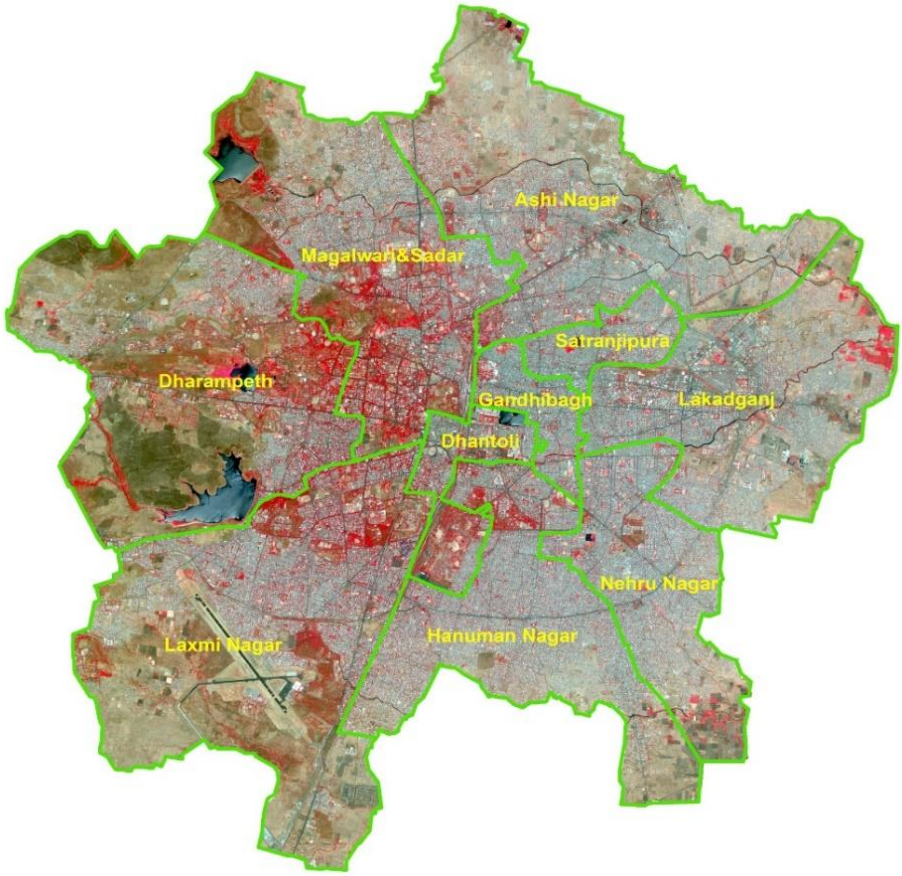

NAGPUR MUNICIPAL CORPORATION ESR (2022-2023)

ENVIRONMENT STATUS REPORT: NAGPUR CITY

CSIR- National Environmental Engineering Research Institute, Nagpur

Executive Summary
ESR 2022-23

1.1 Purpose of the ESR

- Understand the existing state of the environmental health in the city and interlink environmental issues with quality of life of the citizens
    - Pressure on the environment (e.g. discharge of industrial wastewater/ sewage, solid waste management)
    - Impact on population / ecosystem (pesticide contaminated foodstuff, drinking water quality, exposure to pests, loss of biodiversity)
- Provide information support for investment and management decisions for NMC. Be an important input into the annual budgeting and planning exercises of the NMC.
- Serve as a tool for citizens' use, serving as both an information / education resource, and as a way for tracking improvements.

The ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD) established in 1961 having a membership 38 countries, has developed key environmental indicators that can monitor the state of health of a city or target niche.

CSIR-NEERI has been entrusted by Nagpur Municipal Corporation to prepare the Environmental Status Report for the period of 2022-2027. The ESR for 2022-2023 focuses on the following environmental indicators:

- Chapter 1 : Ambient air quality
- Chapter 2 : Climate change
- Chapter 3 : Green open spaces of Nagpur city and biodiversity
- Chapter 4 : Noise environment
- Chapter 5 : Solid waste
- Chapter 6 : Water environment
- Chapter 7 : Ecosystem service valuation of water bodies
- Chapter 8 : Socio-economic profile
- Chapter 9 : Recommendations

Each chapter is prepared to update the environment status and concerns using primary data collected by CSIR-NEERI and using secondary data (quoted and references provided) as well as references from literature available for drawing valuable conclusions.

Chapter 1: Ambient air quality

This chapter discusses the study carried out on ambient air quality and emission inventory of Nagpur to assess the air environment status. The emission inventory of various sources (point, line and area) in Nagpur will help in identifying the pollution-generating hotspots and formulate policies for controlling/reducing the emission load of Particulate Matter of size less than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), Sulphur dioxide (SO_2), Nitrogen oxides (NOx), Carbon monoxide (CO) and Hydrocarbons (HC). Of the different point sources, Nagpur city includes 10356 registered industrial units which have been classified into four different categories depending upon their pollution potential such as; red (maximum pollution potential), orange (moderate pollution potential), green (low pollution potential) and white (have least pollution potential). True area-wide sources, such as bakeries, brick kilns, crematoria, open eat-outs, hotels and restaurants, stone crushers, ready mix plants, open burning, road dust resuspension, and construction activities, etc. are examples of this source type. In addition to the conventional fuels such as LPG, used by different establishments including bakeries and eateries, burning of waste is reported which includes garden waste, paper, plastic, cardboard, etc. was also observed in all zones of the city. Vehicular traffic was considered as the line source of pollution with vehicular movement of light vehicles being highest during the day and, movement of heavy-duty passenger and commercial vehicles on the major roads (State highway, major roads like ring roads etc.) at night.

The assessment of air quality at manual monitoring stations, CAAQM stations, and by MODIS revealed that the air pollution problem in terms of all the parameters except PM_{10} pollution in the city during the study period were not very significant, with PM_{10} and $PM_{2.5}$ emissions (46% and 61%, respectively) majorly being contributed by vehicular followed by the emissions from road dust resuspension (19% and 15%, respectively). Based on the observation of the study, it is recommended to orient the control and management policies to mitigate PM pollution in the city. Real-time data from online sources is a need of the hour to mitigate the pollution generated due to the large number of vehicles on the roads and also to provide traffic management strategies. Traffic congestion and construction debris from the residential and commercial sector is one of the major problems in the city, which needs to be addressed as a priority by better planning, fast and timely completion of the construction work. Appropriate policies need to be implemented to reduce the pollution-induced because of the vehicular traffic halts due to on-street parking. Public awareness programmes and proper guidance on

solid waste management need to be given to the residents and open burning of garbage and leaves to be discouraged to avoid pollution exposure to morning walkers and other persons.

Chapter 2: Climate change

This chapter describes the impact of climate change on water stress in Nagpur city through the Water Poverty Index (WPI) approach by amalgamating scientific precision with the realities, in order to unravel the city's water poverty narrative. This approach encapsulates various aspects of water availability, accessibility, and usability, providing a nuanced understanding of the challenges communities face in securing reliable water sources, through a comprehensive household survey conducted across ten distinct zones comprising of Nagpur City's diverse population (900 households). Within the study, a WPI for the Zones was developed considering its five components: resources, access, capacity, use, and environment to assist the decision-makers in determining the priorities for development in their water sector. The study showed that all Nagpur Municipal Zones fall into the moderate water stress level. However, looking at the increasing population and climate variability, Nagpur City must plan to improve their WPI score to mitigate the impacts of climate variability due to anthropogenic climate change. The study recommends in general to apply the developed WPI periodically to evaluate the improvement in the water sector in each Zone scale and to determine the priorities for resource mobilization, with specific recommendations given for each zone at the end of the chapter.

Chapter 3: Green open spaces of Nagpur city and biodiversity

In this chapter, the assessment of biodiversity health and ecosystem services of cities in Nagpur by City Biodiversity Index (CBI) or Singapore index of biodiversity has been discussed, which depicts the growth of the city towards sustainability. The present CBI assessment was undertaken to estimate values for these 28 indicators. CBI has been upgraded from 23 to 28 parts and is classified into 3 parts i.e. native biodiversity (9 indicators), ecosystem services provided by biodiversity (5 indicators) and governance, management of biodiversity (14 indicators). Each indicator has a value range from 0 to 4. Among the comparison between the different indicators, city has scored 53 points in total from 28 indicators out of a total of 112 points (each indicator has a maximum of 4 points). Within the 9 indicators under the section of native biodiversity in the city, city poorly performs under 4 indicators that include indicator for connectivity measures or ecological networks to counter

fragmentation and Habit restoration (city scored 0) whereas, under the indicator proportion of protected natural areas and indicator proportion of invasive alien species city scored 1. Under the section Ecosystem services provided by the biodiversity under 5 indicators, city poorly performs under 4 indicators that include indicator for regulation of quantity of water, indicator for recreational services (city scored 1), climate regulation - benefits of trees and greenery, food security resilience - urban agriculture (in both the indicators city scored 0). Under the section of Governance and management of biodiversity having 14 indicators, city poorly performs under 4 indicators that include indicator for budget allocated to biodiversity, policy and/or incentives for green infrastructure as nature-based solutions, awareness (city scored 1 for each) and number of biodiversity projects implemented by the city annually (city scored 0). There is a need to integrate natural and green infrastructure in areas where green and blue spaces are declining. Ecological connectivity in the form of avenue plantations is not uniform throughout the wards and zone of the city that will require specific attention from NMC and allocation of budget to maintain and plant avenues for developing connectivity corridors and reducing fragmentation. New high rises should be promoted for nature-based solutions, 33% of greening and also roof top agriculture. WHO and Urban guidelines followed by 3x30x300 approach should be mainstreamed.

Chapter 4: Noise environment

This chapter discusses the effect of noise pollution in Nagpur city, which according to the World Health Organization (WHO), is the third most hazardous environmental pollution problem after air and water pollution. Its impact on prolonged exposure at a high level, is very much harmful to the health of mankind. In India, most cities' noise levels exceed the limit prescribed by Central Pollution Control Board (CPCB), New Delhi. Industrial activity and associated vehicles are the most comprehensive sources of noise in our environment which is further compounded by the growing population, congestion of vehicles and noise in social events. Furthermore, bursting of firecrackers during festivals is the source of high impulsive noise levels and air pollution that can be the cause of various health-related issues that affects humans physically and psychologically, such as hypertension, myocardial infarction, depression, anxiety, and hearing impairment. Crowd sensing solutions have emerged as a promising solution by promoting collaborative monitoring of the populated regions. Mobile technology has made sound level measurement more readily accessible. Within the foregoing context, the current chapter describes the crowdsourcing technique which was used to gather

noise data using CSIR-NEERI mobile application “Noise Tracker”, according to the national and international standard regulations, with the participation of college students residing at different locations across the Nagpur city. Noise data was collected before, during and after the festival in the time interval (06:00 AM to 10:00 pm) according to the land use pattern which indicated that noise the levels in all ten NMC zones exceeded the permissible limits of for Silence, Residential and Commercial zones in most locations during the festival. The noise emission due to the movement of road vehicles, honking, community noise, construction, and other noise-emitting activities occurring regularly in any urban city are responsible for the noise levels observed above the permissible limits.

Noise tracking before the festival duration reveals that out of the ten zones, five NMC Zones such as Dharampeth, Hanuman Nagar, Dhantoli, Satranjipura and Ashinagar had more than 80% of places where noise levels surpass the noise limits. Whereas, in the other five remaining NMC zones namely Laxminagar, Nehru Nagar, Gandibagh, Lakadganj, and Mangalwari noise levels in 50.4-70.8% of locations exceeded the allowable noise limits. **A**fter the festival duration, zones, such as Gandhibagh, Sataranjipura and Mangalwari had more than 80% of locations above the permissible limits, whereas, the other seven remaining NMC zones (Laxminagar, Dharampeth Nehru Nagar, Dhantoli, Hanuman Nagar, Lakadganj, and Ashinagar showed 43-74.4% of locations exceeded the allowable noise limits. Accordingly, in the festive season, noise levels in silence and residential and commercial places in each zone rise due to the bursting of firecrackers. Similarly, the movement of road vehicles, honking, community noise, construction, and other noise-emitting activities occurring regularly in any city are responsible for the higher noise levels observed before and after the festive season, where noise contribution from the firecrackers is negligible in the overall noise. Among the key recommendations, the study recommended the bursting of fireworks in a community in common open space with extra care for providing protection against fireworks to children who were considered most vulnerable to noise exposure. It also recommended the strict implementation of CPCB norms and Noise Pollution (Regulation and Control) Rules 2010 for recommending prohibition of the manufacture, sale, or use of firecrackers breaching the noise limits of 125 dB(AI) or 145 dB(C)pk tested at a 4-meter distance from the point of bursting. Further, the study recommended the tree plantation in the city wherever possible for attenuation of transmitted noise to some extent along with regular monitoring of noise to ensure regulatory compliance with the noise levels.

Chapter 5: Solid waste

In this chapter, the issues related to solid waste management in Nagpur city are discussed with recommendation for its effective management. Inadequate handling of municipal solid waste (MSW) poses risks to both residents and the environment, and its accurate quantification and comprehensive characterization are crucial for planning and designing effective solid waste management systems. In addition to income, other socio-economic factors, including the number of family members, education, occupation, etc., have been identified as influencing MSW generation rates. Based on the available data, the current population of Nagpur city generates around 1315 tonnes per day (TPD) of MSW with an average per capita waste generation is 0.438 kg per day. NMC has recognized SWM as a significant challenge, with several insufficiencies in existing waste management system, which due to inadequate collection services, coupled with limited processing and disposal facilities, have resulted in the large-scale open dumping of waste, posing significant environmental and health risks. In Nagpur city, though NMC has successfully implemented door-to-door waste collection across all 10 zones of the city, aiming to create a bin-free environment, there was a lack of proper waste segregation at the source which was being carried out by laborers involved in house-to-house waste collection. The management systems encompass door-to-door waste collection, waste transportation, street sweeping, and disposal at the Bhandewadi landfill site.

The city boasts an efficient transportation system for managing Municipal Solid Waste (MSW), with a comprehensive waste disposal operation in Bhandewadi village, located in the eastern suburbs of Nagpur. Here, 2,35,864 tonnes of wet waste and about 43,854 tonnes of dry waste was dumped annually, with the biodegradable fraction constituting up to 67% by weight of MSW, 16% is classified as inert, paper, plastic and metals & glasses were 4%, 11% and 2% respectively. The chapter further describes the several initiatives undertaken by NMC for effective management of MSW such as; MoU with waste-to energy company The Netherlands' Sustainable Business Development (SusBDe) for a biomethanation plant; efforts for biomedical waste management; implementation of Brown line specifically for construction and demolition waste; addressing challenges for e-waste and plastic waste; NMCs agreement with Zigma Global Environ Solutions Pvt Ltd for biomining of legacy waste.

Chapter 6: Water environment

The chapter on water environment discusses the current status of surface water bodies (rivers and lakes) and groundwater with reference to its water quality. The chapter presents the

analysis of water samples from three rivers (Nag, Pilli, and Pora) and eight lakes (Sonegaon, Futala, Gorewada, Ambazari, Binaki, Naik, Sakkardara, Pandharabodi) in addition to twelve ground water source (dugwells and borewells). The samples have been characterized for their physico-chemical composition and bacterial load of coliforms along with the aquatic biological parameters (phytoplanktons and zooplanktons). The chapter highlighs the role of lakes on storage of water that helps to maintain ground water table. The study found substantial COD, BOD, and other nutrients (nitrogen and phosporous) concentrations in Naik and Binaki lakes due to high organics associated with anthropogenic activities. Significant count of total and fecal coliforms was also detected in these lakes and in all the samples lakes in general. Similarly, increase in pollution as seen from COD, BOD and nutrient load as the rivers flowed through the city suggested that the water from three rivers Nag, Pilli and Pora was unsuitable for drinking, outdoor bathing, irrigation. The study recommended the discouraging of anthropogenic activities on the banks of rivers and lakes such as disposal of garbage- old and torn cloths, eatables, worship material used in festivals etc., preventing open defecation, shifting of public toilets to prevent fecal matter from contaminating the water bodies. Additionally, dumping of waste by local vendors of fruits-vegetables, meat and other products, wandering of stray animals in the river or disposal of dead animals along the river bank, flow of drains carrying untreated and uncategorized waste from the city's commercial and industrial areas needed to be prevented. Since the hydrogeological analysis of Nagpur city indicated a lot of variation in groundwater level a long-term monitoring was recommended for establishing the groundwater level trend and accorhdingly implementing the rain water harvesting programme.

Chapter 7: Ecosystem services valuation

The focus of this chapter is on evaluating the monetary implications of environmental harm caused by elevated pollutant levels in rivers and lakes by employing the VTM approach to estimate the Environmental Damage Cost Assessment (EDCA). Substantial monetary values were obtained from the analysis which ranged between ₹ 87-148 milllion for the three rivers and ₹ 0.01 – 0.28 million for the three lakes. This underscored the severity of pollution loads affecting the water ecosystems which damaged the aquatic ecosystems by disrupting the delicate balance of the ecosystem by affecting water quality and diminishing oxygen levels and affecting the surrounding habitats thus posing risks to human health through the consumption of contaminated water or aquatic resources. Further, it is important to note that these are just

damage costs, if one was to calculate the remediation and control cost, it would be far more higher. The key takeaway from this study is that early intervention in environmental pollution incurs lower restoration costs. In other words, preventing environmental damage is more cost-effective than addressing it after occurrence. Conveying these damages through monetary terms could create awareness within local municipalities and governing entities and could also align with the implementation of the principle that the party responsible for pollution should bear the associated costs. The chapter further recommends rigorous sewage water treatment practices to minimize pollutants discharged into water bodies; bathymetric study to understand the size and depth of the lakes which have become smaller and shallower due to dumping of waste; determine the discharge values for various stretches of each river for precise damage cost assessment for immediate implementation of corrective actions to minimize the damage.

Chapter 8: Socio-economic profile

The chapter on socio-economic profile describes the issues affecting Nagpur city, related to the implementation of "Housing for all 2022" scheme by allocating leases to private land encroachment holders within Naagri Sthanik Swarajya Sanstha area. It highlights the procedures laid down for this aspect as per the decision taken by the Honourable Cabinet and the terms and conditions under which the decision could be effectively implemented.

Chapter 9: Recommendations

In this chapter, the overall recommendations related to the different environmental aspects discussed in the various chapters, are highlighted.

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Chapter 1

Ambient Air Quality

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Ambient Air Quality

1.0 Introduction

A study on ambient air quality and emission inventory of Nagpur is carried out to assess the status of the air environment. The study of the driving factors of air pollution, which primarily comprises the assessment of emission load from point, area, and line sources, aids in the development of action plans to reduce pollution levels. Another way to assess the air pollution characteristics of the city is through monitoring the air quality using various methodologies such as; manual monitoring, continuous ambient air quality monitoring station (CAAQMS) and sensor-based monitoring. Recently drone-based monitoring in vertical direction has also been initiated. Each approach may have a different outcome in terms of pollution levels over time and space. This study has relied on two major components to assess the air quality in the city:

1. Gridded Emission Inventory and,
2. Air Quality Status through manual monitoring and continuous ambient air quality monitoring system.

These two components are discussed in this chapter followed by the recommendations.

1.1 Methodology

Emission inventory can be carried out by identifying the activity that can emit air pollutants. Primary and secondary data on activity is collected and its emission factor is gathered from CPCB and ARAI studies. The activity is geo-tagged so as to get the gridded (2 km x 2 km) emission inventory. Ranking of grid-wise emission load helps in identifying the hot spot in a city. Any source emission control action is exercised at the identified hot spot. An example could be, if a grid has large number of hawkers / open eat-out /hotel/ restaurants, all of which are using wood or coal for cooking, emissions from that grid can be reduced by changing the fuel. All hawkers can be asked to switch to LPG, which would reduce the emission significantly. The generated emission from a hot spot grid need not necessarily accumulate in the same grid, instead, it may get transported to another nearby grid under the influence of wind. If monitoring of each grid is carried out using CAAQMS on a long-term basis, the grid with highest air pollutant can be identified. However, monitoring of each grid is practically impossible, thus source dispersion modeling is used to determine the grids with highest ambient air pollutant concentration.

CAAQMS are located in four sites in Nagpur. The CPCB web site displays data from only one site (GPO Square, Civil Lines), which is analysed and presented. Manual air quality monitoring can be possible at a limited number of locations, therefore monitored values cannot be used to identify hot spot.

Vertical profile of air quality parameters is determined using drone, however, this is only an additional information on air quality that is beneficial to the residents of high-rise buildings. There is no management plan, which needs information on vertical profile of air quality.

CPCB through its PRANA portal (https://prana.cpcb.gov.in/#/air-quality-data) provides the information on air quality in various cities under the National Clean Air Programme. The AQI repository and air quality data can be obtained via the Automatic Monitoring Data. It links the user to the website of CPCB (https://airquality.cpcb.gov.in/ccr/#/caaqm-dashboard-all/caaqm-landing), which has CAAQMS data.

Air emission inventory is obtained by using primary and secondary data sources as given in the respective section, whereas air quality status is analyzed by using the secondary data obtained from Central and State Pollution Control Board. The next section briefs about the emission inventory characterization.

1.2 Emission Inventory

An air emission inventory is a compilation of air pollutant emissions from sources of anthropogenic and naturally occurring sources. It helps in evaluating the control strategies for prevalent emission sources. The sources are categorized into three sectors; point sources (stationary), area sources, and line sources. The emission inventory of various sources in Nagpur has been prepared for Particulate Matter of size less than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), Sulphur dioxide (SO_2), Nitrogen oxides (NOx), Carbon monoxide (CO) and Hydrocarbons (HC). For this, the city is divided into 2 x 2 km grids as shown in **Figure. 1.1**. The grid-based emission inventory will help to identify the pollution-generating hotspots and formulate policies to control or reduce the emission load. The general equation for emissions estimation is:

$$EL = A \times EF \times (1-ER/100)$$

Where,

EL - Emission Load in Kg/day;

A - Activity rate (quantity of fuel used/burnt per day);

EF - Emission Factor (Kg of pollutant emitted per Ton of fuel burned); and

ER - Overall emission reduction efficiency (%) applicable only for point source emission inventory.

1.2.1 Sources of Air Pollution in Nagpur

The present study has taken into account nearly 11 major and minor sources that are possibly responsible for the city's air pollution issues. The activity data for individual sources is compiled from authentic primary as well as secondary sources. The field campaign was carried out to compile primary data for slums, residential, transport, and brick kilns, etc. The assembled information was closely checked for authenticity before being used in emission estimation. The details of the Point, Area and Line sources in the city are given below:

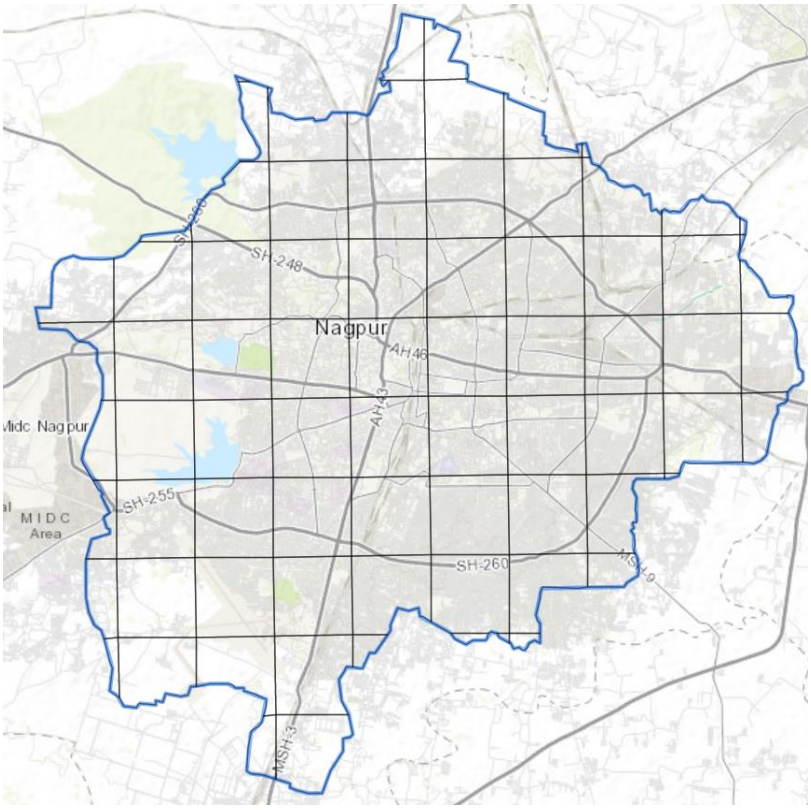

Figure 1.1: 2x2 km Grid over Nagpur City

1.2.1a Point Source

Nagpur district is rich in deposits of Coal, Manganese-ore, Dolomite, Limestone, Iron-ore, Clay, Copper-ore, Chromites, Tungsten-ore, Zinc-ore, Lead-ore, Granite, Quartz etc. Coal reserves are in the North-West belt of the district i.e. from Saoner to Kanhan (Kamptee apart from the high coal found in Umrer tahsil). Manganese ore is found particularly in Ramtek and Saoner tahsils. Good-quality limestone is found in Kandri and Deolapar. Mica and Tungsten are also found in the district. Industrial development exists along the fringe areas like

Kamptee, Hingna, Wadi, Khapri, Butibori and Kalmeshwar. The industrial units in Nagpur have been classified into four different categories depending upon their pollution potential such as; red (maximum pollution potential), orange (moderate pollution potential), green (low pollution potential) and white (have least pollution potential). The red and orange category industries are not permitted in the Nagpur Municipal Corporation (NMC) boundary except in the industrial estate region with proper pollution control measures and approval from Maharashtra Pollution Control Board (MPCB). Nagpur city includes 10356 registered industrial units. The fuel usage pattern is adapted from the consent data provided by the Maharashtra Pollution Control Board, Mumbai.

There are 2 thermal power plants (TPP) located in the vicinity of Nagpur, however being not within the boundary of Nagpur city; these power plants are not included for emission load estimation. For other industries, the information regarding the installed capacity, the number of operational units, the technology, the coal consumption pattern with the Plant Load Factor (PLF%), and the air pollution control system installed in the industry is collected by officially visiting the plant and from the consent data provided by the MPCB, Mumbai. The type of fuel and the quantity required are mentioned below:

Table 1.1: Fuel consumption in industries

Fuel	Quantity	Unit
Diesel	15	KL/day
FO	09	KL/day
Coal	163	T/day
HSD	56	KL/day
LDO	4	KL/day
LPG	5	T/day

(Source: MPCB consent data available on mpcb.gov.in)

1.2.1b Area Sources

The total population is assumed to be 33 lakhs distributed among 6.6 lakhs households with an average household size of five (5). True area-wide sources, such as bakeries, brick kilns, crematoria, open eat-outs, hotels and restaurants, stone crushers, ready mix plants, open burning, road dust resuspension, and construction activities, etc. are examples of this source type. The boundaries of the individual activities associated with these sources are often difficult to determine and/or arbitrary. The data required for area source emission inventory was collected from different wings of municipal corporations. Each type of unit was visited for

a visualization of the fuel consumed and the type of technology in operation. There are total 9 number of registered bakeries in the city. All the bakeries are consuming LPG for product preparation. Open eat-outs are located in all the areas of the city and its very difficult to collect the actual location and data. Hence some of the open eat-outs were visited and the data on fuel requirements was collected. Data on 439 numbers of open eat-outs is available. Open burning cases (garden waste) are reported in all zones of the city. In commercial areas, burning of waste is reported which includes paper, plastic, cardboard, etc. The fuel used for combustion in all sectors of area sources is depicted in **Table 1.2.** The building construction data is collected from MahaRERA portal, where the data on actual area covered and the number of storeys being constructed is readily available.

Silt load is estimated for the roads in the city. For paved and unpaved roads, the silt load is considered as 0.437 and 0.779 gram/m^2 (based on the study by CSIR-NEERI for a city with similar characteristics). The brick kilns are located outside the municipal limit; hence the emission load is not included in the gridded emission inventory.

Table 1.2: Fuel consumption pattern for area sources

Source	Number of units	Wood	Coal	Briquettes	Diesel	LPG
Crematoria	10	5100	0	2000	40	670
Hotels & Restaurants	315	50	75	0	0	282
Open Eat-outs	438	10	20	0	0	183
Bakeries	09	0	0	0	0	127
Domestic Sector	11,00,000 consumers	98	50	15	0	186340
Brick Kilns	18	1500	2100	100	0	0
Stone Crushers	3	0	0	0	150	0

All units in Kg/day or Litre/day

(Source: Census data 2011, CSIR NEERI data repository 2018-19, Nagpur ESR old reports, SA Nagpur report, MPCB consents for brick kilns and stone crushers etc.)

1.2.1c Line Source

According to the Ministry of Road Transport and Highways, the number of vehicles registered in Nagpur district alone were 19 Lakhs till Dec 2020. For public mode of transport, the city has autos rickshaws (three-wheelers), taxis, buses and metro. In this study, the whole road transport system is broadly classified into five categories: two-wheelers (2W), three-wheelers (3W), Four Whelers (4W), Light Duty Vehicles (LCV), and Heavy-Duty Vehicles (HCV).

From the data on registered vehicles, as depicted in **Table 1.3**, it can be seen that 2W appears to contribute about 80% to the total number of vehicles, which is relatively high.

Table 1.3: Fuel-wise registered vehicles in Nagpur district

No.	Vehicle Category	Petrol	Diesel	CNG	LPG	Electric	Total
1	2W	16,55,505	0	0	0	10,410	16,65,915
2	3W	1,12,103	7259	25,301	28,830	5,978	1,79,471
3	4W	41,208	88,781	3,016	0	6,523	1,39,528
4	LDV	0	21,212	2	0	265	21,477
5	HDV	0	14,631	0	0	45	14,676
	Total						**20,21,067**

(Source: Data from Vahan Sewa Portal until Mar 2023)

The specific vehicle category and the type of fuel being used were recorded from official sources like Transport Department and the Ministry of Road Transport and Highways. Currently, Bharat Stage-IV (BS-IV) norms have been implemented for on-road vehicular emissions in Nagpur since 2017. According to the Motor Vehicle Amendment Rule, Govt. of India, BS-VI norms have been made mandatory for all new registered on-road vehicles only from April 2020. **Table 1.4** depicts the Bharat Stage Engine Technology-based vehicles registered in Nagpur.

Table 1.4: **Bharat Stage Engine Technology registered in Nagpur district**

No.	Category	BS I	BS II	BS III	BS IV	BS VI	Total
1	2W	671	139	1,70,573	13,64,712	1,29,820	16,65,915
2	3W	3	0	66,833	1,07,487	5,148	1,79,471
3	4W	0	0	32,058	1,00,311	7,159	1,39,528
4	LDV	14	13,858	5,520	0	2,085	21,477
5	HDV	9	80	6,613	432	3,542	14,676
	Total						**20,21,067**

(Source: GoI-Parivahan portal up to Mar 2023)

The total road length within the corporation area is 4000 Km. 90% (3600 km) of the total road is paved; while the remaining is accounted as unpaved (400 km)**.** Vehicle kilometers travelled (VKT/day) were adopted from primary data collected as per real-time megacity scenario. The weekday vehicular count data was used to estimate the emissions from vehicular sources in Nagpur. Different categories of vehicles were counted at the traffic intersections. It was seen that during the day time, the vehicular movement of two-wheelers, three-wheelers, four

wheelers and light-duty commercial vehicles was highest whereas after 19:00 hrs to the next day till morning 08:00 hrs, the traffic of heavy-duty passenger and commercial vehicles was seen running from the major roads (State Highway, Major roads like Ring roads etc.). It was also seen that the minor roads in residential and commercial areas had vehicular traffic of mostly 2-wheelers and 3-wheelers. The gridded vehicle kilometre travelled (VKTg) was then estimated for each road traffic pattern.

1.2.2 Total Emission Load

The present findings provide detailed accountability of emission load from all 11 sectors responsible for ambient air quality in Nagpur. The total emission load from point, area and line sources is shown in **Table 1.5**. The emission inventory is based on the primary and secondary data collected from authentic sources and emission factors are used from CPCB and ARAI. The change in datasets may change the emission sources and its hotspots.

Table 1.5: Emission load from all the possible sources

No.	Sector	PM_{10}	$PM_{2.5}$	SOx	NOx	CO	HC
		(All units in Kg/day)					
1	Bakeries & OEO	74	57	112	438	117	157
2	Hotels & Restaurants	14	7	11	9	1	21
3	Crematoria	190	93	86	329	983	532
4	Domestic	22	17	82	1618	1712	1685
5	Building Construction	105	68	0	0	0	0
6	Road Construction	216	115	0	0	0	0
7	Brick Kilns	65	24	46	43	68	42
8	Road Resuspension	571	343	0	0	0	0
9	Vehicles	1396	1379	0	9600	20222	6746
10	Industries	389	168	245	1365	1284	2003
	Total	3043	2270	582	13403	24386	11185

From **Table 1.5,** it can be seen that the line source emission load is the highest followed by road dust resuspension. The emission load from two thermal power plants located outside the municipal corporation boundary is not shown here as the two thermal power plants are located outside the Nagpur Municipal Corporation boundary. The daily emission of the targeted pollutants from all the sectors includes 3.04 Ton/day of PM_{10}, 2.27 Ton/day of $PM_{2.5}$, 0.58 Ton/day of SO_2, 13.40 Ton/day of NO_x, 24.39 Ton/day of CO, and 11.19 Ton/day of HC.

From the above emission load estimates, 46% and 61% of the emission load is from the vehicular category for PM_{10} and $PM_{2.5}$, which can be considered the highest contributor followed by the emissions from road dust resuspension (19% for PM_{10} and 15% for $PM_{2.5}$).

A Geographic Information System (GIS) based approach is used for spatial distribution of emissions over selected domains. The grid-wise emission inventory for PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO and HC is depicted in **Figure. 1.2** through **1.7**, respectively. The areas with highest PM_{10} emission load are Hingna MIDC (190 and 156 kg/day), Sitabuldi–Dhantoli–Congress Nagar (164 kg/day), Ganeshpeth (Baidyanath Square)–Great Nag Road–Medical Square (139 kg/day), Jaiprakash Nagar–Somalwada–Sneh Nagar (121 kg/day), Automotive Square (92 kg/day), Khamla–Deonagar–Chhatrapati Square (91 kg/day), Manewada (81 kg/day).

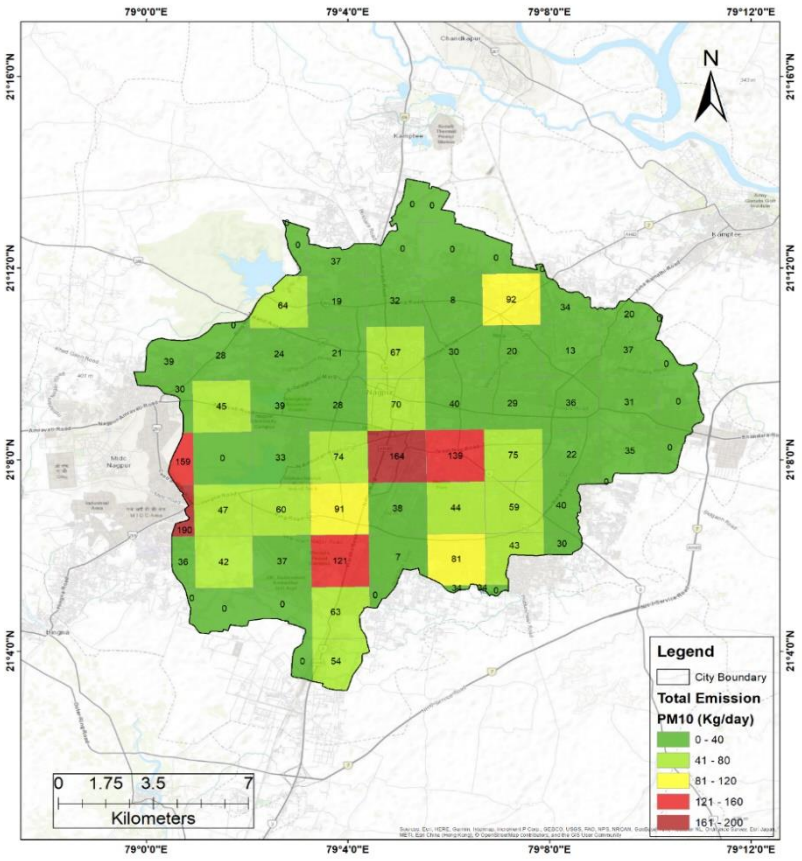

Figure 1.2: PM_{10} Emission load for Nagpur city in Kg/day

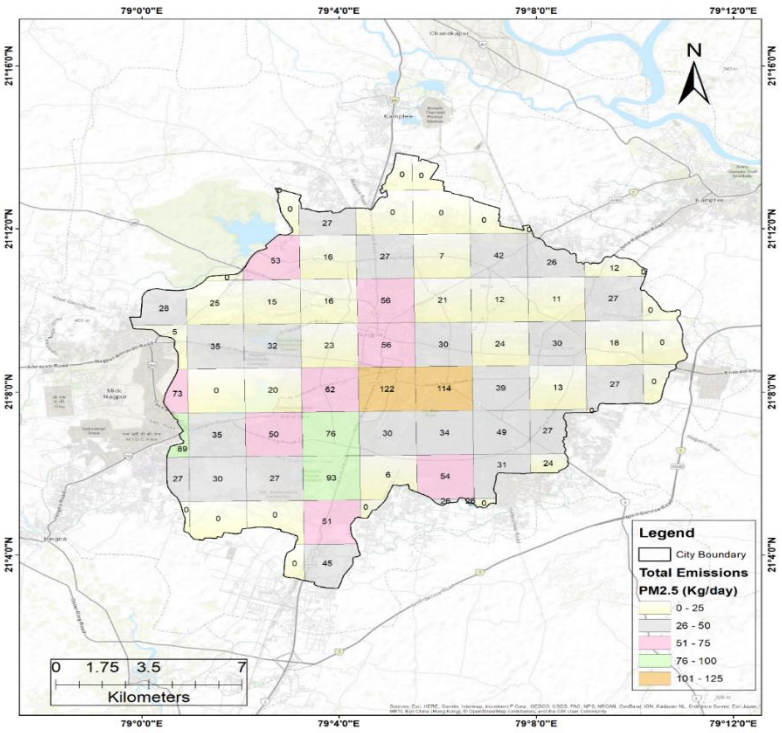

Figure 1.3: $PM_{2.5}$ Emission load for Nagpur city in Kg/day

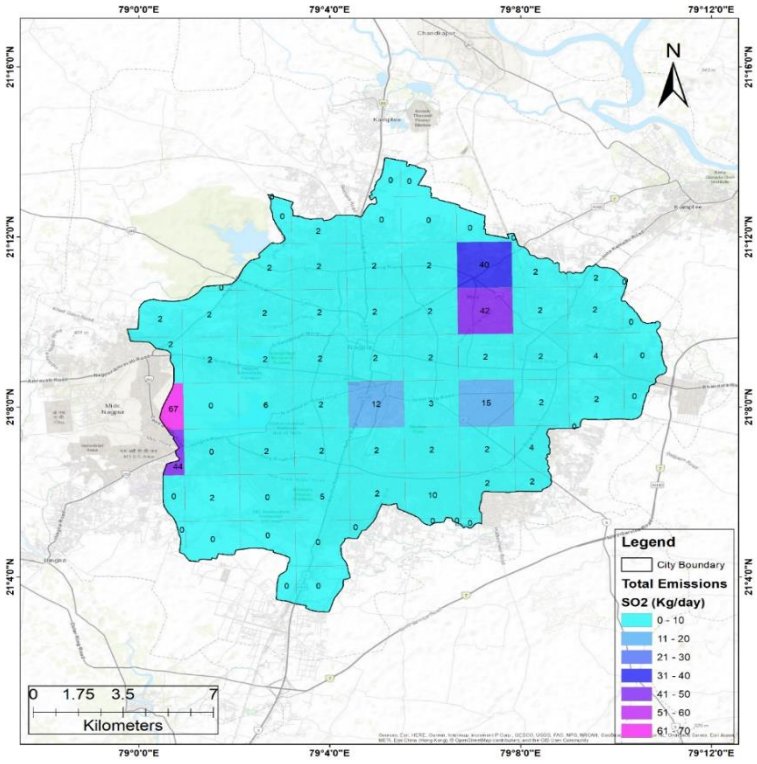

Figure 1.4: SO_2 Emission load for Nagpur city in Kg/day

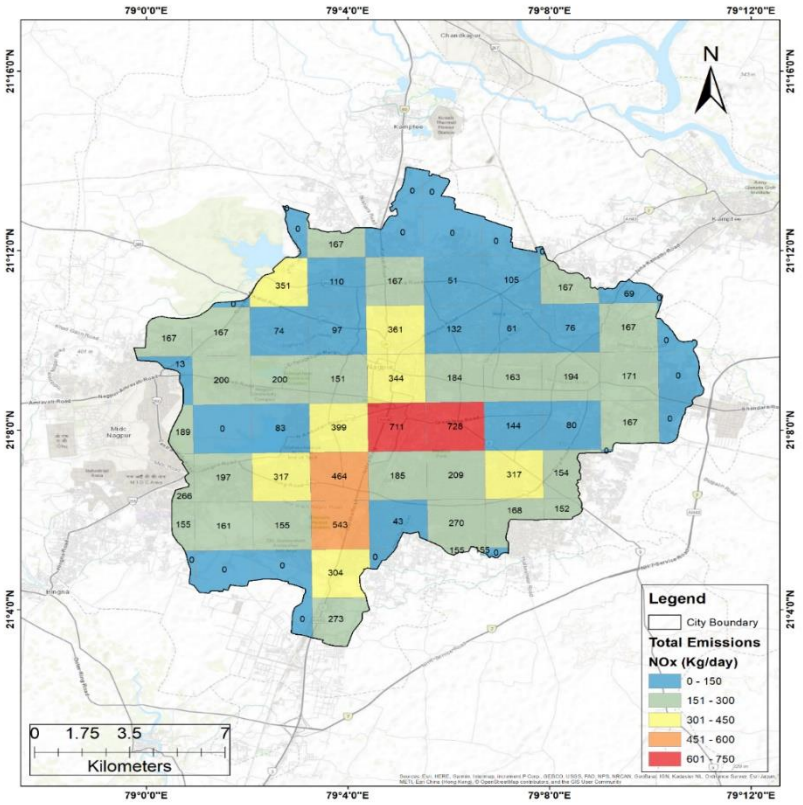

Figure 1.5: NOx Emission load for Nagpur city in Kg/day

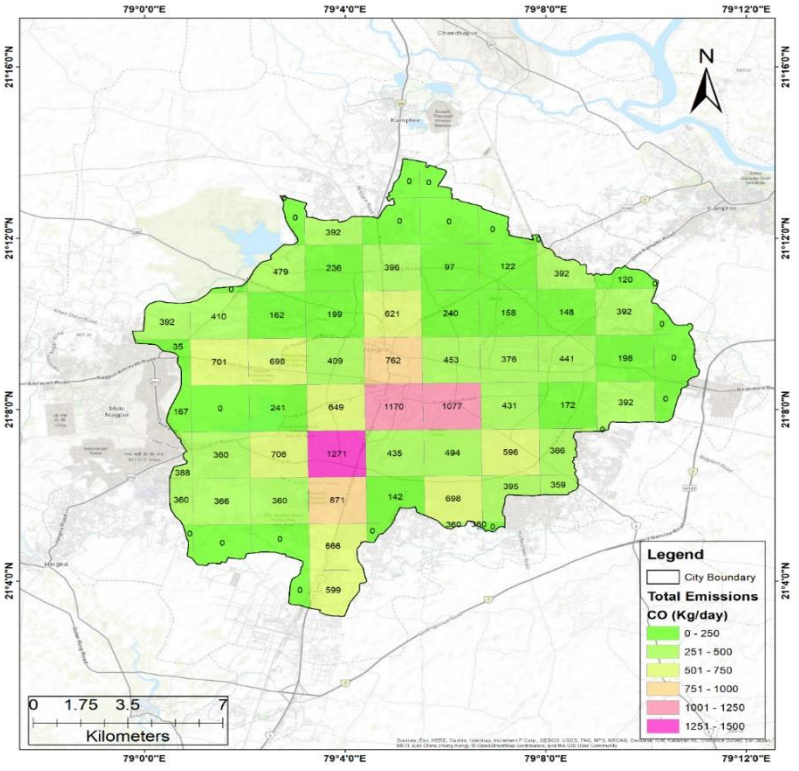

Figure 1.6: CO Emission load for Nagpur city in Kg/day

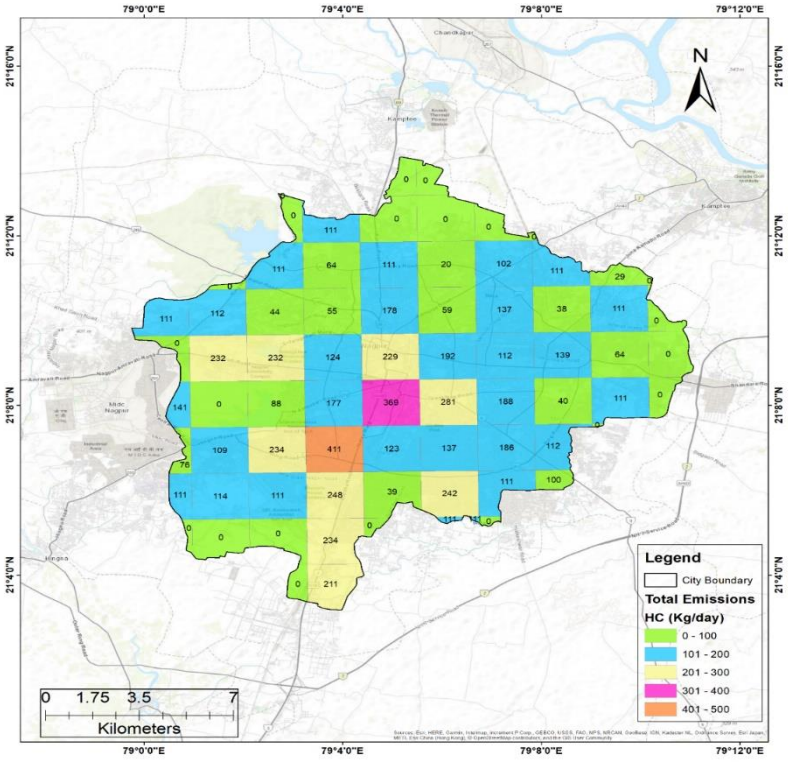

Figure 1.7: HC Emission load for Nagpur city in Kg/day

1.3 Ambient Air Quality (AAQ) Status

To assess the ambient air quality (AAQ) of Nagpur city, the State Air Quality Monitoring Programme (SAMP) run by Maharashtra Pollution Control Board (MPCB) and the National Air Quality Monitoring Programme (NAMP) run by the Central Pollution Control Board (CPCB) are the two air quality monitoring networks that provide the ambient air quality data. MPCB conducts ambient air quality monitoring at five locations, namely at Civil Lines, Divisional Commissioner Office, Sadar, Hingna and North Ambazari Road, across the city and two locations in the outskirts of the city, namely in Kamptee and Wadi. All the locations have manual monitoring setup, whereas one station is also a Continuous Ambient Air Quality Monitoring Station (CAAQMS) near General Post Office (GPO), Civil Lines. The manual monitoring is carried out for three pollutants namely particulate matter (PM_{10}), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) at each of the manual stations. The frequency of monitoring is 24 hours and twice a week. CPCB provides the hourly frequency data at CAAQMS at GPO, Civil Lines for the pollutants namely PM_{10}, SO_2, NO_2, $PM_{2.5}$, ground-level ozone (O_3), nitric oxide (NO), carbon mono-oxide (CO), ammonia (NH_3), benzene, toluene, ethyl-benzene, xylene (also called as BTEX) along with the meteorological parameters such as temperature,

wind speed, wind direction and relative humidity. This data is transmitted from MPCB to CPCB which provides it in the public domain through its website (www.cpcb.nic.in). The ambient air quality data from April 2022 to March 2023 were extracted from MPCB and CPCB websites to carry out ambient air quality assessment.

1.3.1 AAQ Data Analysis: Manual stations

Air quality assessment is carried out for SO_2, NO_2 and PM_{10} concentrations at MPCB-operated stations under SAMP. CPCB guideline values for all the air pollutants are given in **Table 1.6**. The SO_2, NO_2 and PM_{10} concentrations during April 2022-March 2023 are plotted in **Figure. 1.8a-c.** The 24h guideline value is shown in the graph for comparison purpose. It can be seen that SO_2 and NO_2 are well below the regulatory limit except for one occasion when SO_2 is observed to be exceeding the threshold of 80 µg/m^3 at the station located at Divisional Commissioner Office. At few other occasions, it is closer to the threshold. NO_2 concentration is also observed to be exceeding the threshold of 80 µg/m^3 at few instances. PM_{10} concentration has frequently exceeded its regulatory limit of 100 µg/m^3 at many instances. The % exceedance rate for PM_{10} concentration is observed to be 23%, 8% and 12% at Civil Lines and 96%, 60% and 93% at Divisional Commissioner Office in Winter, Summer and Post-monsoon, respectively. At other locations, % exceedance rate is observed to be 21-96% for the four seasons. Spatial analysis during April 2022- March 2023 (**Figure. 1.8d**) suggests that PM_{10} is higher at Hingna followed by North Ambazari Road, Sadar and Divisional Commissioner Office. PM_{10} at Civil lines is less than the other locations and the annual average value is close to the threshold of 60 µg/m^3. At the other four locations, however, PM_{10} exceeds the CPCB threshold.

Table 1.6: National Ambient Air Quality Standards (NAAQS, 2009)

No.	Pollutants	Time Weighted Average	Concentration in Ambient Air	
			Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area
1.	Sulphur Dioxide (SO_2), µg/m^3	Annual *	50	20
		24 hours	80	80
2.	Nitrogen Dioxide (NO_2), µg/m^3	Annual *	40	30
		24 hours	80	80
3.	Particulate Matter, (PM_{10}), µg/m^3	Annual *	60	60
		24 hours	100	100
4.	Particulate Matter, ($PM_{2.5}$), µg/m^3	Annual *	40	40
		24 Hours	60	60

5.	Ozone (O_3), µg/m^3	8 hours	100	100
		1 hour	180	180
6.	Lead (Pb), µg/m^3	Annual *	0.50	0.50
		24 hours	1.0	1.0
7.	Carbon Monoxide (CO)	8 hours	02	02
	mg/m^3	1 hour	04	04
8.	Ammonia (NH_3), µg/m^3	Annual *	100	100
		24 hours	400	400
9.	Benzene (C6H6), µg/m^3	Annual *	5	5
			1	1
10.	Benzo (α) Pyrene Particulate Phase, ng/m^3	Annual *	01	01
11.	Arsenic (As), ng/m^3	Annual *	06	06
12.	Nickel (Ni), ng/m^3	Annual *	20	20

* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

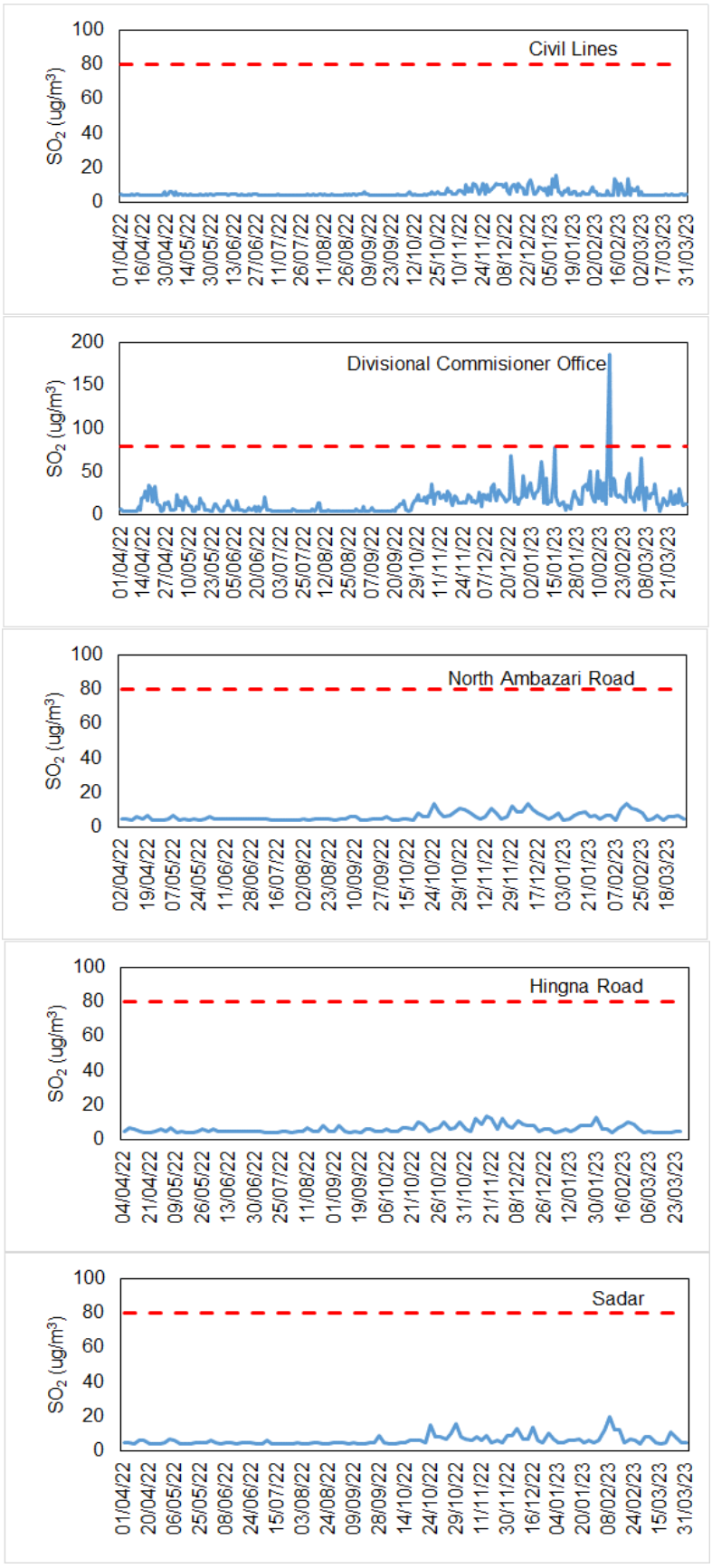

Figure 1.8a: SO_2 concentration at various locations in Nagpur (Source: MPCB). The dashed red line depicts the CPCB guideline value

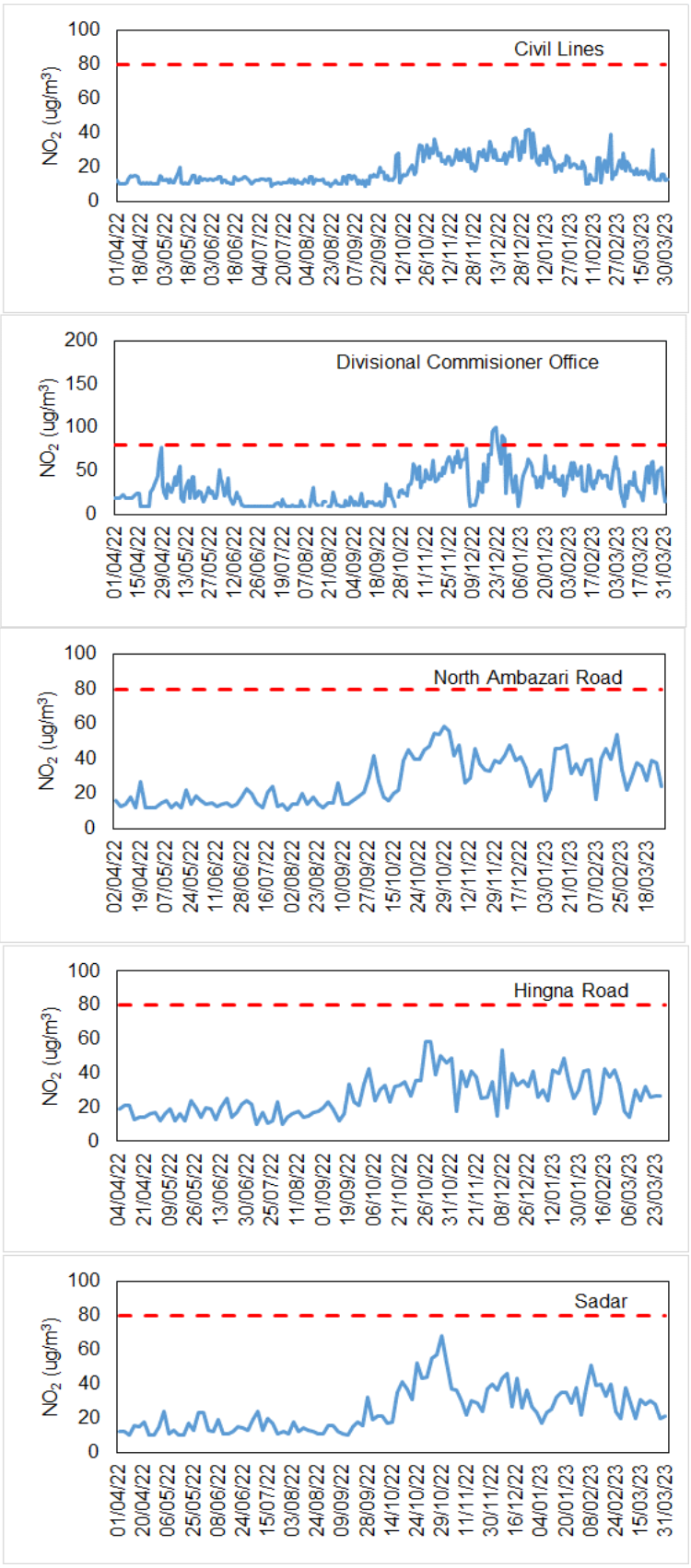

Figure 1.8b: NO_2 concentration at various locations in Nagpur (Source: MPCB). The dashed red line depicts the CPCB guideline value

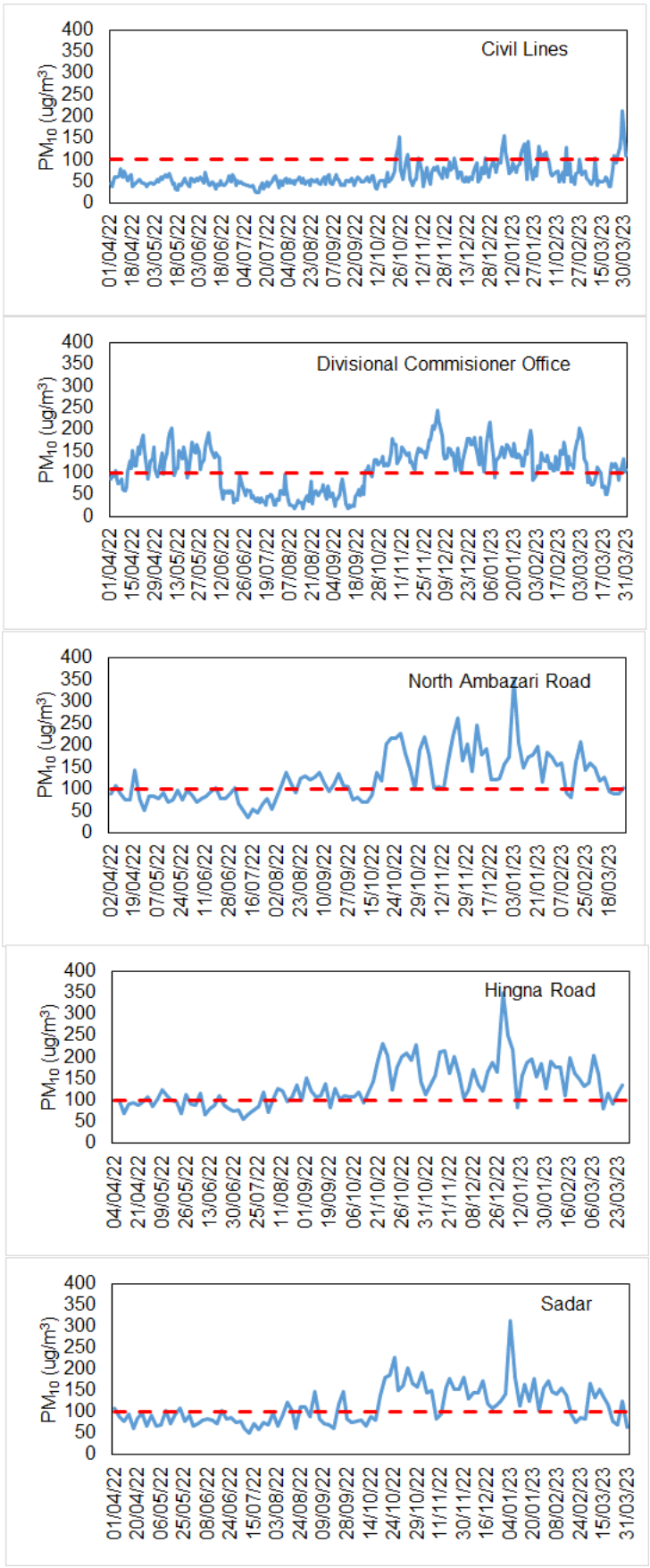

Figure 1.8c: PM_{10} concentration at various locations in Nagpur (Source: MPCB). The dashed red line depicts the CPCB guideline value

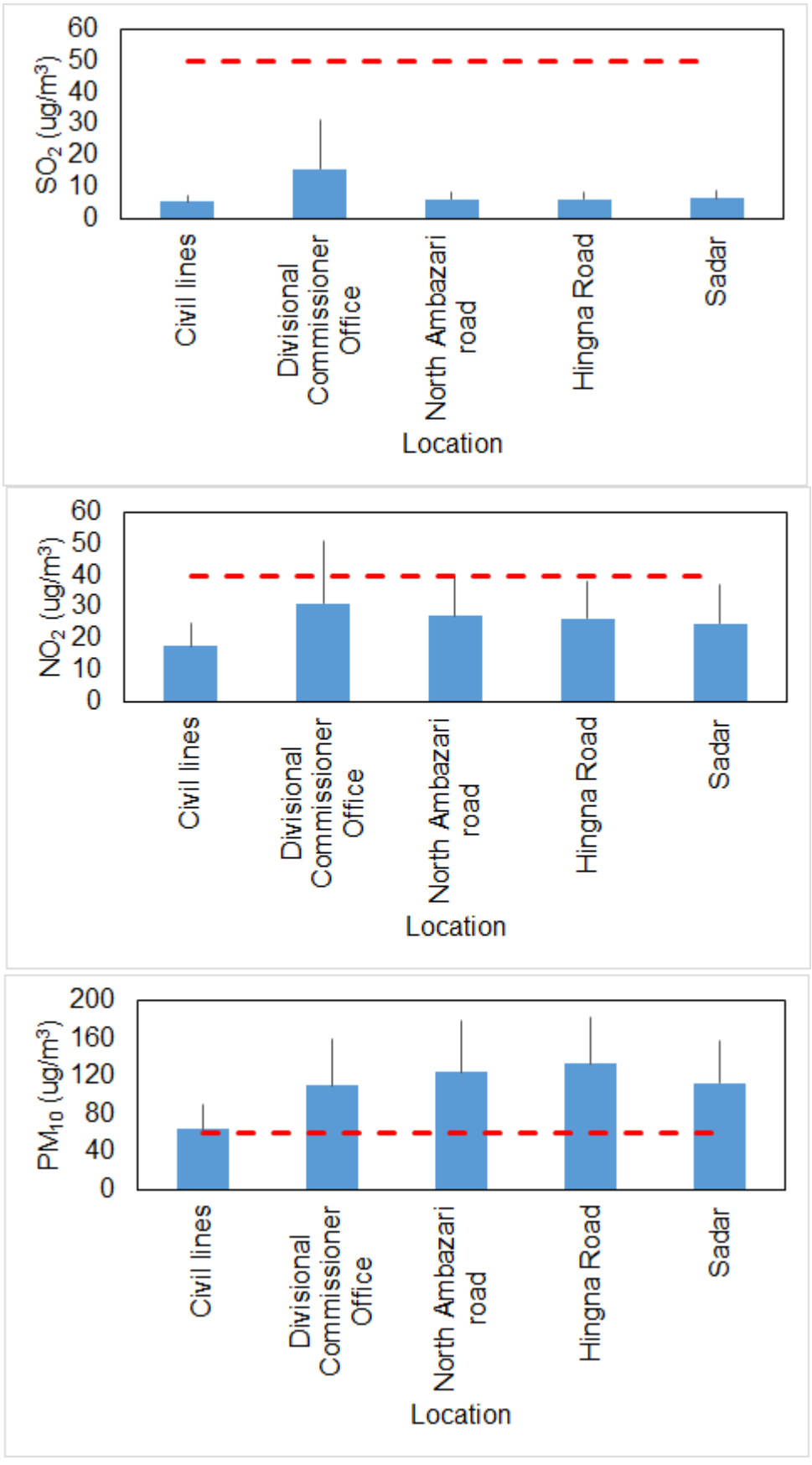

Figure 1.8d: Spatial analysis of AAQ during April 2022 – March 2023 (Source: MPCB)

Further to evaluate the change in air quality, PM_{10} observed during 2017-2023 at the manual monitoring stations operated by MPCB is plotted in **Fig 1.8e**. Since PM_{10} is a significant pollutant in the city, only that is taken into account. The raw data collected during January-December is used to calculate the city average and standard deviation. **Fig 1.8e** suggests that air quality in terms of PM_{10} has witnessed increase from 2017 till 2019 before a subsequent decline till 2021. Nonetheless, PM_{10} exceeds the 60 µg/m^3 annual average CPCB guideline value in every year.

