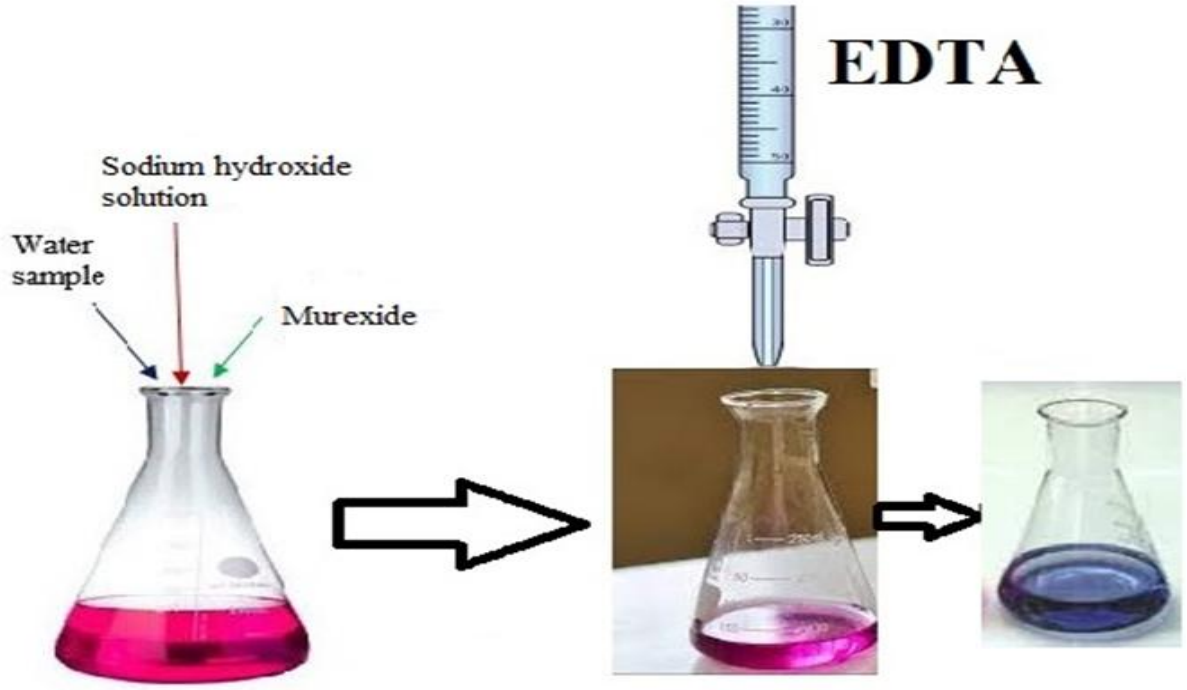


Figure 3.3: Procedure for calcium hardness analysis.

3.2.2.4 Calculation

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

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

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

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

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

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

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

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

3.2.3 Alkalinity

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

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

3.2.3.1 Reagents used for Analysis

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

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

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

2. **Phenolphthalein Indicator**

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

3. **Methyl Orange Indicator**

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

3.2.3.2 Procedure

As shown in Figure 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 endpoint **Methyl orange endpoint**

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 2.26, 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.

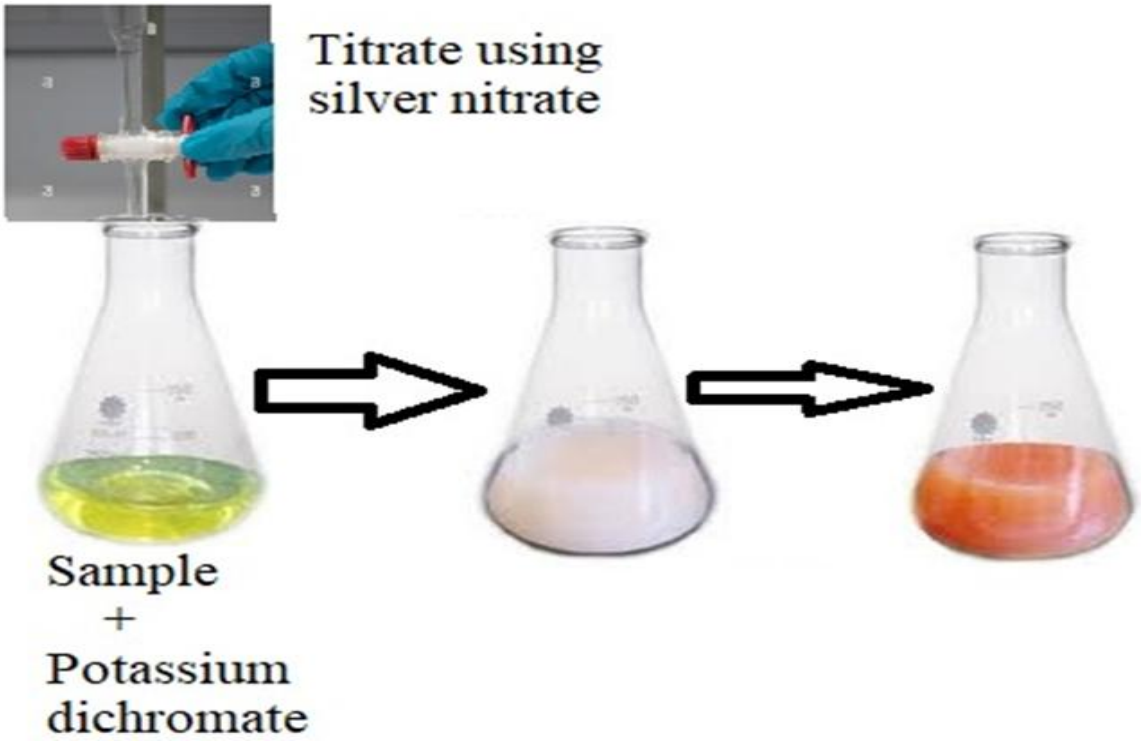


Figure 3.5: Procedure for chloride analysis.

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.

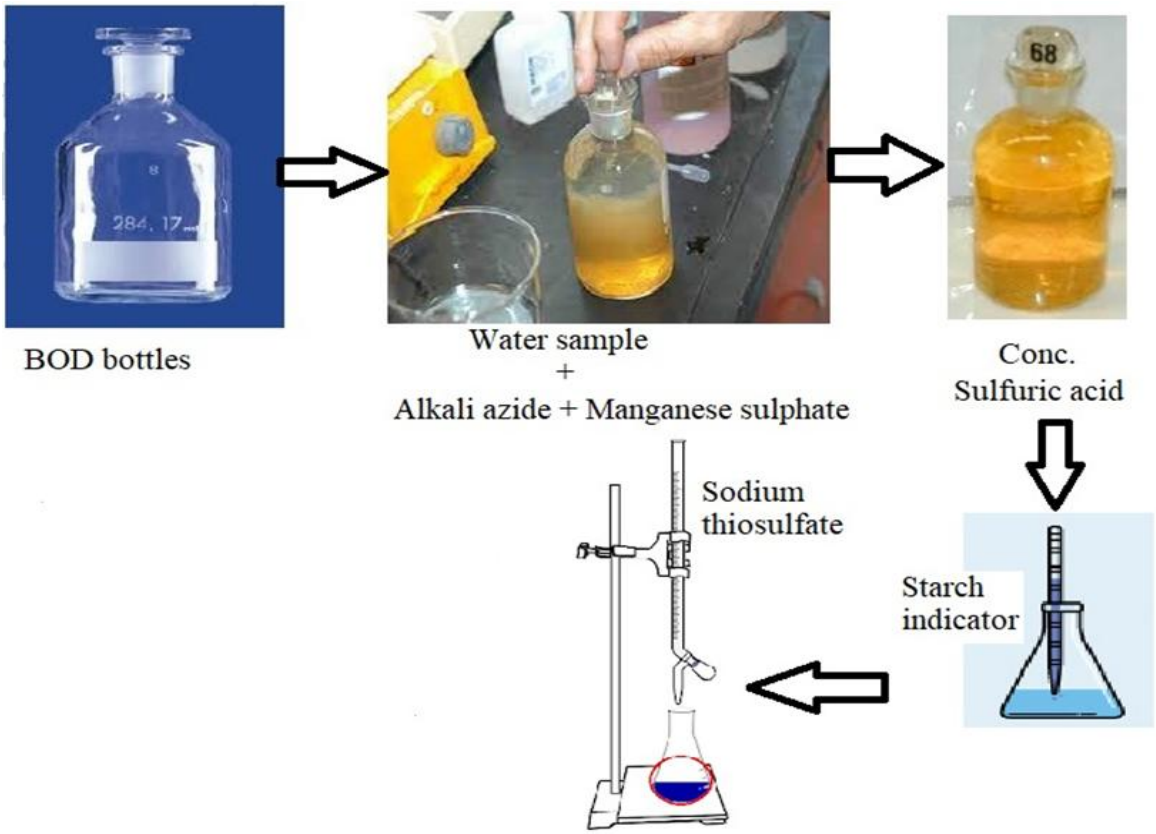


Figure 3.6: Procedure to calculate dissolved oxygen in water sample.

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 pretreatment or disposal program. The BOD value is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C and is often used as a surrogate of the degree of organic pollution of water. Guidelines obtained from CPCB are listed in Table 3.3.

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

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

3.2.6.1 Reagents used for Analysis

The following reagents are used for BOD analysis:

1. **Manganese Sulphate**

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

2. **Alkali Iodide-azide Reagent**

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

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

   b. **For supersaturated samples**

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

3. **Sulphuric acid**

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

4. **Starch Indicator**

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

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

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

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

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

3.2.6.2 Method

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

Figure 3.7: BOD incubator used in analysis.

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

3.2.6.3 Calculations

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

When dilution water is not seeded

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

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**)	%

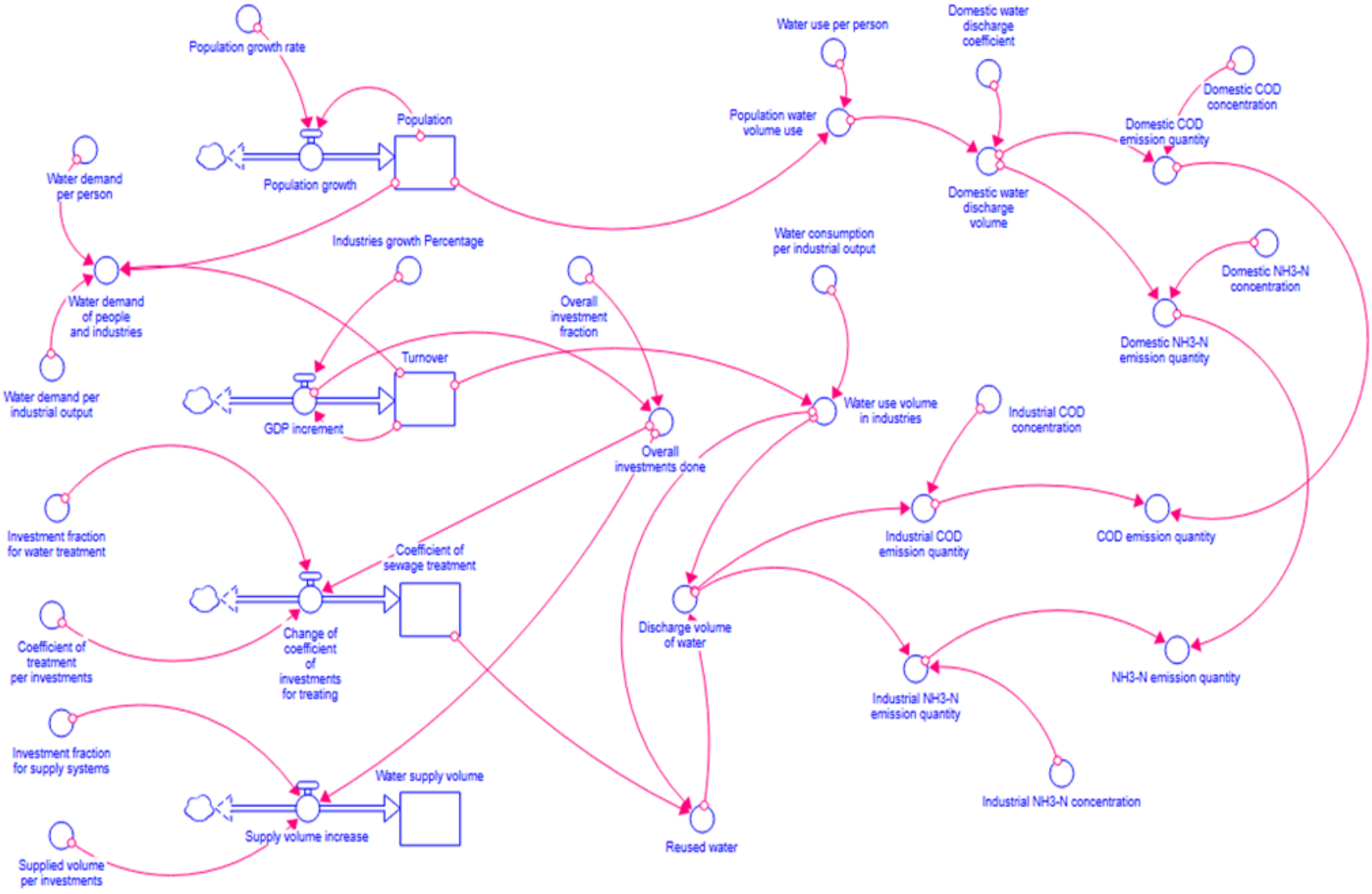


Figure 3.9: Development of water carrying capacity model by STELLA software.

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:

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

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

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

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 Bhilai.

Location ID	Location name	Latitude (°N)	Longitude (°E)
BDW001	Bhilai Power House Railway Station	21.197	81.218
BDW002	CECB Bhilai 32 Bunglow	21.200	81.220
BDW003	Durg Borai Hand Tubewell	21.201	81.221
BDW004	Sikola Talab	21.208	81.291
BDW005	Sakti Ngar Talab	21.210	81.295
BDW006	Bandha Talab	21.183	81.217
BDW007	Nalwya Nala	21.188	81.230
BDW008	Ama Talab	21.151	81.209
BDW009	Sapra Talab	21.154	81.212
BDW010	Anjora (H.P.)	21.153	81.211
BDW011	Bhabani Talab	21.153	81.211
BDW012	Mahamara Chouk (H.P.)	21.172	81.240
BDW013	Dubri Talab	21.152	81.210
BDW014	Khariyad Talab	21.155	81.219
BDW015	Ama Talab	21.158	81.220
BDW016	Nawatariya Talab	21.193	81.219
BDW017	Kukra Mar Talab	21.172	81.240
BDW018	Mahamara (H.P.)	21.188	81.199
BDW019	Shivnath River	21.180	81.252
BDW020	Mahamara (H.P.)	21.176	81.248
BDW021	Talab	21.192	81.191
BDW022	Khapli High School (H.P)	21.092	81.382
BDW023	Daboriya Talab	21.095	81.385
BDW024	Bada Gaon Talab	21.314	81.351
BDW025	Khedamara Talab (H.P)	21.274	81.388
BDW026	Daburi Talab (Ringini)	21.268	81.433
BDW027	Ringini Gaon (H.P.)	21.269	81.433
BDW028	Maroda Govt High School(H.P)	21.166	81.350
BDW029	Sitala Talab	21.161	81.348
BDW030	Bandhia talab	21.212	81.429
BDW031	Bandhia talab 2	21.289	81.643

BDW032	Gatwa talab	21.208408	81.424401
BDW033	Osho upwan talab	21.225617	81.432784
BDW034	Mata sitala mandir talab	21.230450	81.432747
BDW035	Teli talab	21.232408	81.429444
BDW036	Santi nagar talab	21.208533	81.426018
BDW037	Randhwa talab	21.228359	81.403249
BDW038	Goaiya talab	21.230195	81.403249
BDW039	Hat chowk (H.P)	21.227811	81.403593
BDW040	Suriakund talab	21.223056	81.390976
BDW041	Chhawani talab	21.226839	81.392693
BDW042	Gupta gupchup talab	21.222027	81.372563
BDW043	J.P. chowk	21.213852	81.370655
BDW044	Camp 2 talab	21.214740	81.370947
BDW045	Camp 1 talab	21.214857	81.363487
BDW046	Saraswati talab	21.208600	81.363086
BDW047	Kolayani talab	21.22017	81.7377200
BDW048	Boro talab	21.22017	81.7377200
BDW049	Dari talab	21.22017	81.7377200
BDW050	Dari (H.P.)	21.22017	81.7377200
BDW051	Risali talab	21.22017	81.7377200
BDW052	Purina talab	21.22017	81.7377200
BDW053	Tongia talab	21.22017	81.7377200
BDW054	Khanki talab	21.22017	81.7377200
BDW055	Sitla talab	21.22017	81.7377200
BDW056	Tongia (H.P.)	21.22017	81.7377200
BDW057	Khandan talab	21.22017	81.7377200
BDW058	Nawa talab	21.22017	81.7377200
BDW059	Nagin talab	21.22017	81.7377200
BDW060	Nagin (H.P.) kumari	21.22017	81.7377200
BDW061	Urban primary health centre (H.P)	21.232430	81.457798
BDW062	Charoda basti	21.231886	81.455536
BDW063	Sangam chowk (H.P.)	21.234070	81.456331
BDW064	Ringni talab	21.268148	81.433453
BDW065	Ringni (H.P.)	21.268386	81.433413
BDW066	Mohadi talab	21.281890	81.421190
BDW067	Dobri talab	21.268059	81.440087
BDW068	Khamba talab	21.275205	81.403352

BDW069	Khedamara (H.P.)	21.273829	81.387768
BDW070	Natta talab	21.280212	81.381356
BDW071	Basin talab	21.277818	81.377920
BDW072	Bajrang talab	21.296828	81.330831
BDW073	Bandha talab	21.319870	81.354894
BDW074	Santoshi talab	21.272191	81.448670
BDW075	Khapri alisas pipradih (H.P)	21.238056	81.305342
BDW076	Sitala talab	21.234921	81.307063
BDW077	Dabri talab	21.232929	81.302632
BDW078	Dabri tariya talab	21.232929	81.302632
BDW079	Nokta talab	21.238357	81.310252
BDW080	Khapri grampanchayat (H.P)	21.237187	81.312418
BDW081	Alabad talab	21.229891	81.315357
BDW082	Sitala talab	21.230436	81.315803
BDW083	Gandhi sarebor talab	21.227771	81.317245
BDW084	Sitala talab 1	21.221971	81.318298
BDW085	Sitala talab 2	21.221767	81.319423
BDW086	Khamariya basti (H.P.)	21.230579	81.314479
BDW087	Kureta talab	21.235462	81.315328
BDW088	Kutela bhata talab	21.237470	21.237470
BDW089	Doron dabri talab	21.253673	81.304407
BDW090	Dabri talab	21.256953	81.301717
BDW091	Sitala talab	21.257069	81.301050
BDW092	Dhubatariya talab	21.257069	81.301050
BDW093	Sitala talab	21.254732	81.309855
BDW094	Dabri talab	21.256918	81.310290
BDW095	Khadan talab	21.264662	81.306730
BDW096	Jevra sira	21.267276	81.309511
BDW097	Khadan talab 1	21.267276	81.309511
BDW098	Khadan talab 2	21.268304	81.305348
BDW099	Bhata ganv (H.P)	21.269916	81.310543
BDW100	BHATAGANV 1	21.278574	81.313638
BDW101	Ama talab	21.270757	81.301493
BDW102	Aman ganv (H.P.)	21.269916	81.310543
BDW103	Aman pathu talab	21.270674	81.301480
BDW104	Sirsa talab	21.269916	81.31054
BDW105	Sitala taria talab	21.259406	81.271671

BDW106	Ganga talab	21.304005	81.326705
BDW107	Samoda ganv	21.276816	81.315357
BDW108	Sitla mandir talab	21.210212	81.295123
BDW109	Shakti nagar	21.209538	81.293204
BDW110	Sitala talab	21.208171	81.290973
BDW111	Dhamdha village (H.P.)	21.204360	81.290709
BDW112	Kailash nagar talab	21.201704	81.295750
BDW113	Kailash mandir (H.P.)	21.201534	81.292210
BDW114	Titursiha durg (H.P.)	21.200098	81.292301
BDW115	Dusri talab (durg)	21.197897	81.302358
BDW116	Harmabandh talab	21.211944	81.279689
BDW117	Khan talab (Shankar nagar)	21.195555	81.272759
BDW118	Sitala nagar talab	21.198393	81.272759
BDW119	Koshta talab 2	21.198740	81.272181
BDW120	Street 8 sector 4 (H.P.)	21.195116	81.366675
BDW121	MR/ Sector 4(H.P.)	21.192721	81.363388
BDW122	Sector 5	21.193622	81.353869
BDW123	Shivnath talab	21.197980	81.333739
BDW124	Manav seva kendra	21.190935	81.315629
BDW125	Bandha talab	21.183248	81.268838
BDW126	Ganesh para village (H.P.)	21.185911	81.2715841
BDW127	Shiv para (H.P.)	21.191540	81.270693
BDW128	Math para (H.P.)	21.191506	81.269331
BDW129	Babu talab	21.190500	81.268229
BDW130	Tapu talab	21.192397	81.268188
BDW131	Naya talab	21.192397	81.268188
BDW132	Durg (H.P.)	21.190406	81.812656
BDW133	Bhanga diya talab (durg)	21.191709	81.264572
BDW134	Kharia talab (durg)	21.190230	81.264027
BDW135	Rajiv nagar (H.P.) Durg	21.194493	81.263867
BDW136	Dungia para talab (durg)	21.195128	81.264734
BDW137	Baghera village	21.200840	81.263286
BDW138	Pachri para talab	21.201684	81.263092
BDW139	Baghera (H.P.)	21.195626	81.264304
BDW140	Pancha steel nagar(talab)	21.193251	81.259503
BDW141	Pancha steel nagar (H.P.)	21.193417	81.260115

3.3.1 Heavy Metals in Water

Percentage of heavy metals present in different water samples are presented in Figure 3.10. Water samples were from Bhilai-Durg areas, acidified with concentrated nitric acid (Conc. HNO_3) and filtered. Each collected samples were analyzed by AAS and ICP-MS, respectively. Water samples have been collected from different sampling stations of Durg and Bhilai in different seasons. But we don't find any seasonal effect on water metal ions variation. Compositional or percentile variation have been observes in station of place change. Fe has been found as major heavy metal in every sample and is about 78%. Water samples from Durg and Bhilai also contain 'Zn' (14%). Some other metals like; 'Cu', 'Cr', 'Ni' and 'Cd' are also found, but amount is negligible and below toxicity level. The main problem in the sampling station of Durg and Bhilai area is 'As'. 'As' has been detected in every water sample and sometimes it's near to the toxicity level. Beside this 'Pb' is also present in almost every sample and concentration is also very close to the permeable limit. In Figure 3.10, here we have found Pb as 2%. This is alarming for local inhabitants.

