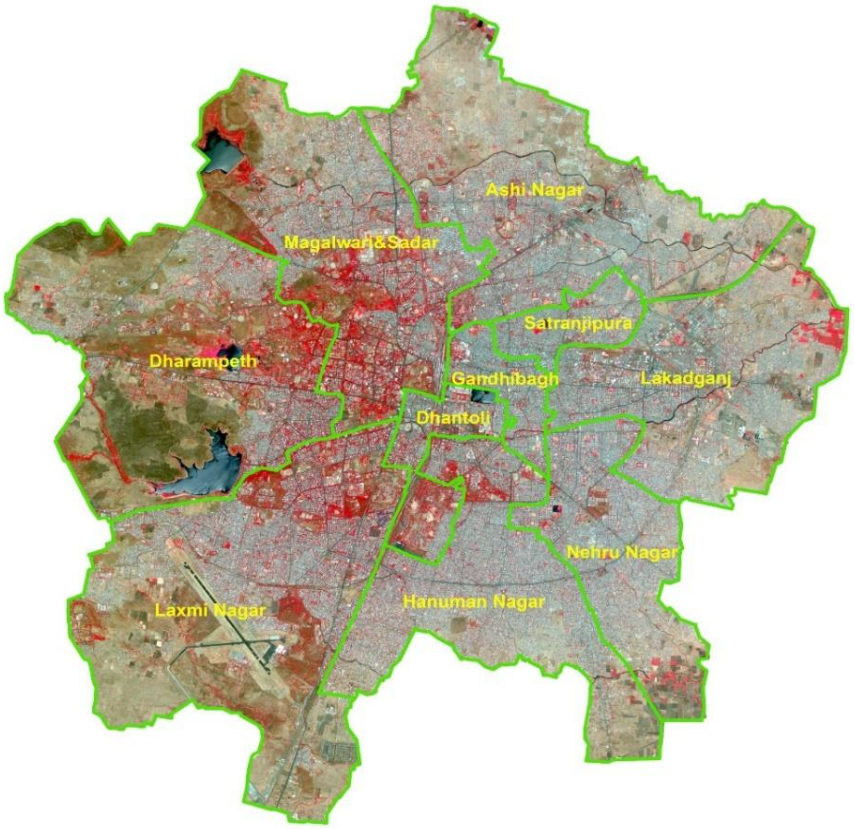

NAGPUR MUNICIPAL CORPORATION ESR (2019-20)

ENVIRONMENTAL STATUS REPORT: NAGPUR CITY

CSIR- National Environmental Engineering Research Institute, Nagpur

Executive Summary

ESR 2019-20

The Environment Status Report is mainly created to record the status of the environment in the city. This will help formulate the correct responses towards environment protection and will provide a logical decision-making structure for responses to planners, policy makers and citizens. Each year, CSIR-NEERI carries out evaluation of different aspects of the environment of the city and formulates recommendations that can be used for improvement. Quality of life is linked with the environment, making this document very essential in planning development of the city. Listed below are the highlights of this year's study;

1. **Climate Change**
    - Local climatic factors that would influence Nagpur's exposure to climate change impacts have been studied, viz., (a) Temperature, and (b) Precipitation.
    - Climate change impact of each risk factor on agricultural production, regional groundwater level, and energy use has been analyzed
    - The number of extreme heat events per year is on the rise with 85% of the years (2000-2019) showing an above-average anomaly
    - The annual rainfall pattern over Nagpur city has not changed significantly over the last 50 years. However, seasonal distribution of rainfall demonstrates significant pattern changes that could have a negative impact on agriculture
2. **Water Environment**
    - The city experienced water scarcity from March to July 2019
    - 96 -97% samples from Orange City Water Works were fit for drinking as per the criteria of Indian Drinking water standards (IS-10500-2012).
    - Water quality data of lakes indicate high pollution levels that need addressing
    - DNA analysis of the metagenome of two lakes indicate antibiotic resistant genes. This may be treated as a warning sign to improve treatment of sewage contaminated lakes, since these niches could act as hotspots for build up of the new emerging health concern – antibiotic resistant bacteria
    - Aquifer mapping indicated shallow ground water levels and results of bacteriological analysis suggested that water was unfit for drinking
    - The three rivers of Nagpur as well as major lakes have been analyzed in detail and indicate polluted status

3. **Urban Green Spaces and Ecosystem Services**
    - Nagpur is witnessing rapid expansion of the city and increasing urban sprawl scenario due to over densification
    - A survey was conducted across 100 wards to understand people's perception of urban green space
    - Ecosystem services of Urban Green Spaces (UGS) are not accessible to all residents of Nagpur. Those who have access have expressed social and cultural benefits
    - Any future planning of the city should factor in UGS development
4. **Solid Waste**
    - On daily basis, Nagpur is generating an average of 1150-1200 tonnes (TPD) of waste, with an average per capita waste generation of 4.46 kg out of which only 150-200 TPD of waste is being processed
    - Biomining at dump sites has been initiated by NMC
    - Segregation practices have been initiated but are not in practice at household level
    - Increasing awareness of citizens is a must to manage solid waste
    - Buffer zones at dumpsites are crucial
5. **Environmental Externalties Evaluation for Solid Waste Dumping at Bhandewadi Dumping Yard, Nagpur**
    - Every year, the CSIR-NEERI ESR aims to study one area of the environment to assess monetary evaluation of economic damage. This report focusses on solid waste
    - Damage cost estimated due to the release of heavy metals into soil in the monsoon was found to be Rs 3.43 lakhs
    - The study estimates a total incurred damage of about 19.424 Million INR or about ₹ 1.94 Crore per year due to externalities from Bhandewadi dumping
6. **Ambient Air Quality**
    - Considerable spatial variations in the particulate matter and gaseous pollutant concentrations was observed
    - The monthly variations in PM10 concentration showed that it is well below the threshold concentration at Industrial site, whereas at Commercial site, it exceeds the threshold during April-June and November, December and February

- Air quality during lockdown showed marked improvement indicating the contribution of anthropogenic activity influence in usual scenarios
- Air quality management plan for the city has been described in detail with reference to source sectors and mitigation methods

7. **Noise Environment**
    - An innovative approach has been introduced in this research study for noise monitoring using cycles mounted sound level meter
    - Spatial noise maps were created which shows the noise exposure of the particular location
    - 374 sampling locations were having noise level greater than 80 dB (A) whereas 325 sampling locations retained noise level between 60-80 dB (A). Only one sampling location was identified where the noise level was below 60 dB (A)
    - The highest noise level of 105.8 dB (A) was observed in ward 33 across the ring road. Ward 35 is second noisiest ward with noise level 105.6 dB (A)
8. **Economic And Social Profile Indicators**
    - Economic and social profile indicators are crucial to understand the growth and quality of life in any city
    - There are 298 notified slums and 128 non notified and 33 new slum areas in Nagpur according to Slum "Patta Watap Cell" Nagpur Municipal Corporation
    - This report chronicles the slums of the city, their rehabilitation plans and initiatives for slum development
    - 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%
    - MIHAN is an acronym expands as 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 location of Nagpur, which is centre of the country and to develop an integrated industrial, commercial, and transport hub.
9. **Recommendations**
    - Chapter 10 lists all the recommendation made for improving the current status of the environment of the city

- CSIR-NEERI can work with NMC to design workable strategies to address key issues plaguing the city, like lack of sewage treatment and solid waste management etc

10. **This ESR contains a supplementary section** that maps the wells of Nagpur. 666 wells, as per the list provided by NMC records were visited and status of each was ascertained. Zone wise mapping of the wells was carried out. Survey demonstrated that of the 666 total wells visited, 230 were found abandoned, 30 were used for drinking water and 36 were contaminated with sewage or solid waste

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CHAPTER 1:

INTRODUCTION

ESR-2019-2020

CSIR-NEERI

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1.1 Introduction

The 74th Amendment to Constitution provides that all the Class A Cities have to publish Annual Environmental Status Report (ESR). This report is indicative of the status of environment management in the city. It also identifies the areas where mitigation measures are required to be considered. As per the Maharashtra Municipal Corporation (MMC) Act 1949, section 67(A), it is mandatory for all Urban Local Bodies (ULBs) of the state of Maharashtra to submit an annual Environmental Status Report (ESR) to General body on or before 31st July. Cities in Maharashtra have been publishing ESRs since 1997.

The ESR indicates the city's environmental concerns, growth factors and its impacts, provides information on the environmental infrastructure including water supply, sewage management, traffic and transportation, solid waste management, biodiversity, overall environmental pollution and degradation and possible mitigation measures required. As per the guidelines published in June 2009 by the Department of Environment, Government of Maharashtra, the ESR has to be developed as per the D-P-S-I-R (Driving Force-Pressure- State -Impact-Response) framework. This frame-work focuses on dynamic relationship between the human activities and its impact on physical and biological processes of the ecosystem.

The ESR highlights in brief the following:

- Status of biophysical environment
- Information for investment and management decisions for the ULB (Urban Local Body)
- Assessment of various natural resources, level of pollution, and its direct or indirect impact on human beings and other life forms.
- Annual budgeting and planning exercises

The objectives of preparing ESR are :

- To assist in drawing meaningful inferences towards status of environment
- To transcend from understanding the Impacts of Driving Forces and Pressures on the State of the Environment within Nagpur Municipal Corporation
- To guide responses towards environment protection
- To provide a logical decision-making structure for Responses to planners and policy makers.
- To communicate the status of environment to all stakeholders including citizens

1.2 Nagpur city

Nagpur is famous as the Orange City of India as it is known for its mandarins. Geographically, Nagpur city marks the center of the country and zero mile stone is located near Gowari Smarak (Memorial) right within the heart of the city (Regional Meterological Center, 2011). City of Nagpur has witnessed reigns of several rulers starting from Yadavas, Khiljis, Gonds and Britishers. However, the foundation stone of the existing city of Nagpur was laid by the prince of Gond tribe "Bhakt Buland" in the year 1703. It enjoys status of administration hub of Central India since medieval time(Census, 2011).

At the time of independence Nagpur came under Central Provinces and later in the year 1960, the Nagpur region was merged with Marathi speaking Maharashtra state, as at that time states were reforming under linguistic basis.

Nagpur, located in the Vidarbha region of Maharashtra is among India's fast growing cities. It is an important political/administrative center and hosts the State Assembly's winter sessions. It is home to several Government agencies and research institutions and is a center for Maintenance Command of Indian Air Force. Nagpur is also a hub of industrial activity in the Vidarbha region. While Butibori is the largest industrial estate in its vicinity (located 25-30 km from Nagpur city), other industrial areas around Nagpur include Kamptee, Hingna, Wadi, Khapri, Butibori and Kalmeshwar. The Government of Maharashtra (GoM) has also initiated efforts to develop the existing airport at Nagpur as a Multimodal International Hub Airport at Nagpur (MIHAN) along with creation of a Special Economic Zone (SEZ) and allied facilities. MIHAN is being developed as a multi-dimensional, multidisciplinary project of global standards. http://smartcities.gov.in/.

The city has a tropical savannah climate (Aw in Köppen climate classification), typically hot, dry and tropical weather with an average annual rainfall of 1018 mm, where summer temperature escalates to 48ºC and the winter temperature dips to 10 -12ºC. Due to the recent socio-economic changes, population growth and urbanization, the city is witnessing spatial expansion in administrative boundaries, thus the natural landscape once forming the edge of the city are now within the city limits [1,2].

In this rapid urban transition scenario faced by Nagpur, the natural and managed public urban green spaces such as lakes, drainage basins of Nag and Pili River, urban forests, institutional green spaces, parks, playgrounds and gardens, are under tremendous pressure of destruction and degradation [3]. Owing to urban sprawl with subsequent land use changes, the urban

dwellers are witnessing increased air and water pollution, shrinking green spaces, increased flash floods due to increased build-up areas and emergence of urban heat islands etc [3]. In a recent study a thematic map of Nagpur city was prepared taking ground truth points based on field visit representing the five classes of Urban Green Spaces. Figure 1.1 gives the distribution of ground truth points in Nagpur city (4).

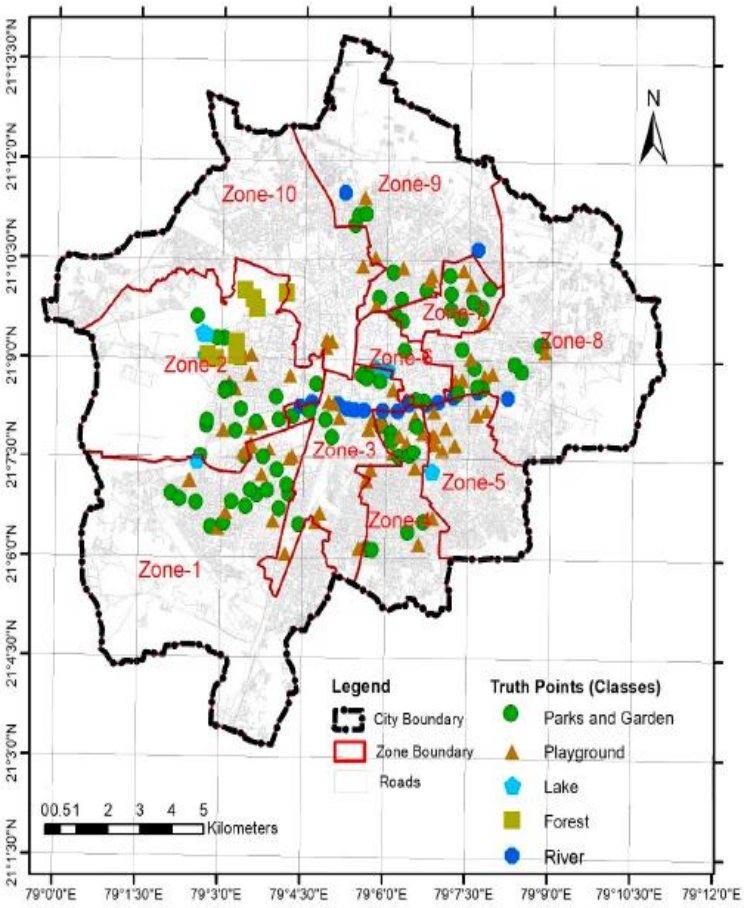

Figure 1.1 Reference Map showing the distribution of ground truth points [1]

1.3 Population

Nagpur's 2020 population is now estimated at 2,893,455. In 1950, the population of Nagpur was 472,859. Nagpur has grown by 216,735 since 2015, which represents a 1.57% annual change. These population estimates and projections come from the latest revision of the UN World Urbanization Prospects. These estimates represent the Urban agglomeration of Nagpur, which typically includes Nagpur's population in addition to adjacent suburban areas (https://worldpopulationreview.com/world-cities/nagpur-population/). It is the third largest city in the state and the 13th largest by population in the entire country. The larger

metro area has a population of over 3.6 million, according to estimates. However, the next census will yield the final numbers. This city is known for being one of the cleanest in India. It is also one of the most livable cities as a leader in healthcare, green spaces and public transportation.

Spread across a total surface area of just over 84 miles, this gives Nagpur a population density of 30,000 people per square mile. Taking a closer look at the population demographics in Nagpur shows that there is a higher concentration of males than females. There are a large number of children in the city, making up over 10% of the total population. There are over 859,000 residents living in slums – or more than 35% of the population. The literacy rate is almost 92%, with a higher rate of literacy among males than females.

1.4 Language

The most commonly spoken language is Marathi, which is also the official language. Hindi is another common language which is spoken well. In businesses and schools, English is often spoken.

1.5 Infrastructure

1.5.1 Highways

Mumbai to Nagpur in just 8 hours via a new super expressway called the Maharashtra Samruddhi Mahamarg, a super communication expressway is expected to be ready by the end of 2020. Currently, it takes anywhere between 14 to 15 hours to complete a journey between the two cities. According to the report, the land acquisition process for the project, worth Rs 55,000 crore, is almost complete. Moreover, with funding in place and the development work has begun on several stretches of the 701-km long Maharashtra Samruddhi Mahamarg corridor. Maharashtra State Road Development Corporation (MSRDC) was quoted in the report saying that the corporation plans to commission the project by 2021. One of the major highlights of the expressway project is that it is a entirely greenfield in nature. A greenfield project is one which is built from scratch without removing any existing structure. The super communication expressway will bring down the Mumbai and Nagpur journey time to 8 hours; Mumbai to Aurangabad to 4 hours and Aurangabad to Nagpur to 4 hours.

1.5.2 Nagpur Railways

Nagpur railway station is one of the oldest and busiest stations in Maharashtra, India. In 1867, Mumbai rail first connected to Nagpur. In 1881, Nagpur was connected to Kolkata via the Nagpur State Railway of Chhattisgarh.[3][4] It was officially inaugurated on 15 January 1925 by then Governor Sir Frank Sly.[4] Prior to 1924, the Nagpur Railway Junction Station was located east of its current location. Nagpur railways building is a grand structure built from red stone brought from Saoner. The columns and pillars add great beauty and even after 95years it still stands tall and magnificent. It is a major tourist destination [5].

Nagpur station is a junction station, catering to North-South & East-West streams of traffic, with a passenger route of 988.336 kms and Goods Traffic route of 176.912 kms. It caters to nearly 94,962 passengers every day (https://cr.indianrailways.gov.in//).

1.5.3 Nagpur Airport

Dr. Babasaheb Ambedkar International Airport is an international airport serving the city of Nagpur, Maharashtra, India. The airport is located at Sonegaon, 8 km (5 mi) South-West of Nagpur. The airport covers an area of 1355 acres (548 hectares). In 2005, it was named after B. R. Ambedkar, the chief architect of the Indian Constitution. The airport handles around 7,500 passengers per day and caters to five domestic airlines and two international airlines connecting Nagpur to Sharjah, Doha and 11 domestic destinations. The airport spread over 1,460-acres is also home to AFS Nagpur of the Indian Air Force. Growth in passenger traffic is fueled by passengers traveling to and from the state capital Mumbai, over 700 km away.

1.6 Nagpur ESR 2019-20

CSIR-NEERI has been entrusted by Nagpur municipal Corporation to prepare the Environmental Status Report since 2016. The ESR for 2019-20 focuses on the following environmental indicators:

- Climate Change
- Water environment: freshwater quality : rivers and lakes, benthic environment and metagenomics analysis and microbial diversity, ground water quality, Aquifer mapping of Nagpur city
- Urban green spaces: Participatory approach to demand supply gap
- Solid waste
- Ecological damage cost due to solid waste

- Air Environment
- Noise Environment
- Slum development and economic profile indicators
- Action plan and recommendations

Each chapter is prepared to update 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. An Annexure document chronicles the water wells in the city from all ten zones.

1.7 References

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CHAPTER 2:
CLIMATE CHANGE

ESR-2019-2020

2.1 Need to understand climate change

Climate change is one most complex problem faced by humanity in the 21st century. The Climate Change problem heavily intertwines with the socio-economic development of any region, and solving climate change riddle is very important in achieving the sustainable development goals put forward by the United Nations. The concentration of greenhouse gases (GHGs) as Carbon Dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are on the rise because of anthropogenic activities, due to the advent of the industrial revolution. It is a proven fact that the consumption of fossil fuels and land use and land changes is emitting copious amounts of GHGs, especially CO_2. Atmospheric CO_2 levels are higher than they have been for at least the last 700,000 years, and the average surface temperature is expected to rise by over 1.5 ºC by 2050 (IPCC, 2018). Most of the changes in climate observed over the last fifty-year period by emissions of GHGs from anthropogenic activities (Hayhoe *et al.*, 2007). Today, an increasing number of scientists and climate researchers believe that we have already crossed into a new weather system with higher frequency and intensity of extreme weather (Secretariat, 2008).

Climate change impacts are very long term in nature as GHGs persist in the atmosphere for a long time. The present emissions of GHGs would affect the people living in the next century. Even if the GHGs increase were to stabilize, the anthropogenic forcing would continue for centuries to come. Since the impacts will be felt not in our lifetime, this makes tackling climate change different and difficult from other policy challenges. Another critical problem is that climate change is global climatological phenomena; the earth's atmosphere does not differentiate GHG emissions based on city/district/state/country.

The modern urban city is home to more than half the population of the world, and by 2050, more than 70% of the world's population is projected to live in the cities(OECD, 2014). Cities have a special relationship with the climate system. This complicated relationship provides a unique set of challenges and opportunities for knowledge generation(Bader *et al.*, 2018). The potential impacts of climate change on urban areas are likely to be(Hunt and Watkiss, 2011):

- Effects of sea-level rise (Coastal cities)
- Effects of extreme events on health
- Effects on energy use
- Impacts on water resources and their availability
- Effects on built-up infrastructure

Cities have a unique opportunity to address and lead the charge against climate change challenges. Adaptation and mitigation choices made in cities would determine the extent and impact of climate change, our ability to achieve emission reductions, and our capacity to adapt to changing situations (OECD, 2014). These adaptation efforts offer co-benefits for climate change mitigation and local economic development (The World Bank, 2011).

2.1.1 Risks Factors evaluated in this report

This report summarizes the local climatic factors that would influence Nagpur's future exposure to climate change impacts. The following climate indicators were considered the most relevant to Nagpur, therefore investigated in the report: 1). Temperature, and 2). Precipitation. The impact of each risk factor on agricultural production, regional groundwater level, and energy use is further analyzed to understand the exact status of the impact of climate change on the city. The climate data for Nagpur city for the last five decades, along with agricultural and groundwater level data, have been statistically analyzed to understand if any relationship between climate parameters and other variables exists. Climate Change will not affect every sector in the same manner or with the same magnitude. To lower community risk, the local governments have a responsibility to ensure that critical community services are adequately prepared to face the impact of climate change (Cains, Websters, and McCabe, 2019).

This section of the report provides the first step in understanding if climate change is affecting Nagpur region, and if yes, then to what degree. It offers future steps and recommendations to understand which sectors in the city are the worst affected and needs further investigation.

2.2 Climate Change Indicators

2.2.1 Temperature

Based on the climate and geographical data, rising average annual temperature and precipitation can be considered as the most significant climate change impacts for Nagpur city. With the mean temperature of 33.3 ºC and the maximum temperature reaching mid-40s, summers are generally hot and dry, but exposure to extreme heat can be severe or even dangerous. This is especially true when the public is not ready or prepared for this eventuality.

Globally, the intensity and frequency of these events are on the rise. Worldwide, 15 of 16 warmest years on record have occurred since 2000 (US EPA, 2016). In addition to deaths, extreme heat causes a range of other health problems such as heat exhaustion, strokes, cramps, etc. Young children and people above the age of 65 and older, persons with specific disabilities,

those living in poverty or social isolation, and the homeless have a high risk of heat-related health problems (Center for Disease Control and Prevention, 2012). Fig 2.1 shows the varying severity and impact of heat events on human beings.

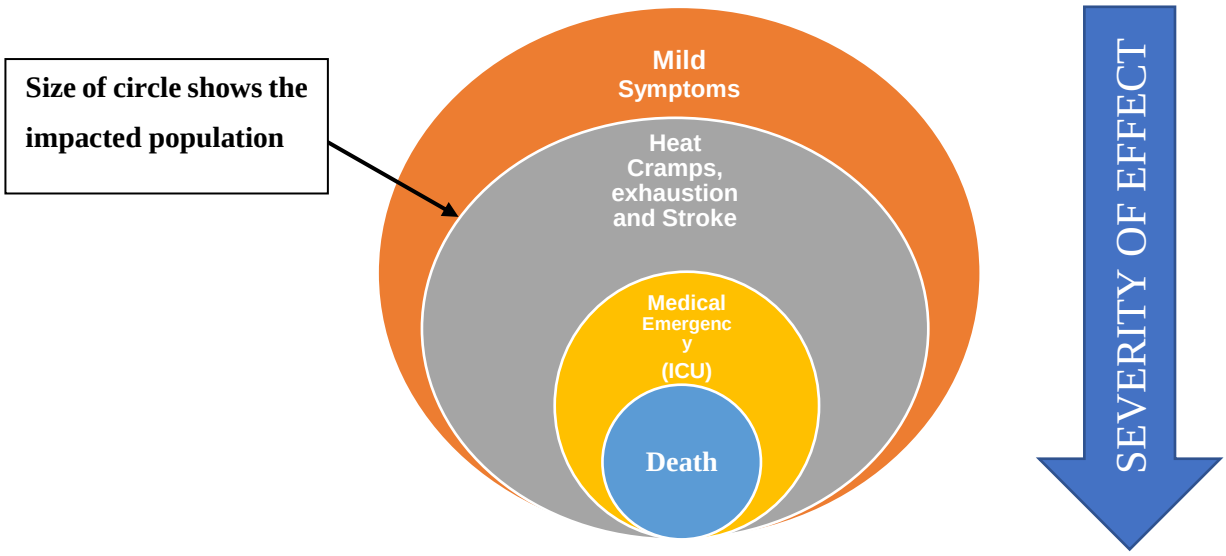


Figure 2.1: Impact of extreme heat events based on severity and population (adapted from Center for Disease Control and Prevention, 2012)

2.2.1.1 Annual Average Temperature

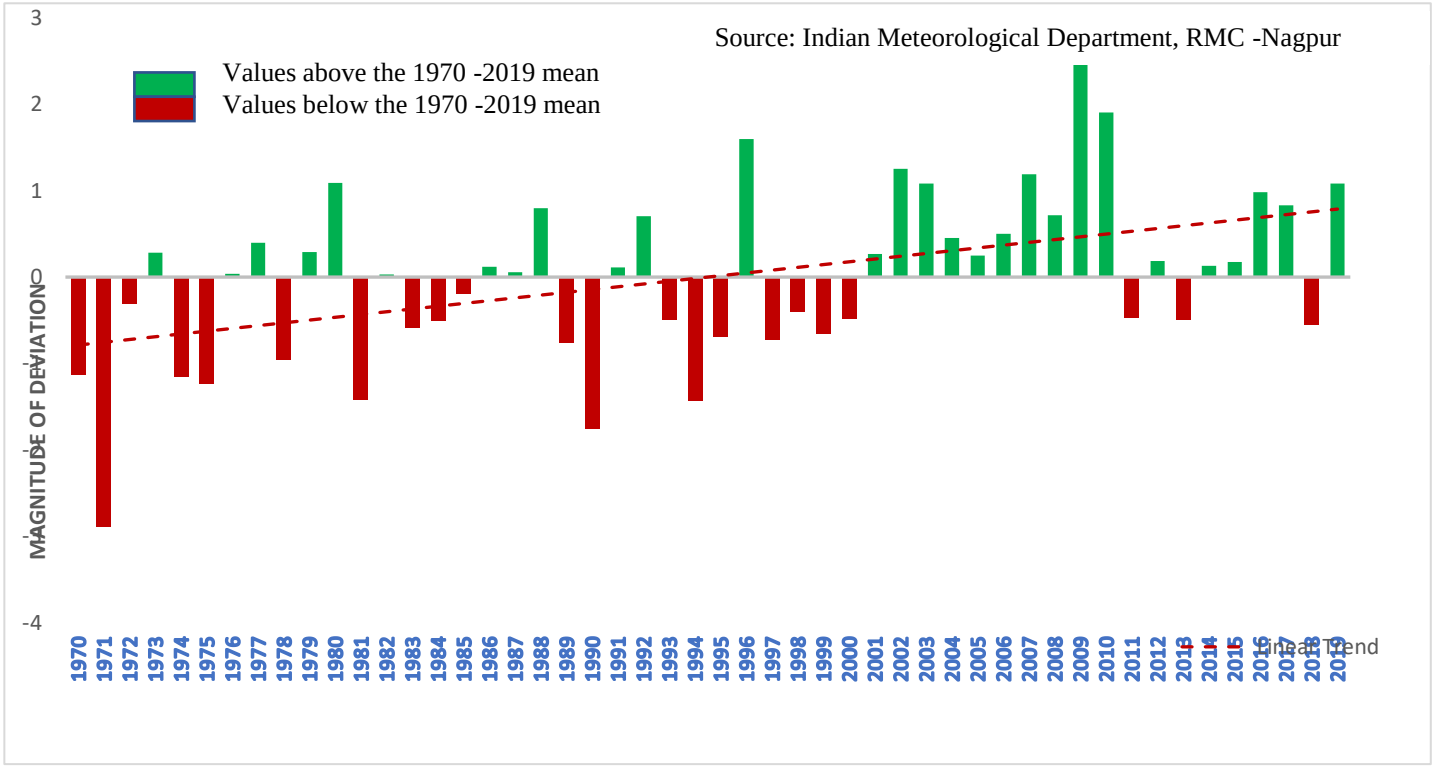


Figure 2.2: Annual average temperature, compared with the 1970-2019 mean.

As seen in figure 2.2, the number of instances where above average surface temperature for 2000 -2019 = 16 (in Green) whereas, for the period from 1980 - 2000, the number of instances = 8 (in Green). We can see the development of a pattern where the average annual temperature (annual average of daily mean temperature) for the last two decades is higher than the 50-year mean with an increasing trend.

2.2.1.2 Extreme Heat Events

Hoosier Resilience Index (Cains, Websters, and McCabe, 2019) defines extreme heat events as days with highs 32.22 ºC or greater and nights with lows 20 ºC or greater. Increasing daytime and night-time temperatures are harmful to human health, especially for sensitive populations. For this study, we have considered the Nagpur conditions when considering the base temperature for calculating the Heat Events. The average maximum and minimum temperature of Nagpur city from 1970 to 2019 was considered was base temperatures for this exercise.

The total number of extreme heats can be quantified as the sum of High heat days, High heat nights, and High heat days and nights (Cains, Websters, and McCabe, 2019).

High Heat Days (HD): T_{MAX} >= 33 ºC and T_{MIN} < 20 ºC

High Heat Nights (HN): T_{MAX} < 33 ºC and T_{MIN} > 20 ºC

High Heat Days and Nights (HDHN): T_{MAX} >= 33 ºC and T_{MIN} >= 20 ºC

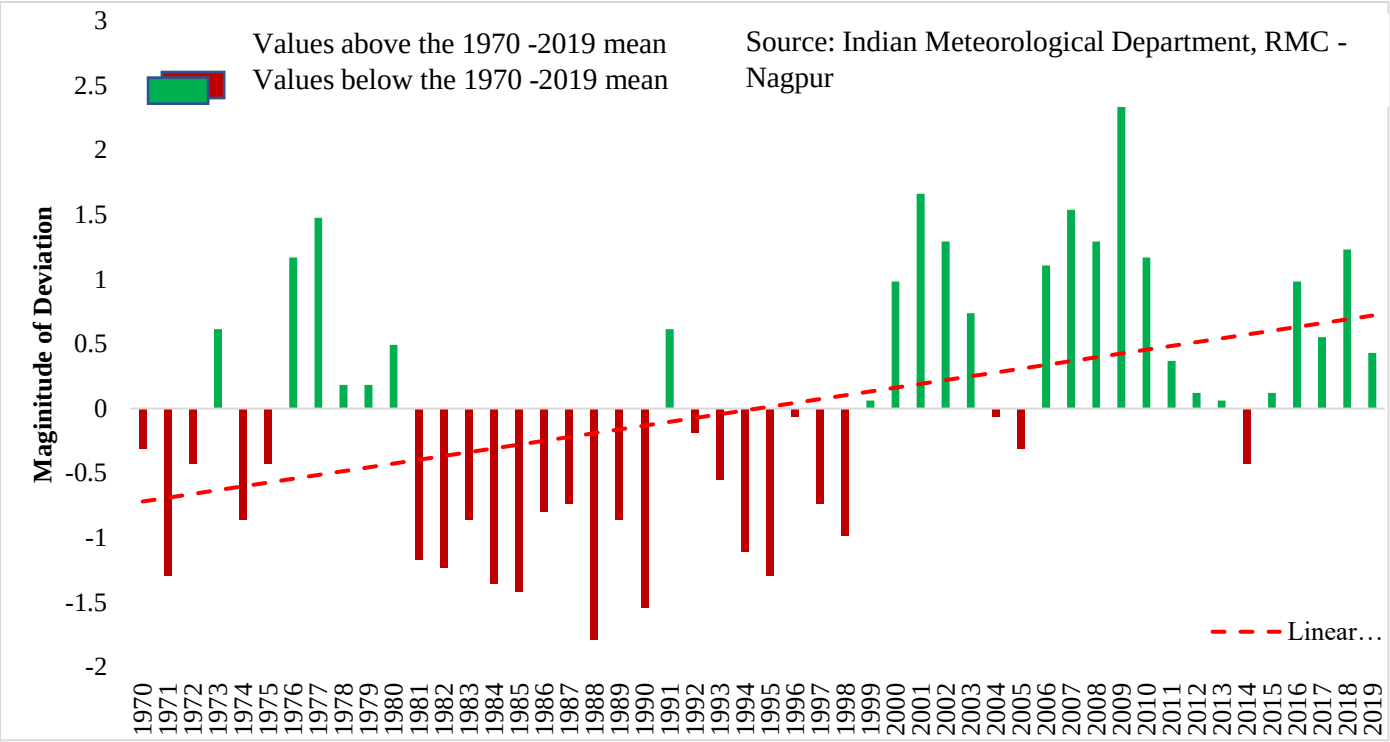


Figure 2.3: Extreme Heat Events Anomaly, compared with the 1970-2019 mean.

As seen in figure 2.3, the number of instances where the extreme events are above average from 2000 to 2019 = 18 (in Green), whereas for the period from 1980 – 2000 = 2 (in Green). An increase in the occurrence of extreme heat events, as specified in the Hoosier Resilience Index, with a positive increasing trend can be seen.

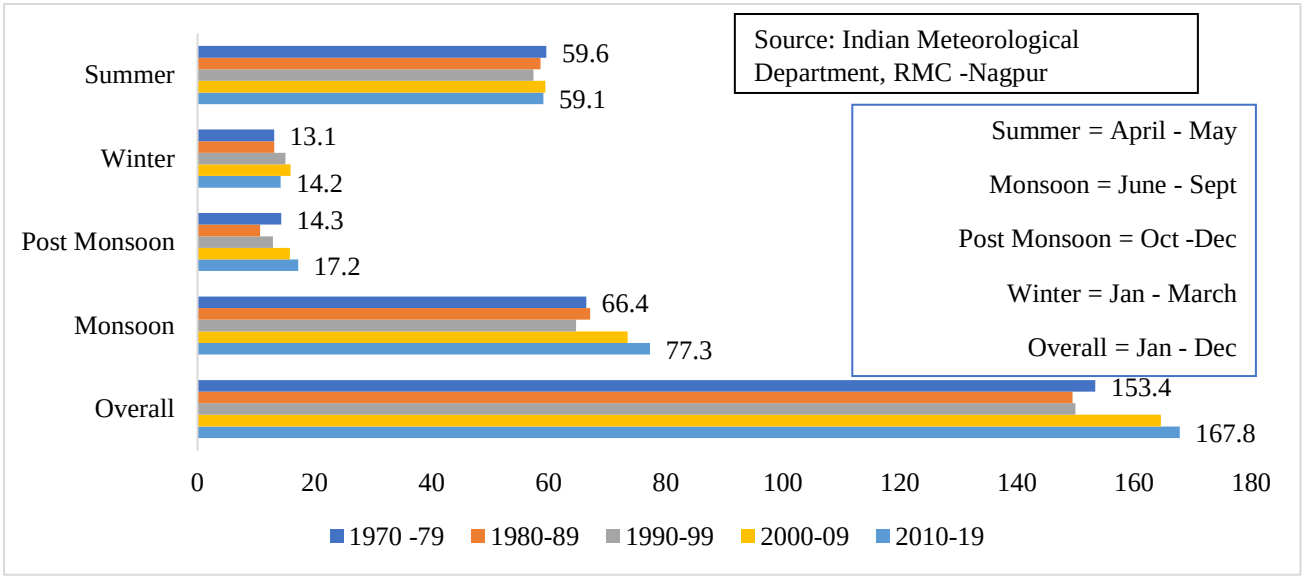


Figure 2.4: Decadal comparison of high heat days and nights.

Figure 2.4 shows the decadal comparison of the occurrence of high heat days and nights (HDHN) in Nagpur. The study shows that in contrast to 1970-1979 decade, the occurrence of HDHN in the last two decades has increased, and for the 2010-2019 decade, the increase is by 14.4 units. If we look at the seasonal occurrence of HDHN, there is an increase in the occurrence of HDHN in the monsoon season, where the gain is by 10.9 units.

Discussion

The study indicates that the average annual temperature (annual average of daily mean temperature) of Nagpur City is in the rise. The study shows that for the 2000-2019 decades, 80% of years are having the annual mean temperature above the 1970-2019 (study period) mean. Further, the number of extreme heat events per year is also on the rise with 85% of the years (2000-2019) showing an above-average anomaly.

When the distribution of extreme heats (high heat day and night) was investigated, the overall number of HDHN for 2010-2019 decade saw an increase of 9.3 %, in comparison to the 1970-1979 decade. The seasonal distribution shows that the monsoon has had an increase of 16.4% in the occurrence of extreme heats for the 2010-19 decade.

2.2.2 Precipitation

Precipitation is one of the most critical variables in the study of climate. The change in frequency and intensity of rainfall is often studied to understand the extent and magnitude of

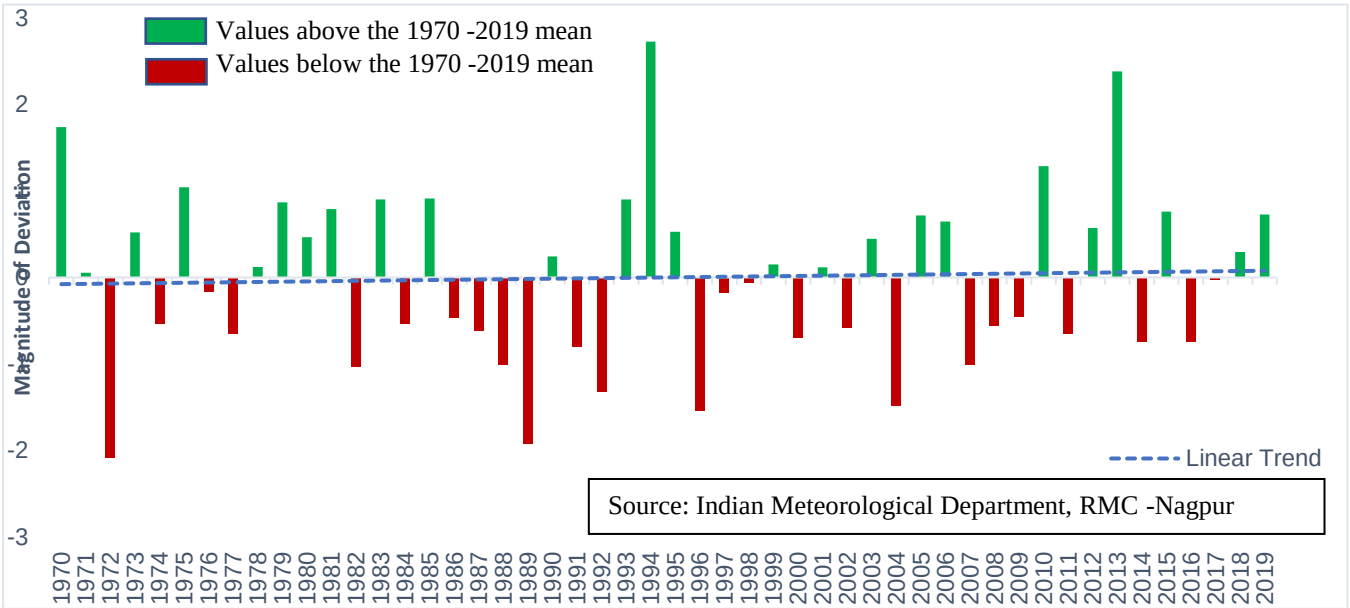


Figure 2.5: Annual Rainfall anomaly, compared to 1970-2019 mean

climate change. This is especially true for India as it is economy is agro-based, which is very much dependent on the south-west monsoon. Therefore, it is important to examine and understand the Spatio-temporal dynamics of this variable to provide credible inputs to policymakers. Agriculture is the mainstay of India's economy and employs 71% of the citizen (Duhan and Pandey, 2013). Also, India is one of the most vulnerable to flooding and drought-prone countries in the world (Joshi *et al.*, 2016). Therefore, it is crucial to understand the changes in the precipitation pattern over the Nagpur to understand the impact of climate change.

Figure 2.5 shows that there is very little change in the annual rainfall over Nagpur City for the period of 1970-2019, with the overall trend (in Blue) being close to the mean. This shows that the total yearly rainfall for Nagpur has not changed in the last five decades. The study further investigates the seasonal rainfall pattern over Nagpur to understand if any changes have taken place in seasonal distribution

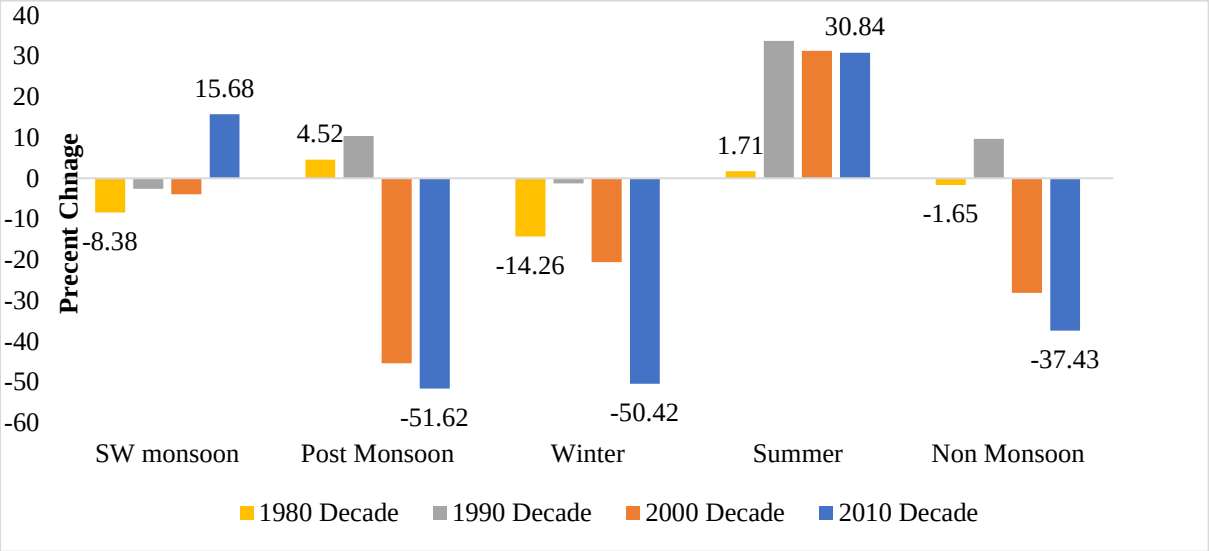


Figure 2.6: Comparison of Decadal Percent change in Rainfall with the baseline decade of 1970-79

Figure 2.6 illustrates in comparison with the baseline decade of 1970-79, the magnitude of south-west monsoon has increased during the 2010-19 decade by 15.68 units. However, for both the post (retreating) monsoon and winter rainfall, which carters to the rabi crops, a drastic reduction in the rain has been observed during the 2010-19 decade when compared to the baseline decade. Similarly, a 37.43% reduction was found for the non-monsoon period (Oct-May).

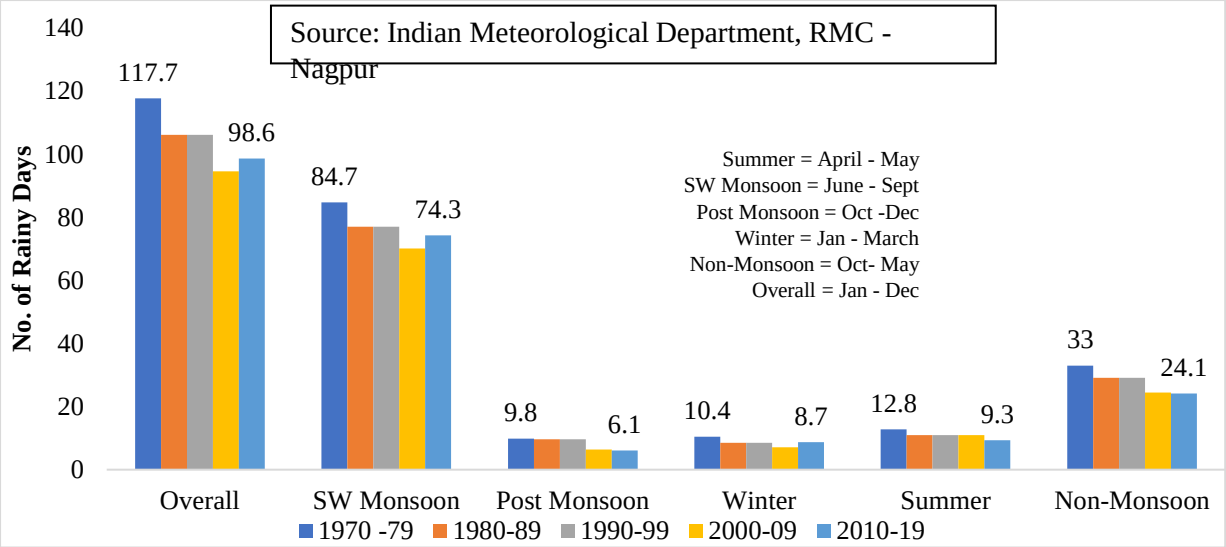


Figure 2.7: Decadal comparison of occurrence of rain days for 1970-2019

Figure 2.7 illustrates the decadal comparison of the number of rain days, both overall and seasonal. The study indicates that there is a gradual decrease in the occurrence of rain days from 1970-2019. When the 2010-19 decade is compared to the baseline decade, a reduction of 19.1 units was observed. Similar observations can be made in the Southwest monsoon season with a decrease of 10.4 units.

Discussion:

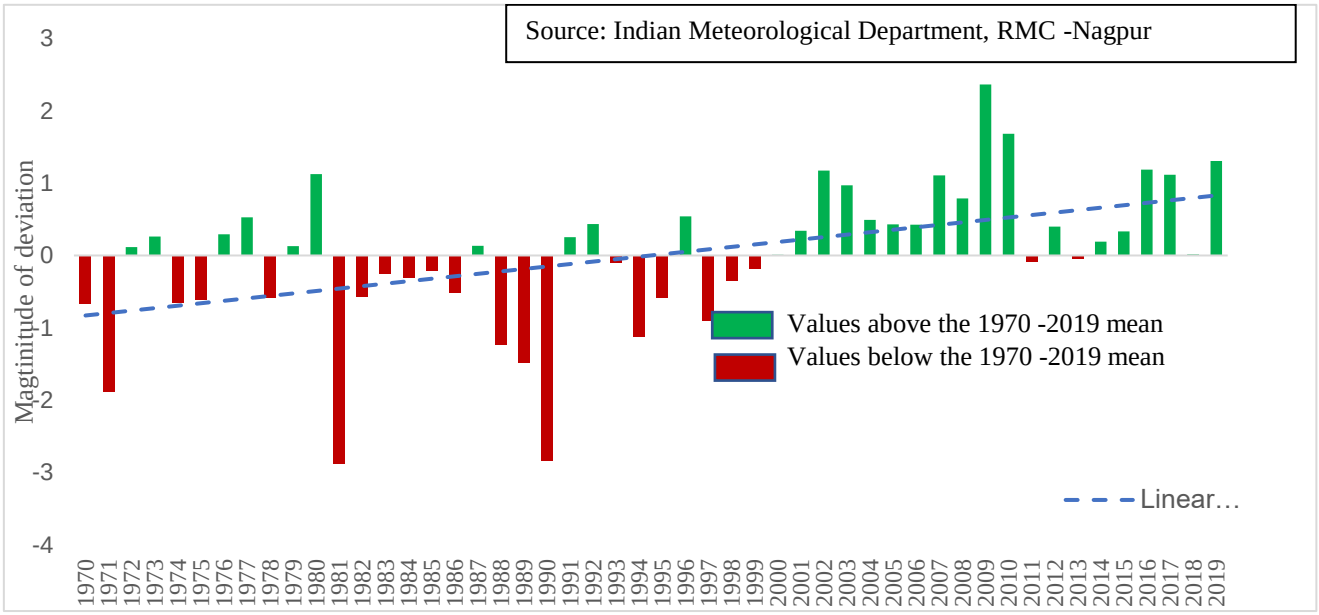
The Study indicates that the annual rainfall pattern over Nagpur city has not changed significantly over the last 50 years. However, the investigation of seasonal distribution of rainfall over Nagpur city shows different picture.

Even though magnitude of rainfall has increased for the southwest monsoon season for the 2010-19 decade, in comparison to the baseline decade of 1970-79 but there has been a drastic reduction in rainfall in the Non-monsoon period as seen in figure 6, with the retreating monsoon and winter rainfall showing high-levels of reduction. Similar studies were performed for the number of Rain days from the period of 50 years and its was seen that the total number of rain days has reduce by 16% for the 2010-19 decade in comparison to the baseline decade. Similar trend can be seen for the south-west monsoon season with a rain days reduction of 12.2% for 2010-19.

2.2.3 Impact on Energy use

The increase in global average temperature and rising demand for buildings with a more relaxed indoor environment leads to an increase in building energy consumption (Bhatnagar,

Mathur and Garg, 2018). This is especially true for Nagpur as it faces high temperatures during the summer and high humidity in the monsoons.



Condition	Calculation Formulae
$T_{MIN} < T_{BASE}$	$D_C = (T_{MAX} + T_{MIN})/2 - T_{BASE}$
$T_{MIN} >= T_{BASE}$	$D_C = (T_{MAX} - T_{BASE})/2 - (T_{BASE} - T_{MIN})/4$
$(T_{MAX} + T_{MIN})/2 > T_{BASE}$	$D_C = (T_{MAX} - T_{BASE})/4$
$T_{MAX} < T_{BASE}$	$D_C = 0$

D_C = the cooling degree days
T_{MIN} = daily minimum temperature
T_{MAX} = daily maximum temperature
T_{BASE} = base temperature

Figure 2.8: Cooling degree days anomaly, compared to 1970-2019

To quantify the demand for energy to heat or cool buildings, the value of degree-days is used. This method assumes that the energy needs for a building are proportional to the difference between the mean daily temperature and a base temperature (Shanmuga Priya *et al.*, 2011). For India, the base temperature is taken 18 ºC. For Nagpur, the study considers the computation of cooling degree-days. For its estimate the following formulae have been utilized (Shanmuga Priya *et al.*, 2011)

Figure 2.8 shows the anomaly of cooling degree days across the annual mean for 1970-2019. The study reported an increasing trend in cooling degree-days from 1970 to 2019. When a 2-decade comparison is performed, it can be observed that from 2000-2019 the number of instances where the cooling degree-days is above the average = 16 (in Green) and for 1980 - 1999 = 5 (in Green).

Discussions:

Degree days is an important climatic indicator in the HVAC industry to estimate the demand for heating or cooling services (Shanmuga Priya Sellvnathan, 2015). Degree-days can be used for the calculation of energy loss from structures. The higher the degree-days higher the energy loss and consequently higher the energy demand.

2.2.4 Impact on Regional Agricultural Production

One of the significant impacts of climate change is on agriculture and food security. As Indian agriculture and, in turn, its economy is very dependent on seasonal rainfall, the difference in global average temperature and precipitation pattern (climate variability) has immense potential to affect the agricultural in India. Therefore, the study aims to understand any relationship between rainfall, temperature, and yield. The agriculture production data was sourced from the Department of Agriculture, Government of Maharashtra.

The study indicates that for Kharif Cotton, temperature shows a low positive trend with 95% and higher confidence level ($r^2 = 0.393$, $p<0.01$), with 39.3% of the variance in cotton yield attributed to temperature. However, rainfall has a non-significant low or negligible negative trend. For Kharif Rice yield, both precipitation and temperature show a weak non-significant negative trend. For Rabi Wheat, Rainfall shows a low negative trend with 90% and high confidence level ($r^2 = 0.341$,

$p<0.1$) with 34.1% of the variance in wheat yield attributed to rainfall.

Table 2.1: Pearson's correlation co-efficient and p-value for Yield vs Rainfall and Yield vs Temperature, Legend: Yield = Crop Yield, Green = positive trend, Red = negative trend, Blue = Statistically Significant

Food Crops		K.H. Cotton	K.H. Rice	RB Wheat
Yield Vs Rainfall	Slope	-0.548	-0.527	-7.853
	R-square	0.026	0.013	0.341
	P-Value	0.552	0.682	0.017
Yield Vs Temperature	Slope	971.69	-225.92	457.57
	R-square	0.393	0.011	0.051
	P-Value	0.009	0.700	0.166

Discussions:

Rainfall and temperature play a very important role in the growth of any plant species. The previous sections show that climate variability is happening in Nagpur City so section 2.4 aims to see if they have any impact on the yield of common crops for both kharif and rabi seasons.

The study indicates that for kharif cotton, temperature plays a much important role when compared to rainfall as temperature shows a low positive trend with 95% and higher confidence level ($r^2 = 0.393$, $p<0.01$) with 39.3% of the variance in cotton yield attributed to temperature.

For Kharif rice, the variance in yield cannot be significantly correlated to either rainfall or temperature.

For Rabi Wheat, the study indicates that rainfall plays a much more important role in comparison to temperature as rainfall shows a low negative trend with 90% and higher confidence level ($r^2 = 0.341$, $p<0.1$) with 34.1% of the variance in wheat yield attributed to rainfall

2.2.5 Impact on Ground Water Level

As per the Central groundwater Board (CGWB), the net annual groundwater availability of Nagpur (urban and rural) is 6498.86 ham/year (Manzar, 2013). This study has tried to understand if there is any correlation between the annual rainfall pattern, temperature, and groundwater level (GWL) in Nagpur city. Groundwater level readings were taken from the Groundwater Survey and Development Agency (GSDA) Nagpur, which has three monitoring wells in and around Nagpur (urban and rural). Further, the study also investigated the extraction pattern of groundwater during the non-monsoon period to understand the trend.

Table 2.2: Pearson's correlation co-efficient and p-value for GWL vs Rainfall GWL vs Temperature and GWL versus Evaporation rate;
Legend: GWL = Ground water level,
Green = positive trend, Red = negative trend, Blue = Statistically Significant (p < 0.1),

Monitoring Well sites		Bahadura (R)	Bokhara (U)	Makardhokara (U)
GWL Vs Rainfall	Slope	-0.0042	-0.00152	-0.00123
	R-square	0.151	0.031	0.078
	P-Value	0.03388	0.34893	0.13541
GWL Vs Temperature	Slope	-0.0362	0.162	0.0669
	R-square	0.0023	0.0662	0.0116
	P-Value	0.8023	0.532	0.57115
GWL Vs Evaporation rate	Slope	-0.01346	0.03008	0.18054
	R-square	0.001	0.028	0.182
	P-Value	0.9	0.54942	0.02659

As seen in table 2.2, for GWL at Bahadura (R) among all investigated parameters, rainfall shows a low negative trend with 90% and higher confidence level ($r^2 = 0.151$, $p<0.1$) and rest show a non-significant weak negative trend. For the GWL at Bokhara (U), rainfall shows a non-significant weak negative trend, and temperature and evaporation rate show a non-

significant weak positive trend. For the final site at Makardhokara (U), evaporation rate shows a low positive trend with 90% and higher confidence level (r^2 = 0.182, $p<0.05$)

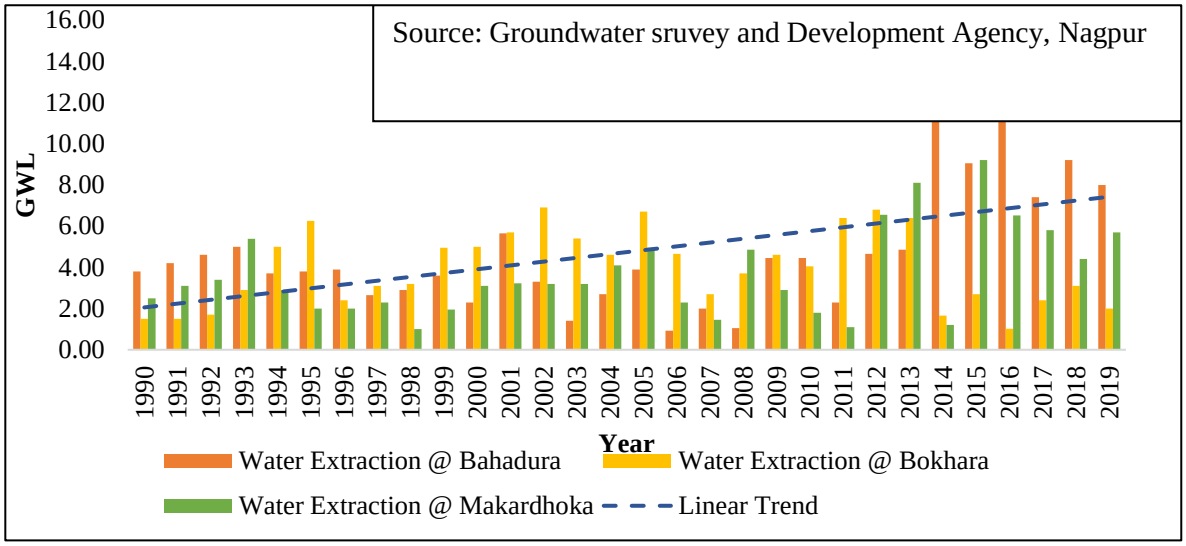


Figure 2.9: Change in ground water level during lean period (JAN-MAY)

Figure 2.9 illustrates that during the lean period (JAN-MAY), there is an increasing trend in the extraction of groundwater from 1990-2019. The GWL during and month of January and pre-monsoon monitoring in May as evaluated to understand the magnitude of extraction in the Nagpur area. The data shows that the extraction at Bahadura (R) shows a low positive trend (R^2 =0.274) from 1990 to 2019.