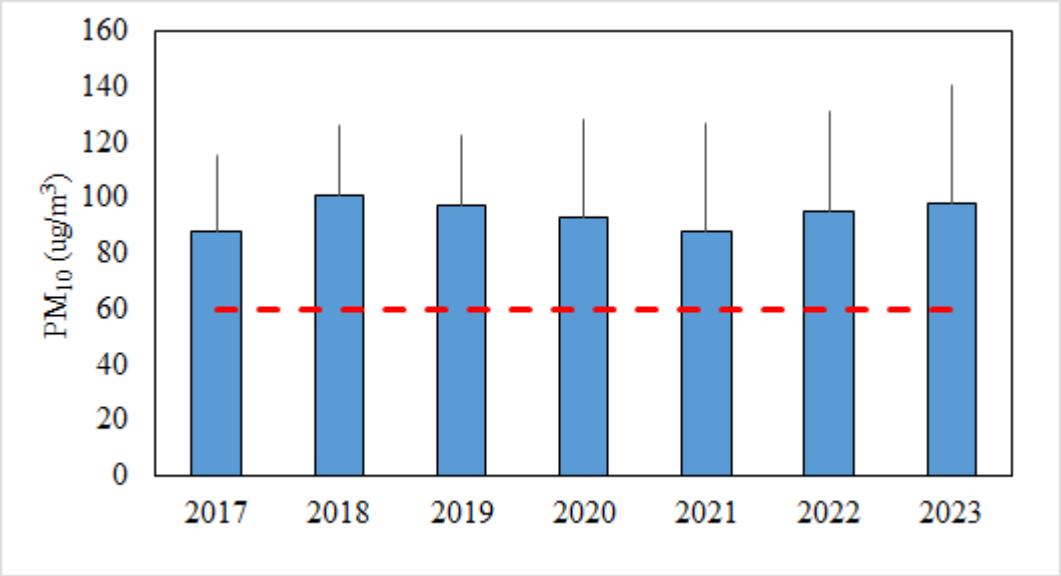

Figure 1.8e: Time series analysis of PM_{10} during 2017 - 2023 (Source: MPCB)

1.3.2 AAQ Data Analysis: CAAQMS Station

Ambient air quality at CAAQMS station which is located at GPO Square, Civil lines is analyzed. The data is available through CPCB. The air pollutants such as SO_2, NO_2, $PM_{2.5}$, PM_{10}, CO, Ozone, BTEX (Benzene, Toluene, Ethyl-benzene, Xylene) are monitored at this station along with the meteorological parameters. The status of AAQ in terms of $PM_{2.5}$, PM_{10}, NO_2, CO, Ozone and BTEX compounds is given in **Figure. 1.9a-b** in terms of monthly plot during April 2022-March 2023.

PM_{10} concentration is lower during monsoon months and higher during winter and post-monsoon (**Figure. 1.9a**), which is as anticipated. The highest PM_{10} concentration was observed in December (160 µg/m^3). A similar pattern is observed in $PM_{2.5}$ concentration (**Figure. 1.9a**) with the highest concentration in December (101 µg/m^3) followed by January (96 µg/m^3).

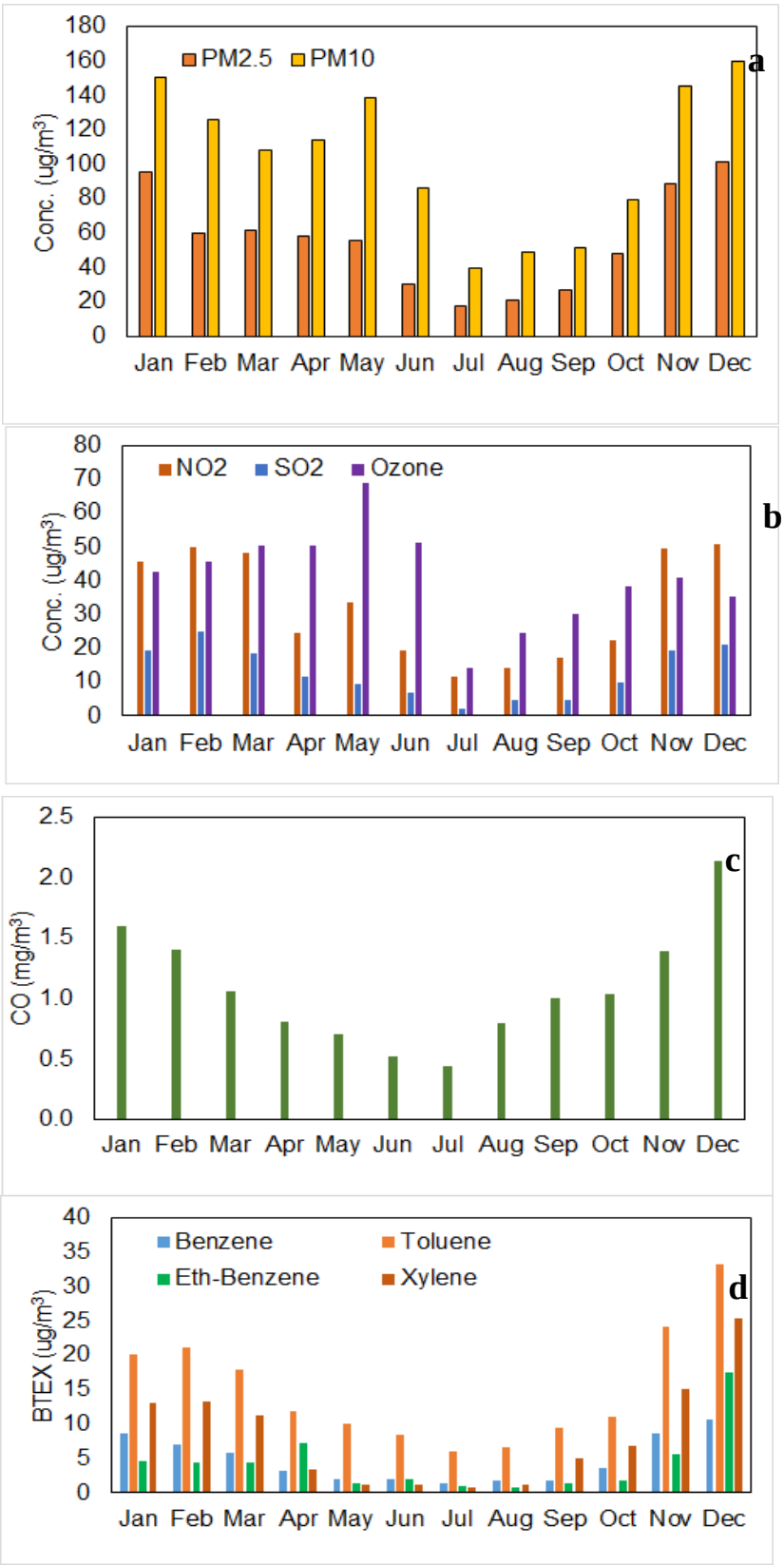

Figure 1.9: AAQ during April 2022 – March 2023 (a) PM10 & PM2.5 (b) NO_2, SO_2, & Ozone (c) CO (d) BTEX (Source: CPCB)

Monthly average NO_2 and Ozone concentrations are observed to be lower than the CPCB standard of 80 and 180 $\mu g/m^3$, respectively (**Figure. 1.9a**). NO_2 concentration is observed to be highest in December, whereas Ozone concentration is higher in May. SO_2 concentration is quite lower than the CPCB standard (**Figure. 1.9a**). CO concentration (**Figure. 1.9b**) is observed to be highest in December and January (2.1 and 1.6 mg/m^3). The monthly variations in BTEX (**Figure. 1.9b**) shows that BTEX compounds are higher in Winter followed by Post-monsoon months. The statistical summary of BTEX concentration is given in **Table 1.7**, which shows the exceedance of PM_{10}, Toluene and Xylene to the prescribed standards by CPCB.

Table 1.7. Air pollutant concentrations at CAAQMS, Civil Lines

Parameter	Unit	Average
$PM_{2.5}$	$\mu g/m^3$	55.7
PM_{10}	$\mu g/m^3$	104.2
NO	$\mu g/m^3$	13.8
NO_2	$\mu g/m^3$	32.2
SO_2	$\mu g/m^3$	12.7
CO	mg/m^3	1.1
Ozone	$\mu g/m^3$	40.8
Benzene	$\mu g/m^3$	4.9
Toluene	$\mu g/m^3$	15.5
Ethyl -Benzene	$\mu g/m^3$	4.5
Xylene	$\mu g/m^3$	8.7

Hourly variations in criteria pollutants depicted in **Figure. 1.10** show that PM_{10} and $PM_{2.5}$ are higher during night hours and start declining in the mid-night from 1 AM until morning 7 AM and again increase afterwards until 11 AM. The decreasing trend continues until 4-5 PM and an increase is observed afterwards until midnight. The peaks and troughs cycle shows that evening and late night hours are critical from a particulate pollution point of view. The diurnal variation in SO_2 is unimodal with a peak oscillatory cycle from 10 AM - 6 PM. NO_2, however does not show a significant activity cycle, however increase is observed after evening hours i.e. 6 PM which continued until 9 PM. In Nagpur, in addition to the office goers, a major chunk of population is traders, who return back home during late evening hours causing

relatively high concentration. 2-wheelers and cars are mostly used by these traders, which emit gaseous pollutants and particulate matter in ambient air.

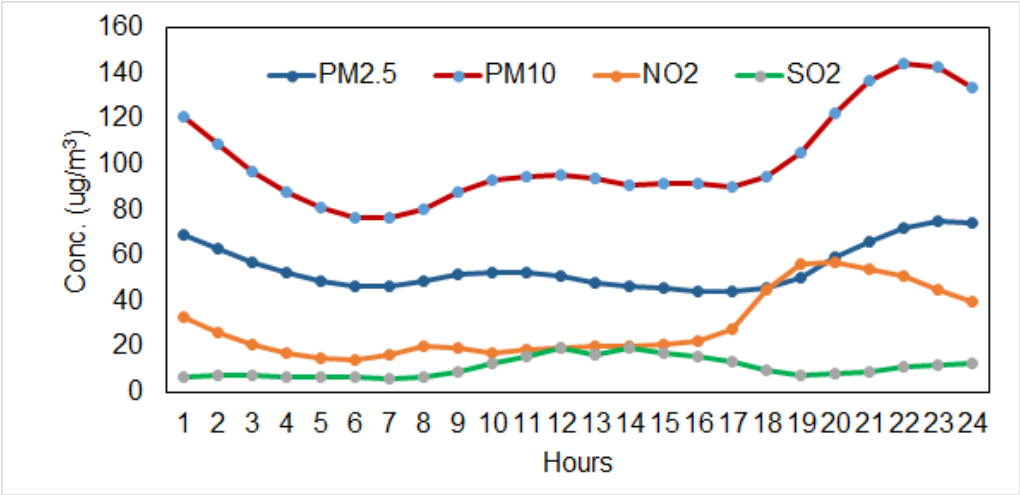

Figure 1.10: Hourly variations in criteria pollutants at Civil Lines (Source: CPCB)

1.3.3 Correlation of Air Pollutant Concentrations

Correlation of various air pollutant concentrations over the study period is computed to qualitatively understand the similarity in the sources. **Table 1.8** shows that $PM_{2.5}$ and PM_{10} are significantly correlated.

Table 1.8: Correlation analysis of air pollutant concentrations at CAAQMS, Civil Lines (Source: CPCB)

Parameter	$PM_{2.5}$	PM_{10}	NO	NO_2	SO_2	CO	Ozone	Benzene	Toluene	Ethyl benzene	Xylene
$PM_{2.5}$	1.0										
PM_{10}	0.9	1.0									
NO	0.3	0.4	1.0								
NO_2	0.5	0.6	0.7	1.0							
SO_2	0.3	0.3	0.1	0.2	1.0						
CO	0.4	0.5	0.7	0.7	0.1	1.0					
Ozone	0.0	0.0	-0.3	-0.3	0.3	-0.3	1.0				
Benzene	0.6	0.6	0.7	0.7	0.2	0.7	-0.3	1.0			
Toluene	0.4	0.5	0.7	0.7	0.1	0.7	-0.3	0.9	1.0		
Ethyl benzene	0.2	0.2	0.3	0.3	0.1	0.3	-0.1	0.5	0.7	1.0	
Xylene	0.4	0.4	0.6	0.6	0.1	0.6	-0.3	0.8	0.9	0.9	1.0

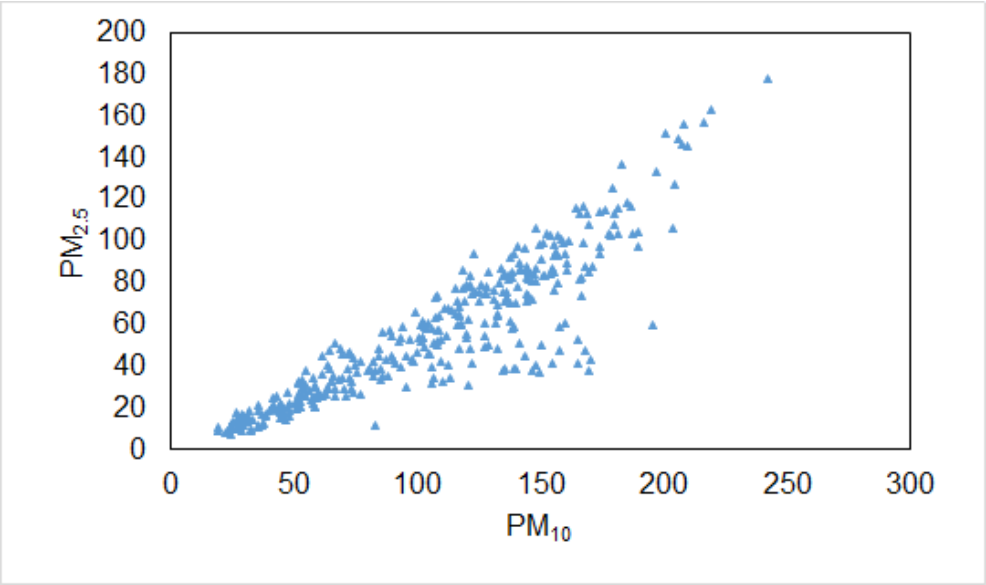

Figure 1.11: Scatter plot of daily $PM_{2.5}$ and PM_{10} (Source: CPCB)

The scatter plot of PM_{10} and $PM_{2.5}$ concentration is also given in **Figure. 1.11** separately to understand the nature of the relationship. NO_2 concentration is correlated positively with CO, and negatively with Ozone concentration. The positive correlation of NO_2 with CO suggests their common source. CO and NO_2 are correlated with Benzene, Toluene, Xylene and negatively with Ozone. BTEX compounds are correlated well with each other. The correlation of Ozone with precursor variables i.e. NO_2 and CO suggests the role of traffic in governing the Ozone formation in Nagpur. This, however needs to be further analyzed deeply to gain insight into the local ozone chemistry.

1.3.4 Air Quality Index

Based on the above data, air quality index (AQI) is calculated as devised by CPCB. The various categories of AQI are given as below:

Table 1.9: Various categories of air quality index as devised by CPCB

AQI Category	AQI	Concentration range*							
		PM_{10}	$PM_{2.5}$	NO_2	O_3	CO	SO_2	NH_3	Pb
Good	0 - 50	0 - 50	0 - 30	0 - 40	0 - 50	0 - 1.0	0 - 40	0 - 200	0 - 0.5
Satisfactory	51 - 100	51 - 100	31 - 60	41 - 80	51 - 100	1.1 - 2.0	41 - 80	201 - 400	0.5 - 1.0
Moderately polluted	101 - 200	101 - 250	61 - 90	81 - 180	101 - 168	2.1 - 10	81 - 380	401 - 800	1.1 - 2.0
Poor	201 - 300	251 - 350	91 - 120	181 - 280	169 - 208	10 - 17	381 - 800	801 - 1200	2.1 - 3.0
Very poor	301 – 400	351 - 430	121 - 250	281 - 400	209 - 748*	17 - 34	801 - 1600	1200 -1800	3.1 - 3.5
Severe	401 - 500	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

* CO in mg/m^3 and other pollutants in $\mu g/m^3$; 2h-hourly average values for PM_{10}, $PM_{2.5}$, NO_2, SO_2, NH_3, and Pb, and 8-hourly values for CO and O_3.

(Source: http://app.cpcbccr.com/ccr_docs/About_AQI.pdf)

The variation of AQI computed using PM_{10}, SO_2 and NO_2 over different manual monitoring stations is given in **Figure 1.12**. It can be seen that AQI is satisfactory at Civil Lines and in Moderate category at all the other locations.

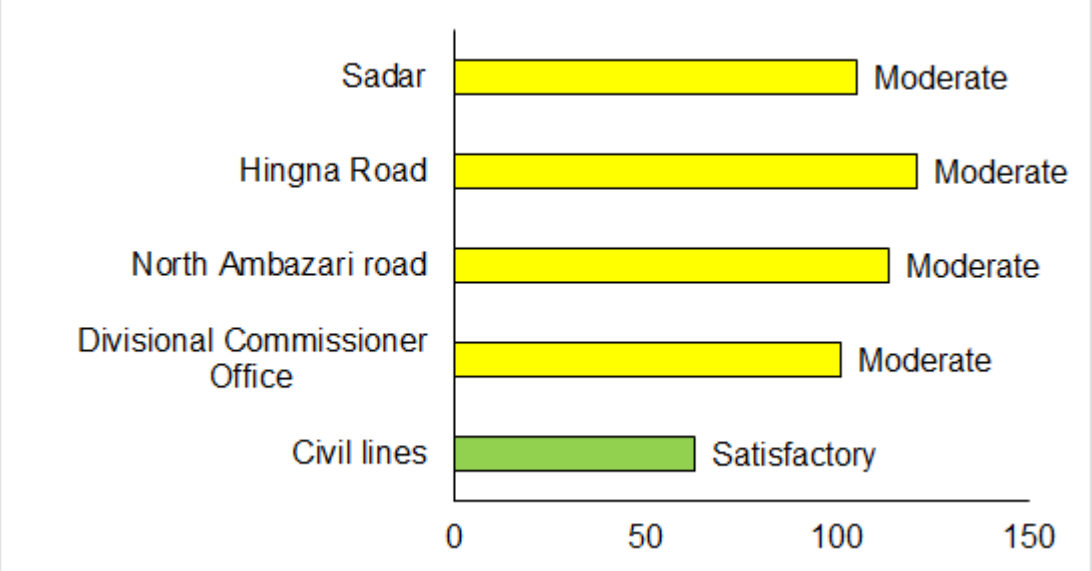

Figure 1.12: AQI observed at various locations (Source: MPCB)

1.3.5 Meteorology

Air pollutant's dispersion in the atmosphere is governed by meteorological parameters like wind speed and wind direction, temperature, and relative humidity. The wind speed and wind direction as gathered at CAAQMS at Civil Lines are used for plotting the windrose diagram.

Figure 1.13 depicts the monthly wind rose diagram for Nagpur. It can be seen that the predominant wind direction is from West and East direction during winter and post-monsoon months. The predominant wind direction during monsoon is from South and South-West direction. During summer, the predominant wind direction is mostly from the South direction.

1.3.6 Aerosol Optical Depth

The temporal and spatial coverage of particulate matter (PM) monitoring has its limitations prompting alternative arrangements for filling up the data gaps. Satellite-based observations may complement to the existing network of PM concentration monitoring. Aerosol optical depth (AOD), an aerosol extinction coefficient in the vertical direction has been derived through various satellite instruments on-board over the satellites/spacecrafts with the help of advanced algorithms. AOD has been obtained through a Moderate Resolution Imaging Spectroradiometer (MODIS) to assess the aerosol load over Nagpur. Ground $PM_{2.5}$ measurements are shown to be correlated with satellite-based AOD at the wavelength of 0.55 µm**.** The aerosol optical depth over both land and ocean is provided twice a day (at 10.30 and 13.30 local solar time) by MODIS sensor on board the NASA-EOS Terra and Aqua spacecraft (Kaufman et al. 1997, Journal of Geophysical Research–Atmosphere 102, 16815-16830; Levy et al. 2007, Journal of Geophysical Research–Atmosphere 112, D13; Tanre et al. 1997, Journal of Geophysical Research–Atmosphere 102, 16971–16988). AOD product for Terra and Aqua sensors derived for different surfaces including bright urban areas and semi-arid areas has been used in this study. The data were archived from the MODIS LAADS-DAAC.

It is observed that AOD ranges between 0.05-2.3 with an average of 0.53±0.3. An area with AOD~1 is usually termed as highly polluted. There were quite a few instances (about 6%) where AOD exceeded 1. The variation of $PM_{2.5}$ concentration and AOD is plotted in **Figure. 1.14a** to assess any correlation in the behavior of the two parameters. The scatter plot between observed $PM_{2.5}$ and AOD (**Figure. 1.14b**) at 24h scale shows that both are not correlated well. However, at coarser time resolution, better correlation may be obtained.

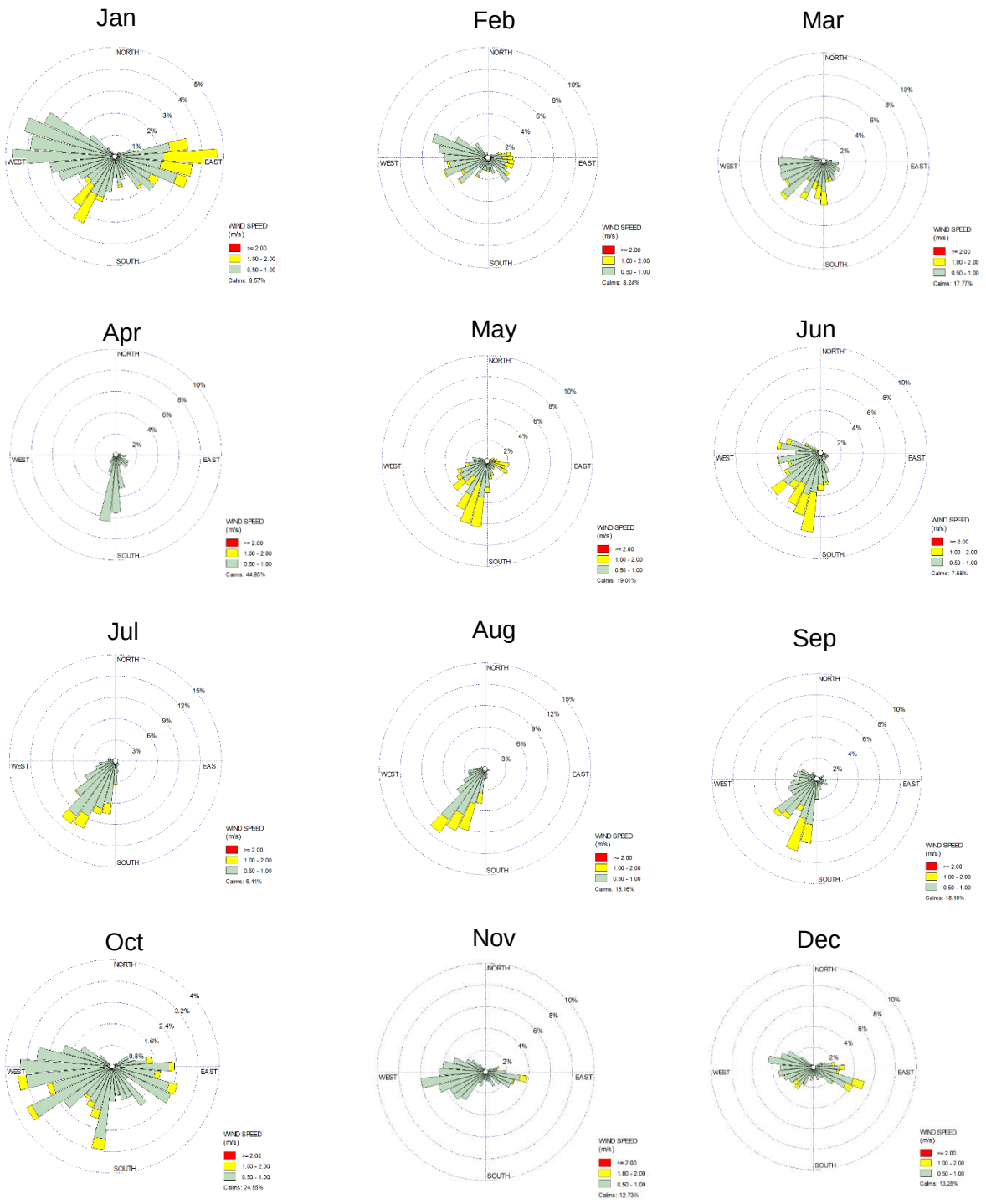

Figure 1.13: Windrose diagram from Meteorological data (Source: CPCB)

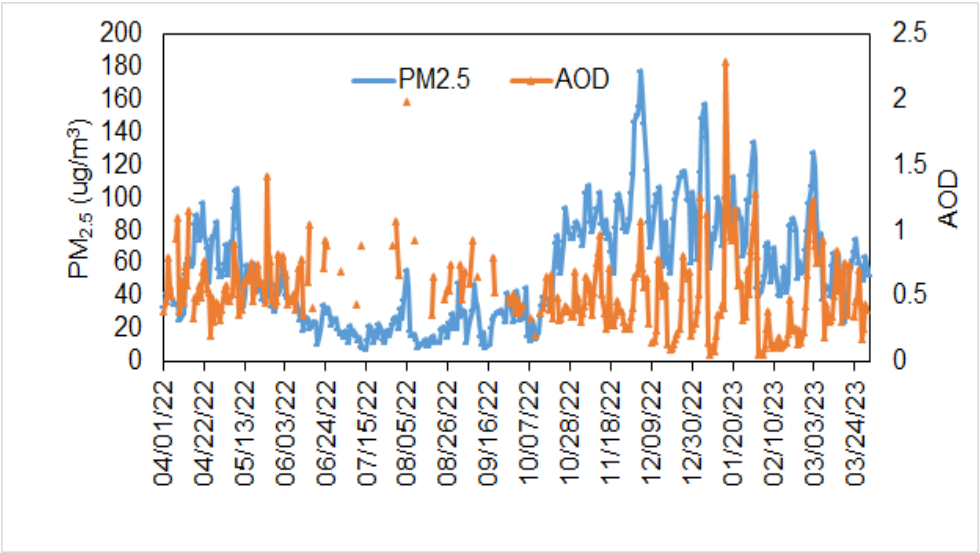

Figure 1.14a: Comparison of 24h AOD and $PM_{2.5}$ variations (Source: CPCB and MODIS)

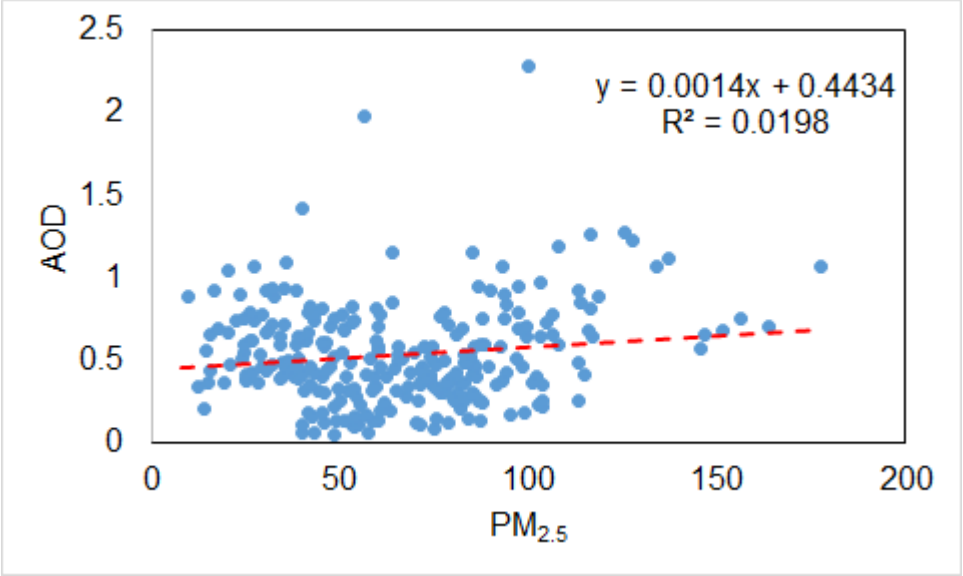

Figure 1.14b: Scatter plot of $PM_{2.5}$ and AOD (Source: CPCB and MODIS)

1.4 Observations and Inferences

The analysis of air quality at manual monitoring sites shows that PM_{10} is the city's most concerning pollutant, while NO_2 concentration surpasses the standard at very few instances. According to a spatial analysis conducted in 2022–2023, PM_{10} levels are highest near Hingna, followed by North Ambazari Road, and Sadar. At Civil Lines, PM_{10} levels are lower than at other places. The assessment of the air quality at the Continuous Ambient Air Quality Monitoring Station revealed that all the parameters, with the exception of PM_{10}, are below the

CPCB level. The aerosol optical depth obtained through MODIS has an average of 0.53±0.3 and ranges from 0.05 to 2.3. AOD is 6% of the times >1. Overall, the issue of air pollution in terms of all the parameters except PM pollution in the city during the study period is not very significant. The emission inventory study reveals that PM_{10} and $PM_{2.5}$ emissions (46% and 61%, respectively) are majorly from the vehicular category followed by the emissions from road dust resuspension (19% and 15%, respectively). Line sources are contributing to 72% of NOx, 83% of CO and 60% of HC emissions followed by domestic sector in the city. The areas with highest PM_{10} emission load are Hingna MIDC (190 and 156 kg/day), Sitabuldi–Dhantoli–Congress Nagar (164 kg/day), Ganeshpeth (Baidyanath Square)–Great Nag Road–Medical Square (139kg/day), Jaiprakash Nagar–Somalwada–Sneh Nagar (121 kg/day), Automotive Square (92 kg/day), Khamla–Deonagar–Chhatrapati Square (91 kg/day), Manewada (81 kg/day).

1.5 Recommendations

Based on the AAQ status and Emission Inventory of the city, the following specific recommendations to control air pollution in the city can be prioritized.

1. It is observed that particulate matter, specifically $PM_{10,}$ is a pollutant of concern. Therefore, the control and management policies need to be oriented to mitigate PM_{10} pollution in the city.
2. Ambient air quality monitoring stations operated by MPCB and CPCB under SAMP and NAMP programmes have been augmented with respect to number of stations and the number of parameters monitored. There is a need to maintain them properly to provide consistent and reliable data. A transparent auditing practice is required for these stations. The capacity building programme for the government officials to train them for the ambient air quality monitoring and emission inventory study can be organized. CSIR-NEERI can impart training to the identified government personnel.
3. Gridded emission inventory of Nagpur city needs to be generated on regular basis. This is possible if the activities causing air pollution emissions are updated regularly in a pre-defined manner. This includes, updating of number of new construction activity, closing of completed construction activity, number of dead bodies in crematoria, new hotels, restaurants etc.
4. The city's road network is changing from flexible to stiff pavement, so it is necessary to assess the silt load from the various routes. This will display the real emission load

resulting from the resuspension of road dust. It is suggested that CSIR-NEERI will carry out study for silt load of Nagpur roads and estimate the road dust resuspension.

5. CSIR-NEERI has developed a vehicular counting tool to count the number of vehicles that pass through a certain road segment. Given that Nagpur's smart city plan includes installation of CCTVs to monitor city activity, CSIR-NEERI can calculate line source emissions, if an access to CCTVs is provided. This could be an effective strategy for significantly reducing the city's pollution load.
6. Dust emissions from tall building construction are one of the major challenges that must be addressed. Residual construction material left outside the construction site, on the roads, is a nuisance and a health risk. It is recommended that no such material be stored outside to reduce the amount of road dust resuspension. With appropriate safety precautions, the material can be stored within the plot area. Regardless of the size of the site or plot, it is possible to prevent the exposure to particulate pollution from residential construction operations by firmly encircling the area with green netting up to the top of the constructed area, or other sheets/tarpaulin to prevent pollution from dispersing. NMC will issue a SOP for building construction with the above measures.
7. Traffic congestion due to parking of cars on both sides of the road in residential neighbourhoods has become a big menace in the city. Many areas are witnessing the narrowing down of the roads due to car parking on the space near the houses. The residents themselves get exposed to the micro-pollutants released due to vehicle halts. Appropriate policies need to be implemented to reduce the pollution-induced because of the vehicular traffic halts due to on-street parking.

Figure 1.15: Photographs of open burning

8. The solid waste department of NMC should issue a SOP for the respective zones mentioning the day and time for collection of garden waste. This will reduce the burning of garden waste in respective zones.
9. Open burning occurs in local and residential areas even though it is prohibited. The legislation therefore needs to be strictly enforced. Residents must observe appropriate guidance on solid waste management. In numerous locations, especially during the morning, at some places authorized workers and/or sanitary personnel assigned to tidy internal lanes and streets sweep the streets, create a pile of trash and leaves, which they then publicly burn (**Figure 1.15**). Open burning is not a good practise from environment point of view and NMC should take strict action to stop such practises.
10. It is important to understand the air pollution contribution from the nearby areas and also the regional contribution. The air-shed of the area needs to be identified to account for the emissions sources present in the area.

ESR (2022-23)

Chapter 2
Climate Change

CSIR-NEERI

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Climate Change and Water Stress in Nagpur City: A Water Poverty Index Approach

2.1 Introduction

The intersection of urbanization, climate change, and water scarcity presents a formidable challenge for cities worldwide, and Nagpur is no exception. Climate change-induced alterations in precipitation patterns, rising temperatures, and increased frequency of extreme weather events compound the intricate issues surrounding water availability and access. In this dynamic landscape, the Water Poverty Index (WPI) emerges as a crucial instrument, synthesizing scientific rigour with on-the-ground realities to comprehensively assess the multifaceted dimensions of water poverty. Scientifically, the Water Poverty Index is a composite measure that encapsulates various aspects of water availability, accessibility, and usability, providing a nuanced understanding of the challenges communities face in securing reliable water sources.

Developed by researchers and policymakers, the WPI incorporates indicators such as water quantity, quality, infrastructure, and socio-economic factors, creating a holistic framework for evaluating the state of water poverty in a given area. Drawing from the successes of WPI implementations in diverse regions, this study takes inspiration from previous endeavours that have shed light on the intricate interplay between water poverty and climate change. For instance, in arid areas facing heightened vulnerability to climate change, WPI has served as a diagnostic tool, identifying key stress points and guiding targeted interventions. Similarly, in urban settings experiencing rapid population growth, the WPI has been instrumental in uncovering disparities in water access and catalyzing initiatives for equitable distribution. Beyond its theoretical underpinnings, the WPI has proven its practical utility as a decision-support tool.

The imperative to comprehensively assess and address water poverty has driven researchers worldwide to devise innovative methodologies, and the Water Poverty Index has emerged as a robust instrument in this pursuit. Internationally, seminal studies such as the World Health Organization's "Global Assessment of Water Supply and Sanitation" and the United Nations Development Programme's "Human Development Report" have utilized variations of the WPI to gauge the impact of water scarcity on human well-being. These studies have not only underscored the global relevance of the WPI but have also set precedents for its adaptability to diverse socio-economic and climatic contexts. Closer to home, within the Indian subcontinent, the WPI has been instrumental in elucidating the complexities of water poverty in varied landscapes. In the arid regions of Rajasthan, studies like the "Water Poverty Index for the

Indian States" have provided granular insights into communities' challenges in accessing clean and reliable water sources. Similarly, the "Urban Water Poverty Index" implemented in cities like Chennai and Kolkata has delineated the nuances of water deprivation in the urban milieu.

Against this backdrop, Nagpur City's unique socio-economic and environmental context beckons a meticulous examination of water poverty through the lens of the WPI. In ESR 2019-20, climate variables and indices were investigated to understand the impact of climate change on the microclimate of Nagpur city. Investigations illustrated that 80% of the annual data for the 2000-2019 period have their annual mean temperature above the reference mean for 1970-2019. The study also indicated the number of extreme heat events is on the rise, with 85% of the annual data for 2000-2019 showing above-average anomalies. For rainfall data, the investigations revealed that the magnitude of precipitation during the monsoon for 2010-19 has increased by 15.68% compared to the baseline decade of 1970-79. However, there has been a drastic reduction in rainfall in the Non-monsoon period, with the post-monsoon (51.62%) and winter (50.42%) precipitation showing high reduction levels.

Further, the analysis of rain days (rainfall > 2.5) shows that the total number of rain days has reduced by 16% for the 2010-19 decade compared to the baseline decade. A similar trend can be seen for the southwest monsoon season, with a rain days' reduction of 12.2% for 2010-19. Therefore, it is imperative to understand the water availability by mapping the water stress zones of the city to tackle the change in water management plans, as water conservation and management issues would be one of the challenging issues that Nagpur City would face in the future due to climate variability. In this regard, WPI can play an important role in mapping water stress zones and provide suggestions for resource prioritization and mobilization for water management.

By amalgamating scientific precision with the realities witnessed by the residents of Nagpur, this study endeavours to unravel the city's water poverty narrative. Through a comprehensive household survey conducted across ten distinct zones, we aim to quantify the Water Poverty Index and contextualize its implications in light of climate change-induced stressors. In doing so, we aspire to contribute actionable insights to inform policy decisions, empower community-driven interventions, and lay the groundwork for a resilient and sustainable water future for Nagpur City. As we delve into the intricacies of Nagpur's water situation, this study aims to build upon the collective wisdom garnered from previous WPI studies, bridging the gap between global insights and local realities. By doing so, we endeavour to lay the groundwork for a resilient and water-secure future for Nagpur City.

2.2 Water Poverty Index (WPI)

Climate Change and Water are integrally related; on the one hand, the water demand is increasing due to socio-economic, demographic and industrial stressors, but on the flip side, the availability of potable water is seriously impacted by human-induced climate changes. Studies have shown that water stress will increase in 62-76% of the global land mass, with 75 to 250 million people projected to face some form of water stress within this decade due to climate change (Kher, Aggarwal and Punhani, 2012). 18% of the world's population lives in India, yet India only holds 4% of the global water resources. This disparity is further exacerbated as the Indian economy is highly dependent on rain-fed agriculture. This study attempts to consider socio-economic and environmental indicators in the water assessment of Nagpur city. The WPI proposed by Sullivan (2001, 2002) is used to assess water scarcity abs stress. The inclusion of the poverty factor into WPI has been proposed by Peter Townsend (1979) and developed in the concept of WPI by the works of Meigh, McKenzie and Sene (1999) and Sullivan (2001, 2002).

The WPI framework has five critical components:

- **Resource**

  The indicators for this component assess the water resources from both qualitative and quantitative perspectives, considering the reliability of supply and seasonal resource variability.

- **Capacity**

  The indicators for this component refer to the effectiveness of people's ability to manage water resources, particularly in social and economic capacity.

- **Access**

  The indicators for this component refer to accessing water for various needs. Water could be accessed for drinking or in-house sanitation and irrigation. It also combines physical access to water resources measured through distance and time to fetch this water.

- **Use**

  The indicators for this component refer to the utilization of water resources for agricultural, domestic or industrial use.

- **Environment**

  The indicators for this component consider environmental sustainability while accessing water for agriculture, industrial or domestic use.

2.3 Study Area

Nagpur City, situated in central India, experiences a tropical savanna climate characterized by distinct wet and dry seasons. The climate is influenced by its central location on the Deccan Plateau, with the Vidarbha region of which Nagpur is a part, being subject to both monsoonal and continental climatic influences. Nagpur falls within the Vidarbha region, which is classified into different agro-climatic zones. The area exhibits variations in climate and soil types, contributing to a diverse agricultural landscape. The agro-climatic conditions are crucial in shaping land use patterns and vegetation in and around Nagpur.

Nagpur experiences significant temperature variations throughout the year. Winters (November to February) are characterized by cooler temperatures, with minimums ranging from around 7°C to 12°C. Summers (March to June) are hot, with maximum temperatures often exceeding 40°C, and the annual average temperature in Nagpur typically ranges from approximately 25°C to 28°C. Nagpur City witnesses a monsoonal rainfall pattern. The Southwest Monsoon, from June to September, brings most of the city's annual rainfall. The average yearly rainfall is around 1,100 mm, contributing to the city's water resources and shaping local vegetation patterns.

The natural vegetation in and around Nagpur comprises a mix of deciduous and dry deciduous forests. The presence of teak and bamboo reflects the region's ecological diversity. Urbanization has led to changes in land use and a reduction in natural vegetation cover. Nagpur's soil composition is diverse, with a prevalence of red and black soils. Red soils are well-drained and suitable for agriculture, while black soils are rich in nutrients, making them conducive to various crops. The soil types influence land use patterns, agricultural practices, and water retention capacities.

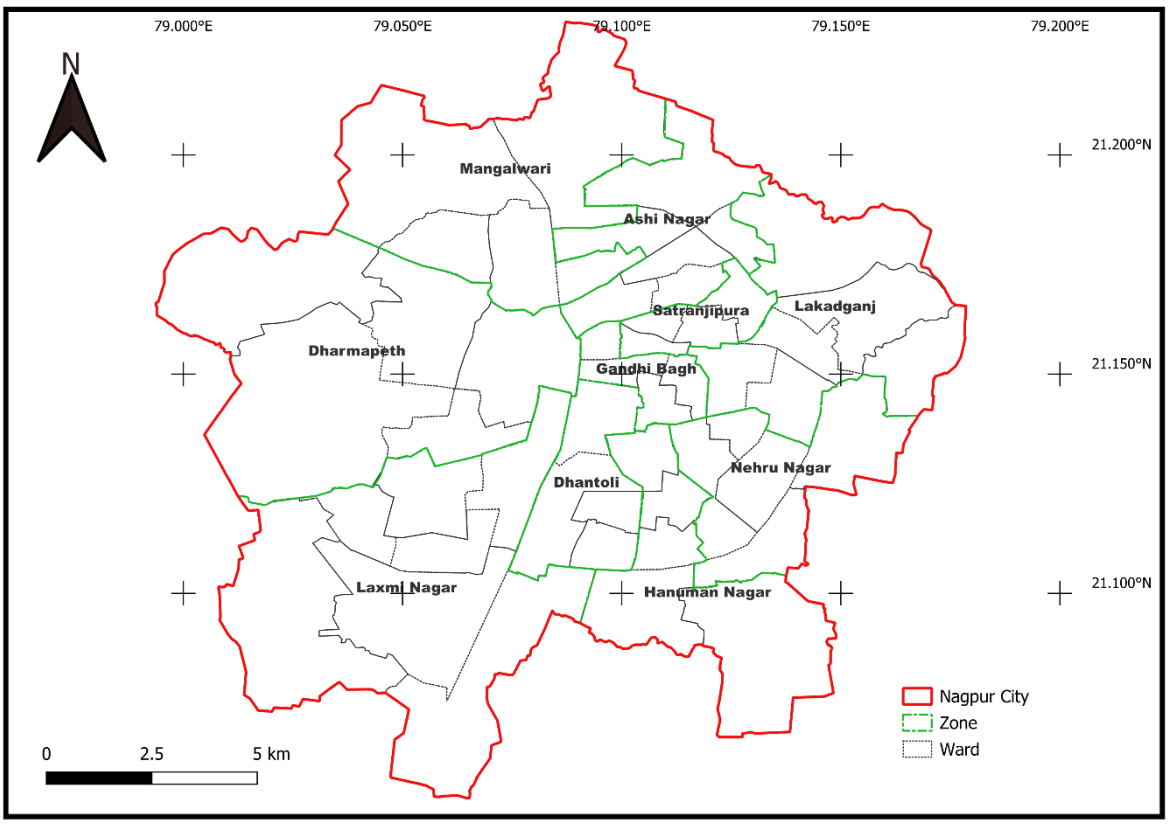

Figure 2.1: Zone-wise map of Nagpur city

2.4 Methodology

1. Survey Design:

The survey is aimed to capture a representative sample of Nagpur City's diverse population; therefore, 900 households were selected for inclusion in the study. The sample size was determined to provide statistically significant insights into the water poverty dynamics across the city while considering the logistical constraints of data collection. Households were selected through a stratified random sampling to ensure a comprehensive representation. The city was divided into ten distinct zones, and households were randomly selected within each zone. This method allowed for the inclusion of various socio-economic and geographical characteristics in Nagpur. Trained surveyors conducted face-to-face interviews with the selected households. The survey questionnaire covered a range of topics, including water sources, consumption patterns, water quality perceptions, socio-economic status, and climate change awareness. Using a structured questionnaire of 16 questions facilitated consistency in data collection across all zones.

2. Water Poverty Index (WPI) Calculation Methodology:

The Water Poverty Index (WPI) estimation is based on the methodology proposed by (Sullivan, 2001, 2002). The WPI combines physical, social, economic, and environmental data on water scarcity, access to water, and the ability to use water for productive reasons. To make sure that all relevant information is included, the index is based on participatory data, which has identified five sub-indices

- Resources (R)
- Access (A)
- Capacity (C)
- Use (U)
- Environment (E)

These sub-indices are composed of subcomponents, and variables are directly measured. For the current study, the different sub-components defined and used are represented in **Figure 2.2: Table 2.1** explains the correlation of various sub-components to the sub-indices of the Water poverty index.

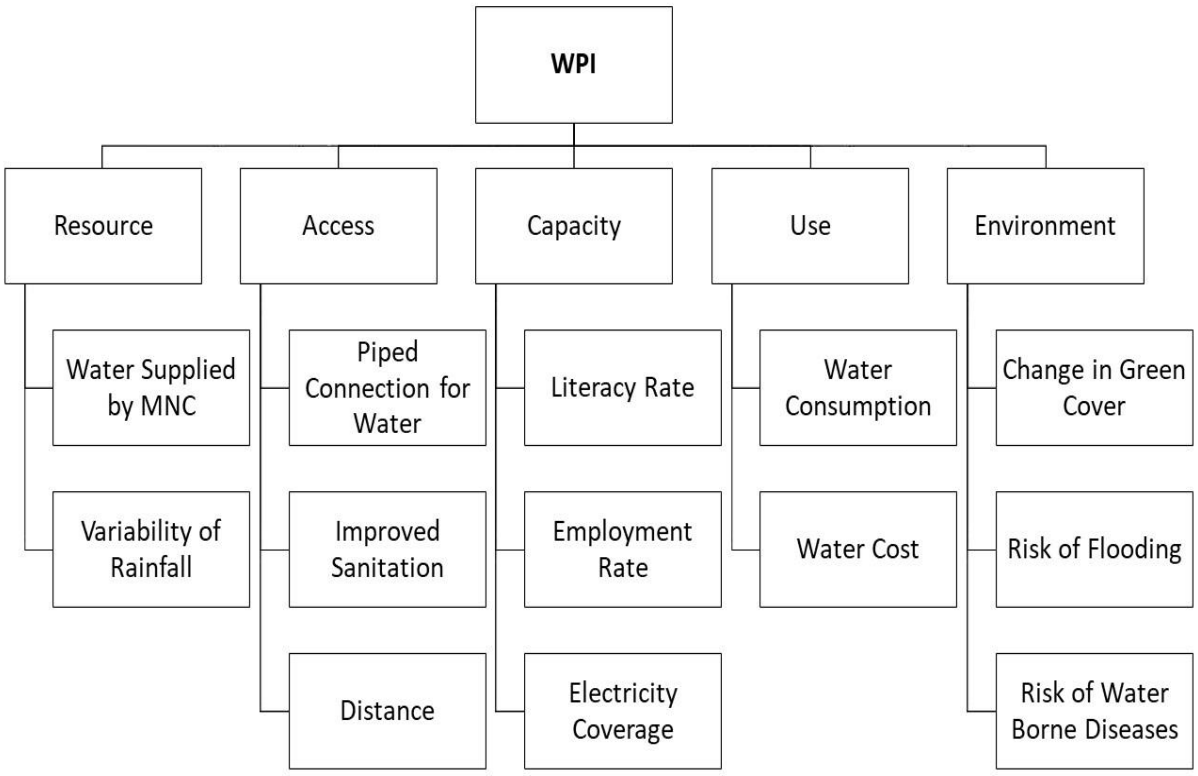

Figure 2.2: Sub-components used for development of WPI

Table 2.1: Description of sub-components used in the Water Poverty Index

Sl. No	Sub Components	Description	Value
1	Water Supply (hrs)	Determines the actual availability of water in 24 hrs for a particular household	No of Households with water supply less than 3 hrs
2	Variability of Rainfall	Determines the change in natural availability of water (1970-2020)	Rainfall data based on IMD and Power Nasa
3	Piped Connection for Water	Determines the safety of drinking water	No of Household having a piped water connection from NMC
4	Improved Sanitation	Determines the treatment and quality of water disposed after use	No of Household having Indian/Western Komodo
5	Distance from Tap	Determines the ease of access to drinking water	No of households having piped water connection more than 50 meters away
6	Literacy Rate	Determines the impact of education on the capacity for proper management of water	Total no of family members who have passed class 10
7	Employment Rate	Determines the impact of employment on capacity for proper management of water	Total no. of family members above the age of 18 who are employed
8	Electricity Coverage	Determines the impact of access to 24-hour electricity for proper water treatment and management	Total no of households having 24 hrs of electricity supply
9	Water Consumption	Determines the daily use of water per household	Daily Consumption of water per household
10	Water Cost	Determines the impact of cost on usage of water	Monthly cost of water per household
11	Change in Green Cover	Determines the impact of water use/extraction on Greenery	Change in Normal Difference Vegetation Index (NDVI)
12	Risk of Flooding	Determines the impact of extreme weather events on the availability and quality of water	No of Households who have faced flooding in the last 24 months
13	Risk of Water-Borne Diseases	Determines the impact of water pollution on health	No of household using traditional (cloth/plastic mesh) or no filtering method for drinking water treatment

The Water poverty index is similar to the Human Development Index (HDI); the five sub-indices are combined using the following expression:

$$WPI = \frac{\sum_{i=1}^{N} w_i X_i}{\sum_{i=1}^{N} w_i} \quad (1)$$

Where:

WPI = water poverty index for a particular location

X_i = component i of WPI structure for that location

W_i = weight applied to that component

Each Sub-indices is composed of a number of subcomponents. The methodology mentioned above combines all the subcomponents to obtain the sub-indices. If we include the sub-indices, equation 1 can be converted into the following:

$$WPI = \frac{(W_r R + W_a A + W_c C + W_u U + W_e E)}{(W_r + W_a + W_c + W_u + W\_e)} \quad (2)$$

An equal-weighted average of the five sub-indices Resources (R), Access (A), Capacity (C), Use (U), and Environment (E) is used to compute the WPI. Each component is first normalized to 0 and 1, resulting in a WPI value between 0 and 1. **The most excellent score, 1, represents the best conceivable scenario (or the lowest possible amount of water poverty/stress), while 0 represents the worst**. There are many models for combining data to create the WPI; the method proposed by (Sullivan, 2001, 2002) is used because of its simplicity and straightforwardness.

2.5 Observation and Inferences

2.5.1 Overall Water Poverty Index (WPI)

As per **Figure 2.1**, this study divides the Nagpur municipal area into ten zones, i.e. 1) Laxmi Nagar, 2) Dharmapeth, 3) Mangalwari, 4) Ashi Nagar, 5) Lakadganj, 6) Nehru Nagar, 7) Hanuman Nagar, 8) Satranjipura, 9) Gandhi Bagh and 10) Dhantoli. Figure 2.3 represents the overall water stress of Nagpur City. The highest value of 1 and the minimum value of 0 were classified for better interpretation of WPI and its components and sub-components, using the same approach as used by (Smakhtin, Revenga Carmen, and Döll Petra, 2004; Juwana, Muttil and Perera, 2012; Jemmali and Sullivan, 2014) as given in **Table 2.1.**

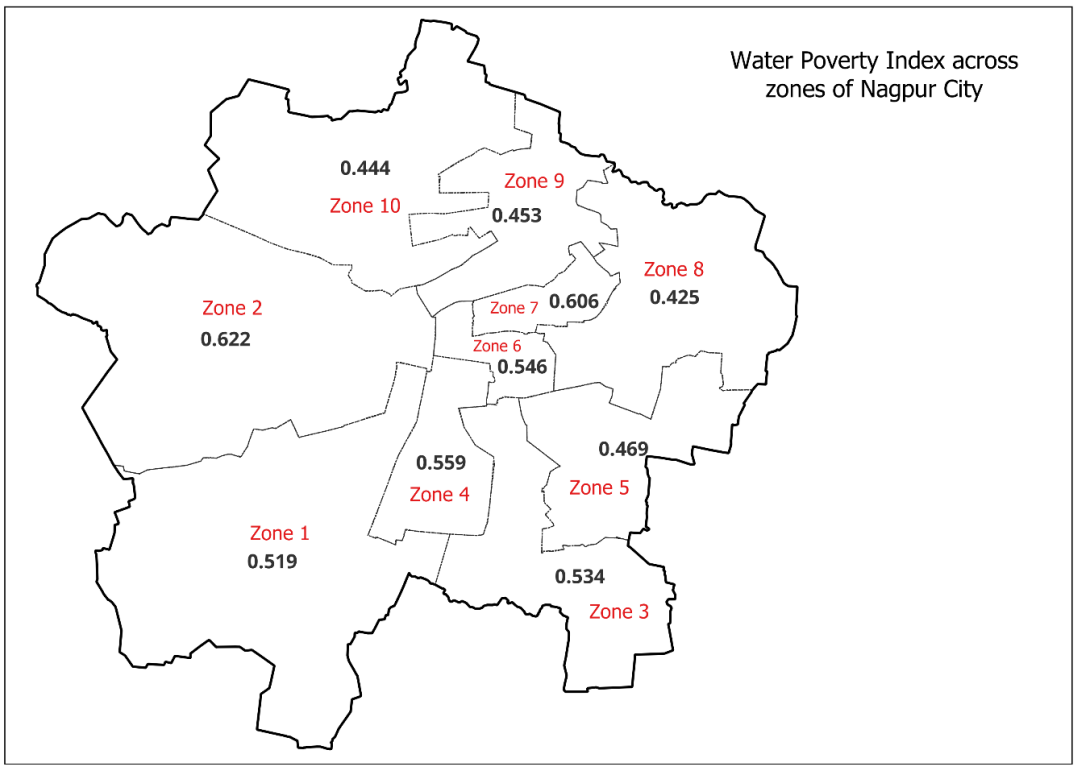

Figure 2.3: Zone-wise water poverty index of Nagpur city

The study shows that the overall WPI for the ten zones in the Nagpur Municipal area ranges from **0.425 to 0.622, which falls in the moderate water stress range,** as seen in **Table 2.2**. The highest stress is in the Lakadganj zone (0.425), and the lowest is in Dharmapeth zone (0.622) in Inter-zonal comparison as seen in **Figure 2.3.** Lakadganj zone is shifting towards water scarcity and hence requires high priority regarding water management and policy actions. This holds especially true as climate variability due to anthropogenic climate change can impact water availability and stress as Nagpur city's water distribution is heavily dependent on the supply from Kahnan and Pench Water Reservoir. Even for other remaining zones, the water stress/scarcity is in the moderate range of 0.4-0.6. Therefore, it is essential to plan proper water management policy strategies for making water quality and availability resilient to future climate variability.

Table 2.2: Classification of WPI and water stress scores

WPI	Scale	WPI	Water Stress
	0.0 to 0.2	Very Low	Absolute Scarcity
	0.2 to 0.4	Low	Scarcity
	0.4 to 0.6	Moderate	Moderate Stress
	0.6 to 0.8	Good	Low Stress
	0.8 to 1	Excellent	No stress

2.5.2 Effect of Sub-indices for proper management of water resources

To precisely determine the priority areas in all municipal zones to achieve progress in water management, each sub-index must be analyzed:

Table 2.3: WPI and sub-indices for the ten zones of Nagpur city

Zone	**Number**	WPI	Resource	Access	Capacity	Use	Environment
Lakadganj	**Zone 8**	0.424	0.075	0.133	**0.008**	0.074	0.050
Mangalwari	**Zone 10**	0.444	0.123	0.132	0.072	**0.048**	0.056
Aashi Nagar	**Zone 9**	0.452	0.101	0.119	0.055	**0.040**	0.087
Nehru Nagar	**Zone 5**	0.468	0.067	0.118	**0.063**	0.080	0.073
Lakshmi Nagar	**Zone 1**	0.519	0.118	0.152	0.088	**0.020**	0.109
Hanuman Nagar	**Zone 3**	0.534	0.113	0.118	0.095	**0.066**	0.122
Gandhi Bagh	**Zone 6**	0.545	0.119	0.133	0.108	**0.006**	0.163
Dhantoli	**Zone 4**	0.558	0.122	0.123	0.132	**0.062**	0.114
Satranji Pura	**Zone 7**	0.605	0.081	**0.095**	0.116	0.106	0.112
Dharampeth	**Zone 2**	0.622	0.133	0.133	0.168	**0.045**	0.149

Red: lowest score and Green: highest. **BOLD:** Zone-wise Priority action areas

A. Resource (R)

Resource component assess the availability and quality of water resources in terms of municipal supply and natural variability in rainfall. It can be seen that Dharmapeth has a high availability of water resources, and Nehru Nagar has the lowest. For prioritizing the development of resource component (R), policymakers may follow the ranking as illustrated in **Figure 2.4**. For example, zones 1) Nehru Nagar, 2) Lakadganj, 3) Dhantoli, 4) Satranji Pura, and 5) Aashi Nagar must be prioritized in terms of the increase of their available water. This can be achieved by increasing the drinking water supply, developing storage areas for harvesting and storing rainwater, restoration of lakes, Nag and Pilli Rivers etc.

B. Access (A)

The access component assesses the access to household drinking water for various needs. From **Figure 2.5**, it can be seen that Lakshmi Nagar has the best accessibility to water resources, and Satranjipura has the lowest. To prioritize the development of access component (A), policymakers may follow rankings as illustrated in **Figure 2.5**. For example, zones 1) Satranjipura, 2) Nehru Nagar, 3) Hanuman Nagar, 4) Aashi Nagar and 5) Dhantoli must be prioritized in terms of the percentage of population with access to safe water (drinking and potable), the distance and wait time for access of safe water and proper & improved sanitation facility.