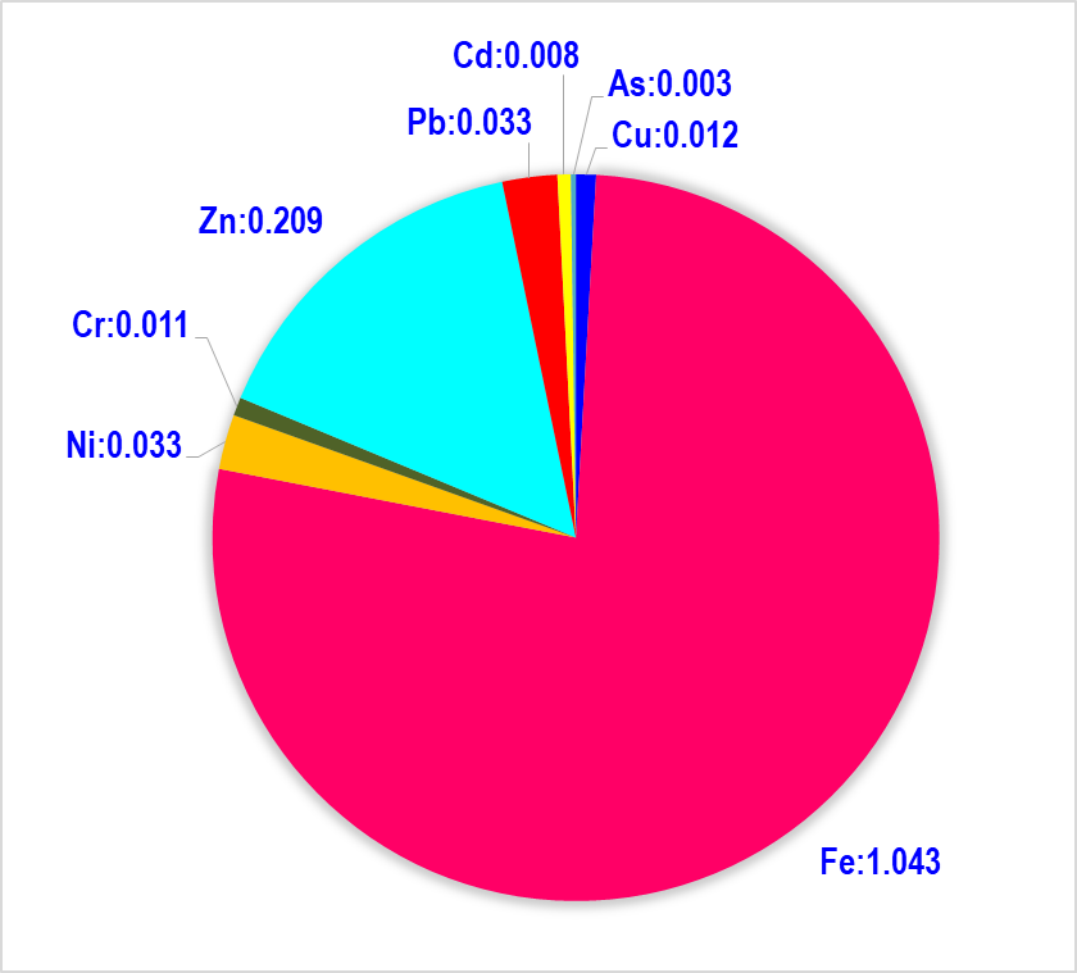


Figure 3.10: Average concentration (ppm) different metals found in different water samples.

3.3.2 Physical and Chemical of Water Samples

Water sample collected from different location in Bhilai in all season. Five parameter i.e. Temperature, pH, Salt, TDS, Conductivity is measured by conductivity or PH meter, where salt and TDS value are very high in almost all the sample. Conductivity of these sample ranges from 300 to 1000 (µs/cm). Then experiment was done to calculate the COD, DO, Alkalinity, chloride, hardness of the water. From the Figure 3.11 we found that hardness in all the sample is within the limit except these four sample i.e. BDW 7, 8, 18 where values are more than 180 mg/l. COD level is within the limit of 200 mg/l. DO level was found within 10 mg/l. Alkalinity range of sample were found to be within 200 mg/l except some sample which shows high alkalinity of 290 mg/l. COD level is within the limit of 200mg/l. DO level was found within 10 mg/l. alkalinity range of sample were found to be within 200 mg/l except some sample which shows high alkalinity of 290 mg/l. However, high alkalinity is good for health but within the limit. BOD level is also higher than the limit which is 1 mg/l. Chloride values of sample are within 170 mg/l. High chloride value in water means high pollution, and also high chloride in human body can kidney stone. We can see the details in statistical analysis.

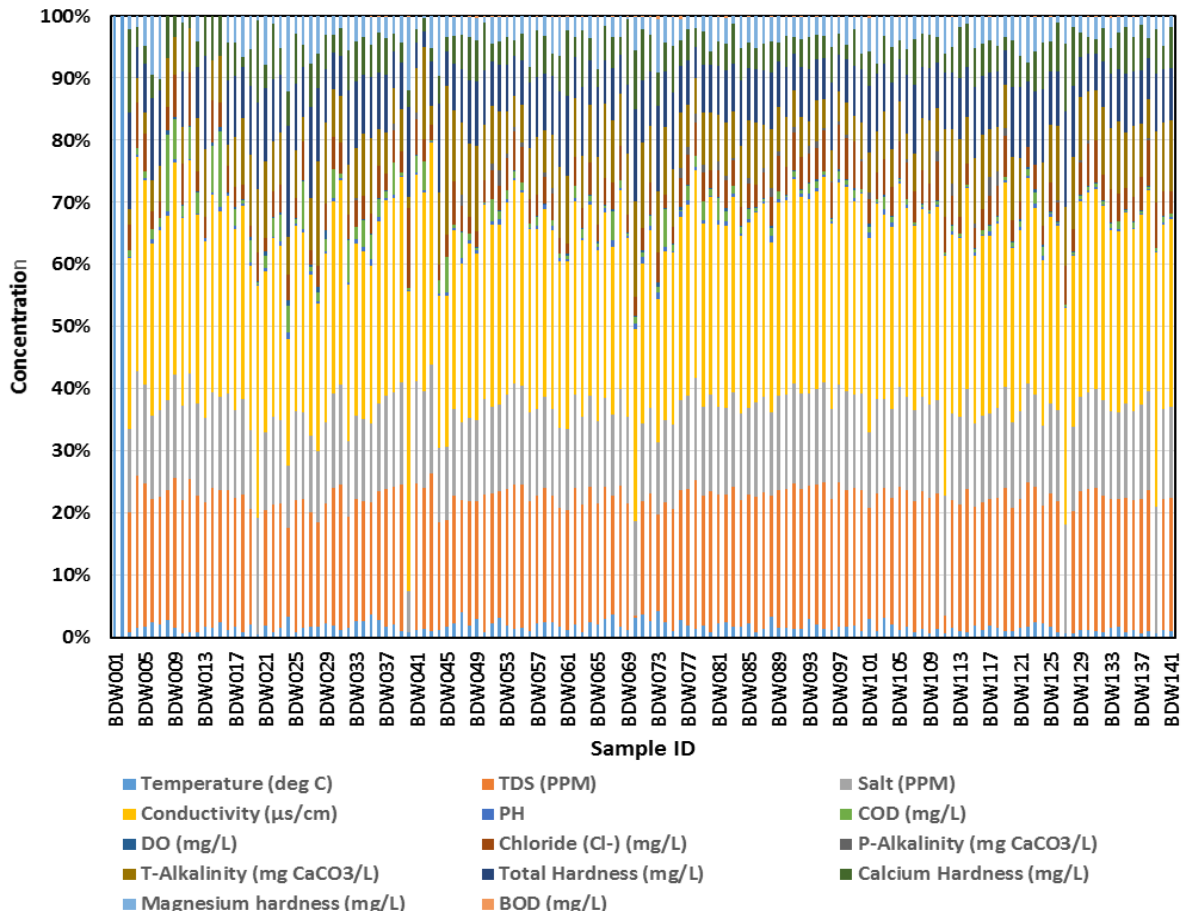


Figure 3.11: Different parameter percentile plot of different water samples collected from Bhilai (Marked as BDW).

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 Bhilai during study period.

	Temperature (° C)	TDS (PPM)	Salt (PPM)	Conductivity (µs/cm)	pH	COD (mg/L)	DO (mg/L)
Max	34.5	943	860	1877	9.33	160	19.6
Min	20.5	1.04	68.5	139.7	5.65	1	0.6
Average	28.75	399.11	299.57	622.04	7.60	28.51	3.23
STDV	2.61	207.60	158.22	334.02	0.74	30.70	2.63
Mean	28.75	399.11	299.57	622.04	7.60	28.51	3.23
CV	0.090	0.520	0.520	0.530	0.09	1.07	0.81
	Chloride (Cl^-) (mg/L)	**P Alkalinity (mg $CaCO_3$/L)**	**T Alkalinity (mg $CaCO_3$/L)**	**Total Hardness (mg/L)**	**Ca Hardnes (mg/L)**	**Mg hardnes (mg/L)**	**BOD**
Max	500	44	518	644	610	460	5.2
Min	21	0	38	52	26	6	0.1
Average	93.07	4.97	171.60	186.73	107.55	77.74	1.55
STDV	65.23	9.28	101.96	113.25	94.56	57.67	1.25
Mean	93.07	4.97	171.60	186.73	107.52	77.74	1.55
CV	0.700	1.86	0.59	0.60	0.87	0.74	0.80

3.3.4 Water Environmental Carrying Capacity Assessment beyond 10 Years

3.3.4.1 Simulation Result of Indicated Value

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

Table 3.7 (I): Result of simulations for the indicated values of 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	705000	30000	1500000	2.12	606
2022	0.802	713868	30606	1521211	2.16	618
2023	0.804	722847	31224	1542851	2.21	631
2024	0.806	731939	31855	1564928	2.25	644
2025	0.809	741146	32499	1587451	2.30	657
2026	0.811	750469	33155	1610429	2.34	670
2027	0.813	759908	33825	1633872	2.39	683
2028	0.816	769467	34508	1657787	2.44	697
2029	0.818	779145	35205	1682186	2.49	711
2030	0.821	788946	35917	1707078	2.54	726
2031	0.823	798870	36642	1732473	2.59	740
2032	0.826	808918	37382	1758381	2.64	755
2033	0.828	819093	38137	1784812	2.70	770
2034	0.831	829396	38908	1811777	2.75	786
2035	0.834	839829	39694	1839286	2.81	802
2036	0.837	850392	40496	1867352	2.86	818
2037	0.840	861089	41314	1895984	2.92	835
2038	0.843	871920	42148	1925195	2.98	851
2039	0.845	882888	43000	1954996	3.04	869
2040	0.849	893993	43869	1985399	3.10	886
2041	0.852	905238	44755	2016416	3.16	904
2042	0.855	916624	45659	2048060	3.23	922
2043	0.858	928154	46581	2080343	3.29	941
2044	0.861	939829	47522	2113278	3.36	960
2045	0.865	951650	48482	2146878	3.43	979
2046	0.868	963621	49462	2181157	3.50	999
2047	0.872	975742	50461	2216129	3.57	1019
2048	0.875	988015	51480	2251807	3.64	1040
2049	0.879	1000443	52520	2288206	3.71	1061
2050	0.883	1013027	53581	2325340	3.79	1082
2051	0.886	1025769	54664	2363225	3.87	1103

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)
8868	21211	39783	0.0005	60	0.065	360000
8979	21640	40157	0.0005	60	0.065	363377
9092	22077	40521	0.0005	60	0.065	366664
9207	22523	40874	0.0005	60	0.065	369851
9322	22978	41215	0.0005	60	0.065	372931
9440	23442	41543	0.0005	60	0.065	375894
9558	23916	41858	0.0005	60	0.065	378730
9679	24399	42157	0.0005	60	0.065	381429
9800	24892	42440	0.0005	60	0.065	383980
9924	25395	42706	0.0005	60	0.065	386373
10049	25908	42953	0.0005	60	0.065	388595
10175	26431	43180	0.0005	60	0.065	390634
10303	26965	43386	0.0005	60	0.065	392478
10433	27510	43568	0.0005	60	0.065	394111
10564	28065	43726	0.0005	60	0.065	395521
10697	28632	43857	0.0005	60	0.065	396692
10831	29211	43961	0.0005	60	0.065	397608
10967	29801	44035	0.0005	60	0.065	398253
11105	30403	44077	0.0005	60	0.065	398610
11245	31017	44085	0.0005	60	0.065	398660
11386	31644	44058	0.0005	60	0.065	398385
11530	32283	43992	0.0005	60	0.065	397764
11675	32935	43887	0.0005	60	0.065	396776
11822	33600	43738	0.0005	60	0.065	395401
11970	34279	43545	0.0005	60	0.065	393614
12121	34972	43304	0.0005	60	0.065	391393
12273	35678	43012	0.0005	60	0.065	388711
12428	36399	42667	0.0005	60	0.065	385543
12584	37134	42265	0.0005	60	0.065	381862
12742	37884	41804	0.0005	60	0.065	377638

Note: Chemical Oxygen Demand (COD)

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

Domestic COD concentration (kg/m^3)	Domestic COD emission quantity (kg)	Domestic water discharge coefficient	Domestic water discharge volume (m^3)	Domestic NH_3-N concentration (Kg/m^3)	Domestic NH_3-N emission quantity (kg)
0.005	183	0.8	36660	0.003	110
0.005	186	0.8	37121	0.003	111
0.005	188	0.8	37588	0.003	113
0.005	190	0.8	38061	0.003	114
0.005	193	0.8	38540	0.003	116
0.005	195	0.8	39024	0.003	117
0.005	198	0.8	39515	0.003	119
0.005	200	0.8	40012	0.003	120
0.005	203	0.8	40516	0.003	122
0.005	205	0.8	41025	0.003	123
0.005	208	0.8	41541	0.003	125
0.005	210	0.8	42064	0.003	126
0.005	213	0.8	42593	0.003	128
0.005	216	0.8	43129	0.003	129
0.005	218	0.8	43671	0.003	131
0.005	221	0.8	44220	0.003	133
0.005	224	0.8	44777	0.003	134
0.005	227	0.8	45340	0.003	136
0.005	230	0.8	45910	0.003	138
0.005	232	0.8	46488	0.003	139
0.005	235	0.8	47072	0.003	141
0.005	238	0.8	47664	0.003	143
0.005	241	0.8	48264	0.003	145
0.005	244	0.8	48871	0.003	147
0.005	247	0.8	49486	0.003	148
0.005	251	0.8	50108	0.003	150
0.005	254	0.8	50739	0.003	152
0.005	257	0.8	51377	0.003	154
0.005	260	0.8	52023	0.003	156
0.005	263	0.8	52677	0.003	158
0.005	267	0.8	53340	0.003	160

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	0.0125	0.11	39600	0.095	34200
0.02	0.0125	0.11	39972	0.095	34521
0.02	0.0125	0.11	40333	0.095	34833
0.02	0.0125	0.11	40684	0.095	35136
0.02	0.0125	0.11	41022	0.095	35428
0.02	0.0125	0.11	41348	0.095	35710
0.02	0.0125	0.11	41660	0.095	35979
0.02	0.0125	0.11	41957	0.095	36236
0.02	0.0125	0.11	42238	0.095	36478
0.02	0.0125	0.11	42501	0.095	36705
0.02	0.0125	0.11	42745	0.095	36917
0.02	0.0125	0.11	42970	0.095	37110
0.02	0.0125	0.11	43173	0.095	37285
0.02	0.0125	0.11	43352	0.095	37441
0.02	0.0125	0.11	43507	0.095	37575
0.02	0.0125	0.11	43636	0.095	37686
0.02	0.0125	0.11	43737	0.095	37773
0.02	0.0125	0.11	43808	0.095	37834
0.02	0.0125	0.11	43847	0.095	37868
0.02	0.0125	0.11	43853	0.095	37873
0.02	0.0125	0.11	43822	0.095	37847
0.02	0.0125	0.11	43754	0.095	37788
0.02	0.0125	0.11	43645	0.095	37694
0.02	0.0125	0.11	43494	0.095	37563
0.02	0.0125	0.11	43298	0.095	37393
0.02	0.0125	0.11	43053	0.095	37182
0.02	0.0125	0.11	42758	0.095	36928
0.02	0.0125	0.11	42410	0.095	36627
0.02	0.0125	0.11	42005	0.095	36277
0.02	0.0125	0.11	41540	0.095	35876
0.02	0.0125	0.11	41013	0.095	35420

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

Overall investment fraction	Investment fraction for supply systems	Investment fraction for treatment	Overall investments done (Lakh Rupees)	NH3-N emission quantity (kg)	Population water volume use (m^3)
0.014	0.5	0.5	8.400	34310	45825
0.014	0.5	0.5	8.570	34632	46401
0.014	0.5	0.5	8.743	34946	46985
0.014	0.5	0.5	8.919	35250	47576
0.014	0.5	0.5	9.100	35544	48174
0.014	0.5	0.5	9.283	35827	48780
0.014	0.5	0.5	9.471	36098	49394
0.014	0.5	0.5	9.662	36356	50015
0.014	0.5	0.5	9.857	36600	50644
0.014	0.5	0.5	10.057	36829	51281
0.014	0.5	0.5	10.260	37041	51927
0.014	0.5	0.5	10.467	37236	52580
0.014	0.5	0.5	10.678	37413	53241
0.014	0.5	0.5	10.894	37570	53911
0.014	0.5	0.5	11.114	37706	54589
0.014	0.5	0.5	11.339	37818	55276
0.014	0.5	0.5	11.568	37907	55971
0.014	0.5	0.5	11.802	37970	56675
0.014	0.5	0.5	12.040	38006	57388
0.014	0.5	0.5	12.283	38012	58110
0.014	0.5	0.5	12.531	37988	58840
0.014	0.5	0.5	12.784	37931	59581
0.014	0.5	0.5	13.043	37839	60330
0.014	0.5	0.5	13.306	37710	61089
0.014	0.5	0.5	13.575	37542	61857
0.014	0.5	0.5	13.849	37333	62635
0.014	0.5	0.5	14.129	37080	63423
0.014	0.5	0.5	14.414	36781	64221
0.014	0.5	0.5	14.706	36433	65029
0.014	0.5	0.5	15.003	36034	65847
0.014	0.5	0.5	15.306	35580	66675

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)
1440000	5000	60	1845825	0.065	1800000
1472985	5000	60	1882764	0.065	1836362
1506796	5000	60	1920444	0.065	1873459
1541454	5000	60	1958882	0.065	1911306
1576986	5000	60	1998091	0.065	1949917
1613414	5000	60	2038088	0.065	1989308
1650765	5000	60	2078888	0.065	2029494
1689064	5000	60	2120508	0.065	2070493
1728339	5000	60	2162964	0.065	2112320
1768618	5000	60	2206273	0.065	2154991
1809930	5000	60	2250451	0.065	2198525
1852304	5000	60	2295518	0.065	2242938
1895771	5000	60	2341490	0.065	2288248
1940363	5000	60	2388385	0.065	2334474
1986112	5000	60	2436223	0.065	2381634
2033054	5000	60	2485021	0.065	2429746
2081222	5000	60	2534801	0.065	2478830
2130652	5000	60	2585580	0.065	2528906
2181383	5000	60	2637381	0.065	2579993
2233452	5000	60	2690222	0.065	2632112
2286900	5000	60	2744125	0.065	2685284
2341767	5000	60	2799111	0.065	2739531
2398097	5000	60	2855203	0.065	2794873
2455932	5000	60	2912422	0.065	2851333
2515320	5000	60	2970791	0.065	2908934
2576306	5000	60	3030334	0.065	2967698
2638939	5000	60	3091073	0.065	3027650
2703269	5000	60	3153033	0.065	3088812
2769349	5000	60	3216239	0.065	3151211
2837231	5000	60	3280716	0.065	3214869
2906973	5000	60	3346489	0.065	3279814

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 4.16 and the corresponding trend with time for the next 30 years are depicted in Figure 3.12 to 3.18. This analysis applied a dynamic system combined with index assessment to evaluate the environmental water carrying capacity. We considered two parts, people and industry. Our results indicate that the environmental water carrying capacity displays a decreasing trend, but it is maintained at an acceptable level.

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

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

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

Year	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
2021	1.326	1.144	0.800	0.813	12.000	0.669	0.721
2022	1.312	1.132	0.802	0.808	11.873	0.668	0.721
2023	1.298	1.119	0.804	0.803	11.743	0.668	0.720
2024	1.283	1.107	0.806	0.799	11.610	0.668	0.720
2025	1.268	1.094	0.809	0.794	11.475	0.668	0.720
2026	1.253	1.081	0.811	0.790	11.337	0.667	0.720
2027	1.237	1.067	0.813	0.786	11.197	0.667	0.719
2028	1.222	1.054	0.816	0.782	11.053	0.667	0.719
2029	1.206	1.040	0.818	0.778	10.907	0.667	0.718
2030	1.189	1.025	0.821	0.774	10.758	0.666	0.718
2031	1.172	1.011	0.823	0.770	10.605	0.666	0.718
2032	1.155	0.996	0.826	0.766	10.450	0.665	0.717
2033	1.138	0.981	0.828	0.762	10.291	0.665	0.717

2034	1.120	0.966	0.831	0.759	10.129	0.664	0.716
2035	1.102	0.950	0.834	0.755	9.964	0.664	0.715
2036	1.083	0.934	0.837	0.751	9.796	0.663	0.715
2037	1.064	0.918	0.840	0.748	9.624	0.662	0.714
2038	1.045	0.901	0.843	0.745	9.449	0.662	0.713
2039	1.025	0.884	0.845	0.741	9.270	0.661	0.712
2040	1.005	0.867	0.849	0.738	9.088	0.660	0.712
2041	0.984	0.849	0.852	0.735	8.902	0.659	0.711
2042	0.964	0.831	0.855	0.732	8.712	0.658	0.710
2043	0.942	0.812	0.858	0.729	8.518	0.657	0.709
2044	0.920	0.794	0.861	0.726	8.320	0.656	0.707
2045	0.898	0.774	0.865	0.723	8.119	0.655	0.706
2046	0.876	0.755	0.868	0.720	7.913	0.654	0.705
2047	0.852	0.735	0.872	0.717	7.703	0.653	0.703
2048	0.829	0.714	0.875	0.714	7.489	0.651	0.702
2049	0.805	0.694	0.879	0.711	7.271	0.649	0.700
2050	0.780	0.673	0.883	0.709	7.048	0.648	0.698
2051	0.755	0.651	0.886	0.706	6.821	0.646	0.696
2021	1.326	1.144	0.800	0.813	12.000	0.669	0.721

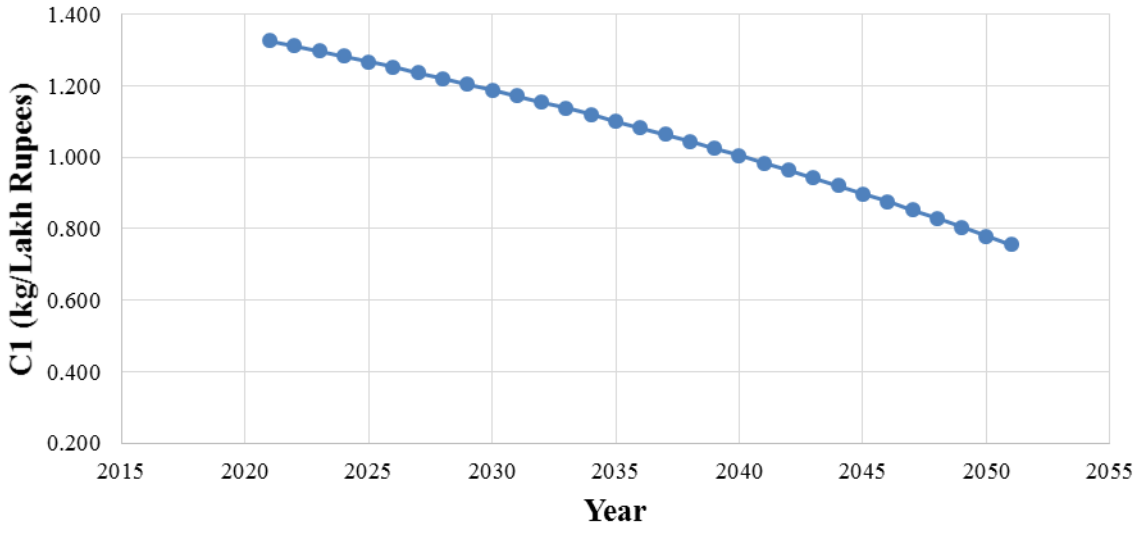


Figure 3.12: Predicted annual variation of indicator C1 for the next 10 years.