Discussions:

Due the changes in the precipitation and temperature pattern, to maintain the agricultural produce, the tapping of groundwater is one the most important methods for bridging this gap. This study tries to understand if the climate variability has any impact on groundwater level and ground water extraction.

For GWL vs rainfall, study shows a low negative trend correlation for all study sites. This indicates that even if the rainfall is high, the GWL decreases. This can be attributed to two factors 1). No proper groundwater recharge and 2) High extraction/exploitation of GWL. The latter can be seen in fig 2.9 where the overall groundwater extraction during the lean period shows an overall increasing trend.

For GWL vs Temperature, the variance in GWL cannot be significantly correlated to temperature for either urban or rural areas

For GWL vs Evaporation rate, the variance in GWL cannot be significantly correlated to Evaporation rate in both Bahadura and Bokhara. However, for Makardhokara (U), the stud shows a positive trend with 90% and higher confidence level ($r^2 = 0.182$, $p<0.05$). This could be attributed to the higher green cover in comparison to the other two sites.

2.3 Acknowledgments

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CHAPTER 3:
WATER ENVIRONMENT

ESR-2019-2020

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3.1 Introduction

On the basis of the geological characteristics of Nagpur city the West part is occupied by the Deccan trap formation and the East occupied by the metamorphic and crystalline series. The west side area does not have the hills of any great height, though it is interspersed with low ranges which are the extension of the prominent Satpura Ranges in the form of Starkey Point, Seminary Hills, Ramnagar Hill and Sitabuldi Hill. The southward area of the city is similar to its west part. To the south east, east and the northeast, the surface area is mostly a plain covered with alluvial deposit of the Kanhan and their tributaries.

There are three rivers flowing through the city. The Nag river forms a part of the Kanhan-Pench river system and it originates in Lavha village and joins the Pili river before pouring into the Kanhan river in Wainganga, sub-basin of Godavari. The second river, called the Pili Nadi, with a length of 17.6 km, is a slow, meandering river. There is one more river named Pora River, which originates near Sonegaon lake and flows towards the south east, just outside the southern part of the city.

Nagpur city receives its water from Gorewada, Kanhan river and Navegaon Khairi Dam on Pench river (Pench-I, II, III and IV) as detailed in the Environment Status report (2018-19). The total supply of water ranges between 700 to 760 MLD. The maximum water supply is from the Pench river.

3.2 Water Stock and Water scarcity 2019-2020

According to a recent report in Hitavada, Nagpur Edition on May 6, 2020 Nagpur city: This year in the first week of May the Totladoh dam, the biggest in Nagpur district that caters the water demand of the whole district, has a live water stock of 89.59 per cent. Exactly a year ago, in April 30,2019, its live water storage stood at 1.7 per cent. After many years, Nagpur district seems to be set for a summer with little or no water woes bringing much relief to farmers in Nagpur district and Vidarbha, especially at a time when the entire state is fighting the coronavirus pandemic. The five major dams of Nagpur district have a total live water stock of 69.98 per cent till date.

The 384 dams across the Nagpur division that have a capacity to hold 4,607.01 million cubic meters of water, have an average live water stock of 2,260.81 mcum or 49.07 per cent, which is almost five times from the previous year's 10.48 per cent. Vidarbha region in last three years have experienced severe water crisis due to below normal monsoon. However, agriculture

department officials believe the unseasonable rains, coupled with a longer winter, helped to retain higher water level in dams. In addition, water conservation work under Jalyukta Shivar in last five years have helped to tackle drought. In dams, where water level had touched zero in April last year, have witnessed a spike in water level the same month this year — in Gosikhurd dam, water level rose from 0% to 20.38% and Lower Wardha saw a rise from 6.53% to 60.13%. Indian Meteorological Department (IMD) have predicted normal monsoon this year but some weather experts are expecting below normal rains due to El Nino effect. However, the satisfactory water level in all dams will not allow to face any kind of water shortage even after less monsoon in the region.

This above report was a relief to Nagpur citizens as in 2019 they experienced delayed monsoon and low water levels in the dams leading to water crisis situations in April and May months for water supply to Nagpur city. The rainfall in July was not sufficient and water supply to the city was restricted to from the Kanhan river. The water supply was cut to three days in a week to some areas during July. The situation only improved in September, 2019 due to excess rainfall. Some of the news reports of the last year summer are as follows:

- Nagpur needs 9.603 MMC more water this summer- March 16, 2019 https://timesofindia.indiatimes.com/city/nagpur/*This summer city will require around 82 million metre cube (MMC) water from March 1 to June 30, 2019 respectively. The low storage will happen due to the reservoirs receiving less water during monsoon.*
- **Raw water scarcity, wind storms, power tripping and delayed Monsoon posing threat to city water supply- June 10, 2019** https://www.nagpurtoday.in/.*The city was facing many problems in supplying normal water due to unavailability of raw water, power failures due to wind storms, frequent tripping and delayed monsoon in the month of* April and May and expected to improve till monsoon arrives. The situation has become so worst that even the tankers could not supply to the affected areas. The NMC along with Orange City Water Works Ltd trying to sort out the problem and also appealing people to kindly store sufficient water for their usage.
- **Citizen of Nagpur reacts on water crisis – July 17, 2019,** https://thelivenagpur.com/2019/07/17/The people were facing the problem of water scarcity when the peak period of monsoon arrived the city. Due to less rainfall in the month of July, the lakes, Navegaon and Totladoh dams got dried and the only supply of water for the city was Kanhan River. Nagpur Municipal Corporation (NMC) officials

had discussed the issue of scarcity of the water and as an outcome the water supplied to the city was reduced by many liters to save water for future crisis. It was decided that the water is to be regulated on alternate days starting from Wednesday, July 17, 2019. Besides turning down the taps the NMC has also stopped the supply through the tankers in the entire city.

- **Nagpur: Water cuts imposed for 3 days due to less rainfall – July 19, 2019** https://www.indiatoday.in/india/story/.The Orange City Water Works Ltd, which supplies water in Nagpur, has decided to impose water cuts due to low water level of Navegaonkhairi Dam and Gorewada lake due to less rainfall received. So, the water will not be supplied on Wednesday, Friday and Sunday of that particular week.
- **Nagpur extends cut on drinking water supply till August- July 23, 2019** https://www.hindustantimes.com/india-news/.The authorities of Nagpur have decided to extend the existing thrice-a-week cut in the supply of drinking water till August due to deficient rainfall in the city as well as in the region.

However, with the total precipitation of 1098.1 mm during June to September, 2019 which was 27%excess than average and 341.6mm rainfall in September which is 131% excess rainfall as compared to average, the water stock in our reservoirs and dams are sufficient to meet the water demands of the city. The total precipitation received from April to Dec 2019 is given in Table 3.1.

Table3.1: Accumulated Precipitation (April 2019 - December 2019)

Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10.4	0.0	134.0	342.0	280.5	341.6	55.6	0.0	9.5
Accumulated Value (April 2019 - December 2019): 1173.6 mm								

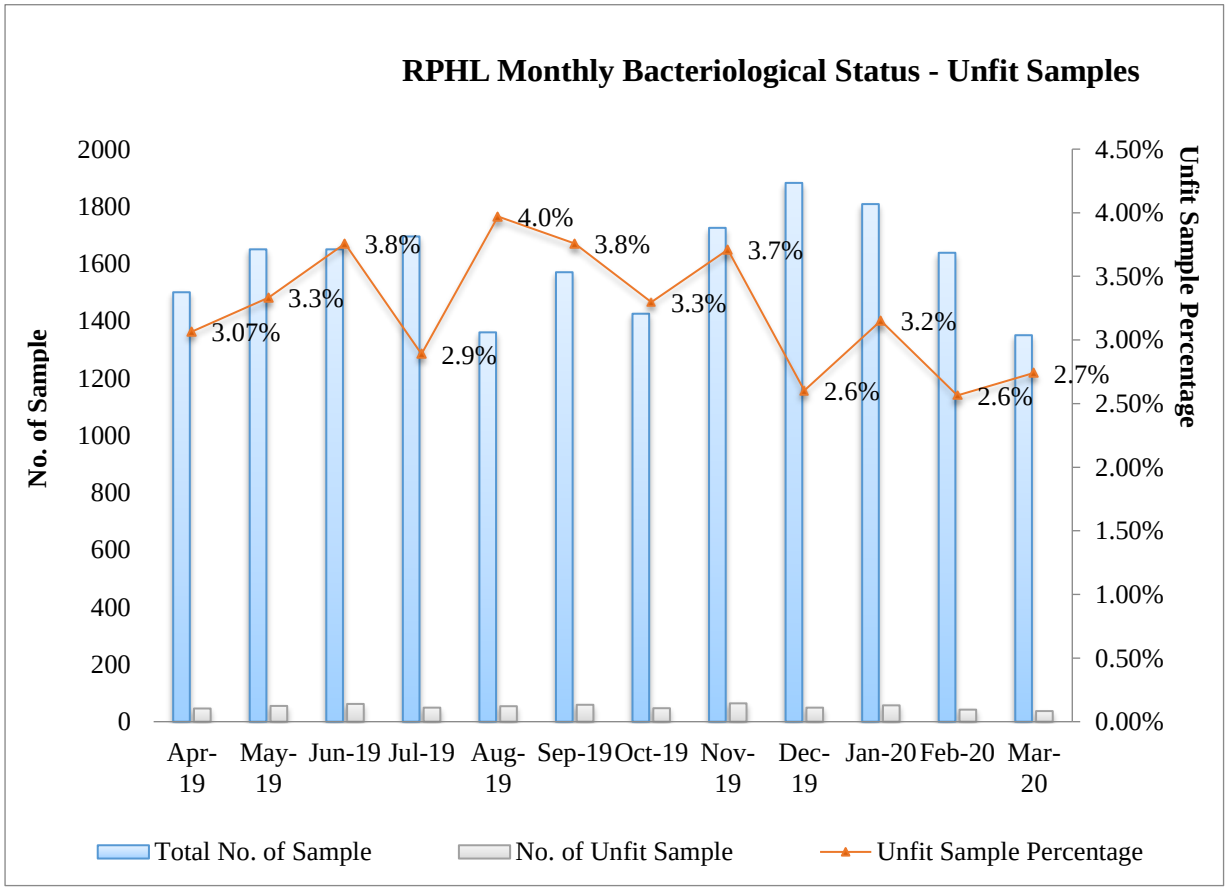
Source: IMD

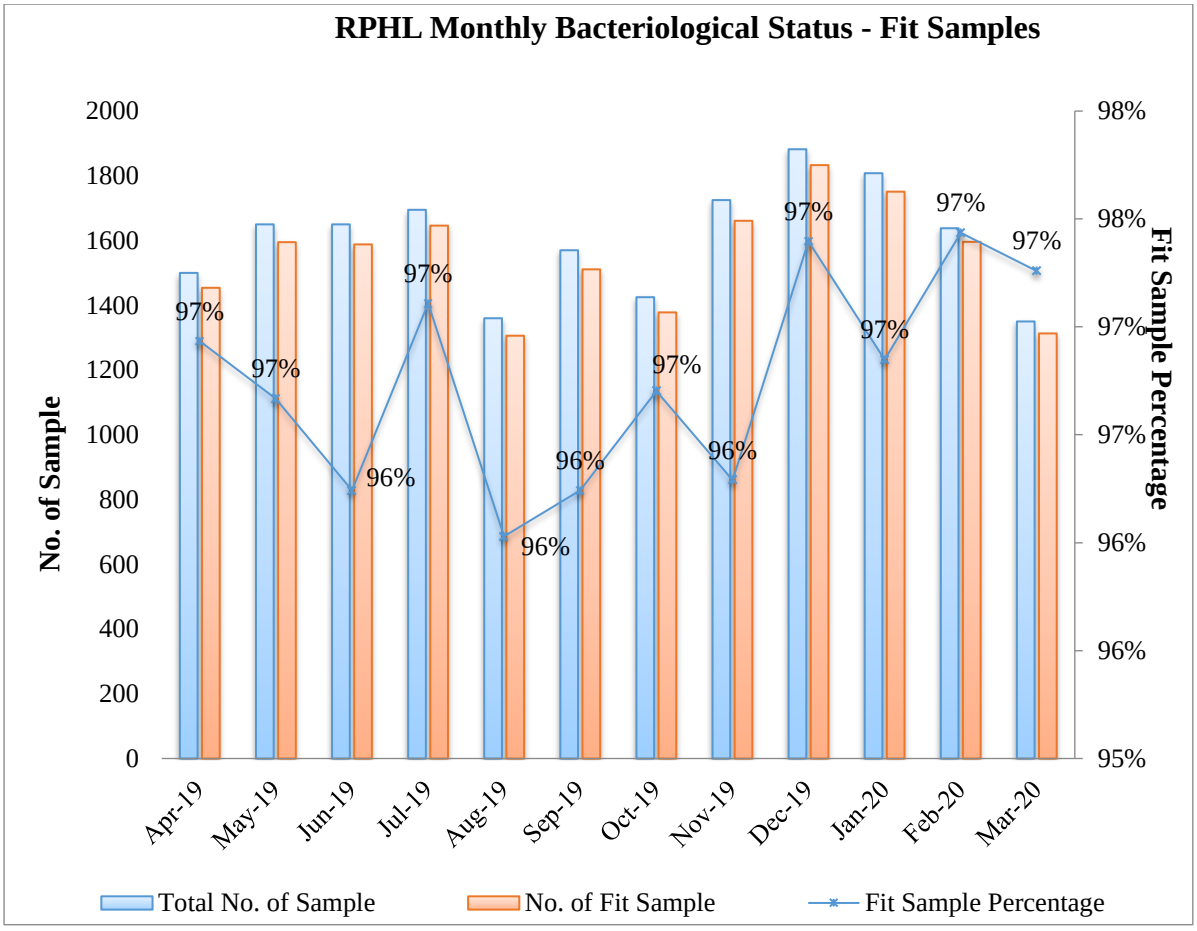
- **Nagpur no longer in a threat of water crisis – September 6, 2019** https://thelivenagpur.com/.According to the Regional Meteorological Centre (RMC), Nagpur has received 10% of excess rainfall in the month of August and July as well. So, the city is safe from the scarcity of water and will not face the crisis in the coming days.

3.3 Water Supply and point of use Water quality:

Nagpur Municipal Corporation (NMC) had launched the 24x7 water supply program in 2012 to counteract unequal supply of water in city. Till date only 21 command areas receive 24x7 water and the rest 47 command areas are not yet covered. The Action Taken Report (June 2019) of NMC states that their leakages in pipeline transporting raw water from Navegaon Khairi to Mahadula which accounts for a loss of 30-40 MLD water daily. NMC has a target of reducing non-revenue water by 10% and increase the billed water to 452 MLD.

The Orange City water, Nagpur gets the water quality 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 Figure3.1. It can be observed that out of 19253 point of use samples analyzed, 96-97% samples were fit and 2.6-4.0% samples were unfit for drinking as per bacteriological testing performed throughout the year (April 2019-March 2020).





Source: OCW, Nagpur, RPHL: Regional Public Health Laboratory

Fig 3.1 Bacteriological Quality at point of use Water supply

3.4 Sewerage system and Sewage treatment plants:

The Nagpur Sewerage System consists mainly of gravity sewers and based on the topography, the system is divided into three zones viz. Central, Northern and Southern zone. A part of the flow generated in the Central zone (100 MLD) is collected, treated at Sewage Treatment Plant (STP) at Bhandewadi and is discharged in the nearby river. However, sewage from Northern and Southern zones and remaining of the sewage from Central zone flow to nallahs without any treatment. Due to groundwater pollution problems in the North zone of Nagpur and more percentage of slum population in the Northern zone, North zone is considered for the sewerage system implementation. As per updated information (March, 2020) from Maharashtra Pollution Control Board (MPCB) Regional Office, Nagpur, about 520 MLD sewage is generated and the treatment capacity at present is 345.3 MLD with a gap of 288.1 MLD (Table3.2). The STP location along with commissioning details, installed capacity are presented in Table 3.3. There

are 4 STPs with an additional total capacity of 207 MLD proposed to meet the gap in sewage treatment. The treated sewage from Bhandewadi (200 MLD) is being reused by MAHAGENCO for their power plant.

Table 3.2: SEWAGE MANAGEMENT, Nagpur City (Updated March 2020)

S No.	Action point	A	B	C=A-B	D
		Existing status	Desired/ Projected	Gap	Timeline
1.	Estimated Sewage Generation	520 MLD	520 MLD	NA	
2.	Treatment Capacity (Projection for 05 years to be taken into consideration)	345.3 MLD	57.2 MLD	288.1 MLD	Two and Half Year
3.	Status of Sewage System (in Km)	1670 Km	--	--	--
4.	No. STPs (Details to be provided as per Annexure- I)	7	5	--	--
5.	Have bulk users identified for reuse of treated water such as Industrial Clusters, Metro Rail, Indian Railways, Infrastructure Projects, Agriculture, Bus Depots and PWD? (Y/N)	Yes	Yes	--	--
6.	Quantity of treated wastewater being used by Bulk User (in MLD)		--	--	--
	Industrial Clusters	130 MLD used by Mahagenco	--	--	--
7.	No. of Water Aquatic Sources (Lakes, Pond, etc) being developed through treated wastewater	NA	--	--	--

Source: MPCB Regional office, Nagpur

Table 3.3: Details of 11 Sewage Treatment Plants run by NMC

Location of STP	Coordinates of STP (Latitude and Longitude)	STP Commissioned in (Year)	Status (Operational/ Non-Operational/ Under Construction)	STP Installed Capacity (in MLD)	Actual utilization of installed Capacity (in MLD)	Technology (UASB/ ASP / OP / SBR / MBR/ FAB etc.)	Consent Status
Bhandewadi	21°08'18.4"N 79°09'18.5"E	2018	Operational	200	200	SBR	31/12/2016
Bhandewadi*	21°08'12.8"N 79°09'32.8"E	2016	Operational	130	130	SBR	COU
Mankapur	21°11'25.05"N 79°04'44.6"E	2017	Operational	5	5	MBBR	Application for C to O return to NMC
Mokshadham	21°08'18.4"N 79°05'44.6"E	2017	Operational	5	5	MBBR	Application for C to O return to NMC
Kachimet	--	2018	Operational	1	1	SBR	Application for C to O return to NMC
Sonegaon	21°05'59.0"N 28°02'53.0"E	Sept. 2019	Operational	0.3	0.3	Phytorid	Application for C to O return to NMC
HazariPahad	--	Oct. 2019	Operational	4	4	SBR	Completed
Hudkeshwar	--	--	Proposed	30	NA	--	Proposed
Chikhali (khurd)	--	--	Proposed	30	NA	--	Proposed
Bhandewadi	--	--	Proposed	82	NA	--	Proposed

Bhandewadi	--	--	Proposed	65	NA	--	Proposed

Source: MPCB Regional office, Nagpur

*Treated sewage reused by MAHAGENCO, POWER PLANT, Nagpur

On January 4, 2020 Nagpur was labelled as having one of the best sewage management systems in India: https://nagpuroranges.com/nagpur-emerges-as-the-only-city-to-have-the-best-sewage-management-system-in-india/ Jan 4 ,2020. The city Nagpur seems to have one more tag attached to it now. Thanks to its effective use of the Sewage management system carried out by the civic body called NMC. The way the systems in Nagpur are set to treat and reuse the water obtained from Sewage up to 90 percent is incredible. As per reports, the city-based civic body called NMC can recycle the project for more than 90 per cent of sewage water received through the gutter line created by the residents of the city.

Currently, we see the NMC is on the verge of rising the capacity of the sewage treatment plant, which can only recycle up to 480 million litres, while with the upcoming system update, we would be able to see the sewage to be managed up to 525 million litre per day of the sewage that it has generated in the city. As per reports, the NTPC alone produces around 150 million litres of water per day, which the city will be getting through the sewage water.

Similarly, the Maharashtra State Power Generation Company Limited has a similar amount of sewage water when it produces 190 million litres per day of being treated for its thermal power stations based in the vicinity areas of the city in Koradi and Khaparkheda. The city-based civic body does not intend to sell back the treated water to these two powers generating companies in the coming future. Earlier the NMC was able to treat and reuse around 130 MLD sewage three years ago. Now, with endearing systems in place, it will be able to do more on this to emerge out as the place to have 90 per cent of sewage water treated with it

3.5 Surface water quality: Lakes

3.5.1 Lake Water Quality: Physico-Chemical

The city of Nagpur has several lakes; the prominent ones are Futala, Ambazari, Gandhi Sagar (Shukrawari / JummaTalav), Sakkardara,Sonegaon and Naik Talav. The presentstudy has explored the water quality of six major lakes namely Futala, Ambazari, Gandhi Sagar,

Sakkardara, Sonegaon and Naik. These lakes are mainly used for recreational activities besides being exploited by unprecedented anthropogenic activities. On the banks of these lakes, slum settlements are located, and the habitants are seen using the readily available lake water for washing, bathing and other domestic activities. **NMC has always been proactive to protect these lakes from being polluted due to local activities. In order to generate lake water quality scenario in the city a total of thirteen number of sampling locations have been identified for examination of lake water viz. 2 sampling locations from Ambazari lake, 3 from Gandhisagar lake, 2 from Sakkardaralake, 2 from Sonegaon lake and 4 from Naik lake and 20 Samples from Futala Lake including surface and depth sampling. Figure 3.2 depicts the sampling locations in Futala Lake while Table 3.4 gives the details of sampling locations of the other lakes understudy.**

The water quality of Gandhisagar, Sonegaon, Ambazari, Sakkardara and Naiklakes pertaining to physico-chemical parameters, metals and COD are presented in Tables 3.5 and 3.6, respectively. The water quality pertaining to physico-chemical parameters, organics, and metals present in Futala Lake is given in Tables 3.7 & 3.8. The pH was found to be in the range of 6.9-8.0 in Gandhisagar, Sakkardara, Sonegaon,Ambazari and Naik lakes. Total Alkalinity (Carbonates) and Total hardness were found in the range of 120-548 mg/L and 166-384 mg/L in Gandhisagar, Sakkardara, Sonegaon, Ambazari and NaikTalav. Sulphates and Nitrates were found inthe range of 36-186 mg/L and 3-40 mg/L respectively in Gandhisagar, Sakkardara, Sonegaon,Ambazari and Naik lakes. Turbidity was found to be above the desirable limits in all the Lakes which was found to be ranging in between 5-100NTU. One water sample collected from Naik Lake (NK-3) was found to have dissolved solids exceeding the desirable value as per the BIS standards and also above the permissible limit of 2000 mg/L. Gandhisagar and Naik Lakes were found to contain organics measured in the form of COD above 100 mg/L. The COD concentration was found in the range of 25-140mg/L in Gandhisagar, Sakkardara, Sonegaon, Ambazari and Naik lakes. The BOD concentration was found in the range 4.6-80 mg/L for same Lakes. The banks of these lakes were seen loaded with garbage dumps.

The pH was found in the range of 7.1-7.9 in Futala Lake. Total Alkalinity (Carbonates) and Total hardness were found in the range of 220-324 mg/L and 210-302 mg/L respectively; while Sulphates and Nitrates were found in the range of 65-88mg/L and 1-3 mg/L respectively in Futala Lake. Turbidity was found to be above the desirable limits in some of the samples of Futala Lake which was found to be ranging between 1-10 NTU. The COD concentration was

found in the range 16-40mg/L; while BOD concentration was found in range 6-20mg/L in the lake. Significant metal contamination was not observed in these lakes when compared with drinking water standards. The Fe concentration was found in the range of 0.02-0.2 mg/L while Mn concentration was found in the range of 0.002-0.09 mg/L.

3.5.2 Lake Water Quality: Bacteriological

Microbial quality of Ambazari, Gandhisagar, Sakkardhara, Sonegaon, Futala and Naik lakes was investigated. The water samples were analyzed for bacterial indicator organisms viz; Total coliforms (TC) and Fecal coliforms (FC) using Membrane Filter Technique culture-based method. Water samples (10^2diluted) were filtered (100 ml) through membrane filtration assembly and membrane placed on specific media plates for detecting and enumerating coliforms. For enumerating thermotolerant coliforms, media plates were incubated at 44.5^{o}C $\pm$ 0.2^{o}C for 24 hours. Total coliform and thermotolerant coliforms (fecal coliforms-FC) were found in the range of 88*10^2-490*$10^2$and 9*10^2-75*10^2 respectively. Out of these lakes the samples collected from Naik Lake viz., NK-1, NK-3 and NK-4 were found to have the highest number of total coliforms (TC) and thermotolerant coliforms (fecal coliforms-FC).Significant number of total coliforms (TC) and thermotolerant coliforms (fecal coliforms-FC) were found in lakes (Ambazari, Gandhisagar, Sakkardhara, Sonegaon and Naik lakes) as is evident from Table3.9. Total coliform and thermotolerant coliforms (fecal coliforms-FC) in Futala lake were found in the range of 20*10^2-242*10^2 and 12*10^2-137*10^2 respectively. Significant numbers of total coliforms (TC) and thermotolerant coliforms (fecal coliforms-FC) were found in Futala lake as is evident from Table 3.10.

Table 3.4: Sampling Location Details of Lakes

S.No	Sample Code	Sample Details / location details	Sources	Latitude	Longitude	Other Observations
1	GS-1	Near Empress Mall Gandhisagar Lake	Lake	21 ˚08′51″	79 05′45″	Anthropogenic Activity - Bathing and Washing Clothes
2	GS-2	Opposite to Raman Science Centre Gate, Gandhisagar Lake	Lake	21 ˚08′44″	79 05′45″	Anthropogenic Activity - Bathing and Washing Clothes
3	GS-3	Near Sindhu Jhulelal Temple, , Gandhisagar Lake	Lake	21 ˚08′41″	79 05′45″	Anthropogenic Activity - all stuff used in worship to Gods, flowers, oil lamps etc.
4	SG-1	Near Police Chowki Sonegaon Lake	Lake	21 ˚06′03″	79 03′16″	Plastics, papers
5	SG-2	Near Hanuman temple Sonegaon Lake	Lake	21 ˚05′59″	79 03′16″	Anthropogenic Activity - all stuff used in worship to Gods, flowers, oil lamp etc.
	AZ-1	Opposite to Krazy Castle Ambazari Lake				

6			Lake	21 ˚07′30″	79 02′36″	Fishes are observed; surrounding area was clean
7	AZ-2	Left Hand Side to Vivekanand Statue Ambazari Lake	Lake	21 ˚07′33″	79 02′38″	Fishes are found; surrounding area was clean
8	SD-1	Near Road, Location outside Area Sakkardara Lake	Lake	21 ˚07′18″	79 6′50″	Anthropogenic Activity - Bathing and Washing Clothes, Plastic, papers oil, Glasses, etc.
9	SD-2	Inside garden and Lawn Area, Sakkardara Lake	Lake	21 ˚07′16″	79 6′45″	Green Floating Leaves, Fishes etc.
10	NK-1	Near Road, Location opposite to residential area, Naik Lake		10	NK-1	Near Road, Location opposite to residential area, Naik Lake
11	NK-2	Near Small Temple, opposite to slum area, Naik Lake	Lake	21 ˚09′43″	79 6′55″	Anthropogenic Activity - all material used in worship of God, flowers, oil lamp etc.
12	NK-3	Near Public toilet, Location opposite to slum area, Naik Lake	Lake	21 ˚09′38″	79 6′40″	Anthropogenic Activity such as Open Defecation, Public Toilet, water was completely covered with algae, all material used in worship of God,

Contd…

S.No	Sample Code	Sample Details / location details	Sources	Latitude	Longitude	Other Observations
13	NK-4	Near Garden, Location near small temple, Naik Lake	Lake	21 ˚09′47″	79 6′43″	Anthropogenic Activity - all material used in worship of God, Flowers, oil lamp along with Green Floating Leaves, Fishes etc.

Table 3.5: Water Quality of Gandhisagar, Sonegaon, Ambazari, Sakkardara and Naik Lakes–Physico-chemical Parameters

Sr. No	Sample Code	pH	EC	TDS	Turbidity	Total alkalinity	Total Hardness	Calcium as Ca^{2+}	Magnesium as Mg^{++}	Sodium	Potassium	Phosphate	Fluoride	Nitrate	Sulphate	Chloride
	Unit		µS/cm	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BIS Limit		6.5-8.5	-	500-2000	1-5	200-600	200-600	75-200	30-100	-	-	-	1.0-1.5	45	200-400	250-1000
1	GS-1	7.3	1199	719	45	286	285	80	20	200	60	0.2	0.08	30	180	188
2	GS-2	7.1	680	408	23	264	230	48	26	265	55	0.6	0.05	18	182	200
3	GS-	7.5	1289	773	18	280	280	64	29	215	50	0.5	0.06	12	186	210
4	SG-1	7.8	400	240	31	168	176	38	19	18	6	0.4	0.8	3	55	32
5	G-2	8.0	395	237	20	172	184	38	21	19	8	0.4	0.8	4	45	36
6	AZ-1	6.9	500	300	22	144	192	42	21	22	7	0.5	0.3	10	45	72
7	AZ-2	7.5	410	246	26	120	166	35	19	25	4	0.6	0.3	6	36	72
8	SD-1	7.1	850	510	10	320	248	51	29	88	12	0.5	0.8	5	77	102
9	SD-2	7.5	890	534	7.9	300	300	72	29	81	15	0.3	0.9	6	89	106

Cintd…

Sr. No	Sample Code	pH	EC	TDS	Turbidity	Total alkalinity	Total Hardness	Calcium as Ca^{2+}	Magnesium as Mg^{++}	Sodium	Potassium	Phosphate	Fluoride	Nitrate	Sulphate	Chloride
	Unit		µS/cm	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BIS Limit		6.5-8.5	-	500-2000	1-5	200-600	200-600	75-200	30-100	-	-	-	1.0-1.5	45	200-400	250-1000
10	NK-1	7.2	1061	637	20	402	284	56	35	106	26	1.6	0.8	20	101	110
11	NK-2	7.1	968	581	7	360	308	59	38	105	25	1.8	0.6	40	96	116
12	NK-3	7.5	3400	2040	100	548	384	21	80	181	129	2.5	0.8	25	140	150
13	NK-4	7.3	1119	671	5	420	328	67	38	105	25	1.3	0.7	25	105	110

Table 3.6: Water Quality of Lakes – Metals, COD, BOD

Sr. No.	Sample Code	Al	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	COD	BOD
BIS: 10500-2012 Desirable/ Permissible limit		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 Detection Limit		0.002	0.007	0.0001	0.01	0.0004	0.0003	0.0001	0.005	0.009	0.001		
1	GS- 1	0.007	BDL	BDL	BDL	0.005	0.1	0.005	BDL	BDL	0.07	120	30
2	GS -2	BDL	BDL	BDL	BDL	BDL	0.1	0.002	BDL	BDL	0.05	90	36
3	GS -3	0.009	BDL	0.002	BDL	0.002	0.05	0.02	BDL	0.009	0.2	50	18
4	SG -1	BDL	0.009	0.0004	ND	0.003	0.08	0.08	0.005	BDL	0.06	26	16
5	SG -2	ND	BDL	BDL	BDL	BDL	0.09	0.09	0.006	0.009	0.08	30	22
6	AZ -1	BDL	ND	BDL	BDL	0.003	0.2	0.09	BDL	BDL	0.06	32	4.6
7	AZ -2	ND	BDL	BDL	BDL	BDL	0.1	0.08	BDL	BDL	BDL	35	4.8
8	SD- 1	BDL	ND	BDL	ND	0.006	0.08	0.09	0.008	BDL	BDL	70	5
9	SD- 2	BDL	BDL	BDL	BDL	BDL	0.02	0.008	BDL	BDL	BDL	25	8

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Sr. No.	Sample Code	Al	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	COD	BOD
BIS: 10500-2012 Desirable/ Permissible limit		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 Detection Limit		0.002	0.007	0.0001	0.01	0.0004	0.0003	0.0001	0.005	0.009	0.001	-	-
10	NK-1	0.009	0.009	0.0005	0.003	0.009	0.08	0.1	BDL	0.009	0.1	100	60
11	NK-2	0.008	0.008	0.0002	0.002	0.005	0.09	0.1	BDL	0.009	0.4	120	50
12	NK-3	0.007	0.008	0.0001	0.003	0.003	0.2	0.1	BDL	BDL	0.09	140	80
13	NK-4	0.009	0.009	BDL	0.001	0.004	0.2	0.09	0.007	BDL	0.1	110	66

NOTE-BDL- Below Detection Limit of ICP-OES; ND- Not Detected; All parameters are in mg/L.

Table 3.7: Water Quality of Futala Lake–Physico-chemical Parameters

Sr.No.	Sample Code	pH	EC	TDS	Turbidity	Total alkalinity	Total Hardness	Calcium as Ca^{++}	Magnesium as Mg^{++}	Sodium	Potassium	Sulphate	Chloride	Nitrate	Fluoride
	Unit		µs/cm	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BIS Limit		6.5-8.5	-	500-2000	01-05	200-600	200-600	75-200	30-100	-	-	200-400	250-100	45	0.5-1.5
1	S-1	7.4	602	361	4	300	280	72	24	44	8.0	88	50	1	0.3
2	S-2	7.5	620	372	3	300	292	75	25	38	5	75	52	3	0.2
3	S-3	7.1	635	381	2	324	300	77	26	38	5	72	48	2	0.4
4	S-4	7.9	665	399	10	300	292	78	23	40	8	65	50	1	0.5
5	S-5	7.2	656	394	3	300	302	77	26	41	9	70	52	1	0.6
6	S-5 Depth	7.6	590	354	1	280	266	66	24	40	5	72	48	1	0.3
7	S-6	7.2	600	360	8	288	268	69	23	41	6	68	46	1	0.4
8	S-6	7.5	598	359	2	296	256	66	22	44	7	70	44	1	0.5

	Depth														
9	S-7	7.6	565	339	9	292	268	72	21	46	4	72	46	1	0.6
10	S-7 Depth	7.7	574	344	8	282	264	58	29	36	9	76	48	1	0.8
11	S-8	7.8	588	353	4	264	238	57	23	38	8	72	46	2	0.7
12	S-9	7.9	566	340	7	220	210	60	14	39	3	70	44	1	0.3
13	S-10	7.9	545	327	1	288	258	68	21	42	5	71	42	1	0.5
14	S-10 Depth	7.5	598	359	9	282	264	72	20	40	4	73	44	1	0.6
15	S-11	7.6	578	347	2	280	244	62	21	43	9	75	40	1	0.2
16	S-11 Depth	7.6	585	351	3	286	260	60	26	46	6	78	42	1	0.4
17	S-12	7.9	578	347	8	274	256	64	23	45	7	75	46	2	0.4
18	S-12	7.9	598	359	1	274	258	68	21	41	4	72	48	2	0.6

	Depth														
19	S-13	7.6	585	351	2	288	256	67	21	40	8	78	46	1	0.5
20	S-13 Depth	7.8	579	347	7	280	262	61	26	42	9	74	48	2	0.8

Table 3.8: Water Quality of Futala Lake –Metals, COD and BOD

Sr. No.	Sample Code	Al	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	COD	BOD
BIS: 10500-2012 Desirable/ Permissible limit		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 Detection Limit (ppm)		0.002	0.007	0.0001	0.01	0.0004	0.0003	0.0001	0.005	0.009	0.001		
1	S1	0.007	BDL	BDL	BDL	BDL	0.2	0.05	BDL	BDL	BDL	30	8
2	S2	BDL	0.007	BDL	BDL	0.0008	0.1	0.04	BDL	BDL	BDL	18	10
3	S3	0.005	0.009	BDL	BDL	0.009	0.2	0.06	BDL	BDL	BDL	32	8
4	S4	BDL	0.007	BDL	BDL	BDL	0.2	0.05	BDL	BDL	0.002	36	12
5	S5	ND	BDL	BDL	BDL	0.008	0.1	0.006	BDL	BDL	BDL	36	10
6	S5 Depth	0.004	ND	BDL	BDL	0.007	0.1	0.006	BDL	BDL	0.004	22	8
7	S6	0.005	BDL	BDL	BDL	BDL	0.07	0.005	0.005	0.009	0.003	38	10

8	S6 Depth	0.006	0.007	BDL	BDL	0.007	0.09	0.004	0.008	BDL	BDL	38	16
9	S7	0.004	0.008	BDL	BDL	0.005	0.1	0.05	BDL	BDL	BDL	40	18
10	S7 Depth	0.005	0.007	BDL	BDL	0.007	0.09	0.07	BDL	BDL	0.005	36	20
11	S8	ND	BDL	BDL	BDL	0.009	0.1	0.06	BDL	BDL	0.007	34	8
12	S9	BDL	ND	BDL	BDL	0.008	0.2	0.05	BDL	BDL	0.02	30	10
13	S10	ND	BDL	BDL	BDL	0.007	0.2	0.04	0.006	BDL	BDL	22	8
14	S10 Depth	0.006	0.007	BDL	BDL	0.007	0.1	0.03	0.005	BDL	BDL	32	16
15	S11	0.007	0.008	BDL	BDL	BDL	0.1	0.04	BDL	BDL	BDL	32	12
16	S11 Depth	0.009	0.008	BDL	BDL	0.0008	0.2	0.03	0.005	0.009	0.05	16	8
17	S12	0.008	BDL	BDL	BDL	0.004	0.2	0.03	BDL	BDL	0.05	36	18
18	S12 Depth	0.005	0.008	BDL	BDL	0.005	0.2	0.04	BDL	BDL	BDL	22	16
19	S13	0.008	BDL	BDL	BDL	0.007	0.2	0.03	BDL	BDL	0.05	20	6
20	S13 Depth	0.009	BDL	BDL	BDL	0.006	0.2	0.03	0.005	BDL	BDL	16	10

BDL- Below Detection Limit; ND - Not Detected; All parameters are in mg/L.

Table 3.9: Water Quality of Lakes - Bacteriological Parameters

Sr. No	Sample code	Total coliform (CFU/100ml) (Dilution Factor - 10^2)	Thermotolerant coliform (CFU/100ml) (Dilution Factor - 10^2)
1	GS- 1	322	20
2	GS -2	318	10
3	GS -3	212	16
4	SG -1	88	19
5	SG -2	144	9
6	AZ -1	333	17
7	AZ -2	305	16
8	SD- 1	233	22
9	SD- 2	96	20
10	NK-1	490	38
11	NK-2	108	56
12	NK-3	480	75
13	NK-4	480	48

Note- GS-Gandhisagar Lake; SG - Sonegaon Lake; AZ - Ambazari Lake; SD - Sakkardara Lake; NK- Naik Lak

Table 3.10: Water Quality of Futala Lake- Bacteriological Parameters

Serial No.	Sample code	Total coliform (CFU/100ml) (Dilution Factor – 10^2)	Thermotolerant coliform (CFU/100ml), (Dilution Factor – 10^2)
1	S1	116	19
2	S2	95	75
3	S3	22	12
4	S4	39	20
5	S5	225	123
6	S5 Depth	236	137
7	S6	20	12
8	S6 Depth	30	22
9	S7	30	21
10	S7 Depth	32	20
11	S8	110	52
12	S9	122	52
13	S10	232	121
14	S10 Depth	242	132
15	S11	96	72
16	S11 Depth	98	78
17	S12	45	30
18	S12 Depth	46	38
19	S13	118	35
20	S13 Depth	110	32

NOTE- S- Futala Lake

3.5.3 Lake Water Quality: Benthic Environment

The Benthic Macroinvertebrates are the organisms consider found in the sediments, logs and living among stones as they acquire both types of reservoir like a lentic and lotic type of water system. They come under invertebrates as they lack a backbone. Benthic organism plays an important role in the food chain because they control and recycle the nutrients outflow from the ecosystem. They transform organic detritus from sedimentary storage into dissolved nutrients. These nutrients are utilized by Phytoplankton and Zooplankton. The various organisms obtain in these environments such as Phylum Platyhelminthes, Annelidans, Molluscan shells, Aquatic Hemipteran Bugs, Odonates larvae, Caddisfly larvae, May fly larvae, Coleopteran larvae and Beetles, Chironomus Larvae, etc., The presence of Benthic organisms is responsible for the various physical status of the environment due to Climatic Shifts, Chemical Pollution and Eutrophication. They are sensitive to habitat characteristics, including interrelated variables such as temperature, oxygen, suspended sediment, turbulence, current, discharge, light, depth, and substrate (Evan & Norris, 1997; Leopold, 1994; Rempel et al., 2000; Southwood, 1977, 1988; Townsend, 1989; Ward, 1992; Haldar, 2016). They are also responsible for Biomonitoring effects because they show organic and inorganic pollution. These organisms are responsible for short term and long-term environmental stress and have a chief role in maintaining biodiversity.

The zoobenthic species found in various lakes such as Gandhi Sagar lake, Sakkardara lake, Ambazari lake and Sonegaon lake. The Gandhi Sagar lake appears greenish colour and also, this lake is located at the center of the city and is surrounded by roadway. Then another lake is the Sakkardara Lake which is located in the garden area. One side of that lake is connected to the roadside. while another side is encircled by frozen soil. As this lake is containing various kinds of plants water lily, Lotus and macro-algae indicate its nutrient status. The Sonegaon lake is having a temple on one side and many people through temple trash nearby it. Another two sides are surrounded by roadway and the remaining one side is fenced by frozen soil. During sample collection, it was observed that some dragonfly species and its nymphs were moving above the surface of the water, which are the ecological indicators for good quality of water. Ambazari Lake is located beside the garden and showing the algae population and small weeds. This lake is quite larger than other lakes and fishes were also observed during sampling.

3.5.3.1 Methodology

The sediment sample was collected from the bottom of the lakes Ambazari, Sakkardara, Gandhi Sagar and Sonegaon lakes. The Benthic Macroinvertebrates were collected by a sieving sediment sample with a sieve of size 500 - 1000 µ. The collected species were stored in 2% formalin. It was noticed that the original coloration was getting lighter due to the preservation of organisms into formalin. The list of sampling locations is as given in Table 3.4.

3.5.3.2 Benthic Diversity

All the four lakes are highly diverse with various kinds of species. The Existence of those species has their bioindication properties. The comparison of an organism of different lakes indicates trophic status of the lake. The species observed in different lakes has been illustrated in the Table3.11.

Table 3.11: Benthic diversity of different lakes

Site	Phylum	Class / Order	Families	Genus
GS	Arthropoda	Diptera	Chironomidae	*Chironomus*
			Simulidae	-
			Tipulidae	-
		Odonata	Coenagrionidae	Ceriagrioncoromandelianum
		Hemiptera	Pleidae	Neoplea striola
			Nepidae	Nepacinera
		Trichoptera	Hydropsychidae	Hydropsyche
		Coleoptera	Dytiscidae	Hydrovatus concerts
			Hydrophilidae	-

	Annelida	Hirudinea	Erpobdelidae	Erpobdella
	Mollusca	Gastropoda	Viviparidae	B. Bengalensis f. colairensis
				B. Bengalensis f. balteata
			Physidae	Physaacuta
			Ampularidae	Pila
			Thiaridae	-
			Planorbidae	-
AZ	Arthropoda	Hemiptera	Belostomatidae	Belostoma
	Mollusca	Gastropoda	Viviparidae	Bellamyabengalensis
			Thiaridae	Melanoides tubercular
				Thiara
	Annelida	Hirudinea	Glossiphonidae	-
			Lumbriculidae	-
SG	Annelida	Hirudinea	Erpobdelidae	Erpobdella
			Tubificidae	Tubifex tubifex
				Limnodrilushoffmeisteri
			Naididae	-
	Arthropoda	Diptera	Chironomidae	Chironomus

SD	Annelida	Hirudinea	Naididae	-
	Arthropoda	Diptera	Chironomidae	Chironomus

*AZ: Ambazari lake, SD: Sakkardara lake, GS: Gandhi Sagar lake, SG: Sonegaon lake

The Saprobic [Biological Monitoring Working Party (BMWP)] Score is the process through which various families of macroinvertebrates were studied. These families show a score scale from 1 to 10 which determines the quality of water. The Saprobic Score is calculated as a total multiplied score divided by a total number of families encountered. Then according to the range of Saprobic Score the water quality has determined (Table 3.12).

Table 3.12: Saprobic index of lakes

Location	Saprobic Score	Water Quality	Water Quality Class	Indicator colour
Gandhi Sagar Lake	4.53	Moderate Pollution	C	Green
Sakkardara Lake	1.5	Moderate Pollution	E	Red
Sonegaon Lake	1.7	Severe Pollution	E	Red
Ambazari Lake	4.6	Moderate Pollution	C	Green

3.5.3.3 Bioindication of observed Macrozoobenthos

The diverse benthic organism found on the lake according to the sustainable environment they live in that lake. Each organism represents its bioindication to that lake. So, the bioindication of Macrozoobenthos have been given as follows:

- **Chironomus larvae -** As this species commonly found in the lake, they are slender and elongated similarly to a pair of forelegs and gill appendages for false movement. It remains in a high amount of organic waste and the lake shows depletion of oxygen.
- **Simulidae** - The species of family simulidae are commonly called as Blackflies. Their indication in the lake is they remain in acidification and at high organic pollution.
- **Tipulidae -** The tipulidae flies are commonly called as Crane fly. They also feed on organic matter. Means, their presence in the lake defines that a lake containing rich organic matter.
- **Cereagrioncoromandelianum -** This species is a slender-bodied and having 3 gills at the last abdomen segment and this species have been found only one in no which means the water quality of pond is polluted.
- **Neoplea striola -** The *Neoplea*sp is belonging to Pleidae family as they are known as backswimmers. They are predators and highly voracious to the mosquito larvae.
- **NepaCinera -** It is an aquatic bug found commonly in slow-flowing water as it is a predator and feeds on small fishes.
- **Hydropsyche -** This is a trichopteran larva generally the trichopteran larvae occur in the freshwater but the *Hydropsyche* is sensitive to water pollution.
- **Hydrovatus concerts -** It belongs to Dytiscidae family and is found in slow-moving also they take oxygen from the atmosphere. It is a sustainable huge level of salinity.
- **Hydrophilidae -** It is commonly found in the lake and it feeds on rotting organic matter.
- **Erpobdella -** It is sustainable to oligosaprobic and polysaprobic too. It is a predator of Midge larvae.
- **Viviparidae -** This species mostly active at night and they feed on algae and organic debris.
- **Physaacuta -** The species is not introduced from India; it is an extrinsic specie. It is a pest of crop and thus it is very critical.
- **Pila -** It is a dextral shell and tolerable to metals concentration in water. this species is also used for a biomonitoring purpose.
- **Melanoid tuberculata -** This species is tolerable to saline water and it sustainable to low oxygen concentration thus it obtained in a polluted water body.
- **Thiaridae-** The species of Thiaridae is tolerable to a depletion of oxygen. Hence it indicates a low quantity of oxygen.

- **Planorbidae -** This family species is sufferable to pollution and thus water containing organic matter also macrophytes.
- **Belostoma -** This specie indicates polluted water with organic matter.
- **Glossiphonidae-** This species is fresh water dwelling.
- **Tubificidae -** The species of this family are remains where the water body polluted by heavy metal.
- **Naididae -** The species of this family covered with hairy kinds of legs from one end. These are species found in gently saline water body.

3.5.4 Microbial Diversity of Lakes: Metagenome analysis of Gorewada (GW) and Gandhisagar (GS)lakes:

Metagenomics is a next-generation tool for microbial ecologists that analyzes all of the environmental DNA and provides answers to the key question: who is there, what they are doing and how they are doing it? The main advantage of using Metagenomics tools over conventional microbiological tools that is can identify even the non-cultivable microbes . It provides a large amount of data rapidly whereas the conventional methods are laborious and time-consuming. Since freshwater bacteria are the hub for biogeochemical cycles and helps to control water quality in lakes, the information about their identity and ecology of functionally significant lake bacteria at molecular level become imperative.

Present study focused on comparative analysis of microbial diversity of two lakes of Nagpur city. Sediment samples from two representative lakes viz; Gorewada (GW) and Gandhisagar (GS) were analyzed for microbial diversity analysis. Total DNA extraction was done using MP biomedicals Fast DNA Spin Kit. Agarose gel electrophoresis was used for DNA purity and integrity and Qubit 2.0 fluorometer quantitation was used for accurate measurement of DNA concentration. Sequencing was performed using the Illumina platform after library clustering with paired-end reads. Metagenome sequences were assembled based on clean raw data after quality control and bioinformatics analysis was performed to compare taxonomic distribution and gene predictions of Gandhisagar and Gorewada lakes.

3.5.4.1 Taxonomic distribution study of Gorewada and Gandhisagar lakes using metagenome datasets:

Taxonomic distribution study involves mapping of metagenomic reads to the taxonomy database (NR database- NCBI GenBank). Taxonomic diversity serves as a way of profiling a

community and can be used to ascertain the similarity of two or more communities. Table 3.13 shows the feature details of metagenomics dataset used for analysis.

Table 3.13: Metagenomic datasets obtained using MG-RAST

(of GW and GS lakes)

Feature (sequence read numbers)	Gorewada_GW	Gandhi Sagar_ GS
Total sequences	31,083,652	27,842,276
Average read length (bases)	150 ± 1	150 ± 1
PostQC sequence	25,347,346	23,708,733
Average GC content	61 ± 12 %	56 ± 13 %
QC passed reads	32,480	45,718
Predicted protein feature	23,473,270	21,704,733
Predicted rRNA features	63,600	89,359
Identified protein features	8,324,368	7,143,484
Identified rRNA features	14,418	21,260

Table 3.14 shows domain level distribution percentage of microorganisms associated with two lakes (GW and GS) based on metagenome sequence analysis. Gorewada (98.3%) has higher bacterial abundance than Gandhisagar (95.9%). Interestingly Gandhisagar (2.22%, 0.16%) was found to have high Archaeal and Viral abundance compared to Gorewada (0.84%, 0.04%) lake.

Table 3.14: Domain level distribution of microorganisms associated with two lakes

Domain level distribution (%)	Gorewada GW	Gandhisagar GS
Bacteria	98.30	95.90
Archaea	0.84	2.22
Eukaryotes	0.59	1.51
Viruses	0.04	0.16
Unclassified sequences	0.22	0.16
Other	0.0	0.0

3.5.4.2 Taxonomic diversity at Phylum level in Metagenomes of Gorewada and Gandhisagar

Phylum level taxonomic diversity revealed the relative abundance of Proteobacteria and Actinobacteria more in Gorewada (GW) lake as compared to Gandhisagar (GS) lake. Presence of high numbers of Actinobacteria indicates that antimicrobial bioactive compounds producers are present in Gorewada lake (Fig 3.2).

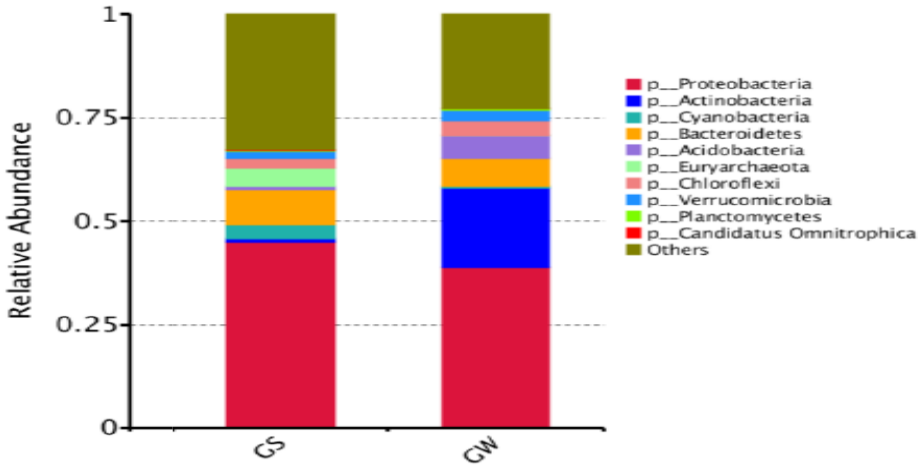


Fig 3.2. Relative abundance (%) of bacterial diversity at Phylum level in Gandhisagar (GS) and Gorewada (GW) lakes of Nagpur city

3.5.4.3 Taxonomic abundance at Genus level in Metagenomes of Gorewada and Gandhisagar lakes

Genus level taxonomic diversity was analyzed by Heat Map which comprised of ß diversity (of dominant 35 genera) showing a significant level of distinction as well as similarity in micro flora between Gandhisagar and Gorewada lakes. In Gorewada lake, Nocardiaceae, Geobacteraceae, Desulfuromonadaceae, Methylobacteriaceae family microbes were found dominant, whereas no similar genera distribution was found in Gandhisagar lake. Bacteria belonging to genus Rhodococcus, Geobacter, Desulfuromonas, Methylobacterium were dominantly present in Gorewada lake (Fig 3.3).

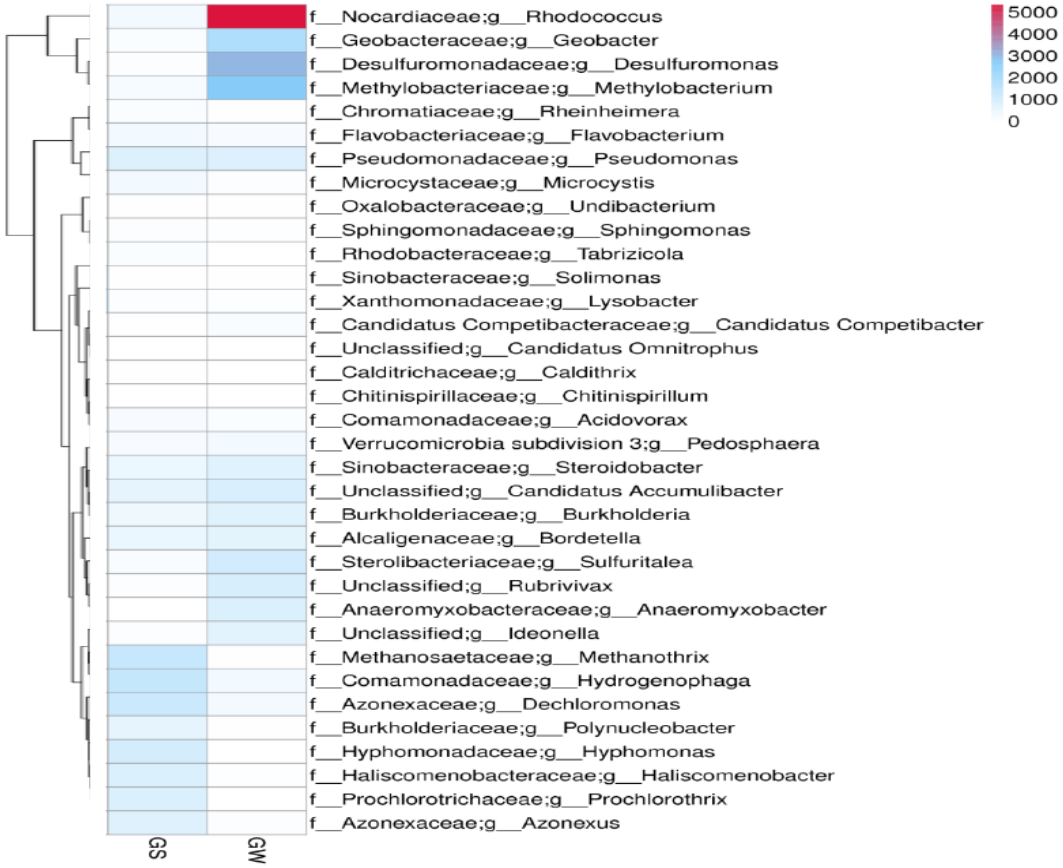


Fig 3.3: Heatmap cluster showing abundance of Rhodococcus, Geobacter, Desulfuromonas, Methylobacterium at genus level in Gorewada (GW) lake than Gandhisagar Nagpur city

3.5.4.4 Gene predictions in Gandhisagar (GS) and Gorewada (GW) lakes of Nagpur city

Functional gene profiling in metagenomes of Gorewada and Gandhisagar lake showed metabolic pathways, which were statistically compared using STAMP software. In total, 26 catabolic features were compared amongst Gorewada and Gandhisagar metagenome sequences (Figure 3.4, which included genes involved in DNA and RNA metabolism, respiration, virulence, disease and defense, cofactors, vitamins, prosthetic groups, pigments, membrane transport, etc. Comparative analysis showed significant association (95% confidence interval) of all the catabolic and housekeeping genes in Gorewada and Gandhisagar diverse microbial communities (Figure 3.4).