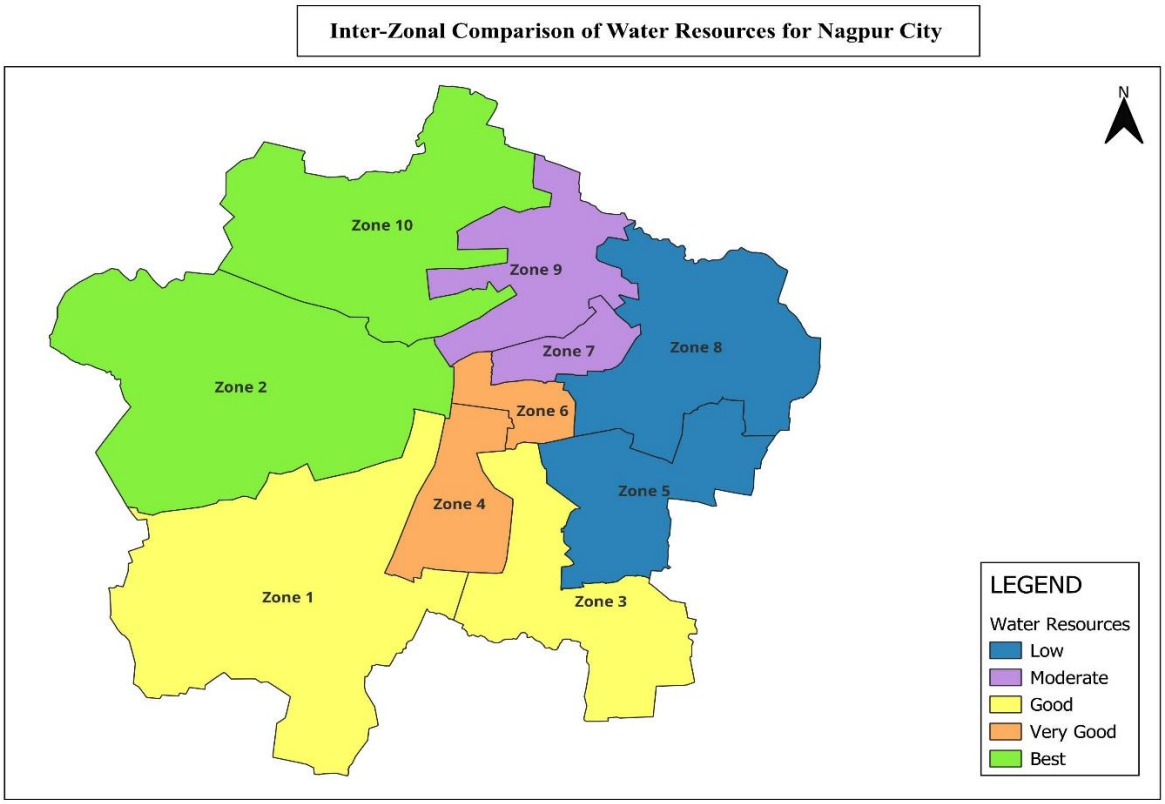

Figure 2.4: Inter-zonal comparative of water resource availability for Nagpur city

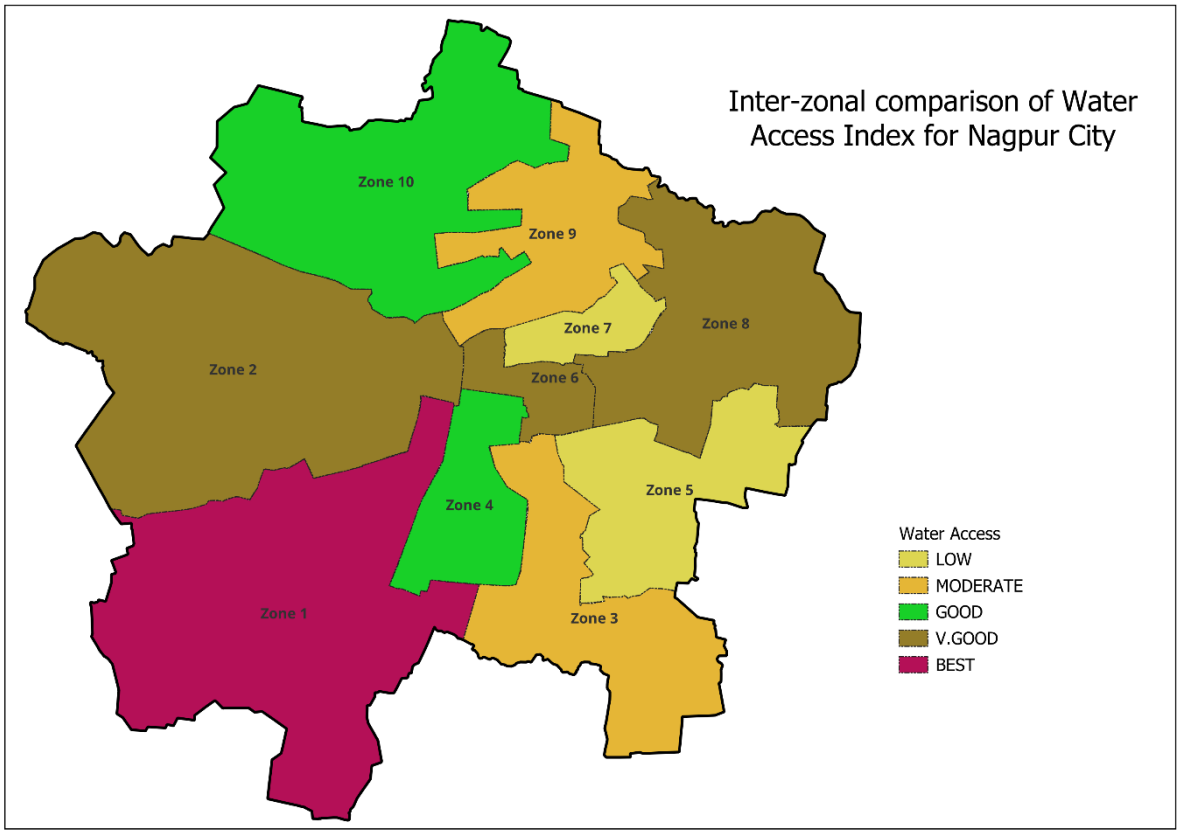

Figure 2.5: Inter-zonal comparative of water access for Nagpur city

C. Capacity (C)

The Capacity component (C) assesses the effectiveness of households' ability to manage water resources in the form of social and economic capital. From **Figure 2.6**, it can be seen that Lakadganj has the lowest capacity for the management of water resources, and Dharmapeth has the highest. To prioritize the development of access component (A), policymakers may follow the rankings illustrated in **Figure 2.6**. For example, zones 1) Lakadganj, 2) Aashi Nagar, 3) Nehru Nagar, 4) Mangalwari, and 5) Lakshmi Nagar must be prioritized in terms of education enrollment & and employability of educated adults.

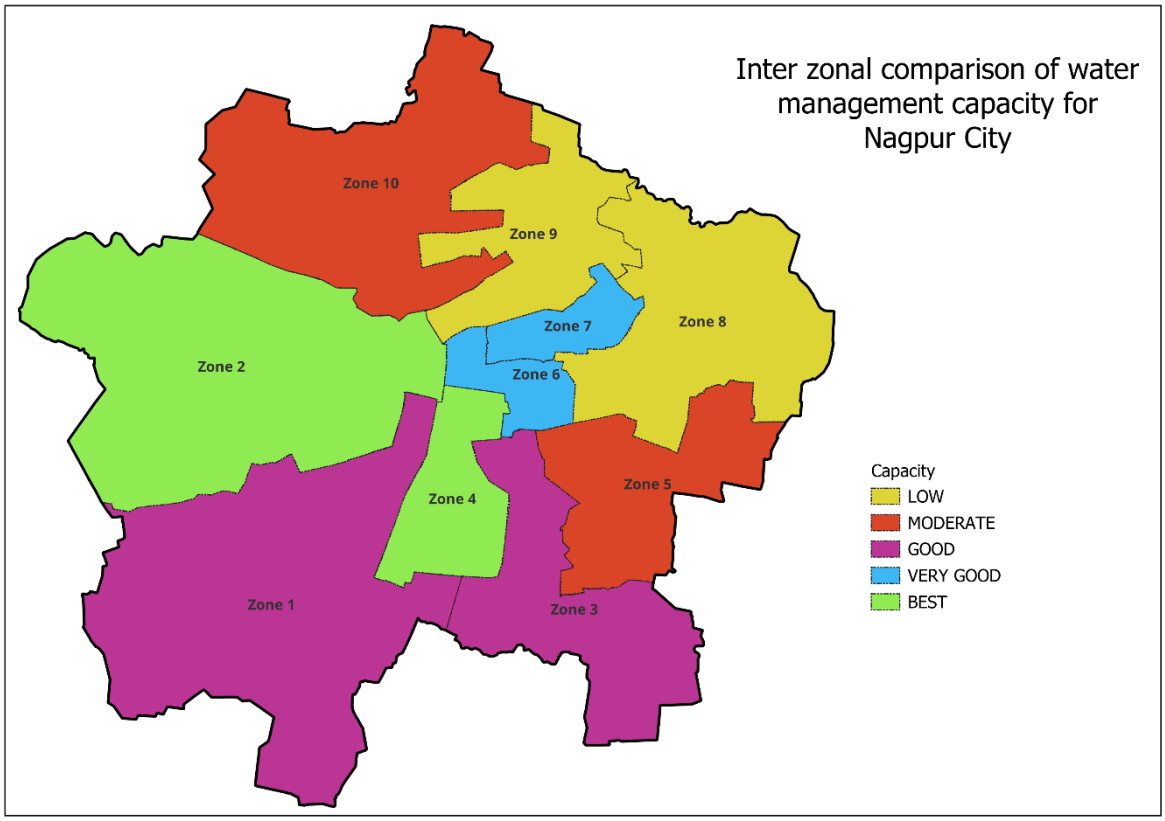

Figure 2.6: Inter-zonal comparative of water management capacity for Nagpur city

D. Use (U)

The use component (U) assesses the utilization of water resources for agricultural, domestic and industrial use. From **Figure 2.7**, it can be seen that Gandhi Bagh has the lowest water utilization, and Satranjipura has the highest. To prioritize the use component (U) development, policymakers may follow the ranking illustrated in **Figure 2.7**. For example, zones 1) Gandhi Bagh, Lakshmi Nagar, 3) Aashi Nagar, 4)

Dharmapeth, and 5) Mangalwari must be prioritized regarding Water consumption and cost of water.

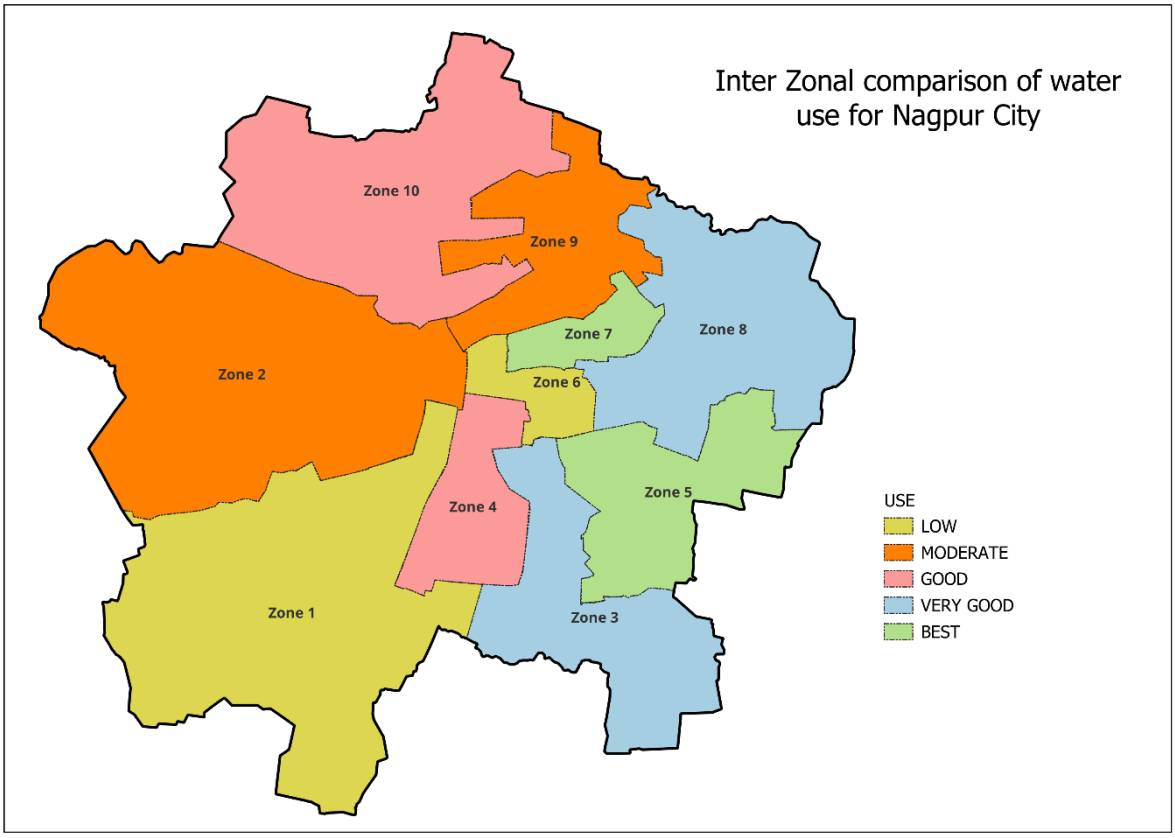

Figure 2.7: Inter-zonal comparative of utilization of water resources for Nagpur city

E. Environment (E)

The environment component (E) assesses the environmental sustainability while accessing water for agriculture, industrial or domestic use. Forest cover was employed as an indicator because it fosters biodiversity, and afforestation negatively influences certain plant species. **Figure 2.8** shows that Lakadganj is the least environmentally sustainable while accessing water resources for domestic use, and Gandhi Bagh is seen as most sustainable. To prioritize the development of Environment (E), policymakers may follow the ranking illustrated in **Figure 2.8**. For example, zones 1) Lakadganj, 2) Mangalwari, 3) Nehru Nagar, 4) Aashi Nagar, and 5) Lakshmi Nagar must be prioritized in terms of expanding their greenery and reduction of flood and water-borne disease risk.

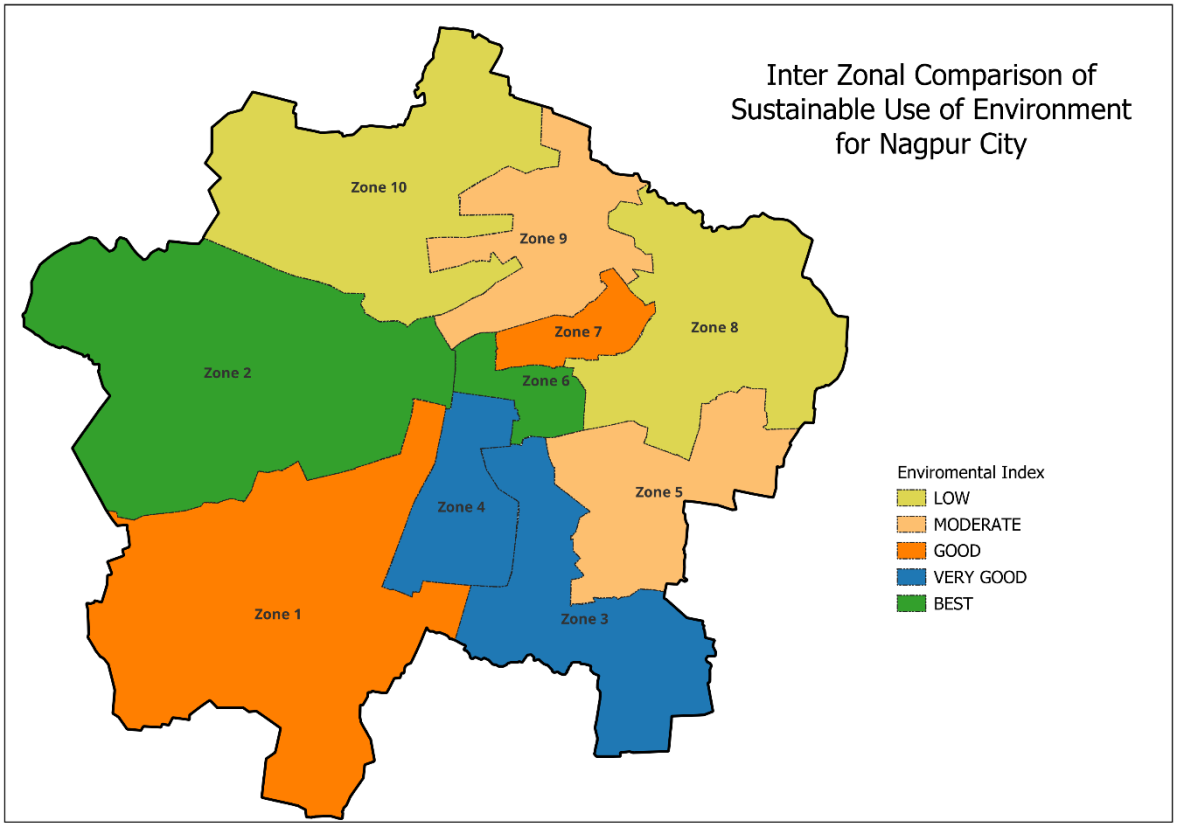

Figure 2.8: Inter-zonal comparative of sustainable use of enviornment for Nagpur city

2.5.3 Zone-wise priority of action for management of water stress

The study also investigates the priority action areas for different Nagpur Municipality Area zones. As seen in **Table 2.3**, the Lakadganj zone has the highest water stress as per the WPI estimated by this study. For this zone, the priority must be placed on improving the capacity for managing water resources (**Figure 2.9**), where policies must strengthen education enrollment and completion along with enhancing the employability of working-age adults in the household in that zone. For Mangalwari, Aashi Nagar, Lakshmi Nagar, Dhantoli, Hanuman Nagar, Dharmapeth and Gandhi Bagh zone, the priority may be placed on the improvement of utilization of water resources as seen in **Figure 2.9**, where policies must strengthen focus on sustainable consumption of water and reasonable cost of water. For the Nehru Nagar zone, the priority must be placed on improving capacity for managing water resources (**Figure 2.8**), where policies must strengthen education enrollment and completion along with enhancing the employability of working-age adults in the household in that zone. Finally, for the Satranjipura zone, the priority must be placed on the improvement of access to water resources (**Figure 2.9**), where policies must strengthen 1) the access of the households to safe drinking water, 2)

improved sanitation and wastewater disposal and 3) distance and waiting time for access of water resources.

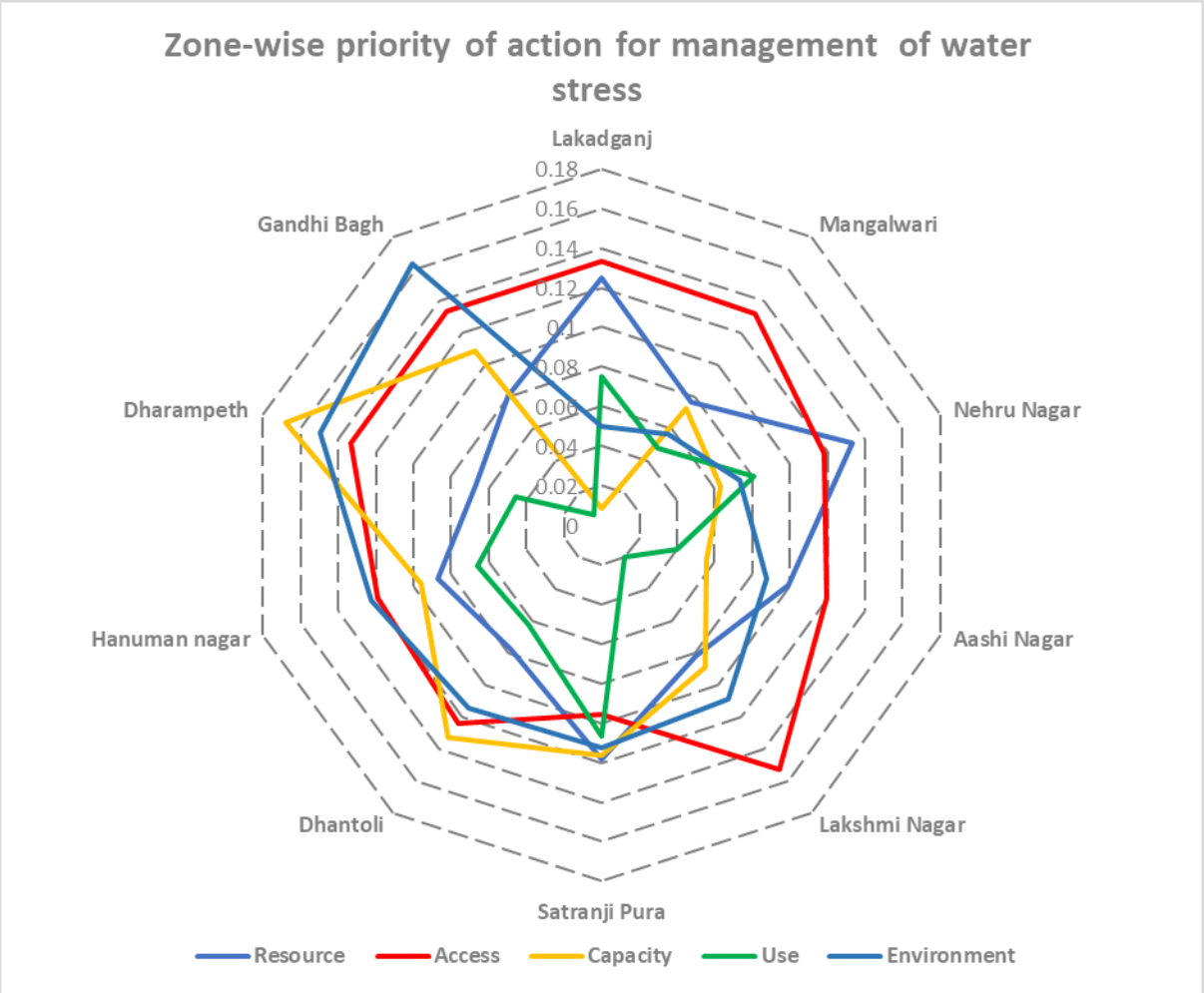

Figure 2.9: Zone-wise priority of action for management of water stress for Nagpur city

2.6 Conclusion

The current study represents the development and application of the WPI at the zone scale in Nagpur City. Within the study, a WPI for the Zones was developed considering its five components: resources, access, capacity, use, and environment. Thirteen WPI sub-components were selected to be applied within the index. Aggregation method - the weighted arithmetic mean was used for calculating the final WPI, and its components were evaluated.

The developed WPI was applied to carry out a relative comparison among ten zones to assist the decision-makers in determining the priorities for development in their water sector. The priorities for development needed for each zone's WPI component and sub-components to improve its water sector were selected and ranked. The study showed that all Nagpur

Municipal Zones fall into the moderate water stress level. However, looking at the increasing population and climate variability, Nagpur City must plan to improve their WPI score to mitigate the impacts of climate variability due to anthropogenic climate change.

In general, the analysis of the WPI of the ten zones illustrated that Lakadganj zone has to have the priority in the water sector strategy of the city, followed by Mangalwari, Aashi Nagar, Nehru Nagar and Lakshmi Nagar (top five water-stressed zones). The study illustrated that, in the analysis of the WPI, it is essential to assess its components and sub-components to have a complete picture of the status of the water sector in the study area and determine its development priorities precisely. The study determined and ranked the most critical development priorities necessary for the WPI components and sub-components. The WPI offers a holistic and visible framework on which water planning and management decisions can be based, which can reduce the demand for water in Nagpur city, which is likely to increase due to changes in the rainfall pattern of the city as suggested by ESR 2019-20. The WPI is a powerful tool for determining priorities for the decision-makers. It empowers decision-makers to act impartially by allowing them to justify their choices based on a rational and transparent framework. WPI can be significantly used for monitoring the development and progress if calculated on a time-interval basis. The study recommends applying the developed WPI periodically to evaluate the improvement in the water sector in each Zone scale and to determine the priorities for resource mobilization.

2.7 Recommendations

Sl. no.	Zone	Recommendations
1.	Lakadganj	• Lakadganj has the lowest WPI (0.425) compared to the other nine zones. Compared to the water stress scale (table 2), the Water availability in this zone is at moderate stress. However, it is moving towards water scarcity category. Therefore, the city's water conservation and management plans should highly prioritize this zone. • To understand where this priority action should focus on, we must look at the sub-indicators. For the Lakadganj zone, the highest priority may be given to improving **capacity for water resource management**.

		• For the development of capacity for management of water resources, policy action must focus on improving household literacy levels, employment rate and electricity coverage.
2.	Lakshmi Nagar	• With a WPI score of 0.519, Lakshmi Nagar Zone ranks 5th in water stress compared to all zones. This shows that the Lakshmi Nagar zone has moderate water stress. • The priority action for the Lakshmi Nagar zone should focus on proper **utilization of water resources.** • In the Lakshmi Nagar zone, to improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water
3.	Dhantoli	• Dhantoli is ranked 8th in the city regarding water stress with a score of 0.558. This score suggests that this zone falls into the moderate water stress level. • For Dhantoli, the highest priority action should be the **utilization of water resources.** • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water
4.	Dharampeth	• Dharampeth has the best score of 0.622 for WPI compared to all other zones. As per the water stress scale, Dharampeth has the lowest water stress level, which shows that water conservation and management are decent in this zone. • However, to further improve the WPI score, policy action may focus on improving **water resource utilization.** • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on

		the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water
5.	Aashi Nagar	• Aashi Nagar zone has the 3rd lowest WPI score of 0.453. A comparison to the water stress scale shows that Aashi Nagar falls in the moderate water stress category. • For Aashi Nagar, the highest priority action should target the **utilization of water resources.** • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water.
6.	Nehru Nagar	• Nehru Nagar zone has the 4th lowest WPI score of 0.469. A comparison to the water stress scale shows that Nehru Nagar falls in the moderate water stress category. • For the Nehru Nagar zone, the highest priority may be given to developing **capacity for water resource management**. • For the development of capacity for management of water resources, policy action must focus on improving household literacy levels, employment rate and electricity coverage.
7.	Hanuman Nagar	• Hanuman Nagar is ranked 6th in the city regarding water stress, with a score of 0.534. This score suggests that this zone falls into the moderate water stress level. • For Hanuman Nagar, the highest priority action should target the **utilization of water resources.** • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water.
8.	Mangalwari	• Mangalwari zone ranks 2nd in the city regarding water stress

		with a WPI score of 0.444. This score suggests that this zone falls into the moderate water stress level. • For Mangalwari, the highest priority action should target the **utilization of water resources.** • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water
9.	Gandhi Bagh	• Gandhi Bagh zone ranks 7th in the city regarding water stress with a WPI score of 0.546. This score suggests that this zone falls into the moderate water stress level. • For Gandhi Bagh, the highest priority action should target the **utilization of water resources.** • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water
10.	Satranjipura	• Satranjipura has the second-best WPI score of 0.605 compared to all other zones. As per the water stress scale, Satranjipura has the lowest water stress level, showing that water conservation and management are decent in this zone. • For Satranjipura, the highest priority action should target the **Accessibility to Water resources.** • To improve the WPI score, the policy action should target the improvement of accessibility to water resources. For this, the focus may be placed on improving access to safe drinking water through piped connections and reducing distance from water sources.
	Overall Recommendation	• Overall out of the 10 zones, 7 zones score low in the proper and sustainable utilization of water. In order improve the sustainable utilization of water the following steps maybe taken.

		○ Water Audit of Nagpur city at zone level to understand the losses due leakages, illegal connections ○ Using of Mapping geo-spatial software like Risk-pinet to identify the leakages in underground pipes ○ Voluntary establishment of rainwater harvesting systems at household or apartment to supplement water supply and reduce demand on NMC supply. ○ Use of reclaimed wastewater for secondary non-potable uses like landscaping etc. especially in government departments ○ Use of water efficient devices like water level sensors, faucet aerators, waterless urinals (can be installed at government departments) ○ Use of nature-based solutions like green wall, roofs and bioswales to capture and regulate stormwater discharge ○ Separation of stormwater sewerage from wastewater sewerage ○ Artificial Intelligence based water monitoring and distribution systems (Control of Network pressure) ○ Training and education for sustainable use of water

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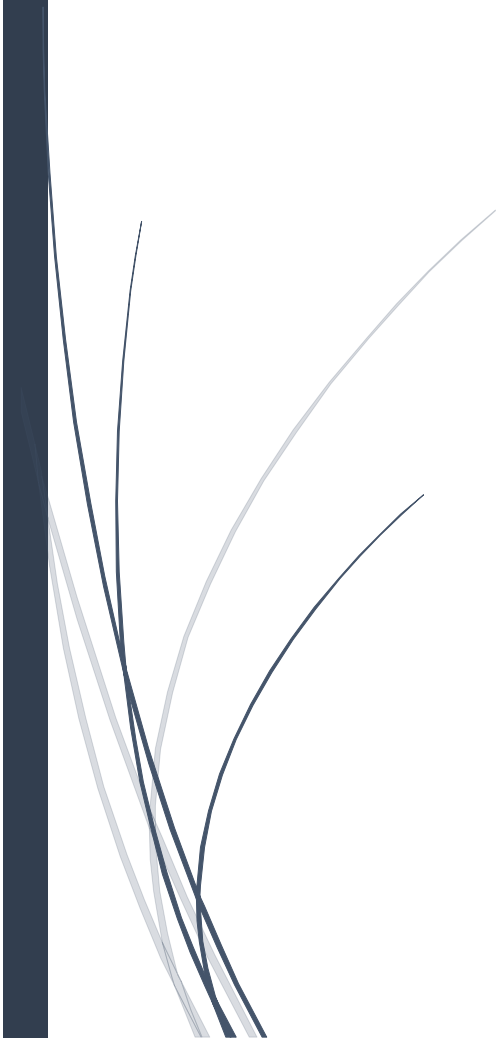
2.9 Data Sources

- The primary data for the calculation of WPI was collected through primary survey of 900 households in all 10 zones of Nagpur City.

ESR (2022-23)

Chapter 3

Green Open Spaces and Biodiversity



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City Biodiversity Index for fast growing urban Nagpur

Summary

In the previous ESR (2020-21), CSIR-NEERI reported on the Decadal change in the avifaunal sighting, potential drivers of avifaunal loss and the management of public urban green spaces in the city. This report analyses the City Biodiversity Index (CBI) of Nagpur to evaluate the different types of biodiversity present in in the city, their importance in terms of ecosystem services, strategies for monitoring the current status of biodiversity and policies for their sustainable management.

Biodiversity health and ecosystem services of cities in Nagpur have been assessed by City Biodiversity Index (CBI) or Singapore index of biodiversity which depicts the growth of the city towards sustainability. The present CBI assessment was undertaken to estimate values for these 28 indicators. CBI has been upgraded from 23 to 28 parts and is classified into 3 parts i.e. native biodiversity (9 indicators), ecosystem services provided by biodiversity (5 indicators) and governance, management of biodiversity (14 indicators). Each indicator has a value range from 0 to 4. Among the comparison between the different indicators, city has scored 53 points in total from 28 indicators out of a total of 112 points (each indicator has a maximum of 4 points). Within the 9 indicators under the section of native biodiversity in the city, city poorly performs under 4 indicators that include indicator for connectivity measures or ecological networks to counter fragmentation and Habit restoration (city scored 0) whereas, under the indicator proportion of protected natural areas and indicator proportion of invasive alien species city scored 1. Under the section Ecosystem services provided by the biodiversity under 5 indicators, city poorly performs under 4 indicators that include indicator for regulation of quantity of water, indicator for recreational services (city scored 1), climate regulation - benefits of trees and greenery, food security resilience - urban agriculture (in both the indicators city scored 0). Under the section of Governance and management of biodiversity having 14 indicators, city poorly performs under 4 indicators that include indicator for budget allocated to biodiversity, policy and/or incentives for green infrastructure as nature-based solutions, awareness (city scored 1 for each) and number of biodiversity projects implemented by the city annually (city scored 0). There is a need to integrate natural and green infrastructure in areas where green and blue spaces are declining. Ecological connectivity in the form of avenue plantations is not uniform throughout the wards and zone of the city that will require specific attention from NMC and allocation of budget to maintain and plant avenues for

developing connectivity corridors and reducing fragmentation. New high rises should be promoted for nature-based solutions, 33% of greening and also roof top agriculture. WHO and Urban guidelines followed by 3x30x300 approach should be mainstreamed.

3.1 Introduction

Urban green as well as blue spaces acts as biodiversity refuge having a critical role in biodiversity conservation and management in fast expanding urban sprawls (Dhyani et al., 2020; 2021). The status of biodiversity in Indian cities has generally been overlooked and there is huge knowledge gap on the role it plays in the urban ecosystem. The Convention on Biological Diversity (CBD) considers the loss of biodiversity due to urbanization of great concern and SDG 11.7 emphasizes on relevance of urban green spaces to develop resilient cities. Hence, a holistic assessment of a cities biodiversity health and ecosystem services is necessary to understand its growth trajectory towards sustainability.

Even though the benefits of urban blue and green spaces for Nagpur has been the subject to many studies (Dhyani et al., 2023; Dhyani et al., 2018), better nature-based management efforts will be required to improve biodiversity concerns. The City Biodiversity Index (CBI) or Singapore index of biodiversity during the CBD COP9, 2008, was introduced for measuring the conservation efforts of different cities.

CBI as a self-assessment tool helps to analyze and track the advancement of city efforts to conserve biodiversity in comparison to their own unique baselines and aims to assess each city separately on CBI rather than comparing them. CBI assessment has so far been assessed for many cities around the world including Indian cities like Pune, Kochi, Pimpri Chinchwad, Siliguri, Gangtok, Raipur, Kolkata, Faridabad *etc.* but not so far for Nagpur city (Das et al., 2022).

3.2 Methodology

Present CBI assessment was undertaken to estimate values for 28 indicators of CBI, using primary data collected between 2018-2023 under previous ESR survey; available secondary data and participatory survey with residents in different wards across the city (1050 individuals). CBI has two parts, namely Profile of the City and Indicators (**Table 3.1 & 3.2**). Profile of the city has already been provided in detail in previous ESRs and also different sections of the present ESR and hence has been excluded from this chapter). There were earlier 23 indicators for CBI that are now upgraded to 28 indicators classified into *viz.* native

biodiversity (9 indicators), ecosystem services provided by biodiversity (5 indicators) and governance, management of biodiversity (14 indicators). Each indicator is valued in the range of 0 to 4 points with a maximum possible total of 112 points **(Table 3.2**).

We assessed public requirements, availability and accessibility to Public Urban Green Spaces (PUGS) [77 gardens were managed by NMC and 50 by NIT and 13 proposed gardens were located in Google Earth Pro to calculate their area followed by ground truthing and benefits derived from them for different wards and PUGS like parks, gardens in Nagpur.

Table 3.1: Framework of the Singapore Index on Cities' biodiversity (Chan et al., 2021)

SINGAPORE INDEX ON CITIES' BIODIVERSITY	
PART I-PROFILE OF THE CITY	**Location** and size (geographical coordinates (latitudes and longitudes); climate (temperate or tropical, etc.); rainfall/precipitation (range and average); including maps or satellite images where city boundaries are clearly defined)
	Physical features of the city (geography, altitude, area of impermeable surfaces, information on brownfield sites, etc.)
	Demographics (including total population and population density; the population of the region could also be included if appropriate, and for the purpose of placing it in the regional context)
	Economic parameters (Gross Domestic Product (GDP), Gross National Product (GNP), per capita income, key economic activities, drivers and pressures on biodiversity)
	Biodiversity features (ecosystems within the city, species within the city, quantitative data on populations of key species of local importance, relevant qualitative biodiversity data)
	Administration of biodiversity (relevant information includes agencies and departments responsible for biodiversity; how natural areas are protected (through national parks, nature reserves, forest reserves, secured areas, parks, etc.)
	Links to relevant websites including the city's website, environmental or biodiversity themed websites, websites of agencies responsible for managing biodiversity

Table 3.2: Indicators of the Singapore Index on Cities' biodiversity (Chan et al., 2021)

SINGAPORE INDEX ON CITIES' BIODIVERSITY			
	Core Components	**Indicators**	**Maximum Score**
PART II - INDICATORS	**Native Biodiversity in the City**	1. Proportion of Natural Areas in the City	4 POINTS
		2. Connectivity Measures or Ecological Networks to Counter Fragmentation	4 POINTS
		3. Native Biodiversity in Built Up Areas (Bird Species)	4 POINTS
		4. Change in Number of Vascular Plant Species	4 POINTS
		5. Change in Number of Native Bird Species	4 POINTS
		6. Change in Number of Native Arthropod Species	4 POINTS
		7. Habitat Restoration	4 POINTS
		8. Proportion of Protected Natural Areas	4 POINTS
		9. Proportion of Invasive Alien Species	4 POINTS
	Ecosystem Services provided by Biodiversity	10. Regulation of Quantity of Water	4 POINTS
		11. Climate Regulation - Benefits of Trees and Greenery	4 POINTS
		12. Recreational Services	4 POINTS
		13. Health and Wellbeing - Proximity/Accessibility to Parks	4 POINTS
		14. Food Security Resilience - Urban Agriculture	4 POINTS
	Governance and Management of Biodiversity	15. Institutional Capacity	4 POINTS
		16. Budget Allocated to Biodiversity	4 POINTS
		17. Policies, Rules and Regulations - Existence of Local Biodiversity Strategy and Action Plan	4 POINTS
		18. Status of Natural Capital Assessment in the City	4 POINTS
		19. State of Green and Blue Space Management Plans in the City	4 POINTS
		20. Biodiversity Related Responses to	4 POINTS

		Climate Change	
		21. Policy and/or Incentives for Green Infrastructure as Nature-based Solutions	4 POINTS
		22. Cross-sectoral and Inter-agency Collaborations	4 POINTS
		23. Participation and Partnership: Existence of Formal or Informal Public Consultation Process Pertaining to Biodiversity Related Matters	4 POINTS
		24. Participation and Partnership: Number of Agencies/Private Companies/ NGOs/Academic Institutions/International Organizations with which the City is Partnering in Biodiversity Activities, Projects and Programs	4 POINTS
		25. Number of Biodiversity Projects Implemented by the City Annually	4 POINTS
		26. Education	4 POINTS
		27. Awareness	4 POINTS
		28. Community Science	4 POINTS
	Native Biodiversity in the City (Sub-total for indicators 1-9)		36 points
	Ecosystem Services provided by Biodiversity (Sub-total for indicators 10-14)		20 points
	Governance and Management of Biodiversity (Sub-total for indicators 15-28)		56 points
	Maximum Total:		**112 points**

3.3 Observations and Inferences

3.3.1 Indicators

3.3.1.1 Proportion of natural areas in the city

Natural areas in the city refer to regions that are not altered due to human encroachment like forests, grasslands, lakes stream etc. and Parks, gardens or avenue plantations are not considered as natural areas. The Urban Forest Working Circle of Nagpur covers an area of 1036.85 ha that includes reserve Forest, unclassed forest. Ambazari, Seminary Hills Reserve Forests, Bharat Van, Ajani, Empress Van and different campus forests (of CSIR-NEERI,

VNIT, NADT, PDKV etc.) are some of the remaining protected urban forests (Dhyani et al., 2021).

The Land Use Land Cover Change (LULCC) for the three decades change i.e. 1990 and 2020 revealed that there is a substantial reduction of natural areas from 40.11sq km to 21.07 sq km, correspondingly there has been a huge increase in the built-up area from 31.66 sq km to 137.42 sq km for the city (**Figure 3.1 & 3.2**).

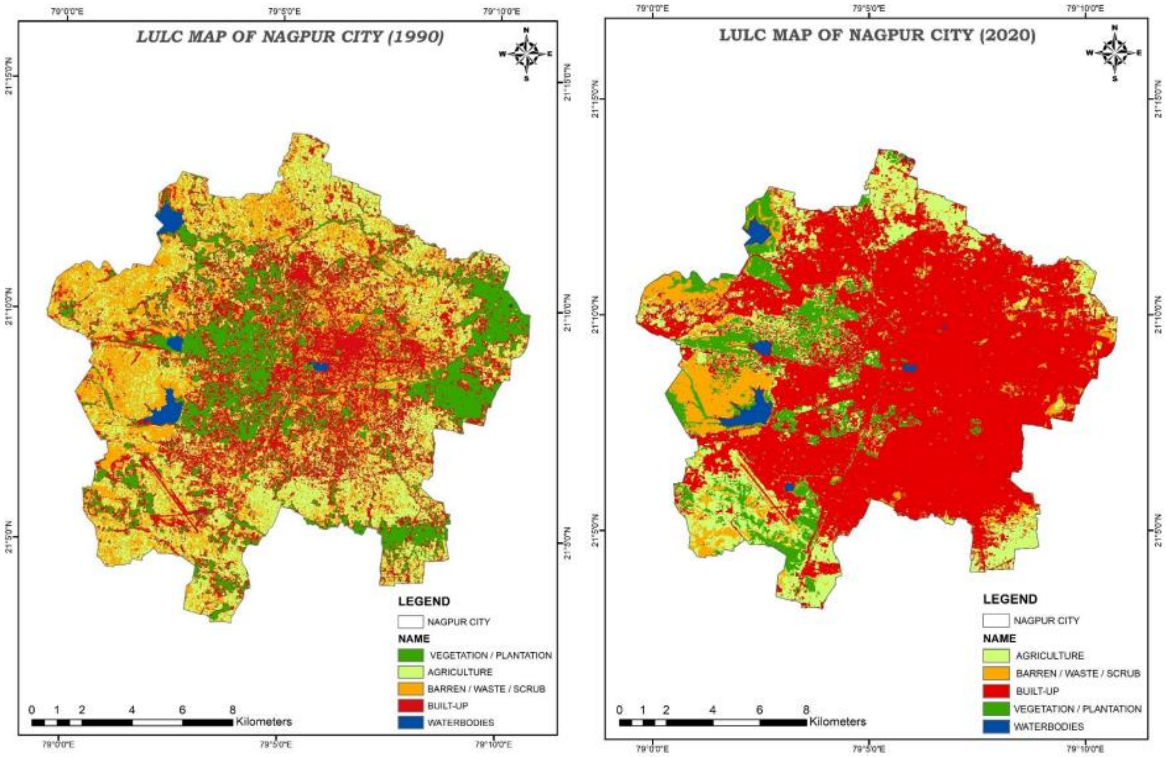

Figure 3.1: LULCC maps of Nagpur city (a) 1990 and (b) 2020 (Source: ESR 2020-21)

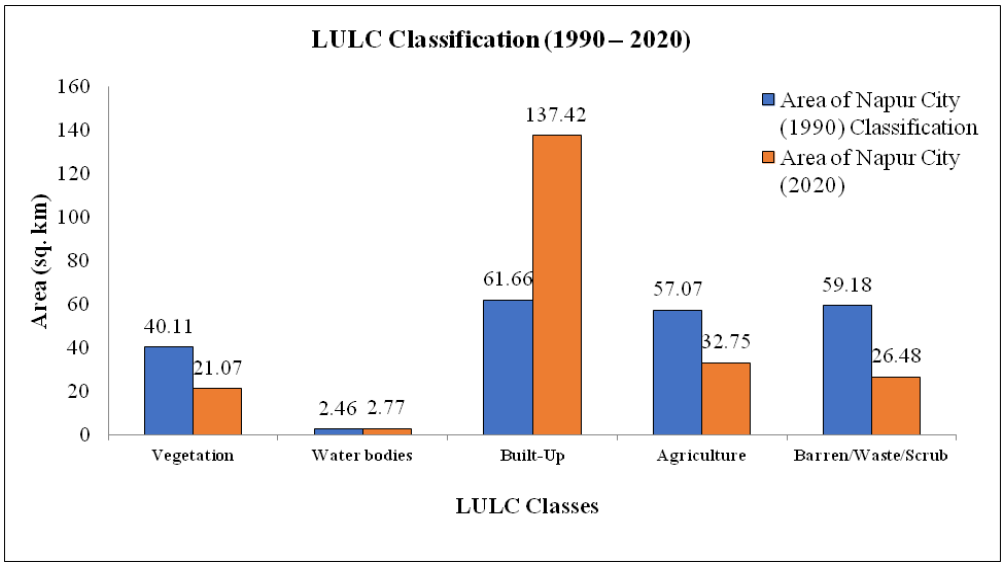

Figure 3.2: Details of LULCC for the year 1990 and 2020

The percentage of total naturalized area against the total area of the city for the year 2020 is 10.81 % and scores 2 points (7.0% - 13.9%).

3.3.1.2 Connectivity measures or ecological networks to counter fragmentation

In Nagpur the urban green spaces have significantly declined over the years due to an increase in buildup (Shukla *et al.*, 2024). Ecological network is highly fragmented and hence following the Effective Mesh Size (EMS), followed by coherence that will normalize for the size of the city. City has several parks and gardens but ecological or corridor connectivity has substantially reduced over years. This is clear from **Figure.3.1 & 3.2** and also our ground truthing of these natural areas from July-Sep., 2023 while, a few wards are having some connectivity but on city level it is negligible. The city scores 0 for this indicator.

3.3.1.3 Native biodiversity in built-up areas

To understand the decadal change in avian species in Nagpur city, study by Kasambe and Sani, 2009 was used as baseline providing details for 283 species belonging to 72 families and 22 avian orders from the city. In 2023, 319 species belonging to 73 families and 22 avian orders are reported from Nagpur (eBird) (**Figure 3.3**).

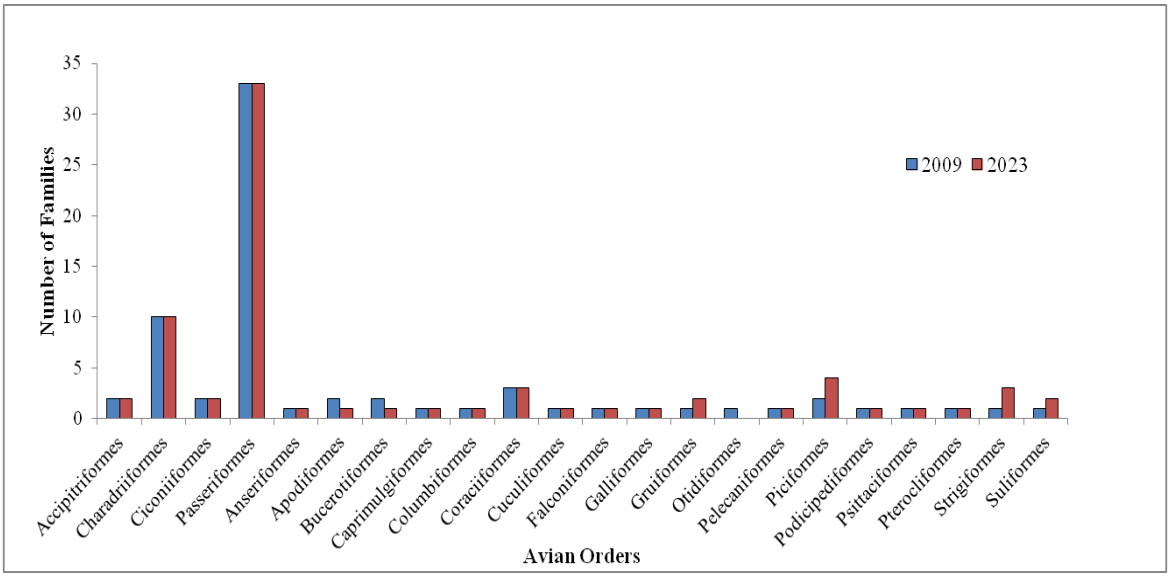

Figure 3.3: Avian families representing different avian orders sighted in the city (2009-2023) (Source :Kasambe and Sani, 2009 & eBird)

This indicator is based on the percentage of native bird species in built up areas relative to the total number of native bird species in the city. Majority of the bird watching and studies in the

city has been carried out in green spaces and wetlands. From Rashtrasant Tukadoji Maharaj Nagpur University (RTMNU) 101 bird species (Hiragond, 2014); Laxminarayan Institute 62 species (Dapke et al.,2015); CSIR-NEERI campus 48 species, VNIT campus 113 species, are have been reported. Total value for native birds is calculated to be 31.66% and city scores 4 points (>20.0%)

3.3.1.4 Change in number of vascular plant species

Nagpur city has a great diversity of 124 tree species and high number of trees with 21, 43,838 tree (Chaturvedi et al., 2013). 73 tree species belonging to 58 genera and 22 families are reported Nagpur city (**Figure 3.4**) (Lahoti et al., 2020). 50 tree species are reported from Nagpur region in one of the earliest survey by forest department. From Seminary hills, 49 tree species belonging to 19 families are recorded (Naqvi et al., 2022; Dhyani et al., 2021). Floristic survey in CSIR-NEERI campus reported 200 vascular plants including 65 herbs, 47 shrubs, and 74 trees species (Dhyani et al., 2020).

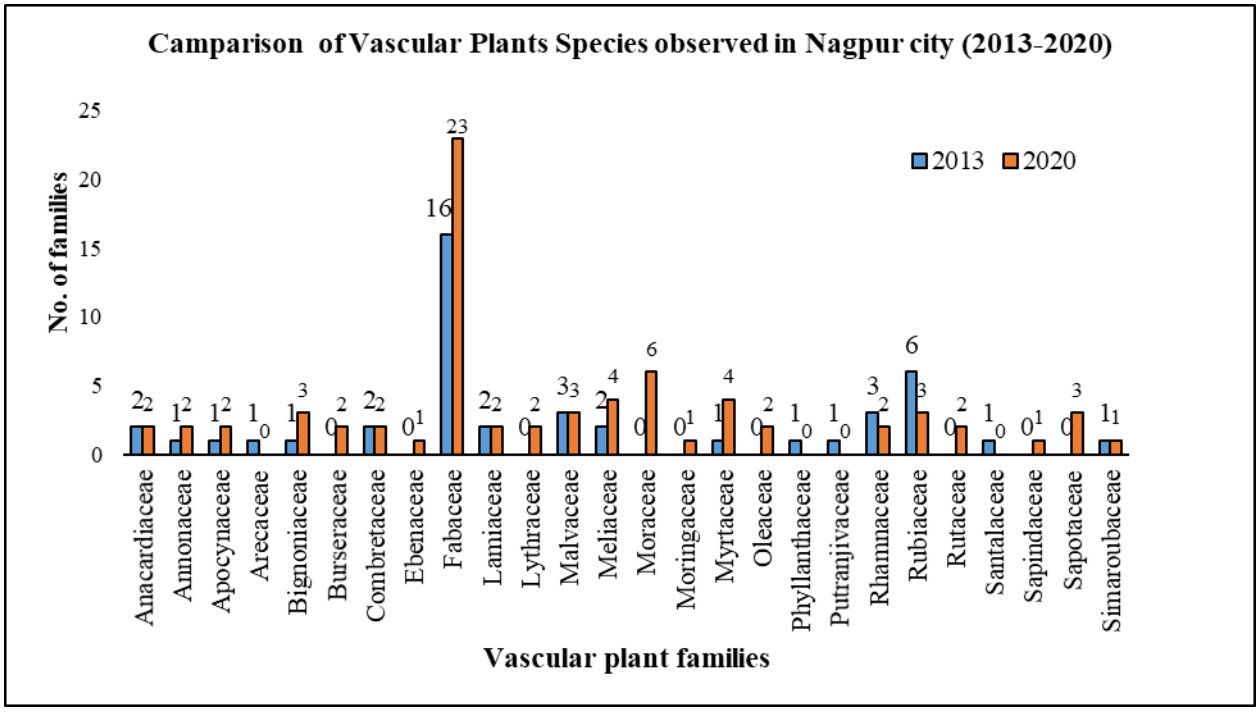

Figure 3.4: Common tree families observed in Nagpur city (Source: Lahoti et al. 2020 & Chaturvedi, 2013)

Within the Fabaceae family show the highest increase. Additionally, there has been an increase in reporting of species across several other families. Moreover, new species have been recorded under various plant families where no species were reported earlier. The family wise distribution of vascular plant species present in the city is high (**Figure 3.4**). The increase in

the number of vascular plant species in comparison to previous years helps city to score 4 points under the indicator (increase of 8 species or more).

3.3.1.5 Change in number of native bird species

A total of 283 bird species were sighted in 2009 that included 184 resident birds, 69 winter migrants, 10 passage migrants, 6 breeding migrants, 4 local migrants, and 10 vagrants (Kasambe and Sani, 2009). In 2019, a total of 368 bird species were sighted that included 239 resident birds, 90 winter migrants, 8 passage migrant, 10 breeding migrants, 12 local migrants, and 9 vagrants (Ebird) (**Figure 3.5**).

Even though some species were not present in 2021 when compared with 2009, additional new species were also reported in 2021. The total increase in number of native bird species cou ld be due to comprehensive survey and interest of locals in bird watching that provides score of point (4 species or more increase). However, loss of urban green and blue spaces may affect this growth in coming years.

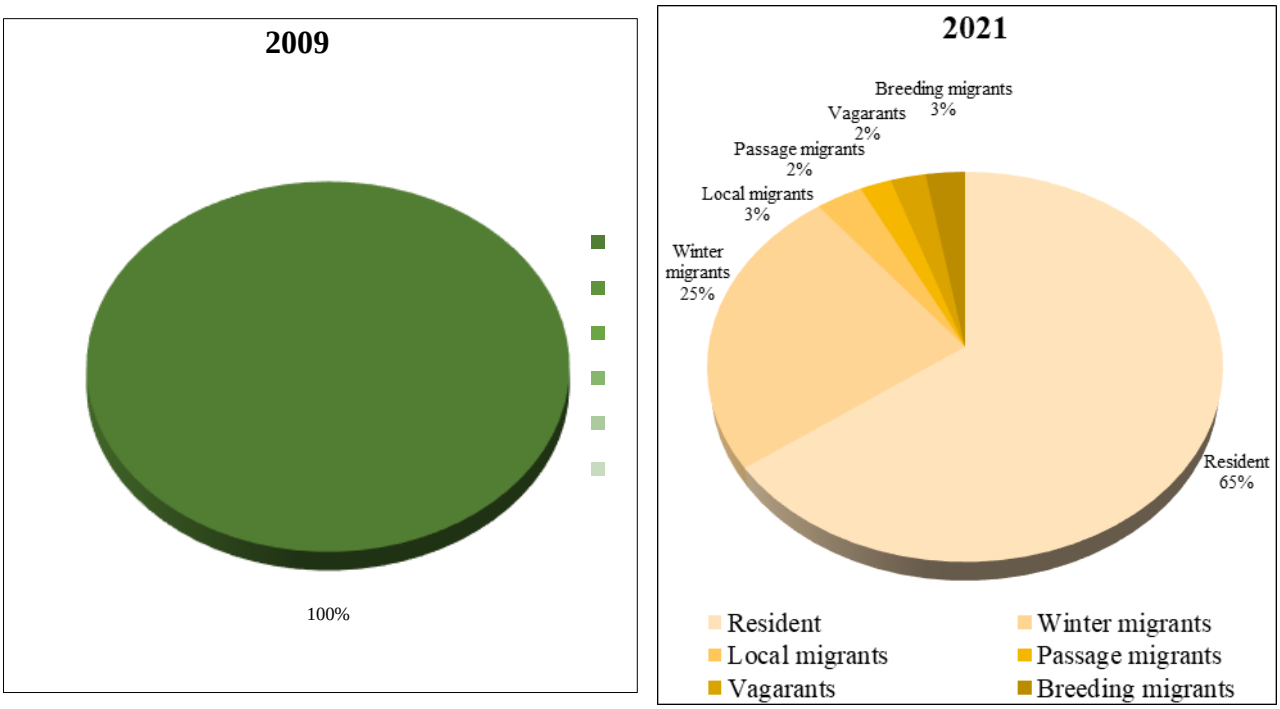

Figure 3.5: Comparison of birds observed in 2009 and 2021 (Source: ESR 2020-21)

3.3.1.6 Change in Number of Native Arthropod Species

This indicator calculates the change in number of native arthropod species (e.g. butterflies, dragonflies, beetles, bees, spiders, *etc.*). A total of 145 species of including 61 species of Rhopalocera are reported from eight sites of Nagpur (Tiple and Khurad, 2009; Pandharipande,

1990) (**Figure 3.6)**. Among them 62 species were reportedly new butterfly species for the city and 24 species of them are threatened and protected under Wildlife Protection Act, 1972.

A total of 92 butterfly species were reported from Gorewada International Bio-park (Patil and Shende., 2014); 38 species from S. M. Mohota College of Science (SMMCS) campus (Gajbe and Badiye, 2023) and 25 species from CSIR-NEERI campus.

A total of 8 species of spiders belonging to six families are reported from VNIT campus, 15 from Central Institute for Cotton Research, 16 belonging to 10 families from Seminary Hills (Masram et al., 2015; Khedkar & Deshmukh, 2021).

8 dragonfly species are reported from Gandhi Sagar lake (Nagare et al., 2015); 34 odonate species from Zilpi lake (Andrew, 2013) and 13 dragonfly species near Koradi lake have been reported (Sharma et al., 2023). This shows increase in odonate diversity reported from the city. Based on increased reporting of different arthropods city scores 2 points on this indicator.

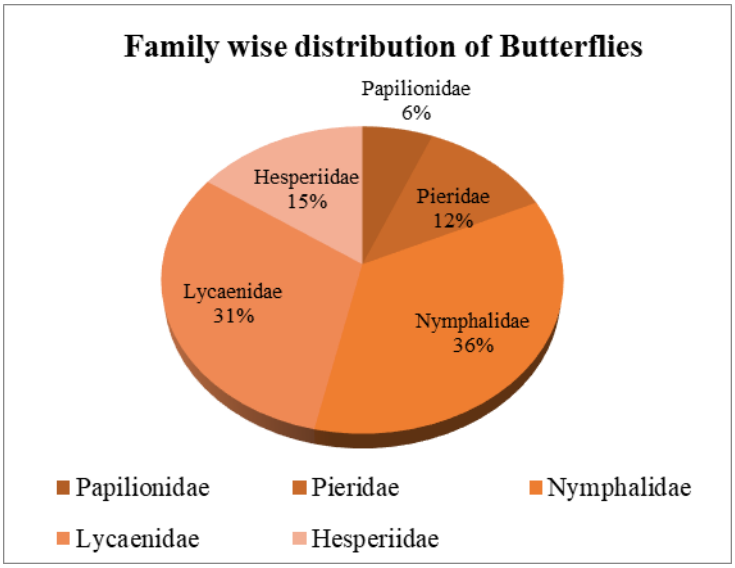

Figure 3.6: Butterfly families reported from Nagpur city (Source: Tiple and Khurad, 2009)

3.3.1.7 Habitat restoration

NMC has made it obligatory regulation to execute compensatory afforestation before cutting down trees of at least 6 feet (Dhyani et al., 2021). The Nag river pollution abatement project is one of the restoration projects happening in the city. This project will lead to biodiversity and rejuvenation of Nag River in Nagpur city. This indicator is calculated by measuring the percentage of area of habitat restored to the area of original degraded habitat. City administration has keen interest in habitat restoration however due to large area and rampant urbanization it will take time to see the restoration efforts on ground. Hence, under this indicator city scores 0.

3.3.1.8 Proportion of protected natural areas

Indicator based on Aichi Biodiversity Target 11 aims to conserve at least 17 percent of the terrestrial and inland water. The protected natural areas of Nagpur city include Seminary hills, different PUGS, lakes, campus forest that may be further include in OECM (Other effective area-based conservation measures) under Kunming Montreal Global Biodiversity Framework, 2022.

Nagpur city consist of 77 gardens and parks which are under Nagpur Municipal Corporation (NMC), 50 under Nagpur Improvement Trust (NIT). Around 0.49 sq km of public green spaces is managed by NMC and 0.45 sq km by NIT in PUGS. Ambazari, Seminary Hills reserve forests, and other gardens by forest department and well-maintained campus forests, like National Environmental Engineering Research Institute (CSIR-NEERI), Visvesvaraya National Institute of Technology (VNIT), NADT and PDKV College of Agriculture are some of the notable protected and healthy green spaces within the city premises (Dhyani et al., 2021).

The city has many natural and artificial lakes such as Futala lake (0.26 km sq), Ambazari (1.39 sq km), Naik (0.08 aq. km), Gorewada (1.28 sq km) etc. that equals to 2.77 sq km. Visvesvaraya National Institute of Technology (VNIT) campus spreads over 0.86 sq km situated close to Ambazari Lake. National Academy of Direct Taxes with a sprawling campus of 0.27 sq km, Seminary Hills is a historically sacred forest located in the north western part of Nagpur city. This reserve forest covers an area of 0.68 sq km (Dhyani et al., 2021). The sum of all the natural areas of the city are around 4.84 sq km. The proportion of protected natural areas in Nagpur was determined to be 2.20 % and scores 1 point (1.0% - 6.0).

3.3.1.9 Proportion of Invasive Alien Species (IAS)

A total of 72 IAS distributed in 57 genera and 33 families have been reported from Nagpur district (Deshmukh et al., 2017). While, a study in the Vidarbha region of Maharashtra from the years 2003-2014 revealed around 100 species in the region which are invasive in nature (Rothe & Dhale, 2016). Invasive species like *Prosopis juliflora, Leucanea, Parthenium hysterophorus, Lantana camara, Ziziphus mauritiana* and so many other introduced and invasive species are reported from Nagpur city (Lahoti et al., 2020; Saha and Bangadkar, 2015). Various lakes in the city have been affected by the growth of *Eichhornia crassipes* and other invasive. Within this indicator, a notable rise is evident in the number of invasive species families in contrast to those of native species (Nagpur Forest Division, 2004) (**Figure.**

3.7). In this indicator, the number of native species has decreased compared to invasive species from previous data. City scores 1 point as 11-20% of the species are invasive in nature.