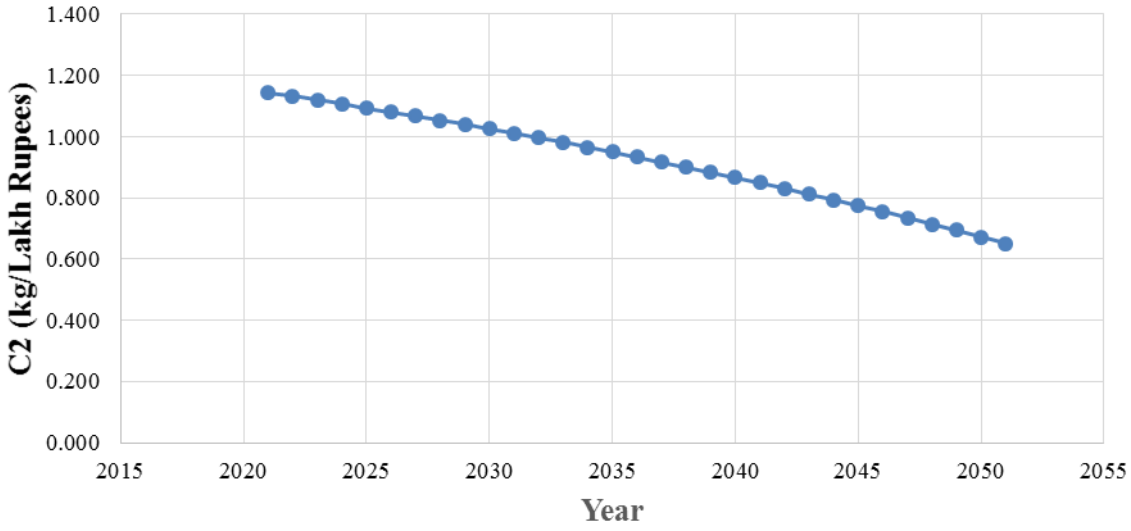


Figure 3.13: Predicted annual variation of indicator C2 for the next 10 years.

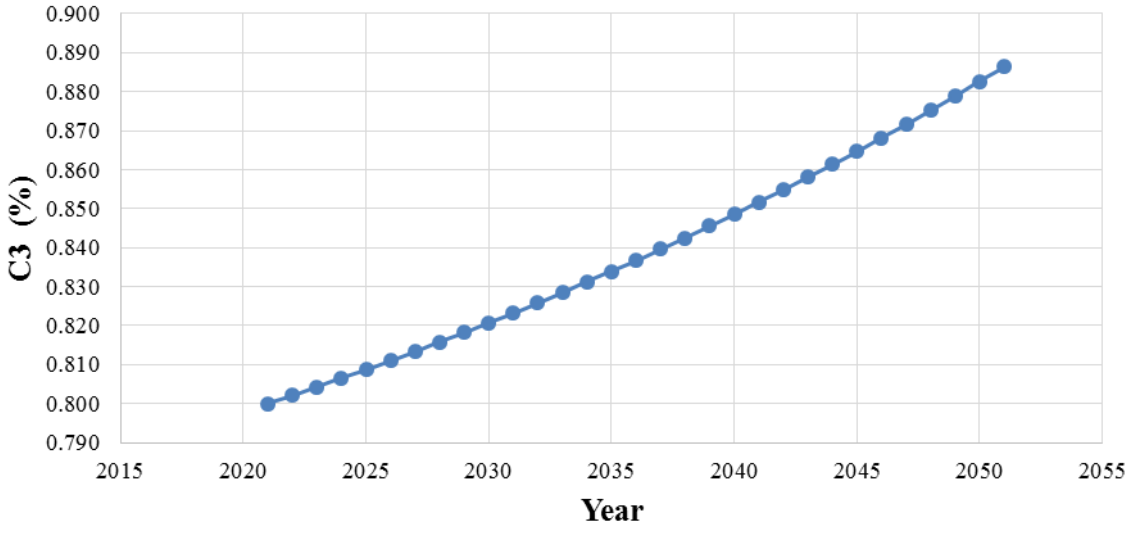


Figure 3.14: Predicted annual variation of indicator C3 for the next 10 years.

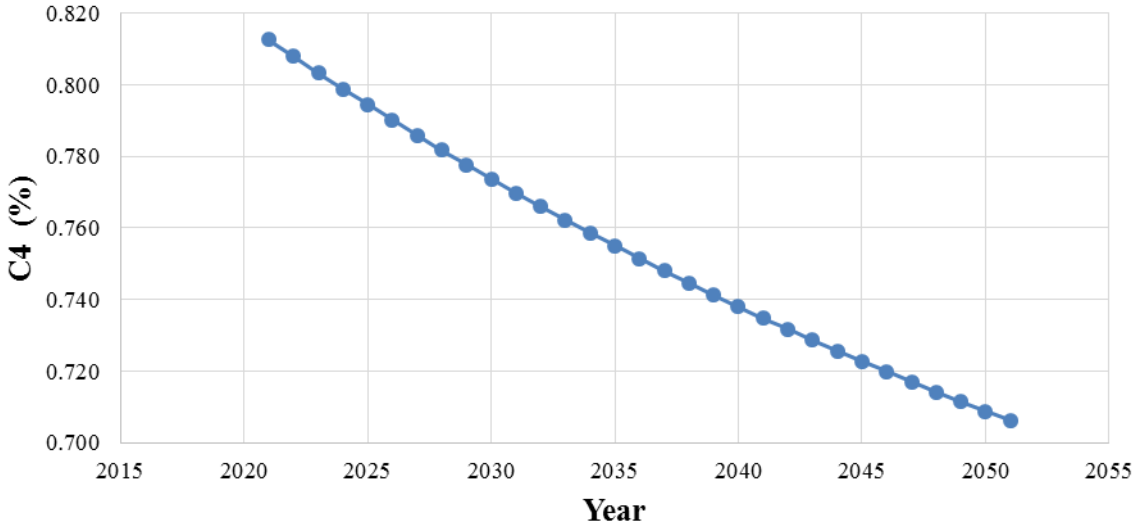


Figure 3.15: Predicted annual variation of indicator C4 for the next 10 years.

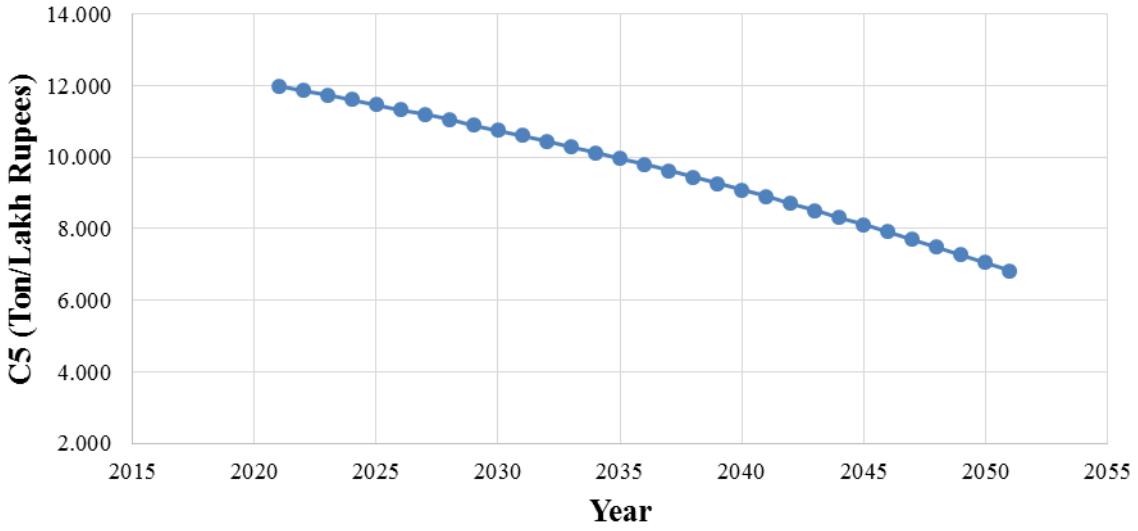


Figure 3.16: Predicted annual variation of indicator C5 for the next 10 years.

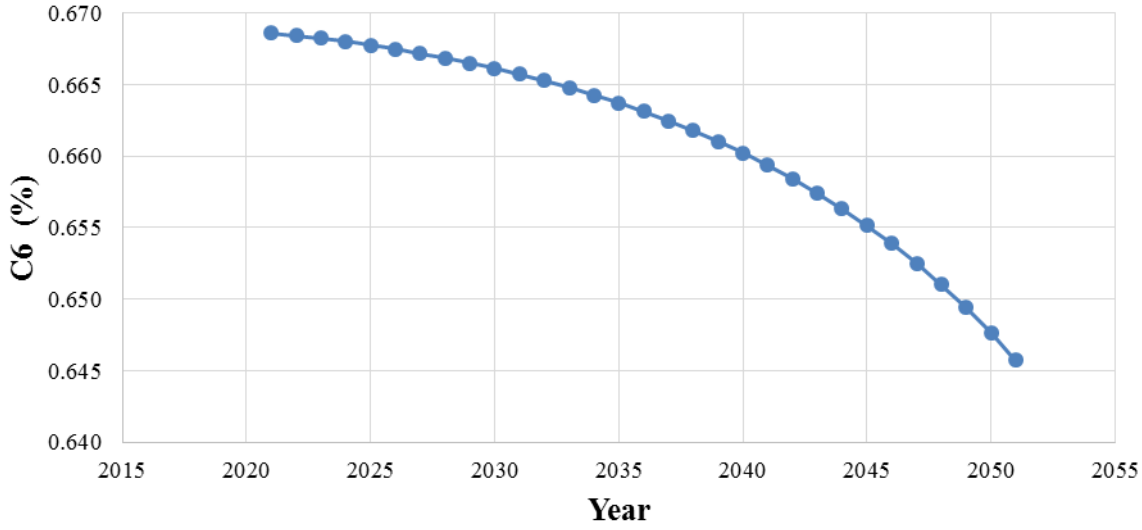


Figure 3.17: Predicted annual variation of indicator C6 for the next 10 years.

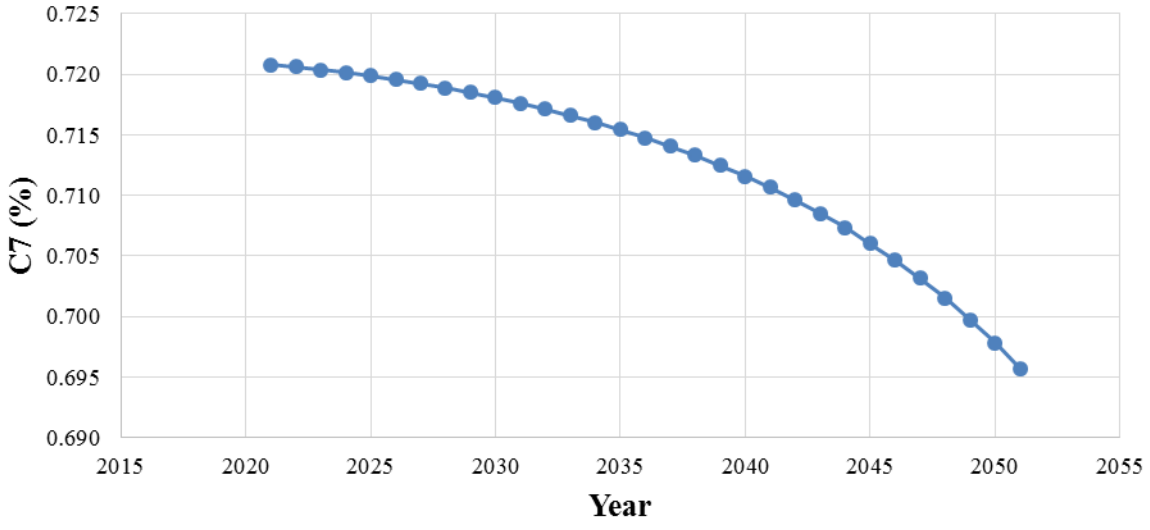


Figure 3.18: Predicted annual variation of indicator C7 for the next 10 years.

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

Indicator	C1	C2	C3	C4	C5	C6	C7
Weight	0.195	0.376	0.019	0.094	0.033	0.269	0.013

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

Indicator	C1	C2	C3	C4	C5	C6	C7
Entropy	0.974	0.950	0.997	0.988	0.996	0.965	0.998

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

Year	Comprehensive Value
2021	0.634
2022	0.623
2023	0.613
2024	0.602
2025	0.591
2026	0.579
2027	0.568
2028	0.556
2029	0.544
2030	0.532
2031	0.519
2032	0.506
2033	0.493
2034	0.480
2035	0.467
2036	0.453
2037	0.439
2038	0.424
2039	0.410
2040	0.395
2041	0.380
2042	0.364
2043	0.348
2044	0.332
2045	0.316
2046	0.299
2047	0.282
2048	0.264
2049	0.246
2050	0.228
2051	0.209

Predicted values of the weight and entropy change of each indicator for water carrying capacity at Bhilai is shown in Table 3.10 and 3.11. Moreover, the obtained values for the comprehensive environmental water carrying capacity at Bhilai 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.

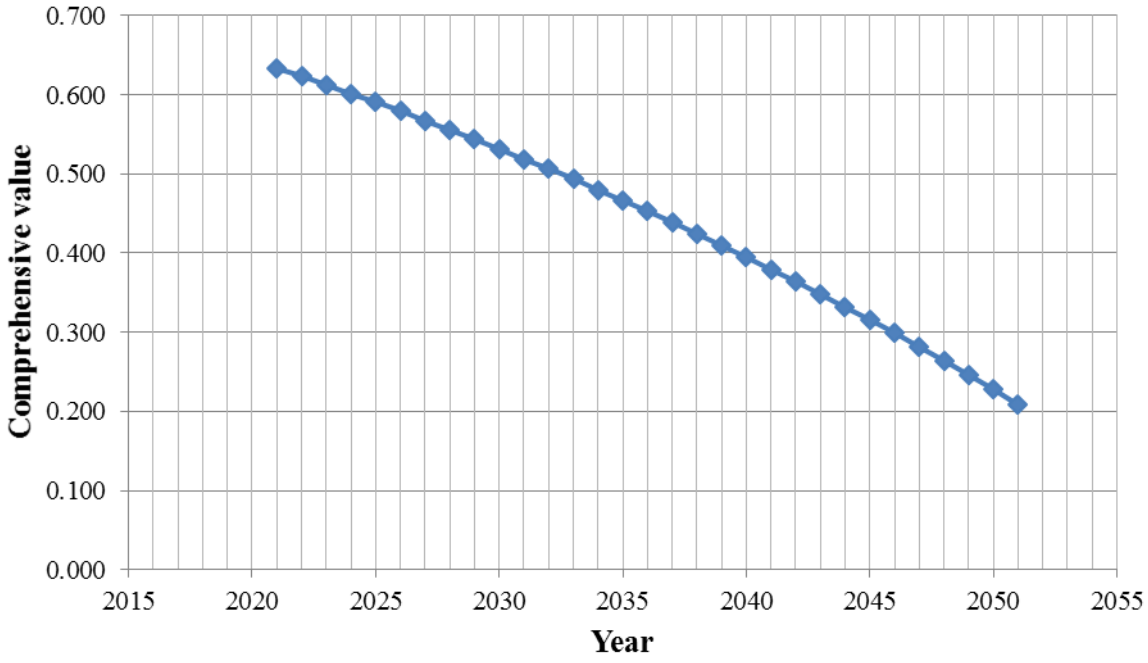


Figure 3.19: Predicted comprehensive environmental water carrying capacity of Bhilai-Durg for the next 10 years.

From Table 3.12 we can see the comprehensive value is 0.634 in 2021, it falls to 0.493 in 2033. At 2039 it reaches the value of 0.410 after that it crosses the normal comprehensive value and goes to the poor comprehensive value and reaches 0.209 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. Near by industries should not dump the solid waste materials including fly -ash un-scientific matter in open lands, which may degrade the quality of water in the study area.
3. It has been found from the water sample analysis data that the concentration of various toxic materials are much below the permissible limit as presubscribed by WHO and CPCB. However, in few places the presence of high concentration of iron reported and this mater need some oxidation and sedimentation pre-treatment for separation. The presence of few toxic and hazardous materials may lead to health hazards. Those waters should be avoided for use and proper treatment methods should be adopted for removal of such contaminates.
4. The rain water harvesting, water reservoir, modification of existing lake/ponds to hold enough water may be attempted.
5. General cleanliness of drains, surrounding areas of ponds, lake, 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 are not acceptable.
6. Regular monitoring of water quality of river, lake, ponds, tube well, underground water etc should be tested periodically through an organization of nati onal repute and enlisted third party as notified by CPCB by CECB to ensure that toxic compounds are not present in the water bodies of Bhilai. 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 began 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 began to appear in large quantities in municipal waste stream. The large population of people in cities and communities are rising to indiscriminate littering and open dumps. These dumps in turn have been formed breeding grounds for rats and other vermin, posing significant risks to public health. The unhealthy waste management practices are resulted in several outbreaks of epidemics with high death tolls. Today, however, most of these countries have effectively addressed much of the health and environmental pollution issues associated with wastes generation. In contrast, the increasing rate of urbanisation and developments in emerging countries is now leading to land pollution.

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

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

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

4.2. Methodology

4.2.1. Land Pollution and Wastes in Bhilai

Solid waste management is a critical issue faced by urban areas worldwide, and Bhilai, located in the district of Durg, Chhattisgarh, is no exception. As a growing industrial city with a rapidly increasing population, Bhilai faces significant challenges in effectively managing its solid waste. The sustainable and efficient management of solid waste is essential to maintain a clean and healthy environment, protect public health, and promote sustainable development.

Steps to be followed for Land Allocation

1. Firstly, background information research and pre-requisites are checked. It's important to gather knowledge of place, history, methods of operation, team, approach, precautions, etc.
2. With the help of GIS, Satellite imagery etc. technologies and Field Survey, Topography, etc. mapping is done to study the location and eliminate all the unsuitable regions for dumping/ landfilling/ incinerating etc.
3. Visualization and interpretation of site and how the whole city would be covered based on preliminary work carried out.

4. Then from the available regions the best ones are selected based on parameters like that of soil/ land cover, network of transport, society around, environment (humans, animals, water bodies, etc.), financial estimates, depth of ground water source, less spread of contaminants, slope or height of site and other factors are to be studied thoroughly.

5. The sites with best combination of all the factors can then be selected for disposing off wastes so that pollution can be controlled to an extent.

6. Now, collection of waste from residential houses, Industries, markets, agricultural farms and other places can be done.

7. Transportation, Clustering, Segregation, Processing, recycle, landfill, disposing off etc. can then be done with the help of different disposing techniques for different category of pollutants and wastes.

8. In addition, monitoring of the disposed wastes and subsequent steps is important.

4.2.2. Measurement of Heavy Metals 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 4.1.

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

4.3 Results and Discussion

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

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

generated from this technique will prove to be of immense importance in the forming of action plans for pollution control and waste management. Land use distribution in Bhilai is shown in Table 4.1 to 4.3.

Table 4.1: Land use distribution in Bhilai for 2001.

LULC of Bhilai Industrial region (15 km radius) for 2001	
Features	**Area (sq. km.)**
River	8.23
Water Body	10.11
Forest (Natural)	271.74
Vegetation	73.58
Agriculture land	246.01
Fellow land	15.31
Built up area	43.69
Industry	37.90

Table 4.2: Land use distribution in Bhilai for 2010.

LULC of Bhilai Industrial region (15 km radius) for 2010	
Features	**Area (sq. km.)**
River	8.26
Water Body	11.03
Forest (Natural)	169.56
Vegetation	108.01
Agriculture land	277.46
Fellow land	9.08
Built up area	85.28
Industry	37.90

Table 4.3: Land use distribution in Bhilai for 2021.

LULC of Bhilai Industrial region (15 km radius) 2021	
Features	**Area (sq. km.)**
River	8.26
Water Body	11.22
Forest (Natural)	83.40
Vegetation	134.28
Agriculture land	320.56
Fellow land	6.83
Built up area	103.66
Industry	38.33

4.3.2 Land Use Land Cover Pattern in Bhilai

LULC (Land use land cover) studies provide better economics and ensure growth, development and stability of the area/ city/ state/ country in general. It aids in predicting the adjustments that is to be made in accordance to the changing land cover and land use pattern over the years. It is essential for best possible utilization of land present/ available for better planning and policy making. Chronological changes of LULC pattern of Bhilai industrial region (15km radius from Bhilai Steel Plant) using satellite image of LANDSAT sensor. Purpose of the analysis of LULC changing pattern of the study area we have used three different period satellite images i.e., 2001, 2010 and 2021. Satellite images are downloaded from Earth Explorer and processed the images using Arc Map with the help of Google earthThe LULC map of the Bhilai Industrial area for the years 2001, 2011 and 2021 are shown in Figure 4.2 to 4.4. In Bhilai, industrial area marginally increased from 5.36% to 5.42% in 2021 since 2001. Moreover, the forest cover also decreased 38.46% to 11.80% in 2021 since 2001. Consequently, the fellow land also decreased from 2.17% to 0.97%, which means dumping areas for waste is decreasing. In, turn proper disposal and designated areas for waste disposal are required. However, great portion of land is being utilized for different purposes. Residential,

transportation, commercial, public & semi-public areas land use will keep rising while the industrial land use would certainly decrease due to the environmental concerns and shifting in future from Bhilai city.