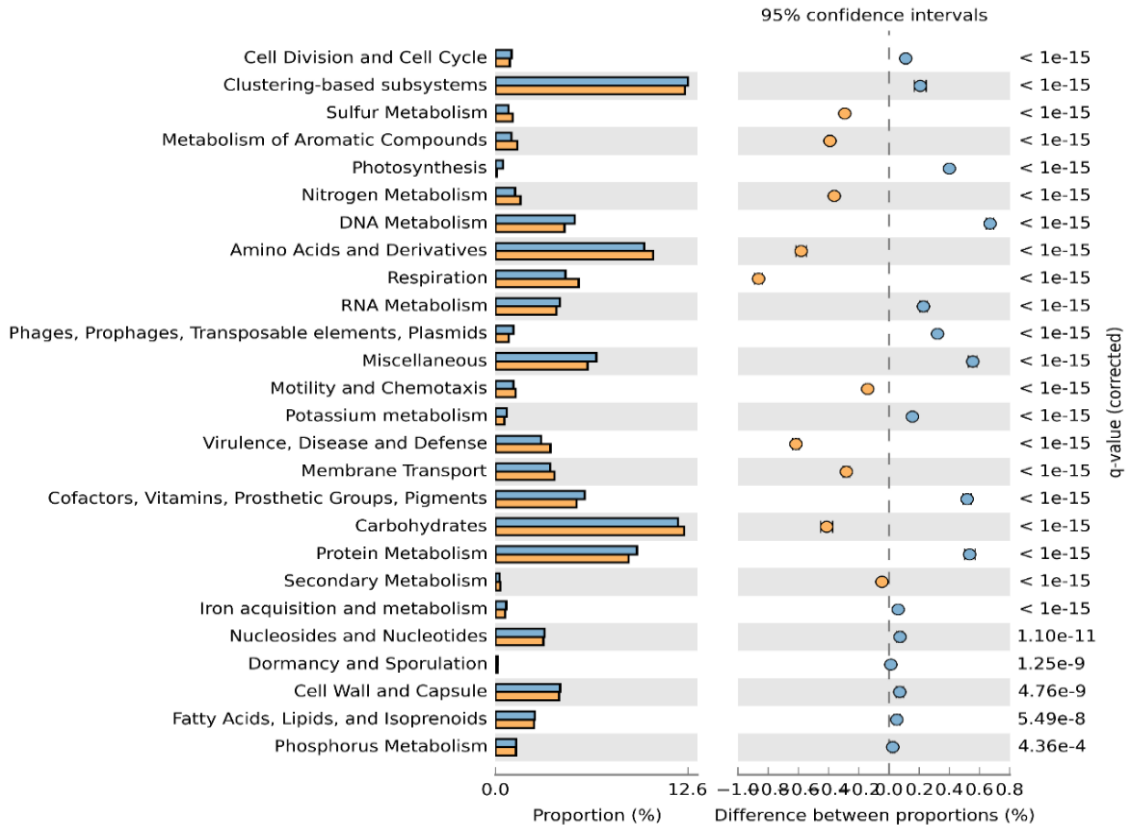


Figure 3.4: Comparative analysis of genes responsible for various metabolic pathways in microbial communities of Gandhisagar (blue) and Gorewada lake (yellow)

3.5.4.5 Distribution of Antibiotic Resistance Genes and Metal resistance genes in Gorewada lake and Gandhisagar lake

Antibiotic resistance genes were distributed abundantly in Proteobacteria phyla in both the lakes. Fig 3.5 illustrates two circles, the inner circle represents the proportion of different phyla contained with ARGs, and the outer ring is the proportion of other genes in different phyla. Diverse phyla such as, Bacteroidetes were evenly distributed in lake Gandhisagar lake, while Gorewada lake showed dominant presence of phyla Proteobacteria.

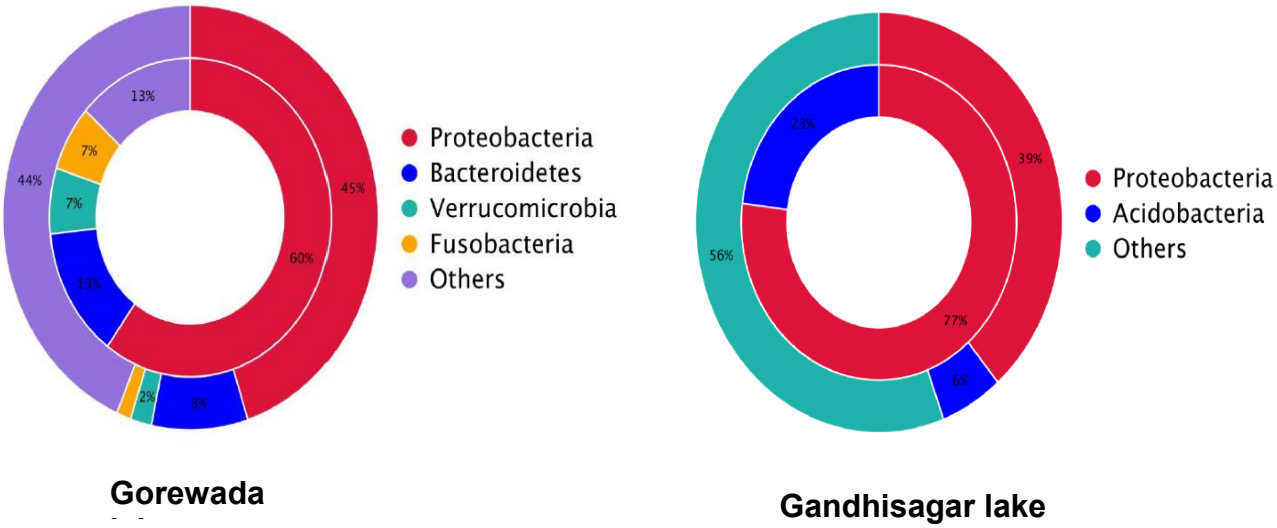


Fig 3.5. Donuts chart showing distribution of Antibiotic Resistance Genes (ARGs) in Gorewada and Gandhisagar lakes of Nagpur

As these freshwater bodies are being used for the supply of drinking water, we explored the types of genes conferring antibiotic and metal resistance. In total 32 types of genes responsible for antibiotic resistance (ARGs) and metal resistance (MRGs) were found. Antibiotic resistance genes encoding for vancomycin resistance "last resort of antibiotics", polymyxin, fluoroquinolones, erythromycin resistance, beta-lactamase, etc. were abundant in both the lakes. Presence of beta-lactamase indicates that there is resistance over lactamase family antibiotics like cephalosporin, penicillin, carbapenems and cephamicin. Resistance genes conferring resistance to metals like copper, cobalt, cadmium, zinc, arsenic resistance etc. were also abundant. These metals play an important role in the co-selection of ARGs in the environments. (Figure 3.6, a, b). **Results act as a warning that we need to ensure clean water in the lakes or they could act as hubs for breeding antibiotic resistant bacteria that will be the new emerging health concern.**

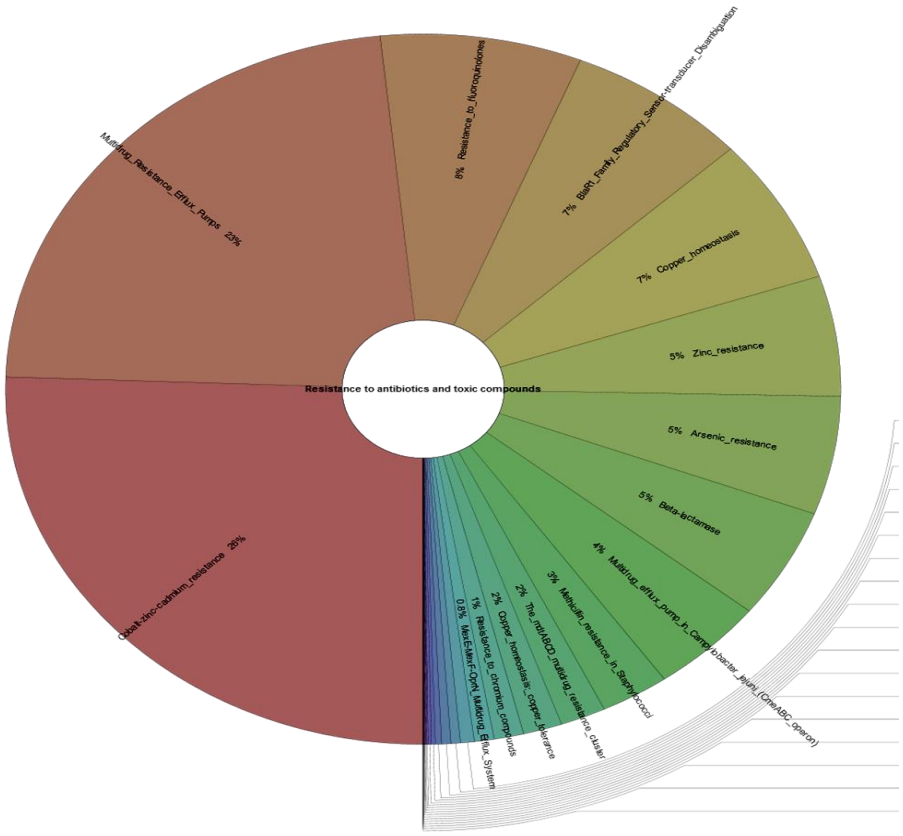


Figure 3.6a: Resistome profile of Gorewada lake

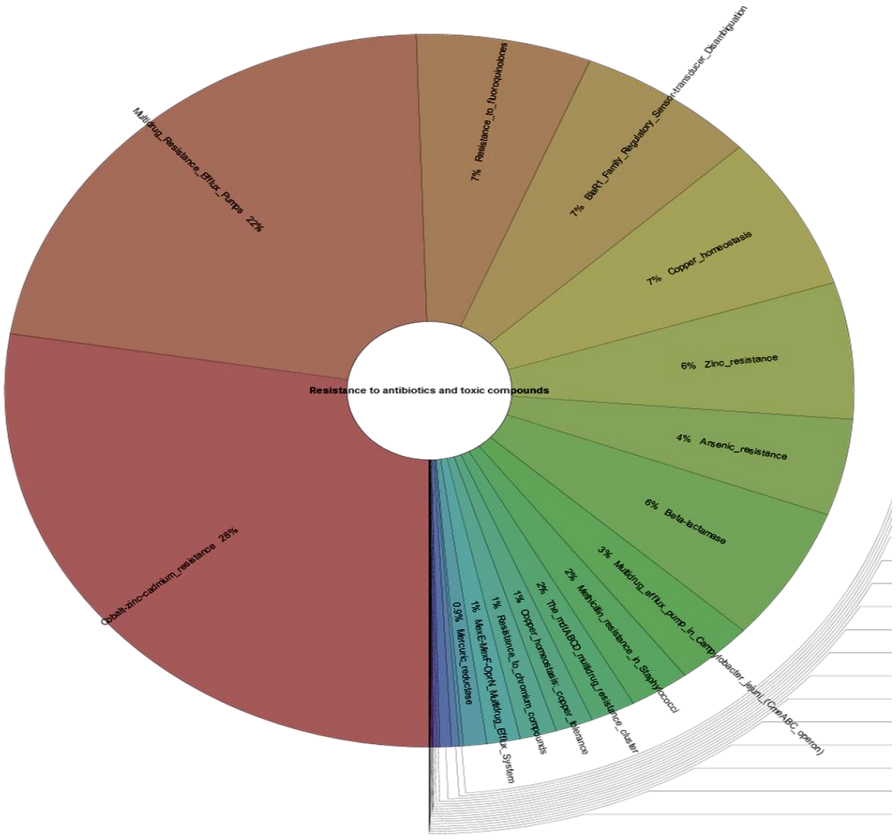


Figure 3.6b: Resistome profile of Gandhisagar lake

3.6 Surface water quality: Rivers

Nagpur which is geographic center of India has three rivers flowing through it i.e. Nag, Pilli and Pora River. The name of the city has been named after Nag River, that originates in Lava hills in wadi and starts an outflow from the western weir of Ambazari lake in west and flows through the length of 17 kms in the city towards east following the natural slope of the landform in order to merge in kanhan River. The Nag River forms a part of kahan-Pench river system. Pilli River has been mapped from near the Gorewada Lake which is in the north-west part of the city flows towards the east and meet Nag river near Pawan Gaon which ultimately merge into Kanhan river. The stretch of Pilli River is 18 kms within the city limit. Pora originates from south west part of the city near Hingna and flows towards south-east of the city.

The volume of sewage received by Pilli and Nag River each day is around 430 MLD. The river is getting polluted due to discharge of domestic and industrial waste, solid waste, agricultural waste, hospitals, slaughter houses, untreated sewage from nallahs etc. So, in short, the river receives fresh water only at the time of monsoon and rest of the year it carries untreated sewage and industrial effluent across the city.

According to Maharashtra Pollution Control Board (MPCB), Nag River is responsible for polluting Gosikhurd dam built on Wainganga River. It is planned that Nag River will be cleaned by installing Sewage Treatment Plant (STP) and the treated effluent will be supplied to MahaGenco, MIHAN and Irrigation Department according to the DPR of Nag River of NMC. At present, Bhandewadi STP is supplying treated effluent for reuse Koradi thermal plant of MahaGenco for power generation.

According to www.thehitavada.com, on 30 March,2020, “Clean Nag, Pilli and Pora rivers in 20 days”, initiative has been taken by NMC to clean the stretch of 48 kms during lockdown. Further, the Nag River project of NMC said that “Nag will be free from sewage by 2034” as per Times of India on 28th Nov,2018.

CSIR-NEERI has monitored the three rivers and are primary data is presented in Tables 3.15-3.19. The water quality analysis of Nag River was carried out by selecting 9 sampling locations while for Pilli and Pora River it was 8 and 4 locations, respectively.

Nag River does not meet the criteria for irrigation, bathing and propagation of wildlife and fisheries according Central Pollution Control Board (CPCB) hence fails to fall under class A-D designated as best use water quality criteria by CPCB. The river appears to be highly polluted

due to high organic load in terms of TSS: 20-600mg/L, COD 62-1880 mg/L and BOD 12-315mg/L as it's half of the length crosses commercial area of the city where dumping of untreated and indiscriminate waste takes place. High levels of Phosphate 2.5 to 11.3 mg/l as P was observed from samples NAG-3 to NAG 9Out of the 8 samples of Pilli River only first sample (Pilli 1) meet the norms laid by CPCB for irrigation, bathing etc., while rest shows increase in TSS from 4 to 1160mg/L, COD 20 to 840 mg/L and BOD 3 to 118 mg/L which confirms the pollution goes on increasing throughout the expanse of river due to mixing of drains in the city.

In case of Pora, the physico chemical characteristics in terms of TSS, COD and BOD i.e. in the range of 37-2155 mg/L, 76-900 mg/L and 17- 255 mg/L, respectively. This indicates increase in organic load due to polluted drains mixing with the river. Both and Pilli and Pora as well doesn't fall in class A-D designated by CPCB.

Table 3.15: Sampling Locations of surface water quality

Sampling Points	**Site description**	**NAG RIVER**	
		Latitude	**Longitude**
NAG-1	Initial sampling point (Ambazari lake)	21°7'30''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 MokshDhamn (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	
Sampling Points	**Site description**	**Latitude**	**Longitude**
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 Mahendra showroom, Koradi road)	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	Pioli 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	
Sampling Points	**Site description**	**Latitude**	**Longitude**
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 3.16: River Water Quality: Physical and Inorganic Parameters

Sample name	**Parameters**				
	pH	**Temperature (°C)**	**Alkalinity ($CaCO_3$)**	**TDS**	**TSS**
NAG-1	8.6	25.4	180	281	29
NAG-2	8.3	22.4	200	358	21
NAG-3	7.8	21.3	260	398	481
NAG-4	7.7	22.7	278	396	600
NAG-5	7.7	24.1	310	424	83
NAG-6	7.7	24.6	286	422	770
NAG-7	7.7	24.6	320	429	73
NAG-8	7.6	25.6	296	436	91
NAG-9	7.6	23.8	310	450	588
PIILI - 1	7.9	19.6	520	320	4
PIILI – 2	8.0	23.9	620	438	114
PIILI – 3	7.9	26.1	880	430	80
PIILI – 4	7.6	25.7	860	481	97
PIILI – 5	7.9	26.7	700	477	1157
PIILI – 6	7.7	25.4	6000	488	272
PIILI – 7	7.4	26.2	720	494	186
PIILI – 8	7.8	25.8	620	502	201
PORA- 1	8.6	25.3	1100	546	37

PORA -2	7.8	25.8	800	502	356
PORA - 3	8.2	25.4	1080	534	1304
PORA - 4	7.2	24.6	1260	546	2153

**All parameters are in mg/L except pH & temperature.*

Table 3.17: River Water Quality: Organic and Nutrient Parameters

Sample name	Parameters				
	DO	COD	BOD	Phosphate (P)	TKN
NAG-1	9.86	86	17	0.5	7
NAG-2	6.05	62	12	0.6	6
NAG-3	2.35	1400	45	3.9	39
NAG-4	1.61	1880	315	4.5	47
NAG-5	0.72	236	62	2.8	32
NAG-6	0.67	222	57	2.5	28
NAG-7	0.92	240	50	2.5	29
NAG-8	0.68	162	35	2.5	27
NAG-9	1.01	1420	25	11.3	52
PIILI - 1	4.57	20	3	1.6	6
PIILI – 2	1.29	232	32	5.1	28
PIILI – 3	0.88	248	33	4.6	29
PIILI – 4	0.51	344	52	5.0	28
PIILI – 5	0.78	640	117	8.2	57
PIILI – 6	0.99	840	150	3.5	26
PIILI – 7	2.14	280	44	4.9	28
PIILI – 8	1.89	400	56	4.6	29
PORA- 1	8.6	76	17	2.3	16
PORA -2	7.8	400	69	3.5	30
PORA -3	8.2	900	255	6.4	54
PORA -4	7.2	380	94	6.2	43

**All parameters are in mg/L*

Table 3.18: River water Quality: Bacteriological data

Sr. No.	Sample Code	CFU/100mL (Dilution Factor –10^6)		
		EC (E. coli)	FC (Fecal coliforms)	TC (Total Coliforms)
1	NR-1	38	48	212
2	NR-3	41	59	272
3	NR-4	40	52	312
4	NR-5	22	33	356
5	NR-6	21	41	388
6	NR-7	32	42	424
7	NR-8	21	26	384
8	NR-9	12	17	404
9	NR-11	18	23	216
10	PR-1	24	30	37
11	PR-2&3	37	41	52
12	PR-4	2	13	24
13	PR-5	25	26	32
14	PR-6	16	21	40
15	PR-7	3	36	35
16	PR-8	3	35	42
17	PR-9	3	18	30
18	P-1	6	14	41
19	P-2	8	22	84
20	P-3	13	31	148
21	P-4	9	21	112

**River Samples: Nag (NR), Pili (PR) &Pora (P)*

3.7 Ground Water Quality:

3.7.1 Physico-Chemical

The data from the Central Groundwater Board (CGWB), Nagpur, estimates that the ground water availability in Nagpur is above 25 MCM per year. The depth of ground water varies from 1.65-1.95m in the central part of the city and extends up to 16 m in the peripheral areas. Ground water 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 outskirts of the city, it is essential to make provisions for exploiting the ground water reserves.

The ground water samples were collected from 19 locations (Fig 3.14). Location details are given in Table 3.20. The ground water samples were analyzed for physic-o-chemical parameters, metals and bacteriological parameters and the results are presented in Tables 3.21, 3.22 and 3.23. All 19 ground water samples collected were observed to be clear and did not have any objectionable odor. The pH of ground water samples was found to be ranging from 7.1 to 7.8 and these values were within the desirable range for Drinking water: 6.5 to 8.5 as prescribed by the BIS10500:2012.

Eight of the 19 samples were found to have dissolved solids exceeding the desirable value as per the BIS standards, however, well below the permissible limit of 2000 mg/L. Almost 15 samples were observed to have total alkalinity above the desirable concentrations of 200 mg/L. Magnesium was found to be exceeding marginally in eight samples above desirable concentrations, however, well below the permissible limit of 100 mg/L. Phosphates were found to range between 0.1 and 0.9mg/L Twelve of the ground water samples were found to have total hardness exceeding the desirable value of 200 mg/L. Other parameters were found to be well within the desirable limits of BIS10500:2012.

The metal contamination in ground water samples were not found significant when compared with drinking water standards BIS 10500:2012. The Fe concentration was found in the range of 0.005-0.2mg/L, while Mn concentration was found in the range of 0.004-0.09 mg/L.

3.7.2 Bacteriological

Out of the analyzed ground water samples, 14 had the load of total coliform and 13 have the load of Faecal coliform ranging from 0.0 to $16x10^2$CFU/100mL and 0.0to $2x10^2$CFU/100mL.

The overall quality of ground water samples was observed to be good in terms of physio-chemical characteristics but was found to be contaminated with coliforms and requires proper treatment before consumption. Significant number of total coliforms (TC) and thermotolerant coliforms (fecal coliforms-FC) were found in ground water samples as is evident from Table 3.23.

Figure 3.7: Ambazari Lake

Figure 3.8: Gandhisagar Lake

Figure 3.9: Sakkardara Lake

Figure 3.10: Futala Lake

Figure 3.11: Sonegaon Lake

Figure3.12: Naik Lake

Fig 3.13: Sampling Locations of Futala Lake

Table 3.19 Sampling Locations for of Ground Water Assessment

Sr. No.	Sample Code	Sample Details / Location details	Sources	Latitude	Longitude
1	HP-1	Playground Near Wankhede Madam Academy Aathrastachowk, Laxmi Nagar	HAND PUMP	21˚07′26″	79˚03′54″
2	HP -2	Shankar Nagar Garden Main Road, Shankar Nagar	HAND PUMP	21˚08′02″	79˚03′40″
3	HP -3	Maratoli Shiv Mandir, Ram Nagar	HAND PUMP	21˚08′42″	79˚03′18″
4	HP -4	Janta Road Line, Control Wadi, Opposite Well Treat Hospital, Wadi	HAND PUMP	21˚09′10″	79˚00′30″
5	HP -5	Dr. Ambedkar Statue,Sanjay Nagar near Rahul BorkarHouse, HINGNA T-Point	HAND PUMP	21˚07′03″	79˚00′54″
7	HP -7	OPP. Yashoda High school near Ganpati Temple, Saoji Point Hotel Trimurti Nagar, Shahane Layout	HAND PUMP	21˚06′39″	79˚ 02′22″
8	HP -8	Near Apex Physiotherapy Center, Mahadev Temple, Manish Nagar	HAND PUMP	21˚05′49″	79˚04′23″

Contd..

Sr. No.	Sample Code	Sample Details / Location details	Sources	Latitude	Longitude
9	HP -9	Veer Hanuman Temple, Ujawal Society, Narendra Nagar	HAND PUMP	21˚06′28″	79˚ 04′42″
10	HP -10	Behind Yashwant stadium Slum area, Dhantoli	HAND PUMP	21˚08′23″	79˚04′54″
11	BW-11	Near kasbhaGarden, House of Mr. Krushnarao Parteki, SADAR	BORE WELL	21˚09′43″	79˚04′32″
12	HP-12	Near St. JosephPublic School, Mohan Nagar	HAND PUMP	21˚09′34″	79˚05′5″
13	BW-13	Mayo Hospital Campus Near Deendayal Bhojnalaya, Mayo Hospital	BORE WELL	21˚09′17″	79˚05′45″
14	HP-14	Near Masjeed, Chota Lohapur, Gandhibagh	HAND PUMP	21˚09′03″	79˚06′10″
15	BW-15	Near Omprakash Agrawal house, Wardhman Nagar	BORE WELL	21˚08′55″	79˚08′14″
16	HP-16	ChotaTajbagh, Gate on Right Hand side	HAND PUMP	21˚07′23″	79˚06′45″
17	HP-17	Near Mr. Dipak Aadmane House plot no 442, Subhedar Layout	HAND PUMP	21˚6′35″	79˚06′48″
18	HP-18	Near Jhanvi Daily Needs Manewada Besa Road	HAND PUMP	21˚05′44″	79˚06′23″
19	HP-19	OPP Medical Stores Manewada Besa Road	HAND PUMP	21˚05′64″	79˚06′24″

NOTE: HP- Hand Pump; BW- Bore Well

Table 3.20: Water Quality of Ground Water – Physico-chemical Parameters

Sr. No	Sample Code	pH	EC	TDS	Turbidity	Total alkalinity	Total Hardness	Calcium Ca^{2+}	Magnesium Mg++	Sodium	Potassium as K^{+}	Phosphate PO_4^{-2}	Fluoride F^{-}	Nitrate NO_3^{-}	Sulphate	Chloride
	Unit		µS/cm	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BIS Limit		6.5-8.5	-	500-2000	1-5	200-600	200-600	75-200	30-100	-	-	-	1.0-1.5	45	200-400	250-1000
1	HP-1	7.5	580	348	10	240	175	40	18	60	2	0.6	0.9	1	22	40
2	HP -2	7.6	670	402	1.8	244	228	38	32	65	3	0.8	0.8	2	20	42
3	HP -3	7.3	700	420	11	296	258	48	33	85	5	0.9	0.9	6	35	50
4	HP -4	7.1	970	582	2.6	320	307	96	16	74	4	0.6	0.9	8	41	80
5	HP -5	7.4	1520	912	3	400	340	124	7.2	110	22	0.9	0.5	4	32	160
6	BW-6	7.5	450	270	1	140	162	52	7.7	15	8	0.4	0.7	11	25	40
7	HP -7	7.2	902	541	1	264	333	65	41	35	6	0.3	1.0	30	60	48

8	HP -8	7.3	790	474	2	220	95	18	12	110	0.5	0.2	0.9	2	48	50
9	HP -9	7.6	1126	676	2.0	320	352	49	55	96	0.7	0.1	0.9	3	98	60
10	HP -10	7.1	460	276	0.6	120	183	58	9	15	2	0.7	0.7	8	22	40
11	BW-11	7.8	380	228	0.9	200	177	49	13	42	3	0.9	0.6	2	26	40
12	HP-12	7.1	720	432	2	280	280	82	18	38	8	0.5	0.8	6	30	60
13	BW-13	7.4	300	180	0.9	88	110	29	9	10	1.9	0.6	0.8	3	26	32
14	HP-14	7.4	800	480	2	300	275	60	30	92	2	0.4	0.9	5	55	48
15	BW-15	7.5	1300	780	0.6	240	224	48	25	150	4	0.3	0.9	8	96	110
16	HP-16	7.1	800	480	2	280	318	64	38	74	6	0.2	0.8	6	45	60
17	HP-17	7.1	866	520	3	320	353	68	44	42	2	0.6	0.6	3	60	60
18	HP-18	7.3	1700	1020	4	300	558	80	86	88	1	0.8	0.9	33	66	160
19	HP-19	7.4	929	557	1	304	140	32	32	68	7	0.9	0.9	36	42	70

Table 3.21: Water Quality of Ground Water – 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 Detection Limit (ppm)		0.002	0.007	0.0001	0.01	0.0004	0.0003	0.0001	0.005	0.009	0.001
1	HP-1	0.01	BDL	BDL	BDL	0.002	0.1	0.06	BDL	BDL	0.08
2	HP -2	0.02	BDL	BDL	BDL	0.001	0.2	0.02	BDL	BDL	0.05
3	HP -3	0.01	BDL	BDL	BDL	0.003	0.1	0.09	BDL	BDL	0.03
4	HP -4	0.02	BDL	BDL	BDL	0.005	0.09	0.08	BDL	ND	0.02
5	HP -5	0.003	BDL	BDL	BDL	0.006	0.005	0.09	BDL	ND	0.008
6	BW-6	0.02	BDL	BDL	BDL	0.004	0.1	0.01	BDL	BDL	0.06
7	HP -7	0.01	BDL	BDL	BDL	0.003	0.05	0.006	BDL	BDL	0.09
8	HP -8	0.01	BDL	BDL	BDL	0.002	0.06	0.06	ND	BDL	0.06
9	HP -9	BDL	BDL	BDL	BDL	0.005	0.04	0.04	ND	BDL	0.6

10	HP -10	0.01	BDL	BDL	BDL	0.003	0.05	0.08	BDL	BDL	0.04
11	BW-11	0.02	BDL	BDL	BDL	0.003	0.06	0.004	ND	BDL	0.06
12	HP-12	0.01	BDL	BDL	BDL	0.005	0.06	0.03	BDL	ND	0.09
13	BW-13	0.01	BDL	BDL	BDL	0.004	0.06	0.004	BDL	BDL	0.09
14	HP-14	0.01	BDL	BDL	BDL	0.001	0.02	0.009	BDL	BDL	0.05
15	BW-15	0.02	BDL	BDL	BDL	0.003	0.04	0.004	BDL	BDL	0.8
16	HP-16	0.01	BDL	BDL	BDL	0.003	0.04	0.005	BDL	BDL	0.06
17	HP-17	0.01	BDL	BDL	BDL	0.01	0.03	0.04	BDL	BDL	2
18	HP-18	0.02	BDL	BDL	BDL	0.005	0.02	0.06	BDL	BDL	1.2
19	HP-19	0.005	BDL	BDL	BDL	0.005	0.05	0.08	BDL	BDL	0.06
15	BW-15	0.02	BDL	BDL	BDL	0.003	0.04	0.004	BDL	BDL	0.8

NOTE: -BDL- Below Detection Limit of ICP-OES; ND- Not Detected; All parameters are expressed in mg/L

Table 3.22: Ground Water Quality – Bacteriological Parameters

Serial No.	Sample Code	Total Coliform (CFU/100mL)	Thermotolerant Coliform (CFU/100mL)
1	HP-1	80	11
2	HP -2	10	5
3	HP -3	46	16
4	HP -4	160	35
5	HP -5	$16x10^2$	$2x10^2$
6	BW-6	2321	1215
7	HP -7	0	0
8	HP -8	0	0
9	HP -9	88	0
10	HP -10	521	410
11	BW-11	88	55
12	HP-12	0	0
13	BW-13	0	0
14	HP-14	522	222
15	BW-15	20	6
16	HP-16	78	33
17	HP-17	56	6
18	HP-18	66	5
19	HP-19	0	0

NOTE: HP- Hand Pump; BW- Bore WelL

3.8 Aquifer Mapping for Nagpur city, Maharashtra

3.8.1 Introduction:

Nagpur city is covered by the Nagpur District. Groundwater exploration has been carried out by Central Groundwater Board and the GSDA over the last 40 years as part of their Annual Action Program. Accordingly, Nagpur (Urban) and Nagpur (Rural) have been covered and

exploratory wells have been set up.

The climate of the district is characterized by a hot summer and general dryness throughout the year except during the south-west monsoon season, i.e., June to September.

The normal annual rainfall of the city is approximately 1018 mm (Source: agri.mah.nic.in) which suggests that the area receives good amount of rainfall.

3.8.2. Hydrogeology

The important water bearing formations are the consolidated formations and are as follows:

3.8.2.1 Consolidated Formations

Archeans and the Deccan trap basalts are the two consolidated formations and the groundwater occurrences are in these formations.

3.8.2.1.1. Archaean

The crystalline rocks comprising of gneiss, schist, pegmatite and quartzite are the main formations. They occur mostly in the region adjoining Pardi in the North east of the city. In these rocks, weathered zone which is down to a depth of 25 mbgl, forms the important shallow aquifer for dug wells. In untethered crystalline rocks, the occurrence of ground water is mainly controlled by joints and fractures. Higher groundwater yields are generally associated with lineaments. Ground water at places occurs in fractured zones at depth in semi-confined to confined conditions at greater depth.

3.8.2.1.2 Deccan Traps

Ground water occurs under phreatic conditions in the exposed lava flows and in semi-confined to confined state in the subsurface flows. Ground water is present in pore spaces in the vesicular unit of each flow and in the jointed and fractured portions of massive unit. However, secondary porosity and permeability developed on account of weathering, fracturing and joints play a very important role in the storage and movement of ground water. This has given rise to good aquifers. Weathering not only produces granular materials but also widens the fractures, joint and shear zones.

3.8.2.2 Aquifer Parameters

The transmissivity of Deccan Traps varies between 0.67 and 248 m^2/day (cgwb.gov.in) while the storage coefficient varies from $5.51x10^{-5}$ to $2.95x10^{-3}$. In Archean gneisses, transmissivity varies from 49.18 to 279.13 m^2/day (BothiaPalora) and storage coefficient varies from $4.12x10^{-4}$ to $8.9x10^{-4}$.

3.8.2.2.1 Groundwater Level

Trend of groundwater level fluctuation in city is recorded as 6.05 mbgl and 5.2 mbgl for pre-monsoon and post-monsoon respectively during 2001-2010 with marginal rising trend of 0.004 m/year. (CGWB, 2013). Piezo meters set up by the NEERI in its premises (Figure 3.14) indicates that the groundwater level was 1.5m in March 2020.

The city's central areas such as Civil lines, HajariPahad, Sadar has very shallow aquifer with less than 2 mbgl water level in the both seasons. Whereas, the peripheral areas (Airport, Airport, Chinchbhuvan), Pardi Naka, Kalmana, Reshim bag Tulibag) of the city has deeper water level (> 6 mbgl). Major part of the city comes under below 4 mbgl water level zone (Parchure, 2011)

3.8.2.3 Groundwater Resource Assessment

Groundwater resource availability in the Nagpur (Urban), Nagpur (Rural) and Hingna Taluka has been carried out on the basis of GEC (1997) norms. The Groundwater stage development is estimated. The groundwater stage development refers to the ratio percentage of amount of water used (domestic/industrial/agriculture) with respect to the Amount of available water. It is observed that the stage development in Nagpur (City), Nagpur (Rural) and Hingna is 31.19 and 29.37 respectively. Hence, the stage development is within the safe limit i.e. <70% (Table 3.24) and there is still scope for further development of groundwater resource.

Figure 3.14: Water level measurement in Piezometer in NEERI

Table 3.23: Stage development criteria (GEC-1997)

Groundwater Stage Development	Category
<70%	Safe
>70% but <90%	Semi-critical
>90%	Critical
>100%	Overexploited

3.8.2.4 Groundwater Quality

Groundwater quality monitoring is being carried out by the Central Groundwater board as part of their Annual Action program. As per the study carried out by CGWB from their network of 36 observation wells in the district which provide the water quality in the district. However, detailed studies carried out by CSIR-NEERI (NEERI report 2005) and Pujari et al. (2007) indicate significant increase in nitrate in groundwater in the vicinity of On-site sanitation systems and Landfill site respectively. Pujari et al. (2007) reported elevated Nitrate concentration ranges from 30 mg/l to 500 mg/l. Nitrate concentration total 8 samples out of 11 samples exceeds beyond permissible limit. In groundwater samples (Hand pumps) close to the landfill site at Bhandewadi. This remains a concern since the hand pumps are used by the population in the area adjoin the landfill site at Bhandewadi.

3.8.3. Aquifer Disposition

There are very few drilling data available for Nagpur city in the public domain. Aquifer disposition in the Narkhed and Katol area carried out in the National Aquifer Mapping programme (NAQUIM). However, it does not cover the NMC city area. Besides, drilling data on lithology for the city area was not available in public domain. An attempt is made in the present study to undertake Geophysical sounding by Electrical Resistivity Tomography to construct the aquifer disposition in the Nagpur city. It needs to be mentioned that Geophysical sounding, especially Resistivity Imaging in urban environment is always a challenging task considering that sufficient open space is often not available to get a straight and long profile which can provide depth information up to say 100-150m depth. However, ERT survey is attempted at different locations in the study area (Table 3.25, Figure 3.15). The ERT survey is carried out using Terrameter LS system (Figure 3.16). The data acquisition was done by Schlumberger configuration (Telford et al. 1976). It was ensured that the contact resistance was maintained below 1000 ohm during the data acquisition. The data collected were inverted using the Res2DInv software (Loke, 1999). The Root mean square error (RMS) was maintained 5% for convergence.

Table 3.24: ERT Profiles with locations in the study area

Sr.No	Profile code	Latitude	Longitude	Description
1	NERT-1	21°09'14"N	79°04'56"E	Kasturchad Park
2	NERT-2	21°07'02.3"N	79°01'53.1" E	Sunday Market, Trimurti Nagar
3	NERT-3	21°07'26.4"N	79°09'6.1"E	Shivchatrapati Nagar, Kharabi
4	NERT-4	21°12'26.3"N	79°6'1.3"E	Shri Taj Traders
5	NERT-5	21°10'40.85"N	79° 5'0.63"E	NADT
6	NERT-6	21°04'21.9"N	79°04'7"E	South of Jayanti Nagari

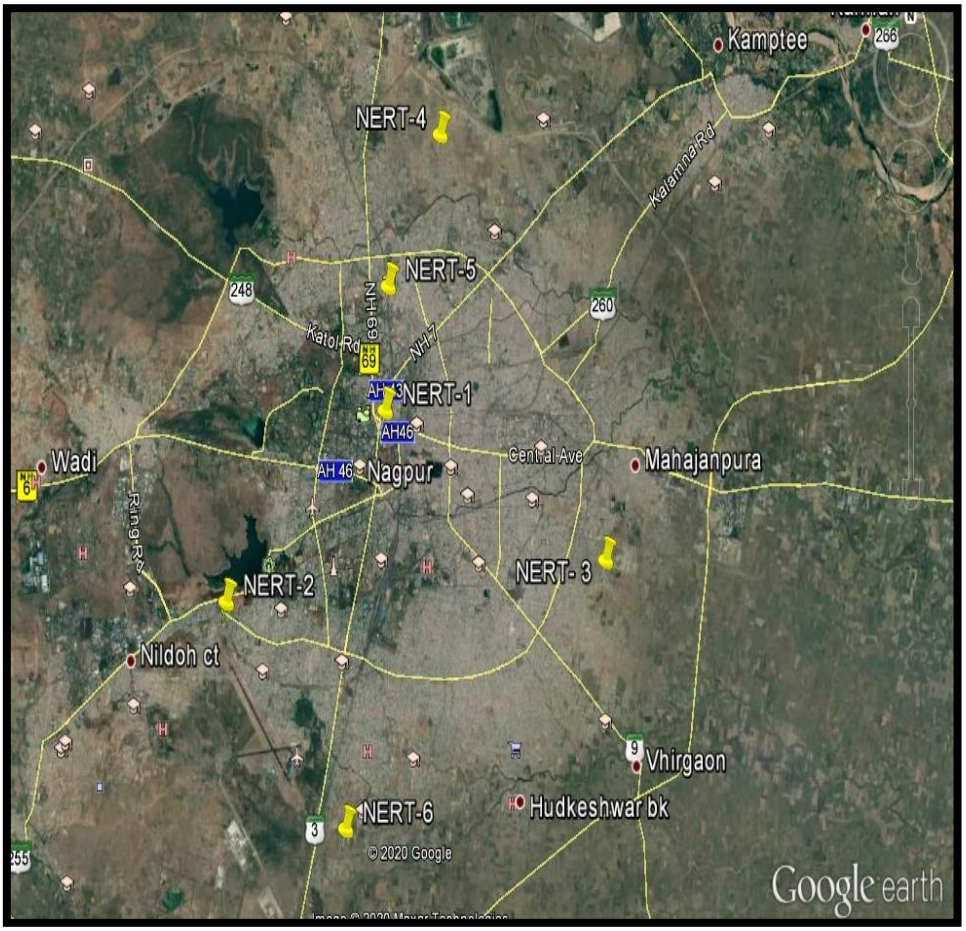


Figure 3.15: ERT locations in the Nagpur city






Figure 3.16: ERT survey at NADT, Shivchatrapati Nagar, Kharabi,behind Shri Taj Traders, Jayanti Nagari, Trimurti Nagar, Kasturchand Park54

NERT-1 (Figure 3.17) is carried out at Kasturchand Park. The survey profile length is about 200 m with 39 m penetration. A critical analysis of the resistivity section indicates that is a heterogeneous. The top layer resistivity varies from 5 ohm-m to 15 ohm-m approximately indicating black cotton soil /clayey soil. A patch of clays can be demarcated in the depth of 6 m to 19 m and horizontal length of 35 m to 55 m and 100 m to 110 m. Fractured basalts lay in between in these patches. This layer is underlain by a thick layer of weathered (< 20 ohm m) to formation and is extended up to 39 m depth. Three blocks of massive basalt (> 70 ohm m) can be seen at a depth of 12 m approximately.

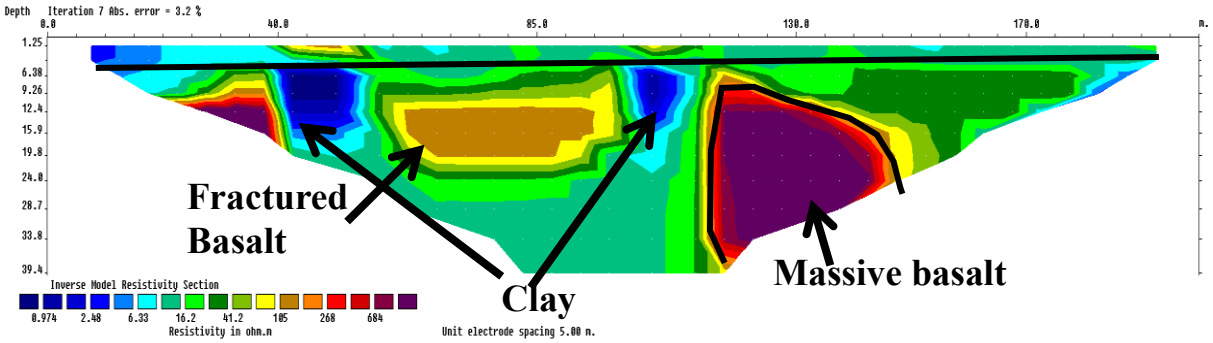


Figure 3.17: Inverted section of NERT-1

ERT-2 (Figure 3.18) was carried out at Trimurti Nagar. The survey profile I about 200 m long with 39 m penetration depth. The soil layer shows resistivity less than 15 ohm-m with thickness of 6 m. Low resistivity formations (may be clay) are present underlying the soil layer up to the depth of 24 m. – 28 m. Followed by fractured and weathered formations having thickness of 10 m to 12 m. The depth to the hard is about 28 m approximately.

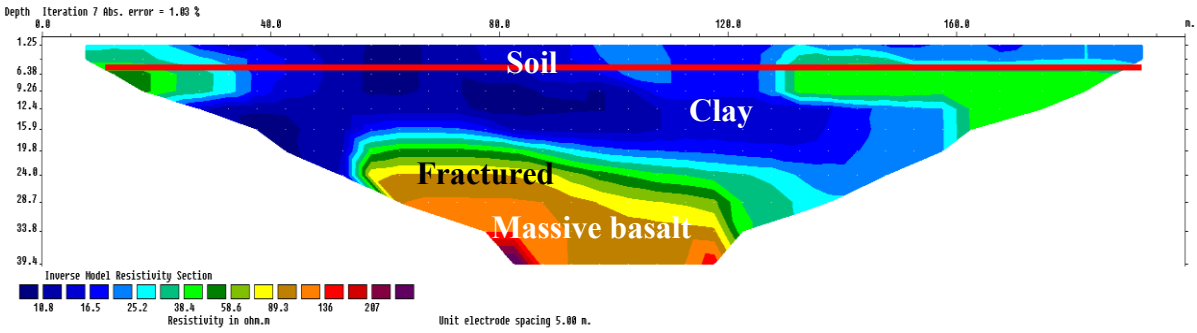


Figure 3.18: Inverted section of NERT-2

ERT-3 (Figure 3.19) was carried out at Shivchatrapati Nagar, Kharabi. The profile length was 200 m long with 39 m penetration depth. The topsoil material shows very conductive nature (< 15 ohm-m), which can be attributed to presence of clayey soil. Followed by, conductive layer (< 3 Ohm-m) which indicates presence of clay. Underlying this layer, weathered and fractured basalt can be seen from the depth of 10 m to 39 m.

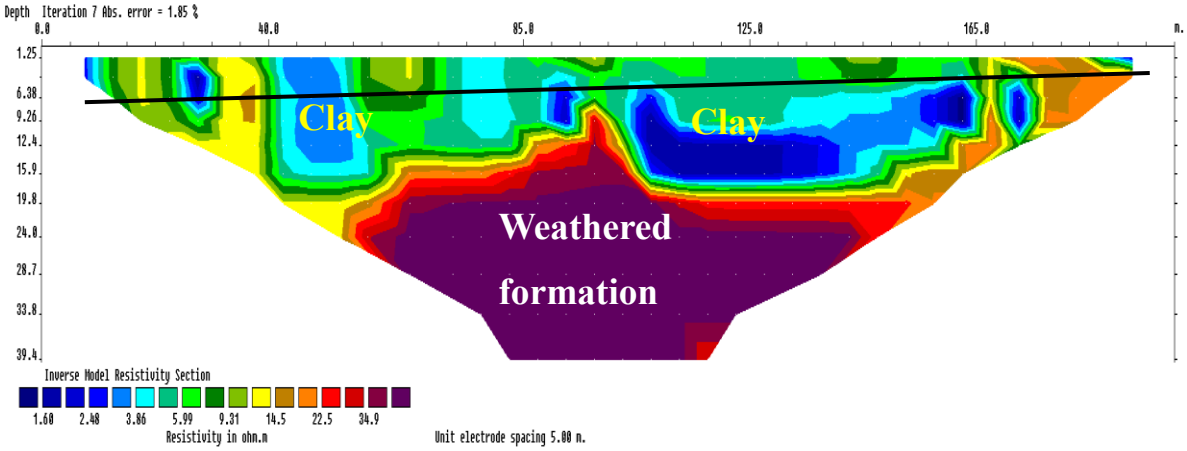


Figure 3.19: Inverted section of NERT-3

NERT-4 (Figure 3.20) is carried out at near to Shree Taj Traders. The survey profile length is about 400 m with 78 m penetration. A critical analysis of the resistivity section indicates that. The top layer resistivity shows from 5 ohm-m to 10 ohm-m approximately indicating clayey soil. A patch of massive rock can be demarcated in the depth of 20m to 78m and horizontal length of 220 m to 400 m. Below the soil layer clay formation are present up to the depth of 39 m. Underlay the clay layer weathered zone exists.

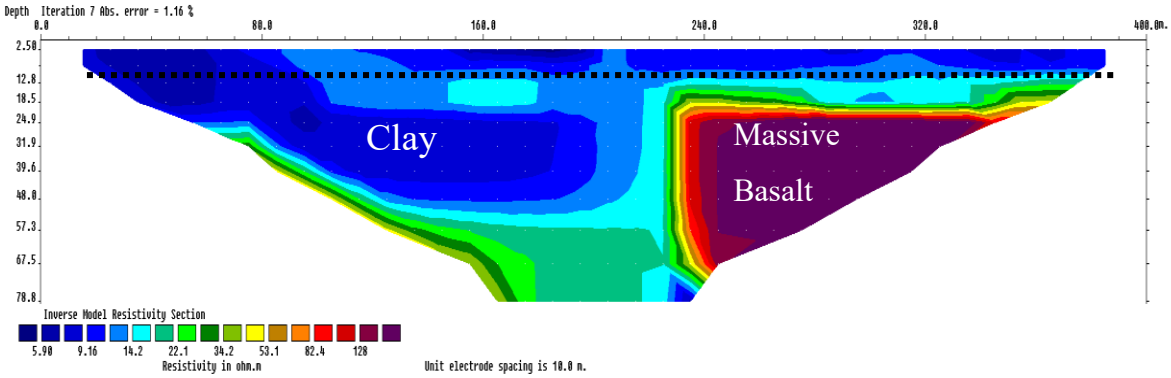


Figure 3.20: Inverted section of NERT-4

NERT-5 (Figure 3.21) is carried out at National Academy of Direct Taxes. The survey profile length is about 280 m with 55 m penetration. A critical analysis of the resistivity section indicates that the top layer resistivity shows from 5 ohm-m to 11 ohm-m approximately attributing clayey soil. Followed by fractured and weathered a formation which has thickness of 13 m to 55 m.

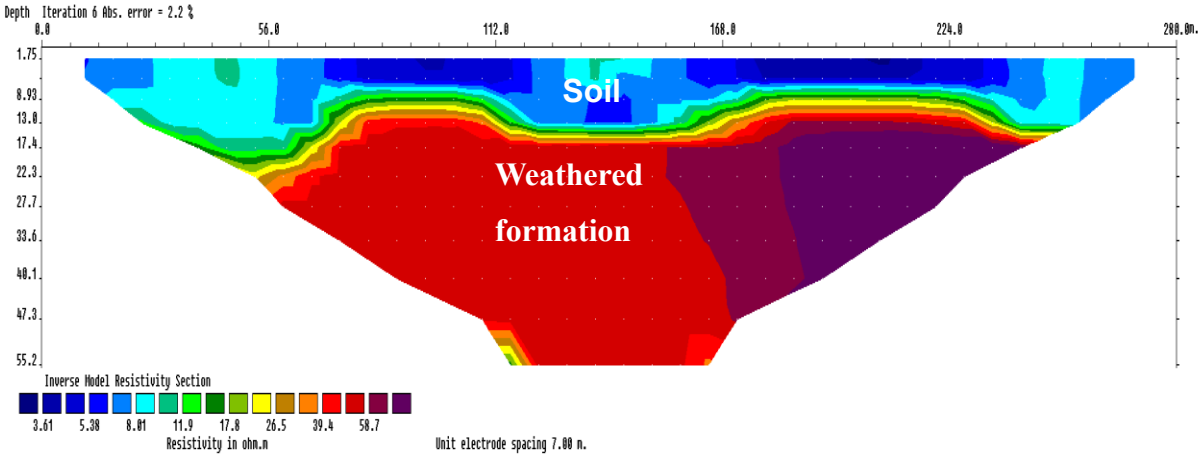


Figure 3.21: Inverted section of NERT-5

NERT-6 (Figure 3.22) is carried out at near south of Jayanti Nagari-3. The survey profile length is about 200 m with 39 m penetration. A critical analysis of the resistivity section indicates that the top layer resistivity is 6 ohm-m attributing clayey soil with thickness of 9 m to 10 m. Weathered layer has thickness of 4 m to 5 m. A patch of massive rock can be demarcated in the depth of 12 m.

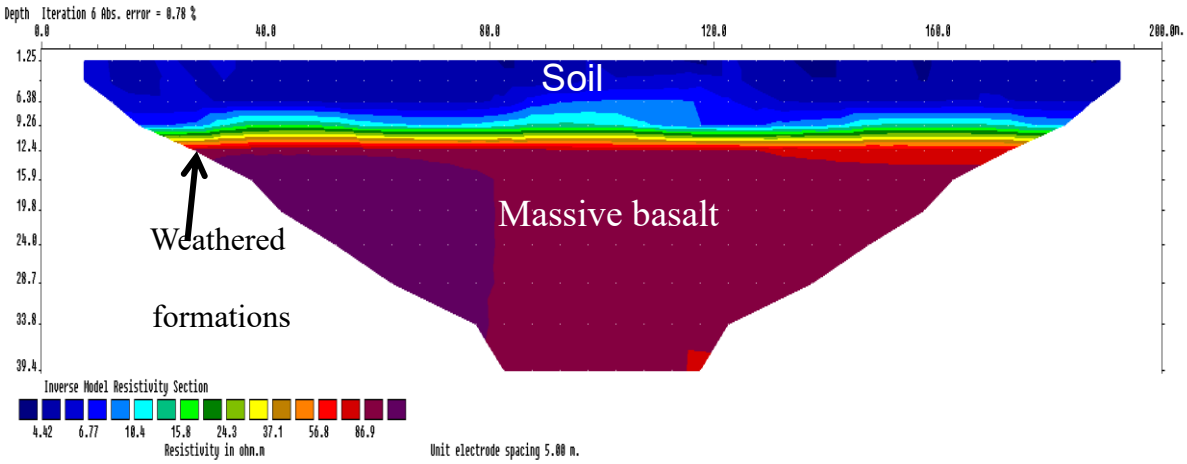


Figure 3.22: Inverted section of NERT-6

Based on the ERT soundings, the Geoelectrical layers can be categorized into the following.

Layer 1: Soil and weathered formations

Layer 2: Fractured formations

Layer 3: Compact rocks

The sub-surface at different locations is accordingly interpreted (Table 3.26).

Table 3.25: Thickness of different layers

ERT Code	Thickness of soil and weathered formation (Layer 1)	Thickness of fractured formations	Thickness of compact formations
NERT1	5m	34m	Small patch is observed
NERT2	26m	9m	Small patch is observed
NERT3	6m	33m	Small patch is observed
NERT4	10m	57m	Small patch is observed
NERT5	15m	40m	Not
NERT6	9m	3m	27m

3.9 Water Environment Conclusions

3.9.1 Surface and Ground Water Quality

- Nagpur has a live water stock of 69.98% in summer 2020 as a result of excess rainfall last year (2019).
- The citizens of Nagpur faced severe water scarcity from March to July 2019 and drinking water cuts were imposed from June to August 2019.
- Bacteriological testing of water supply at the point of use sources shows that 96 -97% samples were fit for drinking as per the criteria of Indian Drinking water standards (IS-10500-2012). This results are for the period April 2019- March 2020 as per Orange City Water Works , the agency responsible for water supply to Nagpur city
- Out of 520 MLD sewage generated, 345.3**.** MLD is treated with a gap of 288.1 MLD .4 STPs with an additional total capacity of 207 MLD proposed to meet the gap in sewage

treatment. The treated sewage from Bhandewadi (130 MLD) is being reused by MAHAGENCO for power generation.

- The water quality of Gandhisagar, Sonegaon, Ambazari, Sakkardara ,Futala and Naik lakes were also monitored by CSIR-NEERI. The COD concentration was found in the range 25-140 mg/L in Gandhisagar, Sakkardara, Sonegaon ,Ambazari and Naik lakes indicating high pollution levels of the lake waters. The nutrient concentration in terms of Phosphate was also found high in the lake waters which may cause eutrophication of the lakes (**Fig 3.23**).

Benthic Environment

- The Saprobic Index exhibits the water quality of the lake. Based on observation of all lakes the Sonegaon lake showing Slight pollution while other three lakes Gandhisagar Lake and Ambazari Lake and Sakkardara Lake showing moderate pollution. It proves that the Saprobicity of Sakkardara, Gandhi Sagar, and Ambazari Lake is higher than the remaining two lakes. The maximum diversity in Gandhi Sagar lake indicates that it supports the growth of various species instead of being at the central place in the city.

The lake which is having more macroplankton showing more no of macro zoobenthos as most of them sustain on plant life. According to the pollution level of lake the water quality indicating the colour of water as Moderate Polluted water showing green in colour while the Slight Polluted water showing Light blue in colour.

Metagenomic study of lakes (Gorewada and Gandhisagar) of Nagpur city

Metagenomic study of two lakes of Nagpur city (Gorewada and Gandhisagar) was performed, as metagenomes provides the ability to unlock the BlackBox of microbial ecosystems. The present molecular study have identified diverse bacteria existing in two lakes and variation with respect to taxonomic abundance.

It was observed that both the lakes (Gorewada and Gandhisagar) harbors rich microbial diversity and have complex resistome profiles. Metagenomic analysis revealed following status of two lakes;

- Metagenomic study enabled to conclude about the richness of metabolically active bacteria existing in Gorewada lake.
- In Gorewada lake, Nocardiaceae family bacteria were abundant (upto 5000 level range), whereas no similar genera distributions were observed in Gandhisagar lake (Fig 4.3).

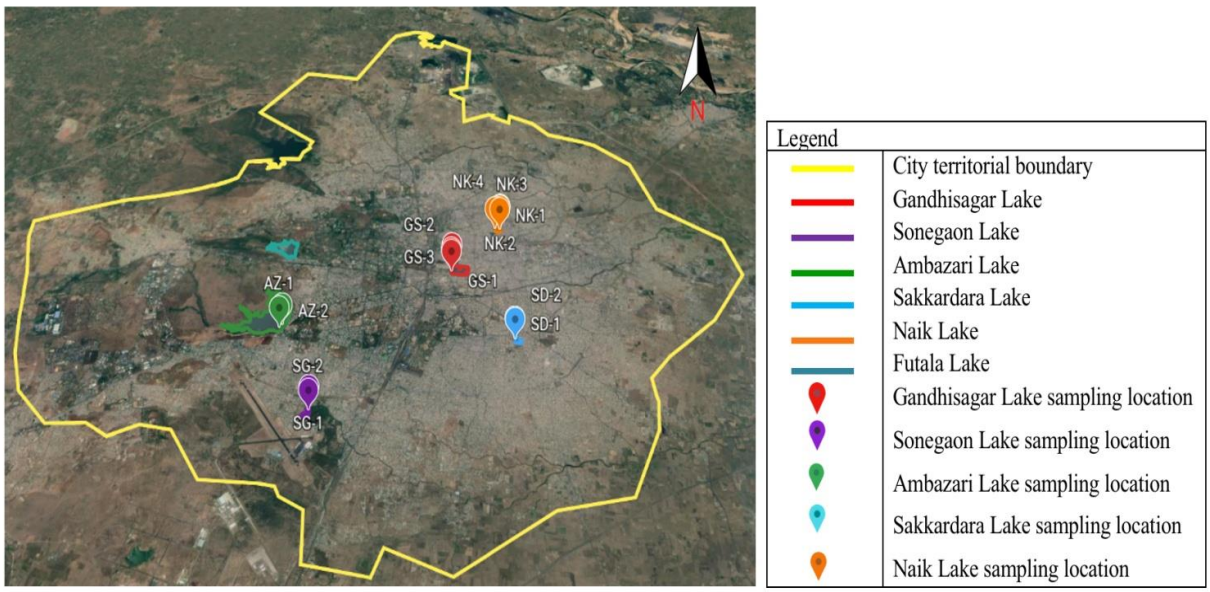
Presence of Nocardiaceas indicates the richness for antimicrobial bioactive compound producers in Gorewada lake (Fig 3.2).