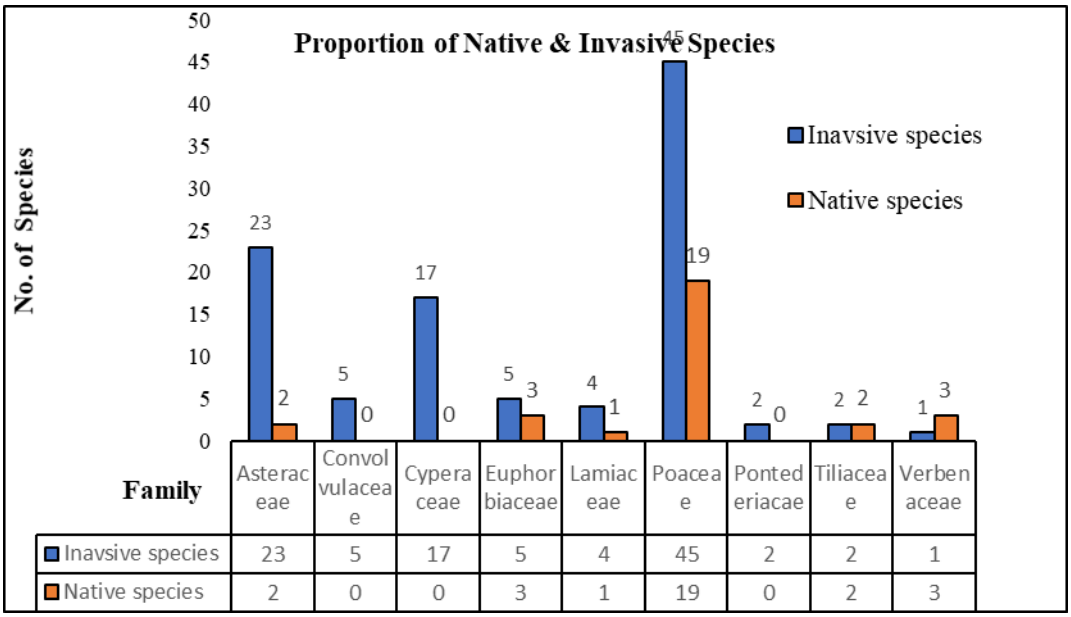

Figure 3.7: Ratio of invasive and native plants present in the city (Source: Rothe & Dhale, 2016; Nagpur Forest Division, 2004)

3.3.1.10 Regulation of quantity of water

The values from 2020 LULCC analysis was used to calculate the indicator (**Figure 3.2**). The total permeable area is 83.07 sq km, which includes land classes like vegetation, agriculture, water bodies and barren land. The total terrestrial area of the city is 217.72 sq km, following the equation the total permeable surface coverage was determined to be 38.15%. City that scores 1 point (30.0%- 39.9% permeable surface coverage).

3.3.1.11 Climate regulation: Benefits of trees and greenery

Public urban green spaces can improve adaptation and reduce the effects of climate variability and vulnerability. PUGS also help in improving local climate and air quality, moderation of extreme events and reduce heat island effect (Urban forests of Nagpur are reported to improve microclimate of the area). Nagpur city has a great diversity of 124 tree species and high number of trees with 21, 43,838 trees (Chaturvedi et al., 2013). The total canopy cover (19.74 sq km) and the total terrestrial area (217.34 sq km) of the city corresponds to tree canopy cover 9.08 % area. City scores however, 0 points (< 10.0 % of tree canopy cover). City

administration need to have attention on enhancing the canopy cover in the city by improving green cover.

3.3.1.12 Recreational services

Public urban green spaces provide invaluable recreational, spiritual benefits (Dhyani et al., 2018; Lahoti et al., 2023). For the city residents using UGS for health benefits and using these spaces for morning or evening walk, jogging or exercise, picnic, social interactions, yoga and meditation *etc.* that are prominent cultural, recreational benefits from green/blue spaces. There has been constant population growth in the city. The sum of all the natural areas provides diverse cultural benefits (4.84 sq km). The discussed responses were interesting to note and it was also clear evidence that UGS have huge cultural ES that needs to be protected by managing, restoring and protecting these spaces. The city as per calculations scored 1 point (0.1-0.3 ha/1000 persons).

3.3.1.13 Health and Wellbeing - Proximity/Accessibility to Parks

The standards for UGS vary country to country, the best available practices of per capita provisions recommend green space of 20m^2 which is "minimum of 1.25 ha open space per 1,000 residents. The Urban and Regional Development Plan Formulation Implementation (URDPFI) guidelines, 2014 by Ministry of Housing and Urban Affairs are used by local bodies, In India to determine the facility requirements. URDPFI guideline recommends 10 -12 m^2 per-capita green space and 1.2 to 1.4 ha of greens per 1000 population (Shukla et al., 2023). During the participatory survey conducted in the city regarding the accessibility to blue and green spaces 93% of the respondents revealed that they were having access green spaces over blue spaces, whereas 7.5% showed their preference towards blue spaces over green spaces (**Figure 3.8.a**). In terms of proximity to PUGS for people residing in different wards, the results reveal that 42.6% respondents need to travel more than 500 m to access public UGS. Only 9% of the respondents have easy accessibility of less than 50m (**Figure 3.8.b**) (ESR, 2019-20).

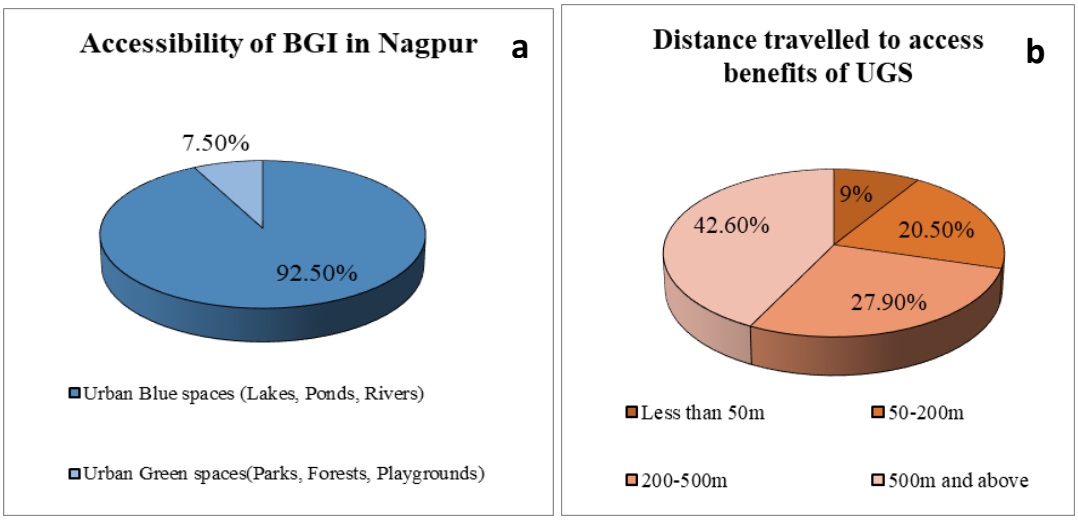

Figure 3.8: (a) Responses of Nagpur residents towards accessibility of urban green and blue spaces in Nagpur, (b) Distance travelled to access benefits of urban green spaces

The data from the participatory survey was used to calculate the population of city living within 400m from a park/ green space i.e. 57.40% of the total population. According to the 2011 census the total population of Nagpur city is 4,653,171. For the study official Census Data 2011 has been used the zone wise data population data have also increased in last 08 years that leads to reduced UGS per capita in Nagpur that varied from 0.27-2.23 sq m. per capita and is too less. The score was determined to be 57.40% and scores 2 points (50.0 – 69.9%).

3.3.1.14 Food Security Resilience - Urban Agriculture

Urban agriculture (UA) is an important Nature-based Solution that can help the urban locals of growing urban sprawls of the country to reduce pressure on rural and peri-urban areas for sustainable growth of urban areas (Dhyani et al., 2019). The total agriculture area dispersed in the various parts of the city as per GIS data is 32.75 sq km (**Figure 3.2**). Nagpur city gets various food supply from the nearby peri-urban and rural areas outside the city. In a study to assess the perceived food security at households of Nagpur only 19.3% of the total 346 survey respondents reported to grow their own fruits and vegetables (Sukhwani et al., 2020). There are currently no plans, regulations or guidelines available to the authors for promoting urban agriculture in Nagpur city. Hence, city scores 0 (No policy, plan or guideline on urban agriculture).

3.3.1.15 Institutional capacity

Institutions provide platforms for knowledge sharing and capacity improvement. Botanical garden, museum, zoological garden, biodiversity center, centers for climate change are some of the common institutions present in a city. It is vital to ensures that the functions of these institutions exist and are properly fulfilled rather than just their physical existence. The Maharashtra State Biodiversity Board (MSBB) located in Nagpur, plays a crucial role in formation of Biodiversity Management Committee (BMC) in the state. CSIR-NEERI, VNIT, Maharashtra Animal & Fishery Sciences University, Museum, Raman Science Centre, an interactive institute working under aegis of Ministry of Culture, Govt. of India, Gorewada International zoological park, Japanese garden and various urban green campuses are some of the notable institutions in the city to improve biodiversity conservation in Nagpur city. City scored 3 points (3 functions)

3.3.1.16 Budget allocated to biodiversity

Insufficient budget is one of the major issues that prevent many cities from implementing their biodiversity action plan. The budget for biodiversity related activities were often interlinked with other sectors of the city administration. The amount of budget allocated towards biodiversity is a representation of the cities commitment to protecting their biodiversity**.** NMC had allocated a budget of Rs.3, 336.84 crore for the year 2023-24, 2,669 crore for 2022-23 and 2,796 in 2021-22. Rs 20.50 crore in 2023 was allocated for sapling plantations on road dividers and Rs 10.12 on traffic islands as well as new gardens. Due to the lack of details regarding budget allocated for biodiversity related administration in previous years, this indicator cannot be fully determined but cosidering the awareness and interest of NMC in biodiversity imporvement efforts we provide a score of 1.

3.3.1.17 Policies, rules and regulations - Existence of local biodiversity strategy and action plan

This indicator evaluates policies, rules and regulations related to biodiversity, particularly if they are oriented to the national agenda and CBD’s initiative. A Local Biodiversity Strategy and Action Plan (LBSAP) was developed for Nagpur city by NMC and the Nagpur Smart and Sustainable City Development Corporation Limited (NSSCDCL) under Urban Low Emission Development Strategies (Urban LEDS II) project. This project was supported by International Council for Local Environmental Initiatives (ICLEI) South Asia and UN-Habitat. A Climate

Resilient City Action Plan (2021-26) for Nagpur city was also developed by ICLEI focusing on sustainable management and enhancement of its biodiversity. Under the Nagar Van (Urban Forests), the Government of India proposes to develop forest near existing forest land or other vacant lands. This indicator is determined based on the status of LBSAPs and the number of associated CBD initiatives. City scores 2 points (LBSAP incorporates elements of NBSAP, and includes one CBD initiatives)

3.3.1.18 Status of natural capital assessment in the city

Natural capital (NC) refers to the assets of the natural environment and it can be used as an indicator of environmental quality and well-being. In a study to assess tree biomass carbon storage potential of Seminary Hills Reserve Forest inside Nagpur city, the total carbon stock of dominant tree species present in Seminary Hills urban forest was assessed 94.53 ± 39.6 t C ha^{-1} (Dhyani et al., 2021). Lahoti et al., (2020) estimated the tree biomass and carbon sink potential of UGS in Nagpur, it was reported that tree biomass varied between 70.42 t ha^{-1} in river side, 334.61 t ha^{-1} in road and 323.68 42 t ha^{-1} in playgrounds. It was also reported that green spaces which were well managed had higher girth trees, resulting in higher C stock. In order to preserve and improve biodiversity and ecosystems, an LBSAP has been prepared and is backed by initiatives like the Tree Census (in an area of 2.77 sq km), Natural Asset Mapping, and Tree Labelling (Climate Resilient City Action Plan, Nagpur, 2021). Nagpur Municipal Corporation (NMC) has claimed 21,43,838 trees within the city limits, amounting to 9871 trees per km^2 by 2012. Despite, the massive tree felling in recent years, the first comprehensive census has put the number of trees within city limits at 21,43,838 bringing almost 9 trees for every 10 persons (Dhyani et al., 2018). In 2023, NMC has resumed the tree census all over the city area (222 sq km). The census expects to count over 25 lakh trees using GIS and GPS. 34 characteristics for each tree will be collected and can be used for research, education, knowledge. NMC releases ESR annually, which evaluates the status of air, soil, water, UGS, climate change, noise, solid waste etc. of the city. Under this indicator based on the information city scores 3 points.

3.3.1.19 State of green and blue space management plans in the city

The provision of open space and public green and blue spaces is a public asset in urban areas, as it helps to minimize the negative impacts of climate variability and vulnerability. During our participatory survey, the response of the locals clearly shows that the management of these

blue space/wetlands/lakes/waterbodies is not carried out sufficiently as expected. While 50% of the city residents were satisfied with the management, another 50% were not happy with the way UGS were managed and taken care of in the city (**Figure 3.10**) (ESR 2020-21).

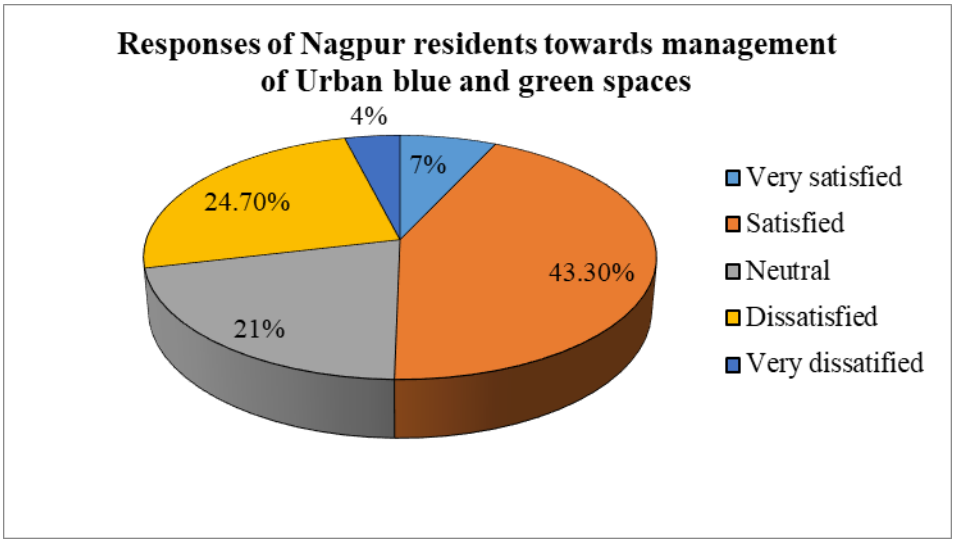

Figure 3.9: Responses of Nagpur residents towards management of urban blue and green spaces in Nagpur (Source: ESR 2020-21)

During this study, it was also observed that not all the green spaces were well maintained, leading to loss of quality of green spaces. East and North Urban Nagpur has highest number of "Not Appropriately" managed parks, i.e. 4, followed by 1 each in Central and Western Zone (ESR, 18-19). NMC also dedicated a huge surplus of ₹100 crore to the rejuvenation of Gandhi Sagar, Sonegaon and Sakkardara lake to be completed by 2024. Additionally, the civic body recently sought ₹1.5 crores for the rejuvenation of Naik, Mangalwari, and Lendi lakes as a part of the central governments Atal Mission for Rejuvenation and Urban Transformation 2.0 (AMRUT) scheme. This indicator is based on the quantity and degree of complexity of the city's green and blue space management plans and scores 3.

3.3.1.20 Biodiversity related responses to climate change

During our participatory survey to understand the sufficiency of PUGS in controlling heat islands and air pollution abatement 29.6% respondents agreed whereas, 5.4% respondents strongly agreed that UGS of Nagpur are sufficient to reduce air pollution and reducing the heat islands. However, another 30.4% were neutral and neither agreed or disagreed to the sufficiency of existing green spaces in air pollution abatement and reduction heat islands

whereas, 30.3% disagreed and remaining 4.3% of respondents strongly disagreed that existing UGS are sufficient to reduce air pollution and heat islands (**Figure 3.10**) (ESR, 2019-20).

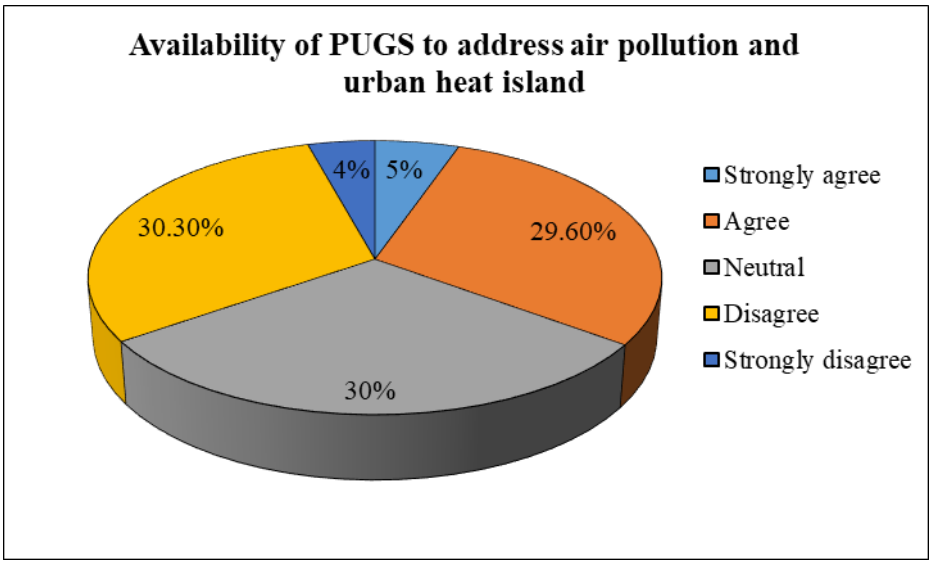

Figure 3.10: Response of Nagpur city residents towards sufficiency of UGS to control air pollution and heat island effects in Nagpur city (Source: ESR 2019-20)

Nagpur recently developed City Climate Resilience Action Plan which takes into account the status of water bodies, biodiversity, urban green spaces and climate risk and vulnerability of Nagpur city and city scores 2 points (One plan for biodiversity-related responses to address climate change in the areas of adaptation, mitigation or ecological resilience has been implemented). However, its implementation will be crucial to achieve the targets corresponding to the expectations of city residents.

3.3.1.21 Policy and/or incentivizes for green infrastructure as nature-based solutions

There has been a significant advancement in the application of Nature-based Solution (NbS) to handle the rising disaster risks (flash floods, heat islands and water scarcity) in rapidly expanding urban sprawls (Dhyani et al., 2020). Green Infrastructure (GI) and Natural Infrastructure (NI) is crucial necessity for sustainability of urban areas (Lahoti et al., 2020). The *Majhi Vasundhara* by the government of Maharashtra focuses on making the improvement of environment to ensure sustainable development. In order to encourage green buildings, the Maharashtra government has proposed incentives for green buildings. In 2019, the Indian Green Building Council (IGBC) signed a MoU with Nagpur Smart and Sustainable City Development Corporation Limited (NSSCDCL) to construct all new buildings as per the

green building norms. NMC is taking measures for creation of green buffers alongside footpaths and road dividers all over the city. Nagpur city also won the nurturing neighborhoods Challenge and Streets 4 People Challenge under the leadership of Nagpur Smart and Sustainable City Development Corporation Limited (NSSCDCL). City scores 1 point (Plans for policies and regulations on green infrastructure to support either local industry competency or building owners/developers within the next 5 years.)

3.3.1.22 Cross-sectoral & inter-agency collaborations

Nagpur city administration works with state government bodies such as Maharashtra Forest Dept., State Urban Development Dept, MPCB and MSBB. NMC coordinates with a number of different governmental agencies, including NIT, MHADA, MSRTC, the Traffic Police, MPCB, etc. for delivering these services like maintenance of roads, parks, water, land use planning and other matter related to biodiversity. Nagpur works in cooperation with Nagpur Smart and Sustainable City Development Corporation Limited (NSSCDCL), NRCD, National Improvement Trust (NIT), Forest Development Corporation of Maharashtra Limited (FDCM), Maharashtra Metro Rail Corporation Limited (MMRCL). City scores 4 points (More than 5 agencies cooperate on biodiversity matters)

3.3.1.23 Participation and partnership: Existence and the state of formal or informal public consultation process

Developing collaborating partnerships with approving bodies, civil society organizations, potential co-investors and technical experts are crucial to biodiversity planning. Indicator 23 evaluates the existence and the state of formal or informal public consultation process pertaining to biodiversity related matters. This indicator ensures that the public has an opportunity to provide inputs to developments that have an impact on biodiversity. Based on our review and understanding city scores 2 points with the expectation that approaches will improve and mainstream formal public consultation process for evidence and data driven decision making for biodiversity, conservation, restoration and management in the study.

3.3.1.24 Participation and partnership: Number of agencies/private companies/NGOs/ academic institutions/international organizations with which the city is partnering in biodiversity activities, projects and programs

Indicator measures the extent of informal and/or formal partnership or collaboration. These are facilitated by private sector, NGOs, academic institutions, international organizations etc. A city like Nagpur requires multiple partnerships for the engagement of all sections of the population should be ensured. Indicator is based on the number of organizations with which the city is collaborating in biodiversity matters. City scores 2 points (City in partnership with 7-12 private companies/NGOs/academic institutions/international organizations).

3.3.1.25 Number of biodiversity projects implemented by the city annually

The number of biodiversity projects implemented annually by a city can vary greatly depending on a number of factors like city size, environmental concerns, availability of funding and specific conservation goals. Indicator 25 evaluated the number of biodiversity-related projects in that Nagpur city authorities are involved. It signifies the level of cooperation between city councils, municipalities, citizens, NGOs, universities, schools, private sectors, and other groups to collectively implement programs or projects focused on biodiversity conservation. Based on awareness on biodiversity projects implemented by city authorities (2022-23). a score of 0 point is given (< 8.0 programs/projects per year per 1,000,000 residents)

3.3.1.26 Education

The Environmental Education Syllabus designed for the Higher Secondary in the state draws its foundation from the National Curriculum Framework-2005 (NCF-2005). Additionally, general tasks are offered to help teachers and students alike with the evaluation process. As part of the *Majhi Vasundhara* led by the Department of Environment and Climate Change, Government of Maharashtra, in partnership with UNICEF and allied organizations, have introduced a unique endeavor known as the "*Majhi Vasundhara* Curriculum" 2020 (Biodiversity Conservation, Solid Waste Management and Personal & Community Health, Water Resource Management, Energy, Air Pollution and Climate Change) to cultivate ecological awareness and values among children through education supported by Government of Maharashtra Regional Centre for Urban and Environmental Studies (RCUES) of All India Institute of Local Self Government (AIILSG), Mumbai, Centre for Environment Education (CEE). City scored 4 points (Biodiversity or elements of it have been fully implemented in the school curricula at all levels)

3.3.1.27 Awareness

Government of India and State Governments arrange numerous programs aimed at fostering the comprehensive development of cities. Additionally, various government departments and local NGOs organize initiatives to enhance urban environments. Similarly, a multitude of programs, schemes, and campaigns actively involve community participation, consistently working towards city improvement. We assessed several awareness programs in Nagpur city dedicated to promoting environmental consciousness. Indicator measures number of outreach or public awareness events held in the city per year per 1,000,000 persons. 12 awareness programs were held in Nagpur city (2022-23) however, there might be many more by NGOs, academic forest and research organizations. City scores 1 point (< 7 outreach events/year per 1,000,000 persons)

3.3.1.28 Community Science

Community science is a developing strategy that organizations can embrace to advance their objectives in continuously promoting science education, fostering connections between science and society, engaging diverse communities, and contributing to solutions for both local and global challenges. Data is compiled from a range of sources, spanning government entities such as Nagpur Municipal Corporation (NMC), various organizations, online platforms such as iNaturlists, eBird and CSIR-NEERI Biodiversity Portal etc. This indicator is determined based on the number of community scientists contributing towards biodiversity conservation efforts and research normalizes for the city's population size. City can score 3 points based on awareness and interest for participation in citizen science and conservation projects in Nagpur.

Table 3.3: City biodiversity index of Nagpur

CITY BIODIVERSITY INDEX OF NAGPUR				
PARTIII-INDI	**Core Components**	**Indicators**	**Maximum Score**	**Acquired Score**
	Native Biodiversity in the City	1. Proportion of Natural Areas in the City	4	2
		2. Connectivity Measures or Ecological Networks to Counter Fragmentation	4	0
		3. Native Biodiversity in Built Up Areas (Bird Species)	4	4

C A T O R S		4. Change in Number of Vascular Plant Species	4	4
		5. Change in Number of Native Bird Species	4	4
		6. Change in Number of Native Arthropod Species	4	2
		7. Habitat Restoration	4	0
		8. Proportion of Protected Natural Areas	4	1
		9. Proportion of Invasive Alien Species	4	1
	Ecosystem Services provided by Biodiversity	10. Regulation of Quantity of Water	4	1
		11. Climate Regulation - Benefits of Trees and Greenery	4	0
		12. Recreational Services	4	1
		13. Health and Wellbeing - Proximity/Accessibility to Parks	4	2
		14. Food Security Resilience - Urban Agriculture	4	0
	Governance and Management of Biodiversity	15. Institutional Capacity	4	3
		16. Budget Allocated to Biodiversity	4	1
		17. Policies, Rules and Regulations - Existence of Local Biodiversity Strategy and Action Plan	4	2
		18. Status of Natural Capital Assessment in the City	4	3
		19. State of Green and Blue Space Management Plans in the City	4	3
		20. Biodiversity Related Responses to Climate Change	4	2
		21. Policy and/or Incentives for Green Infrastructure as Nature-based Solutions	4	1
		22. Cross-sectoral and Inter-agency Collaborations	4	4

		23. Participation and Partnership: Existence of Formal or Informal Public Consultation Process Pertaining to Biodiversity Related Matters	4	2
		24. Participation and Partnership: Number of Agencies/Private Companies/ NGOs/Academic Institutions/International Organizations with which the City is Partnering in Biodiversity Activities, Projects and Programs	4	2
		25. Number of Biodiversity Projects Implemented by the City Annually	4	0
		26. Education	4	4
		27. Awareness	4	1
		28. Community Science	4	3
	Native Biodiversity in the City (Sub-total for indicators 1-9)		36	18
	Ecosystem Services provided by Biodiversity (Sub-total for indicators 10-14)		20	4
	Governance and Management of Biodiversity (Sub-total for indicators 15-28)		56	31
	Maximum Total:		**112**	**53**

3.4 Recommendations:

1. The percentage of total naturalized area against the total area of the city for the year 2020 is 10.81 % with a regular increase in buildup area that has doubled in last three decades. There is a need to integrate natural and green infrastructure in areas where green and blue spaces are declining.
2. Despite, having some good urban campus forests, reserve forests the green infrastructure and wetland health is declining. Ecological connectivity in the form of avenue plantations is not uniform throughout the wards and zone of the city that will require specific attention from NMC and allocation of budget to maintain and plant avenues for developing connectivity corridors and reducing fragmentation.

3. Native biodiversity in the city is on decline due to preference of as well as invasion of hundreds of plants that will further jeopardise habitat quality. NMC is preferring native trees in avenue plantation.
4. Protection of critical ecosystems for avifauna as well as butterflies and dragon flies i.e. wetlands and urban green ecosystems. Enforcement of Wetland Conservation guidelines, 2017 to ensure wetland protection and efforts for restoration and expansion of urban green spaces to preserve the habitat quality and quantity of the avifaunal diversity in the city.
5. Habitat restoration needs specific consideration as most of the parks and playgrounds in the city have historical plantations and there has been observation that most gardens and parks have only peripheral greening.
6. Following Other effective area-based conservation measures' (OECMs) guidelines and under recent Kunming-Montreal Global Biodiversity framework, 2022 existing campus and urban forests like Seminary, Ambazari, Bharat, Empress and Ajani should be conserved and continuous restoration drive under *Nagar Van Yojna* and GBF 30x30 initiative.
7. Vegetated area of the city has potential to improve ground water infiltration hence, ensuring that newly constructed build-up areas should have permeable pavements to address the emerging risks.
8. Multiple heat islands that area growing every year should have vertical greening efforts using recycled water for irrigation. New high rises should be promoted for nature based solutions, 33% of greening and also roof top agriculture.
9. WHO and Urban guidelines for per capita green space requirements needs to be mainstreamed in urban green spaces management.
10. 3x30x300 approach (3 trees from every home. 30 percent tree canopy cover in every neighbourhood. 300 metres from the nearest public park or green space) should be tried to implemented with ward wise local participation.
11. Schools should have compulsory one period for all for awareness on city environment and how to protect neighbourhood green and blue spaces
12. City administration is progressive and proactive in terms of having multiple activities related to conservation however, it will be crucial for NMC to enhance cooperation and involvement of diverse stakeholders including public in urban greening, monitoring activities.

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ESR (2022-23)

Chapter 4:
Noise Environment

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4.1 Noise Environment

4.1.1 Introduction

According to the World Health Organization (WHO), noise pollution is the third most hazardous environmental pollution problem after air and water pollution. Numerous habitants residing in the close proximity to the road and the nearby settlements, communities are affected continuously by such noise. Noise is often defined as an unwanted sound, interference with speech communication, causes annoyance, distracts from work, and disturbs sleep, thereby deteriorating the quality of biological life. Prolonged exposure to a high level of noise is very much harmful to the health of mankind. The negative impacts of increasing noise pollution on animals has also been well reported but actual assessment of such effects is beyond the scope of the project. Today, one of the most comprehensive sources of noise in our environment is industrial activity and associated vehicles.

In India, most cities' noise levels exceed the limit prescribed by Central Pollution Control Board (CPCB), New Delhi. The cities of Maharashtra state are no exception. According to various studies, cities like Mumbai, Kolhapur, Pune, and Nagpur, Noise pollution has surpassed all the limits. Growing population, congestion of vehicles and noise in social events contribute to the increase in noise.

Firecrackers are used in many countries to celebrate various festivals and occasions. In India, these are extensively used in Diwali, Ganesh festival, Gurpurab, New Year celebrations, etc. India is one of the biggest producers of fireworks, primarily for domestic consumption. The major disadvantage associated with them is the emission of high impulsive noise levels and air pollution that can be a severe health hazard and accident-prone. Noise pollution is the cause of various health-related issues that affects humans physically and psychologically, such as hypertension, myocardial infarction, depression, anxiety, and hearing impairment.

In many countries, the fireworks display is organized in a community for entertainment and celebrations, and precautions are undertaken to avoid any health hazards. However, in India, individuals celebrate the occasions and festivals by exploding crackers and, as such are vulnerable to air and noise pollution. The Central Pollution Control Board (CPCB) of India and the Ministry of Environment Forests and Climate Change (MoEF& CC) had recommended prohibition for the manufacture, sale, or use of firecrackers breaching the noise limits of 125 dB(AI) or 145 dB(C)pk tested at 4 meter distance from the point of bursting. Similarly, for individual firecrackers comprising the series (joined firecrackers), the limit mentioned above be reduced by 5 log 10 (N) dB, where N = number of crackers joined together.

Impulsive noise from fireworks is considered more harmful than other types of noise. A single event of such noise exposure can, instantaneously, damage hearing. Many previous studies have confirmed that fireworks can produce noise peaks of about 160 dB(A). The children are considered as most vulnerable to noise exposure and require utmost care for hearing protection against the firecrackers such as by using hearing protectors etc.

The current objective of the project was to measure the noise levels according to the land use pattern at various locations across Nagpur city using the crowdsourcing technique and evaluate the gathered data for noise compliance with the permissible limits prescribed by the Central Pollution Control Board (CPCB). Also, the study attempts to present the NMC zone-wise noise scenario of Nagpur city, designate the hot noise zones, and accordingly suggest recommendations to mitigate noise pollution.

4.1.2 Crowdsourced Technique of data collection

The traditional approach to measuring acoustic pollution is through professional sound level meters, which are of considerable cost and size and have high accuracy and sensitivity. Usually, these measurements are taken at a limited number of places. They are then processed using different statistical techniques to generate acoustic pollution maps for well-defined target areas, thereby providing finer spatial granularity. Recently, crowd sensing solutions have emerged as a promising solution by promoting collaborative monitoring of the populated regions. The basic concept behind crowd sensing is that all users contribute to the same goal by measuring some environmental variables, and then, the different measurements are stored on a server and processed using big data techniques for data merging and analysis.

Mobile technology has made sound level measurement more readily accessible. Worldwide more than 50 Sound level meter applications (apps) are available for the Android as well as for the iPhone platforms. These apps could provide quick, easy, convenient, and inexpensive sound level monitoring opportunities. Furthermore, the rapid adoption of mobile phones, together with the increasing number of sensors these devices are equipped with (e.g., high-quality cameras, microphone, and accelerometers), greatly simplifies the widespread adoption of crowdsourcing solutions, reducing the hardware requirements and costs to a minimum.

Understanding and minimizing the risks of noise exposure are the keys to preventing noise-related hearing loss. The availability of sound measurement apps can serve to raise people's awareness about their work (and off-work) environment and allows them to make informed decisions about the potentially hazardous effects of noise on their hearing and well-being.

Within the foregoing context, the current project sought crowdsourcing technique to gather noise data using CSIR-NEERI mobile application "Noise Tracker" with the participation of college students residing at different locations across the Nagpur city.

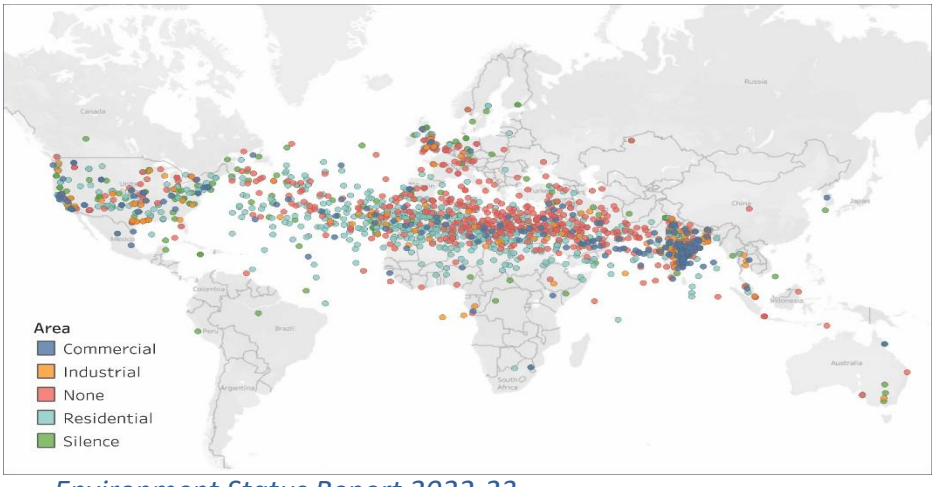
CSIR-NEERI Mobile Application "Noise Tracker"

NOISE TRACKER APP
TO TRACK NOISE AROUND YOU

Noise pollution has become a serious concern worldwide, and the noise scenario, particularly in cities in India, is at alarming levels. Several studies conducted in various parts of the country reported noise levels surpassing the Central Pollution Control Board (CPCB), New Delhi set limits. Noise pollution is the lead cause of various health-related issues such as hearing impairment, hypertension, cardiovascular problems, annoyance, and sleeps disturbance.

In this context, noise experts from CSIR - National Environmental Engineering Research Institute (NEERI), Nagpur have developed a unique Noise Application (App) "Noise Tracker" to measure the real-time noise level using android smartphones. "Noise Tracker" is a handy, essential gadget, highly reliable App and supports pre-calibrated measurements.

CSIR NEERI Nagpur had launched a "Noise Tracker" app in September 2019 on the occasion of CSIR foundation day and since the launching it has profoundly impacted nationally and internationally. Within a short period of launching, it has almost 19,000 plus downloads. It is regularly downloaded in India and other countries such as the United States, Canada, Italy, Spain, Germany, Indonesia, China, etc.



APP LOGO

App Downloads

19k+

Data Received

16.415k+

Data Received Rate

6-15/day

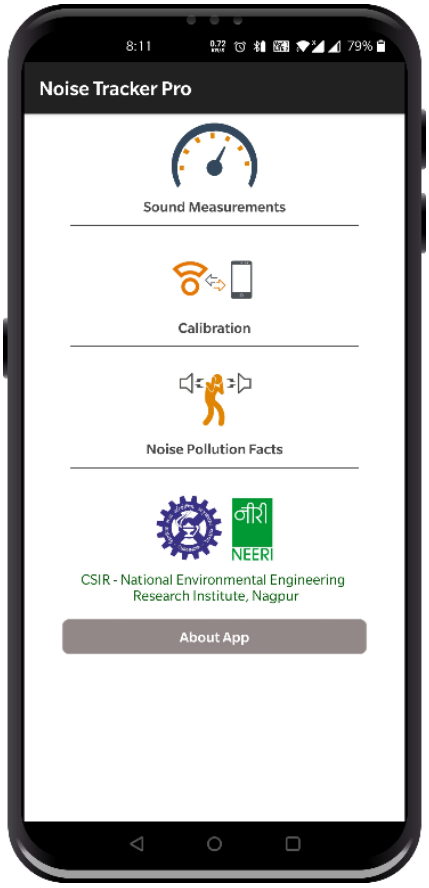
*From India & other countries

Scan the QR code to download

Android App on Google Play

FEATURES:

- Measure Equivalent continuous sound level (LAeq),
- Display SPL, Leq, Average, Minimum and Maximum decibel values
- Indicates decibel by digital gauge meter.
- Quick response on sound level changes.
- Compare the recorded noise level with popular international reference standards.
- Display Elapsed time of decibel
- Create the geo-tagged map for the saved history data
- Very efficient saved record data management
- Data storage in the phone.
- Performance best fits with calibrated SPL meter
- Handy custom Calibration for high precision and accuracy
- One can share the saved and recorded data across multiple platforms such as Gmail, WhatsApp, etc.



4.1.3 Noise Monitoring Methodology

The data collection is one of the most crucial exercises for noise assessment. Therefore, the study performed noise monitoring according to the national and international standard regulations. The research conducted a comparative study of noise levels during the festive season at several locations across Nagpur city. The noise data was collected before, during and after the festival in the time interval (06:00 AM to 10:00 pm) from 5-18 November 2023, with the help of the noise monitoring mobile application "Noise Tracker". The data was gathered according to the land use pattern by using the crowdsourcing technique. For this study, the four reputed colleges of Nagpur city have shown a willingness to enroll their students as volunteers for data collection using the mobile application "Noise Tracker." Before the monitoring, the volunteers were guided through a personal demonstration of the mobile application "Noise Tracker" for noise monitoring, data collection and sharing. In addition, the tutorial video and text guidelines were shared, and they were instructed to take certain necessary precautions during the data monitoring process. The volunteers collected three readings of a minimum of 300secs for each location before, during and after the festival period, and an average of the data sample was considered while assessing noise pollution. Volunteers shared their monitored data via text. Finally, the measured data compared with legal permissible limits prescribed by the CPCB Delhi **(Table 4.1).**

Table 4.1: The Noise Pollution (Regulation and Control) Rules 2010

Sr. No.	Activity	Noise Levels, Leq (dBA)	
		Day time	Night Time
1.	Industrial	75	70
2.	Commercial	65	55
3.	Residential	55	45
4.	Silence Zone	50	40

4.1.4 Observation and Inferences

During the festive season, it is evident that the ambient noise levels of the city rise due to the bursting of crackers, particularly in the nighttime. To curb the noise level, the government has imposed restrictions and permitted firecrackers to blaze only for two hours (8:00 PM to 10 PM) in this festive season, 2023. Across Nagpur City, noise levels were monitored and recorded for three durations before, during, and after the festive period to ensure proper

investigation and evaluation of noise levels. In the study, noise monitoring was accomplished in two classified durations, one between 6:00 AM and 8:00 PM and the second from 8:00 PM to 10:00 PM, to reveal the realistic noise scenario in the nighttime when the bursting of crackers took place. Accordingly, the observed noise levels in the silence, residential and commercial places at different locations is presented in an NMC zone-wise fashion, as summarized in **Tables 4.2, 4.3 & 4.4** at the end of the chapter.

4.1.5 Noise Level Status Before and After the Festive Season

Measuring and evaluating ambient noise levels before and after the festive season is crucial to reveal the extent of the rise in the noise levels due to the bursting of firecrackers during this festive season. The equivalent noise levels (Leq) observed before and after festive season are presented according to the land use pattern and summarized in a zone-wise fashion to provide comprehensive details of noise levels in Nagpur city, as shown in **Tables 4.2 & 4.3**. According to the land use pattern, the data evaluation indicates that noise levels in all ten NMC zones exceed the permissible limits of the Central Pollution Control Board (CPCB) for Silence, Residential and Commercial zones in most locations. The noise emission due to the movement of road vehicles, honking, community noise, construction, and other noise-emitting activities occurring regularly in any urban city are responsible for the noise levels observed above the CPCB permissible limits. This outcome is similar to the findings of various previous noise pollution studies conducted and published by the CSIR-NEERI and other institutions for Nagpur City. Also, many previous published researches conducted across the country confirm that the observed noise scenario is very much prevalent in most of the cities in India. The zone-wise compliance and non-compliance status of noise levels in percentage for silence, residential and commercial places are illustrated in **Figure 4.1(a & b)**.

Similarly, the comparison of the overall collective data of Silence, Residential and Commercial zones before the festival duration reveals that out of the ten zones, five NMC Zones such as Dharampeth, Hanuman Nagar, Dhantoli, Satranjipura and Ashinagar had more than 80% of places where noise levels surpass the CPCB noise limits. Whereas, in the other five remaining NMC zones namely Laxminagar, Nehru Nagar, Gandibagh, Lakadganj, and Mangalwari noise levels in 50.4-70.8% of locations exceeded the allowable noise limits of the CPCB, as shown in **Table 4.5**. However, after the Festival duration, zones, such as Gandhibagh, Sataranjipura and Mangalwari had more than 80% of locations above the permissible limits. Whereas the other seven remaining NMC zones (Laxminagar, Dharampeth Nehru Nagar, Dhantoli,

Hanuman Nagar, Lakadganj, and Ashinagar showed 43-74.4% of locations exceeded the allowable noise limits of the CPCB, as shown in **Table 4.7**.

Table 4.2: Status of noise levels zone wise (Before festive season)

Sr. No.	NMC ZONES	Monitoring Locations	NOISE ZONES	CPCB Compliance & Non-Compliance status in Percentage (%)				Total Non-Compliance in percentage (%)
				(06 AM to 8PM)		(8PM to 10PM)		
				Compliance	Non-compliance	Compliance	Non-compliance	
1	LAXMI NAGAR	28	SILENCE	0	100	100	0	50.4
			RESIDENTIAL	60	40	75	25	
			COMMERCIAL	62.5	37.5	0	100	
2	DHARAMPETH	17	SILENCE	0	100	0	100	88.9
			RESIDENTIAL	16.7	83.3	0	100	
			COMMERCIAL	50	50	0	100	
3	HANUMAN NAGAR	42	SILENCE	16.7	83.3	0	100	81.6
			RESIDENTIAL	37.5	62.5	14.3	85.7	
			COMMERCIAL	16.7	83.3	25	75	
4	DHANTOLI	11	SILENCE	0	100	0	100	90.2
			RESIDENTIAL	33.3	66.7	0	100	
			COMMERCIAL	25	75	0	100	
5	NEHRU NAGAR	69	SILENCE	8.3	91.7	11.1	88.9	69.8
			RESIDENTIAL	40	60	30	70	
			COMMERCIAL	35.7	64.3	55.6	44.4	
6	GANDHIBAGH	09	SILENCE	100	0	0	100	63.8
			RESIDENTIAL	50	50	0	100	
			COMMERCIAL	66.7	33.3	0	100	
7	SATRANJIPURA	09	SILENCE	0	100	0	100	83.3
			RESIDENTIAL	50	50	0	100	
			COMMERCIAL	50	50	0	100	
8	LAKADGANJ	24	SILENCE	33.3	66.7	0	100	67.1
			RESIDENTIAL	40	60	0	100	
			COMMERCIAL	57.1	42.9	66.7	33.3	
9	ASHINAGAR	33	SILENCE	16.7	83.3	33.3	66.7	83.8
			RESIDENTIAL	16.7	83.3	0	100	
			COMMERCIAL	11.1	88.9	20	80	
10	MANGALWARI	30	SILENCE	25	75	0	100	70.8
			RESIDENTIAL	50	50	50	50	
			COMMERCIAL	0	100	50	50	

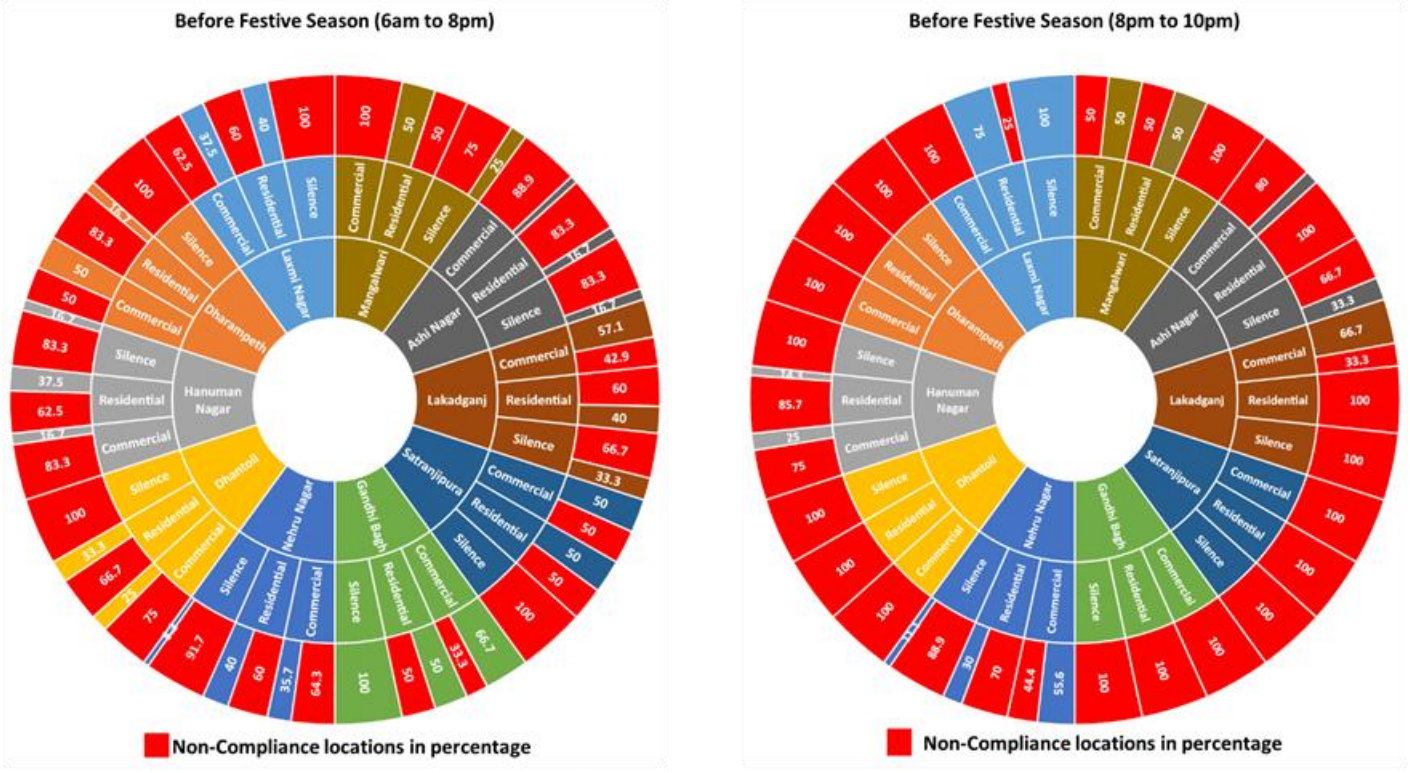
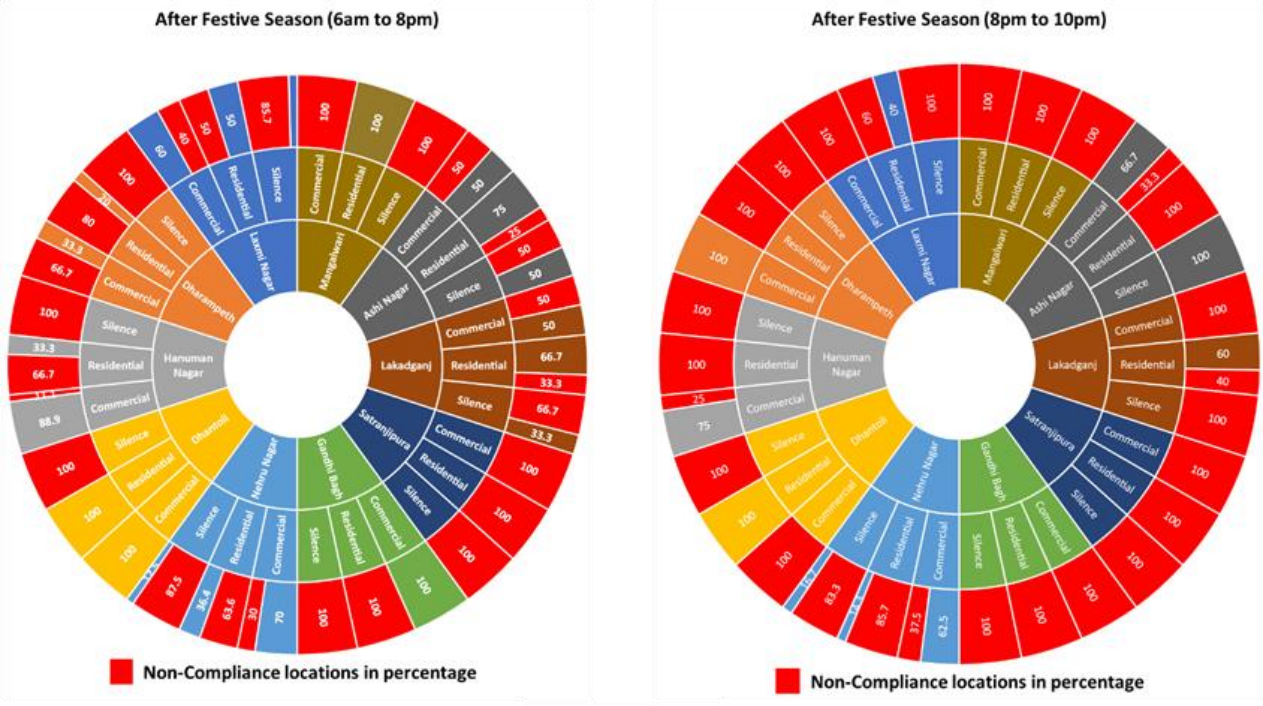


Figure 4.1(a): Zone-wise compliance and non-compliance status of noise levels in percentage for silence, residential and commercial places

Table 4.3: Status of noise levels zone wise (After festive season)

Sr. No.	NMC ZONES	Monitoring Locations	NOISE ZONES	CPCB Compliance & Non-Compliance status in Percentage (%)				Total Non-Compliance in percentage (%)
				(06 AM to 8PM)		(8PM to 10PM)		
				Compliance	Non-compliance	Compliance	Non-compliance	
1	LAXMI NAGAR	26	SILENCE	14.3	85.7	0	100	72.6
			RESIDENTIAL	50	50	40	60	
			COMMERCIAL	60	40	0	100	
2	DHARAMPETH	16	SILENCE	0	100	0	100	74.4
			RESIDENTIAL	20	80	0	100	
			COMMERCIAL	33.3	66.7	100	0	
3	HANUMAN NAGAR	34	SILENCE	0	100	0	100	67.1
			RESIDENTIAL	33.3	66.7	0	100	
			COMMERCIAL	88.9	11.1	75	25	

4	**DHANTOLI**	07	SILENCE	0	100	0	100	50
			RESIDENTIAL	100	0	100	0	
			COMMERCIAL	100	0	0	100	
5	**NEHRU NAGAR**	50	SILENCE	12.5	87.5	16.7	83.3	64.6
			RESIDENTIAL	36.4	63.6	14.3	85.7	
			COMMERCIAL	70	30	62.5	37.5	
6	**GANDHIBAGH**	08	SILENCE	0	100	0	100	83.3
			RESIDENTIAL	0	100	0	100	
			COMMERCIAL	100	0	0	100	
7	**SATRANJI PURA**	07	SILENCE	0	100	0	100	100
			RESIDENTIAL	0	100	0	100	
			COMMERCIAL	0	100	0	100	
8	**LAKADGANJ**	30	SILENCE	33.3	66.7	0	100	65
			RESIDENTIAL	66.7	33.3	60	40	
			COMMERCIAL	50	50	0	100	
9	**ASHINAGAR**	18	SILENCE	50	50	100	0	43
			RESIDENTIAL	75	25	0	100	
			COMMERCIAL	50	50	66.7	33.3	
10	**MANGALWARI**	06	SILENCE	0	100	0	100	83.3
			RESIDENTIAL	100	0	0	100	
			COMMERCIAL	0	100	0	100	



4.1(b): Zone-wise compliance and non-compliance status of noise levels in percentage for silence, residential and commercial places

4.1.6 Noise Level Status During the Festival season

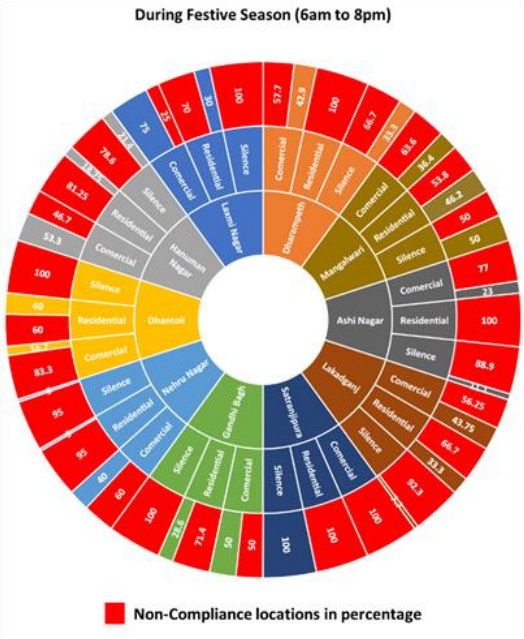
The investigation of noise levels during the festival is the study's primary objective as the bursting of firecrackers is taking place during this period (11-13 November 2023) and especially in the interval 8:00 PM to 10:00 PM. During the festival period, it was observed that noise levels in both the monitoring durations 6AM to 8 PM and 8PM to 10 PM were significantly higher than before and after the festival period. Out of ten NMC zones, four zones (Laxminagar, Dharampeth, Dhantoli, Nehru Nagar and Sataranjipura) show more than 80% of locations above the permissible limits, as shown in **Table 4.4**. The zone-wise compliance and non-compliance status of noise levels in percentage for silence, residential and commercial places are illustrated in **Figure 4.1(c).**

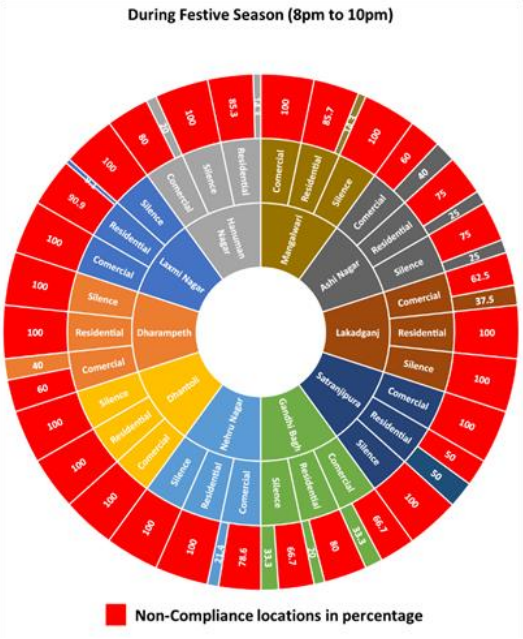
Also, the noise levels evaluated during the monitoring interval 8:00 PM to 10:00 PM show an extreme rise in the noise levels at each NMC Zone due to the bursting of crackers taking place in this noise monitoring interval. Out of ten NMC zones, four zones (Laxminagar, Dharampeth, Dhantoli, and Nehru Nagar) show more than 80% of locations above the permissible limits. However, at the same time NMC Zones such as Hanuman Nagar, Lakadganj and Ashinagar have collective non-compliance noise levels very close to 80% in the range of 78.6 to 79.6. otherwise in all the remaining five NMC zones (Hanuman Nagar, Gandhibagh, Lakadganj, Sataranjipura, Ashinagar and Mangalwari show 72.4 to 79.6 locations exceeding the allowable noise limits of the CPCB, as shown in **Table 4.4**.

Table 4.4: Status of noise levels zone wise (During festive season)

Sr. No.	NMC ZONES	Monitoring Locations	NOISE ZONES	CPCB Compliance & Non-Compliance status in Percentage (%)				Total Non-Compliance in percentage (%)
				(06 AM to 8PM)		(8PM to 10PM)		
				Compliance	Non-compliance	Compliance	Non-compliance	
1	LAXMI NAGAR	46	SILENCE	0	100	0	100	80.9
			RESIDENTIAL	30	70	9.1	90.9	
			COMMERCIAL	75	25	0	100	
2	DHARAMPETH	35	SILENCE	33.3	66.7	0	100	80.7
			RESIDENTIAL	0	100	0	100	
			COMMERCIAL	42.9	57.7	40	60	

3	**HANUMAN NAGAR**	76	SILENCE	21.4	78.6	0	100	78.6
			RESIDENTIAL	18.7	81.2	14.7	85.3	
			COMMERCIAL	53.3	46.7	20	80	
4	**DHANTOLI**	22	SILENCE	0	100	0	100	90.6
			RESIDENTIAL	40	60	0	100	
			COMMERCIAL	16.7	83.3	0	100	
5	**NEHRU NAGAR**	100	SILENCE	5	95	0	100	91.6
			RESIDENTIAL	5	95	0	100	
			COMMERCIAL	40	60	21.4	78.6	
6	**GANDHIBAGH**	38	SILENCE	0	100	33.3	66.7	72.4
			RESIDENTIAL	28.6	71.4	20	80	
			COMMERCIAL	50	50	33.3	66.7	
7	**SATRANJI PURA**	10	SILENCE	100	0	0	100	75
			RESIDENTIAL	0	100	50	50	
			COMMERCIAL	0	100	0	100	
8	**LAKADGANJ**	70	SILENCE	7.7	92.3	0	100	79.6
			RESIDENTIAL	33.3	66.7	0	100	
			COMMERCIAL	43.7	56.3	37.5	62.5	
9	**ASHINAGAR**	45	SILENCE	11.1	88.9	25	75	79.3
			RESIDENTIAL	0	100	25	75	
			COMMERCIAL	23	77	40	60	
10	**MANGALWARI**	45	SILENCE	50	50	0	100	75.5
			RESIDENTIAL	46.2	53.8	14.3	85.7	
			COMMERCIAL	36.4	63.6	0	100	





4.1(c): Zone-wise compliance and non-compliance status of noise levels in percentage for silence, residential and commercial places

4.1.7 Analysis of Silence, Residential and Commercial places in each NMC Nagpur Zones

The average noise levels in silence, residential and commercial places in each zone before and after the festival are depicted in **Figures 4.2 (a, b, e & f**). The pictorial chart indicates that most locations in all ten NMC zones do not comply with the CPCB limit. Similarly, the analysis of the average noise levels in silence, residential and commercial places at each zone during the festival time indicates that the noise levels during the monitoring interval 6 AM to 8 PM show almost similar conclusions as observed in the before and after festival noise data. However, in the monitoring interval 8 PM to 10 PM, the average noise levels in silence, residential and commercial places in each zone significantly rise due to the bursting of firecrackers during this time, as depicted in **Figure 4.2 (c & d).**

Accordingly, in the festive season, noise levels in silence and residential and commercial places in each zone rise due to the bursting of firecrackers. Similarly, the movement of road vehicles, honking, community noise, construction, and other noise-emitting activities occurring regularly in any city are responsible for the higher noise levels observed before and after the festive season, where noise contribution from the firecrackers is negligible in the overall noise. Based on the noise data analysis in each NMC Zone, the study found that Sataranjipura zone has 80% of locations above the permissible limits in common before and after the monitoring duration on this festival occasion. Similarly, Zones such as Dharampeth, Hunaman Nagar, Dhantoli and Ashinagar show almost 80% of locations above the permissible limits before and during the festival. Accordingly, out of ten zones, five, namely Dharampeth, Hunuman Nagar, Dhantoli, Ashinagar and Sataranjipura, emerged as hot noise zones of Nagpur city.

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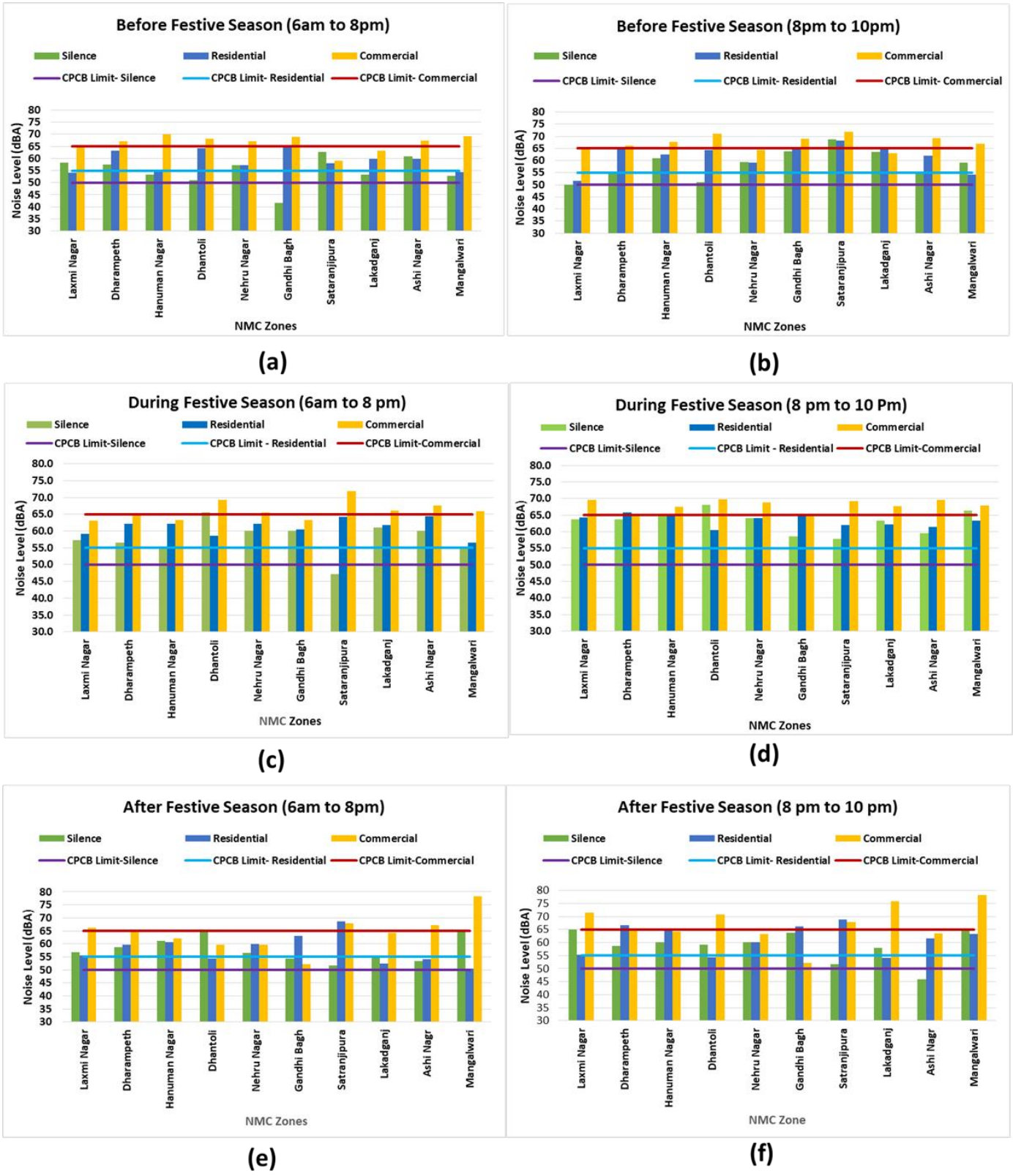


Figure 4.2: Average noise levels status in the ten NMC Nagpur zones

4.1.8 Inferences

The equivalent noise levels (Leq) observed before and after the Festive season indicate that noise levels in all ten NMC zones exceed the permissible limits of the Central Pollution Control Board (CPCB) for Silence, Residential and Commercial zones in most locations. During the festival period, it was observed that noise levels in both the monitoring durations, 6 AM to 8 PM and 8 PM to 10 PM, were significantly higher than before and after the festival period.