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

- **Residential Area:** Majority of area is utilized as residential housing in the city. As shown in Table 4.20, with increasing population and shifting of people from rural areas to urban city like Bhilai, land use for residential purpose is rising.
- **Commercial/ Market Area:** Bhilai is known as the commercial hub or trade hub and has good portion of land being utilized in this sector and will keep increasing in future with increasing population but somehow sluggish as online marketing and shopping flourishing.
- **Industrial Area:** Significant amount of land is being utilized as industrial land since the era of industrialization in Bhilai by small scale and medium scale industries in majority. However, this trend of land use won't increase much unlike the other sectors since in accordance to the smart city program and environmental concerns Industries shall be shifted outside the city thus either decline or constant land use for Industrial area in future.
- **Transportation Area:** Road, railway, airport, bus stand, taxi stand, future metro, etc. kind of public transport facilities covering certain percent of land and would certainly increase in future too because of development programs being carried out.
- **Public/ Semi-Public Areas:** Parks, gardens, temples, government offices, schools, hospitals, banks, playground, etc. kind of land use.

Table 4.4: LULC changing pattern of Bhilai Industrial Region

Features	Area (%)		
	2001	2010	2021
River	1.16	1.17	1.17
Water Body	1.43	1.56	1.59
Forest (Natural)	38.46	24.00	11.80
Vegetation	10.41	15.29	19.01
Agriculture land	34.82	39.27	45.37
Fellow land	2.17	1.28	0.97
Built up area	6.18	12.07	14.67
Industry	5.36	5.36	5.42

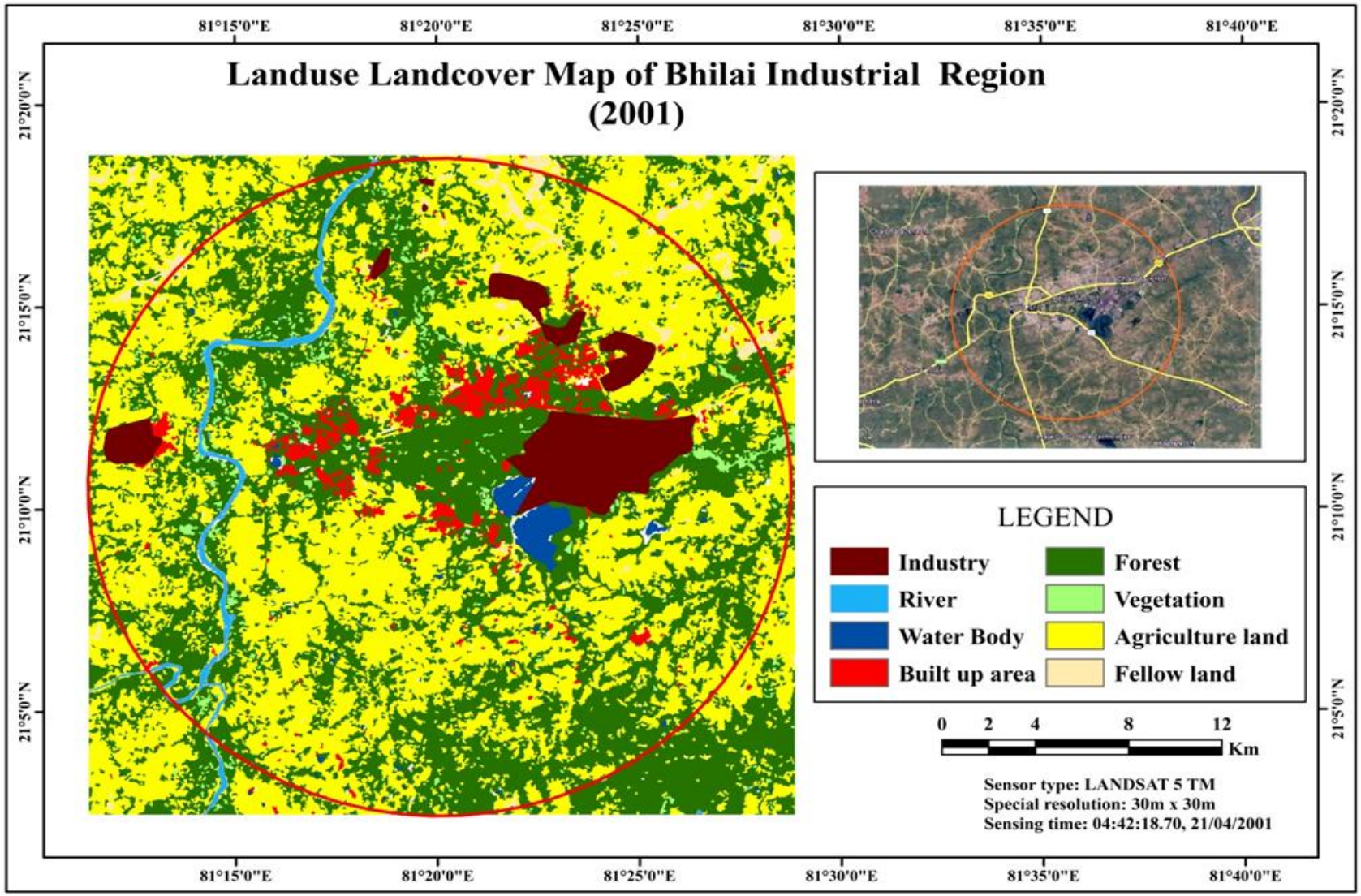


Figure 4.2: LULC map of the Bhilai industrial area for the year 2001.

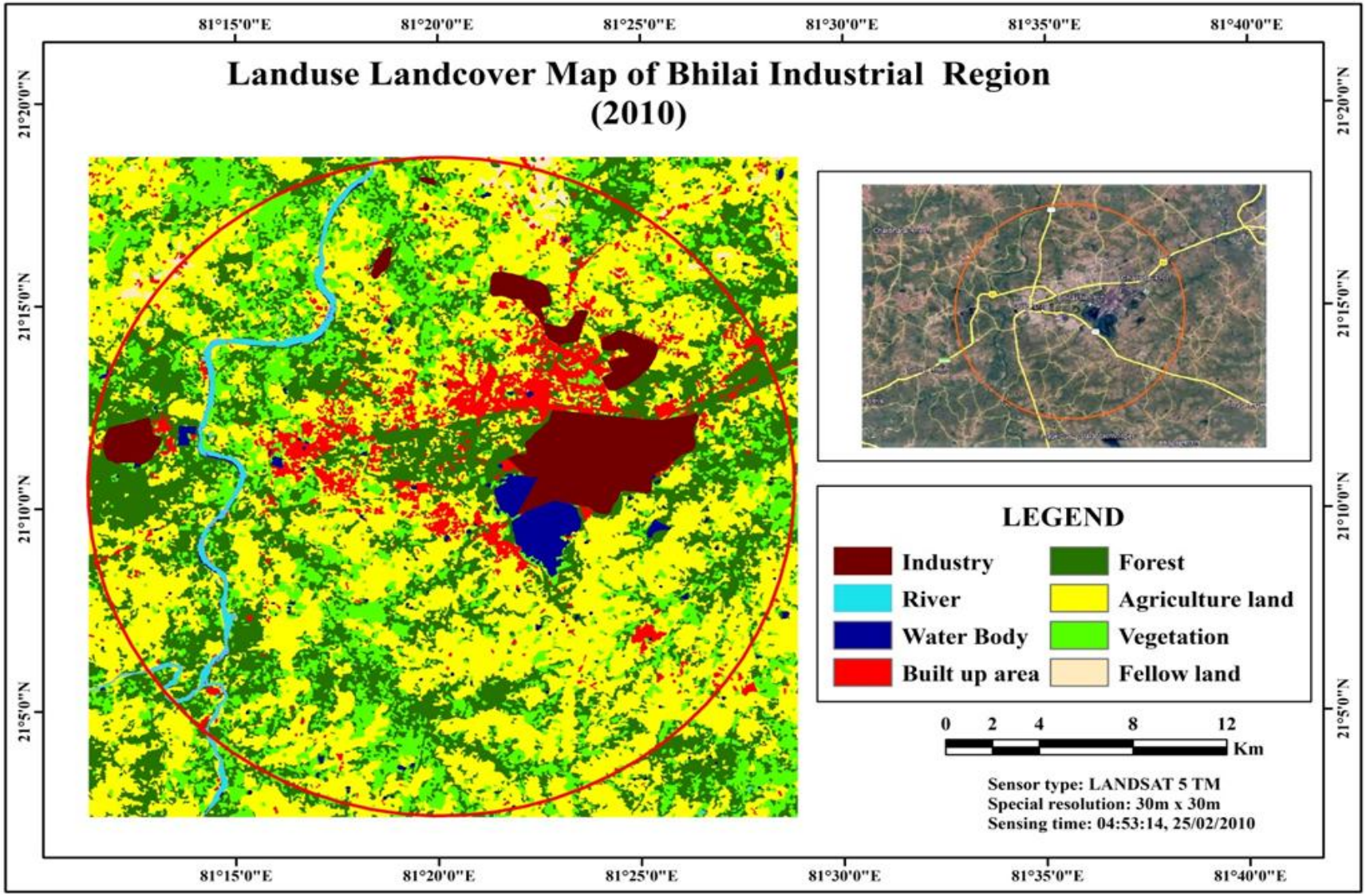


Figure 4.3: LULC map of the Bhilai industrial area for the year 2010.

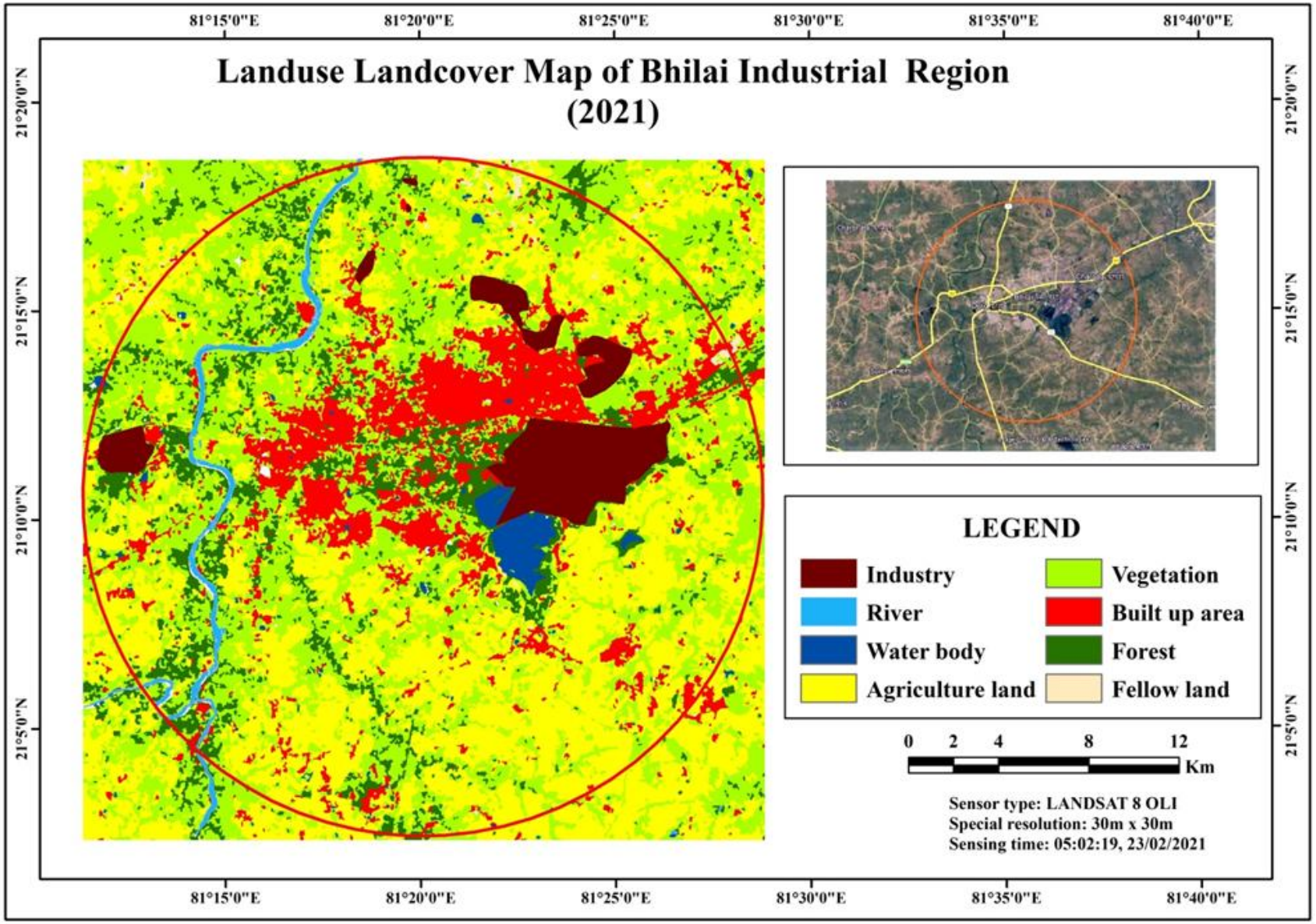


Figure 4.4: LULC map of the Bhilai industrial area for the year 2021.

4.3.3 Current Waste Disposal/ Management Practice in Bhilai

The Bhilai metropolis contains three municipal corporations as shown in Table 4.5 below.

Table 4.5: Amount of Waste Produced in Tonnes per Day (TPD) in Different Municipalities in Bhilai

Different Municipalities of Durg-Bhilai	Waste produced in Tonnes produced per day (TPD)
Bhilai Municipal Corporation	165.38
Durg	76.05
Bhilai Charoda Municipal Corporation	18.9
Risali Municipal Corporation	24.71
Total Municipal Waste	285.04

SAIL Bhilai Steel Plant is a major steel-producing facility located in Bhilai, Chhattisgarh, India. It is part of the Steel Authority of India Limited (SAIL), which is one of the largest steel-making companies in India. This Largest Steel Company contributes majorly to the industrial waste as shown in Table 4.4.

Table 4.6: Different products that SAIL – Bhilai Steel Plant Produce.

Product mix	Tonnes/annum
Semis	5,33,000
80Rail & heavy structural	7,50,000
Merchant Products (angles, channels, Round & TMT bars)	5,00,000
Wire Rods (TMT, plain & ribbed)	4,20,000
Plates (up to 3600 mm wide)	9,50,000
Total saleable steel	**31,53,000**

For producing 1 Tonnes of Steel approximately 0.5 Tonnes of waste got generated. Annual Waste generated from SAIL – Bhilai Steel Plant is 3684044 Tonnes per day 4319.178 Tonnes of waste got generated.

Table 4.7: Amount of Solid waste produced in Tonnes produced per annum along with recycling percentage with their types.

Year	Total waste generated (Tons)	Total waste utilized (Tons)	% utilization	Remarks	Type of Waste
2020	3017602	2653589	87.9	Managed byselling (about 75%) or recycled (about 25%)	BF slag, LD slag, mill scale, flue dust, fly ash, etc.
2021	3071034	2670124	86.9		
2022	3684044	3261992	88.5		

Table 4.8: Amount of Solid waste produced in Tonnes produced per annum along with recycling percentage with their types.

Year	Industrial Waste	Waste Growth Rate
2022	3684044	19.96%
2021	3071034	1.77%
2020	3017602	27.95%
2019	2358400	-8.01%
2018	2563840	30.48%
2017	1965000	0.77%
2016	1950000	12.31%
2014	1736283	2.54%
2013	1693352	-0.21%
2012	1696888	-3.69%
2011	1761920	3.11%
2010	1708756	8.74%
2009	1571425	-

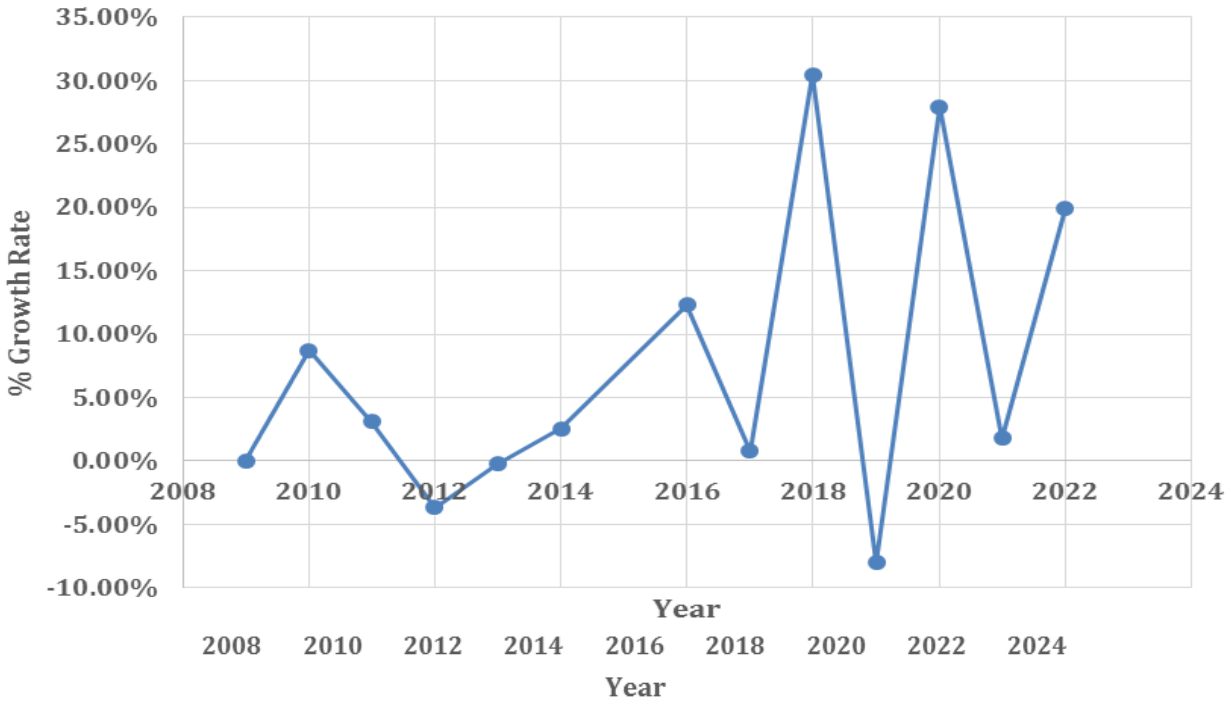


Figure 4.5: Change of Waste Growth Rate in different year.

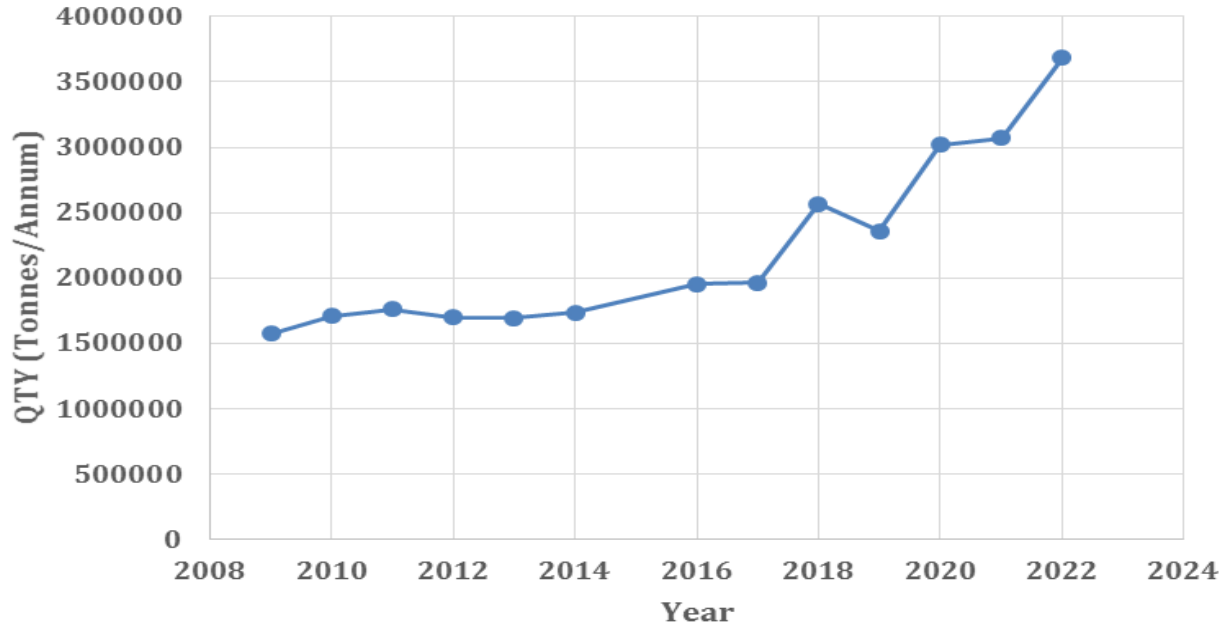


Figure 4.6: Industrial Wastes generated in Tonnes per annum.

Bhilai-Charoda is a municipal corporation and a part of Bhilai city in the state of Chhattisgarh, India. Charoda is an industrial area of Bhilai city therefore a large quantity of Construction and Demolition Waste got produced by this municipality only.

Table 4.9: Amount of Construction and Demolition Waste produced in Tonnes produced per day (TPD) in Different Municipalities in Durg-Bhilai.

Different Municipalities in Bhilai	Waste produced in Tonnes produced per day (TPD)
Bhilai Charoda Municipal Corporation	2200

Plastic waste refers to discarded or unwanted plastic materials that have reached the end of their useful life or have been improperly disposed of. Plastic waste can take various forms, including packaging materials, single-use items like bottles, bags, and straws, as well as plastic products that have become damaged or obsolete. Total Plastic waste produced per Annum is 876 Tonnes Amount of Waste produced in Tonnes produced per day (TPD) in Different Municipalities in Durg-Bhilai is shown in Table 4.10.

Table 4.10: Amount of Waste produced in Tonnes produced per day (TPD) in Different Municipalities in Durg-Bhilai.

Different Municipalities in Durg-Bhilai	Plastic Waste produced in Tonnes produced per day (TPD)
Bhilai Municipal Corporation	1
Durg	0.7
Bhilai Charoda Municipal Corporation	0.3
Risali Municipal Corporation	0.4
Total Municipal Waste	2.4

Hazardous waste refers to any waste material that poses a substantial threat to human health, the environment, or both. It requires special handling, treatment, and disposal methods due to its potential to cause harm. Here are some key points about hazardous waste. In Durg-Bhilai region the major contributor of Hazardous Waste is Bhilai Steel Plant is shown in Table 4.11.

Table 4.11: Amount of Hazardous waste in Tonnes produced per annum along with recycling percentage with their types.