- Relative high abundance of Archaea was found inhabiting sediments of Gandhisagar lake (2.2%), indicating presence of more anoxic conditions and eutrophication in Gandhisagar lake than Gorewada lake (Table 3.14).
- The study on metagenomics endorses the use of Gorewada water for drinking water supply to Nagpur city, in addition to water quality parameters,
- Nowadays the major public concern is towards the presence of antibiotic resistant genes in water bodies or lakes (also revealed from resistome profiles of Gorewada and Gandhisagar lakes). These habitats may serve as a hotspot for exchange of resistant genes (Yadav & Kapley, 2019, Guo et al., 2017). With the current trends of rise in antibiotic resistance, the "post-antibiotic era" will soon become a reality of the 21st century. A multifaceted global approach is required to combat antibiotic resistance. World Health Organization (WHO) had expressed its concern over AMR stating ''No action today means no cure tomorrow''. Therefore, the WHO had proposed a "global action plan (GAP)" to combat antimicrobial resistance. (WHO, 2014; WHO, 2017). BRIC countries are being considered as an epicenter for antimicrobial resistance. India has already adopted "GAP" to fight the epidemic of antimicrobial resistance (AMR).
- The three rivers namely Nag Pilli and Pora were sampled and physicochemical characterization was performed. According to the characteristics the summary or the results and CPCB classification is given in Figures 3.24 to 3.27.

Ground water quality and Aquifer Mapping

- The ground water samples were collected from 19 representative locations and their physicochemical characterization was performed. The samples were compared to IS: 10500 (2012) and found that the sources have bacteriological contamination and hence, are unfit for drinking (Figure 3.28).
- The groundwater development in the city is very low and there is scope for further development of the groundwater in the city. Top weathered and fractured formations up to 30m can be developed for shallow wells. This will be useful in the critical summer period when the supply from the surface water is substantially reduced.
- The groundwater level is also found to be very shallow in the city and it does not reflect large scale ground withdrawal as of now.

- The Geophysical sounding indicates that there are low resistivity
- formations indicative of weathered and fractured formations which are
- typically associated with the top phreatic aquifer.
- In view of the limited space available for the profile, the depth of information was restricted and it varied from 35 m-78 m. This could not provide details about the deeper aquifers (at depth >100 m depth).
- In view of the growing construction activities in the city which lead to use of groundwater, it is necessary that the NMC need to set up Piezo metres (at least 250 m depth) at zones witnessing growth and monitor the water level on a monthly basis. This will facilitate long term analysis and take corrective steps if required as far as groundwater development is concerned.



Parameters	GS Lake (GS1 – GS3)	Sonegaon Lake (SG1 – SG2)	Ambazari Lake (AZ1 – AZ2)	Sakkardara Lake (SD1 – SD2)	Naik Lake (NK1 – NK3)	Futala Lake (S1 – S20)
pH	7.1 – 7.5	7.8 – 8	6.9 – 7.5	7.1 – 7.5	7.6 – 8.0	7.9 – 7.1
Alkalinity (mg/L)	264 – 286	168 – 172	120 – 144	300 – 320	360 – 420	220 – 324
TDS (mg/L)		327 – 399	246 – 300	510 – 534	581–	327 – 399
Turbidity (NTU)	408 – 773	20 – 31	22 – 26	7.9 – 10	2040 5 – 100	1 – 10
COD(mg/L)	18 – 45	26 – 30	32 – 35	25 – 70		16 – 40
BOD (mg/L)		16 – 22	4.6 – 4.8	5 – 8	100 – 140	6 – 20
PO_4^3 (mg/L)	50 – 120	0.4	0.5 – 0.6	0.5	50 – 80	3 – 9
CPCB Class	18 – 36 0.2 – 0.6 D	D	C	D	1.3 – 2.5 E	D

Figure 3.23: An insight: Geographical location and Physico-chemical characteristics of the studied Lakes of Nagpur city

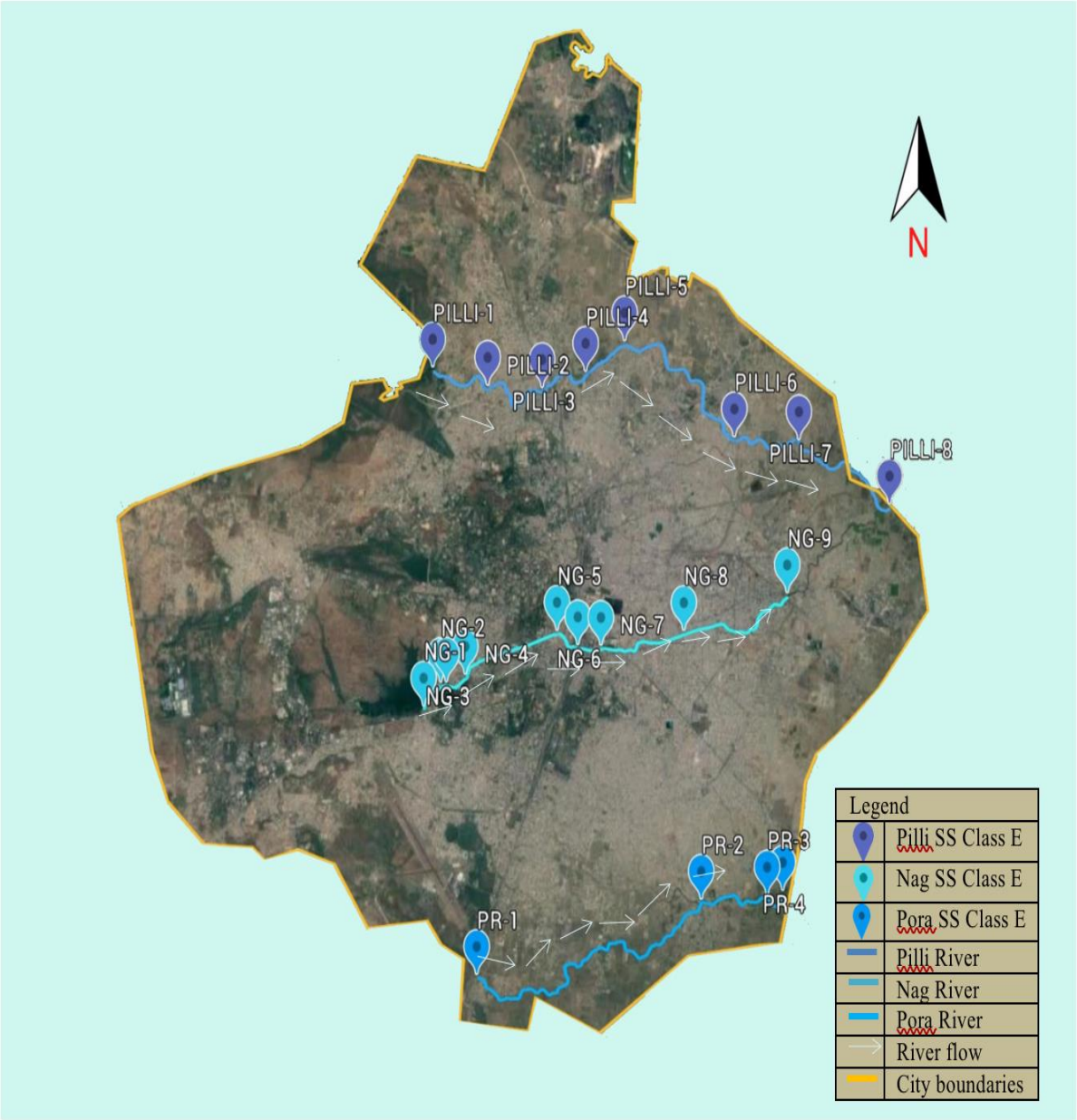


Figure 3.24: Geographical location of sampling sites and classification based on CPCB guidelines

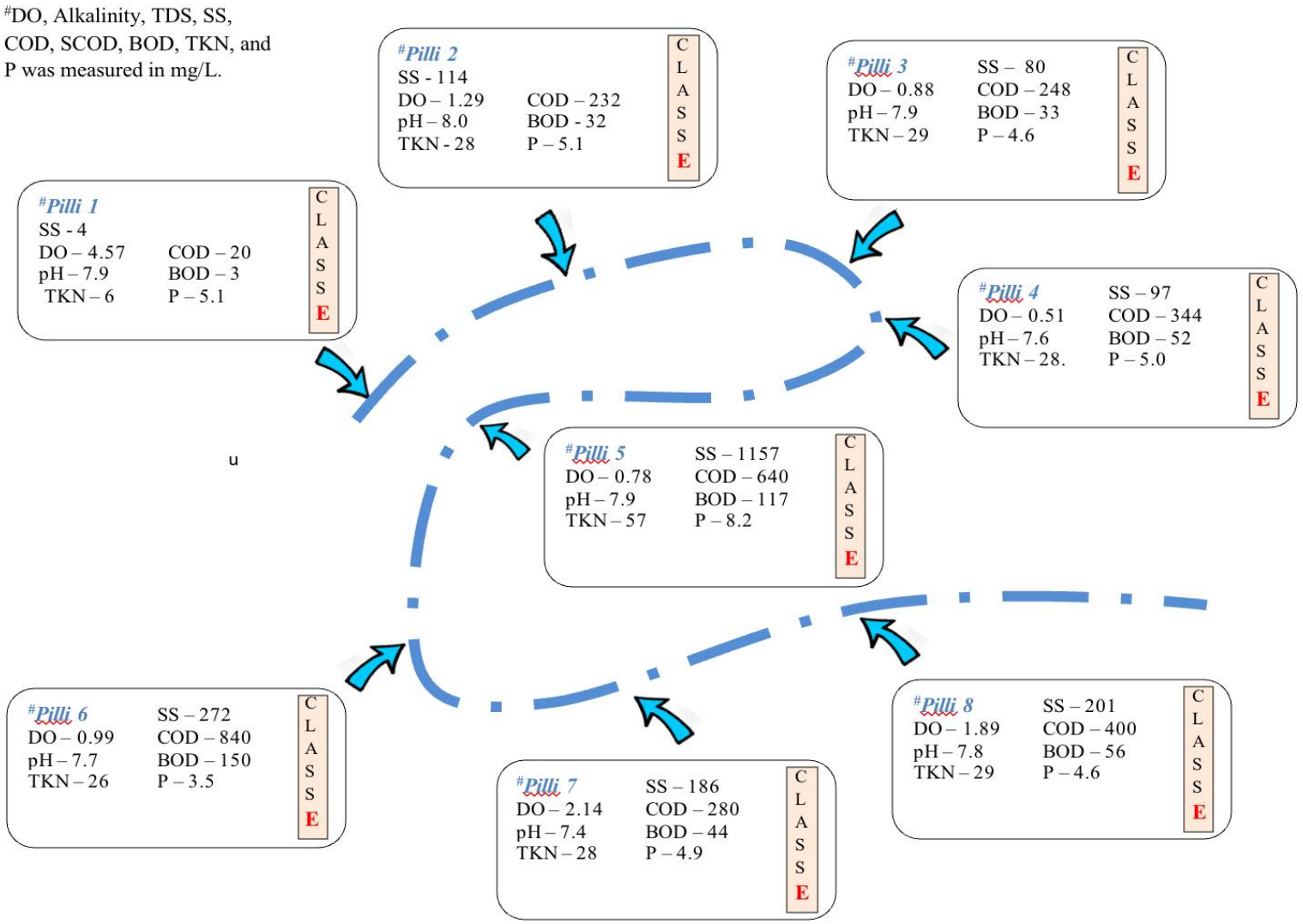


Figure 3.25: Physico- chemical characteristics of Pilli River

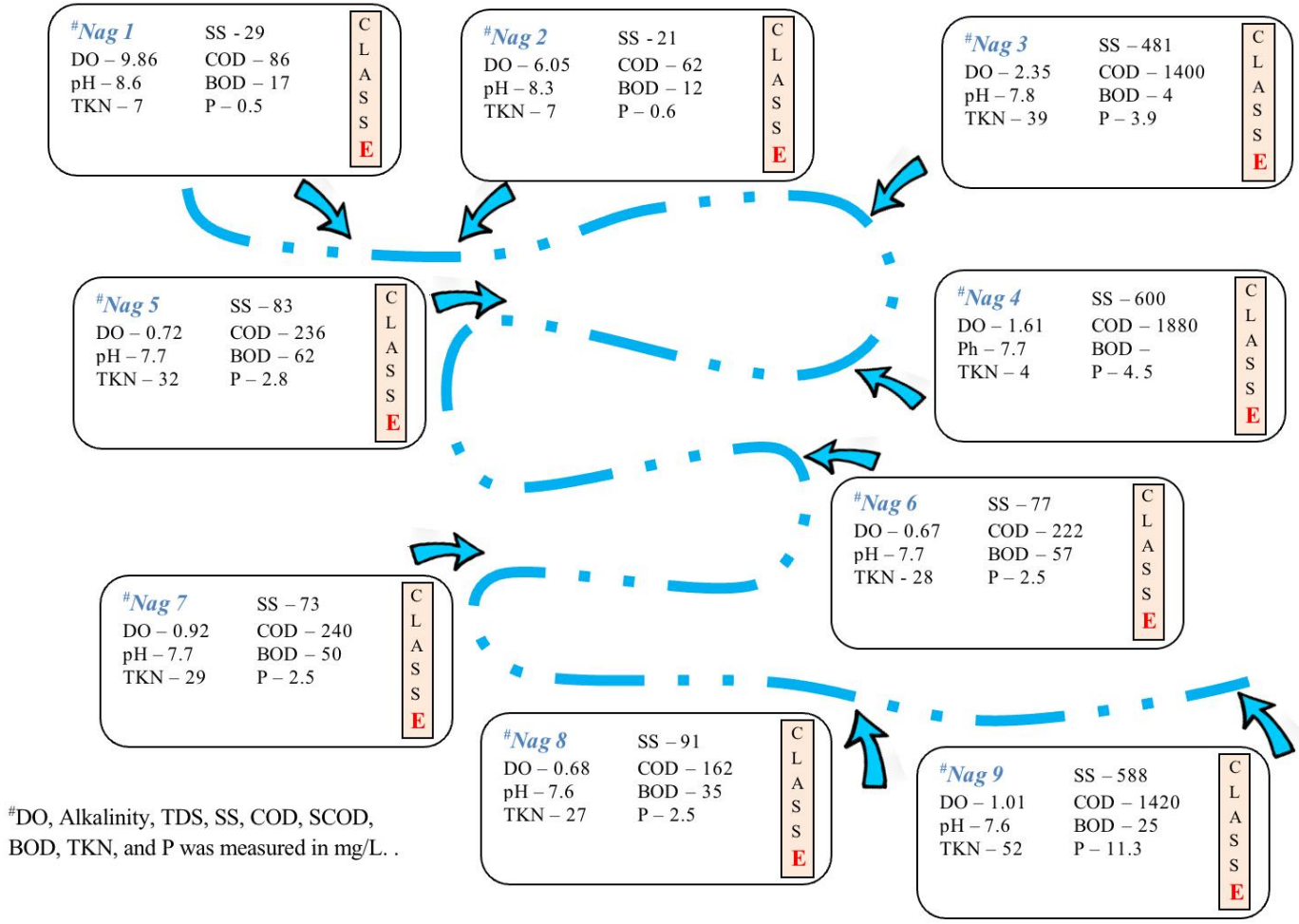
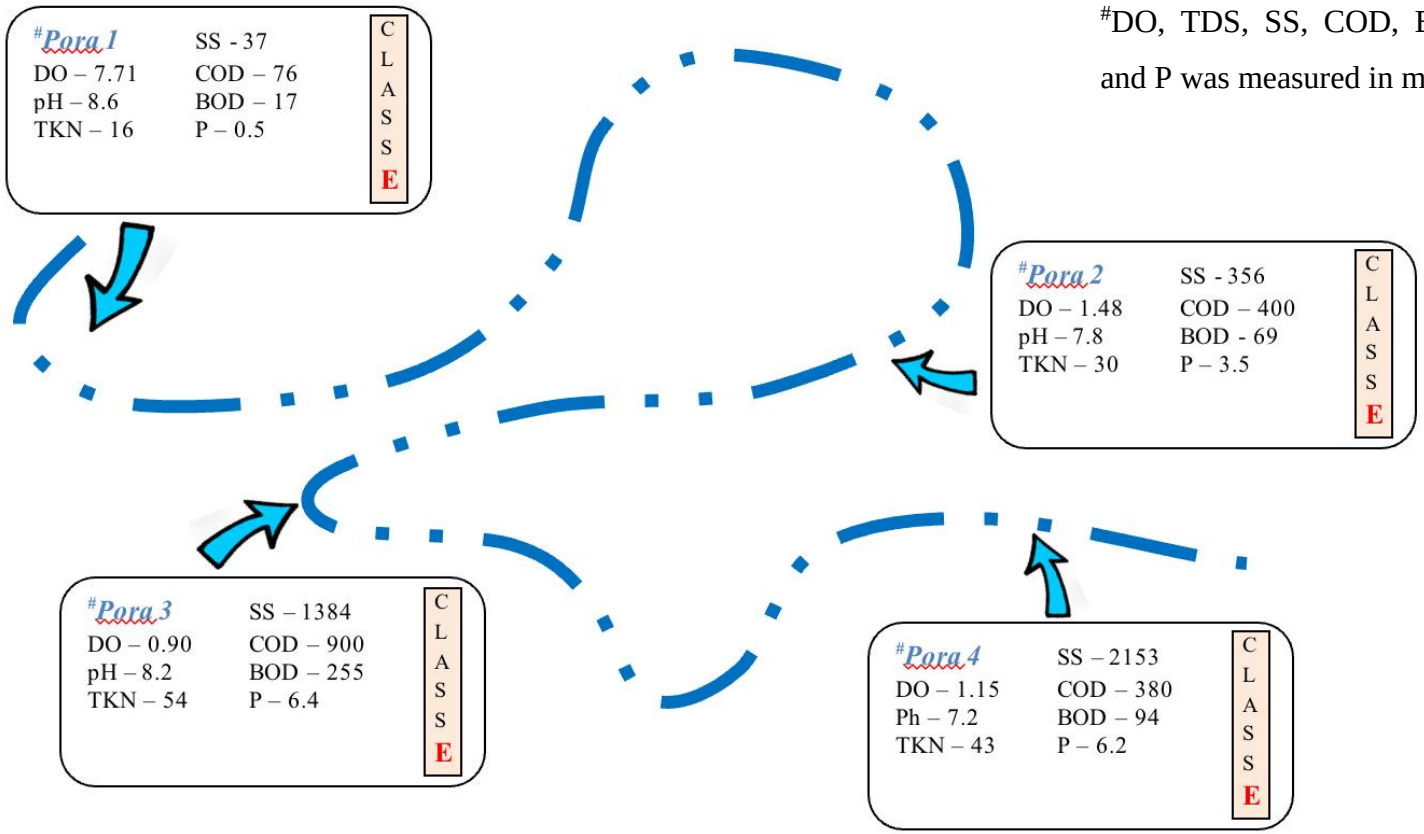
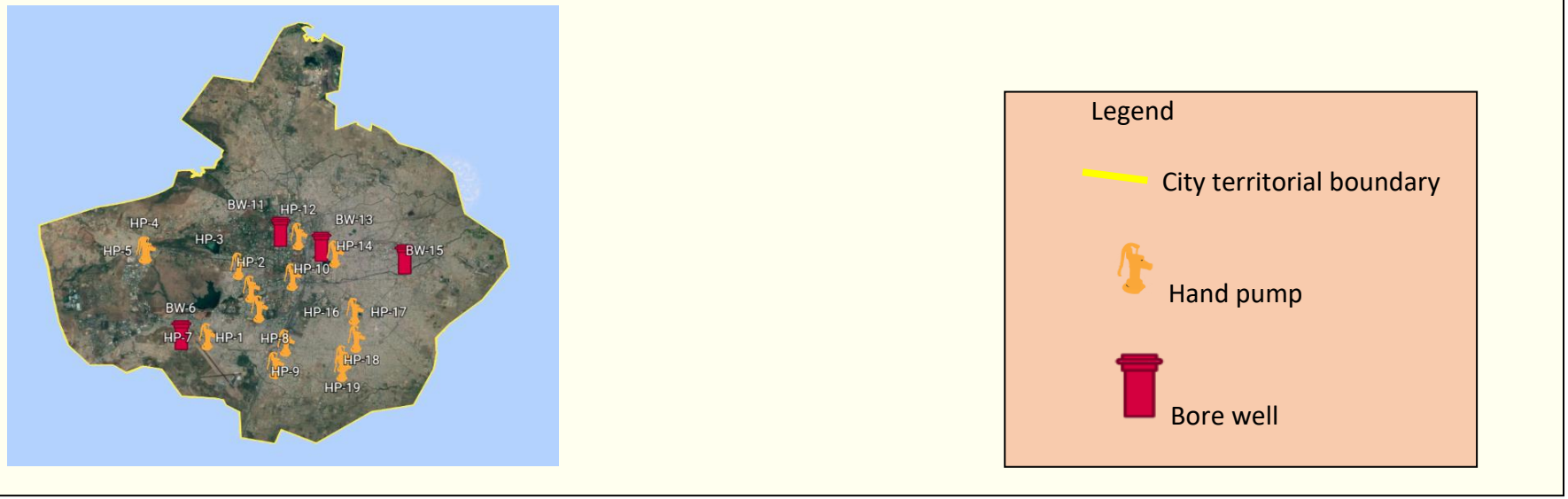


Figure 3.26: Physico- chemical characteristics assay of Nag River



#DO, TDS, SS, COD, BOD, TKN, and P was measured in mg/L.

Figure 3.27: Physico- chemical characteristics assay of Pora River



Parameters	HP-1	HP-2	HP-3	HP-4	HP-5	BW-6	HP-7	HP-8	HP-9	HP-10	BW-11	HP-12	BW-13	HP-14	BW-15	HP-16	HP-17	HP-18	HP-19
pH	7.5	7.6	7.3	7.1	7.4	7.5	7.2	7.3	7.6	7.1	7.8	7.1	7.4	7.4	7.5	7.1	7.1	7.3	7.4
Alkalinity	240	244	296	320	400	140	264	220	320	120	200	280	88	300	240	280	320	300	304
TDS (mg/L)	348	402	420	582	912	270	541	474	676	276	228	432	180	480	780	480	520	1020	557
TH (mg/L)	175	228	258	307	340	162	333	95	352	183	177	280	110	275	224	318	353	558	140
Turbidity(NTU)	10	1.8	11	2.6	3	1	1	2	2	0.6	0.9	2	0.9	2	0.6	2	3	4	1
PO_4^3 (mg/L)	0.6	0.8	0.9	0.6	0.9	0.4	0.3	0.2	0.1	0.7	0.9	0.5	0.6	0.4	0.3	0.2	0.6	0.8	0.9
Total Coliforms (CFU/100ml)	80	10	46	160	1600	2321	0	0	88	521	88	0	0	522	20	78	56	66	0

Figure 3.28: An insight: Geographical location and Physico-chemical characteristics of the studied Ground water sources of Nagpur city

3.10 References

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CHAPTER 4:
URBAN GREEN SPACES(UGS) AND ECOSYSTEM SERVICES(ES)

ESR-2019-2020

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Participatory assessment for demand-supply gap in urban green spaces (UGS) and Ecosystem Services (ES) for Green Infrastructure (GI) planning in Nagpur

A survey was carried to understand citizens' response to public Urban Green Spaces (UGS) and key Ecosystem Services (ES). A total of 1050 individuals from 100 wards were questioned from Feb-mid March, 2020. 11% respondents strongly agreed, while, 40% agreed that there was sufficient greenery around them.19.5% respondents disagreed while, 2.3% strongly disagreed on having sufficient greenery around them. During the survey 42.6% respondents told that they travelled >500 m of distance to access UGS, 28% 200-500 m, 20.5% 50-200 m whereas, only 9% have easy access to UGS. 44% respondents told they were visiting UGS daily, 35% once or twice a week, 15% once a month whereas, 7% were infrequent to UGS and they stated accessibility and maintenance issues as main reasons. 50% respondents were satisfied while, 50% respondents were not satisfied with management of UGS in the city.

ES from UGS were also assessed under provisioning, regulating and cultural service categories. 77.5% of the respondents indicated that they don`t harvest any plant parts for consumption and usage from UGS, though, 20% indicated their involvement in occasional foraging of plant parts. Under services related to regulation (heat islands and air pollution abatement was considered) 30% disagreed to sufficient green spaces available in the city to address the issue whereas, 29% agreed to sufficiency of green spaces and 30% were neutral. A huge interest for using UGS for various cultural benefits by the locals was clear especially for health and psychological benefits. 82% respondents were visiting UGS for fresh air, 63.4% for health benefits, 33.2% for relieving stress while, 22.1% felt that watching birds and butterflies gave them pleasures.

Present study has graded 50 locations as green with good amount of UGS, 44 as orange that need special focus for restoring the degraded UGS and 19 red zones for special planning needs for Green Infrastructure (GI). Our recommendations focus on prioritizing actions and funds in respective green, orange and red wards by taking appropriate plantation, restoration and management plans. The recommendations include planning plantation or developing Natural Infrastructure (NI) as per the ward specific needs depending on population, build up density and area of the wards.

4.1 Introduction

Urban Green Spaces are defined by areas that have grass, trees or any vegetation in an urban setting, while Blue Spaces are defined as any visible water bodies. These are key indicators of quality of life, for urban sprawls. The provision of open space and public green and blue spaces as a public asset in urban areas, can minimize the negative impacts of climate variability and vulnerability, especially since Nagpur falls in the high temperature belt of the country. In fact, one criteria towards the implementation of an urban resilient framework, is to create green and open spaces so as to maintain the sustainability of socio-cultural, economic, and ecosystem services flow. Investment in urban areas, through the provision of creating efficiently planned biodiversity hotspots, is believed to be a form of mitigation by natural space for anticipated environmental change phenomenon. Adaptation capacities will be crucial to ensure urban resilience. From here onwards the green and blue spaces have been considered as urban green spaces (UGS) in the text and it reflects both.

This study was carried to understand the demand supply gap and prominent ecosystem services with a focus on provisioning, regulating and cultural ecosystem services (ES) harnessed by locals of Nagpur city, a rapidly emerging urban center in Central India. The study explored participatory tools to develop thematic map from people's perception about demand supply gaps in access to public urban green spaces (UGS). The objective of the participatory survey was to understand people's requirements, availability and access of public UGS and the key ES harnessed by them. This information is relevant for urban planners and policy makers, to have an overview of the status of availability and distribution of green spaces in Nagpur. Participatory mapping methodology is an innovative approach and has been effective for recording qualitative status, analyzing spatial distribution and prioritizing UGS provisions. Integrating participatory approaches into spatial data can provide broader benefits of UGS provisions. These tools help in better UGS governance that aim at ensuring future urban sustainability via appropriate and planned green infrastructure.

4.2 Methodology

For the participatory survey, all 136 wards of the city were targeted to understand local perceptions about the urban green and blue spaces and ecosystem benefits through a range of questions. A total of 1050 individuals from 100 wards were questioned from Feb-March mid, 2020 (Figure 4.1). The survey was planned and carried out at multiple places in each ward. 39

wards could not be questioned because of lockdown in the city due to the unforeseen COVID-19 pandemic (Figure 4.2).

A semi structured questionnaire was developed and tested before finalizing the questions. Questions were translated in local language too for better outreach and understanding (See Annexure I). Survey respondents were selected randomly and hence, bias was avoided. A total of 18 questions were asked with 10 questions directly related to the understanding, awareness, demands, supply from publicly accessible urban green and blue spaces in the city. First 8 questions were to understand their backgrounds, age, income. Personal face to face interactions and interviews were carried out to understand the local perceptions (Figure 4.3). 10 questions were focused to understand accessibility, availability, ecosystem services flow and management issues related to urban blue green spaces in Nagpur. After analyzing data collected from participatory survey responses, GIS tools (Arc GIS) were used to develop relevant thematic maps.

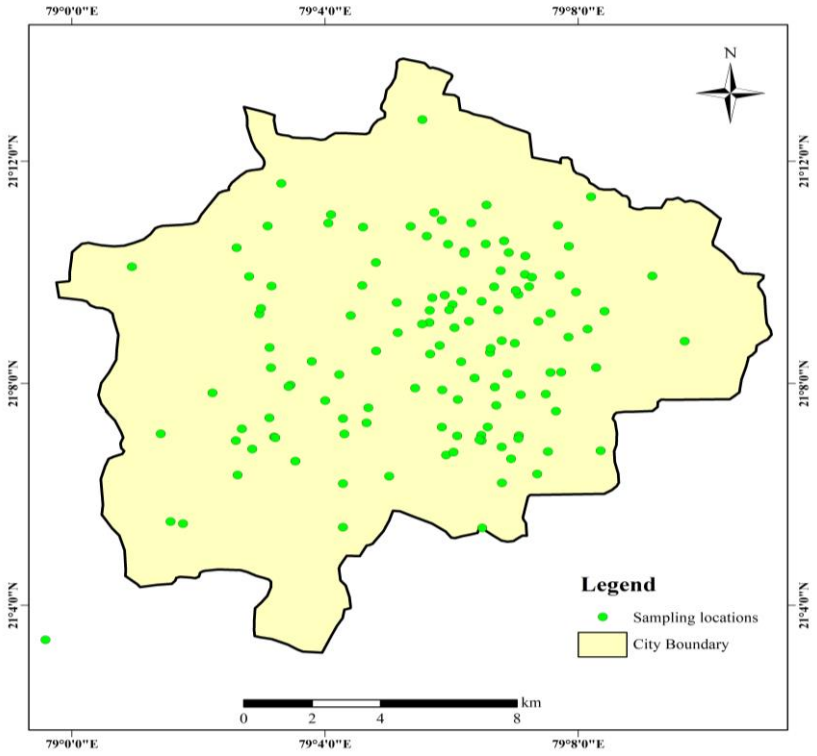

Figure 4.1 Nagpur ward map showing survey locations in 100 wards for participatory assessment

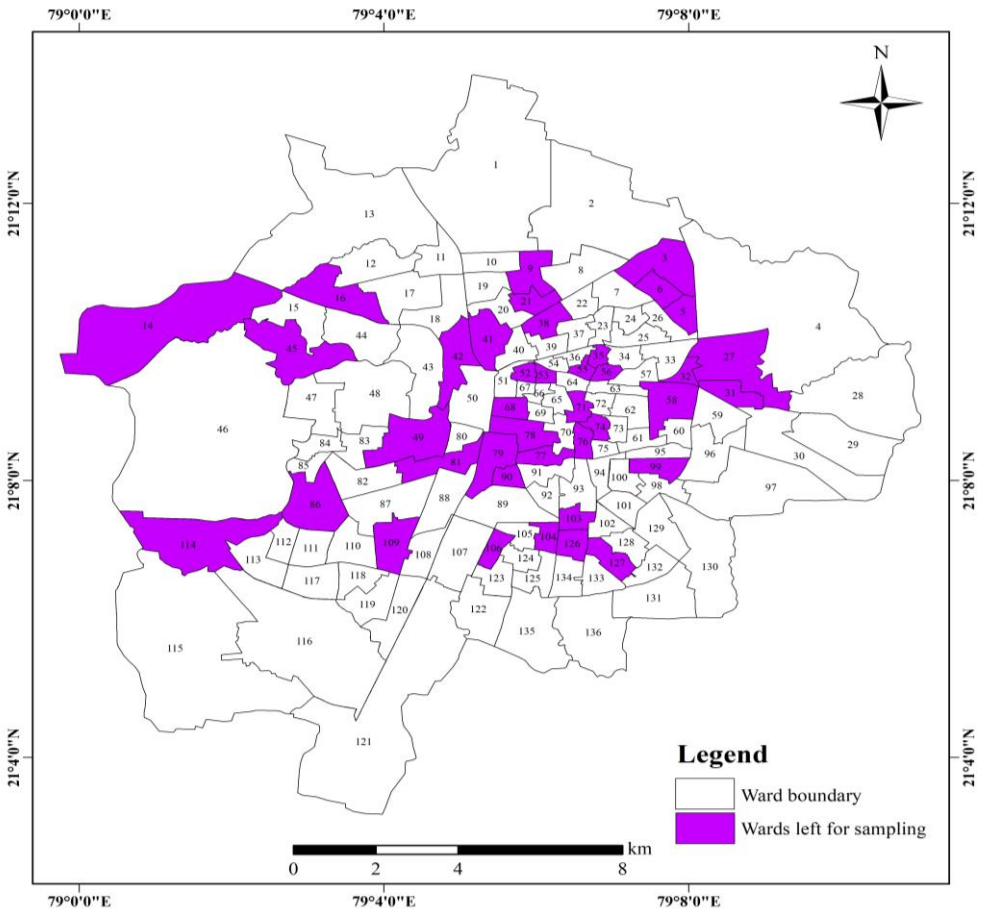

Figure 4.2 Nagpur ward map showing 39 wards not covered for participatory assessment due to pandemic

Figure 4.3 Participatory ecosystem services (PES) survey in different locations, of different wards in Nagpur

4.3 Results and Discussion

4.3.1 Place based identification, availability and access to public green spaces

The results of the participatory survey are presented for place-based understanding of locals for urban green spaces, demand supply gaps, ecosystem services and management issues.

4.3.1.1 Overview of key respondents

To understand the background of our key respondents, we asked them some basic questions related to their age, sex, educational qualifications, employment status and income; i.e., points that influence their interests and responses. A total of 65% male and 35% females participated in the survey. Respondents were further segregated in four age groups starting from 15 years as the minimum target age for our survey. Largest number of respondents 35.2% were in 31-50 years' age followed by 15-30 years (33.6%), 51-65 years (26.3%) and least number of respondents were belonging to >65 years' age group (4.9%). 39% respondents were graduates followed by 27.2% educated till high school, 15.5% were post graduates, 3.5% had doctorate degrees whereas rest of 15% were having other miscellaneous educational backgrounds *viz.* middle school, diploma *etc.* 47% respondents were employed, 5.4% unemployed, 22.5% students, 16% retired from various jobs, and 8.8% were house care givers of housewives. 43% earned <3 Lakh/annum, 22.7% had annual income of 5-10 lakhs, 21% earned 3-5 lakh/annum and only 13.4% were earning >10 lakh. To understand accessibility to UGS we asked respondents questions related to a yes or no following up with distance travelled and frequency of visits to better understand the demand gap scenario in Nagpur city.

4.3.1.2 Access to Urban green and blue ecosystems

As the most important question to understand the access to public urban green spaces we categorized them as green (parks, playgrounds *etc.*) and blue spaces (water fronts, ponds, lakes, wetlands) as both of these categories are important ecosystems and provide many ES to urban residents of rapidly growing Nagpur. A good 93% of respondents were comfortable to access green spaces over blue spaces whereas, only a small 7.5% showed their preference towards blue spaces over green spaces (Figure 4.4). This may be also due to preference to green spaces due to hot climate and being more in number parks are less crowded than lakes and ponds in the city.

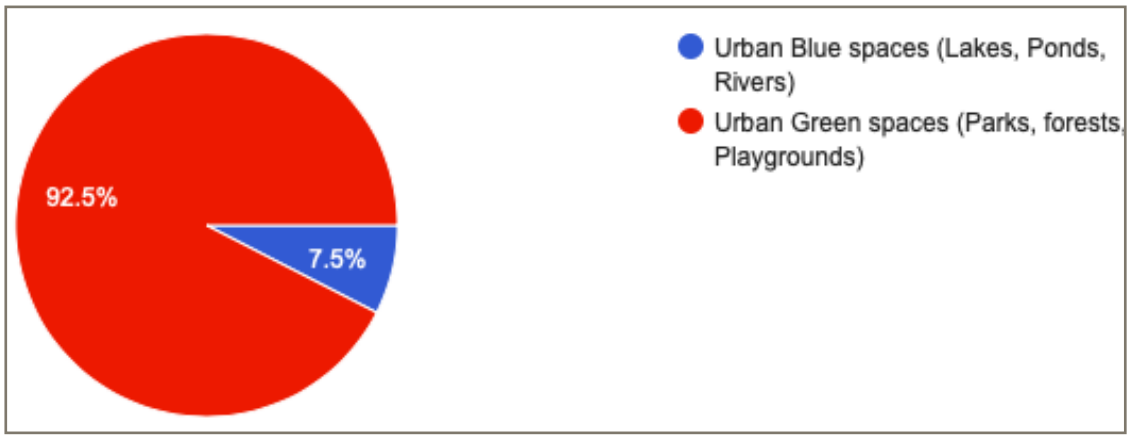

Figure 4.4 Accessibility of urban green and blue spaces in Nagpur

4.3.1.3 Demand supply gap in availability of sufficient green space

There was divide in people's response from different wards of fast expanding Nagpur. Almost 50% respondents agreed to having sufficient greenery in their wards/vicinity whereas, almost equal number of respondents were not satisfied and had mixed responses (neutral or dissatisfied) towards the question (Figure 4.5). We considered neutral response as insufficient understanding to urban green requirements. 11% respondents strongly agreed while, 40% agreed there was sufficient greenery around them though, this was irrespective of their accessibility. This may be avenue plantations, campus greenery, small urban forests, *zudpi jungle etc.* Whereas, 27.6% were neutral to this question, 19.5% disagreed while, surprisingly only 2.3% people strongly disagreed to this question.

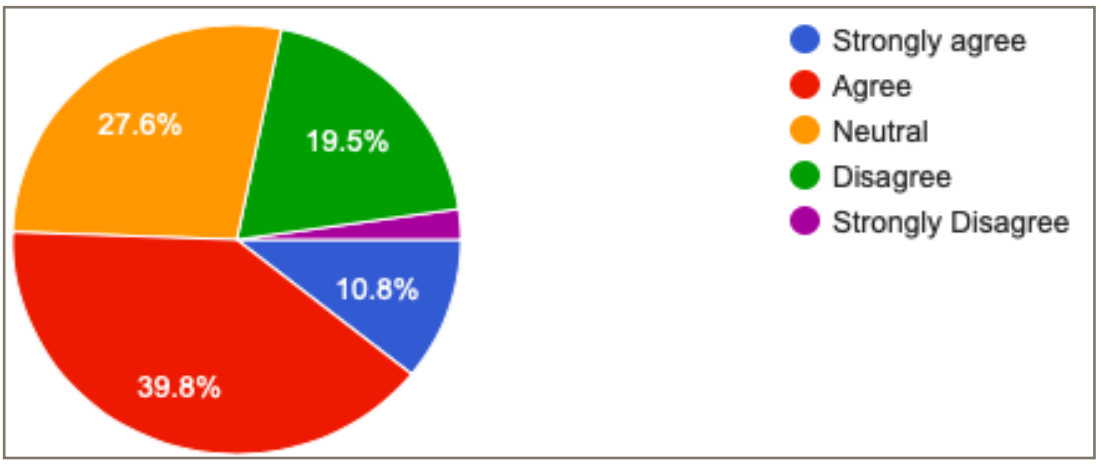

Figure 4.5 Demand supply gap in sufficient greenery in respective wards

4.3.1.4 Accessibility to UGS in terms of distance

We tried to understand the accessibility of urban green spaces in terms of availability for different wards. 42.6% respondents informed that >500 m of distance they travel access the public urban green spaces. This is quite a distance considering these are opinions from large number of respondents. 28% were travelling 200-500 m, 20.5% were travelling 50-200 m and only 9% have easy accessibility close to their places (Figure 4.6). Population density, dense infrastructure is some of the core reasons that reduce accessibility of UGS to local residents.

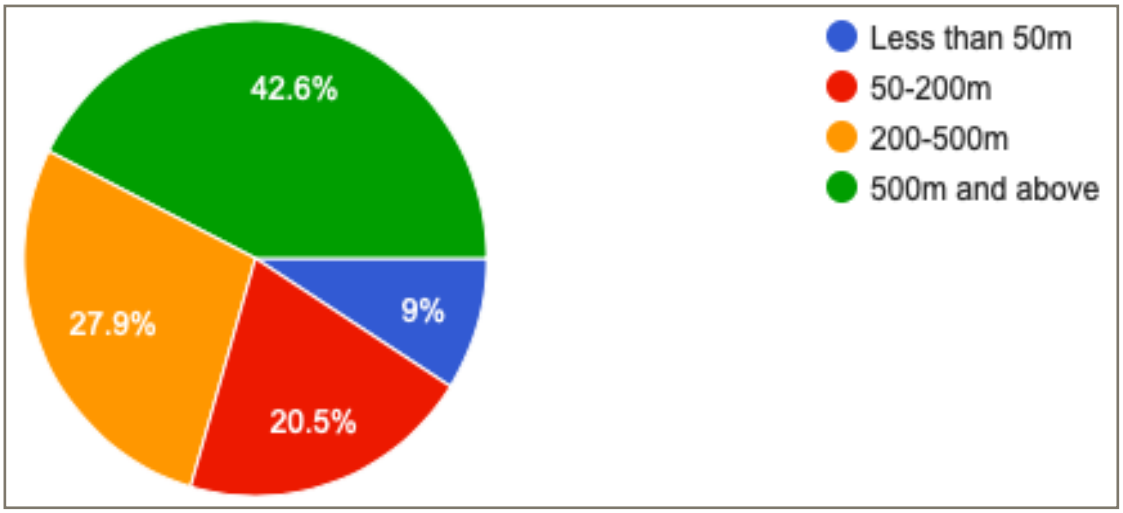

Figure 4.6 Distance travelled to access benefits of Urban green spaces

4.3.1.5 Frequency of visits to UGS

There was huge interest recorded by respondents to avail benefits from UGS available in the city. Almost 44% respondents were visiting the green spaces almost daily, followed by 35% once or twice a week based on time and accessibility. Nearness of green space increases the frequency of visits. Around 15% visited at least in a month whereas, there were still 7% who did not have enough time to enjoy or do not have any park or garden or lake close to their residence to avail this benefit (Figure 4.7). If we closely see these responses it is clear that though less than 50% people can access these green places everyday there is still huge gap of more than 50% respondents who are unable to avail the various benefits from these place.

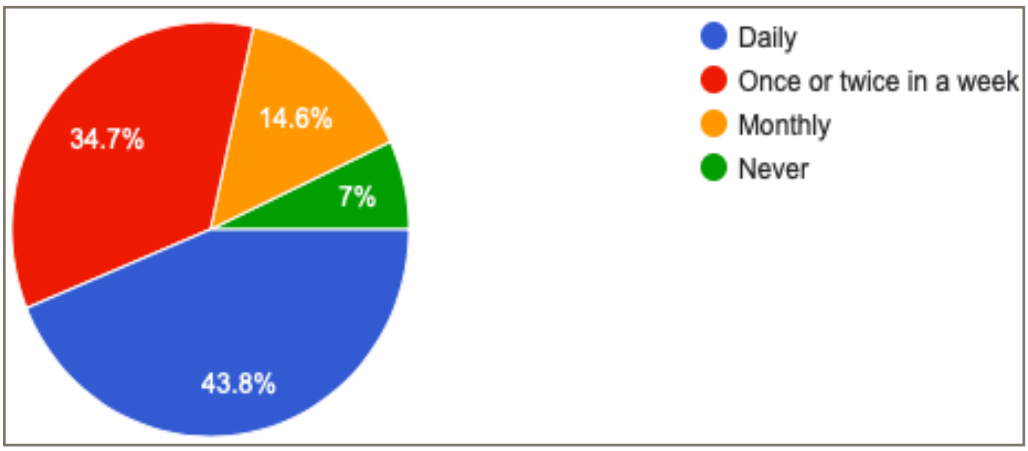

Figure 4.7 Frequency of visits to public UGS to understand accessibility in Nagpur

4.3.1.6 Management of public UGS

During the questionnaire survey while, understanding accessibility to UGS we also tried to understand how many respondents feel the available public UGS in their wards are actually well managed. Managed green places also decide interests of locals to visit them. Sometimes because of unmanaged green spaces also locals walk longer and avail benefits or UGS in far but managed green spaces. Only 7% respondents were very satisfied with the managed green spaces. 43% overall were satisfied and this sums up to around 50%. Whereas, there were 21% who were neutral to this answer, almost 25% were dissatisfied and rest of 4% were very dissatisfied. This shows that accessibility was also guided by the management of green spaces and this was also clear that 50% were satisfied and other 50% were not satisfied with the way UGS were managed and taken care of in the city

(Figure 4. 8).

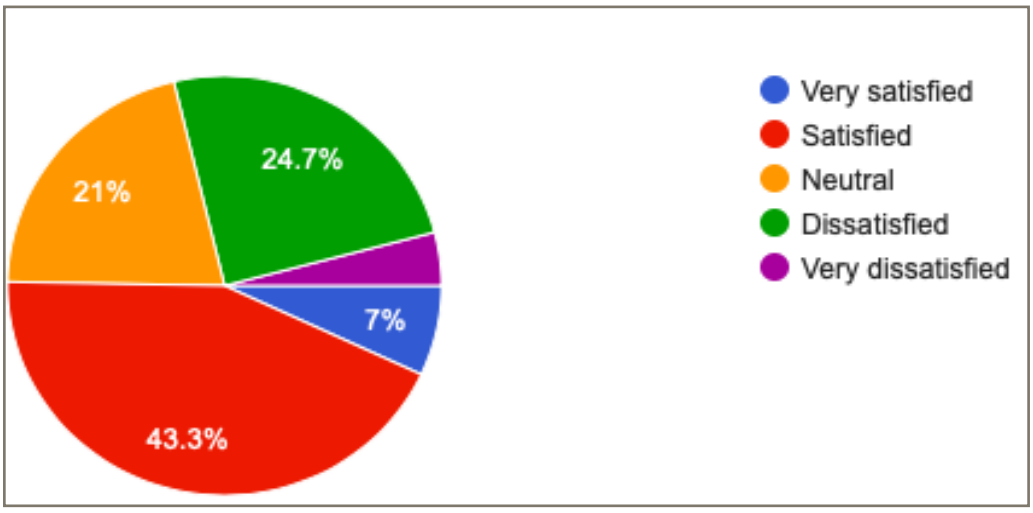

Figure 4.8 Management of Urban blue and green spaces in Nagpur

4.3.1.7 Grading of places (map) *vs* green cover

Based on personal responses of residents we coded the wards in red, orange and green color (Figure 4.9). Here, wards colored in green on the map were wards were respondents were satisfied for the facility, access, availability and management of public UGS. Orange were wards with threatened status and if proper attention is not given there is high probability that they may also shift to red zones of the city whereas, if due care is taken an immediate step there are chances in next coming five years, they may also shift back to green status. Red wards were in alarming situation and is clear that these were red irrespective of size, population and location. Many wards in white in the center of the city may also be red considering their small sizes, high buildup area and less space for plantations. We can also provide a clearer picture once after lockdown the entire city is surveyed covering all the wards with same questions. There are responses providing a clear picture where, still 50 wards are green and have enough availability and access there are another 44 wards close to 50 that require attention to protect existing patches and restore more areas for maintaining enough green spaces in these wards.

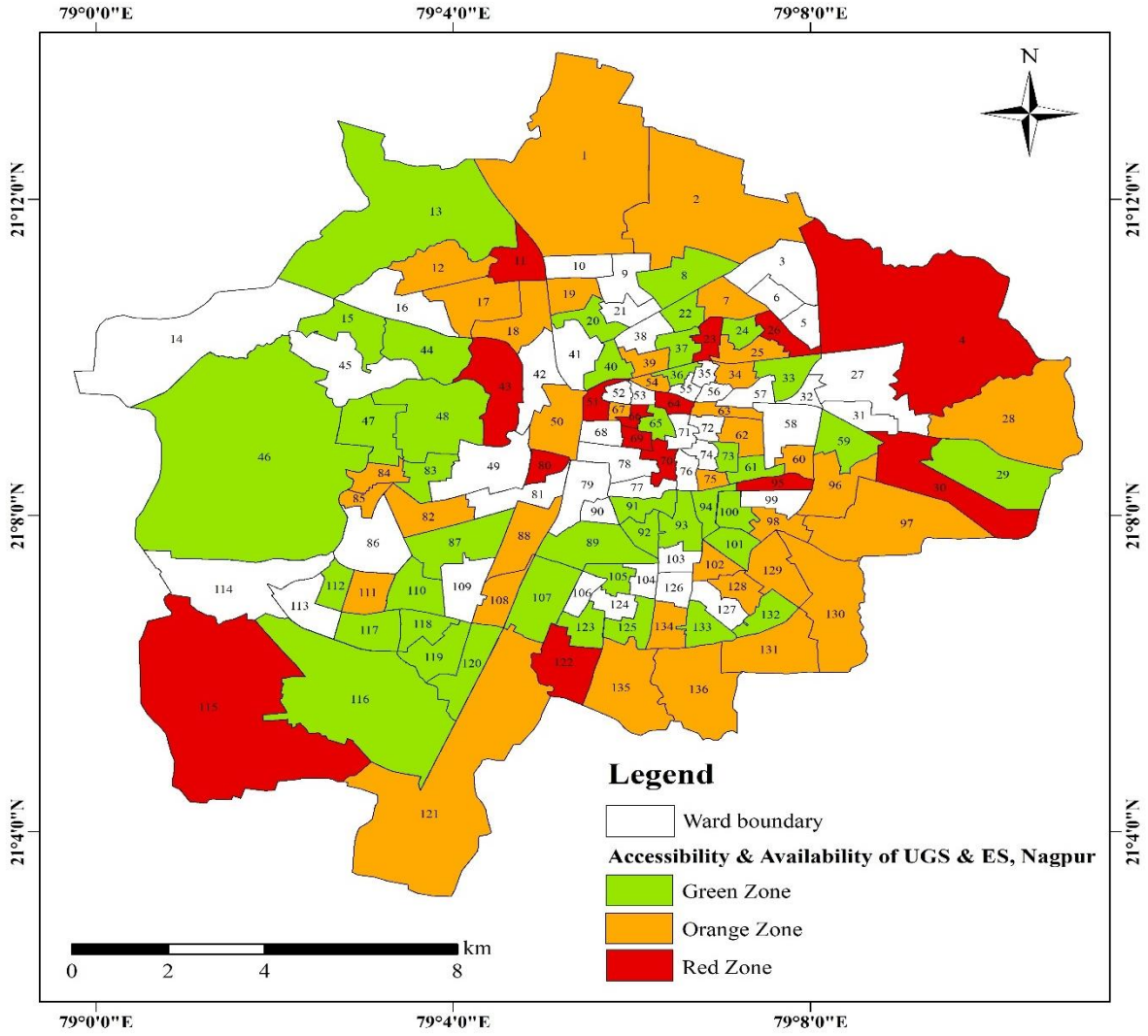

Figure 4.9 Map of Nagpur showing color grades as per local responses for place-based identification for green spaces (wards in white colors could not be questioned for survey)

For better understanding about the respective wards apart from Figure 4.9. Table 4.1 was developed for the area requiring more attention in orange and red zones. It is also to mention that there is need to manage and protect the existing green spaces (Table 4.1) by ensuring no felling, and encroachment.

Table 4.1 Wards and local neighborhoods of Nagpur graded in green, orange and red zones based on availability, access and management of green spaces

Sr. No.	Green Zone	Orange Zone	Red Zone
1	Ajni (107)	Ayodhya Nagar (134)	Bhaldarpura (69)
2	Ambazari (46)	Babulban (60)	Bhandewadi (30)
3	Ashirwad Nagar (132)	Balabhaupeth (39)	Boriyapura (51)
4	Juna Bagadganj (61)	Barse Nagar (54)	Dhammadeep Nagar (26)
5	Bhagwan Nagar	Besa	Hansapuri (66)
6	Binaki (24)	Chhaoni (18)	Hiwari Nagar
7	Chandan Nagar	Chitnavispura (75)	Jogi Nagar (122)
8	Chandramani Nagar (105)	Chunabhatti (108)	Kalamna (4)
9	Chatrapati	Dighori (130)	Lakadganj
10	Civil lines (48)	Ganesh Nagar	Mahal (70)
11	Dhantoli	Gopal Nagar (111)	Mankapur (11)
12	Dharampeth (83)	Hasanbagh (98)	Maskasath (64)
13	Dnyaneshwar Nagar (125)	Hilltop (85)	Near ayachit mandir
14	Dikshabhoomi (87)	Khalasi line (50)	Om Nagar
15	Gandhibagh (65)	Jafar Nagar (12)	Panchsheel Nagar (23)
16	Gorewada (13)	Jail ward (88)	Rajendra Nagar (95)
17	Hanuman Nagar (92)	Jaitala	Sadar (43)
18	Indora (20)	Janki Nagar (136)	Shivangaon (115)

19	Jaiprakash Nagar (119)	Jaripatka (19)	Sitabuldi (80)
20	Juni Mangalwari (73)	Mahendra Nagar (7)	
21	Juni Shukrawari (94)	Manewada (135)	
22	Kawarapeth (33)	Mehandibagh (25)	
23	Lashkaribagh (40)	Mahalgi Nagar (131)	
24	Laxmi Nagar	Mominpura (67)	
25	Medical (89)	Nagsen ngar	
26	Nalanda Nagar (8)	Nara (1)	
27	Nandanvan (100)	Narendra Nagar (121)	
28	Nehru Nagar (101)	Nari (2)	
29	New Subedar Layout (133)	Padole Nagar (96)	
30	Pardi (29)	Parvati Nagar	
31	Prashant Nagar	Police line takli (17)	
32	Pratap Nagar (110)	Prem Nagar (34)	
33	Ramdaspeth	Punapur (28)	
34	Rameshwari (123)	Queta colony (62)	
35	Ravi Nagar	Ram Nagar (84)	
36	Reshimbagh (93)	Ramna maroti (129)	
37	Seminary hills (44)	Sakkardara (102)	
38	Shivaji Nagar	Satranjipura (63)	
39	Siddharth Nagar (22)	Shankar Nagar (82)	
40	Siraspeth (91)	somwaripeth	
41	Somalwada (120)	Tajbagh (128)	

42	Sonegaon (116)	Vathoda (97)	
43	Subhash Nagar (112)	Vishwakarma Nagar	
44	Swavalambi Nagar (117)	Yashodhara Nagar	
45	Tandapeth (36)		
46	Telangkhedi (47)		
47	Friends colony (15)		
48	Vaishali Nagar (37)		
49	Wardhaman Nagar (59)		
50	Khamla (118)		

The participatory and spatial data resulted in improved information that can be used for better green infrastructure planning in Nagpur city. The recorded status of public urban green and blue spaces from survey shows disparity and demand supply gap in different wards of Nagpur. The eastern part of the city lacks UGS provisions, which is compensated by the western part with larger availability of natural green spaces.

4.3.2 Participatory Ecosystem Services Assessment

Increasing awareness of the importance of ecosystem services has led to the involvement of people in sharing information about the ES that will enable informed management. The inclusion of local understanding and identification of strategic management approaches helps in developing appropriate green infrastructure that fulfills the emerging and future demands of the fast expanding cities, like Nagpur. Ecosystem Services (ES) provide social, economic, cultural and health benefits to locals. However, these complex and place-specific ES are often overlooked in rapid land management decisions and are assessed using broad, top–down approaches. We have used place based participatory Ecosystem Service (ES) to examine a novel approach for rapid assessment of local ES provision using inductive, participatory methods. Free-listed responses revealed deeper insight into personal opinion and context. This work serves as a useful case study on how the perceptions and opinions of local people regarding local ES could be accounted for in the future planning of an urban greenspace and

how thorough analysis of ES provision is important to fully inform local-scale conservation and planning for the mutual benefit of local communities and nature.

Our questions about ecosystem services fetched responses related to provisioning, regulating and cultural ES provided by the urban green spaces to city residents. Detailed overview about the responses is detailed below:

4.3.2.1 Provisioning Ecosystem Services

There are many provisioning services provided by UGS not limited to raw materials, fresh water, food and medicinal resources. In this survey we have only considered urban foraging for food, medicine, fuelwood and fodder as important provisioning service from existing UGS in Nagpur. It has been time and again said that UGS provide almost no provisioning services but in a country like India where, a lot of population still prefers wild edibles over market available food because of better nutritional properties or due to unavailability of enough money UGS provided some important provisioning support to locals. Our respondents provided an insight to provisioning benefits from UGS. Middle aged women preferred harvesting some kadi patta, tulsi, moringa flowers, moringa pods, neem leaves, neem flowers, sesbania flowers, fruits and many other plants occasionally for food and other flowers for religious purposes too in a very small amount (Figure 4.10). Urban foraging provides nutritional support to many poor with insufficient options for nutritional and livelihood support and avenue trees, *zudpi jungle* also provide some wild flowers, fruits *etc.* to poor slum dwellers for personal use or for economic benefits that they earn by selling them in local markets. So far, the practice has been poorly understood and goes unacknowledged by urban planners, and authorities. Urban foraging helps to preserve bio-cultural diversity, nature connectedness, sense of belongings while, appreciating dietary benefits of wild edibles. Our survey reported 20.5% respondents availing benefits from various UGS not limited to parks and gardens managed by NMC or NIT for food, nutritional or medicinal benefits. 1.2% reported harvesting leaves in a small amount as fodder for their animals like goats. 2% belonging to slums also collected deadwood for fuelwood while 38% reported other provisions like medicinal plants for some occasional requirements not regular in nature. Still, a large number of respondents 77.5% were not involved in collecting any direct use from UGS (Figure 4.11).