Based on the noise data analysis in each NMC Zone, the study found that Sataranjipura zone has 80% of locations above the permissible limits in common before and after the monitoring duration on this festival occasion. Similarly, Zones such as Dharampeth, Hunaman Nagar, Dhantoli and Ashinagar show almost 80% of locations above the permissible limits before and during the festival. Accordingly, out of ten zones, five, namely Dharampeth, Hanuman Nagar, Dhantoli, Ashinagar and Sataranjipura, emerged as hot noise zones of Nagpur city.

4.1.9 Recommendations

- **Recommendations on Noise Levels Before and after the Festive Season**

The high levels of noise experienced before and after the festive season are mainly attributed to the movement of road vehicles, honking, community noise, construction, and other activities that emit noise. These activities are common in any urban city and are responsible for the noise levels observed above the permissible limits set by the CPCB.

1. Wherever possible, sensitive zones can be protected from excessive noise by implementing acoustic barriers with proper design and material optimisation to estimate higher insertion loss. Noise barriers should be covered with soft material for the highest noise reduction.
2. The noise barriers' efficiency should be evaluated regularly by conducting field tests.
3. Construction activities have been one of the significant contributors to urban noise pollution. To curb noise pollution at the construction site, as suggested by CPCB, 13 to 14 feet of temporary sound barriers should be put around the construction site to limit noise pollution. Also, construction activities must be conducted during the day only.
4. Honking is a critical problem, especially in India. A needless use of the honking creates a noise signal of high intensity. This sound can shake up or have an adverse

effect on the active drivers and passengers of surrounding vehicles, pedestrians and people living in the area. Promoting the use of automated systems or devices in vehicles intended to monitor and restrict honking is recommended.

5. It is suggested to promote tree plantation in the city wherever possible so that the transmitted noise can be attenuated to some extent.
6. Noise monitoring should be conducted every year regularly to ensure regulatory compliance with the noise levels.
7. All vehicles on the road should run within maintained speed limits and not blow horns unless required.
8. There should be strict instructions on regular servicing and maintenance of all the light, medium and heavy vehicles running on the city roads to minimise noise & vibration generation.
9. By identifying suitable places, a speed breaker should be made on the road in a residential and silent zone to reduce the speed of the vehicles; consequently, noise levels emission from the vehicles will be reduced.

- **Recommendations on Noise Levels Before and after the Festive Season**

The high noise level during the festive season was majorly due to the bursting of firecrackers that leads to the rise in the ambient atmospheric noise.

1. The time limits prescribed (Diwali: 8:00 PM to 10:00 PM) for bursting firecrackers on various festive occasions should be stringently implemented to keep the ambient noise levels normal, at least for the rest of the hours.
2. The study recommends that fireworks celebrations be organized in a community in a common open place instead of celebrating the occasion individually so that precautions can be taken very effectively to avoid any health hazards.
3. The children are considered most vulnerable to noise exposure and require utmost care for hearing protection against firecrackers, such as hearing protectors, etc.
4. The Central Pollution Control Board (CPCB) and the Ministry of Environment, Forests and Climate Change (MoEF&CC) in India have recommended a ban on the manufacture, sale, or use of firecrackers that exceed noise limits of 125 dB(AI) or 145 dB(C)pk, tested at a distance of 4 meters from the point of bursting. It is essential to strictly enforce the CPCB regulations to manage noise pollution effectively during festive occasions.

5. Policymakers and authorities must strictly implement permissible limits as defined in the Noise Pollution (Regulation and Control) Rules 2010 to control noise pollution.
6. During the festive season, the loud noise caused by firecrackers can be disturbing and scary for domestic animals, especially those living in urban areas. This can make them vulnerable to the shockwaves created by fireworks. To ensure their safety and comfort, it is recommended to keep pets indoors with windows and doors closed. Similarly, stray animals may seek refuge in residential areas during this time. Instead of avoiding them, people can offer them a quiet place to hide and feel secure.

Table 4.5: **NMC zone-wise noise level of silence, residential & commercial areas-before festive season**

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00PM)	CPCB Permissible Limit (dBA)
1	LAXMI NAGAR	Amar Trupti Nagar, New Sneh Nagar, Chatrapati Sq	SILENCE	57.4	-	50
		Deendayal Nagar, Nagpur 440022		51.6	49.9	
		Priyadarshini Campus, Near CRPF Camp, Hingna		58.0	-	
		Pande Layout, New Sneh Nagar, Khamla 440025		66.4	-	
		Amar Trupti Nagar, Pande Layout, Khamla,	RESIDENTIAL	51.5	45.8	55
		Hingna Rd, Wanadongrict, Wanadongri 441110		61.2	49.0	
		Gandhi Nagar Ambazari 440010		53.5	-	
		NIT GARDEN, Trimurtee Nagar, 440022		43.3	52.1	
		Balaji Nagar, S R P Camp, Digdoh, 440016		-	59.1	
		H.B. Estate, Sonegaon, 440025		41.2	-	
		Police Nagar, Nagpur, Nildohct, 440016		55.0	-	
		Priyadarshini Campus, Near CRPF Camp, Hingna		68.2	-	
		Jaitala, Nagpur, 440036		68.3	-	

		Police Nagar CRPF Road Nagpur		42.7	-	
		Orange City Hospital Sawarkar Nagar, Hanuman Nagar		56.2	-	
		Priyadarshini Campus, Near CRPF Camp, Hingna	COMMERCIAL	63.6	-	65
		Amar Trupti Nagar Pande Layout New SnehNagar		67.1	-	
		Sainath Nagar, Trimurtee Nagar,440022		64.3	65.2	
		Anand Nagar, Pratap Nagar, 440020		63.5	-	
		Hingna Rd, S R P Camp, Nagpur, Digdoh, 440016		72.7	-	
		Jaitala Rd, Pooja Layout, Nagpur, Digdoh,440016		56.4	-	
		Priyadarshini Campus, Near CRPF Camp, Hingna		63.2	-	
		Agne Layout, Shastri Layout, Khamla, 440025		71.1	-	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
2	DHARAMPETH	Marartoli, Ram Nagar, 440010	SILENCE	61.6	55.5	50
		Ram Nagar, Near Ravi Nagar 440001		53.5	-	
		Gorepeth, Nagpur 440010	RESIDENTIAL	65.3	-	55
		Ramdaspeth, Nagpur, 440010		61.5	-	
		E High Ct Rd, Gorepeth, Dharampeth 440010		-	71.2	
		Mata Mandir Rd, Dharampeth, 440010		64.7	-	
		Tanga stand, Near Traffic Park, Dharampeth		67.7	64.4	
		Shankar Nagar, East Shankar Nagar, Dharampeth		64.7	-	
		Marartoli, Ram Nagar, 440010		54.9	61.3	
		Gorepeth, Nagpur 440010	COMMERCIAL	64.7	-	65
		Sitabuldi, Gorepeth, 440012		72.7	-	
		Ram Nagar, Near Ravi Nagar 440001		68.2	66.0	
		W High Ct Rd, Tilak Nagar, Gokulpeth, 440010		62.8	-	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8.00 PM to 10.00 PM)	CPCB Permissible Limit (dBA)
3	HANUMAN NAGAR	Shri Hari Nagar, Manewada 440027	SILENCE	51.1	59.6	50
		VinkarVasahat, Omkar Nagar 440027		45.5	57.9	
		Siraspeth, 440009		-	62.0	
		Somwaripeth, Nagpur, Maharashtra 440009		-	64.5	
		Shri Hari Nagar, Omkar Nagar, 440027		51.4	60.2	
		AtharvaNagri 2, Manewada, 440034		58.0	-	
		New Subhedar Layout, Ashirwad Nagar, 440024		52.3	-	
		Reshimbagh Rd, Shri Krishna Nagar, ReshimBagh,		61	-	
		Shri Hari Nagar, Manewada	RESIDENTIAL	55.5	62.2	55
		Medical Chowk, Hanuman Nagar 440009		57.2	-	
		Siraspeth, Nagpur,440024		-	69.2	
		New Om Nagar Dhande Layout, Hudkeshwar Rd,		-	60.5	
		Somwaripeth, 440009		-	66.1	
		Besa Rd, Geeta Nagar, Besa, 440027		51.0	-	
		kukde layout, Rameshwari, 440027		42.5	55.1	
		AtharvaNagri 2, Manewada, 440034		56.9	-	
		Sakkardara Rd, Ganesh Nagar, Reshimbagh		63.9	69.8	
		Geeta Nagar, Manewada, 440034		44.7	-	
		Rambagh Layout, Untkhana, Nagpur,440003		73.0	-	
		Chatrapati Nagar, Narendra Nagar		-	54.5	
		Sewadal Nagar, Manewada 440024	COMMERCIAL	71.1	-	65
		VinkarVasahat, Omkar Nagar 440027		77.0	68.2	
		Rambagh Layout, Rambag 440003		67.7	-	
		Siraspeth, Nagpur,440024		75.0	-	
		Somwaripeth, 440009		69.1	-	
		ManewadaChowk, Ulhas Nagar, Rameshwari,		73.2	-	
		Kalyaneshwar Nagar, Manewada, 440027		57.9	73.7	
		kukde layout, Rameshwari, 440027		62.6	59.7	
		AtharvaNagri 2, Manewada, 440024		68.5	-	
		Manewada, Nagpur, 440024		69.3	-	

		Vinkar Colony, Vigyan Nagar, Manewada, 440034		76.6	-	
		Uday Nagar Square Manewada		71.2	69.2	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 am to 8:00 pm)	Leq (8:00 pm to 10:00 pm)	CPCB Permissible limit (dBA)
4	DHANTOLI	New Manish Nagar, Somalwada,	SILENCE	51.0	51.0	50
		Abhyankar Marg, Sitabuldi, 440012	RESIDENTIAL	70.8	-	55
		SK Patil Rd, Dhantoli, Nagpur,		79.1	-	
		New Manish Nagar, Somalwada,		43.1	64.3	
		Gandhi Building, Sitabuldi, 440012	COMMERCIAL	70.9	71.0	65
		Sitabuldi, Nagpur, 440012		74.5	-	
		Modi No.3, Sitabuldi, 440012		56.3	-	
		Beltarodi Rd, Manish Nagar, Somalwada		71.1	-	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AMto 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
5	NEHRU NAGAR	New BidiPeth, Solanki PatilWadi	SILENCE	52.1	59.1	50
		New Diamond Nagar, Shaktimata Nagar, Kharbi		44.3	58.9	
		Nandanvan		63.9	-	
		Gonhi		52.0	57.1	
		Dhanwantari Nagar, Chitnis Nagar, 440017		67.2	-	
		Rajendra Nagar, Nandanvan 440009		-	69.7	
		Chandrakiran Nagar, Nagpur, Narsala 440034		-	70.1	
		Shesh Nagar, Shaktimata Nagar, Kharbi 440024		55.6	-	
		Sakkardara Police Chowki Rd, Anand Nagar,		62.3	-	
		Dighori, Nagpur440034		59.8	51.2	
		Ashirwad Nagar, 440024		56.4	-	
		Gohni		53.1	-	

		Shri Krishna Nagar, ReshimBagh, 440009		61.5	70.0	
		Shri Ram Nagar, New Subhedar Layout, Ashirwad		-	56.5	
		New Subhedar Layout, Ashirwad Nagar, 440024		57.4	-	
		Vidhya Nagar, Wathoda Layout, 440017		-	43.3	
5	**NEHRU NAGAR**	Nandanvan	**RESIDENTIAL**	65.4	-	55
		Gonhi		45.0	55.3	
		Jawahar Nagar, Ayodhyanagar 440024		67.4	-	
		Dighori, Nagpur 440024		49.2	66.5	
		Kharbi, Nagpur, 440024		-	58.9	
		KDK College Rd, Rajendra Nagar, Nandanvan		-	71.5	
		Chitnis Nagar, 440017		56.9	-	
		Wathoda Layout, 440017		-	61.4	
		Sakkardara Square, ReshimBagh, Nagpur 440009		57.6	-	
		New BidiPeth, Solanki PatilWadi, 440024		58.4	58.3	
		Mhalgi Nagar, 440024		48.7	52.6	
		New BidiPeth, Ashirwad Nagar, 440024		57.1	-	
		Anmol Nagar, Kharbi, 440024		74.7	-	
		Shivsundar Nagar, Dighori, Nagpur,		53.4	52.4	
		JuniShukrawari, ReshimBagh, 440024		67.6	-	
		Shri Ram Nagar, New Subhedar Layout, Ashirwad		53.1	52.0	
		Padole Nagar, Wathoda 440008		58.9	-	
		Vidhya Nagar, Wathoda Layout, Nagpur,		46.3	-	
		Ambika Nagar, Ayodhyanagar, Nagpur,		-	63.3	
		New Diamond Nagar, Shaktimata Nagar, Kharbi	**COMMERCIAL**	57.5	52.9	65
		Nandanvan		61.5	-	
		Gonhi		66.1	62.0	
		Sakkardara Rd, Raghuji Nagar, 440009		73.0	-	
		Budhawar Bazar Rd, Raghuji Nagar, 440009		72.6	-	
		Kamla Nehru Mahavidyalaya,		73.8	-	

		Raghuji Nagar,				
		Dighori, Narsala, 440034		64.3	-	
		Dhanwantari Nagar, Chitnis Nagar 440017		71.4	-	
		Kharbi, Nagpur, 440024		-	61.2	
		Hasanbagh Rd, Nandanvan,440009		-	68.7	
		Sadashiv Nagar, Kharbi 440024		-	78.1	
		Shesh Nagar, Shaktimata Nagar, Kharbi, 440024		-	57.2	
		Chandrakiran Nagar, Nagpur, Narsala 440034		-	59.8	
		New Nehru Nagar, Mhalgi Nagar 440024		-	69.6	
		Sakkardara Rd, Raghuji Nagar, 440009		65.1	-	
		New BidiPeth, Solanki PatilWadi, 440024		62.4	-	
		Ambika Nagar, Ayodhya nagar,440034		64.1	-	
		GajananMandir, Ashirwad Nagar, 440024		69.2	-	
		Bahadura Rd, Dighori, 441204		69.5	-	
		Anand Nagar, Sakkardhara Square, 440024		67.7	70.7	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
6	GANDHIBAGH	Mangalwari, Mahal, 440032	SILENCE	-	63.7	50
		Badkas Square Rd, Mangalwari, Nagpur,		41.5	-	
		Bhuteshwar Nagar, Mangalwari, Mahal,	RESIDENTIAL	79.9	-	55
		Badkas Square Rd, Mangalwari, Nagpur,		50.4	65.1	
		Mangalwari, Mahal, 440032	COMMERCIAL	63.3	-	65
		Bhuteshwar Nagar, Mangalwari, Mahal,		79.1	-	
		Near Gandhi Gate, Mahal, 440032		64.7	69	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
7	SATARANJIPURA	Tandapeth, Nagpur 440002	SILENCE	62.8	68.6	50
		Tandapeth, Nagpur, 440002	RESIDENTIAL	54.6	69.7	55
		Binaki, Nagpur, 440002		61.5	66.5	
		Tandapeth, Nagpur 440002	COMMERCIAL	66.1	71.9	65
		Binaki, Nagpur, 440002		52.2	-	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit
8	LAKADGANJ	Punapur Road, Pardi 440008	SILENCE	-	72.0	50
		Queta Colony Lakadganj		50.8	-	
		NagpureVidyalayaBharatwada Pardi		62.0	63.4	
		Shantinagar Colony, Nagpur, 440002		47.4	55.4	
		Bhavani Mata Mandir Rd, Pardi 440035	RESIDENTIAL	68.0	-	55
		Gangabag, Pardi 440008		68.5	65.7	
		NetaJi Nagar, Pardi, 440035		-	61.7	
		Queta Colony Lakadganj		53.2	-	
		Shantinagar Colony, Nagpur, 440002		44.8	-	
		Bhandara Rd, Surya Nagar, Nagpur,440008		64.0	68.2	
		Gangabag, Netaji Nagar 440008	COMMERCIAL	60.1	64.1	65
		Shiv Nagar Pardi		59.2	-	
		Queta Colony Lakadganj		42.7	-	
		Shantinagar Colony, Nagpur, 440002		58.6	55.3	
		Sidharth Nagar, Nagpur, 440026		74.3	-	
		Subhan Nagar, Pardi, Nagpur, Maharashtra		69.4	69.5	
		Mangalwari, Nagpur, Maharashtra 440002		78.5	-	

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (6:00AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
9	ASHINAGAR	Kapil Nagar, Dixit Nagar, 440026	SILENCE	62.9	65.1	50
		Vaishali Nagar, Nagpur,440017		49.5	46.0	
		Nari Rd, Sanyal Nagar, Bank Colony, 440002		52.4	-	
		Samyak Nagar, Sanyal Nagar, Bank Colony,		67.5	-	
		Ekta Colony, Yadav Nagar Nagpur,440002		70.0	-	
		Yadav Nagar Near Jaiswal Restaurant Nagpur		-	53.9	
		Nalanda Nagar Bank Colony, Sanyal Nagar,		63.2	-	
		Kapil Nagar, Dixit Nagar, 440026	RESIDENTIAL	56.6	-	55
		Dixit Nagar, Nagpur 440026		57.4	59.1	
		Vaishali Nagar, Nagpur,440017		60.6	-	
		Thawre Colony Indora		54.8	-	
		Tipu Sultan Chowk, Uppalwadi, 440026		-	64.8	
		Samyak Nagar, Sanyal Nagar, Bank Colony,		61.0	61.5	
		Yadav Nagar Near Jaiswal Restaurant Nagpur		-	62.8	
		Sidharth Nagar, Vanjari 440026		68.9	-	
		Dixit Nagar, Nagpur 440026	COMMERCIAL	73.4	72.5	65
		Ring Rd, Dixit Nagar, Nagpur 440026		70.3	-	
		Himanshu Plaza, Ring Rd, Dixit Nagar, 440026		70.4	-	
		Vaishali Nagar, Nagpur,440022		65.6	63.5	
		New Thaware Colony, 440002		55.0	-	
		Kamal Chowk, Nagpur 440002		70.8	-	
		Tipu Sultan Rd, Sidharth Nagar Vanjari, 440026		67.4	67.9	
		Bank Colony		68.1	-	
		Byramji Town, Chitanvis Nagar 440001		-	68.7	
		MeshramChowk, Nagesh Nagar, jaripatka, Kukreja Nagar,		-	73.5	
		Automotive Chowk, Kamptee Rd, Bank Colony,		65.7	-	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
10	MANGALWARI	Civil Lines, Nagpur,440001	SILENCE	54.2	51.4	50
		ZingabaiTakli, Nagpur, 441501		54.4	66.7	
		Gajanan Nagar, ZingabaiTakli, 441501		47.1	-	
		BUPESHNAGAR, Nagpur, 440013		55.3	-	
		Civil Lines, Nagpur,440010	RESIDENTIAL	48.7	-	55
		ZingabaiTakli, Nagpur 441501		52.9	61.3	
		Mecosabagh Christian Colony, Nagpur,		63.5	-	
		Seminary Hills, Nagpur, Maharashtra		68.7	-	
		Bezonbagh, Nagpur, 440004		47.4	-	
		BUPESHNAGAR, Nagpur, 440013		61.7	-	
		New Ahbab Colony, Ring Rd, Anant Nagar		50.8	-	
		Narmada Colony, Nagpur, 440013		45.8	-	
		Veer Chakra Colony, Vrindavan Colony,		37.8	-	
		Anna Baba Nagar, ZingabaiTakli, 441501		55.8	-	
		VCA Stadium Complex, Collectors Colony,		59.0	-	
		Jafar Nagar, Gorewada, 440030		61.7	-	
		Godhni, Nagpur, Maharashtra 441501		-	47.2	
		ZingabaiTakli, Nagpur, 441501	COMMERCIAL	70.4	62.2	65
		Mecosabagh Christian Colony, 440004		71.3	-	
		Gajanan Nagar, ZingabaiTakli, 441501		69.5	-	
		Godhani Road, ZingabaiTakli, 440030		67.1	71.4	
		Shiv Nagar Gorewada		58.7	-	
		Manjidana Colony, Nagpur, 440013		74.5	-	
		Borgaon Rd, Anant Nagar,440013		68.3	-	
		Mangalwari Bazar Rd, Anjuman Complex Koradi Colony,		73.7	-	

Table 4.6: **NMC NMC zone-wise noise level of silence, residential & commercial areas- during festive season**

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM To 8:00 PM)	Leq (8:00 PM To 10:00 Pm)	CPCB Permissible Limit (dBA)
1	LAXMI NAGAR	Deendayal Nagar, Nagpur,	SILENCE	58.2	63.1	50
		Rajendra Nagar, Yahodha Nagar, Nagpur,		57.4	61.4	
		Amar Trupti Nagar, Pande Layout, Khamla,		56.4	57.4	
		Police Nagar CRPF Road Nagpur		52.9	-	
		Hingna rd Parsodi, Jalvihar Colony, Near Ambazari		55.1	67.8	
		Sahakar Nagar, Khamla Nagpur,		-	68.4	
		Balaji Nagar, S R P Camp, Digdoh,		55.1	-	
		Hingna Rd, Yashoda Nagar, Takli Seem,		58.7	-	
		Hingna rd Parsodi, Jalvihar Colony, Near Ambazari		58.4	-	
		Pande Layout, New Sneh Nagar, Khamla		62.8	-	
		Hingna Rd, Wanadongri ct, Wanadongri	RESIDENTIAL	60.7	67.6	55
		NIT Lay out, Swavalambi Nagar,		63.9	66.2	
		NIT GARDEN, Trimurtee Nagar,		56.1	63.7	
		Rajendra Nagar, Yahodha Nagar, Yashoda Nagar,		60.6	61.8	
		Amar Trupti Nagar, Pande Layout, Khamla,		58.3	45.3	
		Police Nagar CRPF Road Nagpur		49.2	-	
		IT Park rd Gayatri Nagar, Trimurtee Nagar, Nagpur,		68.2	-	
		Abhyankar Nagar Rd, Pratap Nagar, Nagpur,		-	69.8	
		Swaroop Nagar Road, Khamla,		66.1	74.0	

		Nagpur,				
		H.B. Estate, Sonegaon,		54.1	59.8	
		Ramdaspeth, Nagpur,		54.7	63.1	
		Balaji Nagar, S R P Camp, Digdoh,		-	55.2	
		Kapil Nagar, New Sneh Nagar, Orange City Hospital		-	79.4	
		Shahane Layout, Sainath Nagar Trimurtee Nagar,	COMMERCIAL	55.3	68.1	65
		Parate Nagar, Sonegaon, Nagpur,		61.1	-	
		Rajendra Nagar, Yahodha Nagar, Yashoda Nagar,		54.7	-	
		Amar Trupti Nagar, Pande Layout, Khamla,		62.2	72.5	
		Pande Layout, New Sneh Nagar,		62.6		
		Central Bazar Road, Bajaj Nagar, Deekshabhumi		-	68.3	
		CRPF Rd, Police Nagar, Nagpur, Nildoh ct,		64.3	-	
		W High Ct Rd, LAXMI NAGAR, Nagpur, 440020		73.8	-	
		Jai Prakash Nagar, Khamla Nagpur,		70.1	-	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM To 8:00 PM)	Leq (8:00 PM To 10:00 PM)	CPCB Permissible Limit (dBA)
2	DHARAMPETH	Marartoli, Ram Nagar, Nagpur	SILENCE	59.5	61.2	50
		Ram Nagar, Near Ravi Nagar		58.3	-	
		Ravi Nagar Cp Club		63.3	66.1	
		Sitabuldi, Nagpur		46.1	-	
		Sahu Colony, Sitabuldi		44.7	-	
		Asha Laxmi Apartment, Ravi Nagar, Nagpur		67.4	-	
		Mata MandirRd, Dharampeth,	SID EN TIA	61.9	70.6	55

		traffic park, Dharampeth, Nagpur,		67.3	62	
		Traffic Park Track, Bhagwaghar Layout, Dharampeth		58.1	-	
		Tanga stand, Near Traffic Park, Dharampeth,		65.8	68.7	
		E High Ct Rd, Gorepeth, Dharampeth		68.0	-	
		Marartoli, Ram Nagar, Nagpur		55.1	57.0	
		Morris College T Point, Sitabuldi,		64.5	-	
		Ravi Nagar, Uday Nagar,		57.3	-	
		Hill Rd, Ravi Nagar, Ram Nagar, Nagpur		66.3	-	
		Ramdaspeth, Nagpur		-	71	
		PKV Agri land, Gorepeth, Nagpur		57.4	-	
		Ravi Nagar, Uday Nagar,	**COMMERCIAL**	65.2	69.5	65
		Mata Mandir Rd, Dharampeth,		58.4	63.2	
		Ramdaspeth, Nagpur,		55.7	56.7	
		Ram Nagar, Near Ravi Nagar		69.6	-	
		Marartoli, Ram Nagar, Nagpur,		65.7	66.7	
		Gokulpeth, Ram Nagar Road Nagpur,		-	67.6	
		RBI Square Sitabuldi, Nagpur,		75.4	-	
		Asha Laxmi Apartment, Ravi Nagar, Nagpur,		64.2	-	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
3	HANUMAN NAGAR	Bardi Rd, Bajrang Nagar, Rameshwari,	SILENCE	45.5	-	50
		Bhagwan Nagar, Rameshwari, Nagpur		42.4	-	
		GMC, Medical Chowk, Rambagh, Nagpur		68.5	-	
		Hudkeshwar, Sanmarga Nagar, Nagpur		55.3	64.7	
		kukde layout, Rameshwari,		39.1	-	
		Medical Chowk, near VR mall, Rambagh, Nagpur		52.2	-	
		Medical Colony, Rameshwari		51.4	67.6	
		Rambagh Layout, Rambagh		56.0	64.9	
		Reshimbagh Rd, Shri Krishna Nagar, ReshimBagh		60.8	65.8	
		Shramjivi Nagar, Rameshwari, Nagpur,		55.4	-	
		Shri Hari Nagar, Manewada		57.3	65.6	
		Siraspeth, Nagpur,		64.9	-	
		Somwaripeth		66.5	62.0	
		VinkarVasahat, Omkar Nagar, Nagpur,		57.3	65.5	
		Abhay Nagar, BadilKheda, Manewada, Nagpur	RESIDENTIAL	79.9	-	55
		Bardi Rd, Bajrang Nagar, Rameshwari, Nagpur		53.1	63.8	
		Besa Rd, Geeta Nagar, Besa,		61.4	-	
		Chandrakiran Nagar, NarsalaHudkeshwar		60.6	-	
		Jaywant Nagar, Omkar Nagar		-	72.8	
		JuniShukrawari, Ganesh Nagar, Azamshah Layout, Reshimbagh		50.5	-	
		Kalyaneshwar Nagar, Manewada,		50.0	53.0	
		kukde layout, Rameshwari,		57.0	40.6	
		ManewadaChowk, Ulhas Nagar, Rameshwari,		-	74.4	
		Manewada Ring Rd, BadilKheda, Manewada,		69.6	70.1	

		Nagpur				
		Medical Colony, Rameshwari,		57.9	69.0	
		Rambagh Layout, Rambagh, 440003		57.0	66.9	
		Sakkardara Rd, Ganesh Nagar, Reshimbagh		61.0	67.0	
		Sanmarga Nagar, Hudkeshwar		58.3	68.3	
		Shri Hari Nagar, Manewada		-	59.6	
		Shri Ram Nagar, New Subhedar Layout, Ashirwad		59.8	-	
		Siraspeth, Nagpur,		67.8	-	
		Somwaripeth, Nagpur,		71.6	67.5	
		Swaraj Nagar, Omkar Nagar, Nagpur,		-	71.0	
		VinkarVasahat, Omkar Nagar, Nagpur,		63.8	63.5	
		Ajni Medical Colony, Ajani, Nagpur,	**COMMERCIAL**	-	72.7	65
		Bardi Rd, Bajrang Nagar, Rameshwari, Nagpur		61.1	-	
		Beltarodi Rd, Manish Nagar, Somalwada,		71.0	-	
		Besa Rd, Geeta Nagar, Besa,		57.7	70.3	
		Kalyaneshwar Nagar, Manewada,		70.8	-	
		kukde layout, Rameshwari,		67.7	67.3	
		Manewada, Nagpur,		59.4	-	
		Medical Chowk, near VR mall, Rambagh, Nagpur		48.6	-	
		Medical Colony, Rameshwari,		60.2	69.4	
		Rambagh Layout, Rambagh, 440003		61.3	66.1	
		Reshimbagh Rd, ReshimBaghChowk,		66.7	67.9	
		Sanmarga Nagar, Hudkeshwar		56.7	68.7	
		Shri Hari Nagar, Manewada		62.7	64.7	
		Siraspeth, Nagpur,		66.9	-	
		Somwaripeth,		67.9	60.5	
		Uday Nagar Square Manewada		68.6	68.0	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
4	DHANTOLI	New Manish Nagar, Somalwada,	SILENCE	56.8	59.4	50
		Ganeshpeth Colony,		-	74.7	
		Service Rd, Dhantoli, Nagpur		-	70.0	
		Ghat Rd, Sitabuldi,		74.3	-	
		New Manish Nagar, Somalwada,	RESIDENTIAL	47.8	55.7	55
		Near Mokshdham, Sugat Nagar, Ganeshpeth Colony,		56.9	-	
		Ganeshpeth Colony, Nagpur,		48.8	59.1	
		Chopkar Road, Ganeshpeth, Nagpur,		71.0	-	
		Yashwant Stadium, Dhantoli, Nagpur,		68.4	66.4	
		Gandhi Building, Sitabuldi,	COMMERCIAL	70.2	69.0	65
		Sahu Colony, Sitabuldi,		68.7	-	
		Ganeshpeth Colony,		-	71.6	
		Beltarodi Rd, Manish Nagar, Somalwada,		69.9	68.9	
		Samarth Nagar East, Nagpur,		74.6	-	
		Chatrapati Nagar, Near Chhatrapati Square Nagpur,		62.6	-	
		GMC Medical Chowk, Rambagh, Nagpur,		69.4	-	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
5	NEHRU NAGAR	Ambika Nagar, Ayodhya nagar, Nagpur,	SILENCE	54.9	-	50
		Azamshah Layout, Nagpur,		60.6	-	
		Bajrang Nagar, Ayodhya nagar, Manewada rd		50.2	-	
		Chitnis Nagar, Nagpur,		62.4	64.5	
		Darshan Colony, Nandanvan, Nagpur		62.6	-	
		Dighori, Nagpur,		52.9	52.6	

		Gonhi		59.5	64.9	
		Rajendra Nagar, Nandanvan, Nagpur,		68.2	68.1	
		Malagi Nagar, Ashirwad Nagar,		78.6	77.6	
		New Neharu Nagar, Sanmarga Nagar,		68.3	75.6	
		New Subhedar Layout, Ashirwad Nagar,		59.2	64.7	
		Shivsundar Nagar, Dighori, Nagpur,		53.3	58.9	
		Shri Krishna Nagar, Reshim Bagh,		57.6	62.8	
		Vidhya Nagar, Kharbi, Nagpur,		53.1	57.9	
		Gajanan Mandir Rd, Raghuji Nagar, Nagpur,		58.8	-	
		New Diamond Nagar, Shaktimata Nagar, Kharbi,		56.2	53.3	
		New Nandanvan Layout, Nandanvan,		65.1	-	
		Ring Road, Ashirwad Nagar,		64.6	-	
		Juni Shukrawari, Reshim Bagh, Nagpur,		69.0	-	
		SARSWATI NAGAR, wathoda,		46.5	68.6	
		Ambika Nagar, nagar, Nagpur,	**RESIDENTIAL**	66.2	72.3	55
		Chandrakiran Nagar, Gandhi Nagar Narsala		65.2	-	
		Chitnis Nagar, Nagpur,		65.3	66.9	
		Dighori, Nagpur,		59.5	61.3	
		Gonhi		58.5	61.9	
		Juni Shukrawari Reshim Bagh, Nagpur,		59.0	70.7	
		KDK College Rd, Rajendra Nagar, Nandanvan		66.0	61.6	
		New Bidi Peth, Ashirwad Nagar, Nagpur,		64.0	-	
		New Neharu Nagar, Sanmarga Nagar, Malgi nagar		72.4	71.6	
		Ring Road, Ashirwad Nagar,		59.4	70.7	
		Sadbhawana Nagar, Nandanvan, Nagpur,		66.0	-	
		Shivsundar Nagar, Dighori,		58.5	59.1	

		Shri Ram Nagar, New Subhedar Layout, Ashirwad		55.7	55.5	
		Vidhya Nagar, Wathoda Layout, Nagpur,		60.8	58.4	
		Ashirwad Nagar Rd, Malagi Nagar, Nagpur,		66.7	-	
		Gajanan Mandir Rd, Raghuji Nagar, Nagpur,		70.3	-	
		Kirti Complex 2, Nandanvan, Nagpur,		51.1	61.4	
		New Diamond Nagar, Shaktimata Nagar, Kharbi,		61.8	57.0	
		Reshimbag, Reshim Bagh, Nagpur,		61.7	-	
		Wathoda Layout, Wathoda Nagpur,		56.9	69.0	
		Ambika Nagar, Ayodhya nagar,	**COMMERCIAL**	69.1	-	65
		Bahadura Rd, Dighori, Nagpur,		65.2	67.2	
		Bapu Nagar, Nandanvan, Nagpur		70.4	-	
		Chandrakiran Nagar, Narsala, Nagpur,		64.9	-	
		Chitnis Nagar, Nagpur,		63.2	67.3	
		Darshan Colony, Nandanvan		58.4	-	
		Dighori, Nagpur,		60.9	63.5	
		Gonhi		69.3	72.4	
		Great Nag Rd, Nandanvan, Nagpur,		68.1	69.5	
		Kirti complex 2,Nandanvan ,Nagpur		68.4	63.6	
		Narsala Main Rd, Dighori, Nagpur		62.1	71.8	
		Near Sakkardhara, Somwaripeth, Nagpur,		57.1	77.7	
		New Narsala Rd, Malagi Nagar, Ashirwad Nagar,		65.2	70.7	
		New Neharu Nagar, Sanmarga Nagar,		78.1	70.7	
		Reshim Bagh, Nagpur		72.5	-	
		Sakkardara Rd, Raghuji Nagar,		69.5	-	
		Shivsundar Nagar, Dighori, Nagpur,		61.7	68.1	

		Ayodhya nagar, Nagpur,		67.2	-	
		Vidhya Nagar, Wathoda Layout, Nagpur		67.1	74.8	
		New Diamond Nagar, Shaktimata Nagar, Kharbi		54	52.2	
		Wathoda Rd, Kharbi,		-	73.3	

Sr. No.	NMC Zone	Location	Noise Zone	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
6	GANDHI BAGH	Badkas Square Rd, Mangalwari, Nagpur,	SILENCE	50.1	45.3	50
		Ganjipeth, GANDHI BAGH, Nagpur,		63.7	65.7	
		Ram Cooler Square, Nagpur,		62.0	64.1	
		Hansapuri, Itwari Nagpur,		-	57.2	
		ChotaMominpura, Bhupesh Nagar,		57.1	49.2	
		Mangalwari, Mahal, Nagpur,		74.6	69.5	
		Central Ave, Ganjipeth, Bajaria,		53	-	
		Badkas Square Rd, Mangalwari, Nagpur,	RESIDENTIAL	50.9	52.1	55
		Chitnis Park, Mangalwari, GANDHI BAGH,		56.5	-	
		Ganjipeth, GANDHI BAGH, Nagpur,		59.6	66.8	
		Ram Cooler Square, Nagpur,		65.0	65.9	
		Hansapuri, Itwari Nagpur,		-	66	
		ChotaMominpura, Bhupesh Nagar,		52.9	-	
		Mangalwari, Mahal, Nagpur,		68.9	73.4	
		Central Ave, Ganjipeth, Bajaria,		69.8	-	

		Badkas Square Rd, Mangalwari, Nagpur,	COMMERCIAL	59.6	56	65
		Natraj Talkies Rd, Mangalwari, Mahal, Nagpur,		-	60.4	
		Chitaloli, BadkasChowk, Ghatate Wada,		66.4	-	
		Ganjipeth, GANDHI BAGH, Nagpur,		65.4	69.3	
		Ram Cooler Square, Nagpur,		61.4	66.5	
		Ansar Nagar, Itwari, Nagpur,		71.4	68.3	
		Mangalwari, Mahal, Nagpur,		71.2	-	
		Near Azam Shah ChowkMahal Road Mangalwari		51.3	-	
		Central Ave, Ganjipeth, Bajaria,		59.8	-	
		Mahal, Nagpur,		-	69.4	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
7	SATRANGIPURA	Tandapeth, Nagpur	SILENCE	47.2	57.8	50
		Binaki, Nagpur,	RESIDENTIAL	63.0	69	55
		Tandapeth, Nagpur		65.4	54.9	
		Binaki, Nagpur,	COMMERCIAL	70.8	-	65
		Kanji House Rd, Binaki, Nagpur,		78.3	-	
		Tandapeth, Nagpur		66.4	69.2	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
8	LAKADGANJ	Bhawani Hospital Pardi	SILENCE	65.2	67.1	50
		Minimata Nagar, Janki Nagar,		47.7	-	
		Nagpure Vidyalaya Bharatwada Pardi		65.2	66.9	
		Netaji Nagar, Pardi		62.8	67.8	
		Pardi, Nagpur,		61.0	-	
		Queta Colony, Lakadganj,		62.4	62.1	
		Satnami Nagar, Lakadganj, Nagpur,		72.8	-	
		Shantinagar Colony		58.1	-	
		Subhan Nagar, Pardi, Nagpur,		69.5	-	
		Babulban, Nagpur,		53.8	59.7	
		Garoba Maidan, Shashtri Nagar, Nagpur,		54.6	55.9	
		Hivri Nagar Uday Nagar, Padole Nagar,		62.2	-	
		Shiv Nagar Pardi		59.3	-	
		Netaji Nagar, Pardi	RESIDENTIAL	57.6	61.0	55
		Queta Colony, Lakadganj,		56.8	66.1	
		Subhan Nagar, Pardi, Nagpur,		51.3	-	
		Balaji Nagar Pardi		63.8	56.0	
		Bharatwada Road Kalamna		52.9	-	
		Bhawani Hospital Pardi		52.9	-	
		Bhawani Nagar, Pardi Nagpur,		68.5	-	
		Ganga Bagh Pardi		61.6	-	
		Garoba Maidan, Shashtri Nagar, Nagpur,		67.4	70.2	
		Near Hivri Nagar, Padole Nagar, Nagpur,		-	63.2	
		Pardi, Nagpur,		57.4	-	
		Satnami Nagar,		72.3	-	

		Lakadganj, Nagpur,				
		Shantinagar Colony, Nagpur,		49.0	-	
		Surya Nagar, Nagpur,		56.8	57.6	
		Babulban, Nagpur,		56.1	60.2	
		Bharatwada Pardi		51.1	55.9	
		Minimata Nagar, Janki Nagar, Nagpur,		52.5	69.6	
		Shiv Nagar Pardi		64.8	-	
		Shree Mangal Deshpande Layout, Nagpur		58.9	-	
		Bhawani Nagar, Pardi Nagpur,	COMMERCIAL	58.7	-	65
		Ganga Bagh Pardi		65.4	-	
		Shantinagar Colony, Nagpur		63.2	74.8	
		Netaji Nagar, Pardi		68.6	66.8	
		Pardi, Nagpur,		73.8	74.1	
		Satnami Nagar, Lakadganj, Nagpur,		70.2	-	
		Subhan Nagar, Pardi, Nagpur,		68.8	69.3	
		Uday Nagar, Padole Nagar, Near Hivri Nagar		63.2	-	
		Babulban, Nagpur,		63.4	60.4	
		Bhawani Hospital Pardi		74.9	-	
		Chapru Nagar, Bagadganj, Nagpur,		73.4	-	
		Garoba Maidan, Shashtri Nagar, Nagpur,		72.3	68.8	
		H.B. Town, Pardi, Nagpur,		73.3	64.4	
		Queta Colony, Lakadganj,		57.6	62.5	
		Bharatwada Pardi		50.8		
		Shiv Nagar Pardi		61.1		

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
9	ASHINAGAR	Vaishali Nagar, Nagpur,	SILENCE	49.0	49.7	50
		Ekta Colony, Yadav Nagar Nagpur,		72.8	71.0	
		Kapil Nagar, Dixit Nagar,		61.6	68.0	
		Nari Rd, Sanyal Nagar, Bank Colony,		56.8	77.0	
		New Thaware Colony, Indora		58.3	-	
		Yadav Nagar Near Jaiswal Restaurant Nagpur		53.9	-	
		Samyak Nagar, Sanyal Nagar, Bank Colony,		64.6	-	
		Bank Colony		54.2	-	
		Sujata Nagar Rani DurgavatiChowk Nagpur		70.0	-	
		Dixit Nagar, Nagpur	RESIDENTIAL	57.4	63.4	55
		Vaishali Nagar, Nagpur,		56.9	53.5	
		Samyak Nagar, Sanyal Nagar, Bank Colony,		66.9	63.0	
		Nari Rd, Sanyal Nagar, Bank Colony,		68.3	-	
		Sidharth Nagar, Nagpur		65.6	-	
		Bank Colony, NALANDA NAGAR, Bhagwan Nagar,		72.4	-	
		Thawre Colony Indora		61.7	-	
		SujataChowk, MehandhiBagh, Vaishali Nagar,		65.2	-	
		Tipu Sultan Chowk, Uppalwadi,		67.7	-	
		Panchsheel Nagar, Rani DurgavatiChowk, Nagpur		-	73.2	
		Bank Colony		62.6	-	
		Tipu Sultan Chowk, Uppalwadi,	COMMERCIAL	67.7	72.8	65
		Panchsheel Nagar, Rani DurgavatiChowk, Nagpur		72.0	73.2	
		Bank Colony		68.1	-	
		Dixit Nagar, Nagpur		67.6	71.9	
		Thawre Colony Indora		65.5	-	
		Samyak Nagar, Sanyal Nagar, Bank Colony,		66.8	-	
		Vaishali Nagar, Nagpur,		62.5	60.4	
		Ekta Colony, Yadav Nagar		69.3	-	

		Nagpur,				
		Kamal Chowk, Nagpur		72.1	-	
		Sidharth Nagar Vanjari,		72.9	60.9	
		Yadav Nagar Near Jaiswal Restaurant Nagpur		61.9	-	
		New Indora, Nagpur,		63.0	-	
		Automotive Chowk, Kamptee Rd, Bank Colony,		69.8	-	

Sr. No.	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
10	MANGALWARI	Seminary Hills, Nagpur,	SILENCE	61.9	-	50
		Civil Lines, Nagpur,		48.2	59.9	
		ZingabaiTakli, Nagpur,		48.0	59.3	
		Godhani Road, ZingabaiTakli,		65.3	-	
		New Ahbab Colony, Ring Rd, Anant Nagar		47.8	-	
		Anant Nagar, Gorewada Nagpur,		57.6	-	
		Seminary Hills, Nagpur,	RESIDENTIAL	58.3	62.2	55
		Civil Lines, Nagpur,		52.6	59.3	
		ZingabaiTakli, Nagpur		59.2	64.7	
		Mecosabagh Christian Colony		64.1	66.8	
		Godhani Road, ZingabaiTakli		50.6	-	
		Friends Colony, Narmada Colony, Nagpur		38.2	-	
		Shiv Nagar Gorewada		58.3	-	
		Mahanubhav Nagar, Gorewada, Nagpur		65.3	-	
		Rajnagar, Nagpur		51.6	61.0	
		Anant Nagar, Gorewada Nagpur,		62.5	70.5	
		Katol Rd, Narmada Colony,		54.4	46.0	
		New Mankapur, Nagpur,		54.2	-	
		Sudarshan Nagar, ZingabaiTakli, Nagpur		64.7	-	
		ZingabaiTakli, Nagpur,	COMMERCIAL	66.5	69.2	65
		Mecosabagh Christian Colony,		71.7	76.8	
		Godhani Road, ZingabaiTakli,		65.6	66.0	
		Near Calcutta Roll Centre, Sadar, Nagpur		-	68.3	
		Anna Baba Nagar, ZingabaiTakli, Nagpur		59.3	-	

		Mahanubhav Nagar, Gorewada, Nagpur		66.0	-	
		Anant Nagar, Gorewada Nagpur,		-	70.1	
		Bezonbagh, Nagpur,		67.4	-	
		Jama Masjid, Adarsh Colony, New Mankapur,		69.8	-	
		Gorewada Rd, Anant Nagar, Nagpur		62.3	66.5	
		New Ahbab Colony, Ring Rd, Anant Nagar		66.2	-	
		Shiv Nagar Gorewada		64.4	-	
		Ganpati Nagar, Sneh Nagar, ZingabaiTakli		64.8	-	

Table 4.7: **NMC zone-wise noise level of silence, residential & commercial areas-after festive season**

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
1	LAXMINAGAR	Police Nagar, Nagpur, Digdoh, Maharashtra 440016	SILENCE	51.9	-	50
		Deendayal Nagar, Nagpur, Maharashtra 440022		59.7	62.8	
		Amar Trupti Nagar, Pande Layout, Khamla, 440025		40.8	-	
		Pande Layout, New Sneh Nagar, 440025		62.0	-	
		Rajendra Nagar, Yahodha Nagar, Nagpur, Maharashtra		60.4	-	
		Parsodi, Jalvihar Colony, Near Ambazari Nagpur,		57.9	67.1	
		Hingna Rd, Yashoda Nagar, Takli Seem, Nagpur,440036		64.9	-	
		Police Nagar, Nagpur, Digdoh, Maharashtra 440016	RESIDENTIAL	55.0	-	55
		NIT Lay out, Swavalambi Nagar, Nagpur, 440022		58.2	61.3	
		NIT GARDEN, Trimurtee Nagar, 440022		57.4	55.8	
		Amar Trupti Nagar, Pande Layout, New Sneh Nagar,		-	46.4	
		Rajendra Nagar, Yahodha Nagar,		62.6	66.2	

		Yashoda Nagar, 440036				
		H.B. Estate, Sonegaon, Nagpur, Maharashtra 440025		47.6	46.8	
		LAXMI NAGAR, Near Water Tank, Nagpur, 440022		53.1	-	
		Police Nagar, Nagpur, Digdoh, Maharashtra 440016	COMMERCIAL	63.9	-	65
		Amar Trupti Nagar, Pande Layout, Khamla, 440025		64.1	-	
		Adarsh Nagar Sainath Nagar, Trimurtee Nagar, Nagpur		68.9	-	
		Sainath Nagar, Trimurtee Nagar,440022		-	71.4	
		Pande Layout, New Sneh Nagar, 440025		71.0	-	
		Hingna Rd, Rajendra Nagar, Takli Seem, Ambazari Lake		63.1	-	

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
2	DHARAMPETH	Ravi Nagar Cp Club	SILENCE	63.5	-	50
		Marartoli, Ram Nagar, Nagpur, Maharashtra 440010		53.8	58.6	
		Ravi Nagar, Uday Nagar, 440001	RESIDENTIAL	55.8	-	55
		Marartoli, Ram Nagar, Nagpur, 440010		50.8	58.9	
		Ramdaspeth, Nagpur, 440010		63.8	67.7	
		Mata Mandir Rd, Dharampeth, 440010		65.3	71.0	
		Tanga stand, Near Traffic Park, Dharampeth, 440001		62.8	69.4	
		Ravi Nagar, Uday Nagar, Nagpur,	COMMERCIAL	67.1	64.7	65
		Asha Laxmi Apartment, Ravi Nagar, Nagpur, 440010		67.0	-	
		Ram Nagar, Near Ravi Nagar 440001		61.4	-	

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
3	HANUMAN NAGAR	Medical Colony, Rameshwari, 440027	SILENCE	53.2	-	50
		Somwaripeth, Nagpur, Maharashtra 440009		62.3	57.5	
		Rambagh Rd, Rambagh, Nagpur, 440003		66.3	-	
		Dnyaneshwar Nagar, Rameshwari Nagpur, 440027		66.5	-	
		Shri Hari Nagar, Manewada 440027		67.2	-	
		Sanmarga Nagar, Hudkeshwar 440034		55.7	-	
		Rambagh, Nagpur, Maharashtra 440003		66.0	-	
		Siraspeth, Nagpur, Maharashtra 440009		52.1	58.3	
		Reshimbagh Rd, Shri Krishna Nagar, Reshim Bagh 440009		-	63.6	
		Vinkar Vasahat, Omkar Nagar, Nagpur, 440027		-	61.3	
		Medical Colony, Rameshwari, 440027	RESIDENTIAL	59.4	-	55
		Somwaripeth, Nagpur, Maharashtra 440024		65.6	60.9	
		Rambagh Rd, Rambagh, Nagpur, 440003		60.2	-	
		Shri Hari Nagar, Manewada 440027		68.9	-	
		Sanmarga Nagar, Hudkeshwar 440034		54.8	-	
		Siraspeth, Nagpur, Maharashtra 440009		54.3	72.2	
		Vinkar Vasahat, Omkar Nagar, Nagpur, 440027		-	60.5	
		Medical Colony, Rameshwari, 440027	COMMERCIAL	64.6	-	65
		Somwaripeth, Nagpur, Maharashtra 440009		63.8	62.3	
		Rambagh Rd, Rambagh, Nagpur, 440003		63.5	63.9	

		Dnyaneshwar Nagar, Rameshwari Nagpur, 440027		63.2	-	
		Shri Hari Nagar, Manewada 440027		70.8	-	
		Sanmarga Nagar, Hudkeshwar 440034		58.7	-	
		Medical Chowk, near VR mall, Rambagh, Nagpur, 440003		61.9	-	
		Siraspeth, Nagpur, Maharashtra 440009		49.6	63.1	
		Reshimbagh Rd, Shri Krishna Nagar, Nagpur, 440009		62.5	67.6	

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
4	DHANTOLI	Somalwada, Nagpur, 440015	SILENCE	63.0	-	50
		New Manish Nagar, Somalwada, 441108		66.4	59.3	
		New Manish Nagar, Somalwada, 441108	RESIDENTIAL	54.4	54.4	55
		Beltarodi Rd, Manish Nagar, Somalwada, 440015	COMMERCIAL	59.6	70.7	65

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
5	NEHRU NAGAR	Dighori, Nagpur440034	SILENCE	51.3	51.0	50
		New Diamond Nagar, Shaktimata Nagar, Kharbi,440024		59.3	-	
		Old Subhedar Layout, Jawahar Nagar, Ayodhya nagar		-	72.2	
		Ring Road, Ashirwad Nagar, 440034		65.9	-	
		Shivsundar Nagar, Dighori, Nagpur,		54.5	54.3	

		Shri Ram Nagar, New Subhedar Layout, Ashirwad Nagar,		-	64.8	
		Shri Krishna Nagar, Reshim Bagh, 440009		50.0	-	
		Darshan Colony, Nandanvan, Nagpur 440024		56.4	-	
		Gonhi		51.1	48.1	
		Nandanvan, Nagpur 440024		64.5	70.0	
		Dighori, Nagpur, Maharashtra 440034	RESIDENTIAL	53.3	64.0	55
		New Diamond Nagar, Shaktimata Nagar, Kharbi,440024		60.9	-	
		Ring Road, Ashirwad Nagar, 440034		70.5	-	
		Shivsundar Nagar, Dighori, Nagpur,		53.7	59.4	
		Shri Ram Nagar, New Subhedar Layout, Ashirwad Nagar,		-	54.6	
		Vidhya Nagar, Wathoda Layout, Nagpur, Maharashtra		56.6	56.6	
		Darshan Colony, Nandanvan, Nagpur 440024		69.0	66.3	
		Gonhi		55.0	55.7	
		Juni Shukrawari, Reshim Bagh, 440024		59.3	64.6	
		Rajendra Nagar, Nandanvan, Nagpur, 440009		69.0	-	
		Reshimbagh, Om Nagar, Azamshah Layout, 440009		52.7	-	
		Wathoda Layout, 440017		60.3	-	
		Dighori, Nagpur 440034	COMMERCIAL	65.2	64.2	65
		Gurudev Nagar, Ambika Nagar, Ayodhya nagar, Nagpur		-	-	
		New Diamond Nagar, Shaktimata Nagar, Kharbi,440024		54.2	65.8	
		New Subhedar Layout, Ashirwad Nagar, Nagpur, 440034		54.0	-	
		Ring Road, Ashirwad Nagar, 440034		66.6	-	

		Shesh Nagar, Shaktimata Nagar, Kharbi 440024		54.7	-	
		Shivsundar Nagar, Dighori, Nagpur,		55.6	50.8	
		Shri Ram Nagar, New Subhedar Layout, Ashirwad Nagar,		54.0	-	
		Bahadura Rd, Dighori, Nagpur, Maharashtra 441204		65.4	63.7	
		Darshan Colony, Nandanvan, Nagpur 440024		64.9	66.6	
		Nagpur, Gonhi, 441204		-	52.6	
		Kharbi, Nagpur, Maharashtra 440024		-	64.8	
		Sakkardara Rd, Raghuji Nagar, 440024		62.8	-	
		Vidhya Nagar, Wathoda Layout, Nagpur, 440009		-	77.5	

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
6	GANDHI BAGH	Central Ave, Mangalwari, Hansapuri, Nagpur, 440018	SILENCE	50.2	-	50
		Ganjipeth, Gandhi Bagh, Nagpur, 440018		58.5	63.8	
		Ganjipeth, Gandhi Bagh, Nagpur, 440018	RESIDENTIAL	63.1	66.3	55
		Central Ave, Mangalwari, Hansapuri, Nagpur, 440018	COMMERCIAL	46.5	-	65
		Ganjipeth, Gandhi Bagh, Nagpur, 440018		58.0	52.2	

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
7	SATARANJIPURA	Tandapeth, Nagpur 440002	SILENCE	51.6	51.6	50
		Binaki, Nagpur, 440002	RESIDENTIAL	69.3	68.8	55
		Tandapeth, Nagpur 440002		68.1	-	
		Tandapeth, Nagpur 440002	COMMERCIAL	68.0	68.0	65

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (06:00 am to 08:00pm)	Leq (08:00 pm to 10:00 pm)	CPCB Permissible Limit (dBA)
8	LAKADGANJ	Garoba Maidan, Shashtri Nagar, Nagpur, 440008	SILENCE	54.8	-	50
		Gurudeo Nagar, Nagpur, Maharashtra 440024		41.0	60.3	
		Hivri Nagar Uday Nagar, Padole Nagar, Nagpur,		57.6	55.5	
		Queta Colony, Lakadganj, 440008		66.9	58.6	
		Minimata Nagar, Janki Nagar, Nagpur, Maharashtra		46.3	50.9	
		Nagpure Vidyalaya Bharatwada Pardi		64.4	64.8	
		Balaji Nagar Pardi	RESIDENTIAL	-	61.8	55
		Pardi, Nagpur, Maharashtra 440035		-	54.0	
		Garoba Maidan, Shashtri Nagar, Nagpur, 440008		62.1	-	
		Gurudeo Nagar, Nagpur, Maharashtra 440024		47.9	-	
		Hivri Nagar Uday Nagar, Padole Nagar, Nagpur,		53.1	53.0	
		Queta Colony, Lakadganj, 440008		57.9	56.6	
		Netaji Nagar Bharatwada Pardi		45.3	45.1	
		Minimata Nagar, Janki Nagar, Nagpur, Maharashtra		47.7	-	
		Garoba Maidan, Shashtri Nagar, Nagpur, 440008	COMMERCIAL	81.3	83.4	65
		Gurudeo Nagar, Nagpur, Maharashtra 440024		56.5	-	

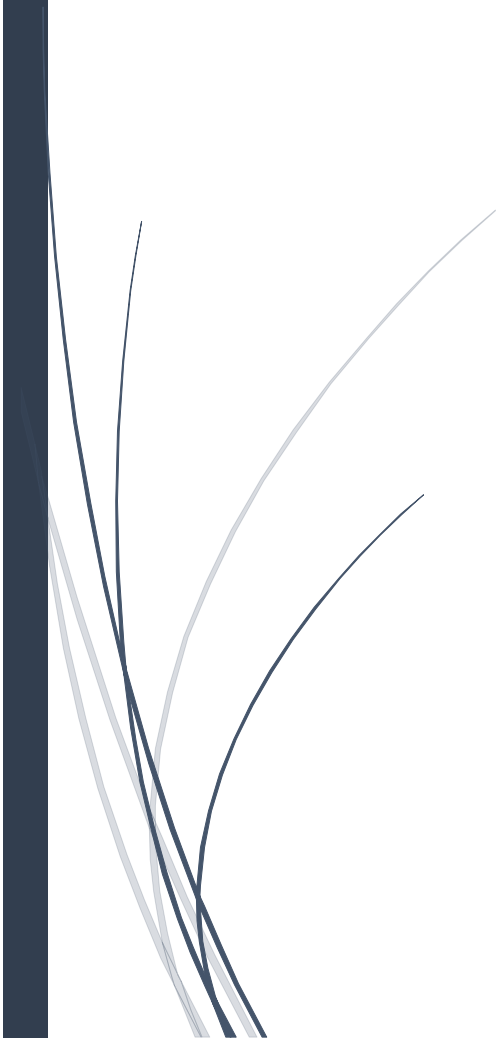
		Hivri Nagar Uday Nagar, Padole Nagar, Nagpur,		51.8	-	
		Queta Colony, Lakadganj, 440008		69.5	-	
		Kalamna Market Rd, Minimata Nagar, Nagpur,		57.1	-	
		Subhan Nagar, Pardi, Nagpur, Maharashtra 440035		69.6	68.5	

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
9	ASHI NAGAR	Kapil Nagar, Dixit Nagar, 440026	SILENCE	61.7	-	50
		Vaishali Nagar, Nagpur,440017		45.2	45.9	
		Dixit Nagar, Nagpur 440026	RESIDENTIAL	54.6	66.7	55
		Thawre Colony Indora		51.9	55.2	
		Vaishali Nagar, Nagpur,440017		56.1	58.7	
		Samyak Nagar, Sanyal Nagar, Bank Colony, 440017		53.5	66.2	
		Dixit Nagar, Nagpur 440026	COMMERCIAL	64.3	71.3	65
		Vaishali Nagar, Nagpur,440017		61.0	56.5	
		Kamptee Road, Teka Naka, Nagpur, 440017			62.6	
		Rani Durgavati CHowk, Nagpur 440018		77.2	-	
		Yadav Nagar Near Jaiswal Restaurant Nagpur 440017		66.2	-	

Sr. No	NMC Zone	Location	NOISE ZONE	Leq (6:00 AM to 8:00 PM)	Leq (8:00 PM to 10:00 PM)	CPCB Permissible Limit (dBA)
10	MANGALWARI	Seminary Hills, Nagpur, 440001	**SILENCE**	64.7	64.7	50
		Seminary Hills, Nagpur, 440001	**RESIDENTIAL**	50.5	63.2	55
		Vayusena Nagar, Nagpur, 440023	**COMMERCIAL**	78.2	78.2	65

ESR (2022-23)

Chapter 5
Solid Waste



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Municipal Solid Waste

5.1 Introduction

Solid waste is the unwanted or useless solid material generated from human activities in residential, industrial or commercial areas. There are several categories of Solid waste such as Municipal Solid Waste, C&D waste, E-Waste, Biomedical waste, hazardous waste etc. Municipal Solid Waste (MSW), commonly known as garbage or trash is a waste from everyday items that is discarded by us. Our daily activities give rise to a variety of solid wastes of different physico-chemical characteristics, which harm the surroundings unless properly managed and processed. Cleaning up of waste contamination is much more expensive compared to its prevention at every stage of possible contamination. The composition of MSW varies greatly from place to place and from time to time. It predominately includes food waste, household waste, market waste, packaging materials and products which are no longer useful. The sources can be residential, commercial, institutional and industrial. In the definition of municipal waste, the industrial waste, agricultural waste, medical waste, radioactive waste or sewage sludge are not included.

Urban areas, particularly in developing countries, struggle with the escalating challenge of providing adequate infrastructure to meet the growing needs of an expanding urban population. Consequently, the production of solid waste in a city is closely tied to its population size. The spatial expansion of the city and the volume of generated waste exhibit a proportional increase. MSW management poses a significant environmental dilemma in many cities of developing countries. Inadequate handling of MSW poses risks to both residents and the environment. It is imperative to update the solid waste management system to align with the waste's quality, quantity, and composition (Kalantarifard and Yang, 2011). Accurate quantification of the rate of waste generation and comprehensive characterization of its composition is crucial for planning and designing effective solid waste management systems in any given region (Gidarakos et al., 2006; Gomez et al., 2008).

5.2 Nagpur City Profile and Population Distribution

Nagpur, known as the winter capital of Maharashtra, stands as a significant urban center in central India. As of the official 2011 census, Nagpur city had a population of 24,05,421 and the urban agglomeration had a population of 25,23,911. The district had a sex ratio of 948 per 1000 males compared to the 2001 census figure 932. The average literacy rate was 89.52% compared to 84.03 in 2001; male literacy was 93.76% and female literacy was 85.07%. 52.5%

of Nagpur's population is in the 15–59 years age category. 10.35% of the population were under six years old. Nagpur Metropolitan Area holds the 13th spot among India's largest urban conglomerations. This fast-growing metropolis ranks third in Maharashtra, trailing only behind Mumbai and Pune.