Year	Total waste generated (Tons)	Total waste utilized	% utilization	Remarks
2019-20	4452	3981	89.4	Managed by selling (about 60%) or recycled (about 40 %)
2020-21	3981	3548	89.1	
2021-22	3415	2939	87	

Electronic waste, commonly known as e-waste, refers to discarded electrical or electronic devices. As technology advances and consumer electronics become more prevalent, the generation of e-waste has increased significantly. E-waste includes a wide range of items such as computers, smartphones, televisions, refrigerators, and other electronic appliances. Amount of E Waste in Tonnes produced per annum is shown in Table 4.12.

Table 4.12: Amount of E Waste in Tonnes produced per annum.

Sr. No.	Producer Name	Qty. MT/ Year
1	SSB, Bhilai	0.171

Biomedical waste refers to any waste generated during healthcare activities that may pose a threat to human health or the environment. It includes a wide range of materials, such as sharps (needles, scalpels), laboratory specimens, blood-soaked bandages, discarded surgical gloves, pharmaceuticals, and other potentially infectious materials.

Table 4.13: Amount of Biomedical Waste in kgs produced per annum.

Sr. No.	Producer Name	Category			
		Red	Yellow	Blue	White
1	Bhilai J.P cement LTD dispensary	1.434	3.4	3.445	1.703
2	Shree Shankracharya Institute of Medical Science	43107.272	53236.36	17809.090	2945.454
	Total	**53246.345**			

The COVID-19 pandemic has not only affected human lives but has also led to a significant increase in biomedical waste generation. The global response to the pandemic, including testing, treatment, and vaccination efforts, has contributed to a surge in healthcare activities, resulting in a substantial rise in biomedical waste production.

The Bhilai Durg Thermal Plant, located in Bhilai, Chhattisgarh, is one of the prominent power generation facilities in the region. As with any coal-fired power plant, the combustion process at the Bhilai Durg Thermal Plant produces fly ash as a residue. Fly ash consists of fine particles that are carried away by the flue gases during combustion and are collected by the plant's electrostatic precipitators or other particulate control devices. Reconnaissance surveys were carried out to locate the industries in Durg-Bhilai and get preliminary data on their activities and operations as well as update data on their operational status. Additional site visits, surveys, and investigations enabled examination of waste management practices. The following are the 7 industries located in the study area that are having coal-based power generation units. The annual fly ash generation and its utilization are as follows for the year 2009-2010. Total Fly Ash waste produced per Annum is 1308090.58 Tonnes fly ash waste in Tonnes produced per annum is shown in Table 4.14.

Table 4.14: Types of Waste in Tonnes produced per annum.

Types of Wastes	Qty (Tonnes/Annum)
Solid Waste	3788083.6
Plastic Waste	876
Biomedical Waste	53.246
Hazardous Waste	3415
E-Waste	0.171
TOTAL	**3802049.417**

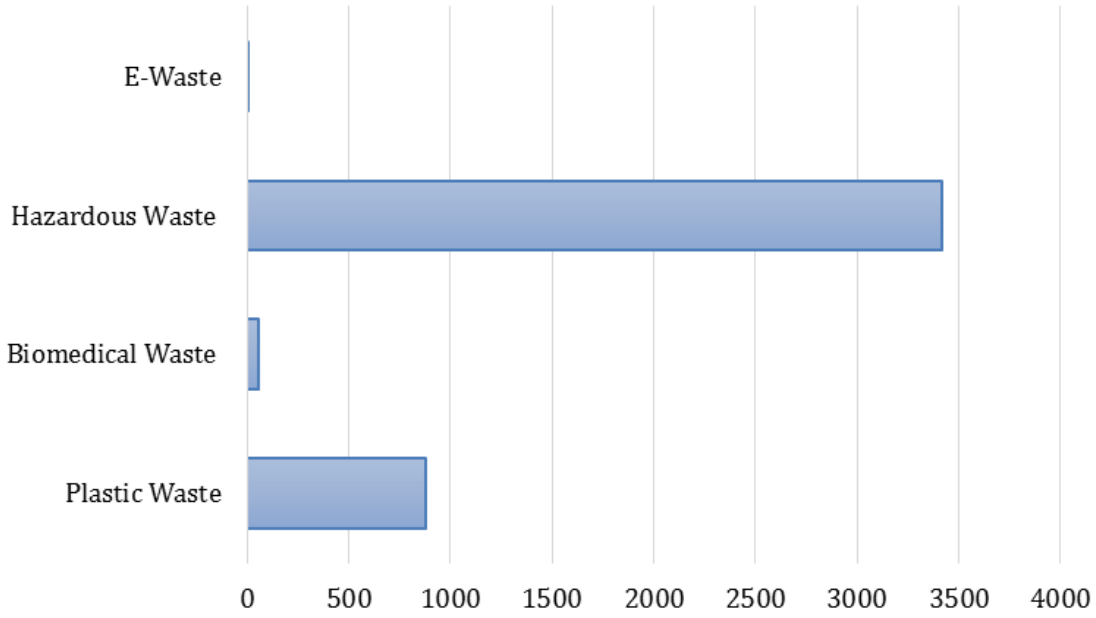


Figure 4.7: Different types of Wastes generated in Tonnes per annum.

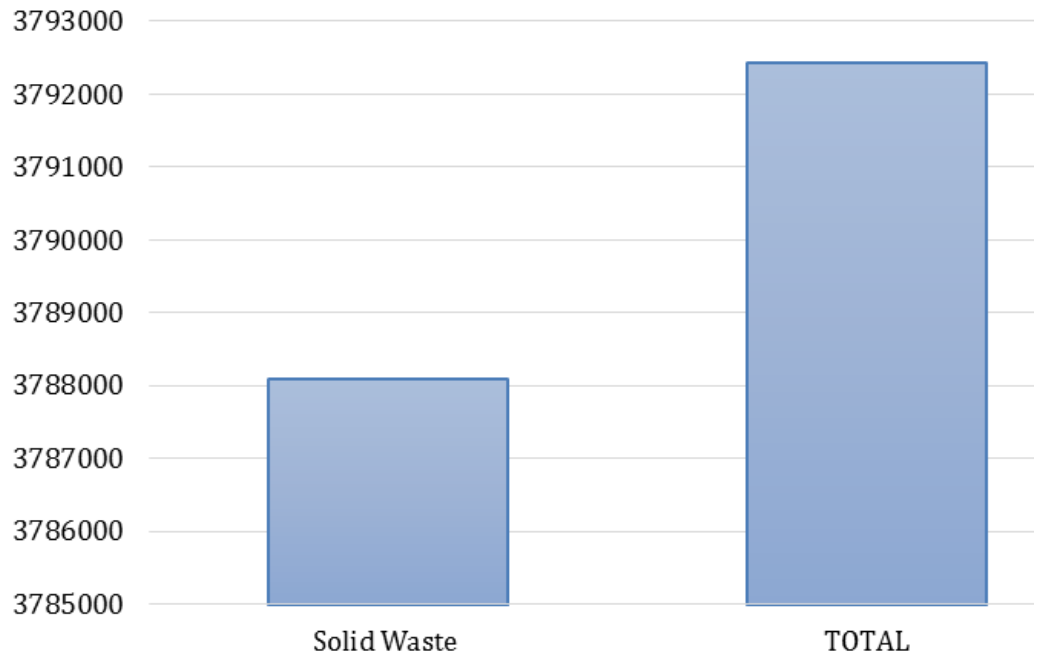


Figure 4.8: Comparison between total waste and solid waste in Tonnes per annum.

Table 4.15: Comparative Analysis of Solid Waste Generation Trends across Different Years.

YEAR	MSW(TPD)	ISW(TPA)	TOTAL SW(TPA)
2022	285.04	3684044	3788083.6
2020	311.4	3017602	3131263
2018	235	2563840	2649615
2017	372.6	1965000	2100999
2016	350	1950000	2077750

4.3.4 Proposed Model being implemented in Bhilai for Disposal

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

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

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

- **Recycling**: It's the collection, treatment, processing and reusing of the waste disposed which are capable with some processing by selling to the companies or in processing plant.

- **Composting**: Beneficial for converting kitchen, biodegradable, organic, excreta, wet, etc. kind of solid wastes. These wastes are transformed to highly nutritious manures to be used in plant growth and recharging soil fertility. Generally composting occurs in absence of Oxygen and bacterial /microbial environment presence.

- **Anaerobic Digestion**: It's similar to composting but oxygen is supplied and no need of microbes for conversion.

Figure 4.9: An overview of new approach for waste management.

➢ Emphasis on reduction of waste released and development of efficient method and technology for disposal of the unavoidable wastes being generated. We know "Prevention is always better than curing". Therefore, measures should be taken with utmost priority.

- A popular and widely used strategy is Integrated Waste Management i.e., minimize the waste generated at source itself, safeguard environment with proper disposal and treatment plants and carrying out remedial/ healing work for already damaged land and environment.

- Some new points to ensure:

  - Monitoring: GPS enabled vehicles should collect and transport the wastes to ensure for proper tracking and monitoring of the waste. Especially in case of E- Wastes and Hazardous wastes, Biomedical and Industrial wastes, since they are much more dangerous and possess greater threat. Moreover, wastes like E-Waste are quite useful and advantageous thus risk of theft.
  - Separate vehicles/ container and processing tools should be used for different kinds of wastes- normal wastes, compost forming waste, hazardous, biomedical, Industrial waste to avoid any kind of transfer and mixing and future problems.
  - Using the sign conventions and boards for indicating waste dumping sites, points and vehicles, more emphasis on hazardous and industrial waste carrying vehicles and collection points- danger symbols can be used to indicate such vehicles and points at dumping sites.
  - Transportation in closed manner, this can be achieved by using lids (replaceable) over the vans.
  - Eye on disposal process of different kind of wastes in accordance to the method allotted/ instructed.
  - Industries shall carry out waste storage process in an isolated place for some days within industrial premises to ensure that the harmful effect are not spread.
  - Maintaining the records of generated waste- hazardous/ recyclable/ industrial etc. in accordance with the CPCB guidelines to ease in monitoring and tracking.

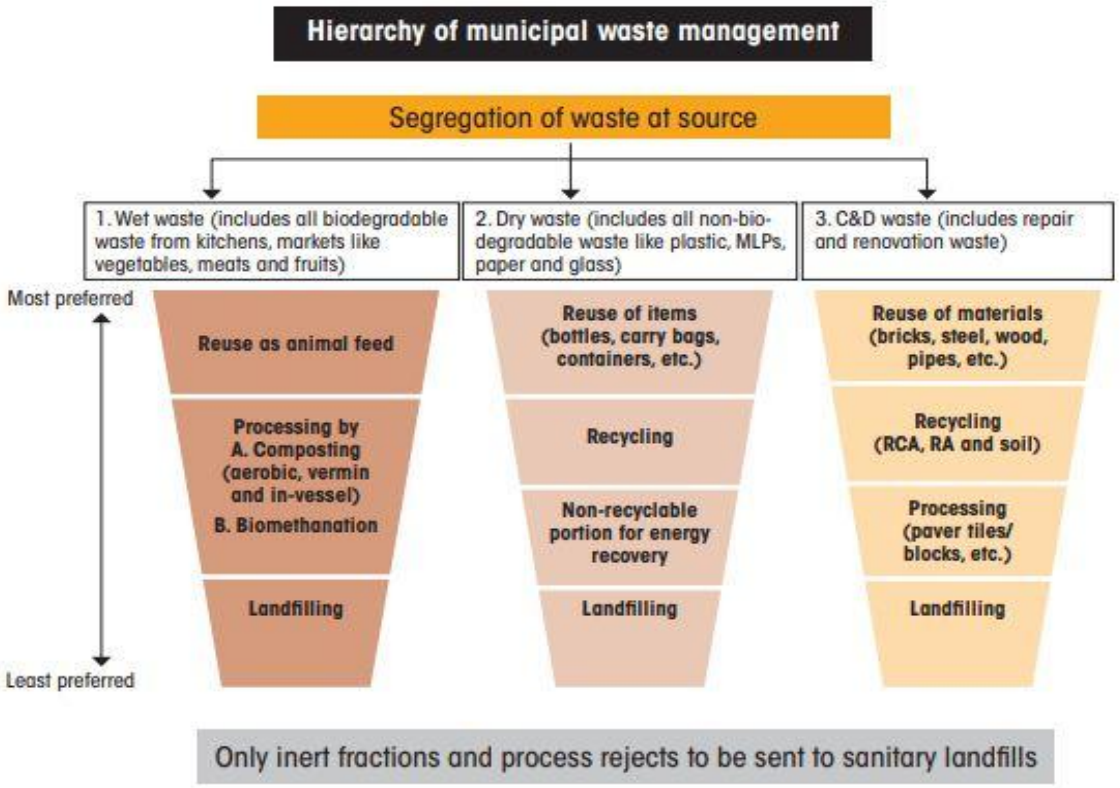


Figure 4.10: The hierarchy of Municipal waste management.

4.3.5 Management Plan for Hazardous Waste

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

Short Term Plan: For short term focus on reducing and discarding the waste rather than processing & treatment.

1. Control regular hazardous waste generating activities and release from industries and labs. Moreover, temporary storing of these wastes within premises for certain period of time (hours/ day/ months) before transporting it for disposal and processing to diminish the effect.
2. Environmental compensation, wherein resource-based compensation is taken instead of monetary fine for harming environment. However, not practical and less successful plan.
3. Disposal (out of the city).

Long Term Plan:

1. Separate collections of such waste in special containers.
2. Segregation in case required.
3. Transporting to the site allotted.
4. Carrying out processing- making it less hazardous by dilution, recovery, separation.
5. And finally disposing it off.
6. Properly sealing/ closing the fills.
7. Stricter rules and policies, especially for hazardous waste.
8. Monitoring is really important for these wastes before and post disposal too.

4.3.6 E-Waste Management

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

Short Term Plan:

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

Long Term Plan:

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

4.3.7 Municipal Waste Management

Short Term Plan:

1. Door to door waste collection from the residence, public places, commercial markets, hotels, government offices and organisations by mini vans, mini trucks and trucks. In addition, the waste collection from different waste points and public bins located throughout the city is done.
2. Maintaining the secondary storage points at different places for temporary collection/ storage/ transport to ensure hygiene, cleanliness and ease of process.
3. Collected Municipal Solid Waste (MSW) is transported to disposal facility.
4. The wet wastes are buried by excavating to form compost while the dry wastes like metal, plastic, etc. are sold to the waste recycle plants and remaining fractions like debris, dusts, useless day to

day solid waste are finally dumped at SLRM (Solid Liquid Resource Management)/ landfilled/ incinerated, etc.

5. Digging out the existing landfilled and dumped waste accumulated at the current dumping sites and transporting them to the respective processing sites and processing the waste and ultimately disposing off.
6. Routine maintenance and cleanliness of the waste processing and disposal facilities from vehicles, machines to plants.

Long Term Plan:

1. Currently, RMC doesn't have enough facility for the MSW disposal within Bhilai City. Thus, the tie up companies are given the responsibility to do the needful. Nearby village Sakri situated at about 20 kilometres from Bhilai towards the north east direction on NH 6 and SH 9 connecting ring road 3, about 27.04 hectares of land is taken on lease for processing and landfill facility set up for waste disposal.
2. RWMPL will manage the waste collection and transportation within the Bhilai City and would be transporting it to the plant setup in Sakri under RMC for further processing in association with kivar group. The processing shall be done by:

- **MRF (Material Recovery Facility):** Separation of useful recyclable materials, hard wastes, etc. to be used as raw material in re-manufacturing processes, those which can form some new material, can be recycled and used again.

- **Accelerated Aerobic Composting:** Composting with continuous aid of microbes, bacteria, fungi, actinomytes environment and producing minerals and energy, organic substrates, etc.

- **Refuse Derived Technology (RDF):** It is quite surprising but the left material which is unused, unidentified, with series of processing, heating, mechanical processes along with additives like rice husk, bagasse can be used as a heating fuel source.

- **Construction Debris and Allied Wastes:** Stones, bricks, dust, sand, concrete, debris, ash rejects, etc. can be used as sand landfilling since they are inert.

- **Sanitary Landfilling:** An engineered landfilling technique which disallows inert wastes, non-biodegradable and other unfit wastes, thus is a much better way of land filling with modern engineering principles

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

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

- **Recycling:** It's the collection, treatment, processing and reusing of the waste disposed which are capable with some processing by selling to the companies or in processing plant.

- **Composting:** Beneficial for converting kitchen, biodegradable, organic, excreta, wet, etc. kind of solid wastes. These wastes are transformed to highly nutritious manures to be used in plant growth and recharging soil fertility. Generally composting occurs in absence of Oxygen and bacterial /microbial environment presence.

- **Anaerobic digestion:** It's similar to composting but oxygen is supplied and no need of microbes for conversion.

- Monitoring, record maintenance and data check.

- Awareness to common people.

- Stricter rules and policies to ensure rules are obeyed.

4.3.8 Industrial Waste Management Plan

Some key points are as follows:

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

Short Term Plan:

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

Long Term Plan:

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

4. Combined Treatment Facilities: Statistics show that the Small-scale industries are the major contributor of wastes. These industries are not capable of treating their solid wastes and effluents because of limited space, monetary send technological constraints. Hence, what can be done is treating the waste generated by these industries in collective way and sharing the resources like recycled products, energy generated, etc. with each other. Combined Effluent Treatment Plants (CETP) is the best example where, sharing of the cost of between individual industries is done.

5. Disposal Methods: Mostly the industrial wastes are categorized as hazardous and non-hazardous industrial wastes and in accordance with the waste category, disposal techniques are finalized. Landfilling, Incineration, Composting is the final step of disposal after recycle, reuse, separation and treatment. Landfilling is the most widely used technique but not suitable for hazardous waste and leachate forming wastes since it causes land and water pollution. Incineration is suitable in such cases because burning takes place in a closed way and aim is volume reduction.

6. Manifest System, i.e., deciding responsibility and distributing role of generator, carrier, employ at different levels from common public, industrialists, and workers to government and local bodies undertaking this work.
7. Monitoring and laboratory tests are an indispensable part of the management process.

8. Stricter rules and regulations.

9. Collaborating with industries, dealers and allied units in this field to carry out the solid waste management work smoothly.

10. Inventorization and analysis.

Cost Effective Waste Management Plans

1. Collaboration between the manufacturing industries, institutes and governmental bodies will reduce load on government and hence would be a cost-effective methodology.

2. Environmental compensation, wherein resource-based compensation is taken instead of monetary fine for harming environment. This can be imposed on individuals, industries and bodies for violating waste/ pollution/ disposal rules. This would sort out two problems: negligence and mishap in solid waste management and an aid coming from compensation.

3. Preparation and Analysis of data, Inventory preparation can be a big asset in bringing down the cost of operation since it will help in preparing strategies.

4. Teaching people about the importance of waste disposal in correct way is the key in long term.

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

4.3.9 Estimation of Assimilative Capacity of the Land Environment

Assimilative capacity depicts the ability/ extent of absorption of pollutants in any environment without any kind of detrimental or harmful impacts. Popularly referred to as receiving capacity or as environmental capacity. It is utilized as a parameter in a variety of environment examination and analysis test and researches carried out on lakes, rivers, oceans, cities, wastes, air, atmosphere and soils. The assimilative capacity is often accompanied by carrying capacity in order to ensure the sustainable development of any environment. Carrying capacity is the peak industrialization that any area can sustain at maximum rate of the consumption of resources or by discharge of waste. It is a linkage in between the assimilative and supportive capacity. Assimilative capacity can also be understood as the ability of environment to heal itself from damages caused as a result of man-made activities and circumstances, its capacity to digest waste and toxic substances without getting damaged/ 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+ Landfilling) in tons.

RC is Remaining Capacity & SWG is Solid Waste Generated in tons.

Validation of the assimilated information can be done from the official detailed data from the respective organization. While, interpretation and conclusions can be drawn from the collected data by plotting graphs and analyzing past data, comparing to the present scenario and predicting the future situation with its help and taking necessary actions accordingly. In June 2020, under ISWM plan, a processing plant costing 127- 197 crore under PPP model was set up for treating the wastes from Bhilai and Bilaspur cities. On an average 500 tons of waste is treated every day and electricity is generated from it. This serves dual purpose: (i) waste treatment (ii) Energy recovery. Prediction of waste amounts that shall be generated in coming years in Bhilai using Forecast function of excel. Data was collected for 2005, 10, 15,17,18,20 waste generated data in tonnes per day from different sources and utilized it to predict future values. The annual waste generated in TPD in Bhilai along with the predicted values till 2033 is shown in Figure 4.11.

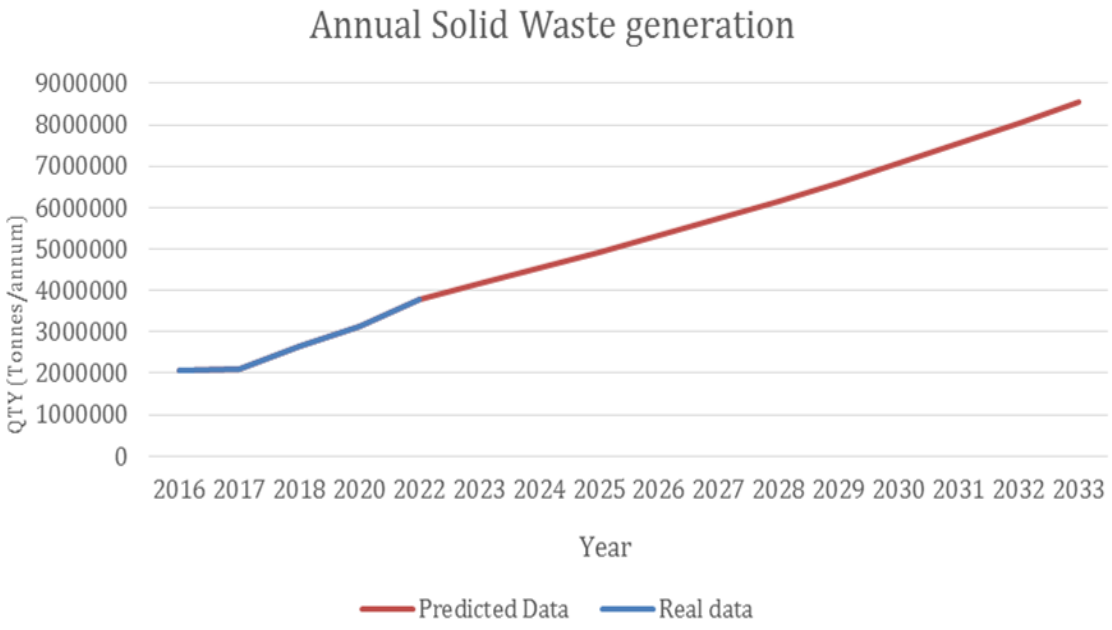


Figure 4.11: Prediction trend for waste generated upto 2033.

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

Approach 1:

- According to EPA chapter 4 for Solid waste Management, 100 tons of waste requires 24000 sq. ft of area approximately if a pile height of 50-60 feet is considered. (14) Thus, implementing this mathematical approach:

- Conversion: 24000 ft^2 means 2229.67 m^2.