Figure 4.10 UGS in Nagpur support provisioning services and promote urban foraging

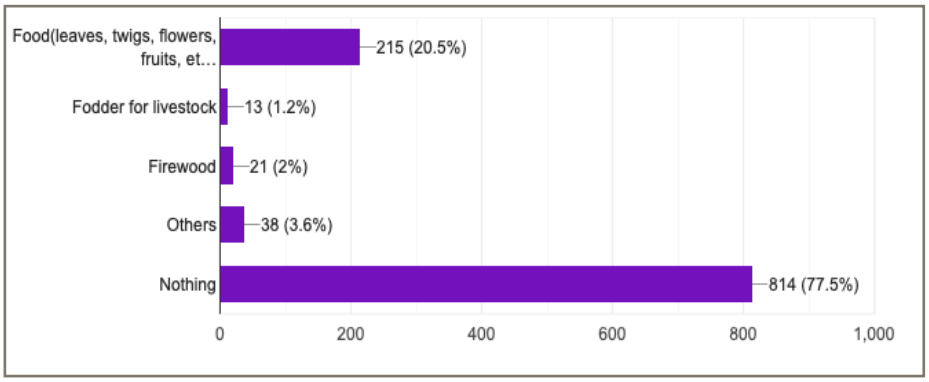

Figure 4.11 Some prominent provisioning (direct use values) benefits of urban green spaces

4.3.2.2 Regulating Ecosystem Services

Improving local climate and air quality, carbon sequestration and storage, moderation of extreme events, and waste-water treatment are some important regulating ES from urban ecosystems. In our survey we focused on sufficiency of UGS in Nagpur in controlling heat islands and air pollution abatement. We asked the city locals if available public green spaces in the city sufficient to address air pollution and heat island effect (city center hotter than outskirts)? We had to explain heat islands in more related terms and linked it with hotter markets and build up areas than areas with green zones. 29.6% agreed whereas, 5.4% respondents strongly agreed that UGS are sufficient to reduce air pollution by absorbing it and reducing the heat islands. 30.4% were neutral and neither agreed or disagreed to the sufficiency of existing green spaces in air pollution abatement and reduction heat islands. 30.3% disagreed and remaining 4.3% of respondents strongly disagreed that existing UGS

are sufficient. This can be well related to the area graded in green, orange and red (Figure 4.12) and can well explained the variations in responses.

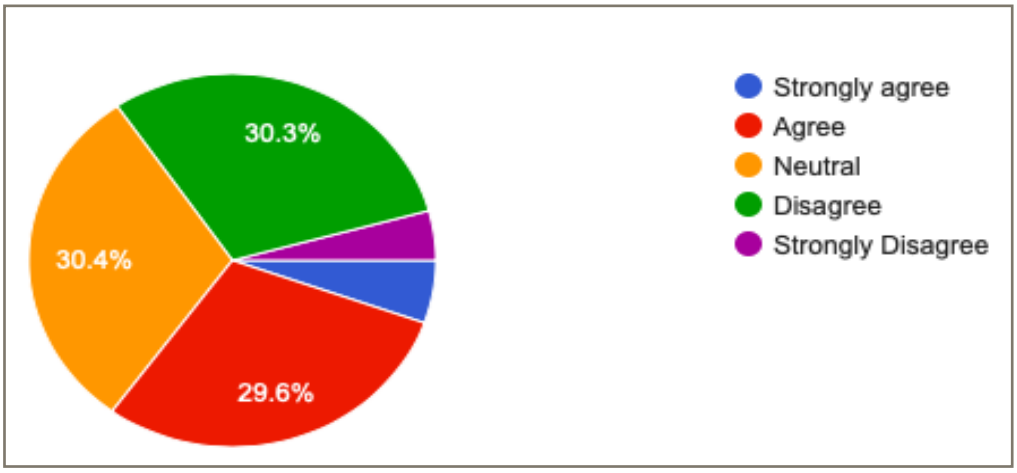

Figure 4.12 UGS to control air pollution and heat island effects (city center hotter than outskirts) in Nagpur

4.3.2.3 Cultural Ecosystem Services

Urban green spaces provide various ecosystem services, especially cultural services for example recreation, spirituality, a sense of place and local identity. 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. We avoided considering religious benefits from UGS as important cultural ES. We also tried to understand the cultural ES by understanding the frequency of visits to UGS (Figure 4.7). Almost 44% respondents were visiting the UGS daily, followed by 35% once or twice a week and 15% visited at least in a month with 7% having no visits even in a month (Figure 4.13).

Our questions focusing on cultural services brought understanding from responses that 58.5% responses were using UGS for morning or evening walk; 48.5% for jogging and exercise; 21.6% in Yoga or meditation and this was interesting to note that people link health with UGS. These were more or less frequent visitors who either visited daily or on alternate days. 6.4% respondents mostly from occasional visitors who visited once a month or more than a month were using UGS for picnics or any other recreational activity. 33.4% also visited UGS in the city for social interactions where they met their friends and enjoyed the ambience (Figure 4.14).

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.

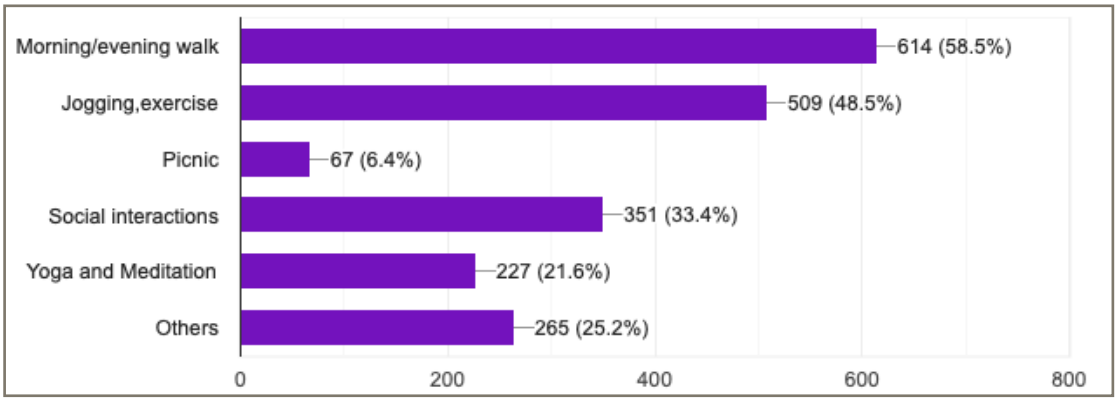

Figure 4.13 Cultural Ecosystem benefits from UGS harnessed by people in Nagpur

Figure 4.14 UGS in Nagpur as important recreation centers and places for immense Cultural ES

Further, in our survey questions we also tried to understand the health and psychological benefits of nature and UGS in the city of Nagpur. Our question was what attracts them to be close to natural places in urban areas? 82% respondents were visiting UGS for fresh air, 63.4% for health benefits, 33.2% considered peace and relieving stress was their main aim. 22.1% felt good while watching birds and butterflies and that gave them psychological benefits and pleasures (Figure 4.15). These benefits also gave them sense of belongingness

and attachability to UGS and the zones coded by red and orange in Figure 4.9; Table 4.1 are the wards where; ward residents don't have access to these regular and required benefits.

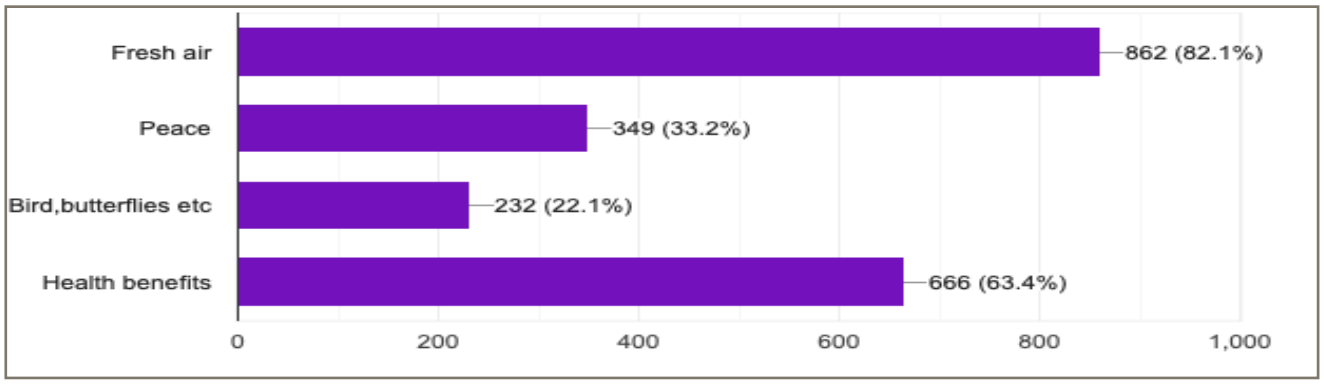

Figure 4.15 Nature connectedness and attachability benefits

4.4 Conclusion

The standards for UGS vary from one country to another. The best available practices of per capita provisions, recommend green space of 20m^2 viz. "minimum of 1.25 ha open space per 1,000 residents (Chaudhry and Chaudhry, 2012). The Urban and Regional Development Plan Formulation Implementation (URDPFI) guidelines, 2014 by Ministry of Housing and Urban Affairs are used by local bodies, 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 (MoUD, 2015 a, b and c). Nagpur is witnessing rapid expansion of the city and increasing urban sprawl scenario due to over densification. Rapid decline and degradation of already stressed public UGS in the city was observed from our participatory survey. Place based understanding and response of locals are helpful in effective planning as they have better understanding about their neighborhood. They should be involved in Green Infrastructure (GI) planning for effective and sustainable development. The conservative statistical based land-use planning lacks availability of local level data that nay hamper the long-term vision towards conservation, provision and planning of UGS. Our participatory survey clearly included urban dwellers, perceptions for UGS demand supply gaps based on accessibility, frequency of visits, distance of UGS from their places. The perception-based survey helped in understanding where GI planning and implementation should be more focused and planned. Proximity and UGS area gap the city reflected wide disparity between eastern, central and western zones. The spatial data was used to facilitate planning, to maximize UGS benefits to larger population. Study also provides importance of the UGS in the city to help manage health benefits and psychological

benefits that also improve resilience of people in long run. The green, orange and red codes can help the city planners to prioritize their efforts and funds in improving UGS in respective wards.

Wards need improvement in UGS in next 5 years so that they cannot turn up as additional red wards in next 5 years.

In 50 green zones identified in Table 4.1 focus should be reduce interferences in UGS, avoiding any kind of encroachment or felling and promoting additional plantations. Most of the parks don`t have sufficient trees regular monitoring for understanding tree density should be a compulsory activity for garden department of NMC involving district forest department and citizen science approaches where NEERI can partner and provide scientific training and support.

4.5 References

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Annexure-I

NEERI P-ESA Survey Questions

- Name
- Area of residence

  Take GPS location of the area of residence
- Gender

  a) Male b) Female c) Others
- Age

  15-30 b) 31-50 c) 51-65 d) 65 and above
- Qualification

  a) Middle school b) High school c) Diploma d) Graduate

  e) Post graduate f) Doctorate g) other
- What is your employment status?

  a) Student b) Unemployed c) Employed d) Retire

  e) House care giver
- What is your economic status?

  a) <3 lakhs/annum b) 3-5 lakhs/annum c) 5-10 lakhs/annum

  d) 10 lakhs and above
- Which Urban Ecosystem is more accessible to you?

  a) Urban Blue spaces (Lakes, Ponds, Rivers)

  b) Urban Green spaces (Parks, forests, Playgrounds)
- Name of the Urban green/blue space used by you frequently
- Is there enough greenery around you?

  a) Strongly agree b) Agree c) Neutral d) Disagree

  e) strongly disagree
- Distance of green spaces or blue places from your house?

  a) Less than 50m b) 50m-200m c) 200m-500m

  d) 500m and above
- How often do you visit your urban blue/green spaces?

  a) Daily b) Once or twice in a week c) Monthly d) Never
- Purpose of visiting urban green or blue space areas?

  a) Morning/Evening Walk b) Jogging, Exercise c) Social interactions

d) Picnic e) Yoga and Meditation f) Others

- What attracts you being close to natural places in urban areas?

  a) Fresh Air b) Peace c) Birds, butterflies *etc.* d) Health benefits

- What do you harvest from the green spaces around you for personal or household consumptions?

  a) Food (Leaves, twigs, flowers, fruits *etc.*) b) Fodder for livestock

  c) Fire wood d) Others e) Nothing

- Do you think the available public green spaces in your area are sufficient to address air pollution and heat island effect (city center hotter than outskirts)?

  a) Very satisfied b) Satisfied c) Neutral d) Dissatisfied

  e) Very dissatisfied

- How satisfied are you with the management of public green spaces and blue spaces in your area?

  a) Very satisfied b) Satisfied c) Neutral Dissatisfied d) Very dissatisfied

CHAPTER 5:
SOLID WASTE

ESR-2019-2020

CSIR-NEERI

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Solid Waste Management

5.1 Introduction

Municipal solid waste management (MSWM) is one of the major environmental challenges in most of the cities of developing countries like India. Improper management of municipal solid waste (MSW) causes hazards to inhabitants and environment. The solid waste management system needs to be updated to suit the waste quality, quantity and composition (Kalantarifard and Yang, 2011). The quantification of waste generation rate and characterization of its composition are essential to plan and design and effective solid waste management systems of any given region (Gidarakos et al., 2006; Gomez et al., 2008). Many studies have reported that the solid waste generation is directly dependent on the income levels, and the higher income individuals tend to consume more industrialized products, their garbage contains more recyclable materials than that of low-income communities. The consumption pattern of household is directly linked to the increase in income which results in changed composition and quantities of household waste (Ogwueleka, 2013). However, it has been found that this is not the only governing factor. Amongst other socioeconomic factors that have been said to influence MSW generation rate are number of family members, education, occupation, etc. (Bandara et al., 2007).

Urban Areas, especially in developing countries are facing ever increasing challenge of providing appropriate infrastructure facilities for meeting growing demands of ever-increasing urban population. Hence the production of solid waste in the city mainly depends upon the population of the city. The spatial growth of the city and the volume of generated waste are increasing proportionately. In case of India, India is rapidly urbanizing. According to the data published by Handbook of Urban Statistics, 2019, level of urbanization in the country as a whole increased to 34.47%. An increase of 3.3 percentage points during 2011 to 2019 was observed. This extent is projected to grow further and by 2050, over half of India's total population will be living in urban areas.

5.2 Population Distribution in Nagpur City

The growth of slum population in Nagpur in the past few decades has been steadily increasing. During 1971, the number of slum pockets in Nagpur was around 47, which has increased by seven times in 1992 and, another 50% slums were added in 2008.

In the year 2018, a slum survey was conducted in Nagpur and published in the form of Slum Atlas for Nagpur. According to the report, the total slum population (LIG) in the city is 8.58

lakh (0,86 million) which is ~ 36% of the total population. A total as of 446 slums both notified and non-notified – are scattered throughout the city area shown in Figure 5.1. In addition, few (13) new slum areas have been identified recently and are yet to mapped.

(Source: Slum Atlas of Nagpur, 2008)

Fig. 5.1 Slum Location Map of Nagpur City

Population resides in the MIG holds the maximum share in Nagpur. Total population residing in these areas is 10.54 Lakhs (42.18%). However, 22.12 % of the city population can be categorized into the HIG (Slum Atlas of Nagpur, 2018).

Population growth in any place depends not only on natural increase but also on in-migration. In addition to Nagpur's rapid socio-economic development that had a significant impact on the urbanization in the city, future growth is governed to a large extent by the development patterns in the city. The extent of in-migration in Nagpur city is mainly the impact of the key projects that are influencing socio-economic development in the city and peri-urban areas.

With such growing population, effective management of MSW (Municipal Solid Waste) generated per day in such areas becomes a major problem. According to the report by Ministry of New and Renewable Energy, as on November 2017, India generated around 1, 45,626 TPD (Tons per day) of MSW. The amount of liquid and solid waste generated in the city has also a direct impact on the land and, hence, it is necessary to dispose of the waste in a scientific manner. Our changing lifestyle has further added to diversity in waste generation ranging from

food to clothes, plastics to E-waste. If not disposed properly, this waste accumulation may lead to various environmental as well as health issues (Swachh Sarvekshan report, 2019)

5.3 Current Status of Nagpur

Nagpur City, more popular known as Orange city is a major Centre of administrative & political, commercial, culture & economic activities. The total area of Nagpur is 217.56 sq. km and the current population is approximately 2.5 million. NMC is responsible for the water supply, sewage treatment and solid waste management (SWM) of the city.

SWM is realized as one of the major problems in the city by NMC. The increase in the quantity of the waste generated, regular change in the quality of waste and inappropriate processing and disposal method is the main aspects involved in SWM.

On daily basis, Nagpur is generating an average of 1150-1200 tonnes (TPD) of waste, with an average per capita waste generation of 4.46 kg out of which only 150-200 TPD of waste is being processed. Evidently, the waste management system in Nagpur is presently inadequate. Nagpur Municipal Corporation (NMC) has been a progressive urban local body and has taken some measures for improvement of waste management in the city; however, still there is a long way to go for considerable improvement. The management and the existing scenario of different components of waste in the city is discussed further

5.3.1 Household Waste

MSW Management system consists of six basic elements viz., waste generation, segregation, collection, transportation, processing and disposal. All these elements are discussed separately in this section.

- **Waste Generation**

In Nagpur city, there are many sources for generation of MSW generation, which are residential/households, commercial places, hotels and restaurants, market place and Institutional places like schools, colleges, Govt. Offices etc.

Nagpur city is divided in to ten zones by NMC for better administration. At present, Nagpur Municipal Corporation (NMC) is facing problems related to MSW collection, waste management, waste disposal and the lack of financial support from State or Central Government. The total solid waste generated in the Nagpur city is 1150-1200 tons/day.

Solid waste generated in city contains paper, textile, leather, plastic, metals, glass, ash with fine earth, and compostable matter. Solid waste is collected from each zone and transferred at

dumping station Bhandewadi, Nagpur. There should be focus on designing intelligent machines for segregation and disposal of wastes in line with intelligent vending machines. One of the prime hindrances in waste management is the revenue needed for different aspects the process. By producing composts, recovering metals and recyclables etc. and selling them, a lot of money can be generated as well as saved by avoiding the future remediation burden that will be caused by indiscriminate disposal of waste into the environment. Revenue and employment can be generated by proper disposal of MSW in Nagpur city and hence help in financing the resources for the propagation of Swachh Bharat Abhiyan.

- **Waste Segregation**

Segregation of solid waste at source is substandard and community is not willing to involve voluntarily despite knowing the importance of the segregation of MSW at source. There are no such recycling facilities available in the city of Nagpur. Local rag pickers often spread the garbage outside the bin to separate the valuable recyclable materials. Recyclable wastes were observed to be comprised of glass bottles, tin, HPDE and LDPE plastics, leather, and cloth bags. If recyclable market can be encouraged by the local government or municipality, it will be helpful to segregate the waste before dumping to the landfill site. It was also observed that local rag pickers also segregate the waste and recover valuable materials at landfill site.

- **Collection of Waste**

Door-to-door Collection

In Nagpur municipality area, a door-to-door collection facility is available. Sweepers and local rag pickers are segregating the waste and recover valuable material from households.

Street Sweeping

Street sweeping is done in all main and sub-roads. It is a very common collection method of solid waste especially in commercial areas. The collected waste from the street sweeping transported separately to the Bhandewadi dumping site

- **Collection of Solid Waste from Hotels/Restaurants and Institutional areas**

Being the 3rd largest city of the state, Nagpur city has 20000 hotels and restaurants in the municipality area. Solid wastes from different hotels and restaurants are collected by NMC. Almost all the hotels are segregating their waste at source (Data received from NMC officials).

- **Transportation of Solid Waste**

NMC has 3 types of transportation vehicles for collection of MSW from the city area. The vehicles used for collection of MSW are Xenon, General Machine and Compactor. The amount

of MSW of the Nagpur city which reaches the Dumpsite is around 1000-1100 TPD (excluding the amount of waste being processed which is around 150-200 TPD).

Figure 5.2 Collection and transportation of MSW

5.3.2 Biomedical waste (BMW)

Nagpur has a well organized, disposal and treatment system of BMW. The Government of Maharshtra has sanctioned a project which is on 30 years lease for the project of BMW that was started in 2004. NMC gets Rs. 23, 50,000 yearly with 10% increment per three years to ensure the proper treatment and disposal of BMW in Nagpur. The project has been taken on BOOT basis. NMC has allotted ¼ acre land to a private agency at Butibori Nagpur. It receives the waste from all indoor hospitals, dental clinics, dispensaries, blood banks, pathology laboratories, private Ayurvedic and homeopathic colleges, etc. Nagpur also has a common BMW waste treatment facility at Butibori Nagpur as Superb Hygienic Disposals under the authorization of Maharashtra Pollution Control Board (MPCB).

5.3.3 Construction &Demolition Waste (C&D)

NMC has started collection and disposal of C&D waste separately. Keeping the ongoing massive constructions activities and infrastructure development in city in view, NMC started Brown line for collection and transportation of C&D waste. NMC is collaborating with ACC Cement (ACC RMX Nagpur, Hingna MIDC) for the production of bricks from the C&D waste.

5.3.4 Electronic Waste (E-waste)

Nagpur is one of the top ten cities and accounting for 4.9 tonnes of electronic waste generation. The city is lacking the segregation process. The E-waste is mixed up the MSW wastes and is a complex global problem. It has been found that in the city, many workers are engaged in the electronic repair shops and they do not have any proper training and are not using any health safety protective measures during the dismantling or segregation process. In the absence of policy and lack of planning, some E-waste gets mixed with garbage while collection process

by NMC. Consequently, the E-waste is disposedoff in an unscientific manner causing a health hazard and environmental pollution.

However, after E-waste management rules, 2016, Maharashtra State Pollution Control Board with NMC made it mandatory to collect and dispose E-waste in a safe manner for the local recyclers and E-waste management firms. Various NGOs like Rotary Club, Eco-centric etc. are currently working for the collection of E-waste. But M/s Suritex Private Ltd. is the only firm working solely on the management, treatment and disposal of the E-waste. M/s Suritex Private Ltd. Recovers Metals and Plastic from the E-waste in granular form and exports it to the various processing units in Maharashtra.

5.4 Present Study

The present study was undertaken within the administrative area of the city of Nagpur. The solid waste generation rate was expected to vary in different socioeconomic groups due to many environmental and social factors. The attempts have been taken this time to assess the solid waste generation and characterisation based on different socioeconomic parameters like education, occupation, income of the family, number of family members etc.

The behavior of household solid waste generation is analyzed, using as a unit of analysis the garbage bags produced by a family during a week. For this analysis the category of socioeconomic is considered where three different socioeconomic strata are included: High socioeconomic, middle socioeconomic and lower socioeconomic on the basis of the income.

The wards of Nagpur Municipal Corporation have been already identified and divided into three different income groups. The map was provided by NMC. The sampling was done from total 23 different locations covering all the ten zones which includes 8 High income group, 8 Middle income group and 7 Low income group.

5.4.1 Reconnaissance & Field Survey

Reconnaissance survey and the subsequent field work was carried out for one-month period in the study area. The following tasks were performed during field visit:

- Primary visit in all identified locations in respective Socio-economic Group of Nagpur City.
- Collection of MSW sample in all the identified locations of Nagpur City.

5.4.2 Sampling of MSW

Waste samples collected from Nagpur city which includes samples from different socio-economic group. During sampling, it was observed that significant quantity of glasses, plastics and construction residue are present along with MSW. The physical composition of MSW was

determined at the site itself. The socio-economic group-wise map of Nagpur city, where the sampling activity was performed, is illustrated in **Fig 5.3.**

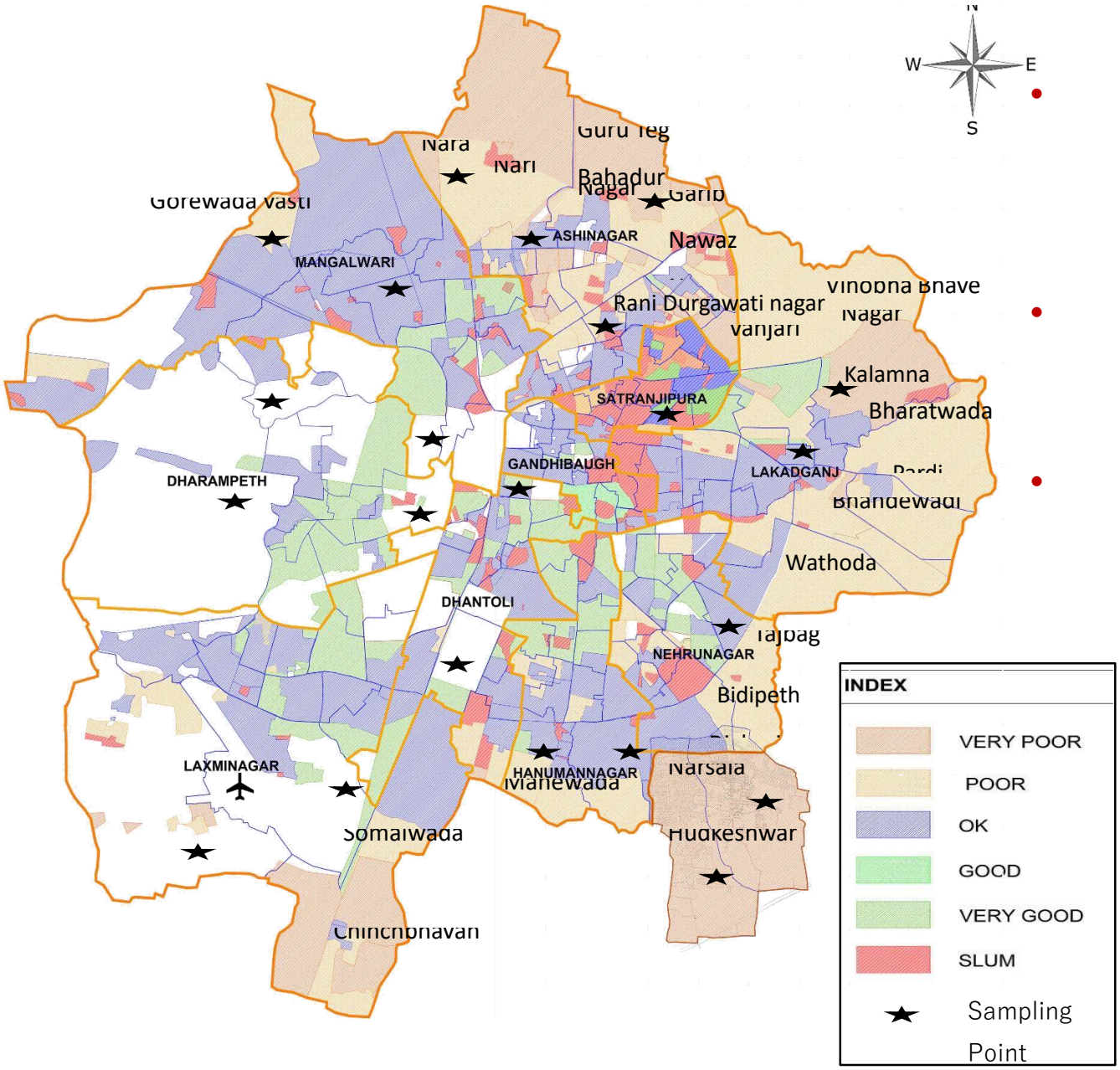


Figure 5.3: Socioeconomic Zones Wise Map of Nagpur City

5.4.3 Methodology Adopted for Sampling of MSW

Physical Characteristics of MSW was ascertained through 'quarter coning method' following CPHEEO guidelines 2000 as the data of waste composition is essential for evaluating feasible techniques for treatment.

The procedures followed for collection of MSW are presented herewith.

- Identification of major waste sample collection sites covering the entire city population.

- The sample collection points covered with all the type of areas, such as residential, commercial, markets (vegetable market) and slums.
- Identification of sampling points based on economic status of the areas, such as high, middle and low income group localities.
- Collection of about 5 kg of MSW from all the identified points.
- All the samples collected were heaped at one place and mixed thoroughly. MSW sampling procedure through quartering method is illustrated in **Figure 5.4.**
- The heaped samples were sieved for determination of particle size with use of 150 mm trommel.
- One quarter of the thoroughly mixed heap was taken out and the quarter portion was again thoroughly mixed and further quarter portion of it was taken out.
- Samples collected for physical and chemical analysis were double bagged in plastic bags, sealed and brought to the CSIR-NEERI laboratory for analysis. Each samples were the range 1-2 kg.

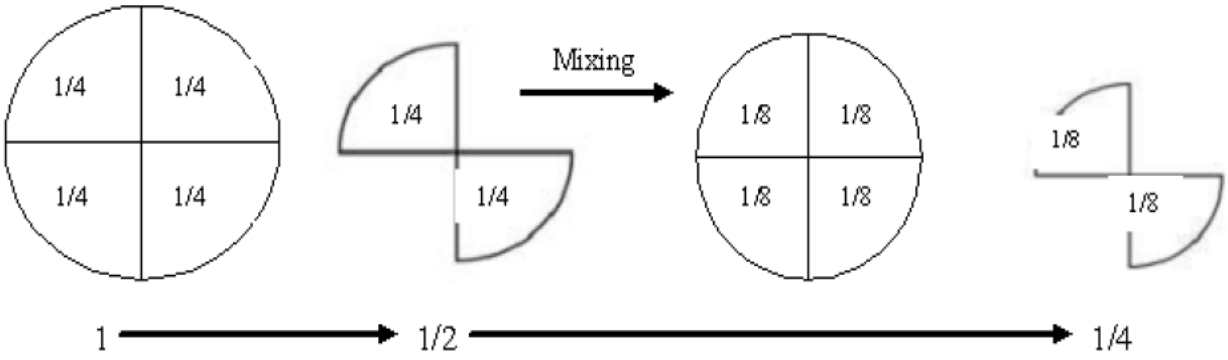


Figure 5.4 MSW Sampling Procedure through Quartering Method

5.5 Physical & Chemical Characterization

5.5.1 Estimation of Different Components of MSW

Manual segregation of MSW sample was carried out for each group near the waste management park in CSIR-NEERI Nagpur after collecting the MSW sample from different socio-economic groups.

Figure 5.5 Sampling Procedure through Quartering Method

5.5.2 Physical Characterization of MSW

MSW samples were collected from the different socio-economic groups i.e. HIG, LIG, MIG covering all the ten zones of the city. Physical characteristics were carried out at CSIR-NEERI. The representative samples were collected from the secondary collection points for all the representative groups. The average data of samples along with their physical characteristics have been shown in Table 5.1

Table 5.1 Physical Characteristics of MSW collected from different socioeconomic group.

Socio-Economic Group	Category	%	Remarks
LIG	Organics	59.27	Total sample collected from 7 locations Total Weight of sample = 14 kg approx
	Paper	2.65	
	Plastics	16.54	
	Metals and glasses	1.69	
	Inerts	19.85	
MIG	Category	%	Total sample collected from 8 locations

	Organics	71.59	Total Weight of sample = 19 kg approx
	Paper	3.36	
	Plastics	2.1	
	Metals and glasses	2.45	
	Inert	20.5	
HIG	Category	%	Total sample collected from 8 locations Total Weight of sample = 17 kg approx
	Organics	68.23	
	Paper	6.54	
	Plastics	14.36	
	Metals and glasses	2.47	
	inert	8.4	

Waste composition is an important factor in the selection of an appropriate waste management system. **Figure 5.6** shows the typical waste composition of MSW in different socio-economic groups of Nagpur (w/w basis). The LIG is mostly observed to produce less amount of waste containing mostly the organics, plastics and inert, whereas MIG & HIG are observed to produce the higher amount of waste as compared to the LIG.

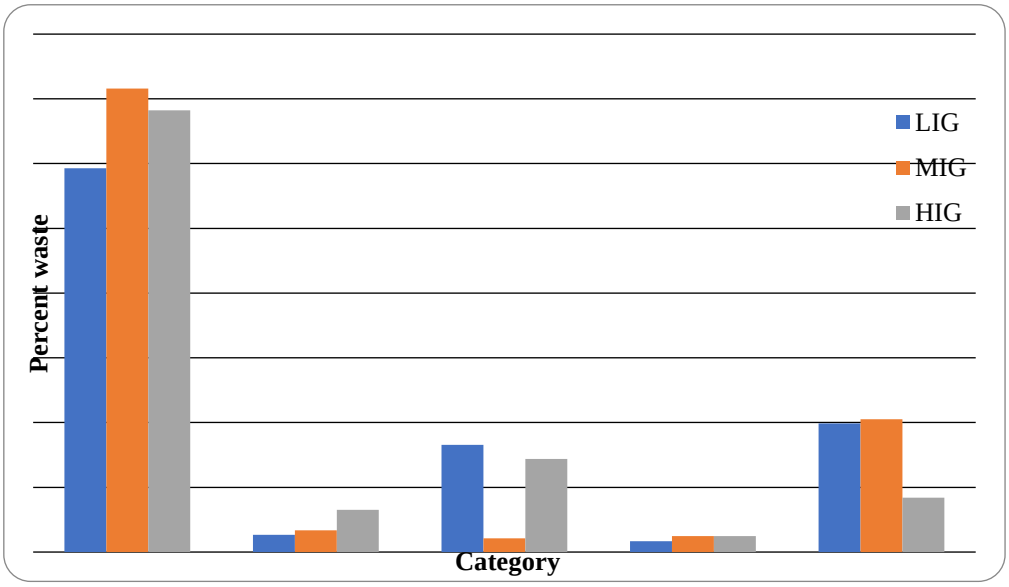


Figure 5.6 Graphical representations of Physical characteristics of different socioeconomic group

5.5.3 Chemical Characteristics of MSW

The MSW samples were characterized for various parameters, such as pH, moisture Content, total solids, loss on ignition, ash, carbon (C), calorific value, nitrogen(N), &C/N ratio which

were analyzed using standard methods. Methods of chemical characteristics for MSW are presented in Table 5.2 and the results for each category are shown in Table 5.3.

Table 5.2 Standard Methods used for Analysis of Different Parameter in NEERI

Sl. No.	Parameter	Methods Adopted
1.	pH	Gravimetric (IS 10158:1982)
2.	Moisture Content	Gravimetric (IS 9235:1979)
3.	Total Volatile Solids	Gravimetric (IS 10158:1982)
4.	Ash Content	Gravimetric (IS 10158:1982)
5.	Carbon Content	Combustion (Pregal-Dumas Method)
6.	Nitrogen Content	Combustion (Pregal-Dumas Method)
7.	Calorific Value	Calorimetric (IS 1350 [Part II] 1970)

Table 5.3 Chemical Characteristic of waste for three different socioeconomic categories

Socio-economic Group	Sample location	MC	TS	Loss on Ignition	Ash	pH	Carbon	Nitrogen	Calorific Value (kcal/kg)
LIG	Hudkeshwar	82	18	84.17	15.84	6.2	48.82	1.58	3980
	Narsala	84.87	15.13	81.68	18.32	5.9	18.32	2.4	3985
	Nara	83.79	16.21	78.61	21.4	6.0	45.6	1.72	3983
	Bahadur Nagar	80.64	19.32	80.13	19.87	6.8	50.8	1.76	3683
	Kalamana	80.68	19.36	79.07	20.07	5.9	45.86	1.94	3693
	Satranjipura	83.49	16.51	77.16	22.85	5.8	44.75	1.89	3685
	Gorewada Vasti	79.55	20.45	78.74	21.26	5.6	45.66	1.94	3876
MIG	Mangalwari	71.28	28.73	80.04	19.96	6.1	43.69	1.18	3879
	Manewada	73.52	26.49	86.68	13.32	5.9	47.22	1.13	3983
	Hanuman Nagar	72.1	27.9	82.25	17.75	5.8	42.16	1.41	3789
	Lakadganj	75.42	24.58	79.28	20.72	4.3	43.19	1.54	3683
	Ashi Nagar	71.97	28.03	77.21	22.8	5.1	42.2	1.42	3986
	Gandhibaugh	72.87	27.13	75.51	24.5	6.7	41.45	1.71	3876

	Nehru Nagar	71.77	28.23	78.54	21.47	6.8	42.29	1.29	3693
	Rani Durgavati Nagar	75.35	75.35	81.58	18.42	7.2	41.8	1.4	3609
HIG	Dharampeth	67.46	32.54	83.26	16.74	6.8	45.65	2.03	4182
	Ramdaspeth	66.74	33.26	81.24	18.76	7.0	46.45	2.29	3899
	Dhantoli	64.11	35.89	80.06	19.94	7.2	44.16	2.12	4005
	Sadar	70.06	29.94	79.1	20.9	7.4	43.25	1.83	4056
	Lakshmi Nagar	70.89	29.11	80.14	19.86	7.6	45.31	1.46	4075
	Bharatwada	65.46	34.54	74.11	25.89	7.7	41.46	1.76	3922
	Pande layout	71.46	28.54	76.22	23.78	7.9	42.78	1.91	4013
	Bharat Nagar	68.44	31.56	81.29	18.71	8.1	45.96	1.75	4076

5.6 Bhandewadi Landfill Site

Bhandewadi landfill in Nagpur was started in the year 1958. Initially, disposal of MSW was being carried at different sites scattered in the city. The geographical location of Bhandewadi landfill site (latitude and longitude) is 21º08' 26.1" N & 79º07'13.8" E (Figure 5.7) and situated at an elevation of 314.79 m above MSL. The focus of the current study is at the Bhandewadi landfill site which is situated in the outskirt that is the southeast corner of the Nagpur city (Figure 5.8). The site receives wastes from residential, commercial, institutional and market areas. Nagpur Municipal Corporation owned the land of about 184.22 ha, the area for disposal of MSW is approximately 21.57 ha. For composting and installing weighbridge etc., 19.64 ha land was utilized.

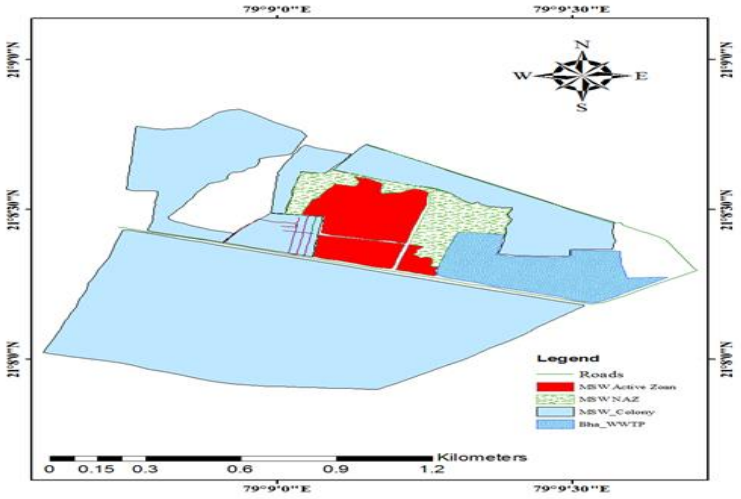


Fig. 5.7 Map of Study area (Bhandewadi Landfill Site)

(a)

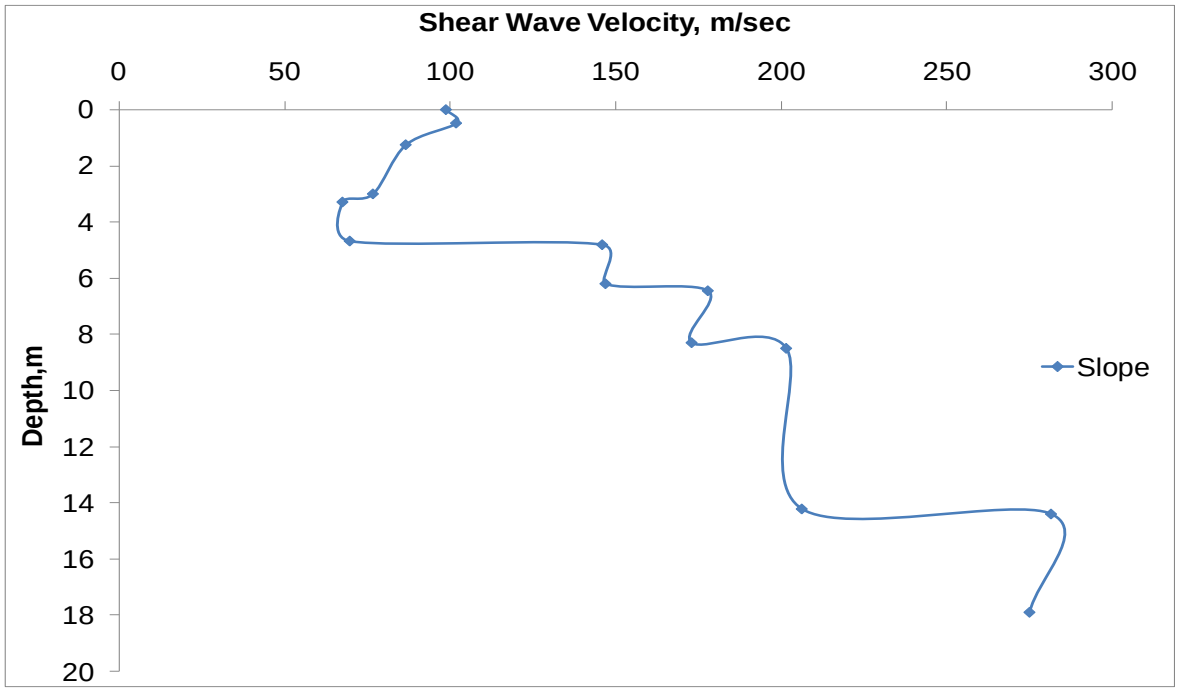
(b)

Fig. 5.8 (a & b) Images captured by drone at Bhandewadi Dumpsite, Nagpur

Fig. 5.9 Images of the active site at Bhandewadi landfill

5.6.1 Seismic Survey at Bhandewadi Landfill Slope

MSW materials are dumped in the landfill. The waste is spread and compacted in cells and layers within a confined area. At the end of the day, the area is covered completely with a thin, continuous layer of daily cover material and is then compacted. The purpose of the daily cover is used to control moisture content, litter, reducing odours, and limiting contact from rodent and birds. It helps for the access of vehicle and prevents fires. In the present study, MSW testing was carried out at Bhandewadi landfill slope. Steep cover slopes are provided in the landfill to maximize the quantity of waste which can be accommodated. The purpose of providing steepness in the slopes of a landfill is to minimize the shearing resistance between components of cover systems. The soil inside the slope is uncompacted solid waste up to 10meters of depth. This results in 1-D shear wave velocity profile from MSW survey as shown in Figure 5.11. The shear wave velocity varies from 80 to 160m/s (frequency ranges 35 to 28Hz) to 5m depth. With the increase in depth 17.5m, the shear wave velocity increase from 160 to 280m/s (frequency range 28to 8Hz). This slope is considered as a soft soil.



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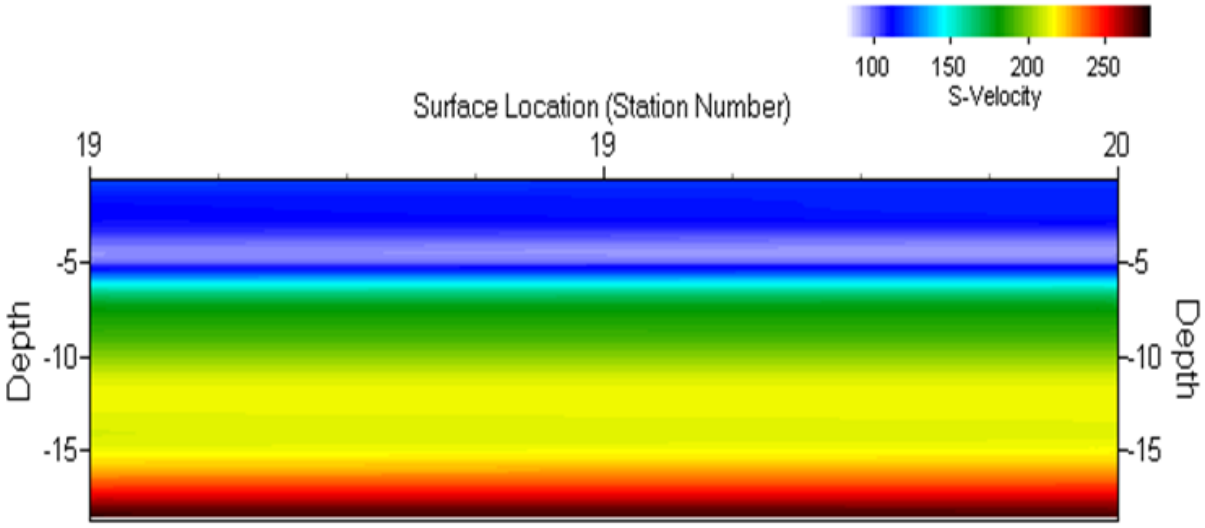


(b)

Fig. 5.10 Results of Seismic Survey at Bhandewadi Landfill site, (a) 1-D Vs profile for landfill slope (b) 2-D Vs profile for landfill slope

5.6.2 Ambient Air Quality Monitoring at Bhandewadi Landfill Site

Ambient air quality in the vicinity of solid waste dumpsites is presented in Table 5.4. Suspended particulates matter refers to particles suspended in the atmosphere, and can remain suspended for a long period where they are a key component of air pollution and smog. Particulates affect human health as they can easily reach the deepest recesses of the lungs leading to respiratory ailments according to the National Air Quality Guidelines. The levels of

particulate matter like (PM_{10} and $PM_{2.5}$) in the study area ranged between 55-73 and 28-41 µg/m3 which indicated that the particulates present in the atmosphere were less than the regulatory limit of 100 and 60 µg/m^3. Nitrogen dioxide (NO_2) is a reddish-brown toxic gas with a characteristic sharp, biting odour. There is some evidence that long-term exposure to NO_2 at concentrations above 40 - 100 µg/m^3 might decrease lung function and increase the risk of respiratory symptoms. NO_2 emissions, in particular, are environmentally relevant as it is a greenhouse gas (GHG) with a global warming potential of 300 times than that of carbon dioxide (CO_2). Of the Swedish contribution to the greenhouse effect, about 9% comes from the NO_2 emissions from landfills. The levels of NO_2 in the study area ranged between 6 - 10 ug/m^3which is below the regulatory limits of 80 ug/m^3. Sulphur dioxide (SO_2) is a major air pollutant and has significant impacts on human health. Inhaling SO_2 is associated with increased respiratory symptoms and disease, difficulty in breathing, and premature death. Also, the concentration of SO_2 in the atmosphere can influence the habitat suitability for plant communities as well as animal life. SO_2 emissions are a precursor to acid rain and atmospheric particulates. The levels of SO_2 in the study area ranged between 4-10 ug/m^3 which is below regulatory limits of 80 ug/m^3. Ammonia (NH_3) is a colourless LFG that is produced by the decomposition of organic matter in the landfill. People are exposed daily to low levels of NH_3 in the environment from the natural breakdown of manure and dead plants and animals. In small concentrations, the gas is detectable by its sharp smell. In high concentrations, the gas is an immediate hazard to life. Ammonia is flammable with its lower explosive limits of 15% and its upper explosive limit of28% and it can pose an explosion hazard. Within the vicinity of the dumpsite, ammonia concentration ranges from 25 to 86 ug/m^3. Reported readings are below the regulatory of 400 ug/m^3.

Methane (CH_4) is an odourless gas and is lighter than air. Hence, it tends to rise and accumulate near the higher, stagnant parts of enclosed buildings and tightly closed manure storage pits. CH_4 is a major GHG. It is produced during anaerobic decomposition of manure and accumulates around manure storage areas. CH_4 can explode at concentrations of 50,000 ppm or more (a level of 5%). Methane is the constituent of LFG that is likely to pose the greatest explosion hazard. Methane is explosive between its lower explosive limit (LEL) of 5% by volume and its upper explosive limit (UEL) of 15% by volume. Approximately 50 percent of gas emitted from landfills is CH_4; CO_2 accounts for about 45 percent, and the remainder is composed of nitrogen, oxygen, hydrogen, and other gases. The levels of CH_4 in the study area ranged between 60.9 to 66.2 mg/m^3 which shows that the molecules present in the atmosphere were less than the regulatory limit of 654.4 mg/m^3 (1000ppm). The Occupational Safety and

Health Administration (OSHA) has no permissible exposure limit for CH_4, but the National Institute for Occupational Safety and Health's (NIOSH) maximum recommended safe methane concentration for workers during an 8-hour period is 1000 ppm (0.1 percent). CH_4 is considered as an asphyxiant at extremely elevated levels of 500,000 ppm and can displace oxygen in the blood at a concentration of 1000 ppm.

5.6.3 Dispersion Model

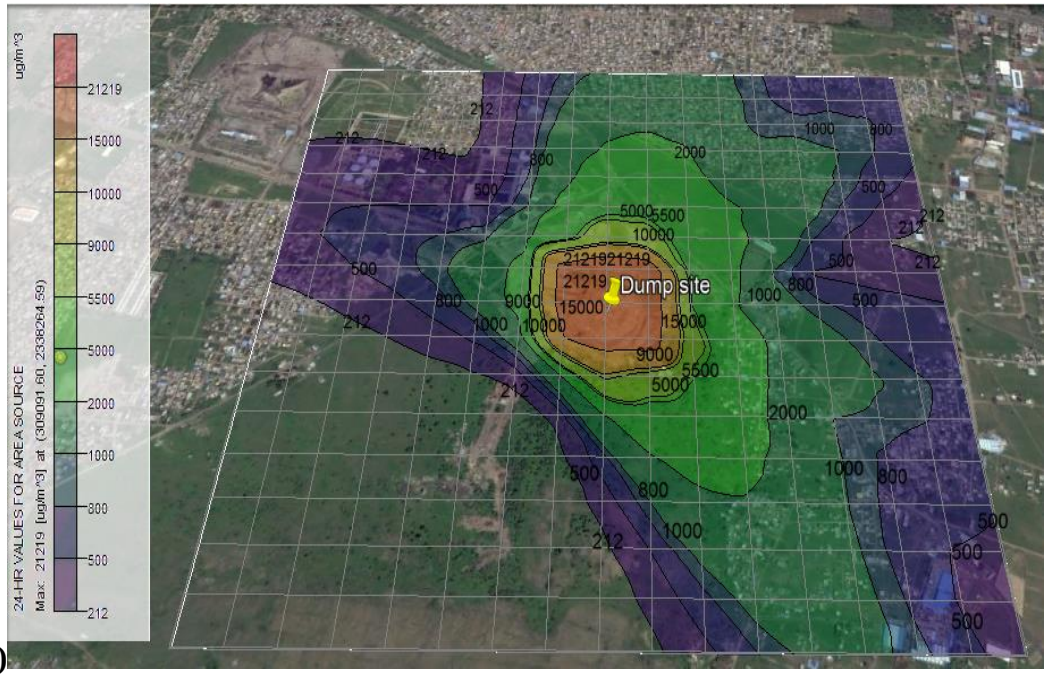
Meteorological area of 1.5 km x 1.5 km with a sub-grid cell size of 100 m x 100 m was prepared. Meteorological data of winter and summer seasons from 2016-17 were processed for simulation at an hourly interval. The main criteria pollutant, expected to be released from the area source of dumping yard LFG. Therefore, simulation of LFG regarding CH_4 is carried out. All the required data was fed into the model and Ground Level Concentration (GLC) of CH_4 was predicted for the study period using only area source.

Gaussian Plume Model has been followed in the survey. The modeling was carried out using the software AERMOD developed by Lakes Environments and certified by the US-Environment Protection Agency (USEPA). The software meets the requirement of CPCB and calculates worst-case scenarios like 24-hour average values (Short Term). Maximum GLC for 24-hour average during summer and winter season was found to be 21.2 mg/m^3 and 38.1 mg/m^3 respectively (Figure 5.11 – Figure 5.12) at the source. Along with the wind, the elevated terrain and land use play a significant role in the dispersion of pollutants. The concentration of CH_4 gradually decreased to 5.5 mg/m^3 and 8.5 mg/m^3 at a distance of 300 m away from the center.

Table 5.4 Air quality data during the the study period

Sampling no.	**Unit in µg/m^3**					**Unit in mg/m^3**
Sr. No.	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**NO_x**	**NH_3**	**CH_4**
	Avg. ± Std.	**Avg. ± Std.**	**Avg. ± Std.**	**Avg. ± Std.**	**Avg. ± Std.**	**Avg. ± Std.**
1	65±24	37±13	8±5	6±3	52±19	63.8 ± 2
2	64±22	36±12	10±5	7±3	53±10	61.9 ± 4
3	73±20	41±12	8±5	8±5	32±13	66.2 ± 4
4	63±25	35±13	8±3	6±3	60±15	64.9 ± 4
5	69±14	31±12	4±2	10±6	74±21	65.9 ± 4
6	66±17	31±11	6±3	8±5	86±19	65.9 ± 3
7	55±19	28±12	5±2	7±4	25±8	62.9 ± 3

8	63±26	35±14	8±4	6±4	60±16	61.9 ± 4
9	69±15	31±10	4±3	10±7	74±22	60.9 ± 4
10	66±18	31±9	6±4	8±6	86±20	64.9 ± 4



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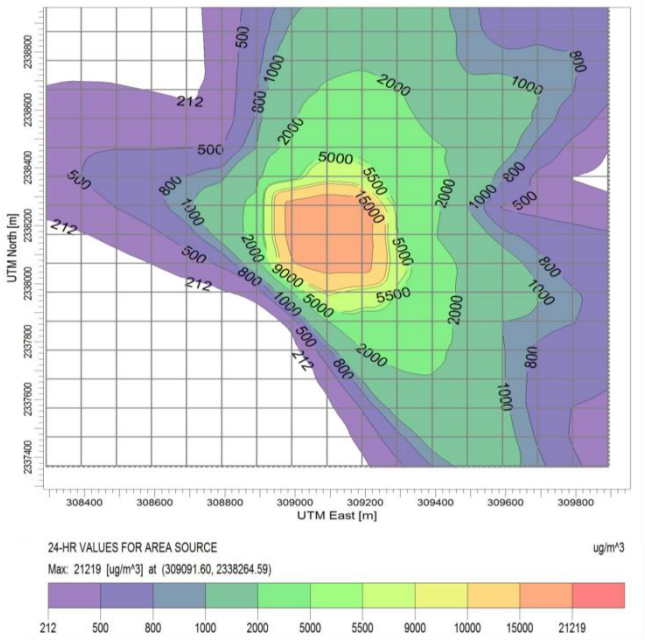

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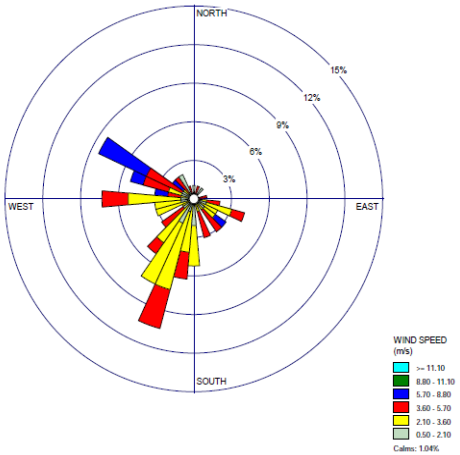
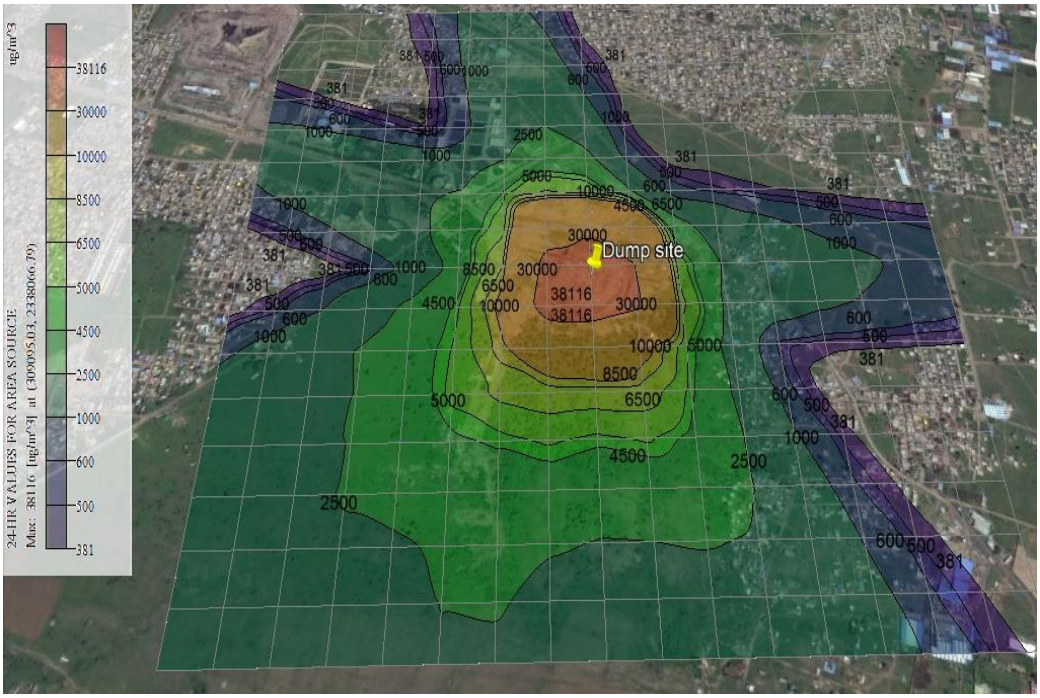


(c)

Fig. 5.11 Summer season dispersion of CH_4 over (a) base map (b) 100 m grid cell and (c) wind rose



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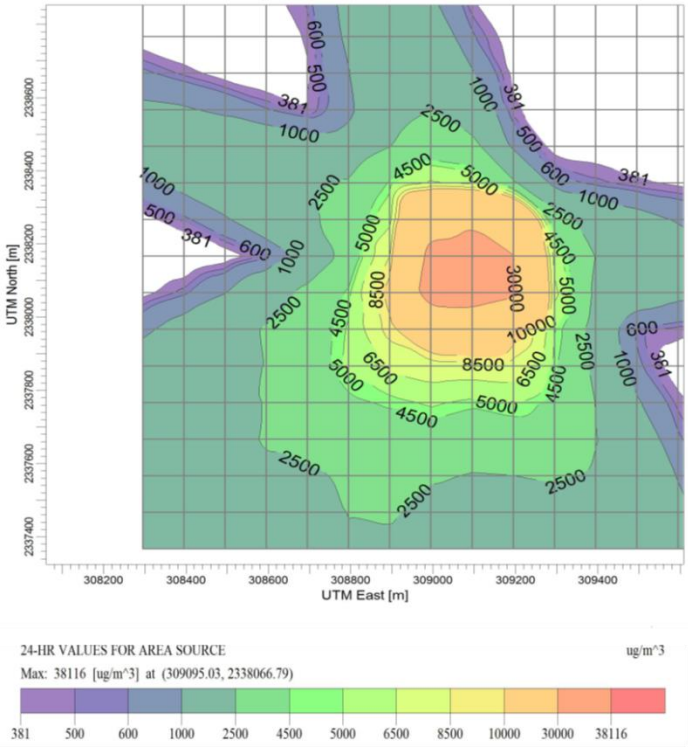

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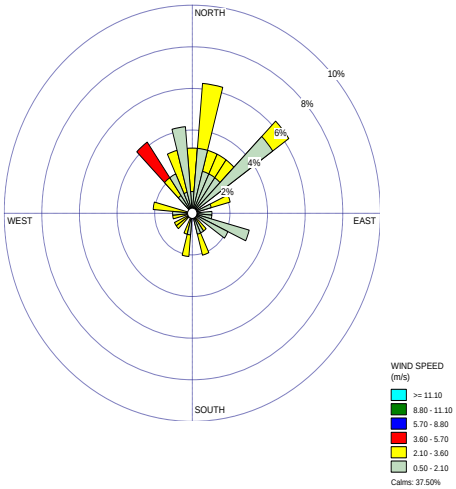

(c)

Fig. 5.12 Winter season dispersion of CH_4 over (a) base map (b) 100 m grid cell and (c) wind rose

As per the analysis, the dispersion of air pollutants will reach maximum upto 237 meters from the disposal site. Hence a buffer zone of around 250 m from the landfill may be considered so that there is no hazard due to the migration of the contaminants through the air.