The generation of municipal solid waste (MSW) is primarily influenced by the size of the city's population. With population growth each year, there's a corresponding increase in waste generation rates. Therefore, effective waste management systems are crucial. The city's population, recorded as 2,405,421 in the 2011 census, has likely grown in the past decade. However, since no recent census data is available, this study relies on projected population figures from 2011 to 2023. It is estimated that the current projected population of Nagpur city is around 30 lakhs. The city is divided into 10 zones and has a total number of 38 wards (**Table 5.1 & Figure 5.1**).

Table 5.1: List of different zones of Nagpur city

Zone	Name of Zonal Office
Zone 1	Laxminagar
Zone 2	Dharampeth
Zone 3	Hanuman nagar
Zone 4	Dhantoli
Zone 5	Nehru Nagar
Zone 6	Gandhibagh
Zone 7	Satranjipura
Zone 8	Lakadganj
Zone 9	Ashi Nagar
Zone 10	Mangalwari

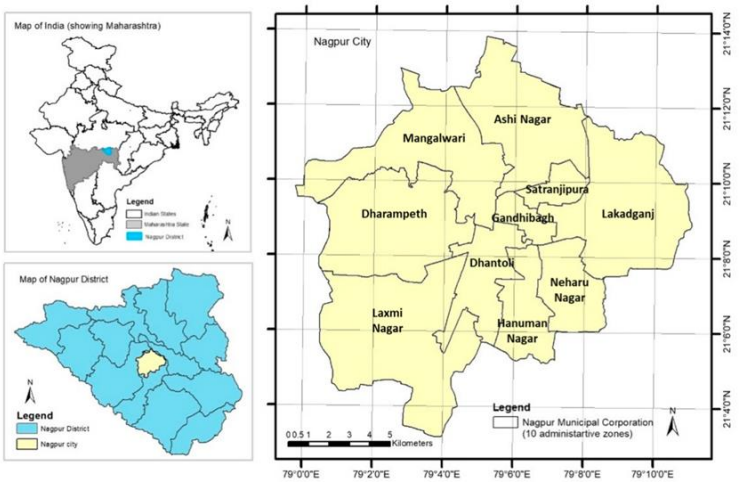

Figure 5.1: Nagpur city map (Zone-wise)

To comprehend the MSW situation in Nagpur city, it's essential to gather sufficient data to understand the patterns and fluctuations in solid waste generation rates. Accordingly, data were sourced from various departments of the NMC for this study, facilitating a comprehensive analysis.

Alongside Nagpur's rapid socio-economic development, which has significantly contributed to urbanization, the city's future growth is largely shaped by its development patterns.

5.3 Observation and Inferences

5.3.1 Current Status of Solid Waste in Nagpur city

Solid Waste in Nagpur City includes household waste from residential areas, hotels, restaurants, lawns, etc., as well as construction and demolition materials, sanitation residue, and waste from streets, hospitals, slaughterhouses, market areas, etc. The sources of waste are primarily the residential and commercial complexes.

5.3.1.1 Municipal Solid Waste

The major quantum of waste is mainly of MSW that NMC manages by the following stages:

- Generation and segregation of waste
- Collection of waste
- Transportation of waste
- Processing and disposal of waste

As per the 2021 report by MPCB, Nagpur city produced 1109.74 TPD of MSW in 2020-21. However, as per NMC, this generation rate has increased to 1315 TPD in the year 2022-23. The total annual MSW collected in the year 2022-23 was recorded to be 4,80,198 tonnes. The per capita generation of MSW is 0.438 kg.

Mostly, the wastes are disposed of at the Bhandewadi Dumping yard. NMC has been a progressive urban local body and has taken some measures for improvement of waste management in the city.

The total annual MSW generation has increased since past few years as shown in the following bar graph **Figure 5.2**.

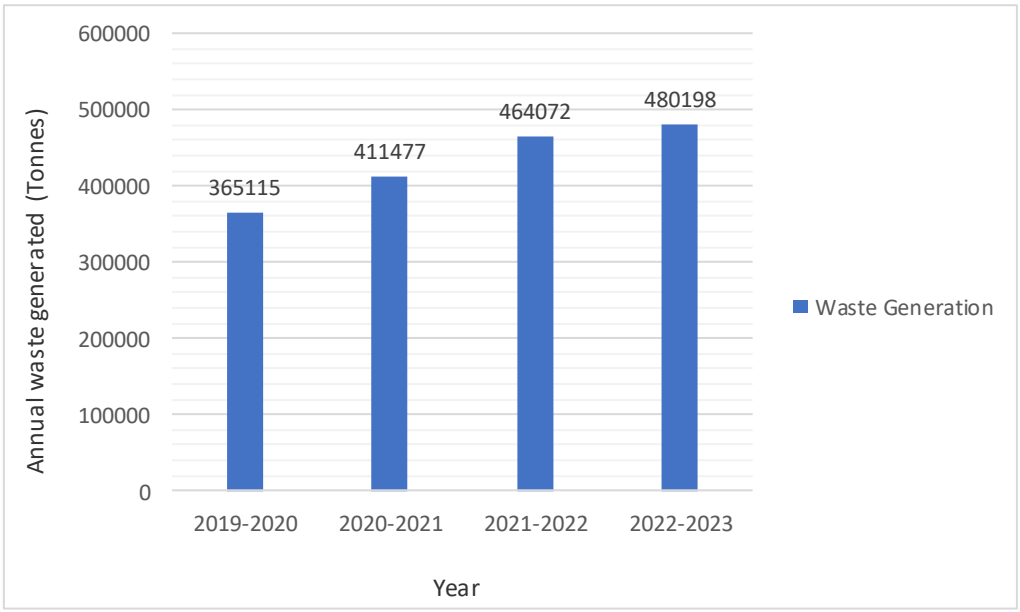

Figure 5.2: Trend in solid waste generation in Nagpur city in last four years

5.3.1.2 MSW collection and segregation

MSW collection plays a vital role in maintaining public health, preserving environmental quality, and promoting community well-being. MSW collection ensures that waste is disposed of or recycled in an environmentally responsible manner, minimizing negative impacts on public health.

The NMC has been effectively carrying out door-to-door waste collection services across all 10 zones of the city. NMC has appointed the services of two agencies, BVG India and AG Enviro, to carry out the door-to-door collection of MSW. AG Enviro Infra Pvt. Ltd. is assigned to collect waste from Zone 1 to 5 while BVG India Ltd collects waste from 6 to 10. So, for door-to-door waste collection, the number of workers from agencies is 1997. Each collection vehicle is equipped with two compartments, one designated for dry waste and the other for wet waste.

The total annual MSW collected in the year 2022-23 was recorded to be 4,80,198 tonnes. The amount of dry and wet waste collected during the year 2022-23 was 43,854 tonnes and 2,35,864 tonnes respectively. However, it has been noted that a portion of mixed waste has been found in both dry and wet waste streams, thereby impacting the processing system. Therefore, there is a need to implement robust management strategies to rectify and address this issue effectively. Additionally, roadside waste, known as sweeping waste, is collected separately which was recorded to be 22,720 tonnes.

According to officials from the NMC, there is no official transfer station established within the city. However, there must be some facility where waste is transferred from primary collection vehicles to secondary vehicles such as compactors. So, it might be beneficial for the NMC to identify and address these unauthorized facilities.

The waste collection system consists of two stages: primary and secondary collection. Different types of vehicles are utilized in each stage, with primary vehicles, including refuse collection trucks. For secondary collection, NMC has introduced specialized hydraulic vehicles such as refuse compactors and tippers, equipped with closed bodies for transferring garbage to the landfill site.

The number of door-to-door collection vehicles is around 380 and that of sweeping vehicles is 52.

NMC is continuously striving to enhance waste segregation technology and emphasizes the importance of raising awareness in society. By engaging with the community effectively, people can better understand the significance of solid waste management for their health and the environment.

5.3.1.3 Processing and disposal of MSW

Processing and disposal of MSW is crucial for safeguarding public health, mitigating environmental pollution, and promoting sustainable resource management. Proper processing helps extract valuable recycling materials, reducing the burden on landfills and conserving natural resources. Effective disposal methods, such as waste-to-energy processes and recycling, ensure the safe containment or conversion of waste, minimizing harmful impacts on ecosystems and communities. Overall, prioritizing sound MSW processing and disposal practices is essential for fostering healthier and more resilient urban environments.

The waste from Nagpur city is disposed of at Bhandewadi dumpsite. It is located in the eastern suburbs of Nagpur. This site has been operational since 1969 and is situated approximately 10 km from the city center, covering an area of 54 acres.

Currently, the NMC employs certain techniques at the Bhandewadi facility to minimize the quantum of waste disposed directly to the dump. This includes composting of biodegradable waste, with approximately 200 TPD composted in the 2022-23 period, producing 8400 tonnes of compost. The compost produced is utilized for various purposes such as gardening and farming. Additionally, the facility utilizes vermicomposting, with a capacity of 5-10 TPD. However, various techniques are required to enhance the current management practices of

biodegradable waste. Considering the significant biodegradable waste generated by markets and residential areas in the city, NMC has already signed a MoU with a Waste-to-energy company SusBDe from Netherlands to establish a biomethanation plant at the Bhandewadi facility to obtain biogas. This approach aims to efficiently manage the city's waste by tackling a larger volume through an integrated waste management strategy.

5.3.1.4 Legacy waste status at Bhandewadi dumping yard

Legacy waste refers to accumulated or historical waste that was generated in the past and remains untreated, unmanaged, or improperly managed for an extended period. This term typically applies to waste materials that were disposed of before the implementation of modern waste management practices or regulations. Legacy waste may include various types of solid waste, such as household trash, industrial by-products, and construction debris, which can pose environmental and public health risks if not properly addressed.

NMC has taken a major initiative to deal with this legacy waste. To clear the legacy waste heaps from Bhandewadi, NMC appointed M/s Zigma Global Environ Solution Private Limited for the biomining of legacy waste accumulated at Bhandewadi. The operation of biomining was started from 2019 and until 2023 M/s Zigma Global Environ Solutions Pvt Ltd has biomined about 16 lakh metric tonnes of legacy waste and reclaimed around 64 acres of area. A significant portion of the waste is being utilized to produce refuse-derived fuel (RDF), supplied to cement factories. Additionally, the process also yields soil that can be provided to farmers.

5.3.2 Bio-medical Waste (BMW) and its Management

Nagpur possesses a well-organized system for the disposal and treatment of Biomedical Waste (BMW). The BMW is collected from 2675 biomedical institutions including hospitals and pathology labs in Nagpur. Around 1705 tonnes of biomedical waste was collected in year 2022-23. The collected BMW is sent to Bhandewadi Biomedical Waste Plant for disposal through the process of incineration.

5.3.3 Electronic Waste Management in Nagpur City

The issue of E-waste, which is intertwined with MSW, poses a complex challenge. The E-waste management is mainly undertaken by the informal sector. Additionally, there is no established collection system for E-waste by NMC, nor have any agencies been designated for

its collection and disposal. However, certain private door to door collection camps from NGOs have be organized to collect the e-waste. The lack of policies and inadequate planning exists in the current scenario and needs to be addressed as some E-waste becomes mixed with regular garbage during the collection process. Consequently, E-waste is disposed of in an unscientific manner, posing health hazards and contributing to environmental pollution. Hence, strict implementation of E-waste Management Rules, 2016 has to be implemented in the city.

5.3.4 Construction & Demolition Waste (C&D)

As Nagpur continues to expand, its infrastructure undergoes daily growth, underscoring the critical need for effective management practices to accommodate this development sustainably. With the city's increasing infrastructure demands, meticulous planning and oversight becomes imperative to ensure optimal utilization of resources and minimize potential challenges associated with rapid urbanization. So NMC has initiated the separate collection and disposal of Construction and Demolition (C&D) waste. Construction and demolition waste can have significant environmental impacts, including habitat destruction, soil erosion, and air and water pollution. Improper disposal of materials such as concrete, wood, metals, and chemicals can contribute to the contamination of soil and water bodies, while demolition activities can disrupt ecosystems and wildlife habitats. Additionally, the large volume of waste generated from construction and demolition activities can exacerbate landfill capacity issues.
NMC has implemented the Brown line specifically for the collection and transportation of C&D waste. In the year of 2022-23 around 150 TPD C&D waste was collected. Currently M/s Hyderabad C&D waste Pvt. Ltd. agency is engaged in processing of C&D waste. The final destination of C&D waste of the city is the Bhandewadi C&D waste processing plant.

5.4 Bhandewadi Dumping Site

Initially, the disposal of MSW took place at various scattered sites across the city. Since 1969, Bhandewadi dumpsite is operational approximately 10 km away from the city's centre (**Figure 5.3**). The geographical coordinates of the Bhandewadi landfill site are 21º08'26.1" N latitude and 79º07'13.8" E longitude, situated at an elevation of 314.79 meters above Mean Sea Level (MSL). This site receives waste from residential, commercial, institutional, and market areas. The NMC owns approximately 184.22 hectares of land, with around 21.57 hectares designated for MSW disposal. An additional 19.64 hectares of land is utilized for activities such as

composting and installing weighbridges. The layout of the Dumpsite as provided by NMC is given in the **Figure 5.4**.

Figure 5.3: Bhandewadi dumping site

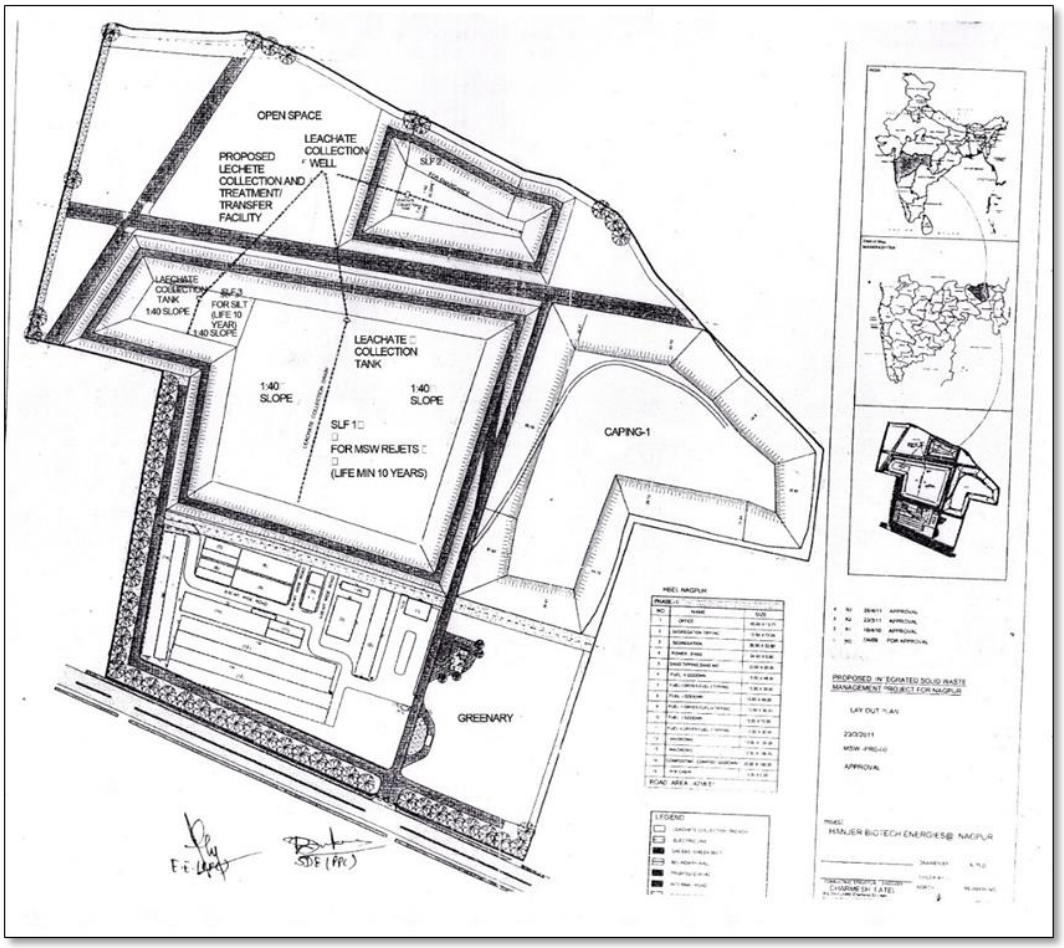

Figure 5.4: Bhandewadi layout map (Source: NMC)

5.5 Role of informal sectors in waste management

The informal sector is characterized by labor-intensive, small-scale, private, and unregistered activities that involve low-technology production or the provision of services and supplies. In

India, the informal sector has played a crucial role in waste management systems, and there is a need for its integration into the formal sector (Kumar et al., 2017). Waste pickers, numbering in the hundreds to thousands and scattered throughout the city, are integral to the process. They collect household, commercial, and industrial waste, separating items with potential value from waste bins, streets, trucks, waterways, and dumpsites. The practice of recovering useful components from waste is a sustainable waste management approach, as the economic value of waste can only be realized through source segregation (Agbefe et al., 2019). Waste pickers rely on waste for their income, despite the associated health and social challenges. Initiatives have been undertaken to process city waste, including composting and the creation of Refused Derived Fuel, with assistance from private operators. The private sector's involvement in waste management has been enhanced through public-private partnership (PPP) activities, and the informal sector, particularly in waste collection, has significantly expanded its participation. The result of these efforts is the essential engagement of the informal sector in the collection of metal and plastic waste for recycling and reuse.

5.6 Recommendations: Sustainable Solid Waste Management

- Encourage and educate residents to segregate waste at the source into categories such as organic, recyclable, and non-recyclable. Foster a sense of responsibility and ownership among residents towards maintaining a clean and sustainable environment.
- Invest in the modernization of waste collection infrastructure, waste collection vehicles, and establishment of transfer stations.
- Implement a systematic and efficient door-to-door segregated waste collection system.
- Promote and establish composting facilities at all the bulk generators (generating more than 100kg) at the community levels as per SWM rules 2016 to reduce the burden on dumpsite and encourage the use of compost in gardens and green spaces in the surrounding.
- Coordinate with different recycling units for processing recyclable materials like paper, plastic, glass, and metal. Collaborate with recycling industries and support the development of a market for recycled products.
- Keep track of all the existing recycling units across the city and regular data monitoring

- Implement a robust monitoring system to track waste management practices and ensure compliance with regulations.
- Explore the use of technology, such as smart waste bins, to optimize waste collection routes and schedules.
- Implement a digital platform for reporting and resolving waste management issues, facilitating communication between residents and municipal authorities.
- Foster partnerships with academic institutions for research and innovation in sustainable waste management practices.

Implementing a combination of these recommendations can contribute to the improvement of municipal solid waste management in Nagpur. It's crucial to have a holistic and integrated approach involving the community, local authorities, and various stakeholders.

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ESR (2022-23)

Chapter 6
WATER ENVIRONMENT

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6.0 Introduction

Nagpur is Maharashtra's third-largest city which is situated near the geographic center of the quadrilateral. The plateaus of the Satpura range surround Nagpur; the hills are forested in the west, while the hills of Ramtek cover the northeast. Kanhan and Pench Rivers are in the center, Wardha in the west and the Wainganga in the east. Wardha and Wainganga rivers later merge as tributaries into the Godavari River. These rivers divide the city into three parts. The Pench-Kanhan river system includes the Nag River. The Pilli River runs through the district, merging with the Nag River near Pawangaon before joining the Kanhan River in Wainganga. Pora is the third river of the city, which flows towards the southeast part of the city. The three rivers meet at the outskirts of Nagpur. They then flow into Gosikhurd Dam in Maharashtra, with a capacity of 1,146 million cubic meters.

The chapter on water environment discusses the current status of surface water bodies (rivers and lakes) and groundwater with reference to its water quality. The chapter presents the analysis of water samples from three rivers (Nag, Pilli, and Pora) and eight lakes (Sonegaon, Futala, Gorewada, Ambazari, Binaki, Naik, Sakkardara, Pandharabodi) in addition to twelve ground water sources (dugwells and borewells). The samples have been characterized for their physico-chemical composition and bacterial load of coliforms along with the aquatic biological parameters (phytoplanktons and zooplanktons).

6.1 Methodology

Data related to following was obtained from secondary sources as given below;

- Water supply systems - provided by Nagpur Municipal Corporation (NMC)
- Water supply and point of use water quality- provided by NMC
- Sewage Management and Sewage Treatment Plant- provided by NMC

Analysis of different physio-chemical and bacteriological parameters for surface waters from sampled rivers, lakes, and groundwater was performed as per Standard Methods (APHA, 2005). **Table 6.1** shows the different methods used for characterization of water samples;

Table 6.1: Standard methods used for physico-chemical, bacteriological, benthic analysis of surface and ground water (APHA, 2017)

Sr. No.	Parameter	Standard Method used / Number
1.	Chemical Oxygen Demand (COD)	Closed reflux method / 5220
2.	Biological Oxygen Demand (BOD)	3-day BOD Test / 5210
3.	Dissolved Oxygen (DO)	Electrochemical (diaphragm electrode method) / 4500-O
4.	Total Kzeldahl Nitrogen (TKN)	Titrimetric with preliminary Distillation/Digestion / 4500-N
5.	Phosphate as P	Stannous chloride method / 4500-P D
6.	pH	Potentiometric method (pH meter) / 4500-H^+B
7.	Total Dissolved Solids (mg/L)	Gravimetric method / 2540-C
8.	Turbidity (NTU)	Nephelometric method / 2130-B
9.	Total Alkalinity as $CaCO_3$ (mg/L)	Titrimetric method / 2320-B
10.	Chloride as Cl^- (mg/L)	Argentometric method / 4500-Cl^--B
11.	Sodium	Flame photometric method / 3500 Na B
12.	Potassium	Flame photometric method / 3500 K B
13.	Fluoride	Electrode method / 4500 F C
14.	Total hardness	Titrimetric method / 2340 C
15.	Calcium	EDTA Titrimetric method / 3500 Ca B
16.	Magnesium	EDTA Titrimetric method / 3500 Mg B
17.	Nitrate	UV Spectrophotometric method / 4500 NO_3 B
19.	Bacteriological analysis (total and fecal coliforms)	Membrane filteration technique / 9222
20.	Benthic (Phyto- and zooplanktons)	Microscopy / 10200
21.	(i) Well locations & (ii) Ground water level	(i) By GPS (ii) Automatic water level indicator (Model-EPP-10/6) manufactured by M/s ENCARDIO-RITE ELECTRONICS PVT LTD)
22.	Heavy metals in ground water	ICP-OES (Model: iCAP 6300 DUO, Make: Thermo Fischer)

6.2 Observation and Inferences

6.2.1 Water supply and point of use water quality

As per information provided by NMC, the city has five water treatment plants (WTPs) with an existing water supply system of a total capacity of 786 MLD, i.e., Pench I WTP of 136 MLD; Pench II WTP of 175 MLD; Pench III WTP of 120 MLD; Pench-IV WTP of 115 MLD and Kanhan WTP of 240 MLD, respectively. The maximum water is received from Pench Dam. The water is supplied to the city from 73 operating command areas (CAs) consisting of GSR/ESR/MBR, through pipelines connecting the ten water distribution zones. The Gross

Water Demand of the city in the year 2022-23 was of 680-700 MLD as reported by NMC. Of the 680-700 MLD water supplied to the city, leakages in pipeline transporting raw water resulted in a 47% loss of water daily. This water which was lost during transportation and remained unbilled was the non-revenue water (NRW), while the total volume of water which reached the consumers and was billed for the period Apr-2022-Mar 2023 was 377.454 MLD (pure water supply of 250.679 MCM) (NMC Month-wise statement of water supplied and billed- **Table 6.2**).

There is a need for NMC to make efforts for reducing the NRW by plugging the leakages in transport pipelines, and increase the billed water.

Table 6.2: Month-wise statement of water supplied and billed by NMC in 2022-2023

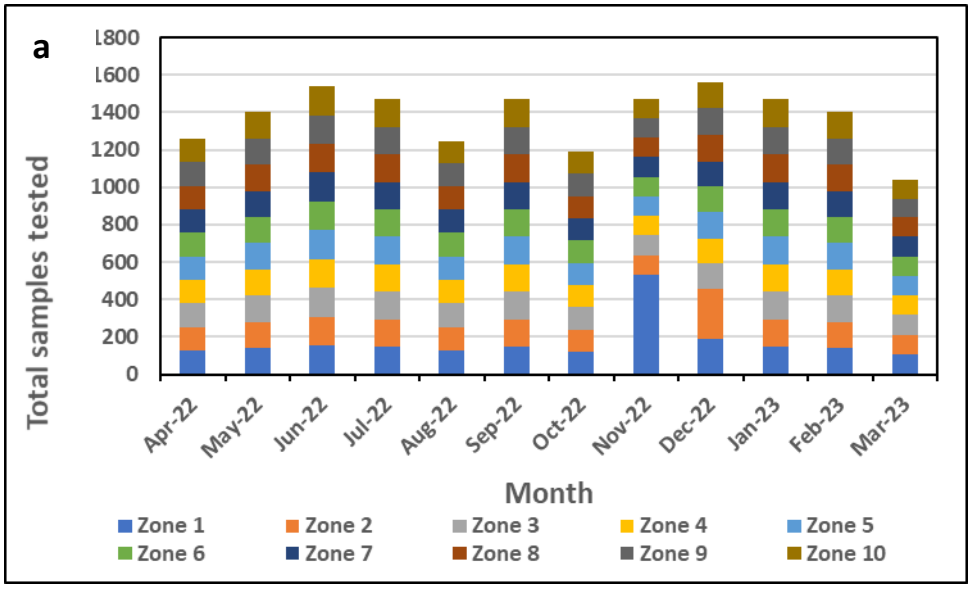
Month	Pure water supply in MM^3
Apr-22	20.788
May-22	21.867
Jun-22	21.007
Jul-22	20.348
Aug-22	20.507
Sep-22	20.227
Oct-22	21.043
Nov-22	20.077
Dec-22	21.419
Jan-23	21.375
Feb-23	19.622
Mar-23	22.392
Total	250.679 MCM
Volume billed	377.454 MLD

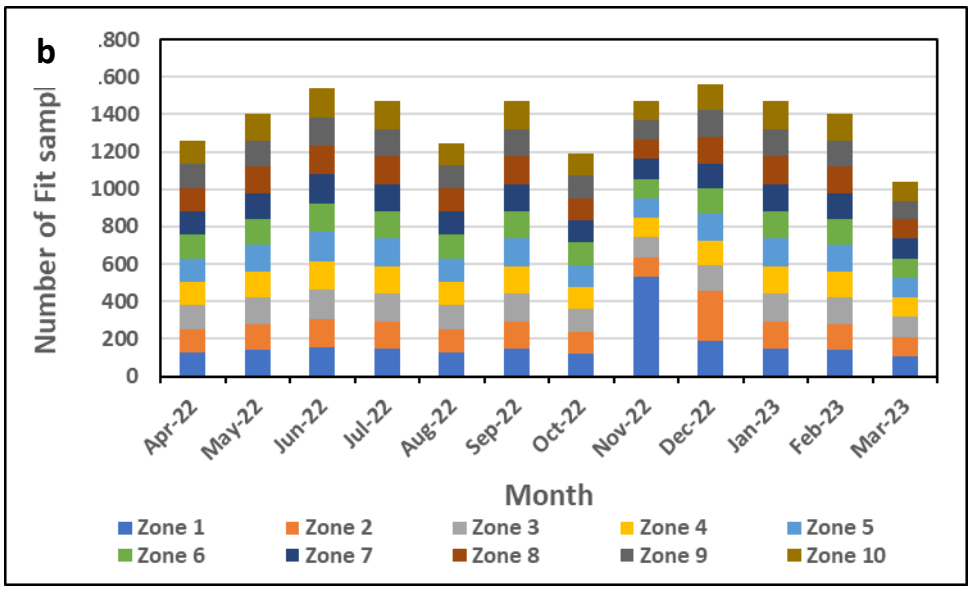
The 24x7 water supply program initiated by Nagpur Municipal Corporation (NMC) to address the city's unequal water supply was sanctioned for 704 km under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) (ESR report, 2020-2021). 377.84 km pipeline was to be laid under the Atal Mission for Rejuvenation and Urban Transformation-1 (AMRUT 1) scheme while remaining (271 km) will be covered under the AMRUT 2.0 scheme. As informed by NMC, the tenders for first phase were invited and so far, the physical progress upto March 2023 shows that work for laying of 345.5 km pipeline had been completed under the AMRUT 1 scheme. The newly laid pipeline has resulted in reduction of number of tankers employed by NMC for supply of water to different parts of the city, from 346 in 2016 to 193 in

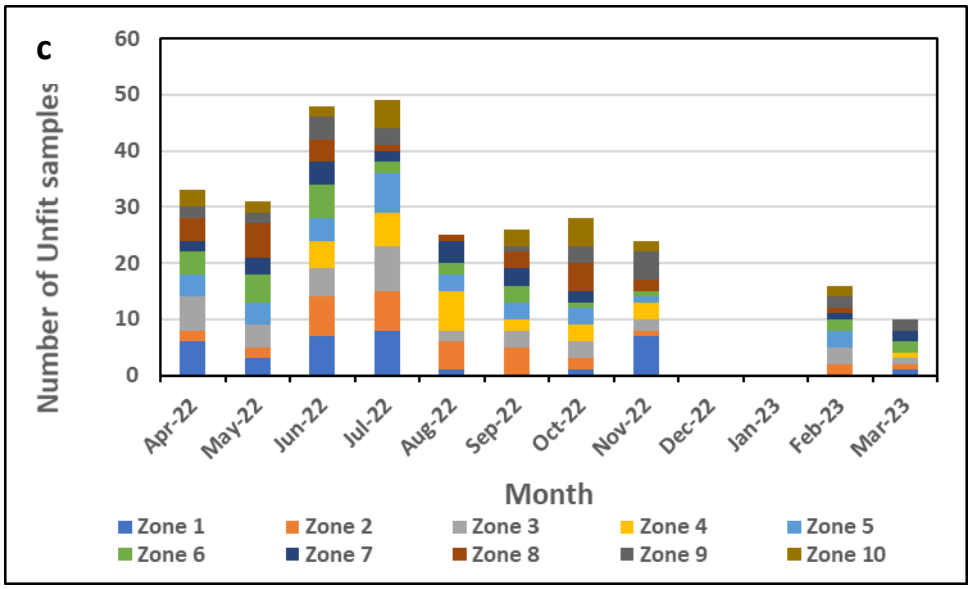
2023. Despite the progress of this scheme, there are certain areas under 39 CAs were considered as dark zones since the water supply was found to be less than 2 h per day.

There was a need for early initiation of the 2nd phase of laying of remaining pipeline for reduction in the number of tankers for supplying water to the different areas of Nagpur city, and effective implementation of the 24x7 water supply program (NESL-NMC, 2023).

As reported by NMC, the water quality was tested by the Regional Public Health Laboratory, Nagpur every month to ensure bacteriologically safe and potable water at the point of use and the results are presented in **Figure 6.1.** It can be observed that out of 16515 point of use samples analyzed, 16225 (98.23%) samples were found to be fit and 290 (1.77%) samples were found to be unfit for drinking as per bacteriological testing performed throughout the year (April 2022-Mar 2023).







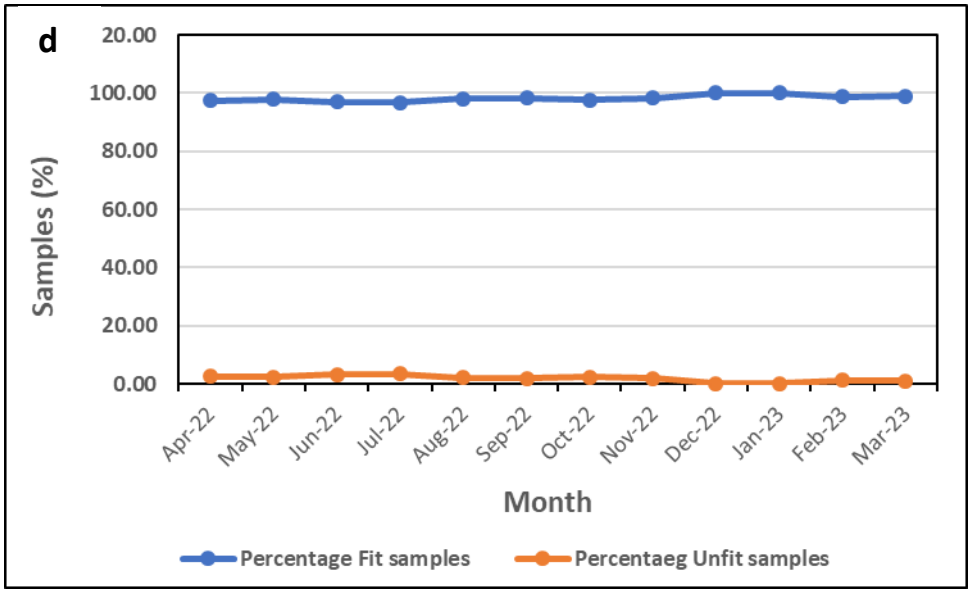


Figure 6.1: Zone-wise monthly bacteriological analysis of water (a) Total samples tested (b) Number of Fit samples (c) Number of unfit samples (d) Percentage of fit and unfit samples (Source: NMC)

6.2.3 Sewage Management and Sewage Treatment Plant

Of the 680-700 MLD of freshwater supplied every day, about 80% (520 MLD) is converted to sewage, of which 75% (403.5 MLD sewage) is treated at 13 STP's operated by NMC across different locations of city **(Figure 6.2** and **Table 6.3)**. There was a need for treating sewage and reusing it to bridge the gap of sewage generation and treatment. NMC should assess the actual quantity of sewage generated daily, since the present scenario does not take into account

the water losses during supply and the supply of water from alternate sources. As informed by NMC, the additional sewage treatment capacities being develop under the JICA scheme (92 MLD), and AMRUT 2.0 scheme (35 + 10 MLD) are likely to bridge the gap between the sewage generation and treatment.

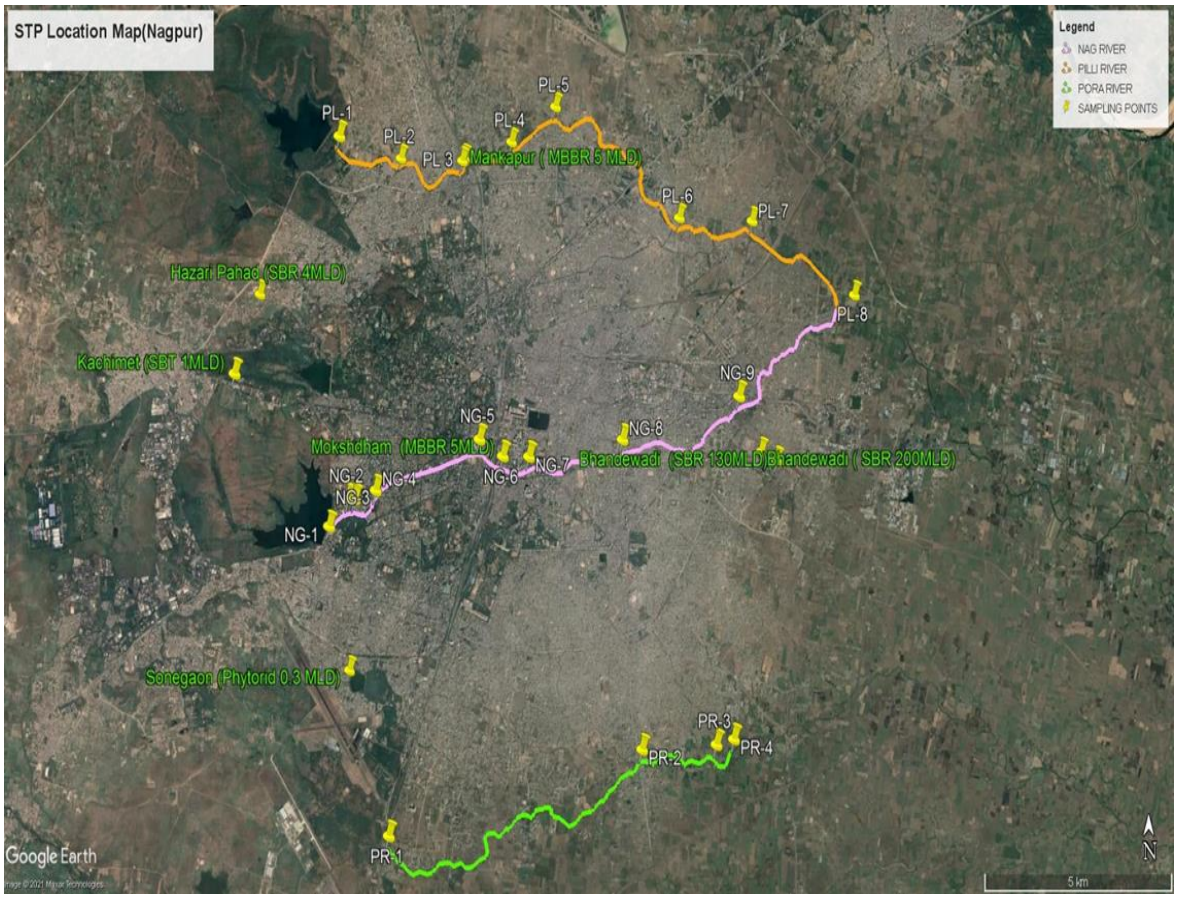


Figure 6.2: Sampling location of river along with Sewage Treatment Plant (STPs) of the city

Table 6.3: Details of Sewage Treatment Plants run by NMC

Location of STP	Coordinates of STP (Latitude and Longitude)	STP Commissioned in (year)	Status (Operational/Non-Operational/Under Constructio	STP Installed Capacity (MLD)	Actual utilization of installed capacity (MLD)	Technology (UASB/ASP/OP/SBR/MBR/FAB etc.)	Consent Status
Bhandewadi, Nagpur	21.1378096: 79.1590347	2016	Operational	130	130	SBR	Consent to operate received by MPCB Mumbai for all 12 STPs on 15.12.2022, valid upto 30.04.2027
Bhandewadi, Nagpur	21.1381883: 79.155832	2018	Operational	200	200	SBR	
Mokshdham, Nagpur	21.137628: 79.088943	2017	Operational	5	5	MBBR	
Mankapur, Nagpur	21.190320: 79.079131	2017	Operational	5	5	MBBR	
Somalwada-1	21.086964: 79.074979	2021	Operational	20	20	SBR	
Hazaripahad	21.166345: 79.026774	2019	Operational	4	4	SBR	
Dabha	21.171881: 79.011537	2018	Operational	5	5	SBR	
Sonegaon	21.099773: 79.049576	2019	Operational	0.3	0.3	Phytorid Technology	
Kachimet	21.15095: 79.020094	2018	Operational	1	1	Soil Bio Technology	
Somalwada-2	21.088322: 79.07091	2022	Operational	20	20	SBR	
Itabhatti	21.172177: 79.121171	2022	Operational	10	10	SBR	
Ambazari	21.129474: 79.018274	2021	Operational	3.2	3.2	Phytorid Technology	
Narsala	21.087: 79.192	WIP	Under Construction	20	20	SBR	

The details of the 13 STPs, their process flow diagrams and the type of reactors used have been given in an earlier report (ESR report, 2020-2021).

6.2.4 Surface water quality: Lakes

6.2.4.1 Lake Water Quality: Physico-Chemical

The city of Nagpur has 11 lakes. The site-specific scenarios in and around the few lakes are evident from **Figure 6.3 & Table 6.4**. The present study explored the water quality of eight significant lakes: Sonegaon Lake, Futala Lake, Gorewada Lake, Ambazari Lake, Binaki Lake, Naik Lake, Sakkardara Lake, Pandharabodi Lake. Sampling was not done at Gandhi Sagar lake

(Shukrawari / JummaTalav), Police line Takli lake, and Lendi lake. As informed by NMC, these lakes were under various stages of development and rejuvenation work including desilting and desludging, walking track, rainwater drain, edge wall, retaining wall, malvahini, yoga shed and visarjan tank, under various schemes and funding sources such as development of basic facilities, 15th Finance Commission, AMRUT 2.0 respectively. Similar development work had been sanctioned and was in different stages of progress, or was proposed under these schemes, with desilting and desludging being an important activity which could lead to increase in water storage capacity of the lakes.

On the banks of these lakes, slum settlements use the lake water for washing, bathing and other domestic activities. Nagpur Municipal Corporation (NMC) has always been proactive to protect these lakes from being polluted due to local activities. To generate lake water quality scenario in the city, a total of 17 sampling locations were selected for examination depending on accessibility and size of lakes viz.: 2 from Sonegaon Lake, 5 from Futala Lake, 2 from Gorewada Lake, 4 from Ambazari Lake, 1 from Binaki Lake, 1 from Naik Lake, 1 from Sakkardara Lake, 1 from Pandharabodi Lake. **Table 6.4** gives the details of sampling locations of the lakes under study along with observations of anthropogenic activities around the lake.

The water quality of Sonegaon, Futala, Gorewada, Ambazari, Binaki, Naik, Sakkardara and Pandharabodi lakes pertaining to physico-chemical parameters, COD, BOD are presented in **Tables 6.5 & 6.6**, respectively. The pH range of 7.35-8.92 was noted in Sonegaon, Futala, Gorewada, Ambazari, Binaki, Naik, Sakkardara and Pandharabodi lake water bodies. Total Alkalinity (Carbonates) and Total Hardness were found in the range of 235-765 mg/L and 70.15-201.3 mg/L, respectively in the lakes. Sulphates and Nitrates were found in the range of 25.7-467.19 mg/L and 0.24-4.81 mg/L, respectively in the lakes. One water sample collected from Sakkardara Lake (Sample code SD-1) had sulphates exceeding the permissible limit of the BIS drinking water standards 10500:2012, which was about 467.19 mg/L. The concentrations of Sodium and Potassium were in the range of 17.21-97.94 mg/L and 6.16-39.67 mg/L, respectively in all the lakes. Sodium and Potassium contents had increased in water samples collected from Sonegoan, Futala, Aambazari, Naik and Sakkardara lakes. Binaki Lake (Samples codes: BK-1) Naik Lake (Sample code: NK-1) had COD above 100 mg/L. The COD concentration was found in the range of <100 mg/L in remaining lakes, whereas the BOD concentration was found in the range 8-91 mg/L. BOD was observed to be maximum (91 mg/L) in Naik Lake (Sample code: NK-1) as compared to other lakes. It is seen that the levels of Total Hardness and nutrient load in terms of phosphates were found to have

increased in the samples from all the lakes compared to the previous year. The nutrient load in the lake waters could support the growth of weeds such as *Eichhornia* (water hyacinth) as was observed from the extensive growth of these floating plants especially in Ambazari lake. CSIR-NEERI took the initiative to deploy the airboat "Jaldost" developed by its sister lab, CSIR-National Aerospace Laboratories (CSIR-NAL) for clearing the weeds (water hyacinth) and garbage from Ambazari Lake.

6.2.4.2 Lake Water Quality: Bacteriological

Microbial quality of Sonegaon, Futala, Gorewada, Ambazari, Binaki, Naik, Sakkardara and Pandharabodi lakes, under study was investigated and the water samples were analyzed for bacterial indicator organisms viz; Total Coliforms (TC) and Fecal Coliforms (FC) using Membrane Filter Technique culture-based method. Samples were collected and analyzed as per Standard Methods for the Examination of Water and Wastewater (APHA, 2017). Standard volumes of 100 mL, 50 mL, and 10 mL were used for dilution of samples. Water samples were filtered through membrane filtration assembly in which membrane was placed on specific media plates for detecting and enumerating coliforms. For enumerating thermotolerant coliforms, media plates were incubated at 44.5℃ + 0.2℃ for 24 hours. To meet the desired minimum colony count, dilutions of samples were done.

Analysis results showed that Total Coliforms were found to be in the range of 1 x 10^4 (10000 CFU/100mL) to 24 x 10^4 (240000 CFU/100mL) and Thermotolerant Coliforms (Fecal coliforms-FC) were found in the range of 1 x 10^4 (10000 CFU/100mL) to 11 x 10^4 (110000 CFU/100mL), respectively, in all the eight lakes. Samples collected from Binaki Lake (BK-1) and Naik Lake (NK-1) showed highest number of TC (BK1-200000 CFU/100mL; NK1-2400000 CFU/100mL) and FC (BK1-110000 CFU/100mL; NK1- 80000 CFU/100mL). Samples from Sonegaon, Futala, Gorewada, Ambazari, Sakkardara and Pandharabodi lakes also showed significant numbers of total coliforms (TC) and thermotolerant coliforms (fecal coliforms-FC) as is evident from **Table 6.7.**

Public toilets were observed to be located adjacent to the Naik Lake. Stray animals like pigs were observed to be loitering in the vicinity of the lake. Animal faeces were observed near the lakeside, which are the main and direct source of fecal contamination. Observation shows that the surrounding areas of these lakes were used for household chores and washing purposes by the habitants in the vicinity. Immersion of idols, plastic bottles, diyas and flower garlands were observed on the bank of all the lakes, which might have led to contamination of the lakes with

respect to Total Coliforms and other pathogens posing pollution in the lakes. Stale foodstuff and household solid waste was found to be strewn along the banks of all the lakes. Alongside, animals like goats, stray dogs, pigs and aquatic birds were observed which may be the main cause of fecal coliform contamination (**Table 6.3**).

Figure 6.3: Prominent lakes of Nagpur

Table 6.4: Sampling location details of lakes of Nagpur city

Sr. No	Sample Code	Sample Details / location details	Sources	Latitude	Longitude	Other Observations
1	SG-1	Near Inlet	Lake	21°05'54.0"N	79°03'01.0"E	Plastics, Papers and others
2	SG-2	Near Temple	Lake	21°05'58.8"N	79°03'15.7"E	Plastics, Papers and others
3	FL-1	Near Inlet	Lake	21˚09′06″N	79˚02′37″E	*Eichhornia*, Fishes.
4	FL-2	Near Pump House	Lake	21˚06′09″N	79˚02′31″E	Greenish water, Fishes
5	FL-3	North Japanese Garden	Lake	21˚09′17″N	79˚02′30″E	Greenish water, Fishes
6	FL-4	Centre Point	Lake	21˚09′15″N	79˚02′34″E	Greenish water, Fishes
7	FL-5	Near Outlet	Lake	21˚09′20″	79˚02′41″	Greenish water, Fishes
8	GD-1	Near Inlet	Lake	21˚11′37.79″N	79˚02′27.84″E	Anthropogenic Activities-Fishing, Worship materials, plastics etc.
9	GD-2	Near Outlet	Lake	21˚11′48.84″N	79˚02′39.48″E	Anthropogenic Activities-Fishing, Worship materials, plastics etc.

10	AZ-1	Near Inlet	Lake	21°07'47.2"N	79°02'43.8"E	*Eichhornia*, Anthropogenic Activities- Fishing.
11	AZ-2	Near Outlet Behind Swami Vivekanand Smarak	Lake	21°07'31.9"N	79°02'34.8"E	*Eichhornia*, Fishes, surrounded areas water clean.
12	AZ-3	Centre Point, Near Pump House	Lake	21°07'39.8"N	79°02'28.3"E	Greenish water, Fishes, surrounded areas was clean
13	AZ-4	Near CCRI Pump House	Lake	21°08'06.9"N	79°02'24.4"E	*Eichhornia*, Greenish water, Fishes, surrounded areas was clean
14	BK-1	Near Saibaba Panch Committee Devasthan	Lake	21°10'09.2"N	79°07'17.7"E	Garbage, worship materials, people swimming
15	NK-1	Lalganj chakna, chowk, near naik talaw	Lake	21°09'45.0"N	79°06'47.8"E	Anthropogenic Activity- Worship materials, Flowers, oil lamps, pots and leaves etc.
16	SD-1	Near Sakkardara Lake Garden Lawn	Lake	21°07'15.8"N	79°06'54.1"E	Green Floating leaves
17	PD-1	Behind Tennis Court	Lake	21°08'33.3"N	79°03'03.0"E	Open defecation, plastics

***Note- SG - Sonegaon Lake; FL-Futala Lake ; GD- Gorewada Lake; AZ - Ambazari Lake; BK- Binaki Lake; NK- Naik Lake;SD - Sakkardara Lake; PD- Pandharabodi Lake.**

Table 6.5: Water quality of lakes of Nagpur city: Physico-chemical parameters

Sr. No	Sample Code	pH	EC	TDS	Total Alkalinity	Total Hardness	Calicum as Ca^{2+}	Magnesium as Mg^{++}	Sodium (Na^{+})	Potassium (K^{+})	Fluoride	Chloride	Sulphate SO_4^{2-}	Nitrate as N
Units		**-**	**µS/cm**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
BIS 10500:2012 (Acceptable/ Permissible limit)		**6.5-8.5**	**-**	**500-2000**	**200-600**	**200-600**	**75-200**	**30-100**	**-**	**-**	**1.0-1.5**	**250-1000**	**200-400**	**45**
1	SG-1	8.83	479	301	245	85.4	28	8.51	32.92	7.71	0.26	32.49	92.5	4.81
2	SG-2	8.92	372	238	290	88.45	22	10.94	32.05	8.16	0.25	32.49	87.82	4.52
3	FL-1	8.46	412	262	330	100.65	36	9.11	24.77	7.59	0.18	37.49	29.07	0.96
4	FL-2	8.43	402	257	315	109.8	46	7.9	25.54	7.35	0.18	37.49	37.61	0.61
5	FL-3	8.44	400	257	325	85.4	32	7.29	24.78	7.14	0.17	42.49	46.26	0.7
6	FL-4	8.46	397	254	305	100.65	30	10.94	24.8	7.17	0.17	37.49	60	0.49
7	FL-5	8.45	399	256	390	97.6	42	6.68	25.41	7.55	0.18	42.49	25.73	0.25

8	GD-1	8.77	279	178	240	76.25	22	8.51	17.24	6.16	0.21	22.49	46.15	1.74
9	GD-2	8.84	277	178	235	73.2	30	5.47	17.21	6.26	0.2	22.49	33.44	3.17
10	AZ-1	8.44	385	245	255	100.65	30	10.94	38.29	8.75	0.19	47.49	31.15	0.77
11	AZ-2	8.42	389	247	260	70.15	26	6.08	37.7	8.27	0.19	52.48	39.28	0.84
12	AZ-3	8.71	378	242	290	73.2	44	1.22	38.17	8.51	0.19	47.49	33.23	0.3
13	AZ-4	8.66	380	242	260	97.6	40	7.29	35.98	8.66	0.19	42.49	73.44	0.83
14	BK-1	7.35	973	620	670	149.45	44	16.4	97.94	39.67	0.28	102.47	264.48	1.91
15	NK-1	7.81	1173	748	765	201.3	58	22.48	97.79	37.16	0.23	97.47	236.57	0.47
16	SD-1	7.93	819	525	360	152.5	46	16.4	94.41	12.07	0.39	72.48	467.19	0.24
17	PD-1	8.46	518	331	275	82.35	34	6.08	46.83	15.63	0.17	87.47	111.67	0.62

***Note- SG - Sonegaon Lake; FL-Futala Lake ; GD- Gorewada Lake; AZ - Ambazari Lake; BK- Binaki Lake; NK- Naik Lake;SD - Sakkardara Lake; PD- Pandharabodi Lake.**

Table 6.6: Water quality of lakes of Nagpur city: Organic and nutrient parameters

Sr No.	Sample CODE	DO (mg/l)	COD (mg/l)	BOD (mg/l)	TKN as N (mg/l)	Phosphate as P (mg/l)
1	**SG-1**	6.14	82	22	5.25	0.53
2	**SG-2**	6.34	64	15	6.3	0.51
3	**FL-1**	5.90	36	8	1.05	0.45
4	**FL-2**	6.32	42	10	1.4	0.4
5	**FL-3**	6.21	45	10	1.75	0.61
6	**FL-4**	5.81	44	10	1.05	0.48
7	**FL-5**	6.13	74	18	1.4	0.46
8	**GD-1**	7.30	64	15	3.5	0.5
9	**GD-2**	6.85	55	12	2.45	0.58
10	**AZ-1**	5.41	47	10	1.05	0.56
11	**AZ-2**	5.95	92	24	1.4	0.55
12	**AZ-3**	6.16	34	8	1.4	0.53
13	**AZ-4**	7.23	85	22	1.05	0.57
14	**BK-1**	5.55	142	87	14.35	6.59
15	**NK-1**	1.92	162	91	11.55	7.22
16	**SD-1**	4.7	70	18	2.8	0.73
17	**PD-1**	6.41	56	12	2.45	7.71

Table 6.7: Water quality of lakes of Nagpur city: Bacteriological parameters

Sr. No	Sample code	Total coliform (TC) (CFU/100ml)	Thermotolerant coliform (FC)
1	**SG-1**	70000	40000
2	**SG-2**	50000	10000
3	**FL-1**	30000	10000
4	**FL-2**	20000	10000
5	**FL-3**	10000	10000
6	**FL-4**	20000	10000
7	**FL-5**	20000	10000
8	**GD-1**	80000	40000
9	**GD-2**	30000	20000
10	**AZ-1**	50000	20000
11	**AZ-2**	80000	60000
12	**AZ-3**	40000	20000
13	**AZ-4**	20000	10000
14	**BK-1**	200000	110000
15	**NK-1**	240000	80000
16	**SD-1**	40000	30000
17	**PD-1**	40000	20000

***Note- SG - Sonegaon Lake; FL-Futala Lake ; GD- Gorewada Lake; AZ - Ambazari Lake; BK- Binaki Lake; NK- Naik Lake;SD - Sakkardara Lake; PD- Pandharabodi Lake.**

6.2.4.3 Lake Water Quality: Benthic environment

6.2.4.3.1 Aquatic Biological Parameters of Nagpur Lakes

The study of biological parameters leads to detecting various factors contaminating or polluting the aquatic environment. The phytoplankton and zooplankton are a practically suitable choice of indicators of water quality due to ease of sampling, their cosmopolitan distribution, and a lot of available information on these groups. The monitoring of biological

parameters is rapid, inexpensive, and reliable requiring only biological examination of the water samples. The impact of pollution is directly reflected by the survival status of flora and fauna. The biological data give an overall picture of the subsequent effects of pollution.

6.2.4.3.2 Sampling Sites

The eight lakes of Nagpur were selected for aquatic biological parameters. These are Sonegaon, Gorewada, Sakkardara, Binaki, Ambazari, Futala, Pandharabodi, Naik. The composite samples of the lakes were collected for phytoplankton and zooplankton analysis.

6.2.4.3.3 Sampling for Phytoplankton and Zooplankton

For the sampling and study of phytoplankton and zooplankton, the method followed was as per the standard methods.

6.2.4.3.3.a Phytoplankton analysis

The name is derived from the Greek terms (photo), which means "plant," and (plankton), which means "wanderer" or "drifter. Phytoplankton is also referred to as microalgae and is similar to terrestrial plants in that they possess chlorophyll and require sunlight to live and thrive. The majority of phytoplankton is buoyant and floats on the upper layers of water bodies, where sunlight enters the water. Inorganic nutrients like nitrates, phosphates, and sulphur are also required by phytoplankton, which they convert into proteins, lipids, and carbohydrates.

Phytoplankton is an important participant in the global carbon cycle and forms the base of the marine and freshwater food webs. Despite accounting for only approximately 1% of world plant biomass, they contribute to almost half of global photosynthetic activity and at least half of global oxygen production. Phytoplankton provides food for a variety of aquatic organisms, in a healthy ecosystem. When there are too many nutrients available, phytoplankton can overgrow and cause toxic algal blooms (HABs). These blooms can contain highly toxic substances, which can kill fish, shellfish, animals, birds, and even humans.

Under the careful analysis of phytoplankton in the water samples of Sonegaon, Gorewada, Sakkardara, Binaki, Ambazari, Futala, Pandharabodi, and Naik talao, the sample consisted of different species of algal and diatom population which are given in **Table 6.8**

The Gorewada, Sonegaon, and Futala lakes had somewhat fresh and clearer waters than the other lakes. The Binaki Lake and Naik were very bad in condition. The water of Sakkardara Lake was green in color. The weeds were spread on Naik, Binaki, and Sakkardara Lake. The

algal bloom was also seen more in Naik and Binaki. The water of Binaki emitted foul smell. Apart from that, *Eichhornia* weed growth was also observed on the Ambazari Lake floating on some parts of the lake. According to the Shannon-Wiener Diversity Index (SWDI) of phytoplanktons, Naik (2.82), Binaki (2.75), and Sakkardara (2.57) could be considered to be eutrophic in nature. On the other hand, the Gorewada (1.60), Sonegaon (1.87), Futala (1.92), Pandharabodi (1.99) and Ambazari (2.03) lakes had mesotrophic quality of water (**Table 6.9**).

Table 6.8: Phytoplankton species observed from lakes of Nagpur

S. No	Location	Phylum	Genus
1	**Sonegaon**	Chlorophyceae	*Chlorella*
			Pandorina
		Cynophyceae	*Cylindospermopsis*
			Anthrospira
			Synecoccus
		Bacillariophyceae	*Nitzschia*
			Tabellia
2	**Futala**	Chlorophyceae	*Chlamydomonas*
			Pandorina
		Cynophyceae	*Oscillatoria*
			Anthrospira
			Anabaena
		Bacillariophyceae	*Navicula*
			Bacillaria
3	**Gorewada**	Chlorophyceae	*Ankistrodesmus*
			Sphaerocystis
		Cynophyceae	*Cylindrospermopsis*
			Synechococcus
		Bacillariophyceae	*Nitszchia*
4	**Ambazari**	Chlorophyceae	*Spirogyra*
			Scenedesmus
			Tetradesmus
		Cynophyceae	*Anabaena*
			Oscillatoria
			Anthospira
		Bacillariophyceae	*Navicula*
			Pinnularia
		Euglenophyceae	*Euglena*
5	**Binaki**	Chlorophyceae	*Chlorella*
			Spirogyra
			Chlamydomonas
			Closterium
			Pandorina
			Pediastrum duplex
			Ankistrodesmus
			Scenedesmus

		Cynophyceae	*Oscillatoria*
			Anthospira
			Merismopedia minima
			Microcystis
		Bacillariophyceae	*Bacillaria*
			Navicula
			Nitszchia
			Synedra
			Pennularia
		Euglenophyceae	*Euglena*
6	**Naik**	Chlorophyceae	*Chlorella*
			Pandorina
			Chlamydomonas
			Scenedesmus
			Spirogyra
		Cynophyceae	*Oscillatoria*
			Cylindrospermopsis
			Microcystis
			Anthrospira
			Merismopedia
		Bacillariophyceae	*Bacillaria*
			Navicula
			Nitszchia
			Synedra
			Pennularia
			Tabellia
		Euglenophyceae	*Euglena*
7.	**Sakkardara**	Chlorophyceae	*Chlorella*
			Crucigenia
			Tetradesmus
			Teraedron
			Chlamydomonas
			Scenedesmus
		Cyanophyceae	*Gomphosphaeria*
			Microcystis
			Cylindrospermopsis
			Anaebaenopsis
			Merismopedia minima
		Bacillariophyceae	*Bacillaria*
			Navicula
			Nitszchia
			Synedra
8.	**Pandharabodi**	Chlorophyceae	*Spirogyra*
			Chlorella
			Chlamydomonas
		Cyanophyceae	*Cylindrospermopsis*
			Oscillatoria
			Merismopedia minima

		Bacillariophyceae	*Navicula*
			Synedra
		Euglenophyceae	*Euglena*

Table 6.9: Biological parameter: Phytoplankton

Sr. No.	Samples	Phyto-plankton No/L	Percentage Composition of Algal Group				SWDI
			Chloro phyceae	Bacillario-phyceae	Cyano phyceae	Eugleno phyceae	
1.	Sonegaon	12857	28.5	43	28.5	-	1.87
2.	Futala	10000	28.5	28.5	43	-	1.92
3.	Gorewada	7143	40	20	40	-	1.60
4.	Ambazari	20000	36	27	28	9	2.03
5.	Binaki	44285	44	28	22	6	2.75
6.	Naik	47142	40	30	25	5	2.82
7.	Sakkardara	41428	40	27	33	-	2.57
8.	Pandharabodi	17143	33	22	34	11	1.99

6.2.4.3.3.b Zooplankton Analysis

The word zooplankton comes from the Greek words zoon, which means "animal," and plankton, which means "wanderer" or "drifter." Zooplankton is heterotrophic plankton that includes everything from microscopic organisms to big animals like jellyfish. Large bodies of water, such as oceans and freshwater systems, are home to zooplankton. Zooplankton is a type of drifting, ecologically significant creature that is an essential part of the food chain. The zooplankton community is a crucial component of the aquatic food web. These organisms act as a link in the food chain, transporting energy from planktonic algae (primary producers) to the larger invertebrate predators and fish that eat them. Zooplanktons are extremely sensitive to changes in aquatic environments. Changes in species composition, abundance, and body size distribution can be used to detect the effects of environmental disturbances.

The analysis of Zooplanktons in waters of Sonegaon, Gorewada, Sakkardara, Binaki, Ambazari, Futala, Pandharabodi, and Naik also consist of different species of Rotifers, Copepods, Cladocerans, Ostracods, and Protozoans which are given in **Table 6.10**. There were more diverse species of rotifers observed in almost all lakes. According to **Table 6.11**, the percentages of Rotifers were higher in Binaki, Naik, Sakkardara, Ambazari, and Pandharabodi. The protozoan members were observed only in Futala and Naik lakes. The Ostracoda members were found only in Ambazari, Binaki, Naik, and Sakkardara. However,

the Cladoceran members were not observed in Ambazari, Binaki, and Naik. The water flea (Daphnia) of Cladoceran is found generally in clean water and it was not observed in Binaki, Naik and Sakkardara. Mostly the rotifers and ciliates are dominant in the polluted water.