- 2229.67 m^2 area can store 100 tons of waste therefore, 5000 m^2 will accommodate 224.248 tons of waste approx. Hence, we are generating about 60 tonnes extra waste as of 2020 (15) in accordance with the land available in Potiyakala for waste disposal.

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

- In 2050 the rate is expected to be 1118.4 tons per day, so:

$$\frac{60}{224.248} = 26.75\%$$

- Now, $1118.4 \times 26.75\% = 299.172\ tons\ per\ day$ i.e., this would be the maximum permissible value. However, in future our infrastructure shall be improved and land allocation too would be more so obviously the waste storing capacity shall increase too which means a little higher waste generation relaxation can be considered.

- May be 1.2- 1.5% based on impacts the plans have i.e., 359.0064 to 448.758 tons per day of waste in 2050 shall be handled with minimum complications and maximum efficiency.

- Thus, $1118.4 - 359.0064 = 759.3936$ & $1118.4 - 448.758 = 669.642$ i.e., 40.125% to 32.1% decrease in the predicted value (1118.4 TPD) shall be disposed off in 2050 effectively.

4.3.11 Analysis of Soil in the Bhilai Region

Soil monitoring data are presented in Table 4.16.

Table 4.16: Soil monitoring station in Bhilai.

Sampling ID	Place	Latitude (°)	Longitude (°)
BDS 001	Khapmikala Soil	21.181944	81.500556
BDS 002	Silada B.S Durg	21.187778	81.22889
BDS 003	Rajanbundh Road	21.163889	81.255556
BDS 004	Anjora	21.149690	81.209572
BDS 005	Mahamara 1	21.174730	81.244296
BDS 006	Mahamara 2	21.180022	81.250193
BDS 007	Yoratariya	21.192573	81.194213
BDS 008	Durg urla	21.204635	81.274180
BDS 009	Sahu bhavan	21.208530	81.426016
BDS 010	Hat chauk ganv	21.225870	81.402655
BDS 011	Sirsa chowk	21.255805	81.309167
BDS 012	Bhatta ganv	21.269916	81.310543
BDS 013	Jayshree pvt	21.186010	81.232751
BDS 014	Khapli road	21.104483	81.386774
BDS 015	Khapali road 2	21.099988	81.386878
BDS 016	Khapali school	21.092942	81.382704
BDS 017	Bisham panchawk	21.101862	81.437004
BDS 018	Dour road	21.114893	81.450705
BDS 019	Ringini village	21.274396	81.428237
BDS 020	Khamata village	21.277251	81.409644
BDS 021	Kherdha village	21.273554	81.396697
BDS 022	Nursery village	21.310006	81.372732
BDS 023	Bendi road	21.119929	81.450760
BDS 024	Bendi village	21.128112	81.452124
BDS 025	Ghughwa village	21.132336	81.462959
BDS 026	Ghughwa village 2	21.148782	81.474672
BDS 027	Durg (bendi)	21.130595	81.456444
BDS 028	ghughwa	21.130511	81.466150
BDS 029	Korsa village	21.151040	81.476523
BDS 030	Auri village	21.161342	81.477992
BDS 031	ringini	21.263637	81.428284
BDS 032	Ringini 1	21.274437	81.428284
BDS 033	khesamara	21.275566	81.391556
BDS 034	Dipra para	21.275586	81.391556
BDS 035	Khuguda village	21.229258	81.499936
BDS 036	Khuguda village	21.223931	81.496645
BDS 037	Radhe shyam vatika	21.219079	81.492557

BDS 038	Urla village	21.21456666	81.48604841
BDS 039	Charoda village	21.20917175	81.47993858
BDS 040	Charoda village 2	21.20250988	81.48575487
BDS 041	Nardhi village	21.19602056	81.4873066
BDS 042	Nardhi village durg	21.18385563	81.48218144
BDS 043	Achanakpur village	21.11402603	81.45338246
BDS 044	Dhamdha	21.27199006	81.45354422
BDS 045	Raghav farm	21.27997877	81.45532852
BDS 046	Dhamdha ravishankar road	21.28703079	81.45922647
BDS 047	Ringni village	21.26181354	81.43120523
BDS 048	Jarway	21.25287216	81.43259732
BDS 049	Bhilai	21.26573711	81.42683267
BDS 050	Durg	21.26083586	81.41240814
BDS 051	Kherdha	21.26853346	81.40070702
BDS 052	Jagratarai	21.19250358	81.18865454
BDS 053	Mumbai Kolkata highway	21.21199783	81.22512616
BDS 054	Mumbai Kolkata highway	21.21294552	81.23002422
BDS 055	durg	21.20954589	81.24724655
BDS 056	Durg bypass	21.21056966	81.25537446
BDS 057	Durg bypass 2	21.21199879	81.26363857
BDS 058	Urla ,durg	21.21199279	81.26639483
BDS 059	Pipperchhedi	21.20884677	81.23678468
BDS 060	Pipperchhedi 2	21.20347734	81.23323738
BDS 061	BSP garden	21.196313	81.382133
BDS 062	Charoda	21.200557	81.448376
BDS 063	Charoda 1	21.193305	81.457924
BDS 064	Sirsabhata	21.188921	81.457177
BDS 065	Gandanal	21.184101	81.451141
BDS 066	Pachpedi road	21.177827	81.44434
BDS 067	Pachpedi 2	21.172352	81.438119
BDS 068	Ganiyari vijendra karrey	21.165662	81.430456
BDS 069	Bhilai	21.171357	81.423620
BDS 070	Bhilai 2	21.171357	81.423620
BDS 071	Charoda	21.178126	81.428835
BDS 072	Durg	21.192310	81.460804
BDS 073	Charoda	21.198030	81.467363
BDS 074	Charoda	21.204476	81.474396
BDS 075	Charoda	21.197186	81.477235
BDS 076	Aundha	21.186085	81.469707
BDS 077	Andhi	21.175253	81.468819
BDS 078	Auri	21.169969	81.472910

4.3.12 Presence of Heavy Metals in Soil Samples Collected from Bhilai

Soil, is the uppermost part of ground-earth or dirt, is a mixture of organic matters, minerals and water. The term *Pedolith*, is commonly used to refer to the soil. Soil is the product of weathering, associated with erosion. Collectively, Earth's body of soil, called the Pedosphere, that interfaces with the lithosphere, the hydrosphere, the atmosphere and the biosphere. Soil contains about 50% solids (45% minerals and 5% organic matters) and 50% pores, which is filled by water and gases. Minerals basically formed by the breakdown of large rocks. Some of the most common minerals found in soil are Iron, Magnesium, calcium, potassium, zinc, chromium, nickel, etc. The production; accumulation and degradation of organic matter are climate dependent parameters. The minerals in the soil are classified into two categories, namely – Primary minerals (These are those minerals which have not been chemically altered since deposition. They are same or similar to their parent materials) and Secondary minerals (Minerals those are formed as a result of weathering of primary minerals).

When soil and its profile is altered by either removal of essential materials or addition of pollutants, which results in the reduction of the productivity or fertility of soil, it is called Soil Pollution. Soil is degraded or polluted due to the mixture of various waste materials like, industrial waste, agricultural waste, acid rain, radioactive waste and sometime some manmade efforts. The collected soil from Durg and Bhilai surroundings are full of iron, silicate and other metal oxides. We have identified and quantified other metals like; 'Al', 'Mg', 'Ca', 'Zn', 'K', 'Ti', 'Ba' and 'Cu' from the collected soil samples. Soils are brownish or yellowish in colour and found in both clay/dirt and granular form. These soil samples don't have any 'Pb' or 'Hg' contamination but some of the collected soils are 'As' contaminated.

According to the mean percentage analysis of various detected heavy metals from different soil samples collected from Durg and Bhilai area, here we have found that Fe is the dominant metal and occupied 22% of the mean percentile diagram. All the collected soils have about 21% 'Si', 5% 'Al', 2% 'Mg' and all metals oxide is about 42%. These soil samples are also Laterite red coloured soil but 'Si' percentage is slightly low than other areas of Chhattisgarh state. Fertility index is also low, due to near about 0% of 'P'. The soil sample collected from sampling station no. 7, is 'As' contaminated (0.063%). A food processing centre named 'Jayashree Grain Processing Pvt. Ltd.' is situated there, may use some 'As' mixed medicine or pesticide

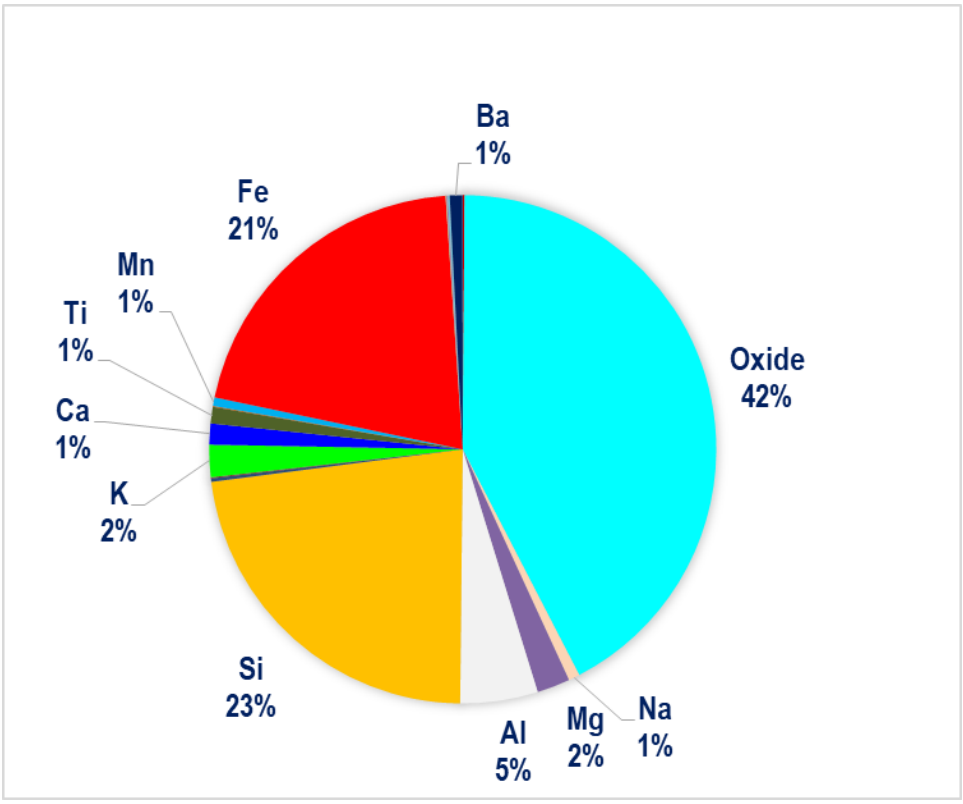


Figure 4.12: Mean metal percentile plot of metal concentrations present in soil of Bhilai.

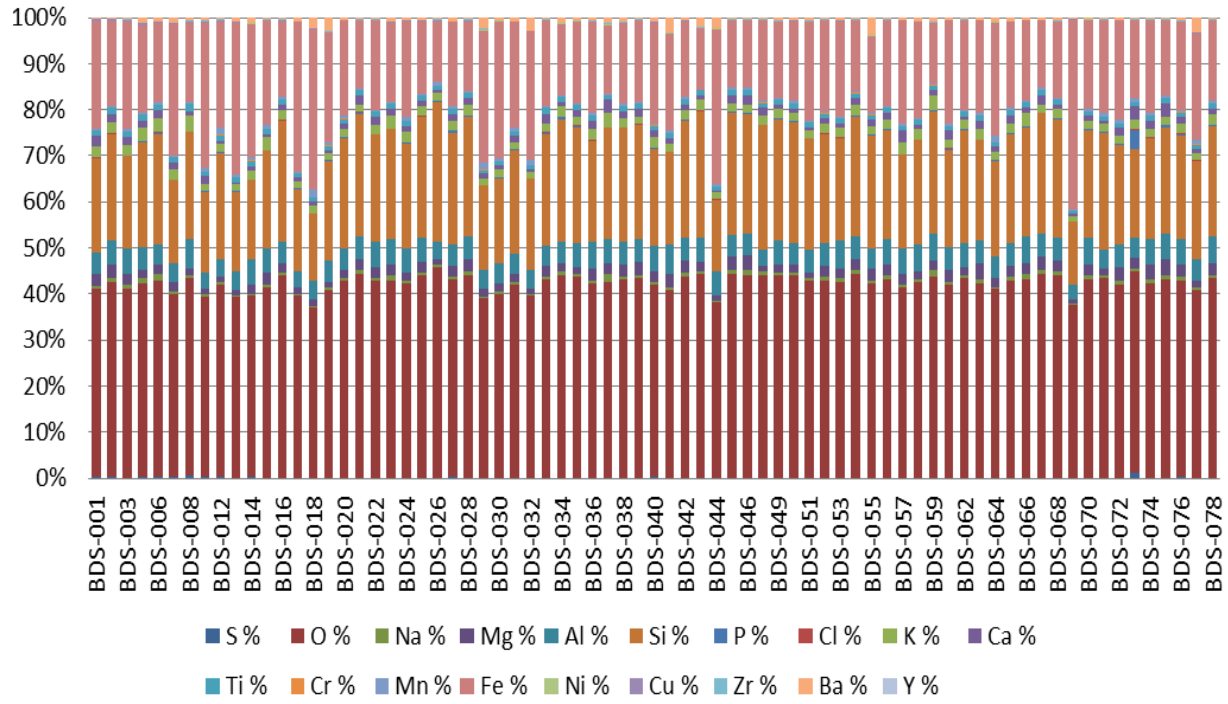


Figure 4.13: Station wise representation of metals composition in the Bhilai soil samples.

CHAPTER-V

NOISE ENVIRONMENT

5.1. Introduction

Sound can be measured in the air using a sound level meter, a device consisting of a microphone, an amplifier, and a time meter. Sound level meters can measure noise at different frequencies (usually A- and C-weighted levels).There are two settings for response time constants, fast (time constant = 0.125 seconds, similar to human hearing) or slow (1 second, used for calculating averages over widely varying sound levels). Sound level meter used in study is shown in Figure 5.1.

Figure 5.1: Sound level meter used in this study.

Noise pollution is a significant environmental issue that can have detrimental effects on human health and well-being. It is crucial to measure and assess noise levels accurately to identify areas of concern and develop effective mitigation strategies. Sources of noise pollution include transportation systems (such as road traffic, aircraft, and trains), industrial activities, construction sites, recreational activities, and even household appliances. The negative impacts of noise pollution are diverse and far-reaching. Prolonged exposure to high noise levels can lead to physical and psychological health issues, including hearing loss, sleep disturbances, stress, hypertension, reduced cognitive performance, and impaired communication. Additionally, noise pollution can disrupt wildlife habitats, interfere with natural ecosystem functions, and disturb the balance of various ecosystems. To address the detrimental effects of noise pollution effectively, it is crucial to accurately measure and assesses noise levels in different

environments. The purpose of this report is to present the findings of a study conducted on noise with following objectives:

i) To determine the relation between the noise levels and the traffic flow parameters namely vehicle flow (Q), Percentage of heavy vehicles (P), and the distance of measurement (d).
ii) To propose a mathematical or empirical relation satisfying all the functional parameters of the present study using Multiple Regression model

5.2. Methodology

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

a) The quantity of cars, motorcycles, trucks and buses that have passed by the observer during the time interval of each measurement;
b) The equivalent and statistical levels in dB(A): L_{eq}, L_{10} and L_{90}, emitted by the traffic at a distance of 10 feet from the center of the nearest road band to the observer.

5.2.1 Equivalent Level (L_{eq})

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

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

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

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

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

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

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

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

Where: P= Percentage of heavy vehicles

Q = Traffic volume in vehicles per hour

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

5.2.2 Noise Pollution Level (NPL)

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

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

5.2.3 Mathematical Model for Basic Noise Emission Level

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

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

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

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

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

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

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

$$y = a \times x + k \tag{2.39}$$

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

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

The values for the constants a and k, found after the statistical methods of linear regression had been applied, are: a = 2.28, k = 70.62. This way, the expression that mathematically represents the adjusted curve and can predict the equivalent levels for the road noise as:

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

5.3. Measurement of Noise Pollution

Noise levels of different locations are measured and present in Table 5.1.

Table 5.1: Noise monitoring data at different station in Bhilai.

Sample Id	Place	Latitude (°N)	Longitude (°E)	Noise level (dB(A))
BDN 001	Bhilai Power House Rail Station PF1	21.209745	81.375709	92
BDN 002	Shri Bholanath Mandir, Bhilai near Bhilai Power House Rail Station PF1	21.223233	81.354001	93
BDN 003	Bhilai chowk	21.208747	81.378086	76.9
BDN 004	Bhiali Gandhi chowk	21.208745	81.878087	79.9
BDN 005	Toll plaza bhilai	21.204964	81.366045	51.4
BDN 006	Kosanagar chowk	21.201029	81.324713	71.5
BDN 007	Durg by pass	21.214632	81.293847	73.7
BDN 008	Koradi chowk	21.222078	81.297403	87.8
BDN 009	Sirsa chowk	21.252234	81.307399	77.6
BDN 010	Surya nagar chowk	21.202437	81.289737	64.7
BDN 011	Sector 5	21.193565	81.353959	79.5
BDN 012	Pratap chowk	21.193598	81.354007	61.1
BDN 013	Borai road	21.202333	81.225549	77.4
BDN 014	Borai primary school	21.202333	81.225549	60.2
BDN 015	Naga chowk	21.175743	81.235486	87.5
BDN 016	Transport nagar	21.207360	81.406036	91.5
BDN 017	Power house chowk	21.207015	81.350046	80.6
BDN 018	Sarvana chowk	21.115855	81.388067	77.7
BDN 019	Motipur road	21.174162	81.538795	68.2
BDN 020	Azad market chowk	21.16859289	81.33531871	75.7
BDN 021	D.P.S. chowk risali	21.17467026	81.33488337	71.2
BDN 022	Sector 10 (utai road)	21.17825212	81.32444421	69.8
BDN 023	Sector 9 (utai road)	21.17850339	81.31540169	77.3
BDN 024	Jawaharlal Nehru hospital chowk	21.18840468	81.31747116	73.7
BDN 025	L-shape bridge Nehru nagar	21.19835172	81.32454268	75.3
BDN 026	Rail chowk	21.18760776	81.33882681	85.9
BDN 027	Asta chowk	21.18872413	81.34445905	73.7
BDN 028	M-7 chowk	21.1907237	81.34905619	74.3
BDN 029	GJR chowk	21.19389915	81.35377334	69.3
BDN 030	Awadhpuri chowk	21.157654	81.33575259	65.3
BDN 031	Kumhari chowk	21.24668949	81.51419266	78.3
BDN 032	Kumhari NP Part	21.23830979	81.4824313	77.1
BDN 033	Bhilai marshalling yard	21.22686712	81.46095305	75.6
BDN 034	Sirsa gate	21.20934199	81.43667111	74.4

BDN 035	Umad road	21.23590943	81.42815612	71.2
BDN 036	CSIDC market complex	21.22908355	81.41166477	77.8
BDN 037	Light industrial area charoda	21.22497725	81.39681108	75.2
BDN 038	Shankar nagar chawni	21.22278588	81.38521986	66.2
BDN 039	Nandini cowk	21.22322106	81.38077846	80.3
BDN 040	ACC cement plant	21.23295472	81.38309542	67.4
BDN 041	Bogad brodge	21.2415854	81.37654682	71.2
BDN 042	Bhagwa chowk	21.23781497	81.36576276	73.4
BDN 043	Kurud chowk	21.23908865	81.35215787	71.1
BDN 044	Rani Avanti bai chowk	21.2226861	81.34375977	83.4
BDN 045	Suryati mall	21.21715069	81.3222623	76.3
BDN 046	Nehru nagar east	21.20161684	81.32386023	85.7
BDN 047	Gurudwara chowk	21.20042197	81.32048623	78.1
BDN 048	Y bridge	21.19578188	81.30327003	74.5
BDN 049	Malviya nagar chowk	21.19319795	81.29304611	81.3
BDN 050	Rajendra park chowk	21.18907312	81.28577308	80.7
BDN 051	Ghadi chowk	21.18537121	81.27623542	72.5
BDN 052	Engineer chowk	21.18201823	81.26855434	7308
BDN 053	Pulgaon pass road	21.16596335	81.2627688	72.4
BDN 054	Anjora chowk	21.15571307	81.21521077	71.3
BDN 055	Kopedeeh chowk	21.15206308	81.20762966	77.6
BDN 056	Patia chowk	21.16956398	81.28505824	73.1
BDN 057	Maharaja chowk	21.17386734	81.2948357	77.2
BDN 058	GSR sector 5	21.19380155	81.35373696	77.3
BDN 059	JPN chowk	21.20302932	81.35019262	73.8
BDN 060	Sourabh park sector 1	21.20586414	81.36288166	72.1
BDN 061	Sector 3	21.199234337	81.36591543	68.7
BDN 062	Central AVE chaowk	21.19693646	81.3596309	76.3
BDN 063	SECTOR 4 RVP	21.18612122	81.35952809	69.3
BDN 064	Forest AVE road	21.18970212	81.37045322	70.3
BDN 065	RPM sector 3	21.1961163	81.38266442	68.1
BDN 066	Central AVE sector 1	21.20205499	81.37783878	71.6
BDN 067	Great easten road	21.20884867	81.37806142	87.4
BDN 068	Kushipur chowk	21.20793274	81.39232913	71.6
BDN 069	Nagar palika nigam	21.20689615	81.4065474	70.6

Sound or noise monitoring done at several locations in Bhilai is shown in Figure 4.56. The highest level of sound was found in BDN001, BDN002 and BDN016 which are above 80 db. Except BDN005 all other level are higher than permissible limit. These areas are the one of the most crowded areas and heavy traffic area. The permissible limit for residencial area at day time is 55 db and in commercial area it is 65 db and for industrial area it is 80 db. As per the result we can cleary see it is way more than the limit (Source:

Noise Pollution (Regulation and Control) Rules, 2000 (ismenvis.nic.in)). The Hierarchy of Controls concept is often used to reduce noise in the environment or the workplace. Engineering noise controls can be used to reduce noise propagation and protect individuals from overexposure. When noise controls are not feasible or adequate, individuals can also take steps to protect themselves from the harmful effects of noise pollution. If people must be around loud sounds, they can protect their ears with hearing protection (e.g., ear plugs or ear muffs). Noise from roadways and other urban factors can be mitigated by urban planning and better design of roads. Roadway noise can be reduced by the use of noise barriers, limitation of vehicle speeds, alteration of roadway surface texture, limitation of heavy vehicles, use of traffic controls that smooth vehicle flow to reduce braking and acceleration, and tire design.