5.6.4 Horizontal Migration of Pollutants through Soil at Bhandewadi

In this analysis, the horizontal migration of chlorides through a clay liner was studied using a software "**POLLUTES".** The input parameters were as given below

Avg. Heavy Metals Concentration = 1468 mg/L

Volume of Leachate Collected = 0.05724 m/a

Width of Waste = 500 m

Waste Density = 600 kg/m^3

Proportion of Mass = 0.2

Hydrodynamic dispersion coefficient = 0.02 m^2/a

Distribution coefficient of clay liner = 1ml/g

A model was created in POLLUTE with waste and a clay liner and the horizontal migration of pollutants was analyzed. The heavy metals concentration in the leachate generated from the landfill was considered as 1468 mg/L. Four-time periods were considered viz 1 year, 5 years, 10 year and 25 years. The concentration at the end of considered time periods and the horizontal distance of migration is shown in Figure 5.13.

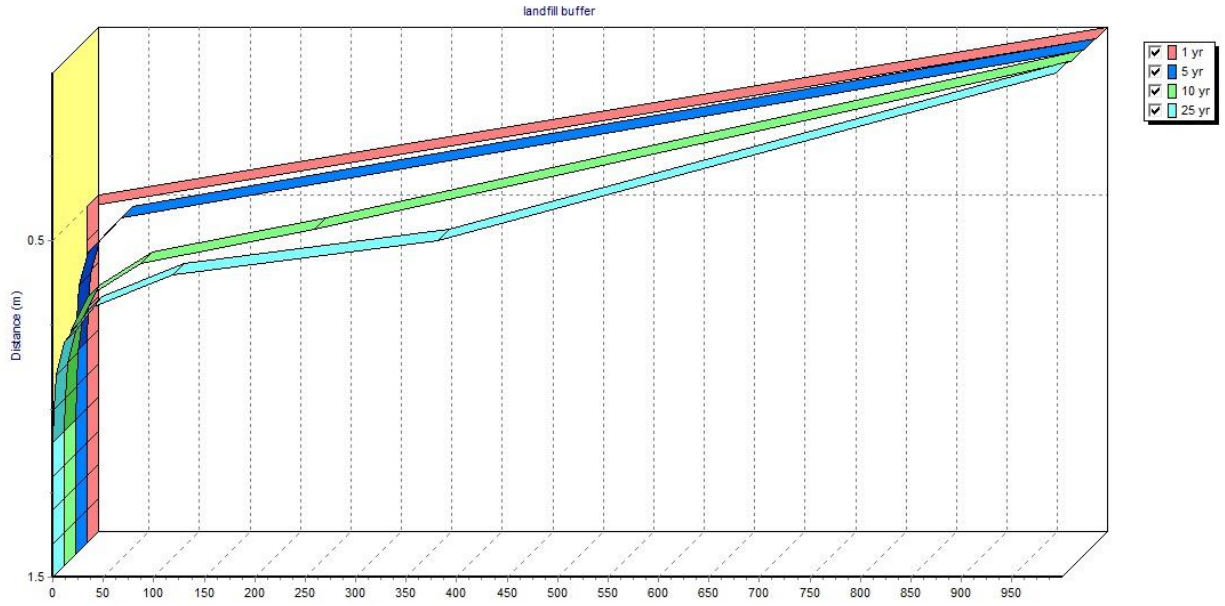

Fig. 5.13: Horizontal Migration of Pollutants through Soil

It is evident from the Figure 5.14 that at the end of 25 years the pollutants migrate to a maximum distance of 0.8m. The maximum horizontal outflow at the surface is 0 m/a and at a depth of 0.5 m below the landfill is 1m/a. (also discussed in ESR 2018-19)

Therefore, it is clear from the analysis that the migration of pollutants through the soil in ground-water will reach up to 410 meters and with an increase in quantum of waste being dumped at Bhandewadi, it might increase.

5.7 Biomining

Nagpur Municipal Corporation (NMC) signed an agreement with **M/s Zigma Global Environ Solutions Private Limited** in October 2019 for biomining of legacy waste dumped at Bhandewadi. As per the agreement, M/s Zigma Global Environ Solutions Private Limited will be treating 10 lakhs metric tonnes (MT) of solid waste in three years.

The MSW is lying in over 60 acres of land at Bhandewadi. the M/s Zigma Global Environ Solutions Private Limited is going to carry out bio-mining at about 56 acres of land. If the waste lying at this land turns out to be less than 10 lakh MT, then it will extend the process to the land where solid waste is currently being dumped.

The MSW is being treated by bio-remedation initially, which reduces the volume of waste by almost 40%. The site workers have already segregated recyclable waste materials. Now, the remaining waste will be segregated at the plant. Maximum part of the waste will be used to obtain refuse derived fuel (RDF), which will be given to cement factories. Apart from this, the process will also produce soil which can be provided to the farmers

Apart from bio-mining, NMC will also be commissioning a waste-to-energy project at Bhandewadi, which is said to be the third-of-its-kind in the country. About two months back, Essel Infraprojects Private Ltd assured the civic body that it would begin work on the project within a month and commission it by end of 2020.

5.8 Landfill Fire

Incidents of Fire at landfill site are also common during summer days. The latest incident of May 23, 2020, entire dumping yard was up in flames burning around 10-12 windrows of solid waste created for bio-composting were destroyed. In fire incident of April 2018, 20 windrows spread over an area of 6-7 acres caught fire, informed the field staffers. According to NMC officials, one windrow holds around 70-80 metric tonnes of municipal solid waste. Further studies on the landfill fire of Bhandewadi landfill site are to be conducted and detailed study will be done.

5.9 Future Scope of Work

- To Study the waste generation pattern in all socio-economic groups, e.g., current and future, per capita waste generation, volume estimates and its variations, and composition of waste.
- Quantification of the leachate being generated at Bhandewadi Landfill site e.g. per day leachate generation

5.10 Summary

Municipal solid waste management (MSWM) is one of the major issues in developing countries like India due to increasing trends of population thereby increased generation of waste. The present solid waste management practices mainly focus on disposal of waste in low-lying areas (few sanitary landfills also) along with application of few treatment options in selected cities and towns. Composting, vermin-composting, anaerobic digestion, refuse derived fuel (RDF), incineration is also being attempted in the country. However, the waste to energy is getting priority due to scarcity of land and to avoid environmental and health threats. The waste to energy process also ensures quick disposal of waste besides avoiding long-term potential threat of landfill/dumpsites and their impacts on environment and health.

The adoption of the waste management hierarchy, viz., waste minimization, reuse, recycling, recovery of energy, treatment of containment and finally waste disposal in landfills, has shown the way of significant diversion of waste from accumulation of waste at landfills. Disposal of wastes in landfills is the least preferred management as it impacts on the surrounding environment severely. Landfill sites encompass waste processing/disposal facilities, which become sources of pollution in terms of air, water, land and noise pollution besides emitting foul smell.

Keeping in view of the importance of the better SWM practices in the city, CSIR-NEERI conducted the reconnaissance survey and the subsequent field work. The various socio-economic classes living in the city were identified and solid waste the generation from respective income groups was assessed. The Seismic Survey was also carried out at the Bhandewadi landfill site, determining the stability of the slope of the landfill. The horizontal migration of the pollutants such as trace metals through the soil liners were also assessed using the POLLUTE Modelling. The existing practices of the collection, transportation, treatment and disposal were thoroughly analyzed in line with the SWM rules 2016 and based on the observations recommendations were given Accordingly CSIR-NEERI has prepared the Environmental Status Report of the Nagpur city for based on the sampling and the actual data generated.

5.11 References:

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11 Swachh Sarvekshan is a survey was conducted by the Quality Council of India (QCI) under the Swachh Bharat Abhiyan to rank 500 cities across the country with a population of one lakh and above, on cleanliness, Annual Report, 2018-19.

CHAPTER 6:

ENVIRONMENTAL EXTERNALTIES EVALUATION FOR SOLID WASTE DUMPING AT BHANDEWADI DUMPING YARD, NAGPUR

ESR-2019-2020

CSIR-NEERI

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6.1 Introduction

Generation of waste is increasing day by day due to modernization in lifestyle of people, in developing countries and modern cities. Solid waste management is turning crucial due to increasing waste generation rate and complexity of handling the same in the present scenario. Municipal solid waste dump site possesses various adverse effects on natural environment mainly due to poor/obsolete waste handling technologies. Greenhouse gases (GHG) emissions, air & soil quality deterioration, leachate, etc are inevitable due to the illicit practices such as open burning and non-engineered dumpsites. These practices serve as breeding ground for disease vectors causing severe health issues. Solid waste management rules were setup based on the waste classes namely; Hazardous waste, Municipal waste, E-waste, Plastic waste, Construction and demolition, and Biomedical waste focusing on the type of treatment and disposal to be followed without disturbing the natural environment. World Bank (2016) reported that on an average, world cities for the year 2016, produced 2.01 Billion MT of waste, resulting in a footprint of 0.74Kg per person every day. The report also stated that due to rapid urbanization and industrialization, waste generation is expected to rise by 70% from current rate (i e., 2016 year) by the year 2050.

India roughly generates 1.5 lakhs MT of waste per day as of year 2019. Approximately 90% out of 1.5 lakhs MT, of the total amount is collected waste. Nearly 15,000 MT of garbage remain exposed every day, resulting in almost 55 lakh MT of solid waste disposed in open areas each year, which leads to "severe" pollution level (URL 05). Out of which 15000 MT of waste generated are plastic waste (URL 01). Of the total collected waste, only 20 per cent is processed and the remaining 80 per cent is dumped in dumping sites. PIB (2018) reported Urban India produces an estimated 54.75 million tonnes of municipal solid waste annually. PIB (2016) reported that India's waste generation is growing at 4% every year. Out of total collected waste segregated at source, 50% constitutes of organic waste, 35% as recyclable waste and remaining constitutes hazardous waste. Organic degradable waste generated from households, restaurants, etc is subjected to composting either at community level or by large scale authorized third parties. Recyclable waste constitutes of 2nd largest class consisting of paper, plastics, E-waste, etc. These are collected by third party authorized rag pickers from door to door approaches and are transported to recycling unit after segregation. Hazardous waste constitutes of industrial wastes, biomedical waste, etc are disposed into engineered dumping with suitable control strategies adopted to trap the GHG's emitted and leachate generated.

In order to manage solid waste effectively, segregation at source is the first key factor to be ensured followed by advanced treatment strategy and disposal. Waste segregated in cities of Delhi, Patna, Gurgaon, Gaya, Imphal is less than 33% Times of India (2018). Due to poor segregation at source, obsolete treatment technology, and unmanaged disposal methods adopted, natural environment and human well-being are prone to impacts. Impacts due to various waste handling process such as transportation, segregation, treatment, and disposal on environment and human benefits are evaluated on monetary basis using various approaches as to generate awareness among dwellers and policymakers to adopt strategic measures and stringent policy towards mitigation. Nagpur city is the third largest city in Maharashtra and second capital of Maharashtra. This city generates about 1000 MT of solid waste per day collected from different sources of waste like household waste, industrial waste etc. the whole waste collected from the different sources and disposed at Bhandewadi dumping site which is located 8km away from the Nagpur city.

This chapter focuses on environmental externalities evaluation for damages to environment and human well-being due to municipal solid waste dumpsite located at Bhandewadi, Nagpur. This chapter evaluated, damage cost due to emission of greenhouse gas (GHG) on climate change, damage cost due to conventional air pollutants on human health, damage cost due to percolation of leachate into soil. The major purpose of externalities is not to reduce the efforts of the developmental activities that are taking place, but as a strategy amount to be kept aside for maintaining sustainability of nature due to reluctant practices in waste handling & disposal followed by ensuring safe practice of treatment in municipal dumpsite from a future perspective.

6.2 Study Area

Nagpur is a city in the central part of India. In Maharashtra State Nagpur district is located between 21˚45’ N to 20˚30’ N and 78˚15’ E to 79˚45’, E, which essentially indicates that Nagpur district is located in the Deccan Plateau. It is situated at elevation 319 meters above sea level. Nagpur has a population of about 2,228,018 making it the 4th biggest city in Maharashtra. Nagpur City generate about 1000 tones and above garbage per day. All these wastes are collected and disposed into the dumping yard which is located at Bhandewadi at a distance of 8 km away from the city head quarter Nagpur. Bhandewadi yard in Nagpur was started in the year 1958. The dumping yard has an area of 22.0 hectors which is poorly managed. The geographical location of Bhandewadi site (latitude and longitude) is 21º08’ 26.1” N &

79º07’13.8” E (Figure 6.1). The main waste generated is from homes, markets from agricultural products, retail and commercial markets, slaughter houses and industries.

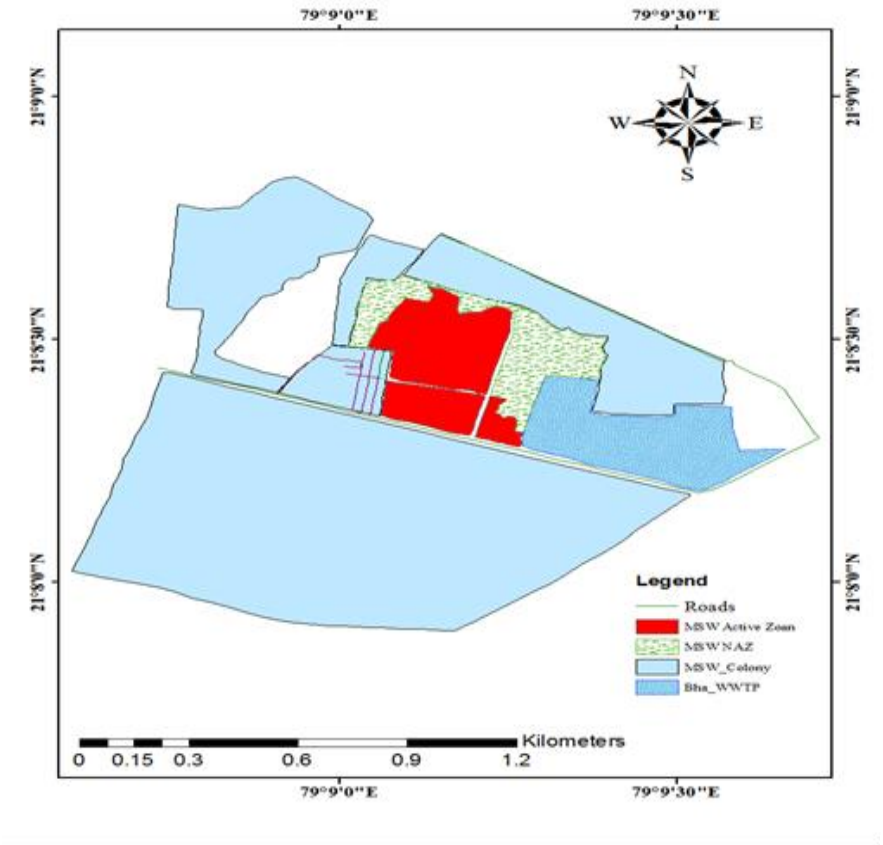

Figure 6.1 Map of Study Area of Bhandewadi Dumping Site

6.3 Methodology

The methodology section focuses on identifying, quantifying and evaluating negative externalities from dumping site at Bhandewadi as shown in Figure 6.2. The methodology followed to quantify and evaluate externalties due to impact drivers are based on onsite monitoring and several referral studies respectively (Bherwani et. al., 2019). Practically, considering all the resulting negative externalities into account from the municipal dumpsite is nearly impossible. Hence available methodology, which was developed to quantify the identified impacts and valuation of the same in terms of monetary losses/diminution were considered to calculate environmental damage cost.

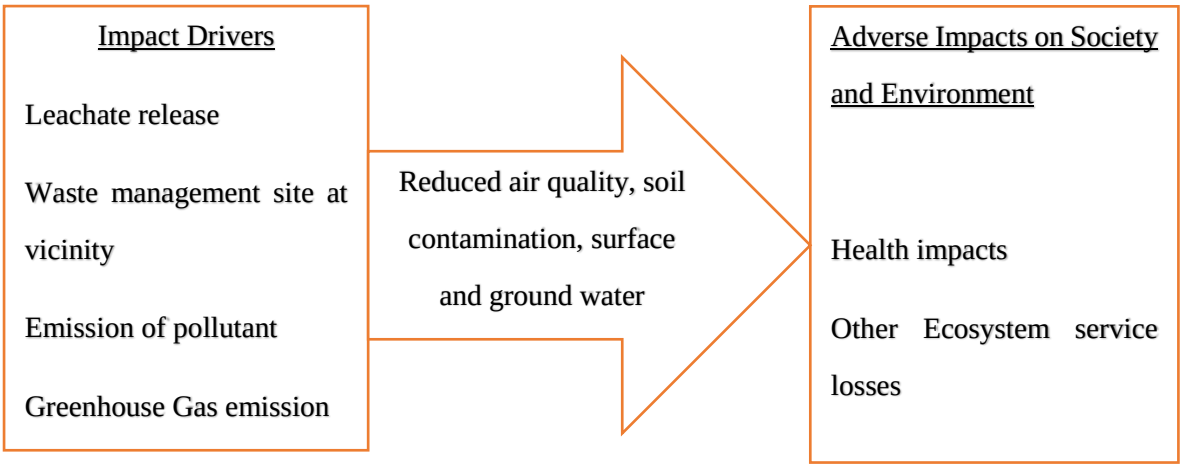

Figure 6.2 Externalities due to dumping site at Bhandewadi (Adapted from Bherwani et.al, 2019)

While identifying the overall negative externalities, the linking causalities on environment and human well-being due to the impact is determined simultaneously along with its pathway. Impact pathway methodology tracks the emission of pollutant from the source till the final impact on the receptor. The impacts from waste collection and extends even after being dumped into the dumping. Harmful emissions due to dumping affecting receptors such as human wellbeing, biodiversity & natural environment are dependent on parameters such as site-specific conditions (Eg: Meteorological condition, water quality, etc), emission type and exposure rate. The exposure of these impact, based on dependent parameters, has long term negative impact which is estimated in monetary terms.

Table 6.1 shows the likely impact due to emission from dumping on human wellbeing and natural environment. The likely occurring damages are identified in terms of measurable and non-measurable impacts. The intangible externalities due to odor and noise were evaluated indirectly in terms of aesthetic loss/disamenity cost.

Table 6.1: Overview of Damage/ Emission from the solid waste dumpsite

Damages / *Emissions*	Medium	Mortality	Morbidity	Soil Quality	Effect on agriculture crop yield	Water Quality	Climate changes	Disamenity
Particulate Matter	Air	×	×					(×)
NOx, SOx	Air	×	×					
CO	Air	×	×				×	
Leachate	Soil & Water	(×)	(×)	×	(×)	×		(×)
CH_4, CO_2	Air						×	
Odor	Air							(×)
Noise	Air	(×)	(×)					(×)

× - Tangible impacts, (×) – Intangible impacts

MSW samples were collected from the different socio-economic groups i.e. HIG, LIG, MIG covering all the ten zones of the city as given in Solid Waste Chapter 5. Physical characteristics were carried out at CSIR-NEERI. The representative samples were collected from the secondary collection points for all the representative groups. The average data of samples along with their physical characteristics are divided into three groups and are given in the Solid Waste Chapter 5 and Annexure I.

6.4 Assessment of Solid Waste Externalities For Bhandewadi Dumping Site

6.4.1 Air Quality

People who are living in and around the dumping site can be subjected to the various issues which may lead to mortality/morbidity, due to the release of pollutants such as SOx, NOx, CO, PM_{10}, and $PM_{2.5}$ from solid waste processing steps. Monitoring and damage assessment have been carried for above pollutants. The identified emission sources are during the collection of waste by vehicles, decomposition of Municipal Solid Waste (MSW) open burning near the dumpsite. Damage estimated is based on emission rate and level of exposure of the people living in and around the site. Health issues are not limited to deteriorated air quality but also by consumption of water contaminated with heavy metals through leachate.

Health Externalities such as respiratory diseases, chronic obstructive pulmonary diseases (COPD), cardiovascular diseases and mortality are likely to be occurred due exposure of pollutants like particulates, NOx, SOx are estimated using WHO-approved methodologies. The threshold values for air pollutants were considered as per the NAAQS permissible limit (NAAQS, 2009).

Mortality and morbidity damage due to air pollutants are evaluated using value of statistical life/ cost of illness method respectively (Bherwani et. al., 2019; Maji et al., 2017). Various morbidity impacts such as respiratory diseases, chronic obstructive pulmonary diseases (COPD), and cardiovascular diseases were considered for monetary damage estimation. Health risk assessment is calculated using factors such as relative risk, baseline incidence and equations suggested by (Maji et al., 2017; Balakrishnan et al., 2011; Dholakia et al., 2014; Zhang et al., 2010b; Shang et al., 2013; Lai et al., 2013; Chen et al., 2010; Wong et al., 2008). Relative risk is the probability that a person is likely to develop diseases via exposure to that of person developing the same diseases without the exposure towards air pollutants (Rothman et al., 2008).

- **Ambient Air Quality Monitoring at Bhandewadi Dumping Site**

Ambient air quality in the surrounding a particular place of solid waste dumpsites is presented in Table 6. 2. Suspended particulates matter refers to particles suspended in the atmosphere, and can remain suspended for a long period where they are a key component of air pollution and smog. Particulates affect human health as they can easily reach the deepest reaches of the lungs leading to respiratory ailments according to the National Air Quality Guidelines.

Table 6.2: Predicted Concentration of Pollutant Emitted from Dumping Site

Sampling no.	Unit in µg/m^3					Unit in mg/m^3
Sr. No.	PM_{10}	$PM_{2.5}$	SO_2	NO_x	NH_3	CH_4
	Avg. ± Std.	Avg. ± Std.	Avg. ± Std.	Avg. ± Std.	Avg. ± Std.	Avg. ± Std.
1	65±24	37±13	8±5	6±3	52±19	63.8 ± 2
2	64±22	36±12	10±5	7±3	53±10	61.9 ± 4
3	73±20	41±12	8±5	8±5	32±13	66.2 ± 4
4	63±25	35±13	8±3	6±3	60±15	64.9 ± 4
5	69±14	31±12	4±2	10±6	74±21	65.9 ± 4
6	66±17	31±11	6±3	8±5	86±19	65.9 ± 3

7	55±19	28±12	5±2	7±4	25±8	62.9 ± 3
8	63±26	35±14	8±4	6±4	60±16	61.9 ± 4
9	69±15	31±10	4±3	10±7	74±22	60.9 ± 4
10	66±18	31±9	6±4	8±6	86±20	64.9 ± 4

6.4.2 Soil & Water Quality

Soil and water (Ground/Surface) is contaminated due to leaching of leachate due to poor lining or by direct discharge of leachate without treatment. Either of cases, various trace metals such as Lead (Pb), Cadmium (Cd), Mercury (Hg), dioxins, Antinomy (Sb), Arsenic (Ar), Barium (Ba), Beryllium (Be), Copper (Cu), Chromium (Cr), Nickel (Ni), selenium (Se) and Zinc (Zn) are found in considerable amount affecting the quality of soil and water. After-effects of the contamination in terms of both environmental and health effects are taken into account for the valuation of damage.

- **Damage cost due to release of leachate into soil**

Fruit and vegetable bearing plants have tendency to extract minerals and nutrient from soil during their growth. Similarly, heavy metals from leachate contaminated soil will be taken up by plants generating an inventory of heavy metals beyond safety limits in fruits and vegetable which when consumed by humans result in health damages. (ExternE, 1995) has suggested damage cost value as in Table 6.3 based on avoided cost method with respect to presence of heavy metals in soil and its impact on environmental values/indices. Due to non-availability of Indian studies related to environmental externalities, European values have been suitably adopted in Indian scenario and used for the current study. Further, the heavy metal concentrations have been taken as it is as there are not India specific soil standards. It is assumed that higher heavy metals than the baseline limit are due to percolation from leachate being discharged into the land. Table 6.4 gives the physico-chemical properties of leachate which have been used in damage cost assessment in comparison to standards/guidelines

Damage due to heavy metal (A) = Concentration of A (Kg/l) x Leachate quantity (L) x Damage Cost due to heavy metal A x Exchange rate x Inflation …Eq. (1)

Where, Exchange rate for 1 EUR = 23.3993 INR as of 1995 (Indian rupee exchange rate history).

Inflation rate from year 1995 to 2019 = 4.81 (Inflation calculator)

Table 6.3: Damage cost due to emission of heavy metal pollutants per Kg into the soil

Pollutant per Kg	Damage cost (Euro, 1995)
Lead (Pb)	5
Cadmium (Cd)	1514
Barium (Ba)	37
Copper (Cu)	1
Chromium (Cr)	320
Nickel (Ni)	4
Zinc (Zn)	1

Table 6.4: Physio – Chemical and Heavy Metal Properties of Leachate Near Dumping Site

Sr.No	Parameter Name	Dumping Leachate (Summer)	Dumping Leachate (Winter)	Dumping Leachate (Monsoon)	Leachate disposal standards for Inland Surface Water*	Leachate disposal standards for land*
1	Colour	Dark Brown	Brown	Pale Brown	-	-
2	pH	8.1	8.9	7.9	5.5-9.0	5.5-9.0
3	Total Solids (mg/l)	1064	829	564	2200	2300
4	Total Dissolved Solids (mg/l)	6026	5925	1848	2100	2100
5	COD (mg/l)	2259	1510	1190.36	250	-
6	BOD_5(mg/l)	677.7	270	137.23	30	100
7	TKN (mg/l)	110.98	35.65	28.12	100	-
8	$N\text{-}NH_4^+$ (mg/l)	96.12	21.34	17.34	50	-
9	SO_4^{2-} (mg/l)	66.23	42.25	35.03	No Standard	No Standard
10	Cl^- (mg/l)	2943	2145	1648	1000	600
11	Cd (mg/l)	-	-	0.0123	2	-
12	Co (mg/l)	-	-	0.0451	No Standard	No Standard
13	Cr (mg/l)	0.1508	0.0231	0.0839	2	No Standard
14	Cu (mg/l)	60.3386	45.2556	31.194	3	-
15	Fe (mg/l)	202.887	201.406	138.52	No Standard	No Standard
16	Mn (mg/l)	0.0933	0.0499	1.019	No Standard	No Standard

17	Mo (mg/l)	0.09958	0.02988	-	No Standard	No Standard
18	Ni (mg/l)	-	0.007679	0.03165	3	-
19	Pb (mg/l)	0.03949	0.01263	0.08593	0.1	-
20	Se (mg/l)	0.0102	0.003929	-	No Standard	No Standard
21	V (mg/l)	0.004261	0.01001	-	No Standard	No Standard
22	Zn (mg/l)	1.011	0.159	0.1191	5	-
23	Total Coliform Bacteria (CFU/mL)	19885	15630	11763	No Standard	No Standard

There are certain assumptions which have gone into the analysis while evaluating environmental damages cost assessment (EDCA):

Due to limited data availability the estimation of leachate quantity has been done using empirical equations. Further, it is presumed that the leachate is contaminating only the soil and not the ground water.

The estimation of EDCA are based on value transfer method using appropriate conversion factors with an underlying assumption that the transfer site adheres to conditions of the original site for value transfer to be applicable

The estimates are to be considered as conservative estimates as detailed site analysis is to be carried out to understand the extent of damage. The present study is based on data collated for the ESR and has its own limitations. The EDCA needs extensive site survey in reference to its context.

6.5 Result and Analysis

6.5.1 Damage cost due to air pollution

From the Table 6.2, it can be noted that pollutants emitted from the dumping site are within the limits as per NAAQS concentration. Hence, no health Externalities are likely to occur due to release of pollutant. The maximum ground level concentration in the study area is ranged from 55-73 µg/m^3 for PM_{10} and 28-41 µg/m^3 for $PM_{2.5}$ which shows lesser than the regulatory limits given by the NAAQS. The levels of NO_2 ranged between 6 - 10 ug/m^3which is below the regulatory limits of 80 ug/m^3. The levels of SO_2 ranged between 4-10 ug/m^3 which is below regulatory limits of 80 ug/m^3. Within the vicinity of the dumpsite, ammonia concentration ranges from 25 to 86 ug/m^3. Reported readings are below the regulatory of 400 ug/m^3.

6.5.2 Damage cost due to the release of leachate in to the soil.

Leachate, when released untreated, not only contaminates water bodies, but also soil quality. Continuous discharge of untreated leachate into soil surface results in the formation of inventory for hazardous heavy metals. Table 6.5 shows the concentration of heavy metals and physio chemical properties of leachate discharged in to the soil. It can be observed that average concentration of as Cr, Cu, Cd, Pb, Ni and Zn is found to be relatively high which probably is due to discharge of leachate into the ground. Economic valuation is carried out using monetary damage value suggested in Table 6.3. The damage valuation is limited to heavy metals such as Cr, Cu, Cd, Pb, Ni and Zn due to lack of damage values available for other polluting heavy metals. Damage cost assessment was carried out with respect to release of total quantity of leachate and corresponding heavy metal concentration using Eq (1). Damage cost is calculated based on the three seasons such as summer, winter and the monsoon. Leachate quantity is calculated by using the following Eq (2).

$V = 0.15 * R * A$ ---------- (2) (Ibrahim et al. 2017)

Where V is the volume discharged in that season (m^3/Season)

R is the rainfall of that season (m/Season)

Rainfall data 1205mm for the monsoon (June-September) reported by Government of Maharashtra [7], 20mm for winter and 17mm for summer in which data is taken in between 1982-2012 [3].

A is the area of the dumping = 22 hectares (220000 Sq. m) (Shubham et al. 2017)

Table 6.5: Damage cost due to the discharge of leachate in to the soil in the summer.

Heavy Metals	Heavy metal concentration (mg/l)	Leachate concertation (Million litres)	Damage cost in Euro (1995)	Total Damage (INR, Lakhs)
Cr	0.1508	0.561	320	0.03
Cu	60.3386	0.561	1	0.038
Pb	0.03949	0.561	5	-
Zn	1.011	0.561	1	-

Table 6.6: Damage cost estimated due to the release of heavy metals into soil in the winter

Heavy Metals	Heavy metal concentration (mg/l)	Leachate concertation (Million litres)	Damage cost in Euro (1995)	Total Damage (INR, Lakhs)
Cr	0.0231	0.66	320	0.005
Cu	45.2556	0.66	1	0.034
Pb	0.01263	0.66	5	-
Ni	0.007679	0.66	4	-
Zn	0.159	0.66	1	-

Table 6.7: Damage cost estimated due to the release of heavy metals into soil in the monsoon

Heavy Metals	Heavy metal concentration (mg/l)	Leachate concertation (Million litres)	Damage cost in Euro (1995)	Total Damage (INR, Lakhs)
Cr	0.0839	39.7	320	1.2
Cu	31.194	39.7	1	1.4
Cd	0.0123	39.7	1514	0.8
Pb	0.08593	39.7	5	0.02
Ni	0.03165	39.7	4	0.006
Zn	0.1191	39.7	1	0.005
Total damage cost (INR, Lakhs) in Monsoon				3.431

Total damage cost due to release of leachate into the soil is estimated to be ~3.54 Lakhs INR. The estimation is done on the basis of total release of heavy metals on soil due to whole of leachate and gives a value of total probable damage due to this heavy metal release. In comparison with all seasons rainy season accounts more damage cost compared with remaining seasons. Damage cost keeps on escalating, in case no mitigative measures are followed in terms of leachate treatment before the discharge.

6.5.3 Damage cost associated with climate change due to the release of CO_2

Social cost of carbon (SCC)

Environmental damage cost due to the emission of GHG's is estimated based on social cost of carbon (SCC). SCC also known as the shadow pricing for carbon emission is the most commonly used metric to calculate economic Externalities from carbon dioxide and has been estimated by USEPA and is based on global averages and hence can be used for India as well. It represents the economic change associated with climate change due to additional release of CO_2. The damage is computed as net difference in climate change with a baseline change in climate pathway with additional increase in CO2. Social carbon cost as of 2019 is reported to be 1065.9 INR per ton emission of CO2 (USEPA, 2017).

Biogas is a combustible mixture of gases. It consists mainly methane, carbon dioxide and is formed anaerobic digestion of organic compounds. Biogas composition are shown in the below Table 6.8.

Table 6.8 Biogas composition of different gases (Jorgensen 2009)

Sr.No	Name of gas	Composition (%)	Average (%)
1	Methane (CH_4)	55-70	62
2	Carbon-dioxide (CO_2)	30-45	37
3	Hydrogen Sulphide (H_2S), Hydrogen(H_2), Aammonia (NH_3)	1	1

Total biogas volume produced per day is 3645.171ml/day by organic waste. Biogas is distributed based on the composition of CH_4, CO_2 and other gases are about 2260ml/day, 1349ml/day and 36.48ml/day. A methane and Carbon-dioxide density is about 0.75kg/m^3 and 1.15 kg/m3 at normal temperature (Jorgensen 2009). Quantity of methane and CO2 is 1695kg/day and 1551 kg/day. Total methane and CO_2 per year is about 618.675tons/year and 566.115tons/year. Carbon-dioxide and Methane GWP values for 100-year time horizon are 1 and 28 from the IPCC fifth assessment (IPCC 2014). Now total CO_{2e} is 17889.015ton/year. Total damage cost values are 19.07 million INR

Table 6.9: Social cost of carbon due to the release of CO2e from dumping site

Year	CO2 emissions (tonnes/year)	SCC cost per ton CO2e emission	SCC (Million INR)
2019	17889.02	1065.9	19.07

6.6 Conclusions

The report focuses on identifying and estimating monetary losses (in 2019 Rupees) on the environment due release of leachate into the soil and release of Greenhouse Gases (GHGs) emissions into the atmosphere at Bhandewadi dumping. The damage was assessed with a consideration that there are no major polluting industries existing in nearby vicinity other than dumping. The study estimates a total incurred damage of about 19.424 Million INR or about ₹ 1.94 Crore per year due to externalities from Bhandewadi dumping. The breakup is shown in Table 6.10. The cost for damages includes drivers of externalities like greenhouse gas emissions, air pollution and soil pollution.

Table 6.10: Break Up of Monetary Estimation of Externalities (reported in 2019 values)

Sr.No	Environment	Estimated Damage Cost in Lakhs, INR (2019)
1	Air	Nil
2	Soil	3.538
3	GHG Emissions	190.7
Total for 2019		194.24

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6.8 Annexure 2

1. Low Income Group (LIG) – waste is collected from 7 locations which are Hudkeshwar, Narsala, Nara, Bhahadur Nagar, Kalamana, Satranjipura and Gorewada Vasti. The total sample collected in these locations is about 14 kg of weight approximately. Material composition of these area is shown in the below table 2.

Table 6.11: MSW composition at low income group

Sr. No.	Material Category	Composition (%)
1	Organics	59.27
2	Paper	2.65
3	Plastics	16.54
4	Metals and glasses	1.69
5	Inerts	19.85
Total		100

2. Medium Income Group: Waste is collected from 8 locations which are Mangalwari, Manewada, Hanuman Nagar, Lakadganj, Ashi Nagar, Gandhi Baugh, Nehru Nagar and Rani Durgavati Nagar. The total sample collected in these locations is about 19 kg of weight approximately. Material composition of these area is shown in the below table 3.

Table 6.12: MSW composition at medium income group

Sr. No.	Material Category	Composition (%)
1	Organics	71.59
2	Paper	3.36
3	Plastics	2.1
4	Metals and glasses	2.45
5	Inerts	20.5
Total		100

3. High Income Group (HIG):

Waste is collected from 8 locations which are Dharampeth, Ramdaspeth, Dantoli, Sadar, Lakshmi Nagar, Baratwada, Pande Layout, Bharat Nagar. The total sample collected in these locations is about 17 kg of weight approximately. Material composition of these area is shown in the below table 4.

Table 6.13: MSW composition at high income group

Sr. No.	Material Category	Composition (%)
1	Organics	68.23
2	Paper	6.54
3	Plastics	14.36
4	Metals and glasses	2.47
5	Inerts	8.4
Total		100

CHAPTER 7:
AMBIENT AIR QUALITY

ESR-2019-2020

CSIR-NEERI

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Ambient Air Quality

7.1 Introduction

The status of ambient air quality of the city is studied using secondary data obtained through various data sources and primary data. Data analysis is carried out to understand the spatial and temporal variations in the city for parameters namely particulate matter of size less than 10 micron and 2.5 micron (PM_{10}, $PM_{2.5}$) and gaseous pollutants (Sulphur Dioxide - SO_2, Nitrogen Dioxide - NO_2, Carbon Monoxide - CO and ground Ozone - O_3). Maharashtra Pollution Control Board (MPCB) carries out manual monitoring for particulate matter &/or respirable suspended particulate matter (RSPM), SO_2 and NO_2 at four locations in the city. Besides this a Continuous Ambient Air Quality Monitoring Station (CAAQMS) at GPO Civil Lines, Nagpur is also operated by MPCB. Central Pollution Control Board (CPCB), New Delhi sponsored National Air Quality Monitoring (NAQM) program is operated by NEERI at three locations, which involves manual monitoring of PM_{10}, SO_2 and NO_2. All data for one year is analysed and is presented here.

7.1.1 Manual Ambient Air Quality Data collected by MPCB

The summary of SO_2, NO_2 and PM_{10} concentration during 2017-2020 (till March) is plotted in Fig. 7.1. It can be seen that both SO_2 and NO_2 are well below the standard stipulated as 80 $\mu g/m^3$ by CPCB whereas PM_{10} concentration exceeded the standard of 100 $\mu g/m^3$ at North Ambazari road, MIDC Hingna and Sadar. Further, SO_2 and NO_2 are increasing during the 2017-2019 but during 2020 the concentration of both the pollutants are observed to be reduced despite of the data period being the critical for air pollution. PM_{10} concentration is observed to have been reduced in 2019 but increased in 2020. As the data during 2020 is considered only for January to March which is mostly the winter period, this seems to be the reason for higher particulate matter concentration. Secondary data analysis indicates that the city has a particulate pollution problem.

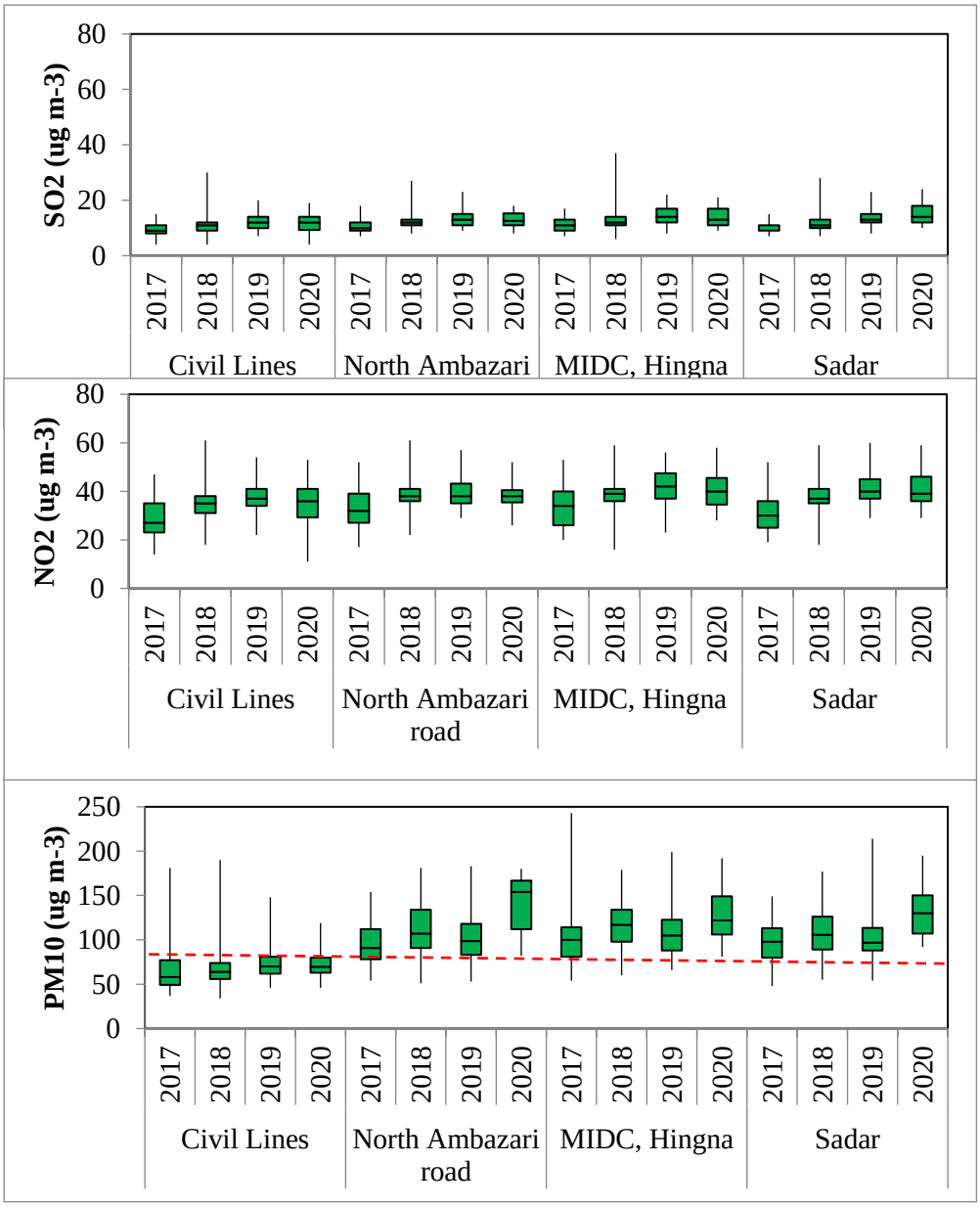


Fig. 7.1 SO_2, NO_2 and PM_{10} Concentration during 2017-2020 (till March) at few Locations in Nagpur (Data Source: www.mpcb.gov.in).

7.1.2 Continuous Ambient Air Quality Monitoring Station (CAAQMS)

MPCB operates a Continuous Ambient Air Quality Monitoring Station (CAAQMS) at GPO Civil Lines, Nagpur. Several parameters namely PM_{10}; $PM_{2.5}$; SO_2; NO_2; Ozone (O_3); CO; Benzene; Ethyl Benzene; m, p-Xylene; Toluene are being monitored at different sampling frequencies. 24 hourly AAQ for all these parameters for each month during 2019-2020 is given in Fig. 7.2 through 7.3. The statistical summary of ambient air quality data during 2019-2020 is given in Table 7.1. It can be seen that the % of missing values varies from 0 - 20% for all the

parameters. The % of exceedances is also observed to be high for PM_{10} and NO_2 concentration followed by $PM_{2.5}$ and Benzene concentration.

Table 7.1. Statistical Summary of CAAQMS data at Civil Lines, Nagpur.

Parameter	Average ± SD	95th Percentile	Max	Missing values (%)	% of Exceedances	CPCB Standard
PM_{10} ($\mu g/m^3$)	68.8 ± 28.3	121.8	161.5	6.4	56.4	60
$PM_{2.5}$ ($\mu g/m^3$)	35.0 ± 17.5	68.2	95.9	5.8	35.5	40
NO_2 ($\mu g/m^3$)	43.5 ± 19.2	68.0	220.6	20	56.7	40
SO_2 ($\mu g/m^3$)	7.4 ± 8.0	22.2	56.7	5.5	0.3	50
CO ($\mu g/m^3$)	741.6 ± 435.0	1460.0	2710.0	0	0.8	2000*
NH_3 ($\mu g/m^3$)	24.7 ± 11.0	43.9	83.0	20	--	100
O_3 ($\mu g/m^3$)	37.2 ± 43.6	136.1	180.4	11.2	14.9	100*
Benzene ($\mu g/m^3$)	4.4 ±2.9	10.1	16.1	5.8	32.1	5
Ethyl Benzene ($\mu g/m^3$)	3.7 ± 4.1	11.8	24.1	10.9	--	--
m, p-Xylene ($\mu g/m^3$)	5.1 ± 5.8	15.6	32.2	17.4	--	--
Toluene ($\mu g/m^3$)	10.2 ± 7.2	23.6	38.6	5.8	--	--

* For 8 hours, - CPCB standard not available

PM_{10} and $PM_{2.5}$ concentration is observed to be higher during November- February and lower in monsoon months. SO_2 and NH_3 concentrations are observed to be lower in monsoon months except in September, NH_3 is observed to be quite high. NO concentration is observed to be higher in November-January, whereas NO_2 concentration is observed to be higher in October-April. As expected, higher ozone concentration is observed in April and May when high solar insolation is usually observed. CO is higher during October-May, whereas Benzene and Ethylbenzene concentration is higher during November-January. A decreasing monthly trend is observed in m, p Xylene and Toluene from April to March.

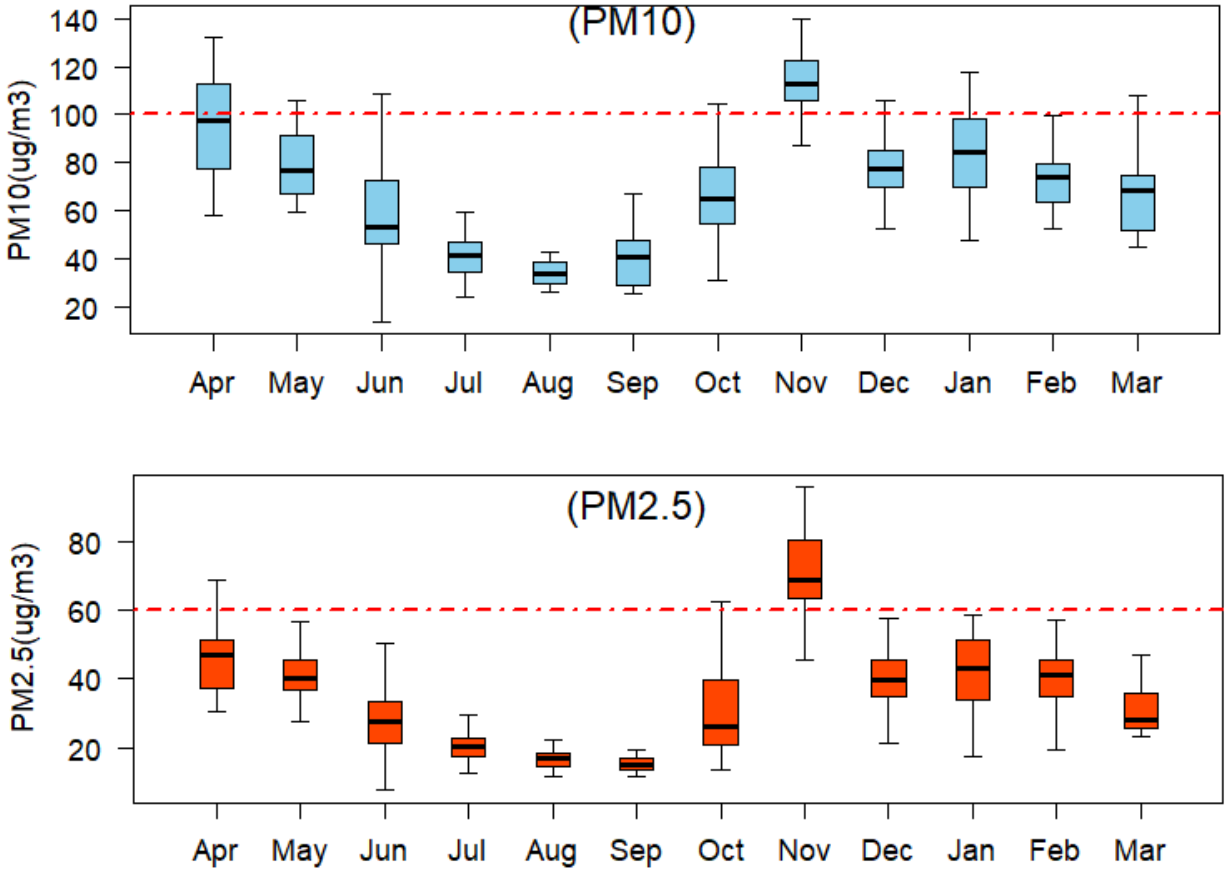


Fig. 7.2 Monthly Variation of PM_{10} and $PM_{2.5}$ Concentration during 2019-2020 at Civil Lines, Nagpur (Data Source: www.cpcb.nic.in).

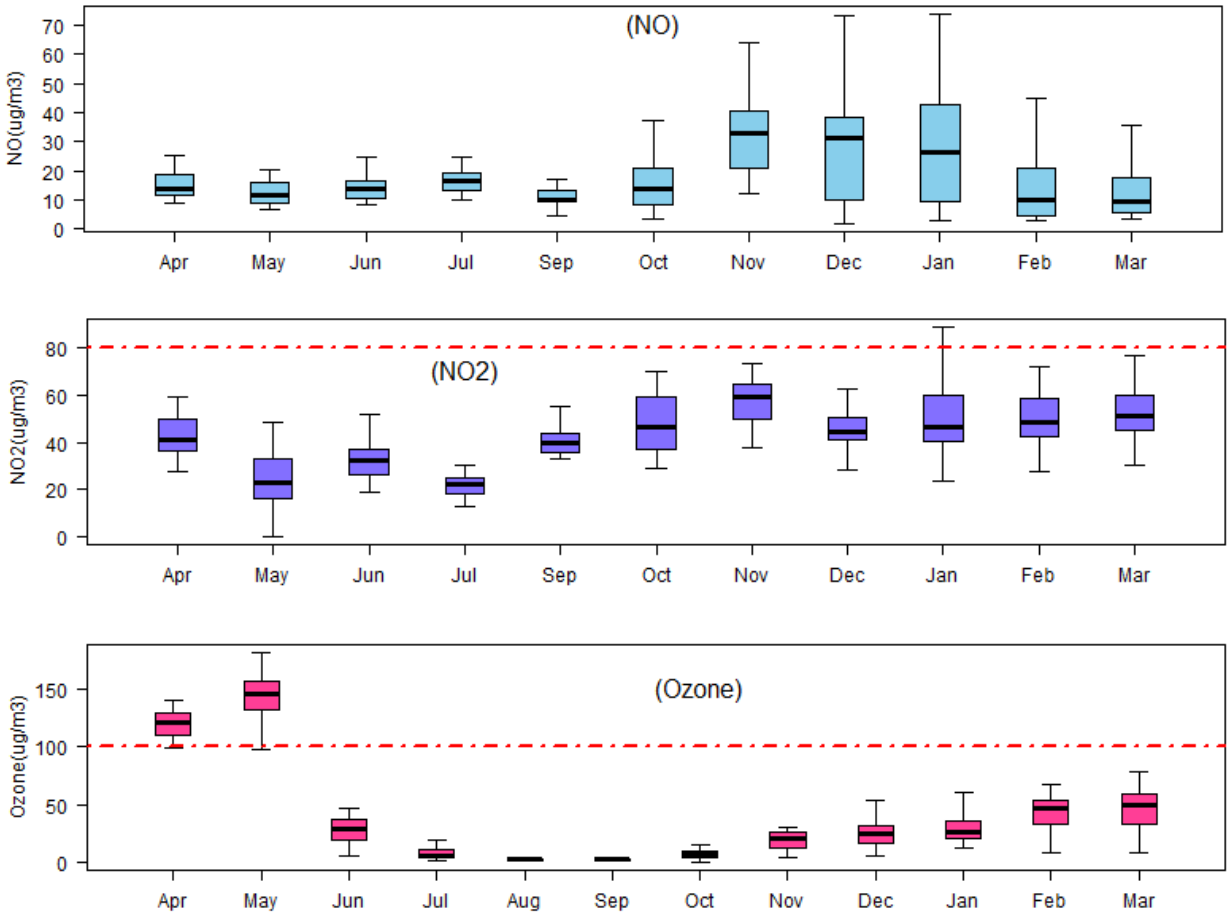


Fig. 7.3 Monthly Variation of NO, NO_2 and O_3 Concentration during 2019-2020 at Civil Lines, Nagpur (CAAQMS Data Source: www.cpcb.nic.in).

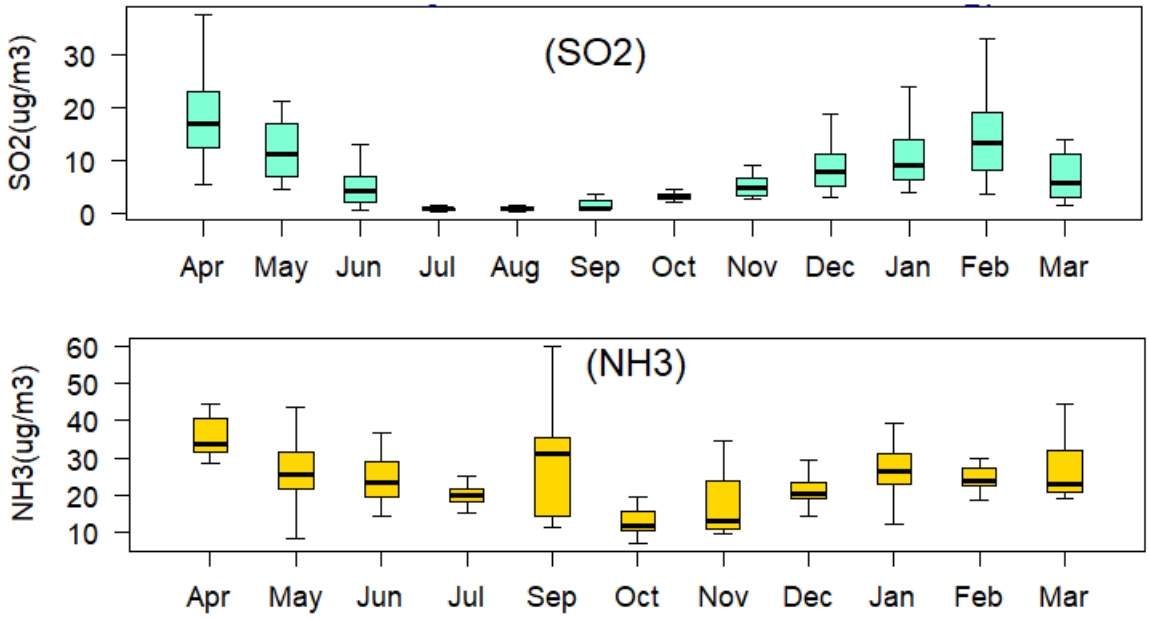


Fig. 7.4 Monthly Variation of SO_2 and NH_3 Concentration during 2019-2020 at Civil Lines, Nagpur (CAAQMS Data Source: www.cpcb.nic.in).