Table 6.10: Zooplankton species observed from lakes of Nagpur

S.No	Location	Phylum/Class	Genus/Species
1	**Sonegaon**	Cladocera	*Daphnia*
			Moina
		Copepoda	*Cyclops*
		Rotifera	*Branchionus plicatilis*
			Branchionus quadridentus
2	**Futala**	Cladocera	*Daphnia*
		Copepoda	*Cyclops*
		Protozoa	*Paramecium*
		Rotifera	*Branchionus diversicornis*
			Branchionus quadridentus
3	**Gorewada**	Cladocera	*Daphnia*
			Leptodora kindtii
			Moina
		Copepoda	*Cyclops*
			Nauplius
			Mysis
		Rotifera	*Filinia longoseta*
			Keratella cochlearis
			Branchionus pllicatlis
			Branchionus quadridentus
4	**Ambazari**	Cladocera	*Daphnia*
		Copepoda	*Cyclops*
			Nauplius
		Rotifera	*Keratella cochlearis*
			Asplancha priodonata
			Branchionus quadridentus
			Brichionus calycifrous
5	**Binaki**	Copepoda	*Cyclops*
			Nauplius
			Pseudodiaptomus sps.
		Ostracoda	*Stenocypris*
		Rotifera	*Asplachna priodonata*
			Keratella tropica
			Testudinella patina
			Branchionus quadridentus
			Brchionus falcatus
			Brachionus forficula
6	**Naik**	Copepoda	*Cyclops*
			Mystus

			Nauplius
		Protozoa	*Entamoeba sps.*
			Balantidium sps.
		Ostracoda	*Heterocypris*
		Rotifera	*Asplachna priodonata*
			Keratella tropica
			Branchionus quadridentus
			Brachionus calyciflorus
			Brachionus diversicornis
7	**Sakkardara**	Copepoda	*Cyclops*
			Nauplius
		Ostracoda	*Heterocypris*
		Rotifera	*Keratella cochlearis*
			Filinia opoliensis
			Testudinella patina
			Branchionus quadridentus
			Brachionus calyciflorus
			Branchionus pllicatlis
8	**Pandharabodi**	Cladocera	*Daphnia*
		Copepoda	*Cyclops*
			Nauplius
			Filinia longiseta
		Rotifera	*Branchionus plicatilis*
			Branchionus quadridentus
			Brachionus calyciflorus

Table 6.11: Biological parameter: Zooplankton

Sr. No.	Samples	Zooplankton No/m^3	Percentage Composition of Zooplankton groups					SWDI
			Cladocera	Copepoda	Ostracoda	Protozoa	Rotifera	
1.	Sonegaon	1786	50	25	-	-	25	1.38
2.	Futala	2143	25	25	-	25	25	1.55
3.	Gorewada	2857	33	34	-	-	33	1.20
4.	Ambazari	9285	14	29	14	-	43	1.90
5.	Binaki	16428	-	37.5	12.5	-	50	2.21
6.	Naik	20000	-	33	11	22	34	2.43
7.	Sakkardara	14643	-	29	14	-	57	2.01
8.	Pandharabodi	10000	20	40	-	-	40	1.89

Based on the results of SWDI of phytoplankton and zooplankton, the trophic levels of the lakes showed the following order as:

Naik > Binaki > Sakkardara > Ambazari > Futala > Pandharabodi >Sonegaon Lake > Gorewada Lake

Ambazari Lake is one of the prominent lakes in Nagpur, but it has faced issues related to pollution. Similarly, Naik, Binaki, and Sakkardara have been very much polluted. Algal blooms, which result from nutrient enrichment, can lead to oxygen depletion and harm aquatic life. To overcome the pollution levels of lake, it is very essential to take proper care for its maintenance and it's a responsibility of both public and government to protect the lakes as they play a big role on storage of water that helps to maintain ground water table.

6.2.5 Surface water quality: Rivers

There are three rivers flowing through the city i.e., Nag, Pilli and Pora. The name of the city has been named after the Nag River. The Nag River, which is part of the Kanhan-Pench river system, flows through the city for 17 km, following the natural slope of the landform to merge with the Kanhan River. Pilli River flows towards the east and meets Nag river near Pawangaon which ultimately merges into Kanhan River. The stretch of Pilli River is 18 km within the city limit. Pora river, which originates from southwest part of the city near Hingna flows towards south-east of the city.

The rivers have been contaminated over time as a result of the discharge of sewage and industrial waste, washing of clothes and animals, and indiscriminate solid waste disposal from residential complexes, commercial centers and hospitals, etc. These polluted rivers further pollute the famous Gosikhurd Dam, a source of fresh water and irrigation for the city. In short, the rivers only receive freshwater throughout the monsoon season, while the rest of the year, it brings untreated waste effluent from the city.

Three rivers of the city were monitored at 21 sampling locations, for the water quality analysis as mentioned in **Table 6.12 and Figure 6.4.** Out of 21 sites, 9 were of Nag River while 8 and 4 were selected for the analysis of Pilli and Pora River, respectively. The primary data of the analysis is presented in **Table 6.13-6.15.**

The Nag River is found to be unsuitable for drinking, outdoor bathing, irrigation and propagation of wildlife fisheries. The initial point of the river has a COD of 24 mg/L due to road and metro development in the surrounding area, while later it increases upto 186 mg/L along the length. As the river flows through the city, the pollution load goes on increasing, leading to an increase in most of the parameters such as, BOD: from 6 to 49 mg/L and Phosphate-P: from 0.83 to 11.01 mg/L.

Some sampling sites show the existence of waste dumped from local vendor shops of fruits, vegetables, meat and other products. In contrast, others show animals wandering in the river

or dead animals floating along the river's bank. Several drains carrying untreated and uncategorized waste from the city's commercial and industrial areas pollute the river throughout its length, as shown in **Figure 6.5**.

The Pilli river water is unfit for drinking, irrigation, outdoor bathing etc. as shown in **Table 6.15,** the COD ranges from 82 to 304 mg/L. In contrast, there was a sudden increase in the value at some points, which is due to the mixing of nallahs from the residential areas leading to an increase in an organic load along the stretch of the river, as shown in **Table 6.15**. The findings also reveal that the BOD and Phosphate-P goes on increasing from 18 to 127 mg/L and from 1.19 to 8.51 mg/L respectively, concluding that the river is getting polluted as it reaches the confluence point near Kanhan river due to an increase in organic load.

The Pora River flows at the city's outskirts near the industrial areas. The polluted nature of Pora river was evident from high organic load as COD, BOD, and Phosphate-P range between 84-172 mg/L, 20-47 mg/L, and 3.77-7.69 mg/L respectively.

Total Coliforms (TC), Faecal coliforms (FC) and Total *E. coli* (EC) were detected in all three rivers (Nag, Pilli, Pora) shown in **Table 6.14,** which were above the desirable level (500 CFU/100 ml) indicating the occurrence of pollution from sewage source and contamination from faecal matter.

Table 6.12: Sampling locations of surface water

Sampling Points	Sample Details / location details	Latitude	Longitude
NAG RIVER			
NAG 1	Initial sampling point (Ambazari lake)	21°7’30.0’’N	79°2’39.6” E
NAG 2	Flow point-2 (NIT swimming pool)	21°7’47.4’’N	79°2’57.3” E
NAG 3	Flow point-3 (VNIT Campus)	21°7’47.5’’N	79°3’3.2” E
NAG 4	NIT cover point near shape up Gym	21°7’53.2’’ N	79°3’22.9” E
NAG 5	Drain mix behind Yashwant stadium (Sitabuldi bridge)	21°8’25.5’’ N	79°4’58.3” E
NAG 6	Drain mix at Mokshdham (Near NMC STP)	21°8’14.76’’N	79°5’19.88” E
NAG 7	Ashirwad talkies, great Nag road, Baidhyanath square Rambagh)	21°8’14.4’’N	79°5’44.0” E

NAG 8	Jagnade chowk, Ganeshnagar, Azamshan layout	21°8’25.3’’N	79°7’10.3” E
NAG 9	Centre point school Wardhmannagar	21°8’52.9’’N	79°8’57.9” E
PILLI RIVER			
PILLI 1	Initial sampling point (Gorewada)	21°11’38.5’’N	79°2’49.0” E
PILLI 2	1st and 2nd drain mix (St. Mary school, 1/F Jafarnagar)	21°11’25.2’’N	79°3’46.1” E
PILLI 3	Suflam seed company (behind Mahindra Showroom, Koradi)	21°11’23.56’’N	79°4’42.76” E
PILLI 4	Nara Kabristan Nara Road (Bridge)	21°11’35.57’’N	79°5’28.11” E
PILLI 5	Pilli river Nari bridge -2	21°11’58.0’’N	79°6’8.7” E
PILLI 6	Bhilgaon road near Rizwan motor	21°10’47.35’’N	79°8’2.90” E
PILLI 7	Kalamnagao police chowki	21°10’45.3’’N	79°9’10.1” E
PILLI 8	Blossom School (Pawangao) (Mixing of Nag and Pilli)	21°9’58.1’’N	79°10’44.4” E
PORA RIVER			
PORA 1	-	21° 4'12.79"N	79° 3'34.68"E
PORA 2	-	21° 5'7.95"N	79° 7'28.32"E
PORA 3	-	21° 5'11.08"N	79° 8'36.91"E
PORA 4	-	21° 5'14.50"N	79° 8'53.06"E

Table 6.13: Water quality of rivers of Nagpur city: Physico-chemical parameters

Sr No	Sample details	pH	EC	TDS	Alkalinity as $CaCO_3$	Total Hardness $CaCO_3$	Calcium as Ca^{2+}	Magnesium as Mg++	Sodium (Na^+)	Potassium (K^+)	Fluoride	Chloride (Cl^-)	Sulphate as SO_4^{2-}	Nitrate as N
Units			**µS/cm**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
BIS 10500:2012 (Acceptable/ Permissible limit)		**6.5-8.5**	**-**	**500-2000**	**200-600**	**200-600**	**75-200**	**30-100**			**1.0-1.5**	**250-1000**	**200-400**	**45**
1	**NAG 1**	6.5	816	408	360	88.45	5.47	360	42.14	9.81	0.22	52.48	37.92	1.7
2	**NAG 2**	6	1066	534	445	149.45	17.01	445	42.38	7.82	0.22	62.48	72.92	6.22
3	**NAG 3**	6.06	1198	599	545	118.95	14.58	545	54.29	27.44	0.21	47.49	46.15	3.04
4	**NAG 4**	5.77	1331	666	505	115.9	5.47	505	54.17	28.4	0.23	57.48	75.73	1.61
5	**NAG 5**	6.01	1231	615	405	100.65	6.68	405	58.11	22.03	0.29	52.48	72.71	1.42
6	**NAG 6**	5.8	1259	629	415	122	11.54	415	59.45	23.58	0.28	62.48	64.38	1.62
7	**NAG 7**	5.8	1281	645	445	149.45	18.23	445	66.8	26.67	0.31	49.98	48.23	2.76
8	**NAG 8**	6.35	1341	670	575	170.8	20.05	575	69.36	27.38	0.3	67.48	92.19	2.58
9	**NAG 9**	6.7	1837	918	595	155.55	13.37	595	102.21	33.55	0.3	102.47	129.69	1.82
10	**PILLI 1**	7.02	932	466	470	134.2	42	13.97	25.91	8.82	0.29	22.49	67.5	0.76

11	**PILLI 2**	7.0	1392	619	435	128.1	58	7.9	71.18	26.7	0.29	72.48	133.86	3.75
12	**PILLI 3**	7.25	1452	726	495	149.45	54	13.37	72.25	26.9	0.3	72.48	134.17	1.74
13	**PILLI 4**	7.13	1480	740	485	158.663	40	19.44	78.60	26.4	0.35	72.48. 53	137.92	1.48
14	**PILLI 5**	7.17	1588	795	495	152.5	48	15.8	85.78	26.66	0.35	72.48	147.71	0.63
15	**PILLI 6**	6.88	1659	830	640	155.55	46	17.01	94.68	28.6	0.36	77.48	146.05	2.95
16	**PILLI 7**	7.06	1689	845	545	146.4	44	15.8	91.56	28.17	0.36	97.47	151.98	1.93
17	**PILLI 8**	6.7	1711	852	540	137.25	50	12.15	93.84	82.47	93.84	28.71	132.4	1.14
18	**PORA 1**	7.53	1784	893	545	186.05	64	17.62	86.85	77.48	86.85	25.64	128.44	8.23
19	**PORA 2**	7.48	1547	773	475	158.6	64	12.15	84.4	72.48	84.4	26.73	106.05	1.82
20	**PORA 3**	7.6	1552	776	535	128.1	50	10.33	87.15	72.48	87.15	26.89	106.78	2.69
21	**PORA 4**	7.6	1647	822	575	137.25	54	10.94	93.13	82.47	93.13	27.76	111.67	3.53

Table 6.14: Water quality of rivers of Nagpur city: Bacteriological parameters

Sr. No.	Sample Code	Total Coliforms (CFU/100ml)	Thermotolerant Coliforms (CFU/100ml)
1	Nag-1	150000	120000
2	Nag-2	60000	20000
3	Nag-3	110000	60000
4	Nag-4	240000	110000
5	Nag-5	220000	140000
6	Nag-6	80000	40000
7	Nag-7	120000	40000
8	Nag-8	80000	30000
9	Nag-9	160000	110000
10	Pilli-1	80000	50000
11	Pilli-2	110000	40000
12	Pilli-3	120000	50000
13	Pilli-4	140000	60000
14	Pilli-5	240000	120000
15	Pilli-6	200000	120000
16	Pilli-7	80000	20000
17	Pilli-8	160000	60000
18	Pora-1	280000	120000
19	Pora-2	240000	180000
20	Pora-3	160000	40000
21	Pora-4	100000	40000

Table 6.15: Water quality of rivers of Nagpur city: Organic and nutrient parameters

Sr No.	Sample details	DO (mg/l)	COD (mg/l)	BOD (mg/l)	TKN as N	Phosphate as P(mg/l)
1	Nag-1	5.01	94	18	4.55	0.83
2	Nag-2	5.45	24	06	7	1.18
3	Nag-3	0.41	60	15	4.9	11.01
4	Nag-4	0.78	126	25	4.55	10.4
5	Nag-5	0.80	120	22	4.2	5.63
6	Nag-6	0.82	92	20	3.85	6.2
7	Nag-7	0.73	142	36	4.2	8.28
8	Nag-8	0.47	186	49	3.15	8.12
9	Nag-9	1.69	140	38	3.15	5.22
10	Pilli-1	1.02	228	127	2.45	1.19
11	Pilli-2	0.56	222	21	8.75	6.44
12	Pilli-3	1.15	304	67	8.75	5.08
13	Pilli-4	1.28	182	21	3.5	5.47
14	Pilli-5	2.21	142	36	4.55	6.91
15	Pilli-6	0.77	82	18	13.65	6.3
16	Pilli-7	0.65	112	28	6.65	8.51
17	Pilli-8	1.33	134	48	3.15	6.64
18	Pora-1	2.57	84	20	9.1	3.77
19	Pora-2	0.72	96	24	3.85	4.54
20	Pora-3	1.07	114	38	11.2	5.1
21	Pora-4	0.66	172	47	5.6	7.69

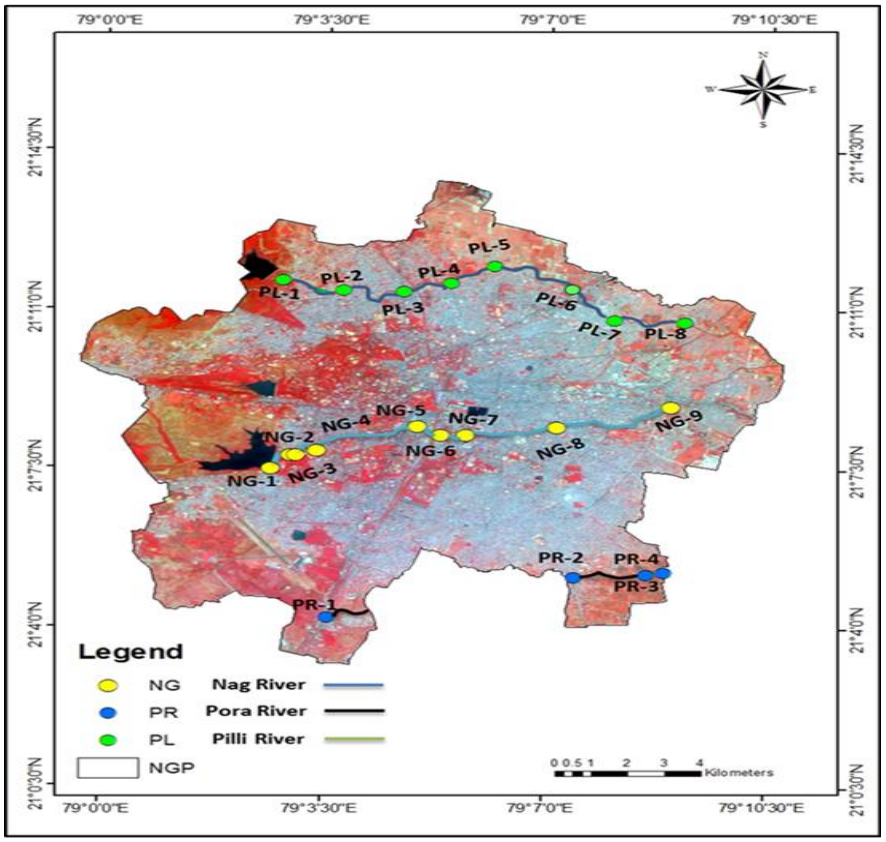


Figure 6.4: Geographical location of sampling sites of all the rivers

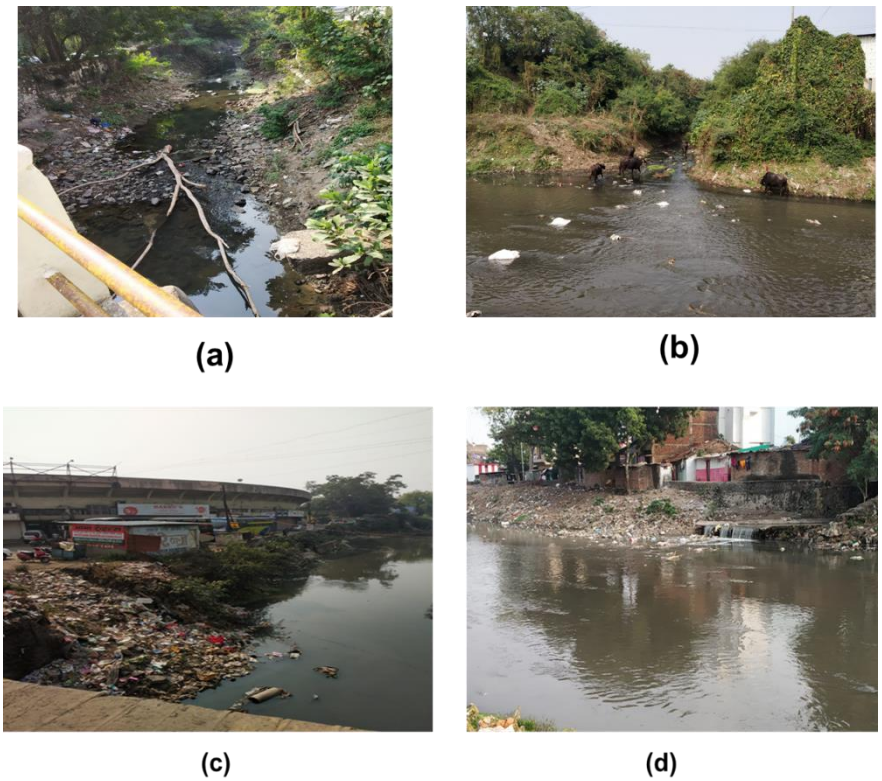


Figure 6.5: Sampling sites of the rivers: Nag, Pilli and Pora

6.2.5 Hydrogeological study for the Environmental Status Report of Nagpur

6.2.5.1 Introduction

Nagpur district is one of the nine districts of Vidarbha Region of Maharashtra State. It is situated on the eastern part of the State abutting Chindwada district of Madhya Pradesh in north. It is bounded by Wardha and Amravati districts in the west, Bhandara district in the east and Chandrapur district in the south. It lies between north latitudes 20°35' and 21°44' and east longitudes 78°15' and 79°40' and falls in Survey on India topo-sheets 55 K, O and P. The district has a geographical area of 9892 sq. km, covering an area of about 100 km^2, is situated at an altitude of over 290 m above the mean sea level. The Nagpur Municipal Corporation has jurisdiction over an area bounded by Latitude 21°03'10"N to 21°13'50"N and longitude 78°59'31"E to 79°10'44"E.

Table 6.16: Groundwater sampling sources locations in Nagpur city

S.N.	Sample Code	Source	Latitude	Longitude	Location Details
1.	NGW-1	DW	21°05'41"N	79°01'34"E	**Owner:** Chandu Dawre (LHS to highway Nagpur to Wardha Shivangaon)
2.	NGW-2	BW	21°04'00"N	79°03'33"E	**Owner:** Bedram Sunak (LHS to drainage line)
3.	NGW-3	DW	21°05'47"N	79°07'30"E	**Owner:** Saurabh Peth (Jaimaa Bhavani Dairy, Tajeshwar Nagar)
4.	NGW-4	DW	21°07'50"N	79°08'21"E	Shitla Mata Mandir, Vidya Nagar
5.	NGW-5	DW	21°06'37"N	79°06'16"E	**Owner:** Anirao shende (Plot No. 39/40 Ladika Layout)
6.	NGW-6	DW	21°07'18"N	79°04'22"E	CSIR - NEERI, Near Gate No. 1
7.	NGW-7	DW	21°10'45"N	79°02'29"E	**Owner:** Rutuj Choudhary (Plot No. 80, Narmada Colony)
8.	NGW-8	DW	21°12'03"N	79°04'5"E	**Owner:** Murlidhar Ghungure (Plot no 163, OM Nagar)
9.	NGW-9	DW	21°09'52"N	79°10'.02"E	**Owner:** Kashi Nath (Bharatwada area)
10.	NGW-10	DW	21°10'06"N	79°06'22"E	**Owner:** Raju Fulzele (Pet unlimited shop Balabhaupeth Kamal Talkies Road)
11.	NGW-11	DW	21°07'58"	79°06'43"E	**Owner:** Durga Diware (Plot N-99B, Reshimbagh)
12.	NGW-12	DW	21°09'18"	79°03'33"E	**Owner:** Krishi Paryatak, Kadimbagh

Note: NGW: Nagpur Groundwater Sample Code; BW: Bore Well; DW: Dug Well

6.2.5.2 Study Area

6.2.5.2.1 Geology

The regional geology of Nagpur is underlain by the basaltic lava flows (Deccan Traps) on the west, Archaean meta sediments of Sausar and Sakoli series and granite gneisses in the east and lower Gondwana group of rocks in the middle (PK Naik et.al., 2005).

6.2.5.2.2 Lithology

The study area (**Figure 6.6**) is characterized by Sandstone in small patches on the northern side of the boundary, while Gneiss/Migmatite rocks are found in the northeast part. Granite, Gnieiss, and Migmatite are found in the eastern part of Nagpur. Limestone is found to be in the patches of central and southern sides of Nagpur.

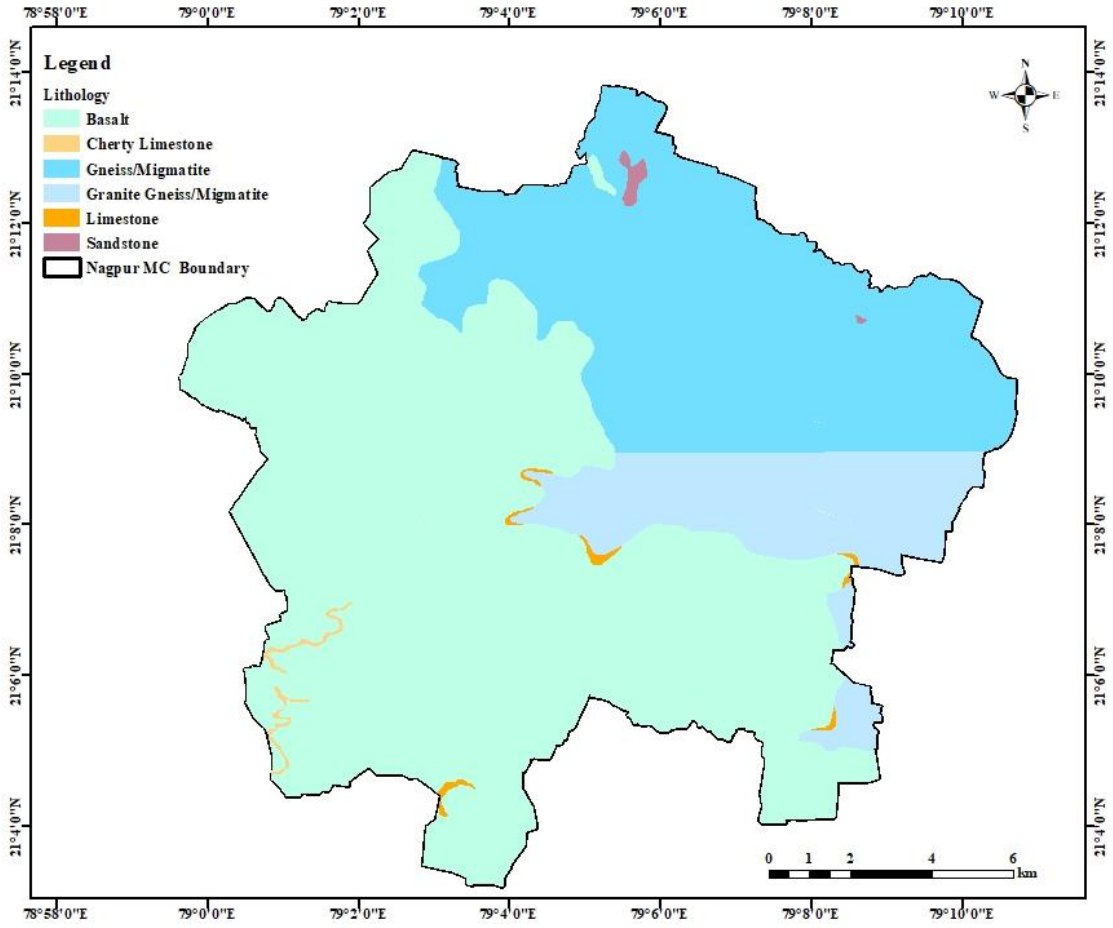


Figure 6.6: Lithological map of study area (Source: bhukosh.gsi.gov.in)

6.2.5.2.3 Topography

The study area has an elevation between 280m and 373m (**Figure 6.7**), and the overall slope is from west to east.

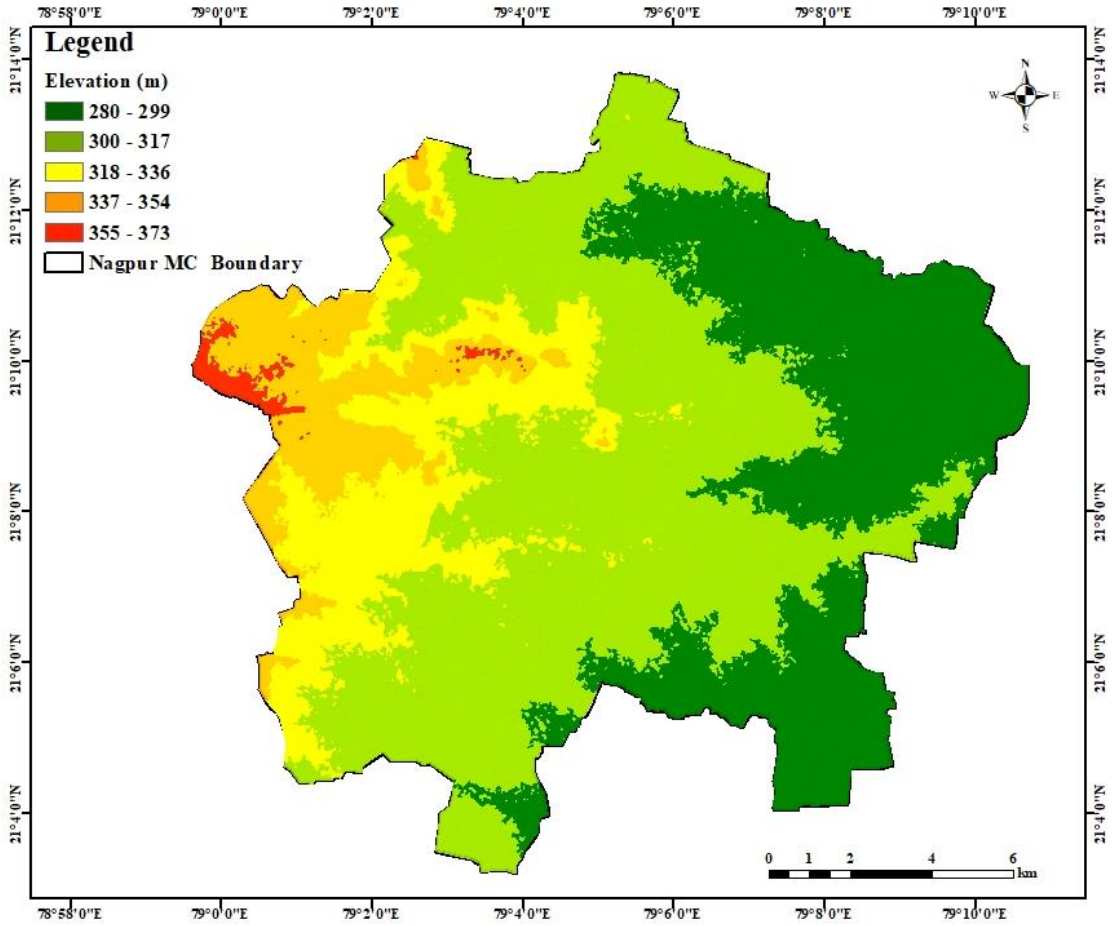


Figure 6.7: Topography map of study area

6.2.5.2.4 Hydrogeology

In the study area, the Archeans and the Deccan trap basalts are the two consolidated aquifer formations. It is observed that the vesicular and weathered basalts are more productive than the massive and jointed basalts. Though the Archaeans are highly weathered, they form moderate potential aquifers. Alluvium is the most potential aquifer occurring in the area. In general, the Gondwana formation gives moderate to high yield while the Lameta is poor yielding aquifer in the study area. The Groundwater stage development is 31.19%, which comes under the safe category (CGWB, 2013). In general, the city has piped water supply for the drinking water requirements.

6.2.5.2.5 Drainage

The drainage pattern (**Figure 6.8**) is controlled by the Nag and Pilli rivers. The Nag River originates in the Lava hills near Wadi. The confluence point of the Nag and Pilli Rivers is near Pawangaon. The drainage pattern is dendritic in nature.

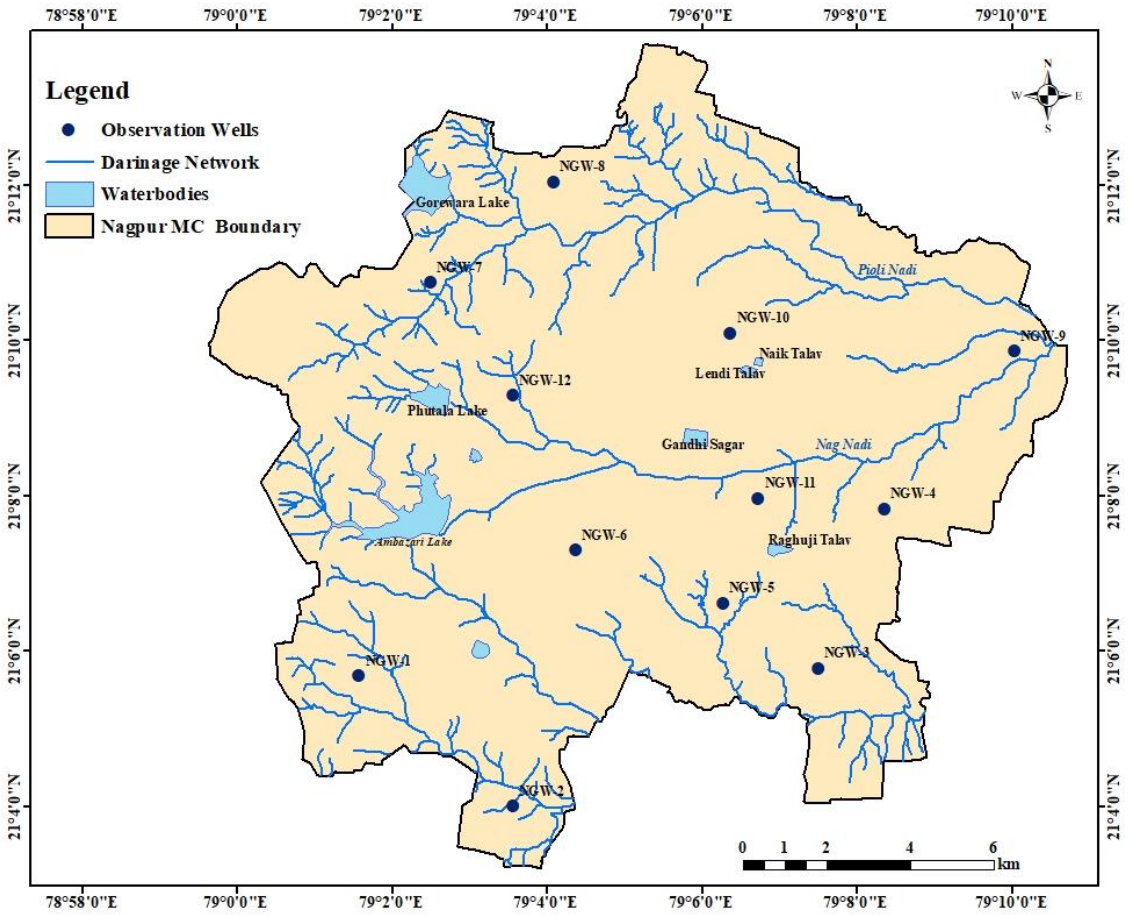


Figure 6.8: Drainage map of study area

6.2.5.3 Methodology for data collection

6.2.5.3.1 Groundwater level measurement

A network of observation wells has been set up **(Figure 6.9)** for monitoring groundwater level and groundwater quality (Major Cations, anions, heavy metals & Microbiological analysis). The wells are used for domestic purpose. The observation well locations were marked by GPS (Garmin Make). The groundwater level **(Figure 6.10)** was obtained by using automatic water level indicator (Model-EPP-10/6) manufactured by M/s ENCARDIO- RITE ELECTRONICS PVT. LTD.).

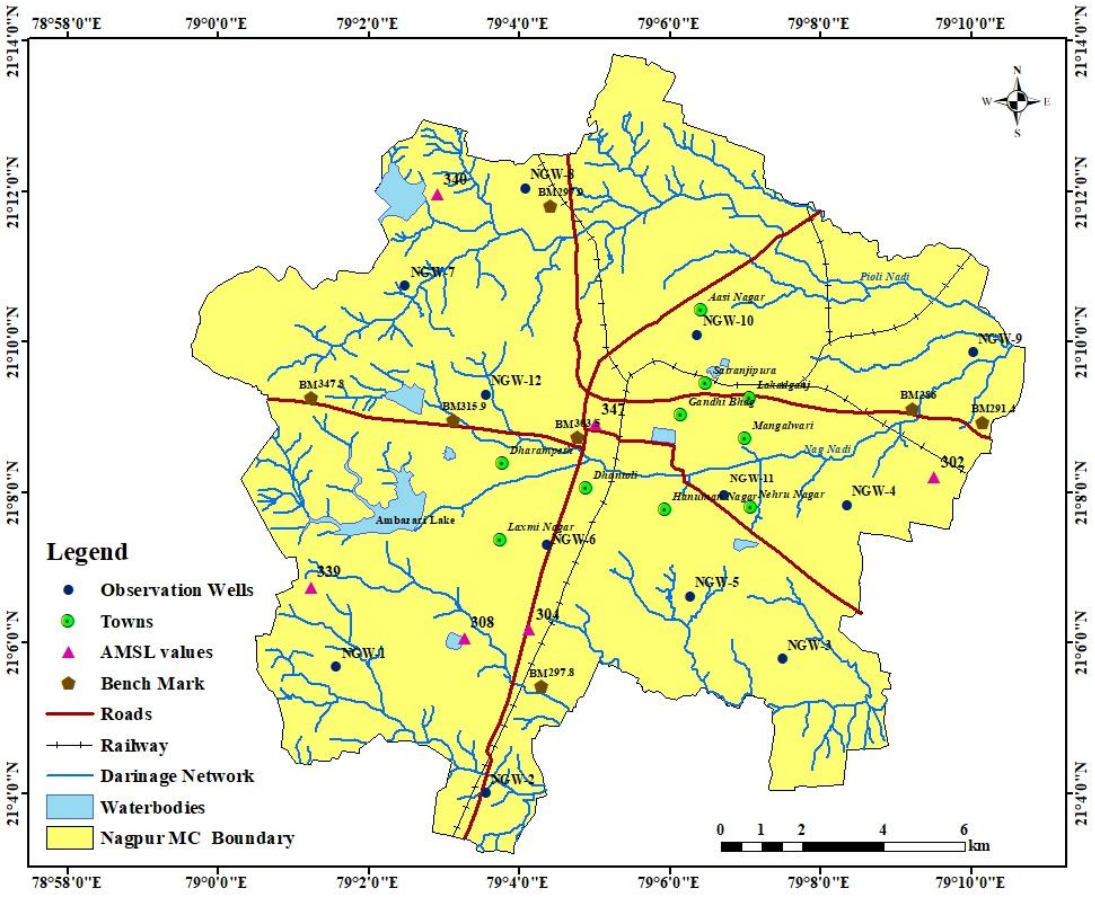


Figure 6.9: Observation well network in study area

Figure 6.10: Measurement of groundwater level using automatic water level indicators

6.2.5.3.2 Groundwater sampling & analysis

Groundwater samples (12 Nos. **Table 6.16**) were collected from the observation well network in the study area. The groundwater sources consisted of Dug well (11 Nos.) and Bore well

(1 No). For physicochemical parameters and heavy metal analysis, the samples were collected in pre-cleaned 1000 mL and 100 mL polyethylene bottles, respectively. Concentrated

HNO_3 was added to the heavy metal samples for preservation.

The physicochemical parameters were analyzed by following the standard protocol (APHA, 2017). The heavy metal analysis was done by ICP-OES (Model: iCAP 6300 DUO, Make: Thermo Fischer).

6.2.5.4 Observations and Inferences

6.2.5.4.1 Groundwater Level

The groundwater levels **(Table 6.17)** from the observation well network in the study area have been measured, and the groundwater level (below ground level) varied between 2.04 (NGW-3) to 8.43 m (NGW-8) during the post-monsoon season of 2023 and varied from 2.12 (NGW-3) to 12.20 (NGW-1) during pre-monsoon of 2024. The groundwater level (AMSL) contours **(Figure 6.11a & 6.11b)** indicate that the groundwater flow direction follows the topography and the flow direction is from west to east direction.

Table 6.17: Groundwater level (m) in the study area – ESR report (NMC)

Sr. No.	Sample Code	Source	Groundwater level (BGL-m)		
			Post-Monsoon-Dec'23	Pre-Monsoon – May'24	Fluctuation (m)
01	NGW-1	DW	6.85	12.20	5.35
02	NGW-2	BW	5.0	7.25	2.25
03	NGW-3	DW	2.04	2.12	0.80
04	NGW-4	DW	3.75	6.42	2.67
05	NGW-5	DW	4.79	6.19	1.40
06	NGW-6	DW	2.2	5.83	3.63
07	NGW-7	DW	2.36	2.65	0.24
08	NGW-8	DW	8.43	10.83	2.40
09	NGW-9	DW	5.25	6.19	0.94
10	NGW-10	DW	3.14	4.36	1.22
11	NGW-11	DW	4.47	6.15	1.68
12	NGW-12	DW	5.54	6.48	0.94

Note: NGW: Nagpur Groundwater Sample Code; BW: Bore Well; DW: Dug Well

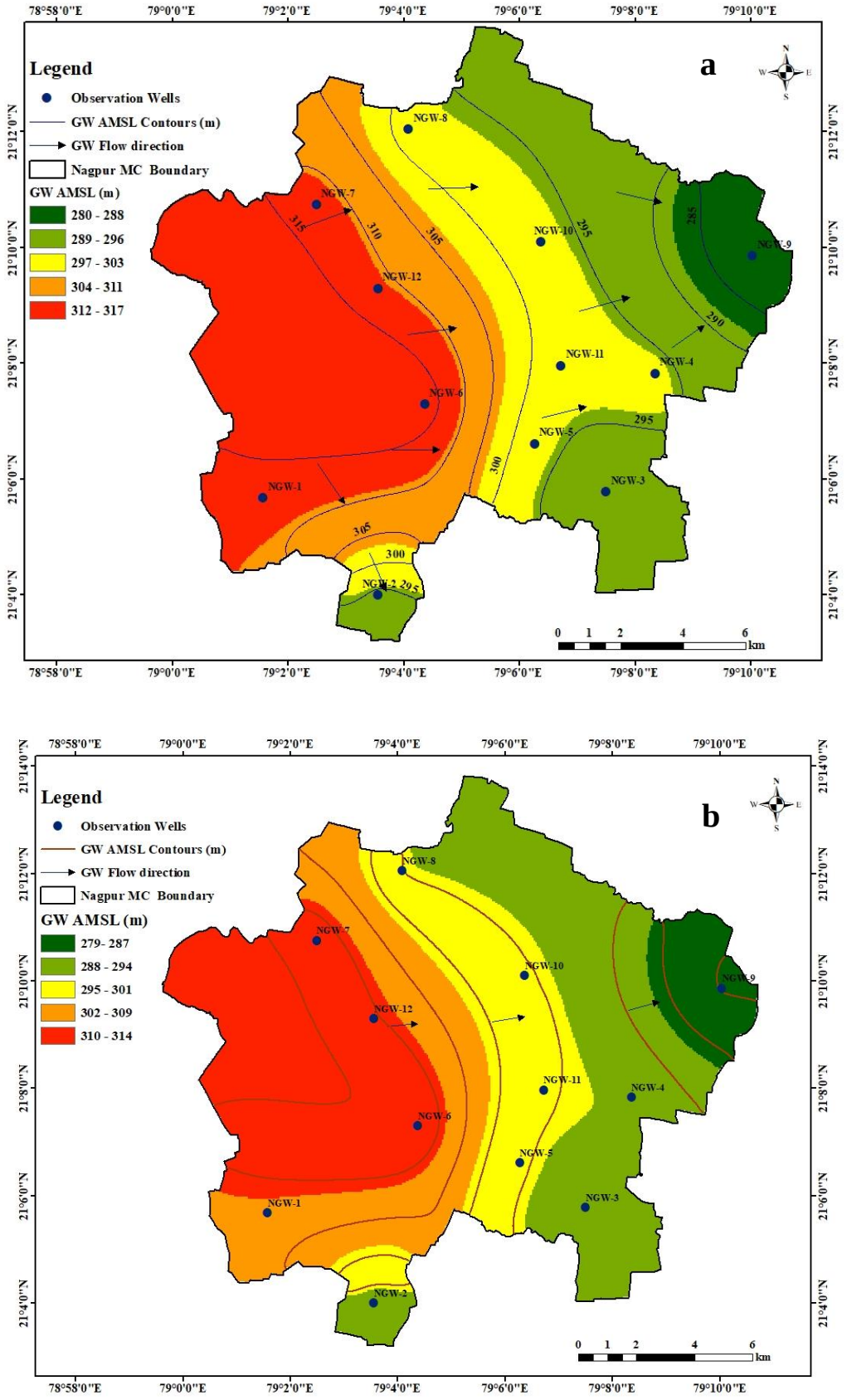


Figure 6.11: Groundwater level (AMSL) contour plot of the study area (a) December 2023 (b) May 2024

6.2.5.4.2 Groundwater Quality

The data from the Central Groundwater Board (CGWB), Nagpur estimates that the groundwater availability in Nagpur is above 25 MCM per year. The groundwater depth varies from 1.65-1.95 m bgl in the central part of the city and extends up to 16 m bgl in the peripheral areas. Groundwater resources can be tapped in the north-eastern part of the city, as it can serve as a supplementary source of water supply. Also, considering the scarcity of surface water during the summer season and insufficient supply in the city's outskirts, it is essential to make provision for exploiting the groundwater reserves.

The groundwater samples were collected from 12 locations. Location details are given in **Table 6.16**. The groundwater samples were analyzed for physico-chemical parameters, metals and bacteriological parameters and the results are presented in **Tables 6.18, 6.19 & 6.20.** All the 12 Nos. groundwater collected samples were observed to be clear and did not have any objectionable odour. The pH of groundwater samples ranged from 7.55 to 8.15, and these values were within the desirable range of 6.5 to 8.5 prescribed by the BIS 10500:2012.

All 12 Nos. samples were found to have dissolved solids (TDS) well below the permissible limit of 2000 mg/L as per BIS standards. All 12 Nos. samples were observed to have total alkalinity above the desirable concentrations of 200 mg/L. Magnesium exceeded marginally in eight samples above desirable concentrations, however, it was well below the permissible limit of 100 mg/L. Phosphates were found to range between 0.16 and 0.47 mg/L. 11 of the groundwater samples were found to have total hardness exceeding the desirable value of 200 mg/L. Other parameters were found to be within the desirable limits of BIS 10500:2012.

Significant contamination was not observed in groundwater sources when compared with drinking water standards BIS 10500:2012. Fe was detected only in one of the samples (0.89 mg/L), which was higher than permissible limits, while Mn concentration was found in the range of 0.01-0.03 mg/L in three samples that were below permissible limits. All the parameters are shown in **Tables 6.18 & 6.19.**

6.2.5.4.3 Groundwater Quality: Bacteriological

Bacteriological analysis of groundwater samples indicated that 12 nos. had a load of Total Coliforms, (TC) and 11 nos. had a Faecal Coliforms (FC) load ranging from 60 to 296 CFU/100 mL and 0 to 196 CFU/100 mL, respectively. The overall quality of groundwater samples was observed to be good in terms of physio-chemical characteristics but was found to be contaminated with coliforms and requires disinfection before consumption since a significant number of TC and thermotolerant coliforms (FC) were found in the samples (**Table 6.20).**

Table 6.18: Water quality of groundwater samples of Nagpur city: Physico-chemical characteristics

Sample	pH	EC	TDS	Sodium	Potassium	Hardness	Calcium	Magnesium	Alkalinity	Chloride	Nitrate	Phosphate	Fluoride	Sulphate
unit		dS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
NGW1	8.15	0.79	394	23.1	0.4	247.05	116	13.97	572.5	36.24	25.66	0.35	0.44	439.17
NGW2	7.85	0.81	409.5	55	0.8	320.25	74	41.31	682.5	66.23	18.21	0.18	0.41	381.36
NGW3	7.85	0.71	343	24.9	0.8	262.3	76	29.16	452.5	52.48	21.72	0.17	0.66	430.53
NGW4	7.84	0.88	509.5	214	2.75	298.9	112	25.52	745	201.19	0.22	0.19	0.99	917.4
NGW5	7.95	0.55	274	22.55	1.45	225.7	62	26.12	422.5	51.23	6.22	0.2	0.48	355.31
NGW6	7.65	0.98	509	188	2.55	338.55	68	46.78	882.5	68.73	0.25	0.47	0.83	601.56
NGW7	7.85	0.68	343.5	31.4	0.2	253.15	84	24.91	532.5	73.73	12.98	0.23	0.79	487.82
NGW8	7.55	0.93	461	620.5	2.05	484.95	168	45.56	737.5	288.66	4.63	0.16	0.49	3257.61
NGW9	7.7	1.23	792.5	222.5	2.4	384.3	130	37.06	712.5	249.92	23.34	0.23	0.56	1240.94
NGW10	8.05	0.86	431	182	5.45	204.35	68	20.05	567.5	96.22	13.75	0.31	0.42	914.79
NGW11	8.05	0.51	254.5	80.9	0.5	88.45	44	4.25	415	31.24	6.9	0.18	1.1	280.63
NGW12	7.65	0.76	392.5	20.95	20.95	268.4	106	21.26	615	74.98	8.82	0.21	0.17	521.25

Table 6.19: Water quality of groundwater samples of Nagpur city: Metals

Sr. No	Sample code	Al	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
BIS Limit (ppm)		**0.03-0.20**	**0.01**	**0.003**	**0.05**	**0.05-1.5**	**0.3**	**0.10-0.30**	**0.02**	**0.01**	**5.0-15**
ICP-OES			**0.007**	**0.0001**	**0.01**	**0.0004**	**0.0003**	**0.0001**	**0.005**	**0.009**	**0.001**
1	NGW1	0.49	0	0	0	0	0.89	0.03	0	0	0
2	NGW2	0	0	0	0	0	0	0.01	0	0	0
3	NGW3	0	0	0	0	0	0	0	0	0	0
4	NGW4	0	0	0	0	0	0	0	0	0	0
5	NGW5	0	0	0	0	0	0	0	0	0	0
6	NGW6	0	0	0	0	0	0	0.01	0	0	0
7	NGW7	0	0	0	0	0	0	0	0	0	0
8	NGW8	0	0	0	0	0	0	0	0	0	0
9	NGW9	0	0	0	0	0	0	0	0	0	0
10	NGW10	0	0	0	0	0	0	0	0	0	0
11	NGW11	0	0.02	0	0	0	0	0	0	0	0
12	NGW12	0	0	0	0	0	0	0	0	0	0

Table 6.20: Water quality of groundwater samples of Nagpur city: Bacteriological parameters

Sr. No	Sample code	Total Coliform (CFU/100ml)	Thermotolerant Coliform (CFU/100ml)
1	NGW1	280	11
2	NGW 2	85	57
3	NGW 3	240	196
4	NGW 4	152	27
5	NGW 5	90	39
6	NGW 6	108	39
7	NGW 7	88	0
8	NGW 8	176	66
9	NGW 9	296	120
10	NGW 10	152	20
11	NGW 11	60	38
12	NGW 12	106	89

6.2.5.5 Recommendations

1. To overcome the pollution levels of lakes, it is very essential to take proper care for its maintenance. It's the responsibility of both public and government to protect lakes as they play a big role on storage of water that helps to maintain ground water table.
2. The garbage dumps near the banks of the lakes under study, i.e., Sonegaon, Sakkardara, Naik and Binaki from Nagpur city need to be reduced by preventing disposal of garbage such as old and torn cloths, eatables, worship material used in festivals etc. by the public on the banks of lakes.
3. Public toilets, faecal matter, loitering stray animals were observed on the banks of Naik, Binaki and Pandharabodi lakes. Significant count of total and fecal coliforms was also detected in these lakes and in all the samples lakes in general. Open defecation needed to be prevented and the public toilets needed to be shifted/removed to prevent faecal matter from contaminating the lakes.
4. The substantial COD, BOD, and other nutrients (nitrogen and phosporous) concentrations in Naik and Binaki lakes due to high organics could be associated with anthropogenic activities which needed to be prevented/reduced in order to prevent the entry of organics into the lakes.
5. NMC may look into the aforesaid issues plaguing the other lakes, and may expedite the rejuvenation and development of remaining lakes by applying similar strategies of desilting,

desludging, boundary/retaining/edge wall, etc. as being done for rejuvenation of Gandhisagar, Lendi, and Police line Takli lakes.

6. All the three rivers Nag, Pilli and Pora were found to be unsuitable for drinking, outdoor bathing, irrigation and propagation of wildlife fisheries due to increase in pollution as seen from COD, BOD and nutrient load as the rivers flowed through the city.
7. There is a need for reducing/preventing such several activities which are responsible for increased pollution load in the rivers, such as; dumping of waste by local vendors of fruits-vegetables, meat and other products, wandering of stray animals in the river or disposal of dead animals along the river bank.
8. The flow of drains carrying untreated and uncategorized sewage/waste from the city's commercial and industrial areas may be directly channelized to STPs to prevent their entry into the river thereby reducing the pollution from anthropogenic sources and the bacterial contamination. The river pollution abatement plan being carried out by NMC under the AMRUT-II scheme should be aggressively implemented for rejuvenating the rivers.
9. The groundwater level (below ground level) in the study area shows a lot of variation in the range of 2.04 (NGW-3) to 8.43 m (NGW-8) during the Post-monsoon season of 2023. In the pre-monsoon season of 2024, the groundwater level was very shallow at locations namely, NGW-3 (2.12 m BGL) and NGW-7 (2.65 m BGL). The groundwater levels varied between 2.12 m BGL (NGW -3) to 12.20 m BGL (NGW -1) during pre-monsoon season.
10. It is observed that the groundwater level is very shallow (<3m) at locations NGW-3 and NGW-7. Based on the present situation, rainwater harvesting structures should not be recommended at the respective locations.
11. Based on the long-term monitoring, the groundwater level trend can be established and rain water harvesting programme can be implemented accordingly (CGWB, 2007).
12. Piezometers (100 – 150m depth) can be installed for monitoring the potential hot spots of groundwater extraction such as industrial clusters, hospitals, gated residential communities and hotels.
13. Implementation of roof top rain water harvesting and recharge activities can be done in public parks and play grounds where the groundwater levels are deepen pertaining to augmentation of groundwater.

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Chapter 7

Ecosystem Services Valuation

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Environmental Valuation of Impacts on Lakes and Rivers

7.1 Introduction

The discharge of untreated or partially treated effluent/sewage has far-reaching consequences on water quality, impacting both surface and groundwater and leading to contamination of soil surface and sediment. This has profound implications for aquatic life, disrupting ecosystems and threatening biodiversity. The river ecosystem, a vital element of natural capital crucial for human well-being and the global economy, confronts substantial challenges to its sustainability due to severe water pollution caused by human activities.

Among these, industrial discharges emerge as a particularly devastating contributor to environmental degradation. The release of both solid and liquid industrial wastes into surface water bodies adversely affects flowing streams and the ecosystems they sustain. Aquatic life, including fish and other organisms, faces significant threats, as pollutants disrupt habitats and impair the reproductive and feeding behaviors of aquatic species. As freshwater resources increasingly confront escalating threats from industrial pollution, the need to quantify environmental damages becomes imperative. Effective measures are crucial to safeguarding water quality, preserving aquatic ecosystems, and mitigating the detrimental effects on aquatic life.

Quantifying these damages in monetary terms proves to be a useful strategy for increasing awareness among local municipalities and governing bodies. The assessment not only emphasizes the magnitude of the harm but also corresponds to the implementation of the polluter pays principle. This study focuses on appraising the monetary extent of environmental damages incurred by various rivers and lakes surpassing standard permissible limits. In addition to employing cost assessment methods like value transfer and market pricing, the study incorporates ecosystem service valuation to offer a comprehensive insight into the impact on the inherent value of the environment.

This study focuses on appraising the monetary extent of environmental damages incurred by various rivers and lakes surpassing standard permissible limits. The Value Transfer Method (VTM) approach is specifically employed, concentrating on deviations in water quality parameters like Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The study confines its focus to evaluating environmental damages arising from exceeded concentrations of these parameters, providing a precise examination of the ecological impacts.

The objective of the study is not solely to measure the economic impact of pollution load in lakes and rivers but also to deepen our comprehension of the broader ecological effects.

7.2 Methodology

Water pollution arises from the prolonged discharge of pollutants into water bodies, leading to adverse effects on the entire ecosystem. The release of pollutants, including toxic chemicals and heavy metals into water bodies can also impact human health, particularly for those in direct contact. Extended exposure to these harmful substances has been linked to health risks such as cancer and other illnesses.

The valuation of environmental damages follows a drivers-outcome-impact-based approach, providing clarity on the specific details of the ecosystem under analysis. This study focuses on organic and nutrient parameters, specifically Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), to comprehend the extent of environmental damage. These parameters serve as foundational pollutants for valuation purposes. The cost of damage for the year 2023 resulting from COD and BOD has been assessed using the Value Transfer Method (VTM), offering a comprehensive understanding of the economic impact associated with these environmental stressors.

The formulae for Environmental Damage Cost Assessment (EDCA) using the Value Transfer Method are given as follows:

1) For River: **Equation 1**

$$EDCA\ (₹) = Pollutant \times Damage\ cost \times Flow\ rate \times Purchasing\ Power\ Parity\ factor \times Inflation \times 365\ days$$

2) For Lake: **Equation 2**

$$EDCA\ (₹) = Pollutant \times Damage\ cost \times Volume \times Purchasing\ Power\ Parity\ factor \times Inflation$$

Assumptions

- We have considered a cuboidal shape for the lakes based on a uniform depth assumption. However, it is crucial to acknowledge that the lakes may exhibit non-uniform depths and shapes.

- The literature review indicates a discharge value of 6 m^3/sec for the Nag River. (S Dutta 2018). However, due to insufficient data for the Pilli and Pora rivers, we are assuming their discharge values to be 6 m^3/sec for our analysis.
- While we based our analysis on past data, it is acknowledged that the current scenario may differ, with continuous dumping and disposal of waste the area and depth may vary considering potential changes over time.
- In the absence of available area data for Sonegaon Lake, Futala Lake, and Pandharabodi Lake, we have computed their areas using the ArcGIS application.
- Average Inflation =6.57% (2010-2023) (Indian Inflation Rates)
- Purchasing Power Parity is taken from the OECD database for 2010 = 19.28

Economic impact assessed for the year 2023 using the Value Transfer Method (VTM), factors of PPP and inflation are taken from OECD and RBI respectively.

7.3 Observation and Inferences

The value transfer method is a commonly employed technique for evaluating the economic impact of environmental benefits or losses in cases where conducting an original valuation study is impractical. This approach calculates parameter values by transferring information gathered from completed studies at one location (study site) to another location (policy site). The value transfer method, a component of environmental damage cost assessment, is not an exact assessment method according to Bherwani et al. (2020a). Nonetheless, it involves economically estimating changes in the environment at the policy site by transferring insights from previous studies on similar environmental quality changes (Barbera 2010; Bherwani et. al., 2020a). While the ideal scenario involves conducting a direct valuation study using other econometric tools, the value transfer method becomes valuable in situations where on-site primary valuation is challenging due to time constraints or data unavailability.

Table 7.1: Damage cost for each pollutant in Euro per kg (Hernández-Sancho et al. 2010)

Pollutant	Damage in Euro per kg (2010)
Nitrogen	16.353
Phosphorous	30.944
Suspended solids	0.005
Biological oxygen demand	0.033
Chemical oxygen demand	0.098

The shadow prices used in the VTM approach is listed in **Table 7.1** are considered for valuation. The estimation of damage cost is done for the year 2023. For conversion, the exchange rate, Purchasing Power Parity (PPP) (PPP, OECD), and inflation rates are used. An average of 6.57% inflation for each year is considered from the base year of calculation (World Wide Inflation Data 2023). The damage cost per kg of the load used for the study is given in **Table 7.1**.

Table 7.2: Standards utilized in the study

Designated Best Use	Class	Criteria
Drinking Water Source After Conventional Treatment and Disinfection	C	Total Coliforms Organism MPN/100ml should be 5000 or less; pH should be between 6 to 9; Dissolved Oxygen should be 4 mg/l or more Biochemical Oxygen Demand 5 days 20^{o}C should be 3 mg/l or less ***(CPCB)***
Water with quality complying with the standard for use class II will support all uses adequately, including properly functioning aquatic ecosystem.	Quality class II	Chemical Oxygen Demand is 10 mg/l. ***(OECD)***

The analysis results for the surface water samples were compared to tolerance limits as specified by CPCB and OECD mentioned in **Table 7.2**. A permissible limit of 10 mg/L for COD and 3 mg/L for Biochemical Oxygen Demand (BOD) has been adopted.

The EDCA for the breached concentration of Chemical Oxygen Demand for Rivers has been calculated and showcased in **Table 7.3**. The calculations have been executed using Equation 1.

Table 7.3: EDCA for breached concentration of Chemical Oxygen Demand for rivers

Sr No.	Sample details	COD (mg/l)	Permissible Limit (mg/l)	Breached Concentration (mg/l)	Damage Cost (Euro/ Kg)	Economic Evaluation (₹) Million
1	Nag-1	94	10	84	0.098	69
2	Nag-2	24	10	14	0.098	11
3	Nag-3	60	10	50	0.098	41
4	Nag-4	126	10	116	0.098	95
5	Nag-5	120	10	110	0.098	90
6	Nag-6	92	10	82	0.098	67
7	Nag-7	142	10	132	0.098	108
8	Nag-8	186	10	176	0.098	144
9	Nag-9	140	10	130	0.098	106
10	Pilli-1	228	10	218	0.098	178
11	Pilli-2	222	10	212	0.098	173
12	Pilli-3	304	10	294	0.098	240
13	Pilli-4	182	10	172	0.098	141
14	Pilli-5	142	10	132	0.098	108
15	Pilli-6	82	10	72	0.098	59
16	Pilli-7	112	10	102	0.098	83
17	Pilli-8	134	10	124	0.098	101
18	Pora-1	84	10	74	0.098	61
19	Pora-2	96	10	86	0.098	70
20	Pora- 3	114	10	104	0.098	85
21	Pora-4	172	10	162	0.098	132

The breached concentration (deviations) is determined by comparing surface water quality parameters with the standards outlined in **Table 7.2** for COD. This serves as a reference for the monetary quantification of COD, utilizing the value transfer approach in the estimation process. Monetary evaluations for all samples are presented in **Table 7.3.**

Table 7.4: EDCA for breached concentration of Biological Oxygen Demand for rivers

Sr No	Sample details	BOD (mg/l)	Permissible Limit (mg/l)	Breached Value (mg/l)	Damage Cost (Euro/Kg)	Economic Evaluation (₹) Million
1	Nag-1	18	3	15	0.033	4
2	Nag-2	6	3	3	0.033	1
3	Nag-3	15	3	12	0.033	3
4	Nag-4	25	3	22	0.033	6
5	Nag-5	22	3	19	0.033	5
6	Nag-6	20	3	17	0.033	5
7	Nag-7	36	3	33	0.033	9
8	Nag-8	49	3	46	0.033	13
9	Nag-9	38	3	35	0.033	10
10	Pilli-1	127	3	124	0.033	34
11	Pilli-2	21	3	18	0.033	5
12	Pilli-3	67	3	64	0.033	18
13	Pilli-4	21	3	18	0.033	5
14	Pilli-5	36	3	33	0.033	9
15	Pilli-6	18	3	15	0.033	4
16	Pilli-7	28	3	25	0.033	7
17	Pilli-8	48	3	45	0.033	12
18	Pora-1	20	3	17	0.033	5
19	Pora-2	24	3	21	0.033	6
20	Pora-3	38	3	35	0.033	10
21	Pora-4	47	3	44	0.033	12

The breached concentration (deviations) is determined by comparing surface water quality parameters with the standards outlined in **Table 7.2** for BOD. This serves as a reference for the monetary quantification of BOD, utilizing the value transfer approach in the estimation process. The calculations have been executed using Equation 1. Monetary evaluations for all samples are presented in **Table 7.4.**

Table 7.5: EDCA for breached concentration of combined COD and BOD for 1 year for rivers

Sr. No	River	Economic Evaluation (₹) Million (2023) for one year
1	Nag	87
2	Pilli	148
3	Pora	95

In total 9 sampling locations were selected for the water quality analysis of Nag River, 8 sampling locations were selected for the water quality analysis of Pili river, and 4 sampling locations were taken for monitoring Pora river quality.