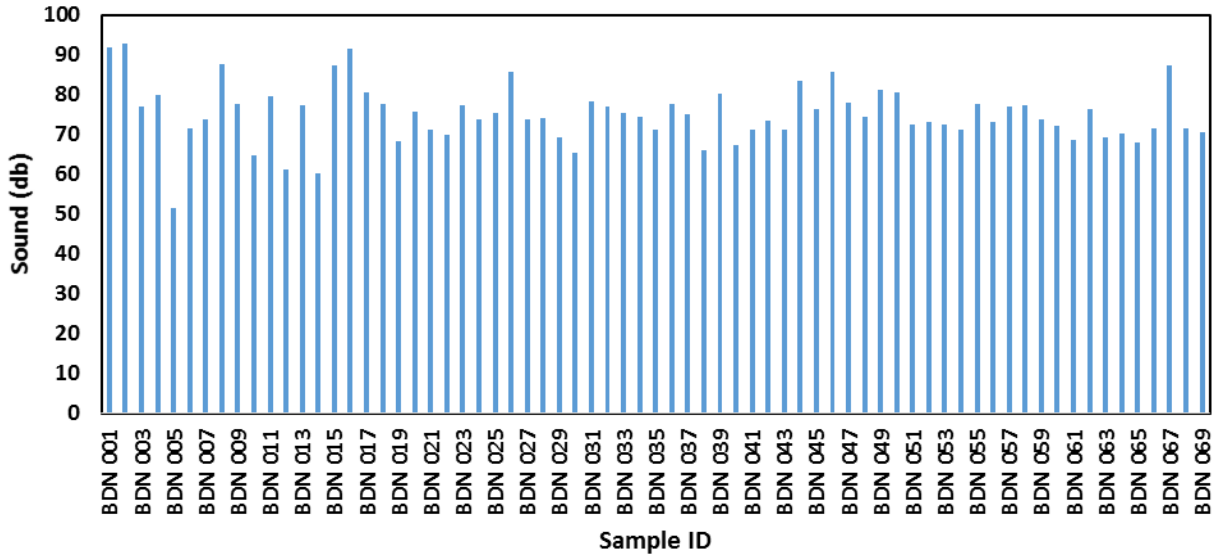


Figure 5.2: Sound level recorded at different monitoring stations at Bhilai.

Moreover, to find the Equivalent noise level (L_{eq}) by using "Griffiths and Langdon Method" at various location in Bhilai city. The data collected from various monitoring stations BDN001 to BDN069 is combined to form 7 zones based on the road passes through that location. For example Bhilai chowk, Koradi chowk, Bhiali Gandhi chowk, Surya nagar chowk, Pratap chowk , Toll plaza bhilai , Bhilai Power House Rail Station PF1, Sirsa chowk , these location lies on Patan Raipur road so I take them as zone 1 as Patan Raipur road zone & similar way for other zone. Similarly, other zone were formed taking into account different monitoring stations falling under them. Therefore, the list of different zones along with their road/ traffic junction is presented in Table 5.1. Furthermore, the comparison of observed L_{eq} with noise pollution level (NPL) of different zone is shown in Figure 5.3. The regression analysis of observed L_{eq} with calculated

L_{eq} is depicted in Figure 5.3. For the validity of newly developed road traffic noise prediction model is then compared with observed values and the obtained values are shown in Table 5.2.

Table 5.2: Classification of different road network in Bhilai 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	JE Road	2756	3.918723	75.78	74.13
2	Nandini Road	1598	12.51564	74.87	73.67
3	Garrage Road	3436	1.979045	76.41	74.64
4	Rajendar Road	1606	10.58531	74.58	73.06
5	Road No=7 Durg To Bemetara	2100	14.57143	76.37	76.26
6	Road No= 22 Utai Road	1302	8.75576	73.38	70.87
7	Central AVL Road	6374	1.694383	79.02	78.92

The scatter plot for model validation is shown in Figure 5.4 has coefficient of determination (R^2) of the 45^0 line is 0.9511. 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 and 2. This consist of JE Road and Nandini Road. Moreover, from Figure 5.3, 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.

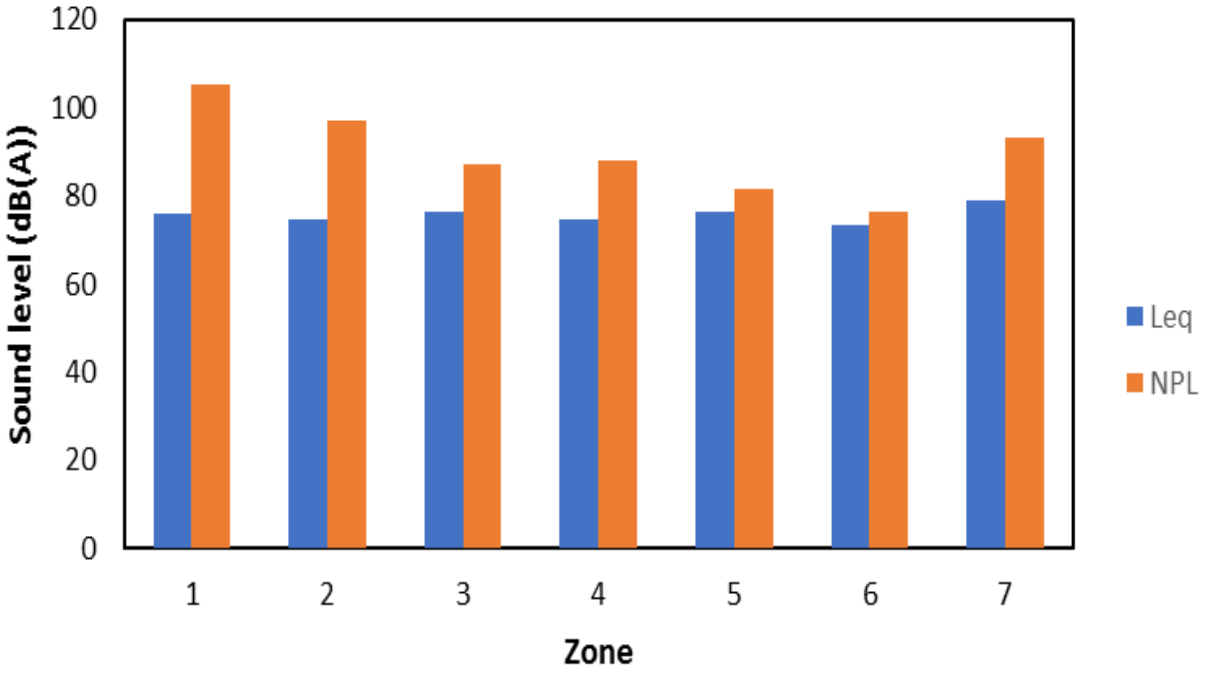


Figure 5.3: Comparison of observed L_{eq} with Noise Pollution level (NPL) of different zone in Bhilai.

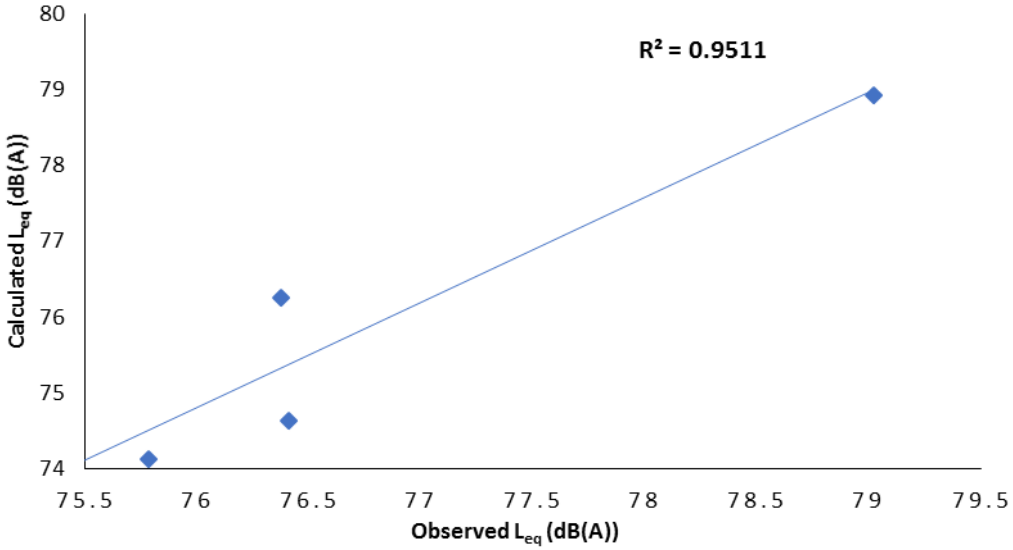


Figure 5.4: Comparison of observed L_{eq} with calculated L_{eq} sound level in the Bhilai region.

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 Bhilai

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

Important Medicinal Plants (MPS) of Bhilai durg region include about 911 genera and 196 genera. These plants belong to 14 taxa at the species level. It contains a total of 1525 plant species, including 1) climbers - 161 sp. 2) Herbs - 808 sp. 3) Shrubs - 262 sp. 4) trees - 294 sp. In the state of Chhattisgarh, the use of traditional knowledge (TK) of medicinal plants (MPS) was practiced by Tribal Group (TGS) living in remote areas of forests and hills. Traditional knowledge (TK) about the healing properties of plants found near local natural forests is a custom and folklore inherent in their culture. It traditionally protects the biosphere and the culture passed on to the next generation which helps to protect/preserve the original/natural form of the Bioresource. Different category of plant found in Bhilai are shown in Table 6.1.

Table 6.1: Different category of plant found in Bhilai.

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

Ginger

Turmeric

Musturd

Winter cassia

Cascabela

Hybiscus

Rose

Figure 6.1: Different flora growing in the Bhilai.

Table 6.2: Different medicinal plant found in Bhilai.

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

Jute-Hairy Caterpillar

Swallowtail butterfly

Honey bee

Figure 6.2: Different insects found in the Bhilai.

House Crow

Indian Peacock

Pied Cuckoo

Common Kingfisher

Figure 6.3: Different birds found in the Bhilai.

Insects are the largest single and most diverse group of successful and dominant taxa on Earth, and because of their diversity, they play an important role in ecology and affect agriculture, human health, and natural resources. Insects are six-legged invertebrates of the class Insecta, phylum Arthropoda, and kingdom Animalia. Insect biodiversity is the difference between living things, organisms from all sources, including terrestrial, marine and other aquatic ecosystems. They come in an amazing variety of sizes, and the ability to fly allows them to escape from enemies and disperse into new environments when they acquire a protective shell or exoskeleton. Insects have a nervous system that makes them similar to ours in the way they see, hear, smell, taste and feel. There are different types of insects according to their habits and habitats are as follows

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

The biodiversity consists of three main parts: genetic diversity, species diversity and ecosystem diversity .The various insect species were collected from the study area to identify the insect species and their diversity. Among them various insect species belonging order Lepidoptera, Coleoptera, to Hemiptera, Hymenoptera, Diptera, Dermaptera, Orthoptera, Odonata, Mantodea, and Isoptera were collected. A total of 603 species from 38 families and 10 orders were identified. In which order Diptera identified with maximum number of ge species 153 with five families i.e. *Syrphidae*, *Trypetidae*, *Muscidae*, *Culicidae*, *Asilidae* in which *Trypetidae* is dominant and Dermaptera is with minimum number of species 2 with *Labiduridae* family *Hymenoptera* is the second rich diverse order with five families *Vespidae*, *Xylocopidae*, *Apidae*, *Formicidae*, *Tenthredinidae* in which Apidae is dominat. Order *Hemiptera* is also rich in number with six families in which *Reduviidae* is dominant. *Coleoptera* is also rich diverse order with six families with 90 species in which *Coccinellidae* is dominant. *Orthoptera* with 66 species of three families in which *Acrididae* is dominant. Order lepidoptera identified with 55 species of six familiesin which *Arctidae* is dominant. Order *Mantodea* with 24 species of one family *Mantiidae*, *Isoptera* with 10 species of one family *Termitidae* and *Odonata* with 16 species of three families i.e. *Coenagnonidae*, *Gomphidae* and *Aeshnidae*.

Table 6.3: Common birds found in Bhilai

Sr. No	Order	Family	Common Name	Scientific Name
1	*Galliformes*	*Phasianidae*	Indian Peafowl	*Pavo cristatus*
			Red Spurfowl	*Galloperdix spadicea*
2	*Anseriformes*	*Anatidae*	Lesser whistling duck	*Dendrocygna javanica*
			Indian Spot-billed Duck	*Anas poecilorhyncha*
3	*Podicipediformes*	*Podicipedidae*	Little Grebe	*Tachybaptus ruficollis*
4	*Falconiformes*	*Falconidae*	Peregrine Falcon	*Falco peregrinus*
		Accipitridae	Brahminy Kite	*Haliastur indus*
			Black Kite	*Milvus migrans*
5	*Columbiformes*	*Columbidae*	Common Pigeon	*Columba livia*
			Laughing Dove	*Stigmatopelia senegalensis*
			Spotted Dove	*Stigmatopelia chinensis*
			Red Collared Dove	*Streptopelia tranquebarica*
			Eurasian Collared Dove	*Streptopelia decaocto*
7	*Psittaciformes*	*Psittacidae*	Rose-ringed Parakeet	*Psittacula krameri*
			Plum-headed Parakeet	*Psittacula cyanocephala*
8	*Strigiformes*	*Strigidae*	Barn Fish Owl	*Ketupa zeylonensis*
			Brown Wood Owl	*Strix leptogrammica*
			Spotted Owlet	*Athene brama*
9	*Apodiformes*	*Apodidae*	Asian Palm Swift	*Cypsiurus balasiensis*
			Little Swift	*Apus affinis*
10	*Upupiformes*	*Upupidae*	Common Hoopoe	*Upupa epops*
11	*Coraciformes*	*Coracidae*	Indian Roller	*Coracias benghalensis*
		Alcedinidae	Common Kingfisher	*Alcedo atthis*
12	*Passeriformes*	*Aegithinidae*	Common Iora	*Aegithina tiphia*
		Corvidae	House Crow	*Corvus splendens*
			Indian Jungle Crow	*Corvus culminatus*

A total of 30 bird species were recorded belonging to 12 orders, 14 families and 30 genera. *Columbidae* family represented maximum number of birds followed by *Accipitridae, Phasianidae and Strigidae.* Rest of the families represents two or one bird. Among the orders *Passeriformes* represent maximum number of birds followed by *Ciconiiformes Falconiformes* and *Columbiformes* (7 bird species); *Piciformes* and *Coraciformes* represent 5 birds each; *Charadriiformes* consist 4 birds; *Cuculiformes* and *Strigiformes* consist 3 birds each; *Anseriformes, Apodiformes, Gruiformes, Psittaciformes, Pelicaniformes and Galliformes* represents 2 birds each. The least 1 number of bird species was represented by *Podicipediformes*

Bengal Tiger

Jackal

Leopard

Figure 6.4: Different wild animals found in the Bhilai.

Table 6.4: Name of animals found in Bhilai region.

Family	Common name	Species
Felidae		
	Bengal Tiger	*Panthera Tigris*
	White Tiger	*Panthera Tigris Tigris*
	Leopard	*Panthera Pardus*
	Jackal	*Canis Aureus Indicus*
	Hyaena	*Hyaena Hyaena*
	Toddy Cat	*Paradoxurus Hermaphroditus*
Ursidae	Himalayan Bear	*Ursus Thibetanus*
	Sloth Bear	*Melursus Ursinus*
Cervidae	Spotted Dear	*Axis Axis*
	Barking Dear	*Muntiacus*
	Antelope	*Antilocapra Americana*
	Blackbug	*Antilope Cervicapra*
Muridae	Whitemouse	*Mus Musculus*
Cercopithecidae	Common Langur	*Semnopithecus Schistaceus*
	Rhesus	*Macaca Mulatta*
	Bonnet	*Bonnet Macaque*
Alligatoridae	Alligator	*Gavialis Gangeticus*
Crocodilae	Crocodile	*Crocodylus Niloticus*
Pythonidae	Python	*Python Molurus*
Bovidae	Nilgai	*Boselaphus Tragocamelus*
Testudinidae	Tortoise	*Geochelone Elegans*
	Star Tortoise	*Geochelone Elegans*
Hystricidae	Indian Porcupine	*Hystrix Indica*
Varanidae	Water Monitor Lizard	*Varanus Salvator*

6.1.2 Ecosystem of Bhilai

Wetlands are areas where water is the main regulating factor for the environment and associated flora and fauna. Birds as the best indicators of wetland performance or measure of the success of wetland management, restoration and creation. Species diversity, species richness and bird dominance were calculated. A total of 1113 birds were recorded from 93 species, 36 families and 14 societies, of these 93 species, 42 wetland and 51 terrestrial species. The highest bird diversity was recorded at Parsada Lake followed by Bandha Dam and Khanduwa Dam. Bird abundance and vegetation cover were also recorded. Species richness was highest in Parsada Lake followed by Bandha Dam and Khanduwa. Most birds were recorded at Parsada Lak, followed by Bandha Dam, Khuteri I Lake and Khandwa Dam, which has only one endangered species, the Egyptian vulture Neophron percnopterus. Lantana Camara (28.25%) was observed in most wetlands followed by Ipomea carnea (15.28%). They cover an

area of more than 05 hectares and support a rich food web from microscopic algae and underwater vascular plants to other organisms such as birds, reptiles and mammals. These wetlands have good birdlife and the area has good food availability and spatial space and undisturbed habitat. These places will be protected from birds in the future.

Table 6.5: Some of the commonly observed terrestrial venomous animals in the Bhilai

Animal Category	Venomous Creatures	Habitat
Invertebrates : Arthropods		
Arachnids	Spiders	Gardens & Fields
	Scorpions	Fields with moist soil
Chilopods	Centepedes	Agricultural Lands & Gardens
Insects	Bees	Vegetation & Abandoned places
	Wasps	Vegetation & Abandoned places
	Mosquitoes	Dark niches, Gardens
	Flies	Fields
	Ticks	Fields
	Mites	Fields
Vertebrates : Reptiles	Snakes	Gardens, Agricultural lands
	Lizards	Gardens
	Calotes	Gardens & Fields

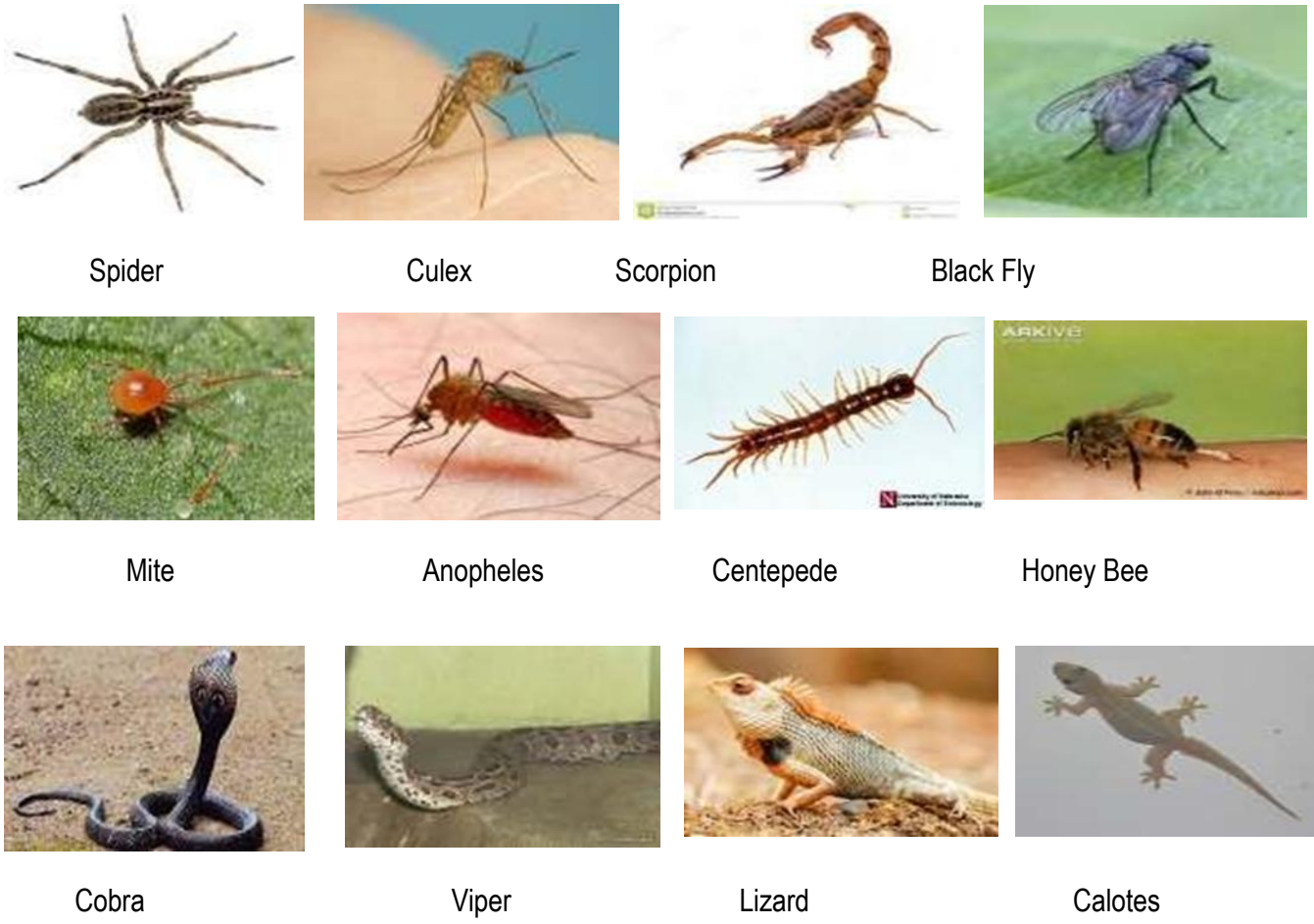


Figure 6.5: Different reptiles found in the Bhilai.

6.1.3 Algal Biodiversity in Fresh Water Reservoir of Bhilai

A study has been carried out to understand the physico-chemical properties of water and seasonal algal diversity of Shivnath river at a stop dam constructed near Durg city of Chhattisgarh state. The study revealed the presence of 25 different species of algae. During the study period members of *Chlorophyceae* dominated the algal community, followed by members of *Cyanophyceae* and *Euglenophyceae*, *Zygnematales* and *Chlorococales* shows maximum species diversity in comparision to *Rivulariales*, *Volvocales* and *Euglenales*. Thallus diversity from prokaryotes to eukaryote at cellular level and motile Euglena to non motile all other member and morphologically unicellular Chlamydomonas to well organised thallus or Chara and Nitella shows tendency towards tree habit through coenobial Volvox and colonial Nostoc filamentous S*pirogyra*, *Mougeotia*, *Zygnema*, *Oedogonium*, *Ulothrix* etc.

6.1.4 Threat to Agriculture Biodiversity

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

6.1.5 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 Gastroenterititis, Trachoma, Poliomyelitis and Protein-energy malnutrition. Prevalence of high incidence of respiratory illness among the urban children is an indication that air is getting polluted.