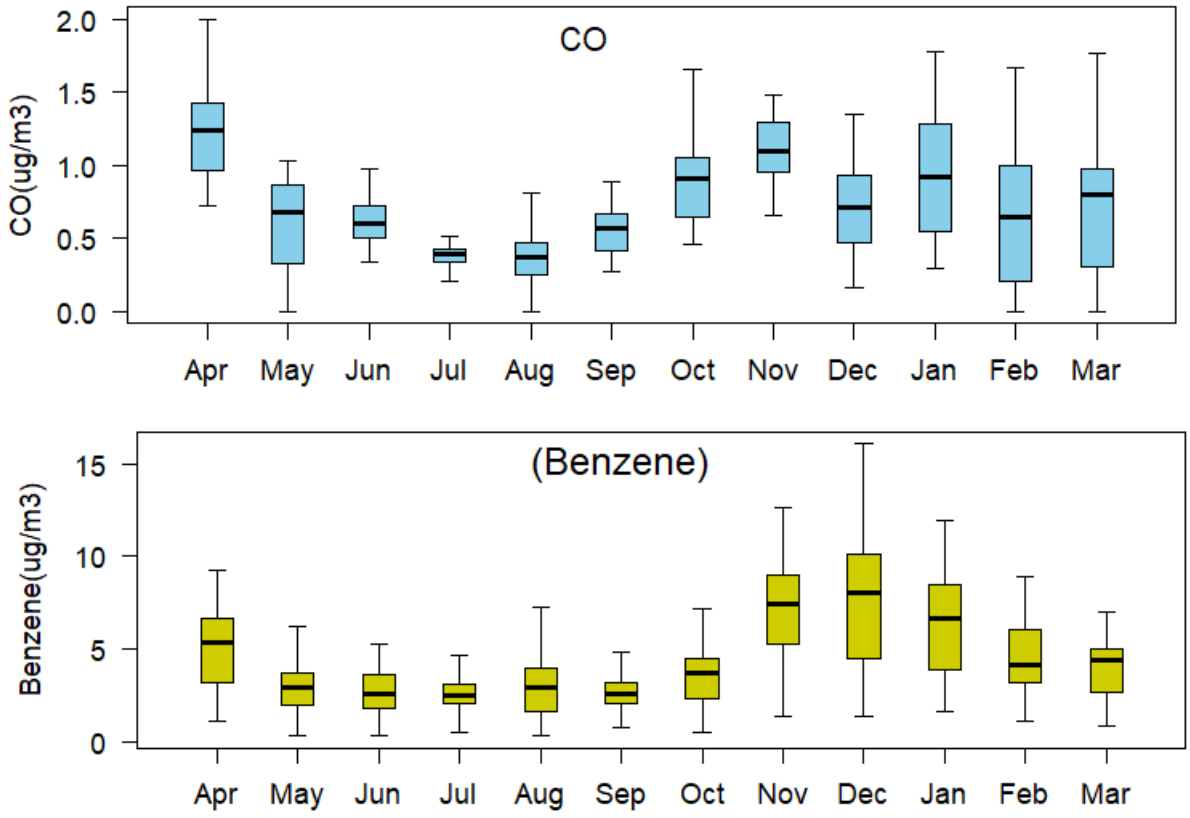


Fig. 7.5 Monthly Variation of CO and Benzene Concentration during 2019-2020 at Civil Lines, Nagpur (CAAQMS Data Source: www.cpcb.nic.in).

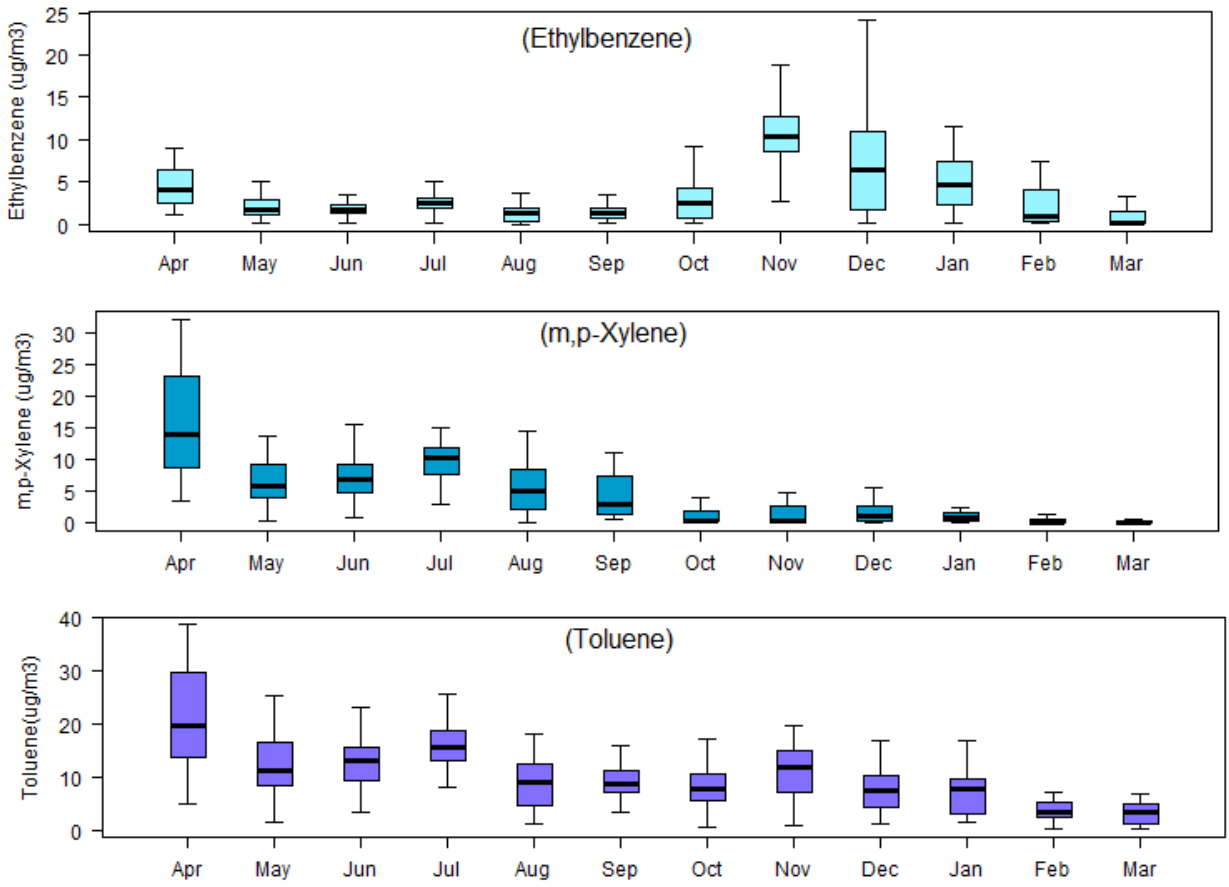


Fig. 7.6 Ethyl Benzene; m, p-Xylene; and Toluene during 2019-2020 at Civil Lines, Nagpur (CAAQMS Data Source: www.cpcb.nic.in).

7.1.3 Manual Ambient Air Quality Monitoring by NEERI

Ambient air quality monitoring was carried out during April 2019 to February 2020 at three locations across the city that were selected based on the land-use characteristics, meteorology, logistic facilities such as security, power supply etc. The location of the stations is given in Fig. 7.7. The description and characteristics of the selected stations is given in Table 7.2. Major activity zones such as Industrial; Residential and Commercial were represented by the selected sampling locations. Ambient air quality sampling has been carried out for the pollutants viz., PM_{10}, NO_2 and SO_2 concentration during 2019-2020 at three sites. For $PM_{2.5}$, CO and O_3 concentration, the sampling was carried out at Residential site only. The sampling was carried out as per the methods and protocols prescribed by CPCB. A short description of the methods is given in Table 7.3.

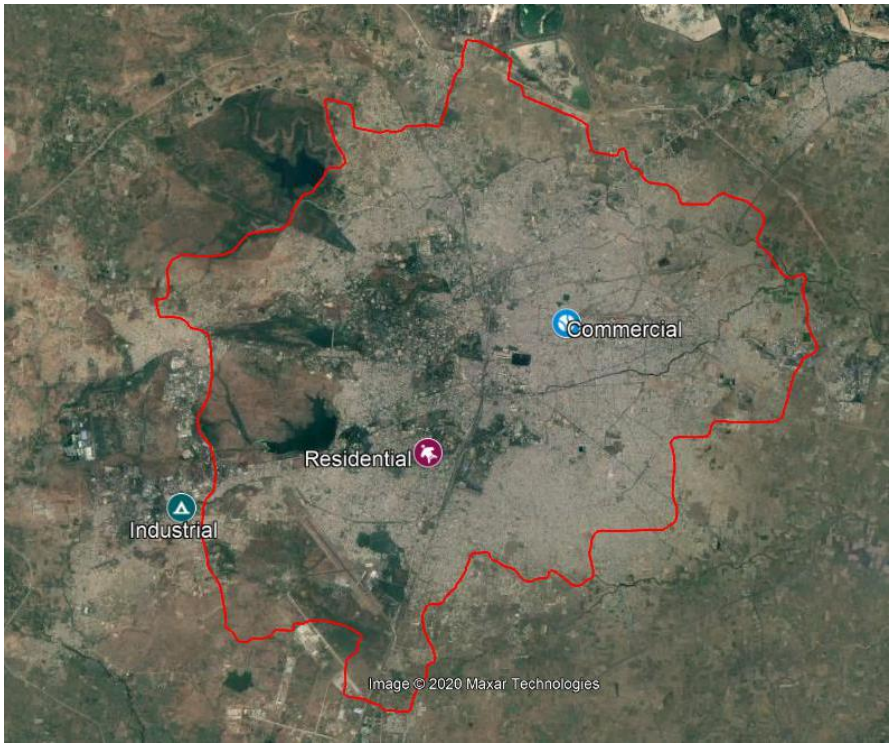


Fig. 7.7 Location of Sampling Station under NAQM.

Table 7.2 Characteristics of AAQ Stations.

No.	Station Name	Geographic Location	Station Classification	Observed Sources
	MIDC Hingna	21° 6'59.12"N 79° 0'44.25"E	Industrial	Industrial location with influence of traffic
	NEERI	21° 7'20.00"N 79° 4'17.21"E	Residential	Very few vehicles around the station
	Maskasath (Near Itwari)	21° 9'42.88"N 79° 6'57.92"E	Commercial-Traffic	A busy commercial area with congested roads and traffic

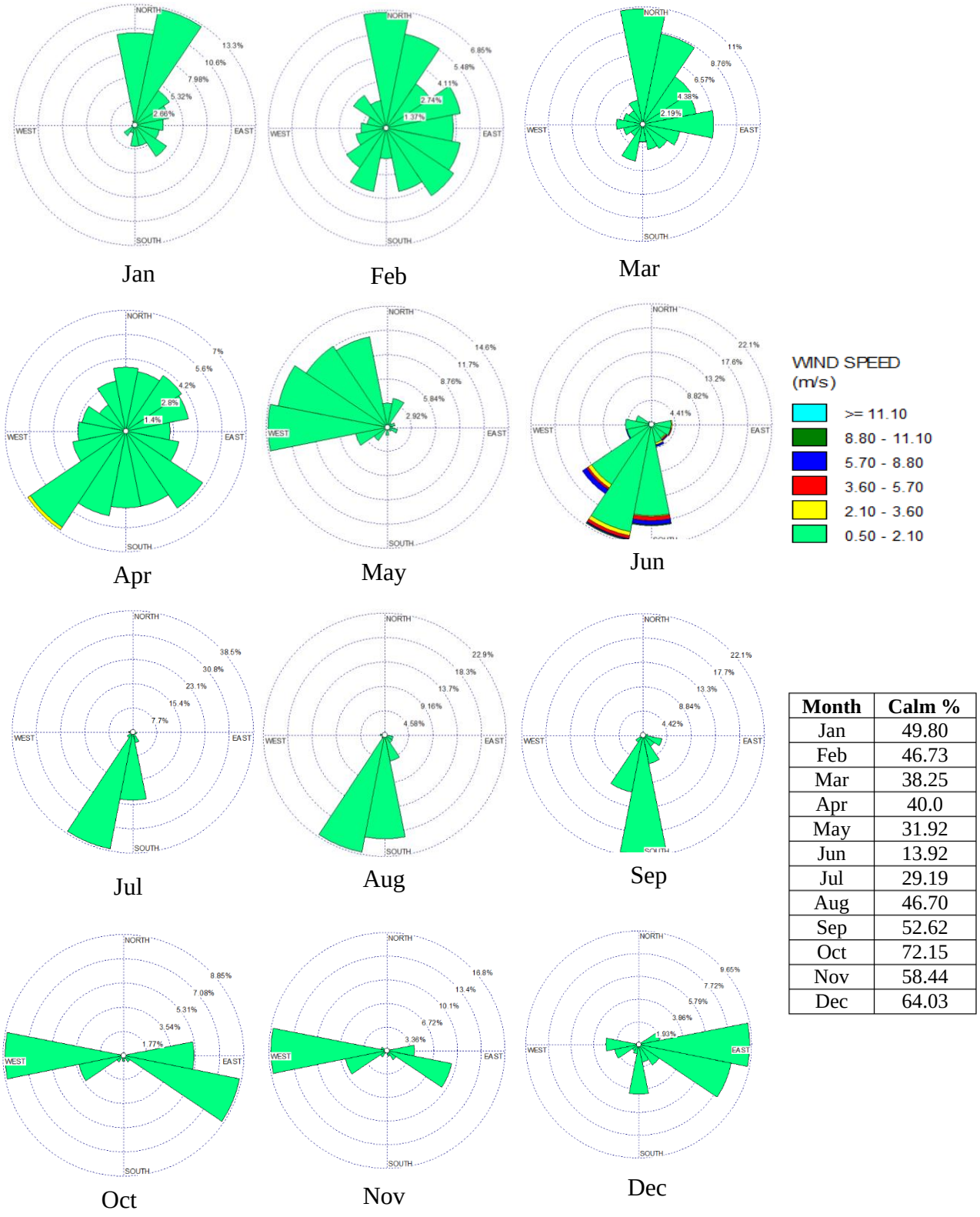
Table 7.3 Sampling Instrument and Analysis Method.

Particulars	***PM***	**NO_2**	**SO_2**	**CO**	**Ozone**
Sampling Instrument	PM_{10}/$PM_{2.5}$ (indigenous) samplers - Envirotech-Model APM 550 with GFF Filter, Envirotech-Model APM 460 with PTFE FIlter	Impinge attachment with Envirotech APM 460	RDS with thermo electrically cooled gaseous sampling attachment	TESTO make CO monitor	Chemical method
Sampling frequency	24h for twice a week for 104 days in a year	8 Hourly	8 Hourly	Hourly	8 Hourly

For details, refer CPCB guidelines (2009) (www.cpcb.nic.in)

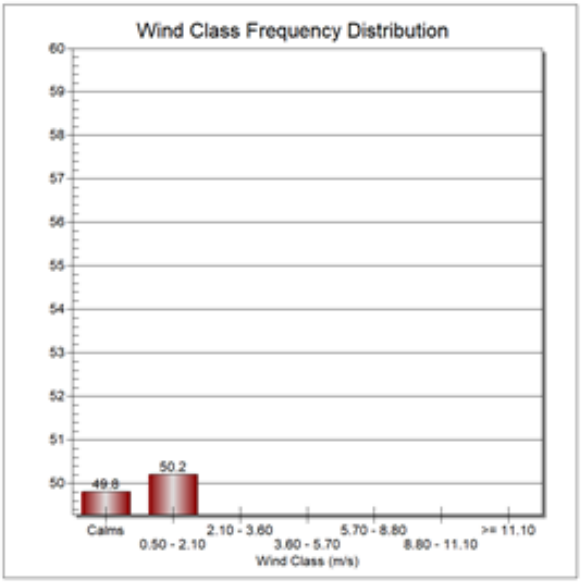
7.2 Meteorology

The wind speed and wind direction as gathered at CAAQMS at Civil Lines, operated by Maharashtra Pollution Control Board (MPCB) is used for plotting the wind rose and wind speed frequency diagram. Fig. 7.8 shows the wind rose diagram for different months of 2019. It can be seen that the predominant wind direction is from N, NE and E direction during winter months and W, ESE direction during post-monsoon months. The predominant wind direction during monsoon is from S and SSW direction. During summer, the predominant wind direction is mostly from W, N and S-SW sector. Wind speed frequency plot in Fig. 7.9 shows that wind speed is mostly in the category 0.5-2.10 m/s in all the months. In June, the wind speed is also moderately observed in the higher categories from 2.10-8.80 m/s. High percentage of calms during winter and post-monsoon suggests lower dispersion and dilution capacity of the atmosphere causing high air pollution at ground.

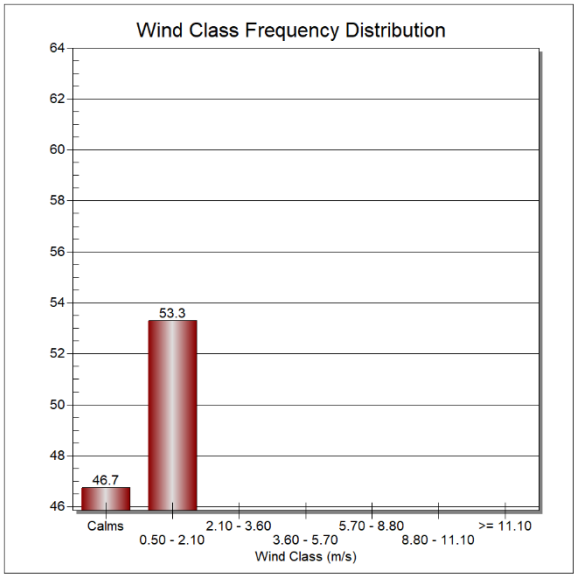


Month	Calm %
Jan	49.80
Feb	46.73
Mar	38.25
Apr	40.0
May	31.92
Jun	13.92
Jul	29.19
Aug	46.70
Sep	52.62
Oct	72.15
Nov	58.44
Dec	64.03

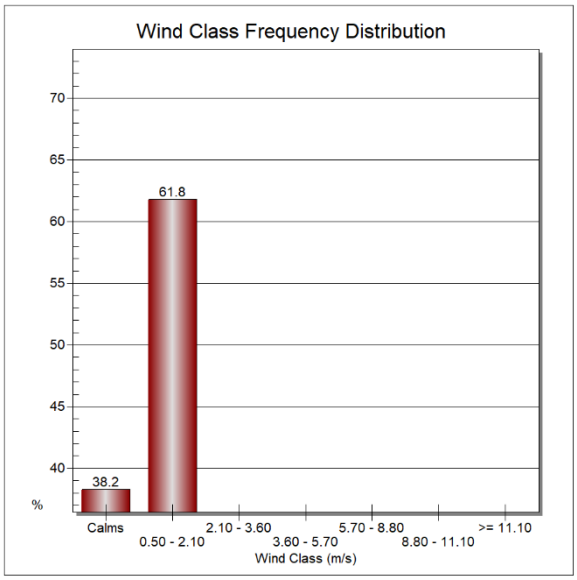
Fig. 7.8 Monthly Windrose Diagram for Nagpur (2019).



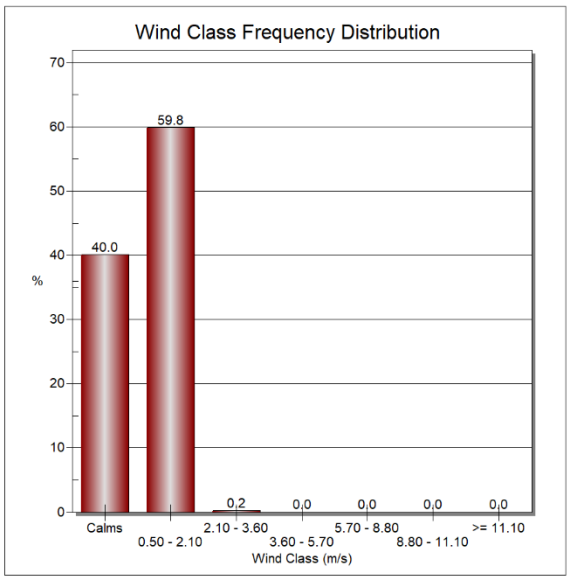
January



February

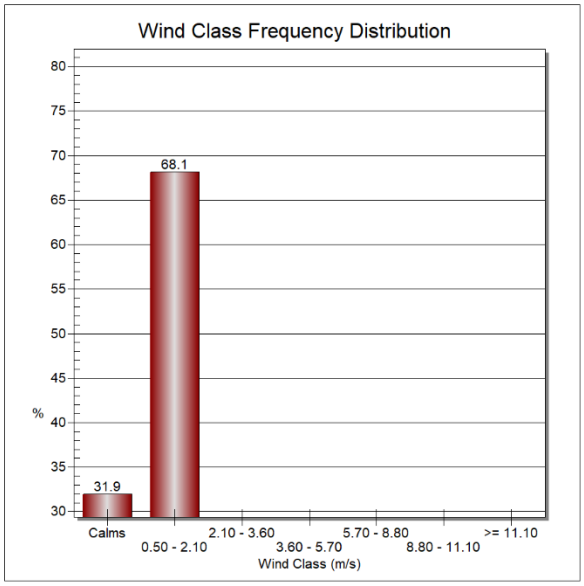


March

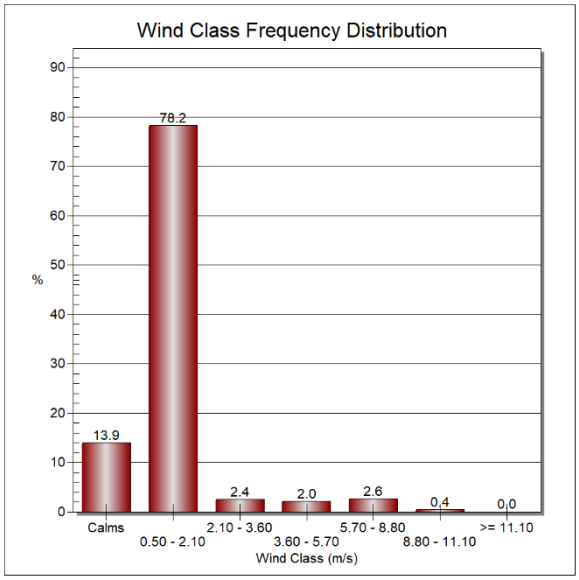


April

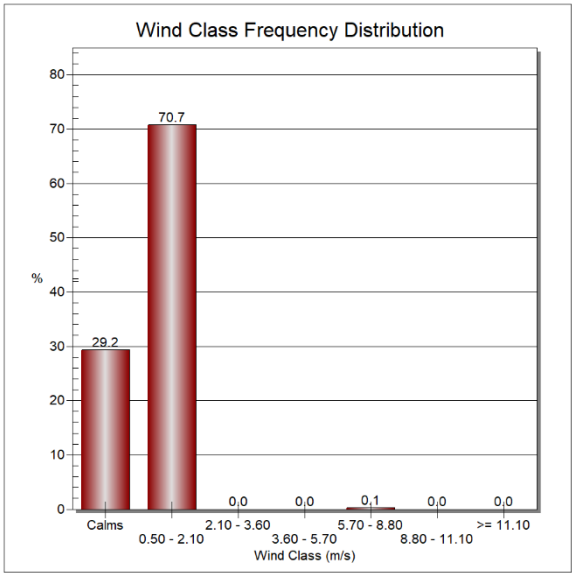
Fig. 7.9 a. Wind Speed Frequency Plot.



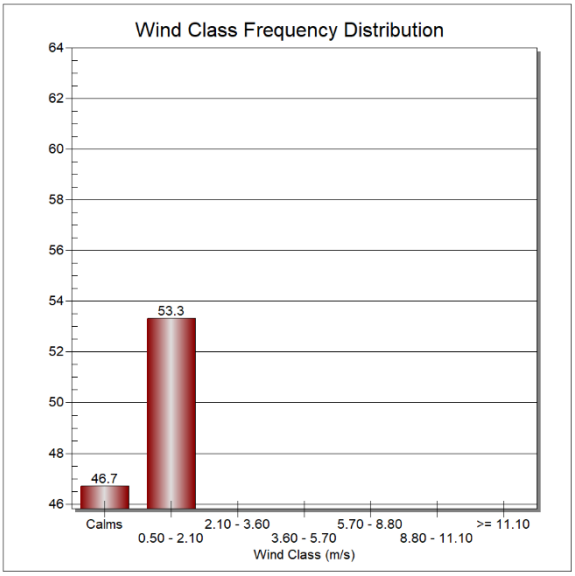
May



June

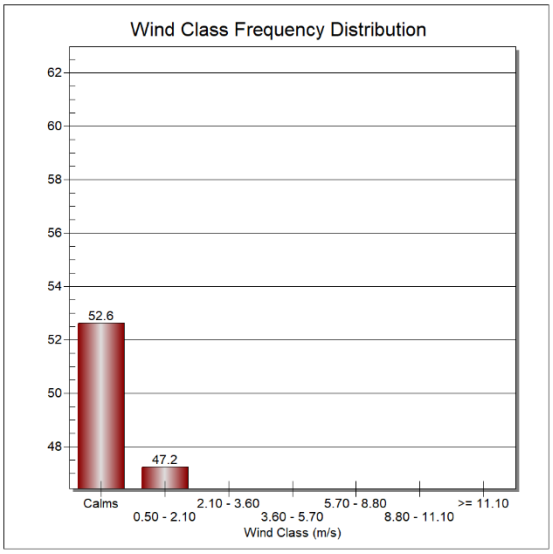


July

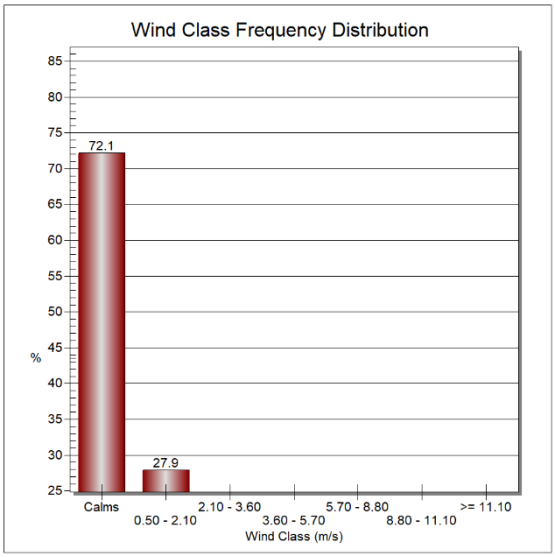


August

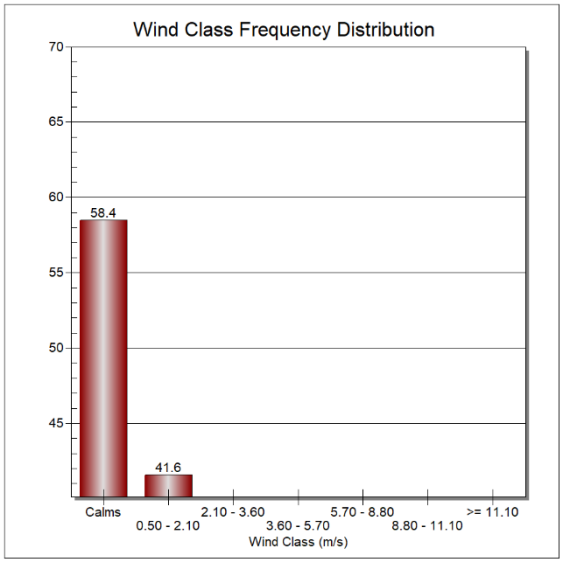
Fig. 7.9 b. Wind Speed Frequency Plot.



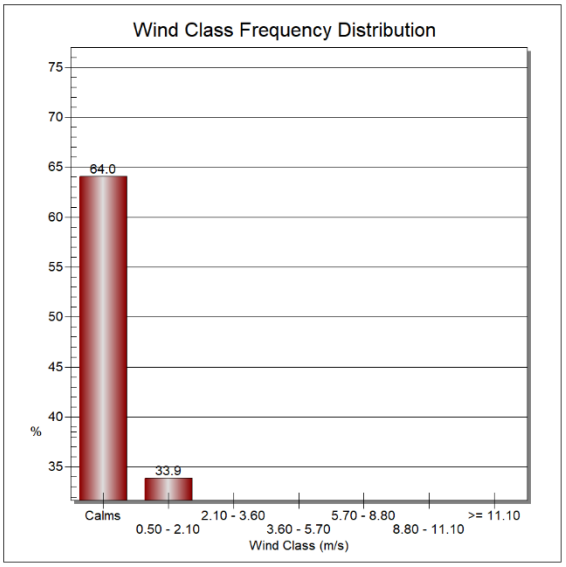
September



October



November



December

Fig. 7.9 c. Wind speed Frequency Plot.

7.3 Ambient Air Quality Status

Ambient air quality status in terms of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 concentration during 2019-2020 is summarized in Fig. 7.10 through 7.14. It is observed that SO_2 and NO_2 concentrations are well below the CPCB standard of 80 $\mu g/m^3$ (not shown here), except once, NO_2 concentration has exceeded the threshold on 20th January, 2020 at Industrial and Commercial site. The monitoring for $PM_{2.5}$ was carried out only at NEERI i.e. residential site only. The % of exceedances for PM_{10} at Industrial, Commercial and Residential sites is 14.4%, 47.2% and 52.1%, respectively. The % of exceedance for $PM_{2.5}$ concentration is 11.8%. It can be seen from Fig. 7.10 that annual average SO_2 and NO_2 at three sites are not statistically different whereas PM_{10} concentration is lower at industrial site (see Fig. 7.11). Annual average of PM_{10} concentration is highest at Residential site followed by Commercial site and at both the sites, it exceeded the CPCB limit of 60 $\mu g/m^3$. Although Residential site has relatively less activity, but during the study period, construction activity near the site was observed.

The monthly variations in PM_{10} concentration is given in Fig. 7.12. It can be observed that PM_{10} is less than the threshold concentration at Industrial site, whereas at Commercial site, it exceeds the threshold during April-June and November, December and February. At Residential site, PM_{10} concentration exceeds the standard in May, August, October-December. High concentration in August at Residential site is mainly due to the construction and renovation activity near the site. Transportation of construction debris and site cleaning was observed in August, which is reason for the high concentration. Overall, averaged PM_{10} concentration over all the sites (Fig. 7.13) exceeds the CPCB threshold in November, December and May.

Average $PM_{2.5}$ concentration is observed to be below the CPCB standard limit of 60 $\mu g/m^3$. Monthly variations in $PM_{2.5}$ concertation plotted in Fig. 7.14 shows that it is higher during April-June and exceeding the threshold in May.

Monthly $PM_{2.5}/PM_{10}$ ratio is plotted to have an understanding of the prevalence of particulate fraction in the city. It can be seen from Fig. 7.15 that $PM_{2.5}/PM_{10}$ ratio is less than 0.5 in all the months except in January, May and June, which suggests that coarser size particulates are dominating. High $PM_{2.5}$ concentration is observed during May and June, causing high ratio in these two months, whereas in January, heating either of commercial or domestic in nature might have caused high ratio.

The data for CO and Ozone concentration is available for October-February. O_3 and CO concentration observed at Residential site is depicted in Fig. 7.16, which shows that both the pollutant concentrations are well below the threshold of 100 μg/m^3 and 2 mg/m^3, respectively. Average O_3 concentration is observed to be 37.9±22.0 μg/m^3 and average CO concentration is observed to be 1.0±0.5 mg/m^3, which is well below their respective CPCB limits.

Summarizing the above results, it can be seen that particulate pollution is significant in Nagpur. Winter and post-monsoon are critical as during both the seasons, high concentration of PM_{10} is observed.

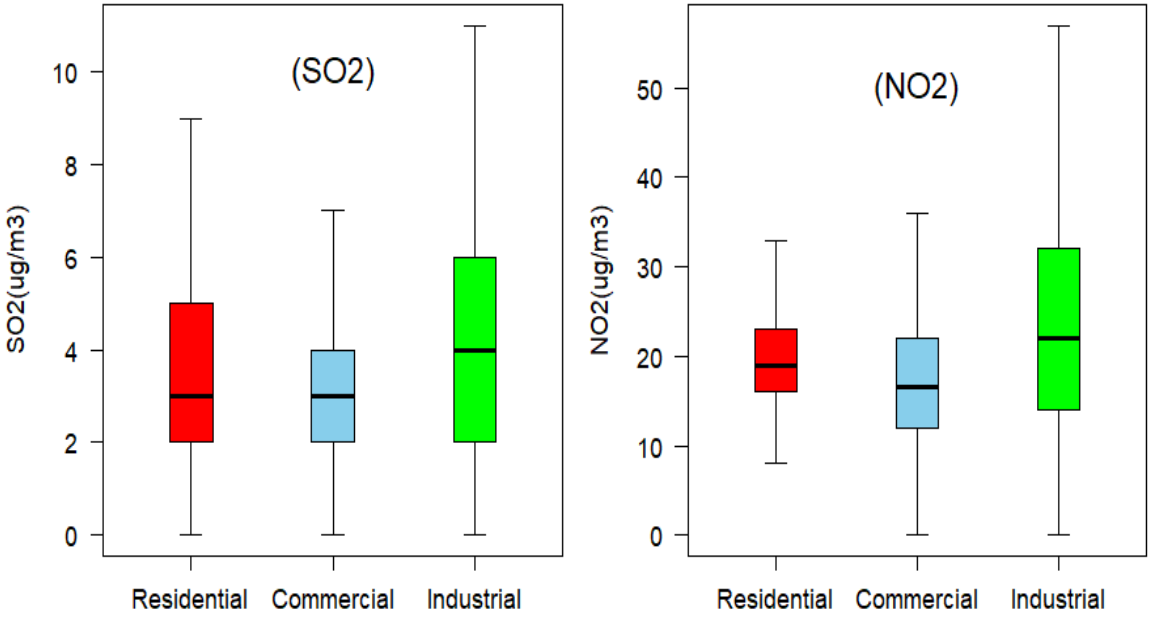


Fig. 7.10: SO_2 and NO_2 Concentration in Ambient Air of Nagpur at Three Sites.

Table 7.4 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
	Sulphur Dioxide (SO_2), µg/m^3	Annual *	50	20
		24 Hours **	80	80
	Nitrogen Dioxide (NO_2), µg/m^3	Annual *	40	30
		24 Hours **	80	80
	Particulate Matter, (PM_{10}), µg/m^3	Annual *	60	60
		24 Hours **	100	100
	Particulate Matter, ($PM_{2.5}$), µg/m^3	Annual *	40	40
		24 Hours **	60	60
	Ozone (O_3), µg/m^3	8 hours*	100	100
		1 hour**	180	180
	Lead (Pb), µg/m^3	Annual *	0.50	0.50
		24 Hours **	1.0	1.0
	Carbon Monoxide (CO) mg/m^3	8 Hrs**	02	02
		1 Hr**	04	04
	Ammonia (NH_3), µg/m^3	Annual *	100	100
		24 Hours **	400	400
	Benzene (C6H6), µg/m^3	Annual *	5	5
			1	1
	Benzo (□) Pyrene Particulate Phase, ng/m^3	Annual *	01	01
	Arsenic (As), ng/m^3	Annual *	06	06
	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. ** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98 of the time in a year. 2 of the time, they may exceed the limits but not on two consecutive days of monitoring.

Note: Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigations.

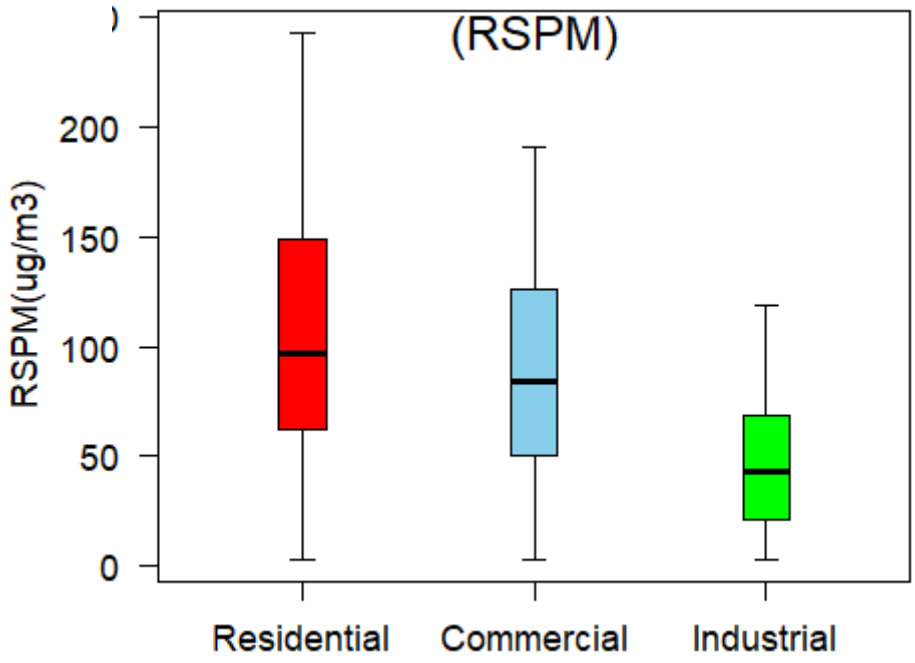


Fig. 7.11 PM_{10} Concentration in Ambient Air of Nagpur at Three Sites.

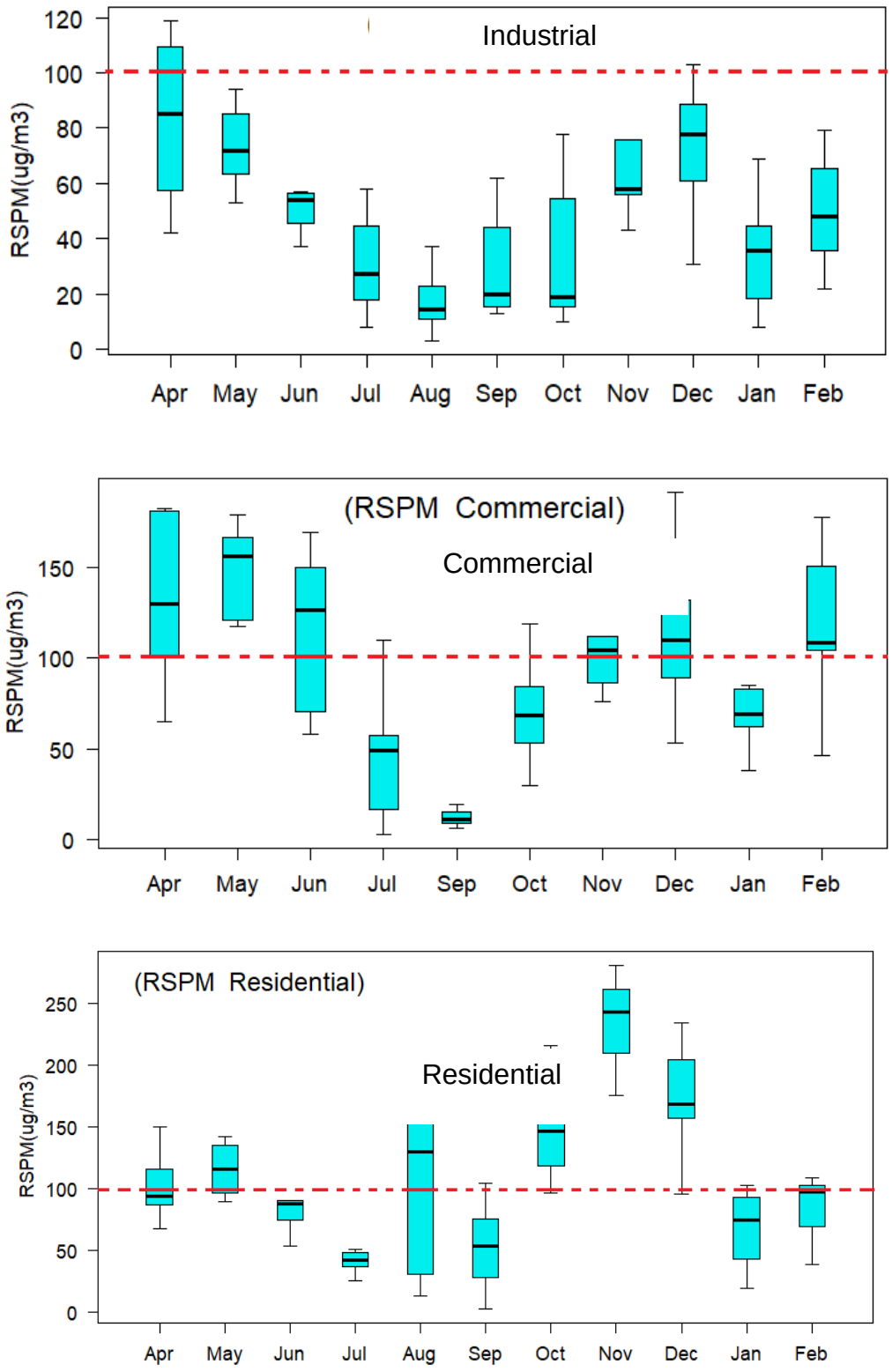


Fig. 7.12 PM_{10} Concentration in Ambient Air of Nagpur.

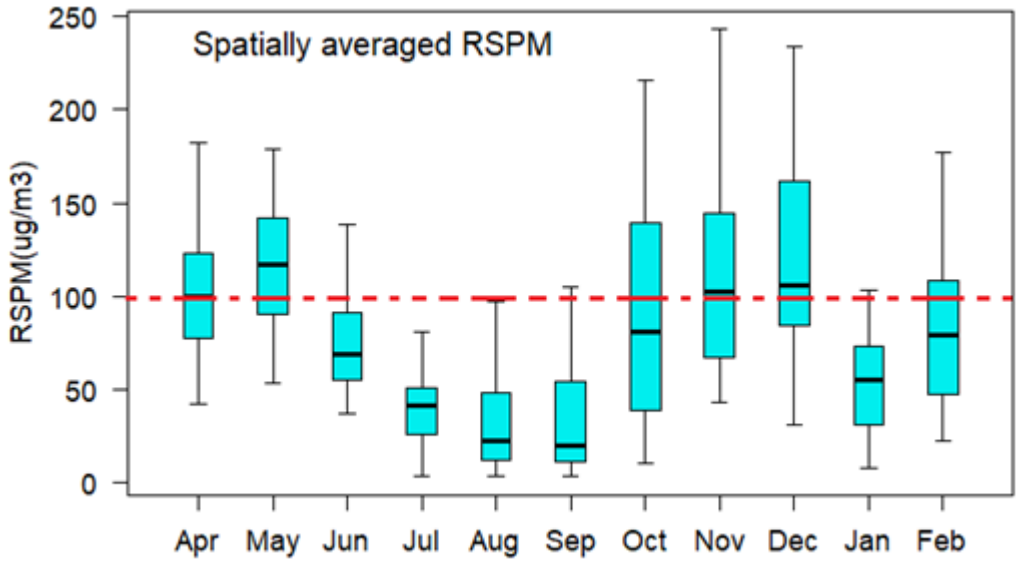


Fig. 7.13 Spatially averaged (Overall) PM_{10} Concentration in Ambient Air of Nagpur.

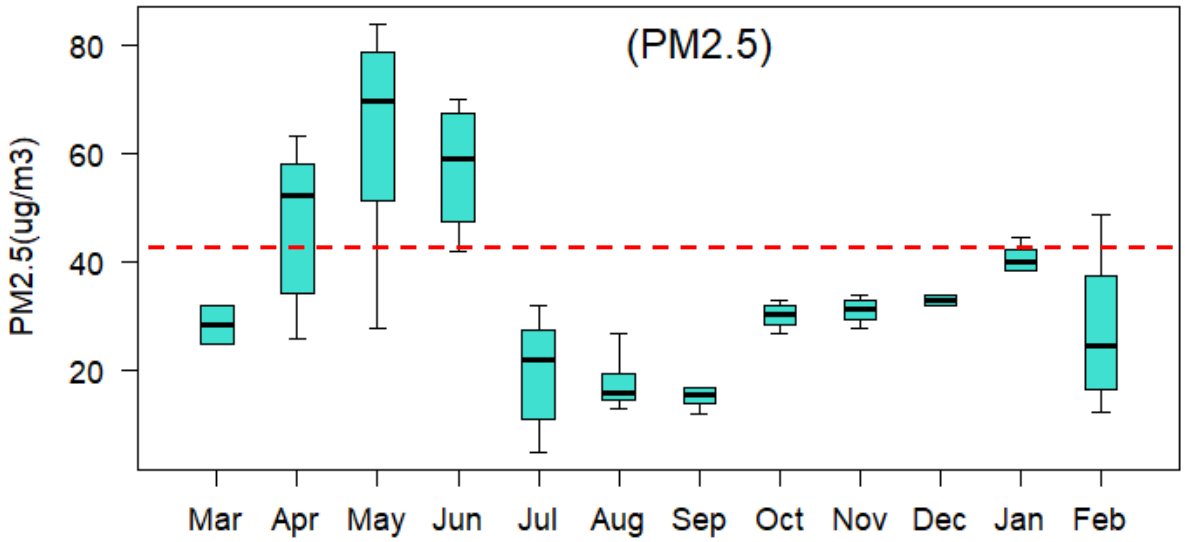


Fig. 7.14 $PM_{2.5}$ Concentration in Ambient Air of Nagpur at Residential Area

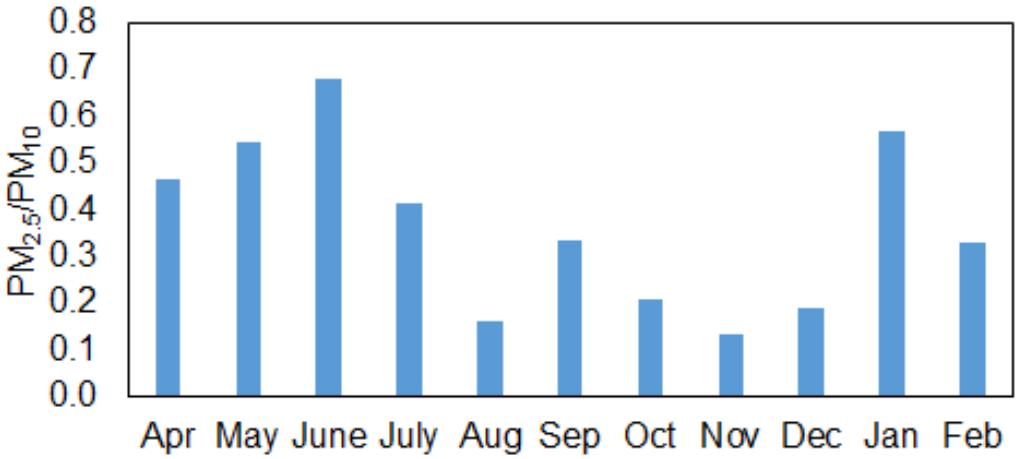


Fig. 7.15 Monthly Variations in $PM_{2.5}/PM_{10}$ in Ambient Air of Nagpur (Residential).

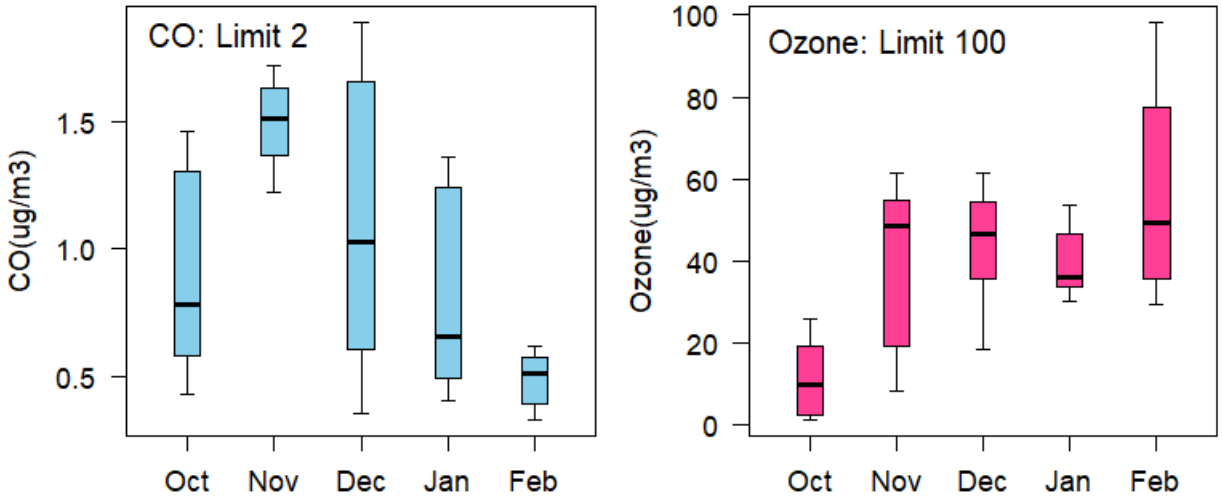


Fig. 7.16 Monthly Variation of CO and Ozone in Ambient Air of Nagpur (Residential).

7.4 Effect of Diwali on Ambient Air Quality of Nagpur

In order to assess the effect of Diwali when usually huge number of fireworks are burnt, the ambient air quality of Nagpur is studied during the event. As the Diwali festival fell on 27th October 2019, the period from 19th October to 24th October is considered as before the event, the period from 25th October to 30th October is considered as during the event as it is usually celebrated for five-six days and the period from 31st October to 5th November is considered as after the festival. The data of National Ambient Air Quality Monitoring Programme of CSIR-NEERI (called as NAAQM) and data of CAAQMS, MPCB (called as CAAQMS) is considered to assess the influence. It can be seen from Fig. 7.17 that PM_{10} concentration increases during

and after the event. The increase is more pronounced in the after period as on 27th October, 2019 (i.e. on Diwali), rainfall was witnessed which would have resulted in only the slight increase in the PM_{10} concentration. $PM_{2.5}$ concentration also has increased during the Diwali period but NAAQM data shows sudden decrease in the period after Diwali, whereas CAAQMS data shows significant increase. Further, NO_2 concentration also shows slight increase in during and after period but the increase in not significant.

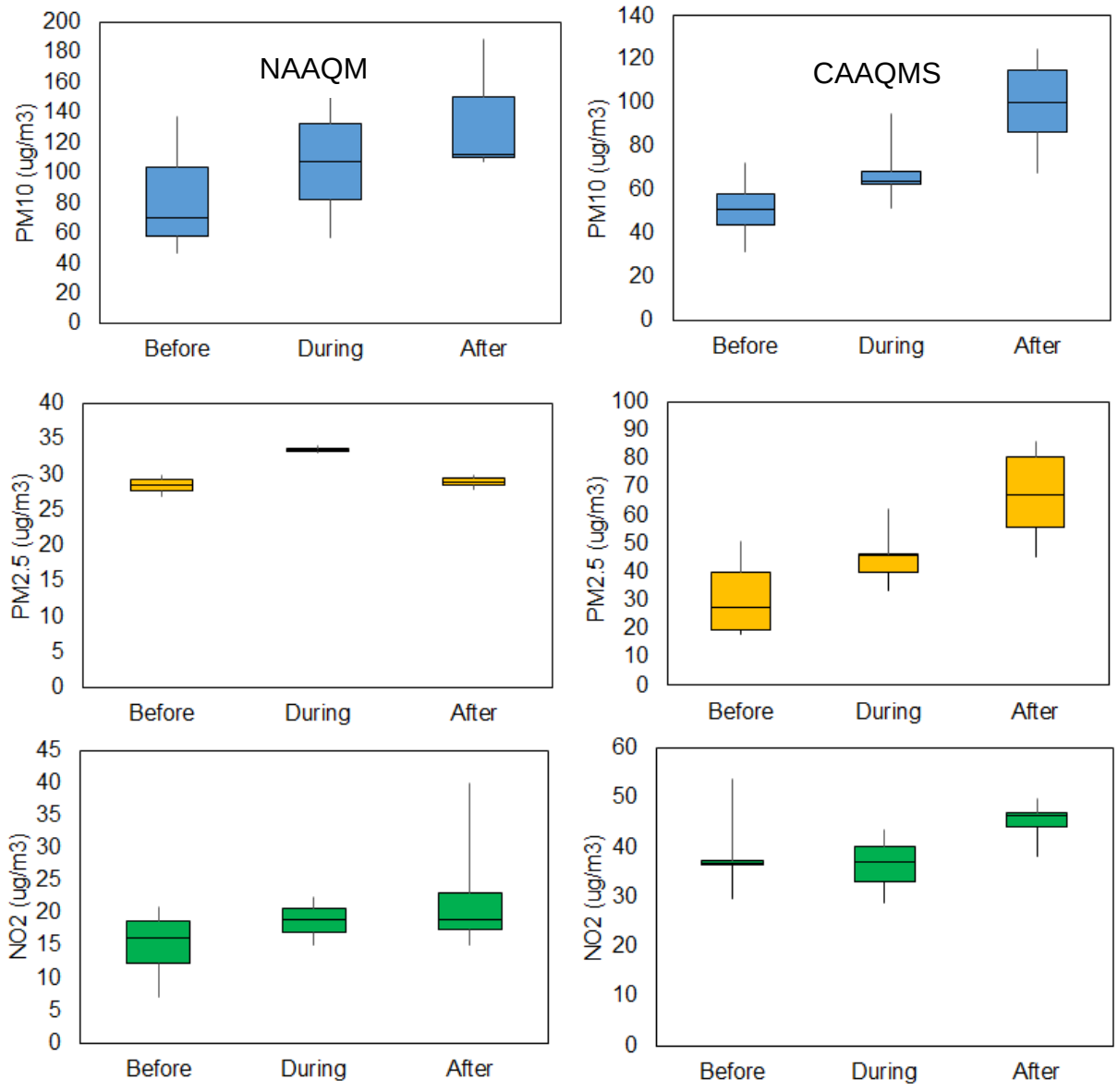


Fig. 7.17 Ambient Air Quality in Nagpur Before, During and After Diwali, 2019.

7.5 Effect of Lockdown on the Ambient Air Quality of Nagpur

The influence of lockdown when all the activities are either stopped or at very low level and that could result in zero or very low emissions from the activities such as traffic, commercial activities, construction and small scale industries, is assessed on the air quality of Nagpur. For this, the ambient air quality data of SO_2, NO_2, PM_{10} and $PM_{2.5}$ are considered during March 1, 2020 – March 21, 2020 as before lockdown period and March 22, 2020 - April 15, 2020 as during lockdown period. The comparison period before lockdown is considered keeping in view the seasonal effects on ambient air quality. CAAQMS data of CPCB is considered for the comparison purpose. The statistical summary of ambient air quality is given in Fig. 7.18. It can be seen that all the four pollutant concentrations have considerably reduced during the lockdown period. The reduction in average PM_{10}, $PM_{2.5,}$ SO_2, NO_2 and CO concentration is observed to be 46.3±8.6, 22.6±3.3, 2.0±1.3, 23.0±8.6, 522±390 from 64.8±16.7, 30.8±7.9, 6.5±4.3, 51.6±12.3, 695.7±488.3 μg/m^3, respectively. The % reduction for PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO concentration is around 28.7%, 26.6%, 69.6%, 55.3% and 25%, respectively, which suggests the significant contribution of traffic emissions, commercial activities, small–scale industries and construction activity on ambient air quality of the city.

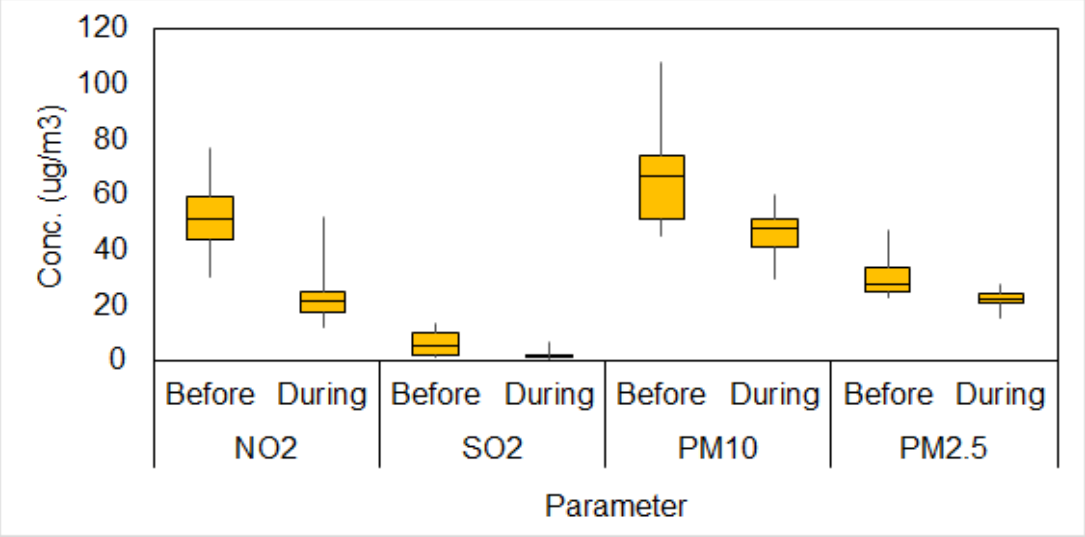


Fig. 7.18 Ambient Air Quality in Nagpur before and during Lockdown.