In the report, presented the calculation of EDCA for each sample code, as tabulated in **Table 7.3** and **Table 7.4**. Utilizing the data from these tables, we computed the average value of EDCA for the breached concentration of combined COD and BOD for one year for each river individually.

The Environmental Damage Cost Assessment (EDCA) for one-year amounts to ₹87 million for Nag River, ₹148 million for Pilli River, and ₹95 million for Pora River as illustrated in **Table 7.5**.

For the lakes, the Environmental Damage Cost Assessment (EDCA) has been computed for the breached concentration of both Chemical Oxygen Demand and Biochemical Oxygen Demand.

Table 7.6: EDCA for breached concentration of Chemical Oxygen Demand for lakes

Sr No.	Sample Code	COD (mg/L)	Permissible Limit (mg/l)	Breached Value (mg/l)	Volume (Litres)	Damage Cost (Euro/Kg)	Economic Evaluation (₹) Million
1	SG-1	82	10	72	247836250	0.098	0.08
2	SG-2	64	10	54	247836250	0.098	0.06
3	FL-1	36	10	26	1604565000	0.098	0.18
4	FL-2	42	10	32	1604565000	0.098	0.22
5	FL-3	45	10	35	1604565000	0.098	0.24

6	FL-4	44	10	34	1604565000	0.098	0.24
7	FL-5	74	10	64	1604565000	0.098	0.44
8	PD-1	56	10	46	43925000	0.098	0.01

The breached concentration (deviations) is determined by comparing surface water quality parameters with the standards outlined in **Table 7.2** for COD. This serves as a reference for the monetary quantification of COD, utilizing the value transfer approach in the estimation process. These calculations were performed utilizing the formulation presented in Equation 2.

Table 7.7: EDCA for breached concentration of Biological Oxygen Demand for lakes

Sr No.	Sample Code	BOD (mg/L)	Permissible Limit (mg/l)	Breached Value (mg/l)	Volume (Litres)	Damage Cost (Euro/Kg)	Economic Evaluation (₹) Million
1	SG-1	22	3	19	247836250	0.033	0.007
2	SG-2	15	3	12	247836250	0.033	0.004
3	FL-1	8	3	5	1604565000	0.033	0.012
4	FL-2	10	3	7	1604565000	0.033	0.016
5	FL-3	10	3	7	1604565000	0.033	0.016
6	FL-4	10	3	7	1604565000	0.033	0.016
7	FL-5	18	3	15	1604565000	0.033	0.035
8	PD-1	12	3	9	43925000	0.033	0.001

The breached concentration (deviations) is determined by comparing surface water quality parameters with the standards outlined in **Table 7.2** for BOD. This serves as a reference for the monetary quantification of BOD, utilizing the value transfer approach in the estimation process. Monetary evaluations for all samples are presented in **Table 7.7.**

Table 7.8: Average EDCA for breached concentration of combined COD and BOD for lakes

Sr. No	Lake	Economic Evaluation (₹) Million
1	Sonegaon	0.08
2	Futala	0.28
3	Pandharabodi	0.01

A comprehensive assessment of lake water quality involved the examination of 17 sampling locations. These included 4 locations from Ambazari Lake, 5 from Futala Lake, 2 from Gorewada Lake, 2 from Sonegaon Lake, 1 from Binaki Lake, 1 from Naik Lake, 1 from Sakkardara Lake, and 1 from Pandharabodi Lake. Based on the availability of data, economic valuation was conducted for three lakes, specifically Sonegaon, Futala, and Pandharabodi lakes.

In this report, we break down the Environmental Damage Cost Assessment (EDCA) for each sample code, detailed in both **Table 7.6 and Table 7.7.** Using the information from these tables, we calculated the average EDCA value for the breached concentration, including combined COD and BOD, for each specific lake under consideration. The resulting Environmental Damage Cost Assessment (EDCA) is presented in **Table 7.8**, showing values of ₹0.08 million for Sonegaon Lake, ₹0.28 million for Futala Lake, and ₹0.01 million for Pandharabodi Lake.

7.4 Conclusion

The focus of this study is on evaluating the monetary implications of environmental harm caused by elevated pollutant levels in three rivers (Nag River, Pilli River, and Pora River) and three lakes (Sonegaon, Futala, and Pandharabodi). The assessment employs the VTM approach to estimate the Environmental Damage Cost Assessment (EDCA) based on certain assumptions which are highlighted in the report. The calculated costs are ₹87 million for Nag River, ₹148 million for Pilli River, and ₹95 million for Pora River. Furthermore, the EDCA for the lakes is ₹0.08 million for Sonegaon Lake, ₹0.28 million for Futala Lake, and ₹0.01 million for Pandharabodi Lake. The substantial monetary values obtained from the analysis underscore the severity of pollution loads affecting the water ecosystems. Pollution loads in rivers and lakes can inflict substantial damage on aquatic ecosystems. Elevated levels of pollutants, such as chemicals and contaminants, disrupt the

delicate balance of the ecosystem by affecting water quality and diminishing oxygen levels. This can lead to the decline of aquatic species, including fish and other organisms, disrupting food chains and biodiversity. Additionally, the accumulation of toxins can result in long-term harm, causing diseases and reproductive issues among aquatic life. The overall impact extends beyond the water, affecting surrounding habitats and posing risks to human health through the consumption of contaminated water or aquatic resources. These high Figures reflect the extensive environmental damage caused by elevated pollutant levels in the assessed rivers and lakes, emphasizing the urgent need for effective mitigation measures to safeguard these crucial water resources. Conveying these damages through monetary terms proves to be a potent strategy for creating awareness within local municipalities and governing entities. This assessment not only emphasizes the magnitude of the harm but also aligns with the implementation of the principle that the party responsible for pollution should bear the associated costs.

Further, it is important to note that these are just damage costs, if one was to calculate the remediation and control cost, it would be far more higher. (Bherwani et.al.2020). The key takeaway from this study is that early intervention in environmental pollution incurs lower restoration costs. In other words, preventing environmental damage is more cost-effective than addressing it after occurrence. The study suggests that assessing the monetary value of environmental damages serves as a valuable tool to gauge the scale of harm resulting from pollutants exceeding prescribed standards or being released without treatment. This evidence can further guide policymakers to implement timely and essential measures for environmental protection.

7.5 Recommendations

1. Promote rigorous sewage water treatment practices to minimize pollutants discharge into water bodies.
2. A detailed bathymetric study should be carried out to understand exactly how big and deep the lakes are now. Dumping waste and pollution have made the lakes smaller and shallower. So, it's important to do a detailed survey to understand their current condition accurately.
3. Additionally, it is recommended to determine the discharge values for each river at various stretches. This will contribute to a more precise assessment of the Environmental Damage Cost evaluation.

4. While current valuations are based on certain assumptions, it is important to recognize the magnitude of damage and start corrective actions to minimize the damage immediately. Furthermore, it is important that baseline economic costs may be evaluated in detail with on-ground assessments to validate or modify the values obtained through VTM.

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Chapter 8

Socio-Economic Profile

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8. Introduction

8.1 Slums areas growth, legalization and rehabilitation

8.1.1 Profile of slums

In early 19th century, the people from western part of Vidarbha & Chhattisgarh migrated in search of jobs and started settling in old city area of Nagpur i.e. near Empress Mill (Cotton Industry). The squatting in Nagpur has taken place in proximity to the place of work and open land or low-lying unused areas. The development plan of Nagpur in 1971 for the first time identified 45 slum pockets. In 2012, there were a total of 439 slums in city, out of which 421 were recognized in the official data of Nagpur Municipal Corporation (NMC). Out of the 439 slums, there were 279 notified (Slum has legal status) and 142 non-notified (Slums do not have any legal or administrative status) and 18 newly identified slums. The number of households in slums was 2, 09,001 and the average size is about 6 per family. The land ownership of slum was 18% slums on the private land, 34% slums on mix which included government, industrial and private ownership and remaining 48% slums on government land. The securities of tenure or tenure right were not allocated to any of the slums situated in Government land.

The NMC has commenced a drive to identify plots, occupants, and issues of ownership to slum dwellers on lands owned by the state government. Currently there are a total of 428 slums in Nagpur city of which, 299 are notified slums while and 129 are non-notified slums according to Nagpur Municipal Corporation. Detailed mapping exercises (Plane table maps) of slums of the city has been conducted by Centre for Sustainable Development (CFSD), Nagpur, for the flagship “Patta-watap” program in close co-ordination with the “Patta-watap cell”. This is a single window system for the slum dwellers where the maps and surveys are submitted for further processing. wherein, detailed socio-economic surveys of the slum dwellers have also been done in order to ensure that they get their ‘Pattas”.

The slum population has grown to 6.69 lakhs in the notified slum areas and 1.37 Lakh in the non-notified slum areas (**Figure 8.1).**

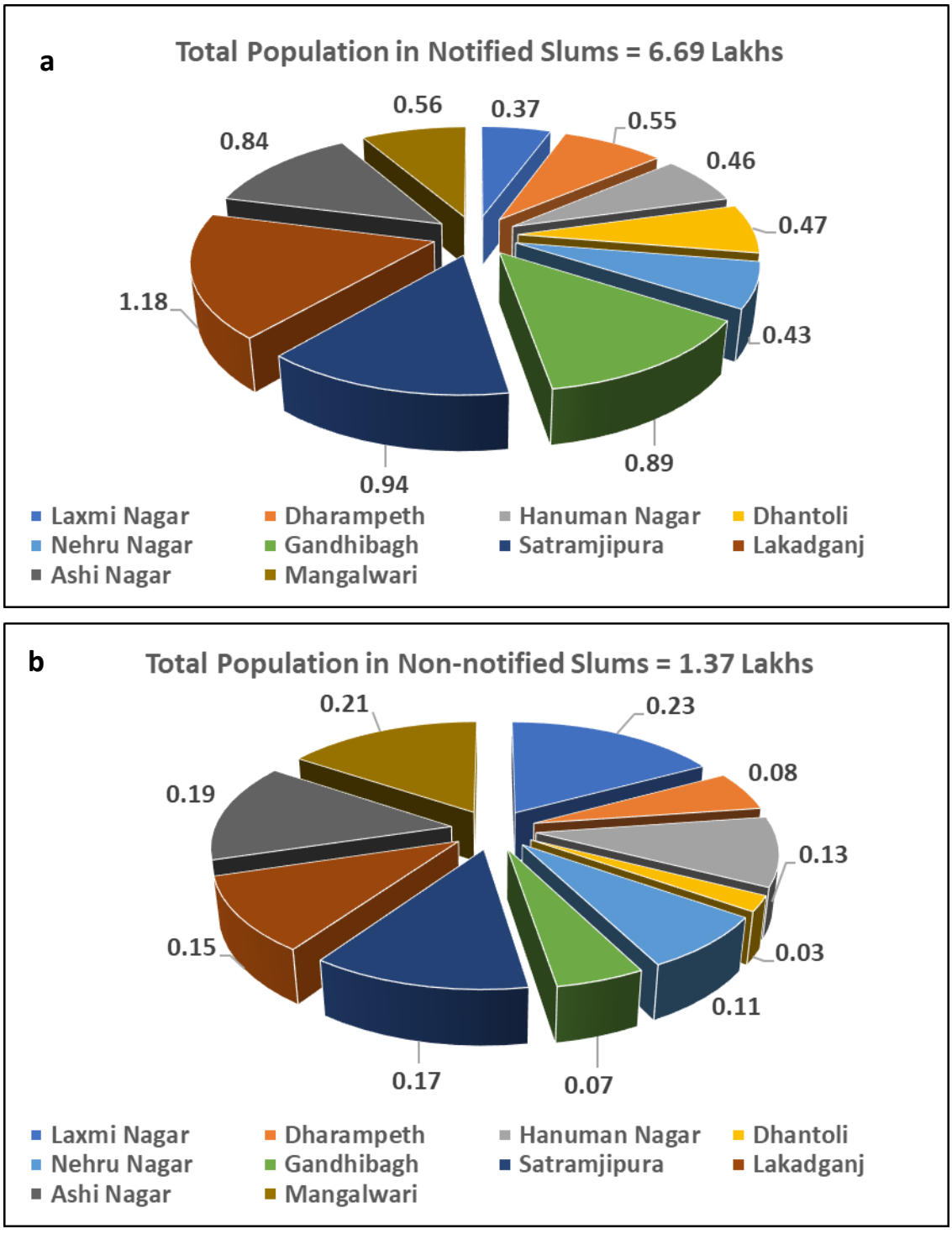

Fig 8.1: Total population in (a) Notified and (b) Non-notified slums in Nagpur city (Source: NMC)

8.1.2. Types of slums in Nagpur

Three main types of settlements are identified in Nagpur in terms of settlement development processes, land tenure and settlement characteristics.

1. **Organic Settlements**: These settlements are traditional, thickly built-up high density traditional/organic old areas in central city, which have grown and are shaped by changing socio-political and economic forces.
2. **Unauthorized Housing Layouts:** The settlements where land is subdivided without prior approvals and sold, are termed as 'unauthorized housing layouts'. The land ownership of buyers is legal but land subdivision regulations, zoning and building codes are violated. Municipal services are, therefore, not provided by local bodies. Such developments are also found on lands earmarked for facilities and “green belt” in the Development Plan. The infrastructure standards are poor but the community generally belongs to the middle and lower middle-income group. Densities vary between low to medium.
3. **Squatters (Zopadpattis)**: These Settlements have come up by illegal occupation of public or private land mostly by low income population. Generally, the shelter conditions are poor with "kaccha' and "semi-pucca' structures and dwelling sizes are small. These settlements do not have a secure legal tenure and as such are vulnerable for clearance.

8.1.3 Slum Rehabilitation for Nagpur

Most of the slums are notified in the Lakadganj zone (47 slums) followed by Ashi Nagar zone (44 slums), Satranjipura zone (36 slums), and Mangalwarai zone (31 slums). Remaining zones had notified slums ranging between 17 and 28. On the other hand, the maximum number of non-notified slums were located in the Ashi Nagar (29 slums), Mangalwari (23 slums), and Laxmi Nagar (20 slums) zones with lower number of non-notified slums in the remaining zones.

There are around 1.41 lakh dwelling units (DUs) in slums, out of which around 40% of the DUs are pucca structure while 38% and 22% are semi pucca and kutcha structure respectively. Out of 428 slums, around 19% are on private land, while 17.5% are located on the government owned land. Other 20.5% of the slums are located on the land belonging to authorities like NMC, NIT, Revenue Department, University, airport/cargo hub/civil aviation and Indian Railways. Almost 43% of slums are located on land having mix ownership.

8.2 Initiatives for slum improvement

8.2.1 Slum Improvement Programme (1972-1994)

- The scheme was implemented by NMC in the year 1972 with an aim to provide basic infrastructure in slum settlements like water supply, roads, street lighting, drainage, sewer line etc.

8.2.2 Basic Services for Urban Poor (BSUP) (2006- Ongoing)

- This scheme was introduced in 2006 under JNNURM (Jawaharlal Nehru National Urban Renewal Mission) and implemented by Slum Rehabilitation Authority (SRA) Nagpur on the behalf of NMC.
- In this scheme 6,252 dwelling units (DUs) along with the infrastructure and facilities were proposed and sanctioned in 18 slum communities in Nagpur.

8.2.3 Rajiv Awas Yojana (RAY) (2007)

- In this, survey of 130 slums was already completed and socio-economic surveys as per formats issued by GoI were underway.
- Initial surveys were completed by SRA and mapping for 1 cluster (which consists of 5 slums) was taken up for implementation on project basis under RAY.
- Draft plan of Slum-free City Plan of Action (SFCPoA) was prepared by SRA based on the data available on slums.

8.2.4 Ramai Awas Yojana (2008- Ongoing)

Ramai Awas Yojana is the scheme of Government of Maharashtra which was introduced in 2008 and is ongoing project.

- This project was implemented by the Social Justice Department, and aims to provide housing for poor SC families and neo-Buddhists. No objective was kept for the year 2022-2023, however, during the preceding year 2021-2022, the Department sent a list of 3000 beneficiaries to the NMC, of which, 1000 were approved.

8.2.5 Slum Rehabilitation Scheme, Nagpur (2006-Ongoing)

- This scheme was launched by Government of Maharashtra in 2006 and is ongoing project which uses land as a resource to redevelop slums. The scheme has two models in Nagpur in which first had 70% funding from central government and the 30% was from builders, while second had a ratio of 50% central government, 20% state government, 9% municipal grant and remaining 11% beneficiary contribution.
- The Slum Rehabilitation Authority (SRA) in Nagpur decided to build around 13,600 houses for poor but the target over the time was revised to 3,000 houses. But the scheme failed due to lack of response from people, flat size being offered and impracticable financial model.

8.2.6 Pradhan Mantri Awas Yojana (PMAY) (2015-Ongoing)

- The PMAY 'Housing for All' scheme announced by Union Minister & Chief Minister had a schedule of 17th June 2015-31st March 2022, where it was planned to build 50,000 houses for poor by NIT and Maharashtra Housing and Area Development Authority (MHADA).
- Accordingly, as per the Maharashtra Government order dated 17/11/2018, NMC has commenced a drive for effective implementation of the "Housing for all 2022" mission by allocation and regularization of leases to private land encroachment holders within Naagri Sthanik Swarajya Sanstha area, with the land referred to as slum strip and the encroachment holders referred to as slum dwellers. The encroachment holders who had encroached private land within the civil sector would be excluded from availing the benefits under this scheme. The said government decision has been made available on the website www.maharashtra.gov.in of the Government of Maharashtra (Code 201909111500180525) which entails the following terms and conditions;
    1. While proceeding in accordance with the above procedure, the provisions of all the laws/rules/governance decisions pertaining to the tenure of such private land shall be implemented. Complete confirmation should be made.
    2. Regarding such land, if any court cases are filed, the current status of the same should be considered. Also, with respect to such land, if an order has been passed by the

Hon'ble Court, it will be the responsibility of the concerned Commissioner/Chief Officer of the Civil Local Bodies to ensure that such orders are not violated.

8.3 Economic profile

At present Nagpur is the third largest city in the state of Maharashtra after Mumbai and Pune and is the largest city in central India. Nagpur is also being developed as a Smart City under the Government of India (GoI) Smart City Program (Federation of Indian chambers of commerce and Industry, 2018). NMC spreads over an area of 227.29 sq. km with a total estimated population of 3.316 million in the year 2023. Nagpur city makes up 4.73% of the total urban population of the Maharashtra state (Arcadis Germany, 2017). The city is now among the fastest growing cities in India and is rapidly emerging as commercial, retailing and logistic hub. As per the report published by Oxford Economics, Nagpur is the fifth fastest growing city in the world growing at the GDP of 8.41% (Chakraborty, 2018).

8.3.1 Demography analysis

Demography analysis of a city includes of influential factors such as size, structure and distribution of the population, birth rate, death rate, aging, and migration. This helps in studying the previous and existing demographic status of the Nagpur city. Population forecasting till the year 2031 was worked out in the section.

8.3.2 Current population

Latest population survey of the Nagpur City was conducted in the year 2011 under the nationwide Census of 2011 performed by the Union Government of India. As per the Census, Nagpur had a population of 4.65 million of which Nagpur city accounted for 2.405 million that was a change of 14.40% over the population as per 2001. Out of the total Nagpur population for 2011 census, 68.31% resided in urban regions while 31.69% resided in the rural regions of district. The scheduled census in 2021 was postponed due to Covid, hence the population of Nagpur city for the year 2022-23 was estimated to be 3.316 million which was based on past growth rate.

8.3.3 Nagpur literacy rate and sex ratio

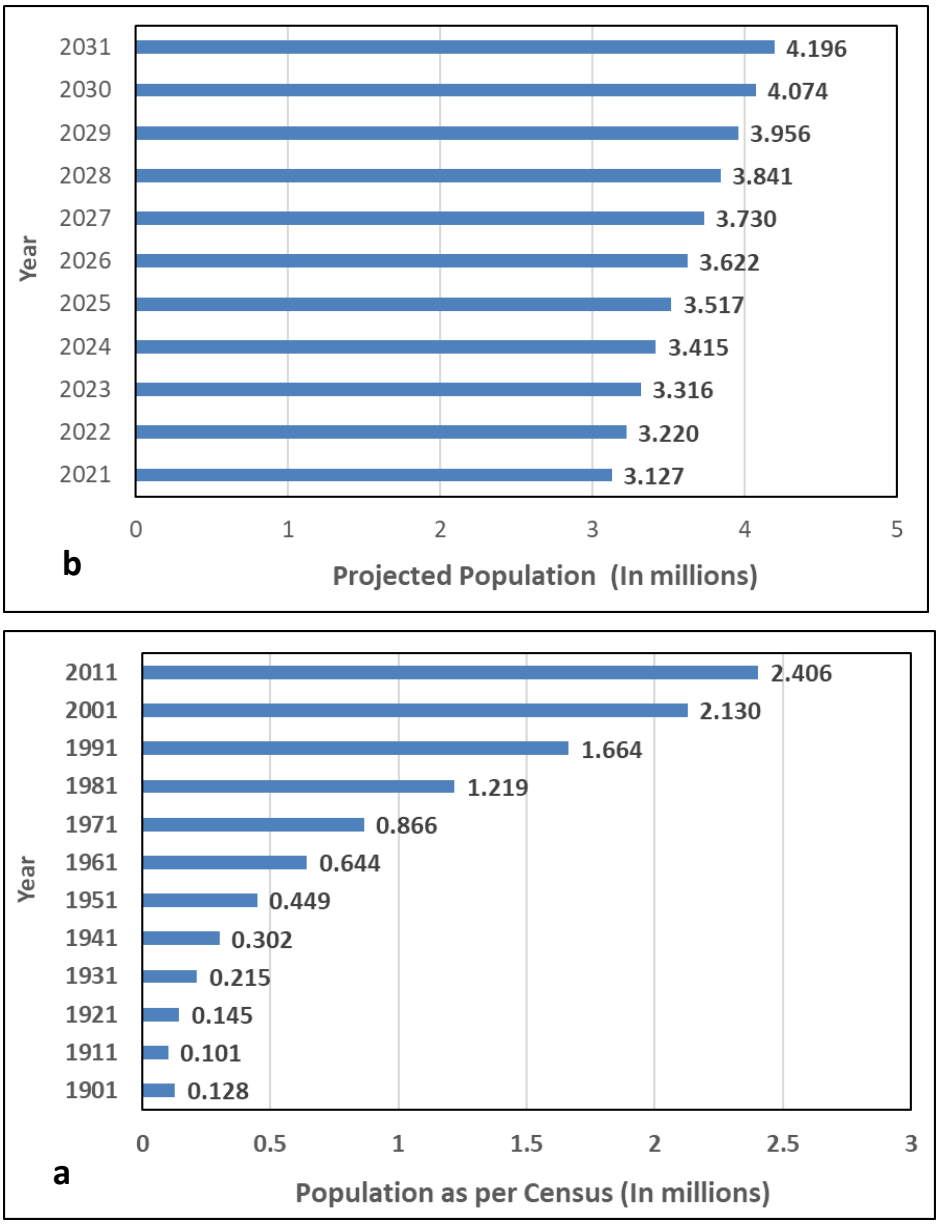

Figure 8.2: (a) Decadal population growth rate (1901-2011) (b) Projected population (2021-2031) for Nagpur city (Source: https://www.ceicdata.com/en/india; https://www.census2011.co.in/ /census/city)

As per Census 2011, the average literacy rate of Nagpur city was 91.92% which was higher than the National Urban Average of 85%. The total literate population in Nagpur city was comprised of 1,984,123 literates of which 1,036,097 (94.44%) were males while 948,026 (89.31%) were females. The sex ratio of female to male in Nagpur city was found to be higher at 963 females per 1000 males in comparison to National Urban Average of 926 females per 1000 males. The

child sex ratio (0-6 y age) was 926 girls against the National Average of 902 girls per 1000 boys. The decadal growth rate of the city during the last decade is 17.24%, which was less than the state and country urban population growth rate of 22.57% and 31.80% respectively.

The overlay of decadal growth rates of the city on the decadal population as per multiple censuses for the period 1901-2011 is depicted in the **Figure 8.2a.** The average decadal growth rate of the study period was 32.29%. Rapid increase in the decadal growth rate was observed in the decade of 1911-1921. Thereafter, flatter growth rate curve was observed till 1991. After that continuous fall in the decadal growth rate was recorded. However, city's population continues to rise throughout the period and is projected to rise in the future years too and population forecast for the decade 2021-2031 is shown in the **Figure 8.2b**.

8.4 Pillars of Nagpur economy

8.4.1 Trade and commerce

8.4.1.1 MIHAN

MIHAN an acronym for Multi-modal International Cargo Hub and Airport at Nagpur, is the India's biggest economic development project and the flagship development project started by Government of Maharashtra. The project is planned to exploit the geographical central location of Nagpur in the country for developing an integrated industrial, commercial, and transport hub. The project which sprawls over an area of 4,354 hectares, houses Special Economic Zone (SEZ), air cargo terminal, rail terminal, and a road terminal. The major components and their highlights are presented in **Figure 8.3.**

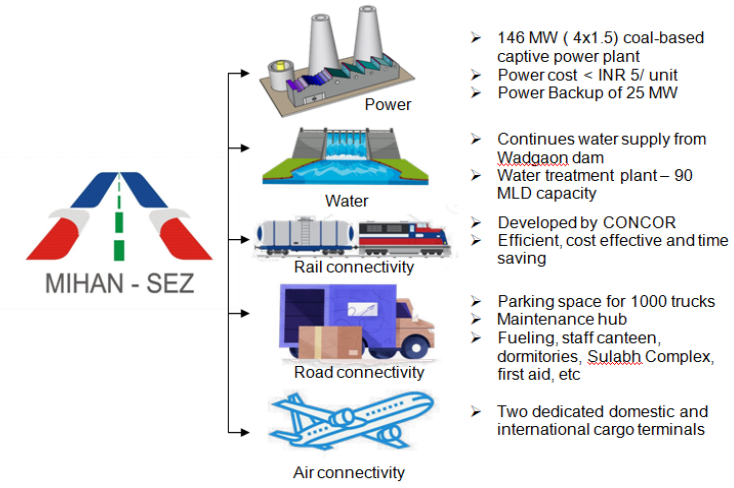

Figure 8.3: Components of MIHAN

The project is envisaged to develop a 'Zero Mile Market' for the nation and to bring investments and prosperity to the Nagpur region. Big industries and IT companies have already invested in the project such as Boeing, Mahindra Satyam, L and T Infocity, Ambuja Reality, HCL Technologies, TCS, Infosys etc.

The construction and development cost of the project is around Rs. 2,581/- crore and expected investment by the private investor will be Rs. 20,000 crore. MIHAN project will generate employment for over 4.5 lakh youth of Nagpur region over next 10 years (Mihan SEZ, 2020).

8.4.1.2 Startups and new businesses

Nagpur is also a hub on new startups with intensive initiatives taken by the center and state governments. As highlighted in **startupblink.com**, the startup scenario of Nagpur has become more promising since its improvement in Global Ecosystem Index by 11 spots to 660th rank. The startups that have come up in the last few years are covered under diverse areas such as Healthtechs (e.g. YourPhysio, ErlySign,), Edtechs (e.g. Techquadra Soft, MenuLao, Lockene), Software-Datas & Hardware-IoTs (e.g. COJAG, AOTOM Technology, SMM growth, Tsecond Generation), Ecommerce & Retails (e.g. Sthenic Technologies, Logrow Technologies).

8.4.2 Transportation

Commuting facilities are the backbone of a metropolitan city. Commuting facilities includes Metro rail system, public buses, private cabs, auto rickshaw, etc. The city of Nagpur owns the country's greenest metro rail network operated by MAHA Metro. Also, one of the oldest railway stations too exists in Nagpur which is being in operation since 1867. The city transport in Nagpur was being catered by Aapli Bus which was earning an average daily income of Rs. 24 Lakh to the NMC. 345 buses were being operated by Aapli Bus which were being used by 1-1.11 lakh passengers along with 16,000 students, on a daily basis (https://timesofindia.indiatimes.com). This included 50 AC and 96 e-Buses purchased under central government's 15th Finance Commission (https://government.economictimes. indiatimes.com). As per a survey by NMC, Nagpur city which was spread over an area of 227.29 sq km, had a road network comprising of 1491.19 km of tar roads while, 666.78 km were converted to cement roads by 2021 along with 144 km kuccha roads in this period (https://timesofindia.indiatimes.com). Nagpur city had the distinction of having a unique four-layer transport system which included (from bottom to top)

an existing road with a railway bridge over it, followed by a flyover and elevated metro railway track at the top-most level (**Figure 8.4)**. As the nucleus of the country, major highways of the country also pass across the city, connecting major metropolitans such as Mumbai, Delhi, Bhopal, Hyderabad, Indore, and Raipur. Key initiatives and projects under commuting facilities are discussed in the flowing sections.

Figure 8.4: First of its class 4-layer transport system (Source: https://timesofindia.indiatimes.com)

8.4.2.1 Nagpur Metro

Nagpur metro is the 13th metro railway system of the country (**Figure 8.4**), and is the greenest one with 65% of its electricity requirement meeting from solar energy. Phase-I of the Nagpur city metro rail project which was developed at a cost of more than Rs. 8650 crore was inaugurated by the honorable prime minister and dedicated to the nation in December 2022. The phase-I which covered a distance of 40 km has 36 stations, 2 depots and a fleet of 69 metro cars. At the same time, the foundation stone of Phase-II of the rail project was also laid by the prime minister, which will be developed at a cost of Rs. 6700 crore and will have 32 stations covering a 43.8 nm distance (https://economictimes.indiatimes.com).

8.4.2.2 Railway connectivity

Nagpur city enjoys railway connectivity since long back. Nagpur railway station is one of the oldest railway stations of the country and functional since 1867. It is a junction of Howrah-

Mumbai and New Delhi–Chennai main lines. The station has daily availability of the trains connecting to the major metropolitans such as Mumbai, Delhi, Chennai, and Kolkata. Recently, Nagpur railway station was shortlisted with 22 stations in the country that will be developed to the international standards. Apart from it, there are five minor railway stations within the city at Ajni, Itwari, Kalamna, Kamptee, and Khapri. Indian railways have developed Ajni railway station into a terminus. Indian Railways has announced that Ajni railway station will be all-women run railway station.

Accordingly, the foundation stone was laid by honorable prime minister in December 2022 for redevelopment of Nagpur and Ajni railway stations (**Figure 8.5)** at an estimated cost of Rs. 589.22 crore and Rs. 359.82 crore and a project completion of 36 and 40 months respectively. The redeveloped stations would have all the modern amenities for passengers and will have green buildings with solar energy, water conservation, and rainwater harvesting. Additionally, the Government Maintenance Depot at Ajni (Cost Rs. 110 crore) and Nagpur-Itarsi 3rd line project (Cost Rs. 450 crore) were dedicated to the nation (https://www.pib.gov.in).

Figure 8.5: Nagpur station redevelopment plan (Source: https://www.pib.gov.in)

8.4.2.3 Maharashtra Samruddhi Mahamarg

To boost economy of Nagpur and its connectivity with the business capital of the country i.e., Mumbai, the government of Maharashtra initiated the ambitious super expressway project named Maharashtra Samruddhi Mahamarg. The project which would cost an estimated Rs. 55,000 crore, stretched up to 701 km and will include over 50 flyovers, over 24 interchanges, more than 5

tunnels, more than 400 vehicular and over 300 pedestrian underpasses at strategic locations. Phase-I of 701 km expressway, i.e. 520 km between Nagpur and Shirdi was inaugurated by the honorable prime minister in December 2022 (https://indianexpress.com). The expressway is estimated to be used by 30000-35000 vehicles daily with a top speed of 150 kmph and will connect 10 districts in Maharashtra, while the inter-connecting highways and feeder roads will connect 14 other districts. This super expressway would cut short the travel time between Nagpur and Mumbai by nearly half of the earlier and would enable to travel within 8 hours. It was aimed at providing ease of connectivity of Nagpur with the business capital of country, Mumbai, bring prosperity to the region, and link MIHAN to the country's largest container port – JNPT.

8.4.2.4 Air connectivity

Nagpur had an air strip operated at the time of World War-I and World War-II, which was converted to a fully functional airport after the independence from British rule in the year 1949. This airport was associated the unique "Night Air Mail Service" of India Post wherein four airplanes each originated from a major metropolitan i.e. Delhi, Kolkata, Chennai, and Mumbai lands at Nagpur, exchange mails of the destination city and fly back to the originated city. This practice of exchanging mails was practiced from January 1949 until October 1973.

Aviation of the city is backed by Dr. Babasaheb Ambedkar International Airport, which is operated by MIHAN India Limited, with a terminal building of approx. 25000 sq. m. The airport has following facilities including parking bays for aircrafts, check-in counters, separate domestic and international boarding gates, customs & immigration counters (https://mihanindia.in/airlines-operator). The airport currently has three domestic offering flights to thirteen cities and two international airlines with a significant footfall of 9000 passengers/day and 150 metric ton cargo/day (http://www.madcindia.org/air_avia_hub_ngp). The existing runway is to be extended by 200 m and an additional runway is to be constructed alongside. The upgraded airport will be capable of handling daily passenger load of 14 million and cargo load of 8,70,000 tonnes (MihanSEZ, 2020). Passenger aircraft manufacturer Boeing invested $100 million for setting up of its regional aircraft service and maintenance facility. Inclusion of airport with the MIHAN is attracting lot of global firms to invest in the region. As the strategic location of Nagpur, gives an upper hand in logistic and managing the business across the country.

8.5 Educational Institutes

Nagpur is an educational hub of central India and comes right after Mumbai and Pune in terms of premier educational Institutes. Nagpur University formally named as Rashtrasant Tukadoji Maharaj Nagpur University is the pioneer institute for higher education and was established in the year 1923. Subsequently, entry of national level institutions like Government Medical College, Indra Gandhi Government Medical College, and Vivesvaraya National Institute of Technology has improved stature of Nagpur as educational hub. Over a last few years, key national level institutions such as AIIMS, IIM, IIIT and NLU were established in the city while, prestigious private universities like Symbiosis International University have also opened their campus. The region around Nagpur has 27 engineering colleges with about 8,600 engineering students passing out of these colleges every year.

Opening of prime institutes has made availability of skilled human resource in the region. This will complement the MIHAN project and will attract industries, BPOs, businesses in the city. Apart from prime institutes, Nagpur also has many private and government aided colleges offering courses in academic and professional course. There are 503 colleges affiliated under Nagpur University alone (RTMNU, 2020). A Dataquest-IDC study of the top ten IT cites in India ranked Nagpur seventh, based on parameters such as manpower availability, information, communication and technology (ICT) infrastructure availability and usage, lifestyle and environment. Also, as per the KPMG – NASSCOM survey, Nagpur is one of the top four tier II cities that have a huge potential for information technology and IT enabled services. Nagpur also possesses a strong primary and secondary education structure. In the year 2017-18 with 12,805 primary and 3,216 secondary and higher secondary schools, Nagpur region had best Student- Teacher Ratio (STR) in the state at 29.4 and 27.5 respectively.

8.6 Key indicators

8.6.1 Human development index (HDI)

HDI, measures the quality of life of the citizens on basis of their life expectancy, education, and per capita income. Developed by economist Mahbub ul Haq, it relates development of a state in terms of the ability of its citizens to “be” and “do” desired things in life. As per the data published in Economic Survey of Maharashtra 2022-23, by the Directorate of Economics and Statistics, Government of Maharashtra, HDI of Nagpur was 0.786, while among the important

cities of Maharashtra with >20 lakh population, only Thane (0.800 HDI), Pune (0.814 HDI) and Mumbai (0.841 HDI) had higher HDI in the state. However, Nagpur's HDI was higher than the state's average 0.752. **Figure 8.6** represents the HDI of the cities of Maharashtra as per census 2011, with few representative cities depicted under each category of HDI status viz., low, medium, high, very high

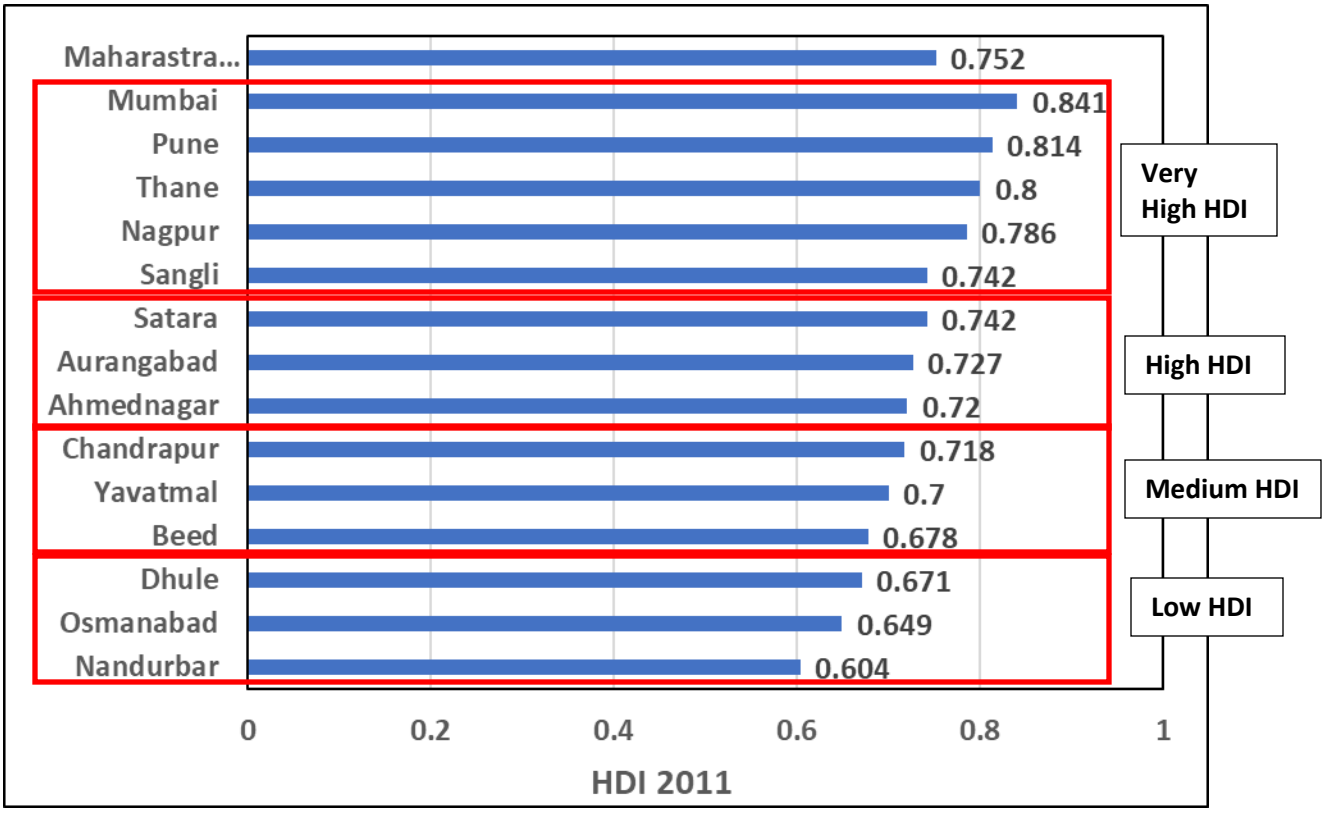

Figure 8.6: HDI of representative cities of Maharashtra (Source: https://mahades.maharashtra.gov.in/)

8.6.2 New business registrations

In India 95% of the business establishments come under small and medium enterprise sector which serve as the backbone of the country's economy. To identify, regularize, and promote micro, small, and medium enterprises, the GoI has launched Udyog Adhaar. The registrations of Udyog Aadhar done in region directly indicate the state of trade and commerce of that region. In Maharashtra, Nagpur stood fourth in the enrolment for medium industries, fifth in the enrolment for small industries, and sixth in the enrolment for micro industries and succeeded by Mumbai, Konkan and Pune till November 2022. This has generated employment to nearly 7.7 lakh population.

8.6.3 Gross value added (GVA)

GVA is used to check how much value is added (or loss) from a particular region, district, or state. GVA gives a clear outlook of the region's economy as it adds up the subsidies induced by the government and subtracts the taxes imposed on the tax payers. Sector wise percent share of GVA of Nagpur revenue division and GDP is presented in the **Figure 8.7** for the period from 2011 to 2022.

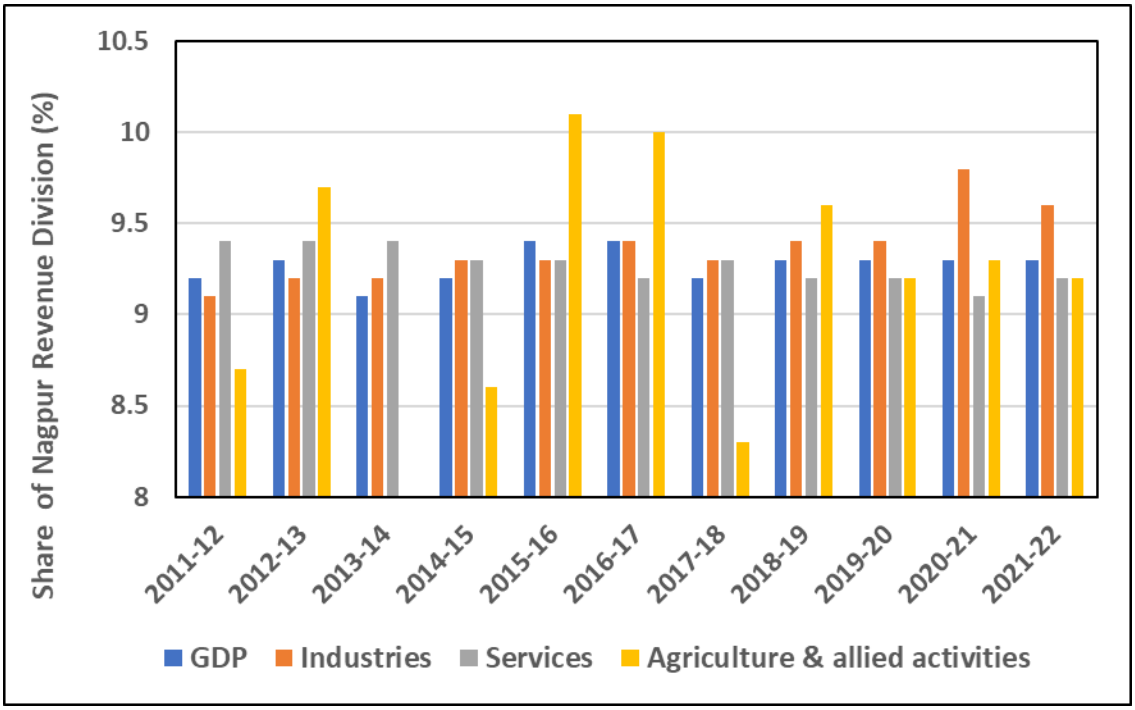

Figure 8.7: Sector wise percent share GVA of Nagpur revenue division (2011 - 2022) (Source: https://mahades.maharashtra.gov.in/)

8.7 Summary & Conclusions

Being located exactly at the geographical center of the country, Nagpur offers an exclusive coverage and command over pan India. This unique characteristic of Nagpur was utilized since the independence. The first instance of taking advantage of the geographical location of Nagpur was observed when India Post exchanged mails from the major metropolis at the Nagpur through airplanes and then flown back to respective city with respective mails. The most recent effort made the government, in this direction is introducing the Multi Modal international cargo hub and industrial center named as MIHAN.

MIHAN is set to boost development of Nagpur region and will attract international companies and investors to invest in the project. The economy of Nagpur was revitalized by the inception of MIHAN with big players like Boeing, Infosys, TCS, Mahindra etc setting up their firms and offices. This has created employment opportunity to the youth of Nagpur. Nagpur always has national level educational institutions but the job opportunities always remains insignificant leading to migration of highly skilled youth to other cities. MIHAN provides a relevant option for employment to the youth within Nagpur.

The upgradation of Nagpur railway station in the lines of international standards and conversion of Ajni railway station into terminus has been initiated. Samruddhi Mahamarg will strengthen the connectivity of Nagpur with Mumbai, the economic capital of the country. Also, entry of premier national level institutes such as AIIMS, IIM, IIIT, NLU, and NIPER adds up the educational profile of the city.

Nagpur is a home for successful start-ups under diverse areas such as Healthtechs (e.g. YourPhysio, ErlySign,), Edtechs (e.g. Techquadra Soft, MenuLao, Lockene), Software-Datas & Hardware-IoTs (e.g. COJAG, AOTOM Technology, SMM growth, Tsecond Generation), Ecommerce & Retails (e.g. Sthenic Technologies, Logrow Technologies). The development of Nagpur is planned well but the government must anticipate the demand and need of the growing Nagpur city with appropriate planning, policy and implementation well in advance.

ESR (2022-23)

Chapter 9
Recommendations

CSIR-NEERI

WWW.NEERI.RES.IN

9.1 Recommendations: Chapter 1: Ambient Air Quality

Based on the AAQ status and Emission Inventory of the city, the following specific recommendations to control air pollution in the city can be prioritized.

1. It is observed that particulate matter, specifically $PM_{10,}$ is a pollutant of concern. Therefore, the control and management policies need to be oriented to mitigate PM_{10} pollution in the city.
2. Ambient air quality monitoring stations operated by MPCB and CPCB under SAMP and NAMP programmes have been augmented with respect to number of stations and the number of parameters monitored. There is a need to maintain them properly to provide consistent and reliable data. A transparent auditing practice is required for these stations. The capacity building programme for the government officials to train them for the ambient air quality monitoring and emission inventory study can be organized. CSIR-NEERI can impart training to the identified government personnel.
3. Gridded emission inventory of Nagpur city needs to be generated on regular basis. This is possible if the activities causing air pollution emissions are updated regularly in a pre-defined manner. This includes, updating of number of new construction activity, closing of completed construction activity, number of dead bodies in crematoria, new hotels, restaurants etc.
4. The city's road network is changing from flexible to stiff pavement, so it is necessary to assess the silt load from the various routes. This will display the real emission load resulting from the resuspension of road dust. It is suggested that CSIR-NEERI will carry out study for silt load of Nagpur roads and estimate the road dust resuspension.
5. CSIR-NEERI has developed a vehicular counting tool to count the number of vehicles that pass through a certain road segment. Given that Nagpur's smart city plan includes installation of CCTVs to monitor city activity, CSIR-NEERI can calculate line source emissions, if an access to CCTVs is provided. This could be an effective strategy for significantly reducing the city's pollution load.
6. Dust emissions from tall building construction are one of the major challenges that must be addressed. Residual construction material left outside the construction site, on the roads, is a nuisance and a health risk. It is recommended that no such material be stored outside to reduce the amount of road dust resuspension. With appropriate safety precautions, the

material can be stored within the plot area. Regardless of the size of the site or plot, it is possible to prevent the exposure to particulate pollution from residential construction operations by firmly encircling the area with green netting up to the top of the constructed area, or other sheets/tarpaulin to prevent pollution from dispersing. NMC will issue a SOP for building construction with the above measures.

7. Traffic congestion due to parking of cars on both sides of the road in residential neighbourhoods has become a big menace in the city. Many areas are witnessing the narrowing down of the roads due to car parking on the space near the houses. The residents themselves get exposed to the micro-pollutants released due to vehicle halts. Appropriate policies need to be implemented to reduce the pollution-induced because of the vehicular traffic halts due to on-street parking.

Figure 1.15: Photographs of open burning

8. The solid waste department of NMC should issue a SOP for the respective zones mentioning the day and time for collection of garden waste. This will reduce the burning of garden waste in respective zones.
9. Open burning occurs in local and residential areas even though it is prohibited. The legislation therefore needs to be strictly enforced. Residents must observe appropriate guidance on solid waste management. In numerous locations, especially during the morning, at some places authorized workers and/or sanitary personnel assigned to tidy internal lanes

and streets sweep the streets, create a pile of trash and leaves, which they then publicly burn (**Figure 1.15**). Open burning is not a good practise from environment point of view and NMC should take strict action to stop such practises.

10. It is important to understand the air pollution contribution from the nearby areas and also the regional contribution. The air-shed of the area needs to be identified to account for the emissions sources present in the area.

9.2 Recommendations: Chapter 2: Climate Change

Sl. no.	Zone	Recommendations
1.	Lakadganj	• Lakadganj has the lowest WPI (0.425) compared to the other nine zones. Compared to the water stress scale (table 2), the Water availability in this zone is at moderate stress. However, it is moving towards water scarcity category. Therefore, the city's water conservation and management plans should highly prioritize this zone. • To understand where this priority action should focus on, we must look at the sub-indicators. For the Lakadganj zone, the highest priority may be given to improving **capacity for water resource management**. • For the development of capacity for management of water resources, policy action must focus on improving household literacy levels, employment rate and electricity coverage.
2.	Lakshmi Nagar	• With a WPI score of 0.519, Lakshmi Nagar Zone ranks 5th in water stress compared to all zones. This shows that the Lakshmi Nagar zone has moderate water stress. • The priority action for the Lakshmi Nagar zone should focus on proper **utilization of water resources.** • In the Lakshmi Nagar zone, to improve the WPI score, the

		policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water
3.	Dhantoli	• Dhantoli is ranked 8th in the city regarding water stress with a score of 0.558. This score suggests that this zone falls into the moderate water stress level. • For Dhantoli, the highest priority action should be the **utilization of water resources.** • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water
4.	Dharampeth	• Dharampeth has the best score of 0.622 for WPI compared to all other zones. As per the water stress scale, Dharampeth has the lowest water stress level, which shows that water conservation and management are decent in this zone. • However, to further improve the WPI score, policy action may focus on improving **water resource utilization.** • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water
5.	Aashi Nagar	• Aashi Nagar zone has the 3rd lowest WPI score of 0.453. A comparison to the water stress scale shows that Aashi Nagar falls in the moderate water stress category. • For Aashi Nagar, the highest priority action should target the

		utilization of water resources. • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water.
6.	Nehru Nagar	• Nehru Nagar zone has the 4th lowest WPI score of 0.469. A comparison to the water stress scale shows that Nehru Nagar falls in the moderate water stress category. • For the Nehru Nagar zone, the highest priority may be given to developing **capacity for water resource management**. • For the development of capacity for management of water resources, policy action must focus on improving household literacy levels, employment rate and electricity coverage.
7.	Hanuman Nagar	• Hanuman Nagar is ranked 6th in the city regarding water stress, with a score of 0.534. This score suggests that this zone falls into the moderate water stress level. • For Hanuman Nagar, the highest priority action should target the **utilization of water resources.** • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water.
8.	Mangalwari	• Mangalwari zone ranks 2nd in the city regarding water stress with a WPI score of 0.444. This score suggests that this zone falls into the moderate water stress level. • For Mangalwari, the highest priority action should target the **utilization of water resources.** • To improve the WPI score, the policy action should target the

		management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water
9.	Gandhi Bagh	• Gandhi Bagh zone ranks 7th in the city regarding water stress with a WPI score of 0.546. This score suggests that this zone falls into the moderate water stress level. • For Gandhi Bagh, the highest priority action should target the **utilization of water resources.** • To improve the WPI score, the policy action should target the management of water consumption in households, focusing on the sustainable use of water supplied by NMC. This can be approached by disseminating information on the sustainable use of potable water
10.	Satranjipura	• Satranjipura has the second-best WPI score of 0.605 compared to all other zones. As per the water stress scale, Satranjipura has the lowest water stress level, showing that water conservation and management are decent in this zone. • For Satranjipura, the highest priority action should target the **Accessibility to Water resources.** • To improve the WPI score, the policy action should target the improvement of accessibility to water resources. For this, the focus may be placed on improving access to safe drinking water through piped connections and reducing distance from water sources.
	Overall Recommendation	• Overall out of the 10 zones, 7 zones score low in the proper and sustainable utilization of water. In order improve the sustainable utilization of water the following steps maybe taken. o Water Audit of Nagpur city at zone level to understand the

		losses due leakages, illegal connections o Using of Mapping geo-spatial software like Risk-pinet to identify the leakages in underground pipes o Voluntary establishment of rainwater harvesting systems at household or apartment to supplement water supply and reduce demand on NMC supply. o Use of reclaimed wastewater for secondary non-potable uses like landscaping etc. especially in government departments o Use of water efficient devices like water level sensors, faucet aerators, waterless urinals (can be installed at government departments) o Use of nature-based solutions like green wall, roofs and bioswales to capture and regulate stormwater discharge o Separation of stormwater sewerage from wastewater sewerage o Artificial Intelligence based water monitoring and distribution systems (Control of Network pressure) o Training and education for sustainable use of water

9.3 Recommendations: Chapter 3: Green Open Spaces and Biodiversity

1. The percentage of total naturalized area against the total area of the city for the year 2020 is 10.81 % with a regular increase in buildup area that has doubled in last three decades. There is a need to integrate natural and green infrastructure in areas where green and blue spaces are declining.
2. Despite, having some good urban campus forests, reserve forests the green infrastructure and wetland health is declining. Ecological connectivity in the form of avenue plantations is not uniform throughout the wards and zone of the city that will require specific attention from NMC and allocation of budget to maintain and plant avenues for developing connectivity corridors and reducing fragmentation.

3. Native biodiversity in the city is on decline due to preference of as well as invasion of hundreds of plants that will further jeopardise habitat quality. NMC is preferring native trees in avenue plantation.
4. Protection of critical ecosystems for avifauna as well as butterflies and dragon flies i.e. wetlands and urban green ecosystems. Enforcement of Wetland Conservation guidelines, 2017 to ensure wetland protection and efforts for restoration and expansion of urban green spaces to preserve the habitat quality and quantity of the avifaunal diversity in the city.
5. Habitat restoration needs specific consideration as most of the parks and playgrounds in the city have historical plantations and there has been observation that most gardens and parks have only peripheral greening.
6. Following Other effective area-based conservation measures' (OECMs) guidelines and under recent Kunming-Montreal Global Biodiversity framework, 2022 existing campus and urban forests like Seminary, Ambazari, Bharat, Empress and Ajani should be conserved and continuous restoration drive under *Nagar Van Yojna* and GBF 30x30 initiative.
7. Vegetated area of the city has potential to improve ground water infiltration hence, ensuring that newly constructed build-up areas should have permeable pavements to address the emerging risks.
8. Multiple heat islands that area growing every year should have vertical greening efforts using recycled water for irrigation. New high rises should be promoted for nature based solutions, 33% of greening and also roof top agriculture.
9. WHO and Urban guidelines for per capita green space requirements needs to be mainstreamed in urban green spaces management.
10. 3x30x300 approach (3 trees from every home. 30 percent tree canopy cover in every neighbourhood. 300 metres from the nearest public park or green space) should be tried to implemented with ward wise local participation.
11. Schools should have compulsory one period for all for awareness on city environment and how to protect neighbourhood green and blue spaces
12. City administration is progressive and proactive in terms of having multiple activities related to conservation however, it will be crucial for NMC to enhance cooperation and

involvement of diverse stakeholders including public in urban greening, monitoring activities.

9.4 Recommendations: Chapter 4: Noise Environment

The high noise level during the festive season was majorly due to the bursting of firecrackers that leads to the rise in the ambient atmospheric noise.

1. The time limits prescribed (Diwali: 8:00 PM to 10:00 PM) for bursting firecrackers on various festive occasions should be stringently implemented to keep the ambient noise levels normal, at least for the rest of the hours.
2. The study recommends that fireworks celebrations be organized in a community in a common open place instead of celebrating the occasion individually so that precautions can be taken very effectively to avoid any health hazards.
3. The children are considered most vulnerable to noise exposure and require utmost care for hearing protection against firecrackers, such as hearing protectors, etc.
4. The Central Pollution Control Board (CPCB) and the Ministry of Environment, Forests and Climate Change (MoEF&CC) in India have recommended a ban on the manufacture, sale, or use of firecrackers that exceed noise limits of 125 dB(AI) or 145 dB(C)pk, tested at a distance of 4 meters from the point of bursting. It is essential to strictly enforce the CPCB regulations to manage noise pollution effectively during festive occasions.
5. Policymakers and authorities must strictly implement permissible limits as defined in the Noise Pollution (Regulation and Control) Rules 2010 to control noise pollution.
6. During the festive season, the loud noise caused by firecrackers can be disturbing and scary for domestic animals, especially those living in urban areas. This can make them vulnerable to the shockwaves created by fireworks. To ensure their safety and comfort, it is recommended to keep pets indoors with windows and doors closed. Similarly, stray animals may seek refuge in residential areas during this time. Instead of avoiding them, people can offer them a quiet place to hide and feel secure.

9.5 Recommendations: Chapter 5: Solid Waste

- Encourage and educate residents to segregate waste at the source into categories such as organic, recyclable, and non-recyclable. Foster a sense of responsibility and ownership among residents towards maintaining a clean and sustainable environment.
- Invest in the modernization of waste collection infrastructure, waste collection vehicles, and establishment of transfer stations.
- Implement a systematic and efficient door-to-door segregated waste collection system.
- Promote and establish composting facilities at all the bulk generators (generating more than 100kg) at the community levels as per SWM rules 2016 to reduce the burden on dumpsite and encourage the use of compost in gardens and green spaces in the surrounding.
- Coordinate with different recycling units for processing recyclable materials like paper, plastic, glass, and metal. Collaborate with recycling industries and support the development of a market for recycled products.
- Keep track of all the existing recycling units across the city and regular data monitoring
- Implement a robust monitoring system to track waste management practices and ensure compliance with regulations.
- Explore the use of technology, such as smart waste bins, to optimize waste collection routes and schedules.
- Implement a digital platform for reporting and resolving waste management issues, facilitating communication between residents and municipal authorities.
- Foster partnerships with academic institutions for research and innovation in sustainable waste management practices.

Implementing a combination of these recommendations can contribute to the improvement of municipal solid waste management in Nagpur. It's crucial to have a holistic and integrated approach involving the community, local authorities, and various stakeholders.

9.6 Recommendations: Chapter 6: Water Environment

1. To overcome the pollution levels of lakes, it is very essential to take proper care for its maintenance. It's the responsibility of both public and government to protect lakes as they play a big role on storage of water that helps to maintain ground water table.
2. The garbage dumps near the banks of the lakes under study, i.e., Sonegaon, Sakkardara, Naik and Binaki from Nagpur city need to be reduced by preventing disposal of garbage such as old and torn cloths, eatables, worship material used in festivals etc. by the public on the banks of lakes.
3. Public toilets, faecal matter, loitering stray animals were observed on the banks of Naik, Binaki and Pandharabodi lakes. Significant count of total and fecal coliforms was also detected in these lakes and in all the samples lakes in general. Open defecation needed to be prevented and the public toilets needed to be shifted/removed to prevent faecal matter from contaminating the lakes.
4. The substantial COD, BOD, and other nutrients (nitrogen and phosporous) concentrations in Naik and Binaki lakes due to high organics could be associated with anthropogenic activities which needed to be prevented/reduced in order to prevent the entry of organics into the lakes.
5. NMC may look into the aforesaid issues plaguing the other lakes, and may expedite the rejuvenation and development of remaining lakes by applying similar strategies of desilting, desludging, boundary/retaining/edge wall, etc. as being done for rejuvenation of Gandhisagar, Lendi, and Police line Takli lakes.
6. All the three rivers Nag, Pilli and Pora were found to be unsuitable for drinking, outdoor bathing, irrigation and propagation of wildlife fisheries due to increase in pollution as seen from COD, BOD and nutrient load as the rivers flowed through the city.
7. There is a need for reducing/preventing such several activities which are responsible for increased pollution load in the rivers, such as; dumping of waste by local vendors of fruits-vegetables, meat and other products, wandering of stray animals in the river or disposal of dead animals along the river bank.
8. The flow of drains carrying untreated and uncategorized sewage/waste from the city's commercial and industrial areas may be directly channelized to STPs to prevent their entry into the river thereby reducing the pollution from anthropogenic sources and the bacterial

contamination. The river pollution abatement plan being carried out by NMC under the AMRUT-II scheme should be aggressively implemented for rejuvenating the rivers.

9. The groundwater level (below ground level) in the study area shows a lot of variation in the range of 2.04 (NGW-3) to 8.43 m (NGW-8) during the Post-monsoon season of 2023. In the pre-monsoon season of 2024, the groundwater level was very shallow at locations namely, NGW-3 (2.12 m BGL) and NGW-7 (2.65 m BGL). The groundwater levels varied between 2.12 m BGL (NGW -3) to 12.20 m BGL (NGW -1) during pre-monsoon season.
10. It is observed that the groundwater level is very shallow (<3m) at locations NGW-3 and NGW-7. Based on the present situation, rainwater harvesting structures should not be recommended at the respective locations.
11. Based on the long-term monitoring, the groundwater level trend can be established and rain water harvesting programme can be implemented accordingly (CGWB, 2007).
12. Piezometers (100 – 150m depth) can be installed for monitoring the potential hot spots of groundwater extraction such as industrial clusters, hospitals, gated residential communities and hotels.
13. Implementation of roof top rain water harvesting and recharge activities can be done in public parks and play grounds where the groundwater levels are deepen pertaining to augmentation of groundwater.

9.7 Recommendations: Chapter 7: Ecosystem Services Valuation

1. Promote rigorous sewage water treatment practices to minimize pollutants discharge into water bodies.
2. A detailed bathymetric study should be carried out to understand exactly how big and deep the lakes are now. Dumping waste and pollution have made the lakes smaller and shallower. So, it's important to do a detailed survey to understand their current condition accurately.
3. Additionally, it is recommended to determine the discharge values for each river at various stretches. This will contribute to a more precise assessment of the Environmental Damage Cost evaluation.
4. While current valuations are based on certain assumptions, it is important to recognize the magnitude of damage and start corrective actions to minimize the damage

immediately. Furthermore, it is important that baseline economic costs may be evaluated in detail with on-ground assessments to validate or modify the values obtained through VTM.