6.1.6 Measures for Protection and Conservation of Biodiversity

Flora

a) Introduction of Grass species since they are drought tolerant and can colonize fast in low nutrient soil due to the presence of fibrous roots.
b) Plant more native plants.
c) Long term plans like Forest fire protection plan.
d) Development of Wetland habitat.
e) Monitoring of conservation and management action plans and continued updation whenever required.

Fauna including Wildlife

a) To collect and survey all the information about wildlife, especially, their number and growth.
b) To protect habitat by protecting forests.
c) To delimit the areas of their natural habitat.
d) To protect wildlife from pollution and from natural hazards.
e) To impose complete restriction on hunting and capturing of wildlife.
f) To impose restrictions on export and import of wildlife products and severe punishment to be given to those who indulge in this activity.
g) To make special arrangements to protect those species whose number is very limited.

Migratory Avi-fauna

a) Fostering bird-friendly farmland.
b) Reduce your plastic food print.
c) Protect birds from cats.
d) Keep your woods wild.
e) Making renewable energy bird-safe.
f) Ending illegal bird killing by changing attitudes.

Rare and Endangered Species

a) Learn about endangered species in this area.
b) Create a backyard wildlife habitat. Put bird feeders and other wildlife attractants, such as bird houses and baths.

c) Minimize use of herbicides and pesticides.
d) Do not buy plastic products.
e) Don't litter and destroy sensitive habitats, which may be home to native/visiting species that are endangered or threatened.
f) Never purchase products made from endangered species.

Medicinal Plants

In-situ conservation

a) Conservation of a given species in its natural habitat or in the area where it grows naturally is known as in-situ conservation.
b) It includes Gene bank / Gene sanction, Biosphere reserves, national parks, sacred sites, Sacred grooves etc.
c) It is only in nature that plant diversity at the genetic, species and eco-system level can be conserved on long-term basis.
d) It is necessary to conserve in distinct, representative biogeographic zones inter and intra-specific genetic variation.

Ex-situ Conservation

Conservation of medicinal plants can be accomplished by the ex-situ i.e., outside natural habitat by cultivating and maintaining plants in botanic gardens, parks, other suitable sites, and through long term preservation of plant propagules in gene banks (seed bank, pollen bank, DNA libraries, etc.) and in plant tissue culture repositories and by cryopreservation).

6.1.7 Green Belt Development Plan

Greenbelt means planting of special type of plants suitable to that particular agro-climatic zone and soil characteristics in a place which will make the area cooler, reduce air pollution, prevent soil erosion and further improve the soil fertility status. A green belt around the periphery of boundary and road side will be created to avoid erosion of soil, prevention of landslides, minimize the air pollution and noise pollution in the project area. The green plants are capable of absorbing air pollutants and forming sinks for pollutants. Leaves with their vast area in a tree crown, absorb pollutants on their surface, effectively reducing their concentration and noise level in the ambient.

6.1.8 Selection of Plant Species for Green Belt Development

The selection of plant species for the development depends on various factors such as climate, elevation and soil. The plants would exhibit the following desirable characteristics in order to be selected for plantation.

1. The species should be fast growing and providing optimum penetrability.
2. The species should be wind-firm and deep rooted.
3. The species should form a dense canopy.
4. As far as possible, the species should be indigenous and locally available.
5. Species tolerance to air pollution like SO_2 and NO_2 should be preferred.
6. The species should be permeable to help create air turbulence and mixing within the belt.
7. There should be no large gaps for the air to spill through.
8. Trees with high foliage density, leaves with larger leaf area and hairy on both the surfaces.
9. Ability to withstand conditions like inundation and drought.
10. Soil improving plants (Nitrogen fixing rapidly decomposable leaf litter).
11. Attractive appearance with good flowering and fruit bearing.
12. Bird and insect attracting tree species.
13. Sustainable green cover with minimal maintenance.
14. The species should be perennial and evergreen.
15. The trees should maintain regional ecological balance and conform to soil and hydrological conditions. Indigenous species should be preferred.

6.1.9 Tree Species Suitable for Afforestation

Anthropogenic climate change is affecting both organisms and ecosystems. The increasing a concentration of greenhouse gases in atmosphere is a major cause of global warming. Over the past century, carbon dioxide levels, which have risen from 300 ppm to 400 ppm, have increased the ambient temperature by 0.5 °C. Over the next 100 years, the temperature is expected to rise by a further 0.5-0.6°C. However, China is the largest emitter of carbon dioxide, followed by the United States and India. Based on current CO_2 emission trends, it is clear that concrete steps must be taken to reduce the effects of global warming, such as improving sources of carbon emissions and increasing public awareness of reducing the carbon footprint.

Trees absorb major pollutants such as carbon dioxide from cars and industry before they reach the upper atmosphere, trapping heat and contributing to global warming. Absorbed CO_2 is processed

through photosynthesis and trees are considered efficient natural carbon sinks. Planting trees is therefore a step towards controlling climate change. Fast-growing and long-lived tree species are ideal carbon sinks, but these qualities are usually mutually exclusive, as fast-growing trees are short-lived and long-lived trees tend to grow slowly. Forests are important carbon sinks, but forest areas are decreasing due to deforestation for non-forestry purposes. That is why air pollution and greenhouse gases are constantly increasing. While there are 422 trees per person on Earth, that ratio has dropped to 28:1 in India.

A total of 438 individual trees of 37 species and 17 genera were recorded. The largest number of trees and their relative abundance was Peltophorum pterocarpum, followed by Samanea saman, Senna siamea, Azadirachta indica and Alstonia scholaris. The high relative abundance of these species indicated that they were the most popular roadside crops in Bilaspur. These tree species, with the exception of Azadirachta indica, are exotic and were introduced for their rapid growth and high survival in a wide variety of soils. Therefore, these species increased in wastelands, road and canal banks, and near railways. Azadirachta indica was the most abundant of the primary trees, with a relative abundance of 6.84%. Other trees such as Terminalia arjuna, Dalbergia sissoo and Tamarindus indica had a relative abundance of 2.05-3.88% and were rarely found in roadside plantations. Large native trees known for their longevity and pollution mitigation potential (eg, *Mangifera Indica*, *Ficus Benghalensis*, and *Ficus Religiosa*) ranged from 1.82 to 2.51%. Because these trees grow slowly and are grazed by livestock, officials rarely select them for roadside plantings. However, these species can be found among roadside plantations through seed dispersal by animals and birds, or planted and protected by residents due to their religious significance. These trees effectively filter soot and clean the air in the long term, and also act as "green highways" that facilitate the movement of birds, insects and other animals.

Table 6.6: List of trees present on the road side of Bhilai

S. No	Botanical Name	Family	Common Name
I.	*Acacia Leucophloea* Roxb.	*Mimosoidaceae*	Ronih
2.	*Acacia Nilotica*	*Mimosoidaceae*	Babu
3.	*Acacia Awiculiformis* A.Cunn.	*Mimosoidaceae*	Australian Babool
4.	*Aegle Marmelos L.*	*Rutaceae*	Bel
5.	*Ailanthus E, Xcelsa Roxb.*	*Simamubaceae*	Mahaneem
6.	*Albizzia Lebbek L.*	*Mimosoidaceae*	Siris
7.	*Albizzia Procera L.*	*Mimosoidaceae*	Siris Safed
8.	*Alstonia Scholaris R.*	*Apocvnaceae*	Chhatim
9.	*Annona Reticulate R.*	*Annonaceae*	Ramphal
10.	*Annona Squamosa L.*	*Annonacea*	Sheetafal
11.	*Anthocephalus Cadamba Miq.*	*Rubiaceae*	Kadam

12.	*Artocarpus Heteroplryllus L.*	*Moraceae*	Katttl1al
13.	*Artocarm1s Lacucha L.*	*Moraceae*	Badhal
14.	*Azadirachta Indica A.Juss.*	*Meliaceae*	Neem
15.	*Balumia Pwvurea L.*	*Caesalpiniodeae*	Kachnar
16.	*Bauhinia Ve1ie1wta L.*	*Caesalpiniodeae*	Kaclu1ar
17.	*Bombax Malabmica L.*	*Bombacaeae*	Semal
18.	*Butea Monosperma Lamk.*	*Papilionaceae*	Chhoela
19.	*Caesalpinia Bonducella L.*	*Le=inaceae*	Flem
20.	*Careya Arborea Roxb.*	*Myrtaceae*	Kumahi
21.	*Carthamus Tincto1ius*	*Compositae*	Kusum
22.	*Cartivia Adansonii*	*Capparidaceae*	Bama
23.	*Carvota Wrens*	*Pahnae*	Salfi
24.	*Cassia Fistula L.*	*Caesalpiniodeae*	Amaltas
25.	*Ceiba Pentandra*	*Bombacaceae*	Kapok
26.	*Cordia Mixa Auct*	*Rutaceae*	Lasoda
27.	*Dalberf!:la Sisso Roxb.*	*Papilionaceae*	Shisham
28.	*Delonix Ref[la Baier*	*Caesalpiniodeae*	Gulmohar
29.	*Diospyrus Melanoxylon Roxb.*	*Verbenaceae*	Tendu
30.	*Drypetes Roxbu11?:Hii*	*Eupho1biaceae*	Putraniivika
31.	*Eucalvvtus F[Randis*	*Myrtaceae*	Neilgir. i
32.	*Euf!Enia Iambolana*	*Mvrtaceae*	Jamun
33.	*Ficus Benf!Alensis Krislmae L.*	*Moraceae*	Baniad
34.	*Ficus Benf!Alensis L.*	*Moraceae*	Baniad
35.	*Ficus Elastic*	*Moraceae*	Rubber
36.	*Ficus F!Lomerata Roxb*	*Moraceae*	Gular
37.	*Ficus Infectoria Roxb*	*Moraceae*	Pahi
38.	*Ficus Microcarpa L.*	*Moraceae*	Laurel fig
39.	*Ficus Virens D1yander*	*Moraceae*	Pakar
40.	*Ficus Religiosa L.*	*Moraceae*	Pipal
41.	*Gardinia Latifolia Ait*	*Rubiaceae*	Piprol
42.	*Gmelina Arborea Roxb*	*Verbenaceae*	Khamer
43.	*Hardwikia Binata Roxb*	*Lemuninaceae*	Anian
44.	*Kigelia Pinna Ta Lam.Benth*	*Bie:noniaceae*	Sasuage II'ee
45.	*Laf[Estoromea Perviflora Roxb*	*Lytharaceae*	Nana
46.	*Laf[Estoromea Speciosa Roxb*	*Lytharaceae*	iarnl
47.	*Laucaenea Leucocephala*	*Mimosoidaceae*	Subabul
48.	*Madhuca Indica L.*	*Sapotaceae*	Malma
49.	*Manf[Ifera Indica L.*	*Anacardiaceae*	Mango
50.	*Melia Azadirachta L.*	*Meliaceae*	Bachain

Neem Tree

Mango Tree

Rubber Tree

Shisham Tree

Figure 6.6: Trees found in the roadside of Bhilai and suitable for afforestation.

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6.1.10 Environmental Management Plan for Biodiversity

From the study it has concluded that due to the development activities in the past decade there has been a great deal of deforestation as shown in the classified satellite landuse maps prepared using Remote Sensing Technology. Studies have shown that there has been a decrease in the vegetation cover of Bhilai. Measures to reduce the extent of deforestation and promote afforestation have been identified with the help of 'Environmental Impact Assessment Reports' of various mining companies. According to the land conditions many native species have been identified for plantation and greenbelt development and mitigatory measures were taken. Delineation of appropriate environmental management programme plan for development of 'Green Cover' in the study region has done based on government policies and environmental impact assessment reports.

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

CHAPTER-VII

CONCLUSION AND ACTION PLAN

7.1 Conclusion

A comprehensive carrying capacity study has been carried out within a radius of 15 km from the centre of CPA Bhilai-Durg. 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 16 sampling stations in the Bhilai-Durg region during summer, winter, and pre/post monsoon seasons. The highest average PM_{10} concentration of 400 µg/m^3 for summer and post/pre monsoon season is found for B03 and B08 as the main reason could be the nearby industries and transport sources. Moreover, the highest $PM_{2.5}$ level were found in B01, B02, B03 as it is very heavily traffic area an 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 Bhilai, shows that there is no supportive carrying capacity and the pollution load in terms of PM_{10}, is exceeding the Assimilative Carrying Capacity.

The SO_2 values observed at these stations are well within the NAAQS limit of 80 µg/m^3 but the stations B03, B10, B13 that is mainly because of steel industries, power plant and other industries. Furthermore, the NO_2 variation in different seasons are within the limit of 80 µg/m^3. However, high concentration were found in B03, and B05 and the main reason could be the nearby industry such as wood industry and other industries as NO_2 in air is because of vehicals, power plant and industrial emission etc. In Bhilai 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 0.75µg/m^3 to 0.83µg/m^3 among all air quality monitoring stations. Similarly, we have found TC values ranging from

1.13 µg/m³ to 1.87 µg/m³ among all air quality monitoring stations. Carbonaceous compounds are mainly organic or house hold type in Durg and Bhilai's. Carbonaceous compounds are mainly organic or house hold type in Bhilai 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 Bhilai carbonaceous particulate matters are mainly organic and may comes from open or uncontrolled burning. Peoples' awareness about environment pollution and protection is very essential to control this carbon pollution. VOCs (mainly benzene) are present in the ambient air of Bhilai and varying with seasons.During summer, VOCs concentration in the ambient air in Bhilai have been decreased and sometimes become lower than the permeable limit.

Metallic and non-metallic nanoparticles are also found in the ambient air of Bhilai and are varying with season. In every extracted samples we have found 'Cu', 'Ni', 'Fe', 'Zn', 'Cr', 'Pb', 'Cd' and 'As'. 'Fe' has been found as main metal in the ambient air samples of different sampling stations. 'Cu', 'Zn', 'Ni' and 'Cr' are also found in very low amount. Most important thing for Bhilai and Durg area, 'As'and 'Pb' have been detected from every sampling stations beyond the limit (6 ng/m^3 as per CPCB, India).

Furthermore, the spatial distribution of SO_2, NO_x, SPM, CO and HC from main industrial point sources, line sources and area sources of Bhilai-Durg was modelled using AERMOD software. The proposed study is an attempt towards better understanding on the nature of the air pollution within the developing industrial region. The simulation results can help the policy makers to identify the areas of high pollution exposure risk for the EIA guidelines. From the AERMOD modelling result hotspot are obtained which have high concentration of pollutants. For point sources modeling, SPM hotspot are found to be Mangata and maximum concentration 24-h obtained as 72.50 µg/m^3. SO_2 hotspot are obtained as Shyam Nagar and maximum concentration 24-h 77.31 µg/m^3. NO_x hotspot found to be Nehru Nagar with maximum concentration 24-h of 52.41 µg/m^3. For the line sources modeling, 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 64.86 µg/m^3 with hotspot near by Nehru Nagar. For the area source modeling, we have considered different garbage dumping yard, stone crushers zones in the Bhilai city. Here hotspot is found to be Bhilai Steel Plant with SPM concentration 24-h of 85.54 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 141 locations within Bhilai city. Five parameters i.e. Temperature, pH, salt, TDS, conductivity is measured and salt and TDS value are very high in almost all the samples. Conductivity of these samples ranges from 300 to 1000 µs/cm. Moreover, hardness in all the samples is within the limit except for samples collected at Nalwya Nala, Ama Talab and Mahamara (H.P.) where value is more than 180 mg/l. COD level is within the limit of 200 mg/l. DO level was found within 10 mg/l. Moreover, Cl^- values of samples are within the limit of 170 mg/l. Furthermore, the Fe has been found as major heavy metal in every sample and is about 78%. Water samples from Durg and Bhilai also contain 'Zn' (14%). Some other metals like; 'Cu', 'Cr', 'Ni' and 'Cd' are also found, but amount is negligible and below toxicity level. The main problem in the sampling station of Durg and Bhilai area is 'As'. 'As' has been detected in every water sample and sometimes it's near to the toxicity level. Beside this 'Pb' is also present in almost every sample and concentration is also very close to the permeable limit. Subsequently, water environmental carrying capacity assessment values for comprehensive environmental water carrying capacity shows a decreasing trend. Therefore, the proper management planning is needed for long term use and further industrial development. The comprehensive value is 0.634 in 2021, it falls to 0.493 in 2033. At 2039 it reaches the value of 0.410 after that it crosses the normal comprehensive value and goes to the poor comprehensive value and reaches 0.209 in 2051. Thus till 2039 whatever the industrial and people activities that are present does not affect the environment significantly, but after that it starts to affect the environmental water carrying capacity highly. Therefore, we need to take appropriate steps to maintain the value in normal range or else in upcoming years it can fall to poor values.

Furthermore, the land pollution and waste generated in Bhilai are also analysed. Subsequently, assimilative capacity of the land environment was estimated which predicted 1120 TPD of waste will be generated by 2050. Moreover, the Soil of Bhilai analyzed through XRF by collecting it from 78 sampling stations. The collected soil from Durg and Bhilai surroundings are full of iron, silicate and other metal oxides. We have identified and quantified other metals like; 'Al', 'Mg', 'Ca', 'Zn', 'K', 'Ti', 'Ba' and 'Cu' from the collected soil samples. Soils are brownish or yellowish in colour and found in both clay/dirt and granular form. These soil samples don't have any 'Pb' or 'Hg' contamination but some of the collected soils are 'As' contaminated. According to the mean percentage analysis of various detected heavy metals from different soil samples collected from Durg and Bhilai area, here we have found that Fe is the dominant metal and occupied 22% of the mean percentile diagram. All the collected soils have about 21% 'Si', 5% 'Al', 2% 'Mg' and all metals oxide is about 42%. These soil samples are also

Laterite red coloured soil but 'Si' percentage is slightly low than other areas of Chhattisgarh state. Fertility index is also low, due to near about 0% of 'P'.

The noise pollution was measure at 69 monitoring station in Bhilai. The highest level of sound was found in Bhilai Power House Rail Station and Transport nagar, 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 Bhilai city. The highest Noise pollution level (NPL > 90) is observed at Zone 1 and 2. This consist of JE Road and Nandini Road. 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 Bhilai region was also analyzed through field survey. This shows different flora and fona in the region. There are some adverse effect of the increasing environmental pollution on these biodiversity. However, measures like afforestation and preserving of wetlands are the mesure which are needed to conserve the biodiversity of Bhilai. Altogether, the assimilative capacity of all the component of environment namely, air, water, land, noise, biological and socio-economic are thoroughly analysed and estimated. The result shows within range values of the obtained parameters. However, there are certain areas where there is an urgent need for policy making and government intervention. Therefore, in this regard a detailed environmental management plan is presented in the subsequent section.

According to the above studies on different types of environment (air, water, land and noise), it may be concluded that both PM_{10} and $PM_{2.5}$ loads in Korba industrial area are above the limit. Both PM_{10} and $PM_{2.5}$ carrying capacities are negative. But secondary data predicts that industrial, transports emissions and constructions are mainly responsible for negative air carrying capacity of this city. Therefore, there are scopes for setting up new industries, provided State Government take appropriate plan to reduce other sources like; road dust and transports emission.

7.2 Delineation of Environmental Management Plans (EMP)

On the basis of baseline data of different environmental components, identification, prediction and evaluation of impact, appropriate strategies needs to be formulated for each environmental components for minimization of adverse impact. The following are the components and appropriate management plans.

Table 7.1: ACTION 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 Bhilai-Durg 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	As and when needed	10 lakhs	High

		Department / Construction companies			
	Water spraying on roads through tankers in the polluted cluster.	CSIDC / CGPWD/ Urban Administration and Development /NHAI/ Panchayat and Rural Development Department	As and when needed	25 lakhs	Medium
	Maintenance of road to avoid dust emission	CSIDC / CGPWD/ Urban Administration and Development /NHAI/ Panchayat and Rural Development Department	As and when needed	5 Cr	High
	Plantation /green belt development in open areas, garden parks /community places, schools and housing societies.	Concern Government Department / Urban Administration and Development / Construction companies / Industrial Units/ Panchayat and Rural Development Department/ CECB	24 months	2 Cr	Medium
	Plantation /green belt development in open areas of Bhilai industrial area.	CSIDC/ Industrial Units/ Sponge Iron Association / Construction companies	24 months	1 Cr	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 /	As and when needed	-	High

		CSIDC			
	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 / modification of bag filter as per requirement in sponge iron plant, power plant and ferro alloys plant.	All Industries / CECB	As and when needed	25 lakhs	High
	• Minimizing the height of raw materials/ coal/ solid wastes drop to the stockpile and ensuring water spray system	All Industries / CECB	6 months	10 lakhs	Medium
	• Use of water spray system/ dust suppression system/ chemical fog system/ rain guns in crusher, coal crusher, ground hopper/ screen, raw materials, fuel, solid wastes storage areas and yards and handling / conveying system	All Industries / CECB	12 months	50 lakhs	Medium
	• Storage of solid wastes from pollution control system like bag filter/ scrubber in pucca and covered area and ensuring environmentally safe disposal of these wastes through transportation in covered vehicles.	All Industries / CECB	6 months	-	Medium
	• Ensuring transportation of iron ore, sponge iron, coal, fly ash,	All Industries / CECB	6 months	-	Medium

	washed coal / reject coal in covered vehicle.				
	• 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/ Shivnath river.	All Industries / CECB	3 months	-	High
	Provision of wind breaking wall, installation of rain gun, wheel washing arrangement, treatment of wash water and arrangement of CCTV cameras at coal / washed coal/ reject coal handling and storage areas, entrance	All Coal Washeries / CECB	12 months	25 lakhs	Medium

	and exit gates in all coal washeries.				
	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 Bhilai and Durg industrial area.	CECB	6 months	-	Medium
	Making pucca road / area at all entrance of Industrial area from National Highway.	NHAI	24 months	5 Cr	High
	Plantation in between the area of industry boundary (outside) and road	ALL Industries / CSIDC/ Construction companies	12 months	2 Cr	Low
Sewage Treatment	Cleaning of drains before monsoon.	Nagar Palika Nigam	6 months	25 lakhs	Medium
	Prohibition of disposal of municipal solid waste and plastic waste in river as well as in municipal drains and levy of fine in case found violation.	Nagar Palika Nigam	6 months	-	Medium
	Requirement of E-flow in the river must be maintained.	State Water Resources Department	As and when needed	-	Low
Strengthening of Monitoring	Installation of two CAAQMS in industrial cluster area.	CECB/ Industrial Units	12 months		High
	Installation of two CWQMS in Kharun River.	CECB/ Industrial Units	6 months		High
	Measurement of flow of river and record maintained.	State Water Resources Department	6 months		High
	Requirement of E-flow in the river must be maintained.	State Water Resources Department	As and when needed		Medium
	Collection of information on irrigation water used per hectare for different crops by Agriculture Department	Agriculture Department	12 months		Medium

	and evaluate whether use of irrigation water per hectare has decreased or not? Based on the data obtained techniques like drip irrigation etc. should be promoted.				
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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