7.6 Air Quality Management Plan

Air quality management plan targeting the various source sectors viz., Area Sources (household and commercial fuel combustion, solid waste burning), Point Sources (Industries) and Line Sources (Vehicles) is envisaged in Table 7.5 to target the emission sources to reduce the emissions.

Table 7.5. Air Quality Management Plan for Nagpur

Source Sector	Mitigation Measures
1. Area Sources	
a. Combustion	
Bakery, Hotels and Restaurants, Open eat-outs	To reduce of wood and coal usage, fuel shift to electricity or LPG and use of alternate fuel such as solar power may be explored.
Domestic Emissions	To reduce the usage of coal, wood and cow dung, increase in LPG usage need to be encouraged (through Ujjwala schemes). Better cook-stove designs can reduce emissions from wood. If wood cannot be avoided in domestic cooking, better ventilation to houses should be suggested. Awareness drive through various campaigns. Alternate energy use e.g. solar may be explored.
Crematoria emissions	Installation of scrubber /cyclone for emission control and its release through chimneys. Shift from wood to biomass briquettes as the emission factor for wood is much higher than that of biomass briquette. Preference of electrically operated crematoria. Increase in green belt around the crematoria is recommended.
Solid Waste emissions	Open burning to be strictly prohibited. Public awareness drives to stop open burning. Source segregation of solid waste at domestic level should be encouraged and enforced by appropriate legal mechanism. Existing municipal solid waste disposal facility should have additional provision of waste segregation particularly for separation of metal and plastics. Organic solid waste must be used for composting or bio-gas generation depending on the quantity collected on daily basis. Possibility of power generation from bio-gas should be explored and installed.
b. Non-Combustion Activities	
Construction and demolition, Road dust	The management plan for the construction related activities is given below. Enforcement and follow-up of Building Construction and Demolition Rules considering the emission control of PM. Improvement in pedestrian infrastructure viz near RUBs / ROBs / Footpaths, Pedestrian crossing etc. are necessary for proper transport system. Special provision for bi-cycle pathways need to be made to reduce PM emissions.

	Increase in green belt and creation of green buffers along the traffic corridors and highly populated area. Regular maintenance of road, sweeping at regular intervals can reduce resuspension of dust contribution to PM in the city. To control resuspension from construction sites, appropriate covering or barricading should be done to avoid dispersion of the dust. Constructing a water pit at the entry/exit points of the construction site to avoid dispersion of particulate matter through movement of trucks while entering and exiting the site. Ensure carriage of construction material in closed/covered Vessels. Control measures for fugitive emissions from material handling, conveying and screening operations through water sprinkling, curtains, barriers and suppression units. Reduction in unpaved roads by paving.
2. Point Sources	Fuel shift and inclusion of air pollution control technologies in the existing industries needs to be explored so as to reduce air pollution. For the other industries, the old boilers need to be replaced. Boiler performance audit to be made for phasing out old boilers. Water sprinkling in fugitive dust areas to be on periodic and regular basis. Regular audit of stack emissions for QA/QC.
3. Line Sources	As the significant influence of lockdown period on ambient air quality of the city is seen, the following measures can be suggested for line sources: Shift to public transport system e.g. Metro Rail: As the work has already been under progress and the rail is already in running over two tracks, encouraging the public to use the facility is the need of the hour. For heavy duty vehicles, retro-fitment of Diesel Particulate Filter in 4- wheeler public transport may be assessed. Mechanism of regular inspection /maintenance of all commercial vehicles should be formulated. Two wheelers are significant contributor to PM load. With proper maintenance, the emissions are assumed to be same in-spite of increase in number of vehicles. For reducing the traffic congestion, parking zones need to be delineated. Roads hindering the smooth traffic movement need to be identified and either may be closed and traffic may be diverted. Roads need to be identified for widening. Maintain pot-holes free roads for free flow of traffic. Introduce bi-cycle tracks /paths and encourage the use of bi-cycles. Launch public awareness campaigns for air pollution control, vehicle maintenance, minimizing use of personal vehicles, lane discipline, switching off vehicles during red light at traffic intersections etc. NGOs need to be involved for this purpose. Immediate launch of extensive drive against fuel adulteration by random monitoring of fuel quality data.

The phase-wise adaptation of above measures in the above sectors shall reduce the air pollution in the city.

7.7 Summary

The study on the ambient air quality in Nagpur suggested considerable spatial variations in the particulate matter and gaseous pollutant concentrations. The monthly variations in PM_{10} concentration showed that it is well below the threshold concentration at Industrial site, whereas at Commercial site, it exceeds the threshold during April-June and November, December and February. At Residential site, PM_{10} concentration exceeds the standard in May, August, October-December. High concentration in August at Residential site is owing to the construction and renovation activity near the site. Monthly variations in $PM_{2.5}$ concentration showed that it is higher during April-June and exceeding the threshold in May. O_3 and CO concentration are also observed to be below the respective CPCB standards. In all, particulate pollution is observed to be significant in Nagpur. Winter and post-monsoon are critical as during both the seasons, high concentration of PM_{10} is observed. The influence of lockdown on ambient air quality in the city showed the significant contribution of traffic emissions and construction activity to the ambient air pollution in the city. The remaining contribution is by the power plants. It is therefore suggested that KTPS and KHTPS need to strictly follow the emission norms and adopt control options as per the National Clean Air Programme. The study on the contribution of emissions from nearby areas need to be carried out.to understand the local and sectorial emissions.

CHAPTER 8:

NOISE ENVIRONMENT AN INNOVATIVE APPROACH OF NOISE MONITORING USING CYCLE

ESR-2019-2020

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8.1 Introduction

Noise monitoring is important and critical in urban areas since it was difficult to identify the sources and receptor-based on land use categories (Stein et al. 2005, Mangalekar et al. 2012). Further, representative monitoring of noise location is complex in the vast area of urban localities. Noise measurement is significant analytic approach in noise abatement technology. In advance way, the sound level meter is replaced with the sensor, but conventionally noise monitoring is carried out using the sound level meter and tripod fixed at the stationary location with logging of sound levels during a particular time period in day and night time (Santini and Vitaletti 2007, Rode and Shewales 2014). Sensor-based noise monitoring has more advantage nevertheless some sensors are required an internet connection so there is a risk for security point of view that data may be hacked or tracked by malicious users (Agrawal et al. 2017). Based on these facts, an innovative approach has been introduced in this research study for noise monitoring using cycle in the city. The purpose of the noise monitoring through cycle mounted sound level meter is to identify noise pollution at large numbers of location in the city for better representation and monitoring in congested /noise affected area.

8.2 Study Area

Nagpur City is one of India's developing cities. Nagpur Municipal Corporation (NMC) expanding between latitude 21° 5′ 1″ to 21° 11′ 43″ N and longitude 78° 59′ 27″ to 79°10′ 4″ E and covers an area 220 km^2 (Vijay et al. 2014; Sharma et al. 2014). The city has average elevation 290 m above sea level rising up to 350 m adjacent to, south-west, west and north-west of the city (Vijay et al. 2013). The total road length of the city is 1200 km^2 (Puri et al. 2010). Nagpur is the winter capital of the state Maharashtra, which has been significantly affected by noise pollution due to urbanization, industrialization, development in the road network and increase in the number of vehicles (Vijay et al. 2015). Nagpur is the third city in Maharashtra after Mumbai and Pune where there is a lot of traffic congestion, especially in the road intersection due to increment number of vehicles. Drivers keep engines of a vehicle running until signal turns green and unnecessarily hoot horn on the intersection (Vijay et al. 2013). This results increase in traffic noise pollution (Rode and Shewales 2014). The population growth of Nagpur has raised from 16.2 lakhs in 1991 to 24 lakhs in 2011 (Census 2011). This increase in population associated with economic growth and extended road stretch directly escalated the number of vehicles. In this city, currently, the estimated number of vehicles is around 12.9 lakhs (Motor Vehicle Population of Maharashtra 2017). All major

highways NH-6 (Mumbai– Sambalpur–Calcutta) and NH7 (Varanasi–Kanyakumari) are connected to the city. Fig 8.1 shows the geographic location of Nagpur City and the locations of noise monitoring as per noise source in the city.

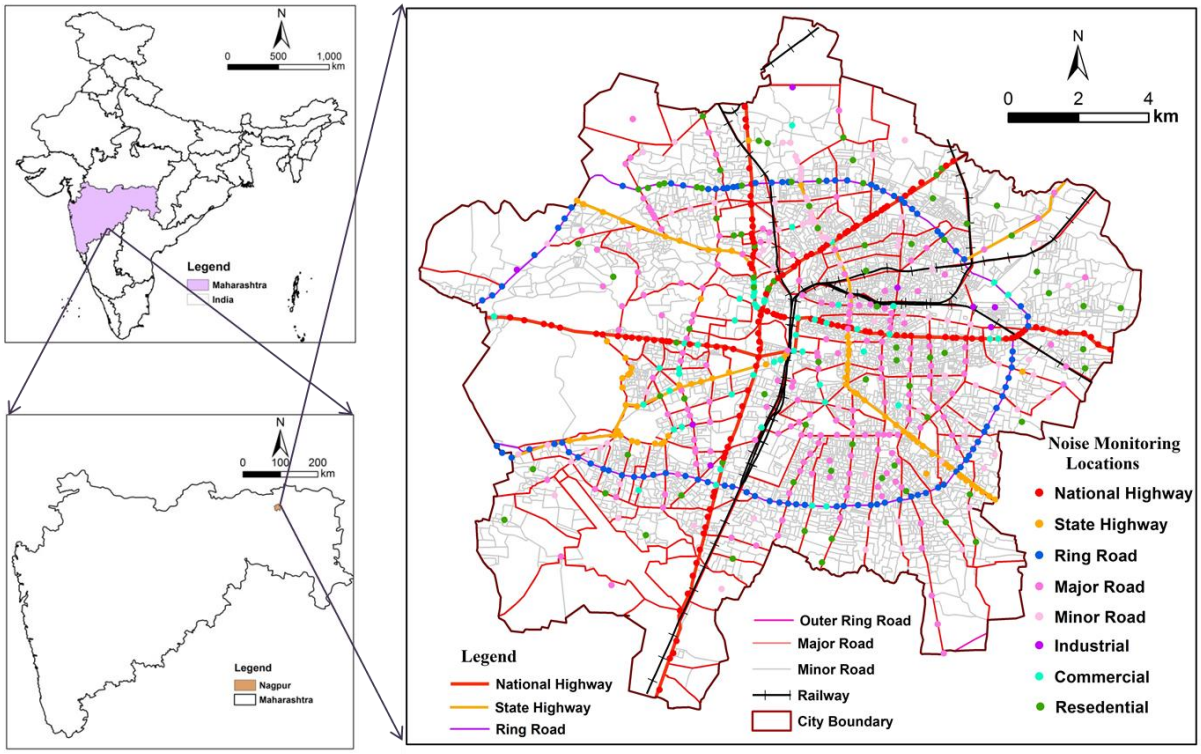

Fig 8.1 Study Area and Noise Monitoring Locations of Nagpur city

8.3 Methodology

Ambient noise along with the increased vehicular traffic and the consequential honking leads to an increase in noise pollution levels. An innovative approach of noise monitoring using cycle mounted sound level meter has been thought of under this study against conventional monitoring using the sound level meter and tripod on a certain location as per CPCB guidelines during daytime (6:00 to 22:00) and nighttime (22:00 to 6:00). Cycles are the most economical mode of transport and at the same time eco-friendly. Another added benefit is their efficiency to be noise-less and easily manoeuvrable to move along the roadside during peak traffic rush to record cumulative noise levels along major roads, minor roads and other small lanes winding through many locations under categories such as railways, industrial, commercial, residential and silence zone. Special mould for noise meter has been designed, developed and mounted on cycle under this study as shown in Fig 8.2.

Fig 8.2 Special mould for noise meter and volunteer cyclists ready for Noise Monitoring

Methodology adopted under this study has been considered in three sections.

8.3.1 Site Selection

Noise locations are selected based on traffic flow on road stretches and land use pattern of the city considering residential, commercial, and industrial zones. Silence zone is not considered in this study since cycles are not allowed in a silence zone. Noise monitoring locations are categorized as a national highway (137), state highway (68), ring Road (100), major Road (188), minor road (88), industrial (54), commercial (24), residential zones (41). Different colors are designated for each category of location as shown in Fig 8.1 and details are given in Table 8.1. Noise monitoring through cycles was carried out along designated routes and identified area given to the cyclist to cover 700 locations in the city covering both noise sources and receptors. The individual route was traced on the Google map by Google map timeline application and transferred on GIS for preparation of sampling location and noise map.

8.3.2 Data Collection

The noise measurements are carried out using calibrated Sound Level Meters with fast response mode keeping in view the quickly changing nature of noise levels. 'A' weighting is applied for measuring the sound level as it replicates the response of the human ear to noise and the measuring unit is denoted as dB (A). Data is logged at an interval of 1 second.

To conduct the noise monitoring activity noise meters were installed on every cycle with the help of mould which was designed and developed by CSIR-NEERI to enable the cyclist to easily record the ambient noise levels of the surrounding areas. Cycles were considered to hold the noise meters because the cycle itself does not produce any noise. 700 sampling locations of different road category like NH, SH, ring road, major road, minor road, railway crossing and different land-use category covering different transportation category and land use category

like residential, commercial, industrial, were considered for noise monitoring. At each location, the cycle was stopped and noise levels were recorded on cycle mounted sound level meter for five minutes with an interval of 1 second during peak hours of traffic mainly 09:00 – 11:00 am and 06:00 – 08:30 pm. At each location, 300 readings are recorded to analyze the noise data at 700 locations.

8.3.3 Data Analysis and Mapping

Noise monitoring data at each location were analyzed and corresponding L_{eq}, L_{max}, L_{min}, L_{90} and L_{10} and TNI are calculated. The equivalent continuous sound level (L_{eq}) is the average sound pressure level during the given period. L_{max} denotes as the maximum Sound Pressure Level (SPL) value measured during noise measurement L_{min} denotes as the minimum Sound Pressure Level (SPL) value measured during noise measurement. L_{90} and L_{10}, are the sound intensities that exceeded 90% and 10%, respectively for the duration of the monitoring period in dB (A). Traffic Noise Index (TNI) is determined to the measurement of noise nuisance created by vehicles. It is a noise index which measures the degree of annoyance in traffic flow by reason of vehicular noise.

Mathematically, TNI is given by (equation 1).

$$TNI = 4 * (L_{10} - L_{90}) + (L_{90} - 30) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Noise maps are generated with the help of latest state-of-the-art Geographical Information System (GIS) software. Noise monitoring data collected from 700 noise monitoring location was integrated into GIS software. Spatial map of the noise level in the city is prepared based on the noise level at the noise monitoring location while strategic noise maps of the city are generated using geo-statistical analysis which provides better display and interpretation of noise in the city.

8.4 Results and Discussion

8.4.1 Noise Level

Sampling sites were divided into eight categories viz. National highway, State highway, Ring road, Major road Minor road, Industrial, Commercial and Residential to measure the ambient noise level concerning different categories. To enhance the visualization of data strategic noise map was developed indicating the L_{eq} dB (A) of respective location. Out of 700 sampling locations, 137 locations belong to three National Highways passing through city Nagpur i.e.

NH-6, NH-7 and NH-69. L_{eq} and TNI level of sample points on National Highway is 90.0±7.2 dB (A) and 99.3±12.4 dB (A) respectively. The maximum level of L_{eq} was observed in the commercial area in the city due to the traffic congestion with the inclusion of honking noise from the vehicles at intersections.

L_{eq} and TNI value in the residential area were 84.1±6.6 dB (A) and 98.2±11.1 dB (A) respectively with 41 sampling locations. Total sampling sites in the commercial area were 24 corresponding L_{eq} and TNI level were 92.9±7.9 dB (A) and 96.5±12.9 dB (A). The minimum L_{eq} level was observed in the Industrial area with 54 sampling locations. L_{eq} and TNI value in the industrial area were 81.2±4.8 dB (A) and 99.4±10.6 dB (A) respectively. Total sampling sites representing Ring roads were 100 out of 700 and corresponding L_{eq} and TNI level measured was 91.4±6.3 dB(A) and 98.4±13.8 dB(A) respectively. Across Minor roads, 88 sampling sites where traffic volume is relatively low. 90.7±7.4 dB (A) and 100.9±13.9 dB (A) were the respective L_{eq} and TNI in minor roads. With 188 and 68 sampling sites of the Major road and State highway, the L_{eq} level response was 90.0 ±6.8 dB (A) and 89.4±6.6 dB (A) respectively with TNI levels of 101.6±13.7 dB (A) and 97.2 ± 11.2 dB (A). The values of L_{eq}, L_{min}, L_{max} and TNI along roads are presented in Table 8.1.

Table 8.1: The values of L_{eq}, L_{min}, L_{max} and TNI along roads

Categories	Sampling Points	L_{eq} dB(A)	L_{min} dB(A)	L_{max} dB(A)	TNI dB(A)
National Highway	137	90.0±7.2	61.2±4.3	97.6±9.6	99.3±12.4
State Highway	68	89.4±6.6	60.9±4.3	96.0±9.0	97.2±11.2
Ring Road	100	91.4±6.3	61.4±5.0	97.4±8.4	98.4±13.8
Major Road	188	90.0±6.8	61.0±6.0	97.6±8.8	101.6±13.7
Minor Road	88	90.7±7.4	59.5±7.6	96.7±9.1	100.9±13.9
Industrial	54	81.2±4.8	60.0±5.5	94.3±5.7	99.4±10.6
Commercial	24	92.9±7.9	63.1±3.3	99.4±10.5	96.5±12.9
Residential	41	84.1±6.6	58.7±5.5	95.4±8.5	98.2±11.1

8.4.2 Noise Mapping

To create an effective noise exposure scenario of the city L_{eq} value of the 700 different noise monitoring locations were considered. To generate the strategic noise map, all the points data (L_{eq} of every noise monitoring point) and line (roads, railway and different land-use category) data were used to create Triangulated Irregular Networking (TIN) model with the help of spatial analysis tool of Arc Map software. The TIN model is very efficient for interpolation technique to generate continues surface data using discrete spatial point and line data. TIN model plays a crucial role to describe the surface at the different level of resolution. It is efficient for storing of the mass of data (Wenzhong 2000). TIN is a proficient model to generate a noise surface for the entire city. Thus, the model TIN is very functional to assess the noise exposure of the entire study area. After the creation of TIN, it was converted into raster format using natural neighbor tool to slot in break lines into the interpolation. It may enlarge the result of the interpolation (David 1994). The Natural Neighbor interpolation algorithm tool discover the adjoining separation of key samples to an enquiry point and relate weights to them based on balanced areas to interpolate a value (Sibson 1981).

Noise maps provide a wide overview of the noise pollution problem in the city so it is a key tool for managing urban noise. Out of 700 monitoring points, almost all locations are exposed to noise levels exceeding the standards. The noise data generated form the cycle monitoring over designated routes in Nagpur city was used to generate spatial noise maps of L_{eq}, L_{min} and L_{max} as presented in Fig 8.3 (a to c).

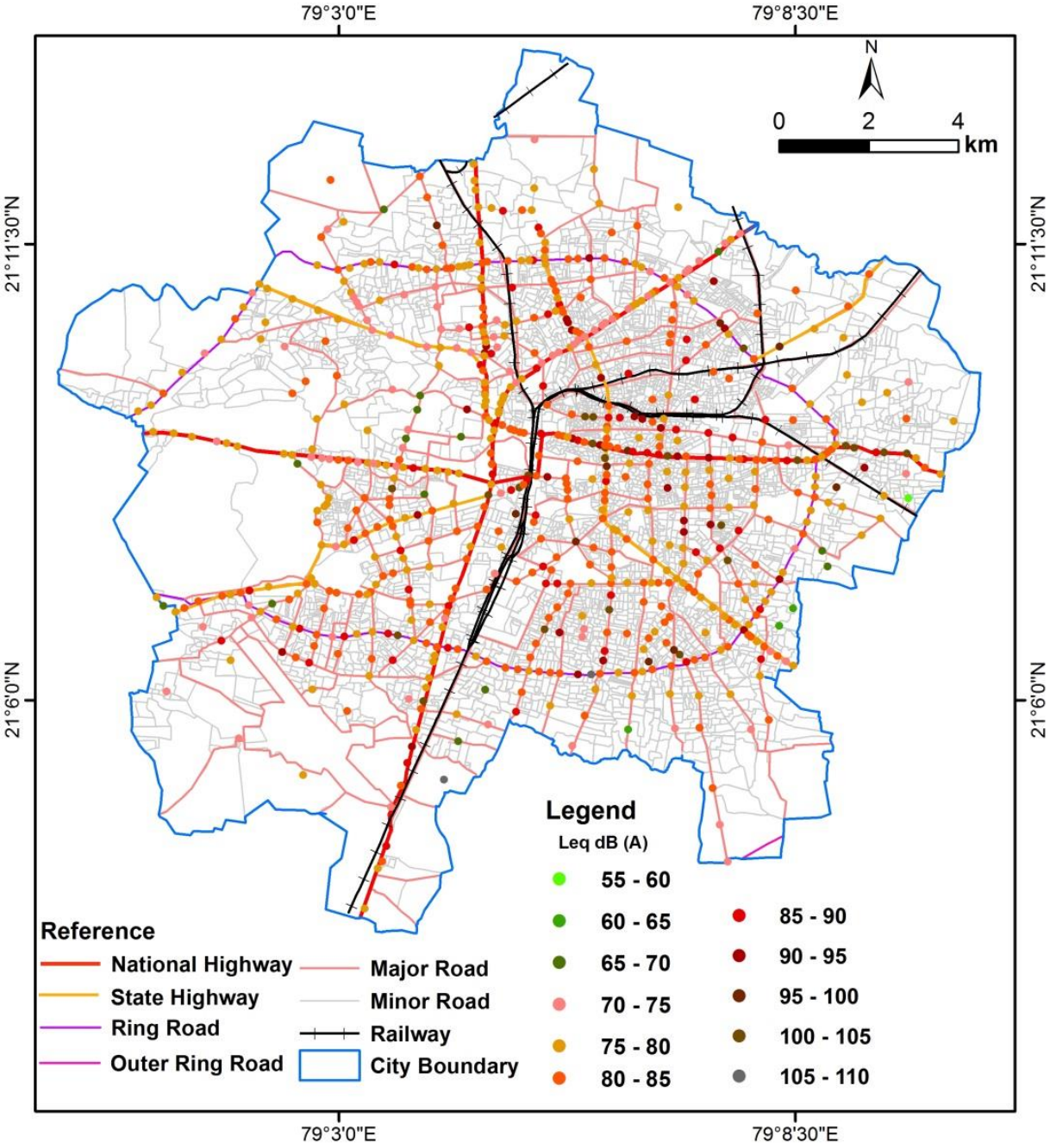

Fig 8.3(a) Spatial Noise Map of L_{eq} (Equivalent Noise Level)

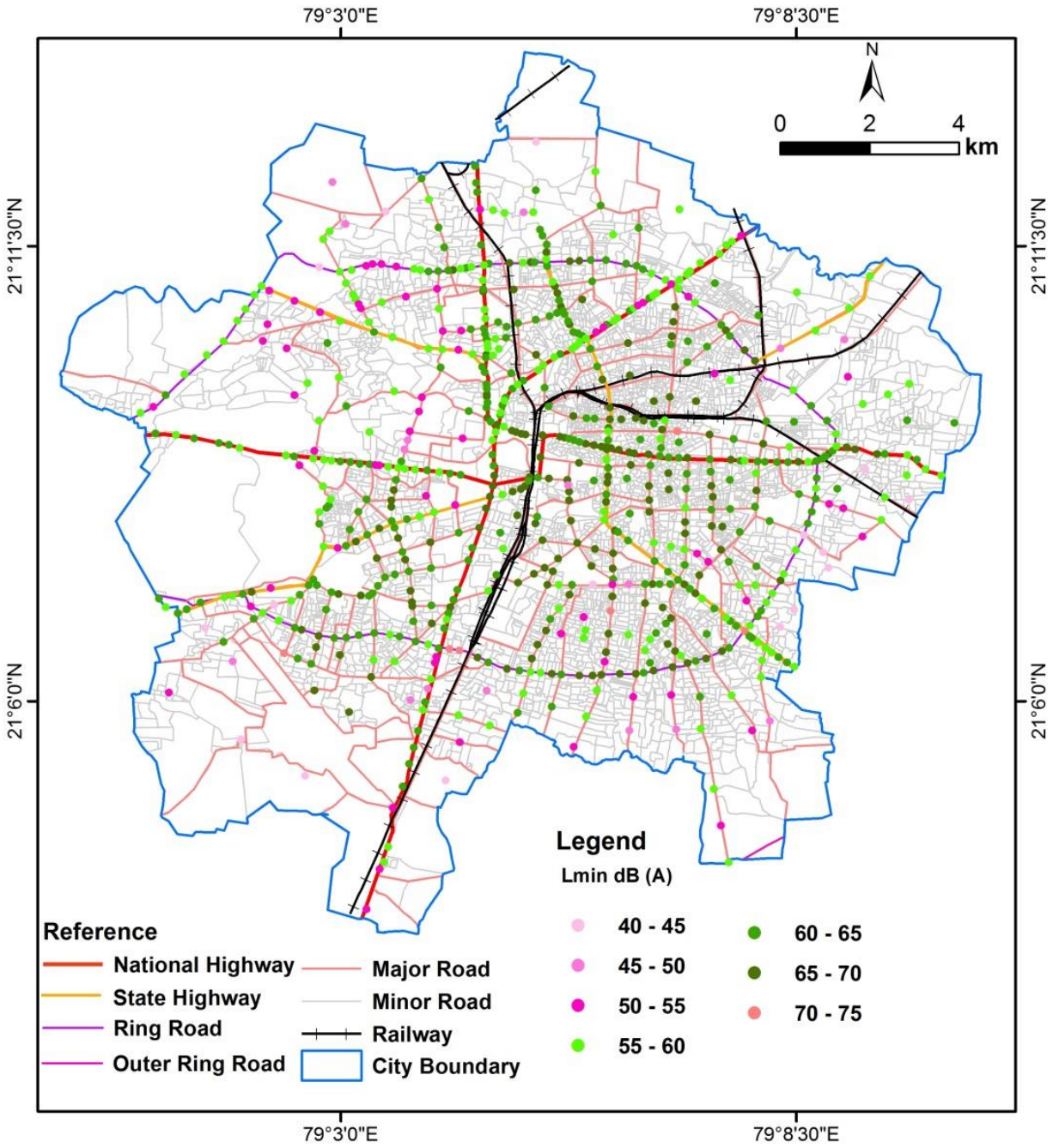

Fig 8.3 (b) Spatial Noise Map of L_{min} (Minimum Noise Level)

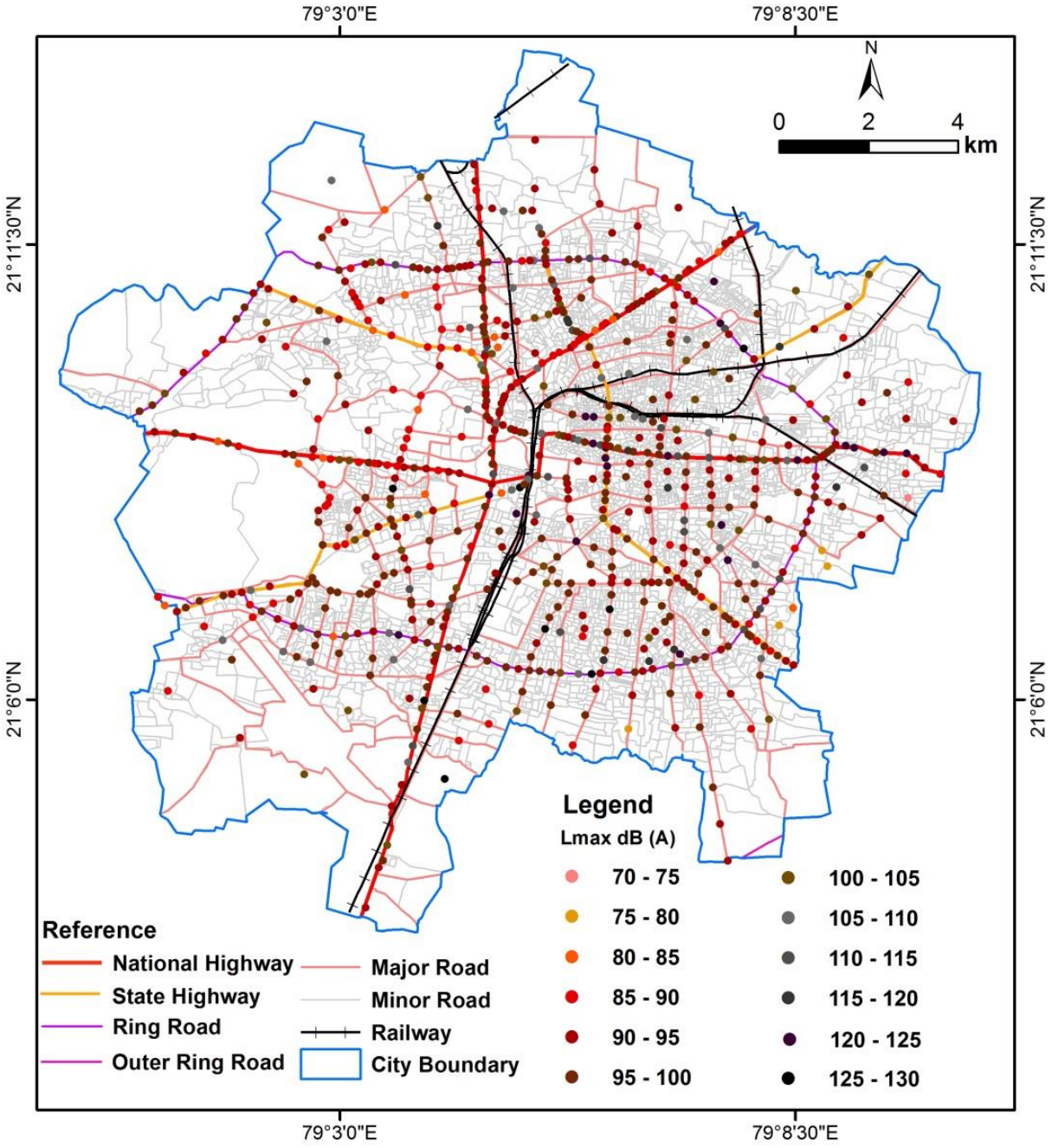

Fig 8.3 (c) Spatial Noise Map of L_{max} (Maximum Noise Level)

Spatial noise map is a special kind of noise map which shows the noise exposure of the particular location. To prepare this spatial noise map L_{eq} value were symbolized according to the different ranges of the noise level in the city. Using ArcMap software graduated symbols from quantities option and value field was considered as L_{eq}, L_{min} and L_{max} value. In this study spatial noise map is showing the different colour of the circle based on their intensity varying from light pink to black. Light pink circle represent the lowest noise level and black colour circle represent the highest noise level in the study area.

The noise levels were used to classify the number of sampling point based on three categories less than 60 dB (A), 60-80 dB (A) and greater than 80 dB (A). 374 sampling locations were having noise level greater than 80 dB (A) whereas 325 sampling locations retained noise level between 60-80 dB (A). Only one sampling location was identified where the noise level was below 60 dB (A). It is observed by the above classification that most of the sampling locations are dominated by high noise levels. The average values of noise levels in three categories i.e. less than 60 dB (A), 60 to 80 dB (A) and greater than 80 dB (A) were found to be 56.2, 76.2 and 85.6 dB (A) respectively. L_{eq} in Nagpur city was found to be above 70 dB (A) at the majority of the locations (Fig 8.3a). This exceeds the WHO guideline value of L_{Aeq} 70 dB (A) for industrial, commercial, shopping and traffic area, indoors and outdoors and can lead to hearing impairment. L_{min} values ranged from 40.6 to 72.2 dB (A) and L_{max} values ranged from 72.4 to 129.2 dB (A) as presented in Fig 8.3 (b and c). L_{min} at the majority of the locations in Nagpur city was found to be in 55-70 dB (A) which itself is exceeding the guideline values for annoyance set at 55 dB (A) by WHO (WHO Guidelines for Community noise, 1999).

Nagpur city is divided into 38 wards as shown in Fig 8.4. It can be observed from the strategic noise map that the highest noise level 105.8 dB (A) is observed in ward 33 across the ring road. Ward 35 is second noisiest ward with noise level 105.6 dB (A) across the minor road. Greater than 100 dB(A) noise levels are observed in ward number 16, 15, 19, 22, 27, 23, 24, 25, 3, 34, 36, 18, 33, 32, 8, 28 across NH7, NH6, minor road, ring road, Chandrapur-Nagpur highway, WHC road, SH-255, Rameswari road, Manewada road, Hudekeswar road, Bakramandi main road, Timki bazar road and Ramna maruti road. Lower noise levels are observed in wards 1, 2, 4, 12, 13, 14, 26, 28, 29, 34, 37, and 38. These wards are situated along outskirts of the city and also possess good vegetation cover which helps in mitigating noise levels.

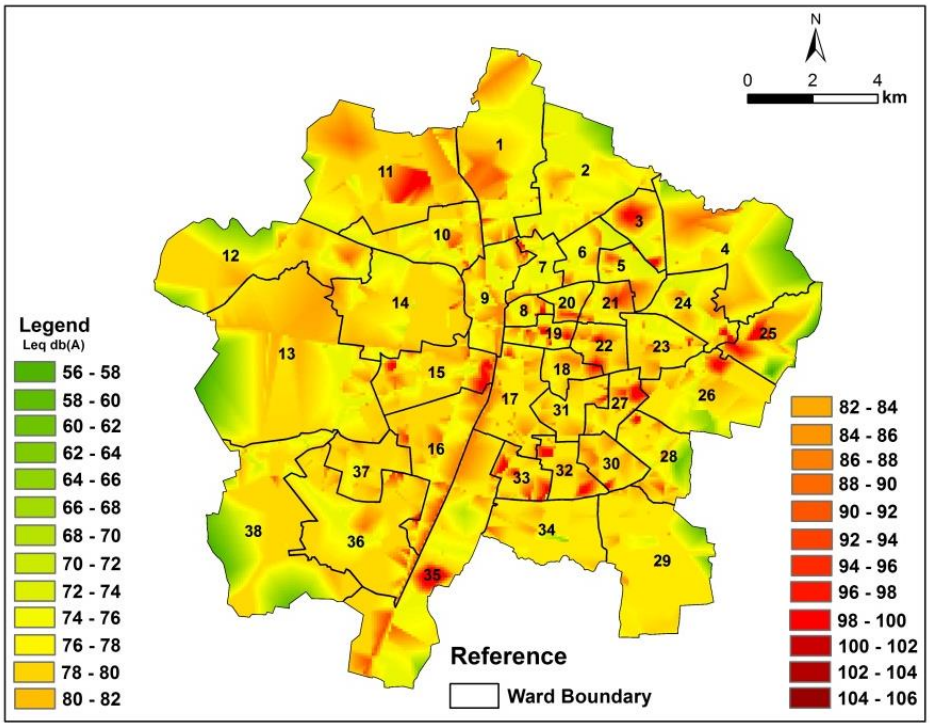

Fig 8.4 Strategic Noise Map of Nagpur city

8.5 Summary

The purpose of the cycle-mounted sound level meter noise monitoring is to identify noise pollution at large numbers of locations in the city for better representation and monitoring in the congested / noise area affected. A total of 700 sampling locations were selected including various road category like National Highways (NH), State Highways (SH), ring roads, major roads, minor roads, railway crossings and different land use categories for different transport types. Moreover, residential, commercial and industrial were also considered for noise monitoring.

At each sampling site, the cycle was stopped and noise levels registered on the cycle mounted sound level meter for five minutes with an interval of 1 second during peak traffic hours primarily at 09:00 a.m. to 11:00 a.m. and 06:00 p.m. to 08:30 p.m. Spatial maps of the city's noise level are prepared on the basis of the noise level at the noise monitoring site, while strategic area noise maps are created using geostatistical analysis to better view and analyze the noise in the region.

Spatial noise map shows that out of 700 sampling sites, 374 sampling sites had a noise level greater than 80 dB, while 325 sampling sites had a noise level between 60-80 dB. Only one

sampling position was found where the noise level was below 60 dB. This shows that majority of the sampling sites are affected by high noise levels.

Strategic noise map shows that More than 100 dB of noise levels are detected in Ward 16, 15, 19, 22, 27, 23, 24 , 25, 3, 34, 36, 18, 33, 32, 8, 28 through NH7, NH6, Minor Road, Ring Road, Chandrapur-Nagpur Highway, WHC Road, SH-255, Rameswari Road, Manewada Road, Hudekeswar Road, Bakramandi Main Road, Timki Bazar Road and Ramna Maruti Road. Lower noise levels are observed in wards 1, 2, 4, 12, 13, 14, 26, 28, 29, 34, 37, and 38 due to their locations being outskirts of the city.

8.6 References

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CHAPTER 9:
ECONOMIC AND SOCIAL PROFILE INDICATORS

ESR-2019-2020

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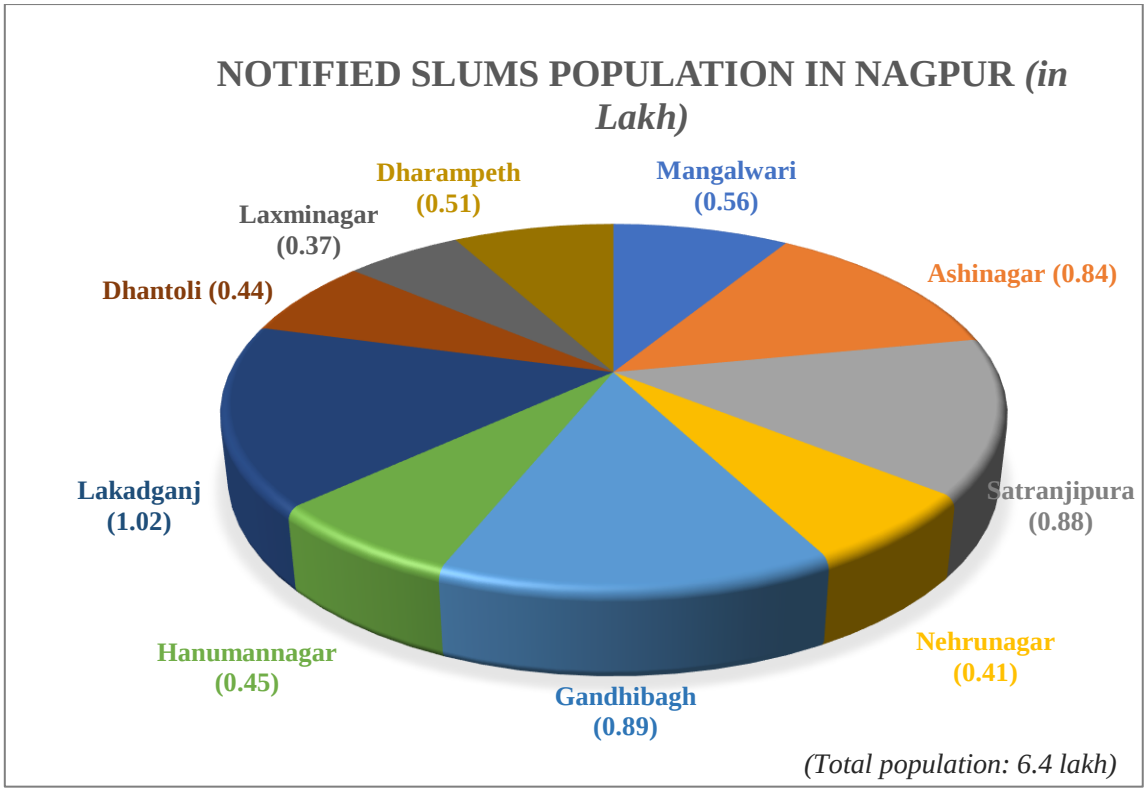
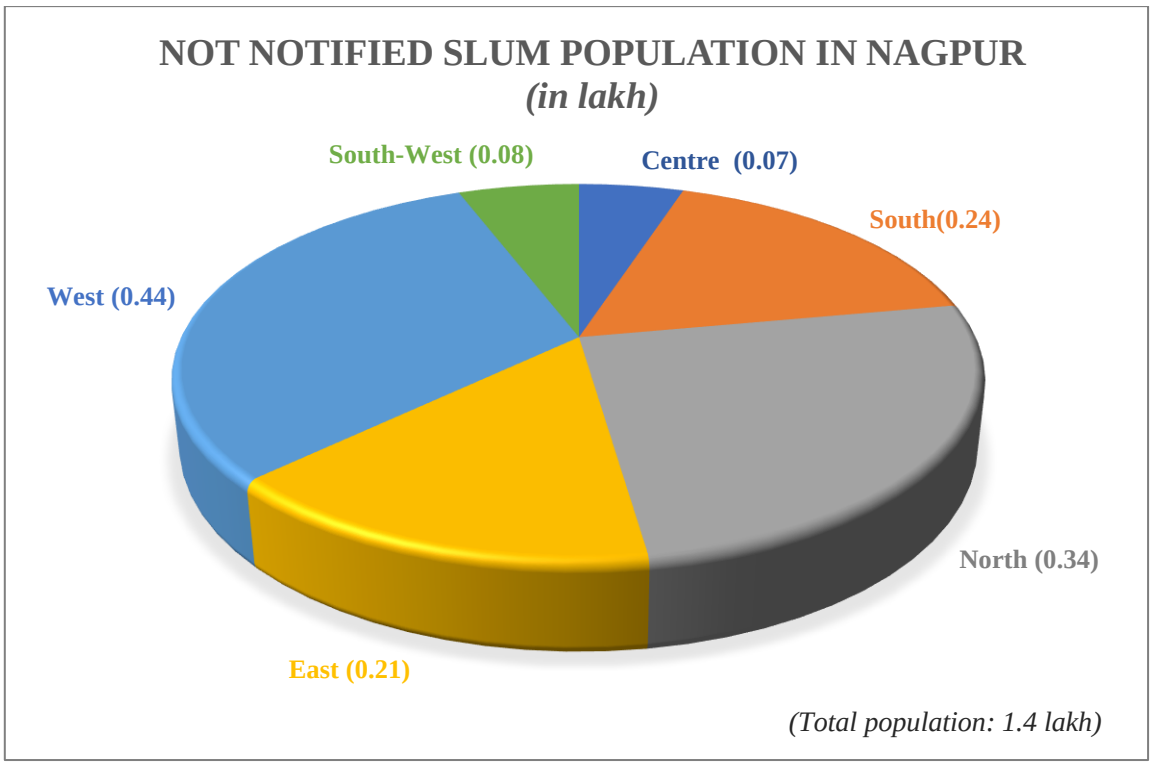
9.1 Slums areas growth, legalization and Rehabilitation

9.1.1 Profile of Slums:

In early 19th century, the people from western part of Vidarbha & Chhattisgarh migrated in search of job 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 are a total of 439 slums in city, out of which 421 were recognized in NMC official data. 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 includes government, industrial and private ownership and remaining 48% slums on government land. The securities of tenure or tenure right are not allocated to any of the slums situated in Government land.

The Nagpur Municipal Corporation (NMC) has recently commenced a drive to identify plots, occupants, and issues of ownership to slum dwellers on lands owned by the state government. There are 298 notified slums and 128 non notified and 33 new slum areas in Nagpur according to Slum “Patta Watap Cell” Nagpur Municipal Corporation . The slum population has grown to 6.4 lakhs in the notified slum areas and 1.4 Lakh in the non-notified slum areas (**Figure 9.1).**





Data Source : Housing & Slums : Nagpur Smart city, Feb 21, 2019

Fig 9.1: Notified and non-notified slums in Nagpur

This catalog describes the slum and housing infrastructure details of the Nagpur city.
Released Under: National Data Sharing and Accessibility Policy (NDSAP)

9.1.2. 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 old areas, 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:** In Nagpur 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 . B. Recommendations of GTZ Nagpur Municipal Corporation has been appointed to German Technical Committee (GTZ) as a consultant for detailed study of slums in Nagpur City.

Committee has suggested the following recommendations.

1. Slums on lands earmarked for non-residential use may need relocation. 2. Settlement with poor soil conditioned and drainage should be considered for relocation. 3. Relocation proposal should be formulated with the consent and cooperation of community and concerned corporators (Elected representatives) 4. Slums for relocation to be prioritized on the basis of extent to which communities face hazards of flooding, willingness of community to shift and availability of relocation of site. 5. Proposal to be formulated in close cooperation with

authority. 6. Availability of serviced sites for relocation to be examined in terms of available area, distance from existing settlement and cost of development. 7. Slum Rehabilitation Authority (SRA) : SRA has identified 55 slums in Nagpur city for relocation due to the reservation of land uses, ownership of land (security of tenure) and un-notified status of slums

9.1.3 Slum Rehabilitation for Nagpur

Most of the slum are notified in the Dhantoli zone (44 slums), following by Sataranjipura and Lakadgunj zones with 40 slums in each zone. Ashinagar and Mangalwari zones have the maximum number of non-notified slums, which is 24 and 25 slums, respectively.

There are around 1.5 lakhs 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 459 slums around 17% are located on private land, while 19% are located in the government owned land. Other 14% of the slums are located on the land belongs to authorities like NMC, NIT, Revenue Department and Indian Railways. Almost 50% of slums are located on land having mix ownership.

A report in Economics time on August 23, 2019 entitled said “The state cabinet on August 20 approved a policy to give ownership titles to slum-dwellers residing in slums on lands owned by private persons. The policy has been approved as part of the Housing For All Scheme-2022. "The government in November 2018 approved a policy to give ownership titles to encroachers on revenue department owned lands within the limits of urban self governing bodies. Similar decision was taken for encroachments on lands owned by other government agencies, excluding zudpi jungles. A large number of people are residing on private lands by constructing unauthorized houses for last many years. Need was also to pass on the benefits of Housing For All Scheme-2022 to such encroachers," the cabinet note said.

As per data with NMC, there are 82 unauthorized slums on lands owned by private persons, of which 64 lands are reserved for residential while remaining 18 comprise of various other reservations. There are 149 unauthorized slums on lands owned by private persons as well as government agencies. Of these, 107 are reserved for residential and remaining 41 have other types of reservations.

The number of slums on private lands account for 54.35% of all slums across the city, which makes the latest decision a populist one to woo slum-dwellers, who are considered dedicated voters. The city comprises of 425 slums, which have around 1.50 lakh houses. NMC officials told TOI a survey will be conducted to identify exact number of houses on

private land, and area of encroachers after issuance of notification by the government. "Survey of slums on revenue and government owned lands is nearing completion. Ownership titles have been issued to around 2,500 slum-dwellers by NMC, NIT and collector office as on date," the officials said.

9.2 Initiatives for Slum Improvement

9.2.1 Slum Improvement Programme (1972-1994)

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

9.2.2 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 Nagpur Municipal Corporation (NMC).
- In this scheme 6,252 dwelling units (DUs) along with the infrastructure and facilities have been proposed and sanctioned in 18 slum communities in Nagpur.
- 4064 dwelling units have been completed (2018) and allotted to respective beneficiaries

9.2.3 Rajiv Awas Yojana (RAY) (2007)

- In this, survey of 130 slums has been already completed and socio-economic surveys as per formats issued by GoI are underway.
- Initial surveys have been completed by SRA and mapping for 1 cluster (which consists of 5 slums) is taken up for implementation on project basis under RAY.
- The pilot project having a mixed bag of EWS, housing, livelihood and rental housing alternatives has already conceptualized, prepared and submitted to Maharashtra Housing and Area Development Authority (MHADA) and State Level Sanctioning Committee (SLSC) for their approval.
- Draft plan of Slum-free City Plan of Action (SFCPoA) was prepared by SRA based on the data available on slums.

9.2.4 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 for poor SC families and neo-Buddhists aim to provide housing. The Department sent a list of 4,706 beneficiaries to the NMC but only 1,031 were selected from 1st April 2014-31st March 2018.
- Later, new announcement was done by the government in which they sanctioned more than 1 lakh houses under this scheme for poor families and also increased their subsidy from INR 70 thousand to 1 lakh for households.
- The houses were sanctioned in the various divisions of Maharashtra including Nagpur for FY 2018-2019 under this scheme.

9.2.5 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.

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

- The PMAY 'Housing for All' scheme was announced by Union Minister & Chief Minister has a schedule of 17th June 2015-31st March 2022, planned to build 50,000 houses for poor.
- It will be built by NIT and Maharashtra Housing and Area Development Authority (MHADA).
- The construction has already been started by NIT in four different location in Mouza Wathoda (264 houses), Khasara No. 63 Mouza Tarodi khurd (2,374 houses), Khasara No. 62 Mouza Tarodi khurd (942 houses) and Mouza Wanjri (960 houses) for economically weaker section (EWC).

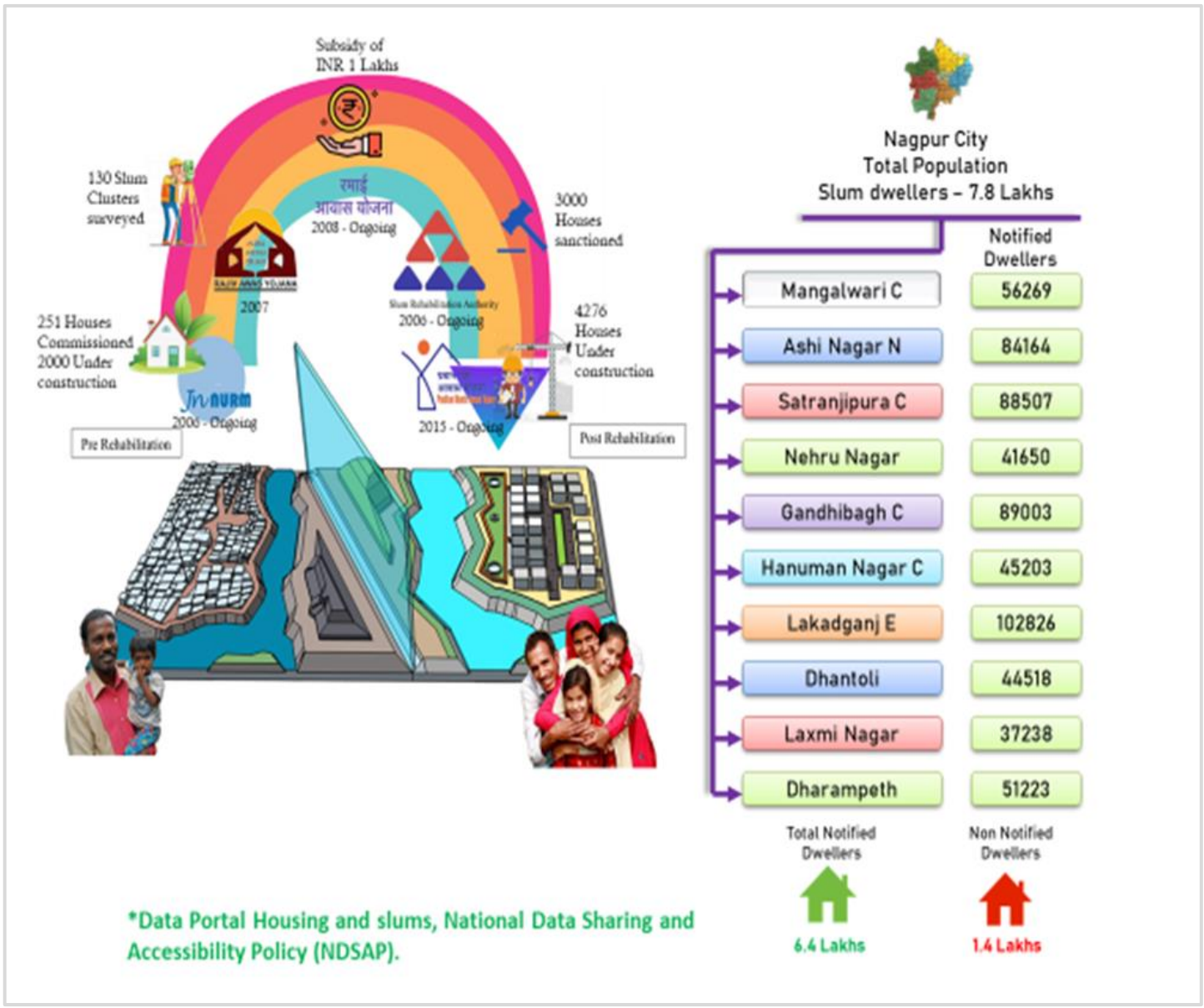


Figure 9.2: Summarized pictorial representation of current slum rehabilitation

9.3 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 programme (Federation of Indian chambers of commerce and Industry, 2018). Nagpur Municipal Corporation (NMC) spreads over an area of 227.38 sq. km with a total estimated population of 29.30 lakhs (2.9 million) in the year 2020. 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).

9.3.1 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 2051 was worked out in the section.

9.3.2 Current Population

Latest population survey of the Nagpur City was carried in the year 2011 under the nationwide Census of 2011 performed by the Union Government of India. Nagpur city's population tally was 2.405 million in the year 2011 which is 20 times of the population existed in the year 1901.

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.

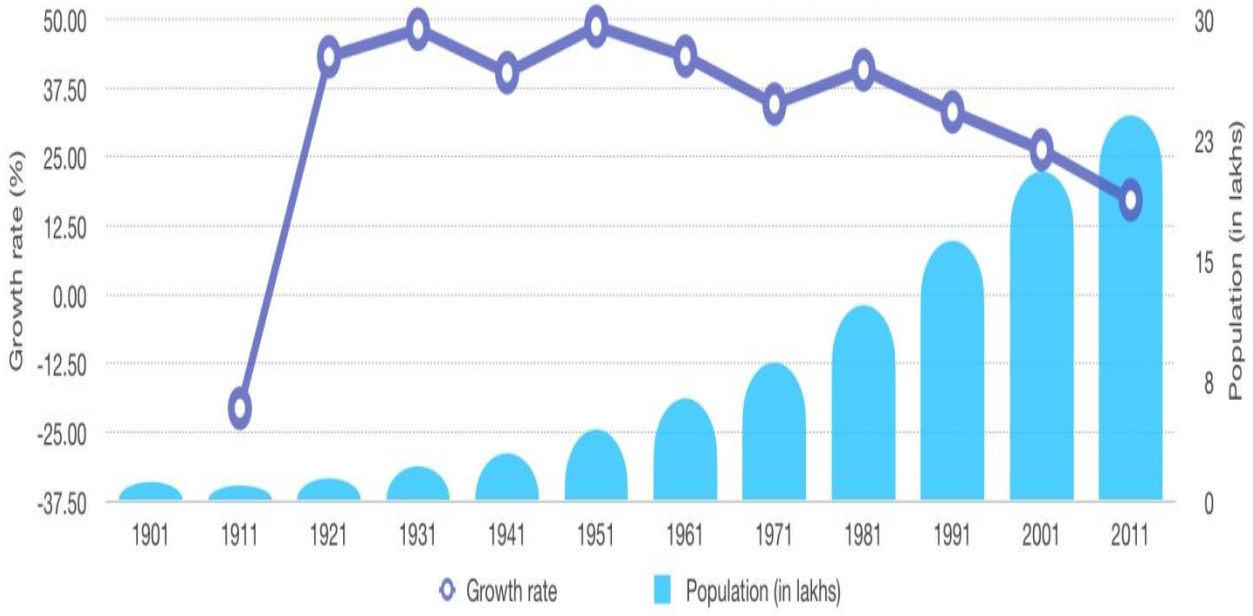


Figure 9.3: Decadal population growth rate for Nagpur city (1901 -2011)

The overlay of decadal growth rates of the city on the decadal population for the last fourteen decades is depicted in the **Figure 9.3**. 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 1911-21. 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 next four decades is shown in the **Figure 9.4**.

Population forecasting was done by adopting three population forecasting methods namely, Geometrical Increase method, Incremental Increase method, and Arithmetic Mean method. The quoted population projection was the mean of the future population projected by each method. The major factors behind the population growth are induction of massive development projects in the city such as MiHan, Metro, industrial corridors that directly or indirectly creates mass employment opportunities for the population leading to migration of people residing in the adjacent region and states. The nearest city with population of more than 5 lakhs, Amravati is situated at 70 Km from the city Centre (GoI, 2011).

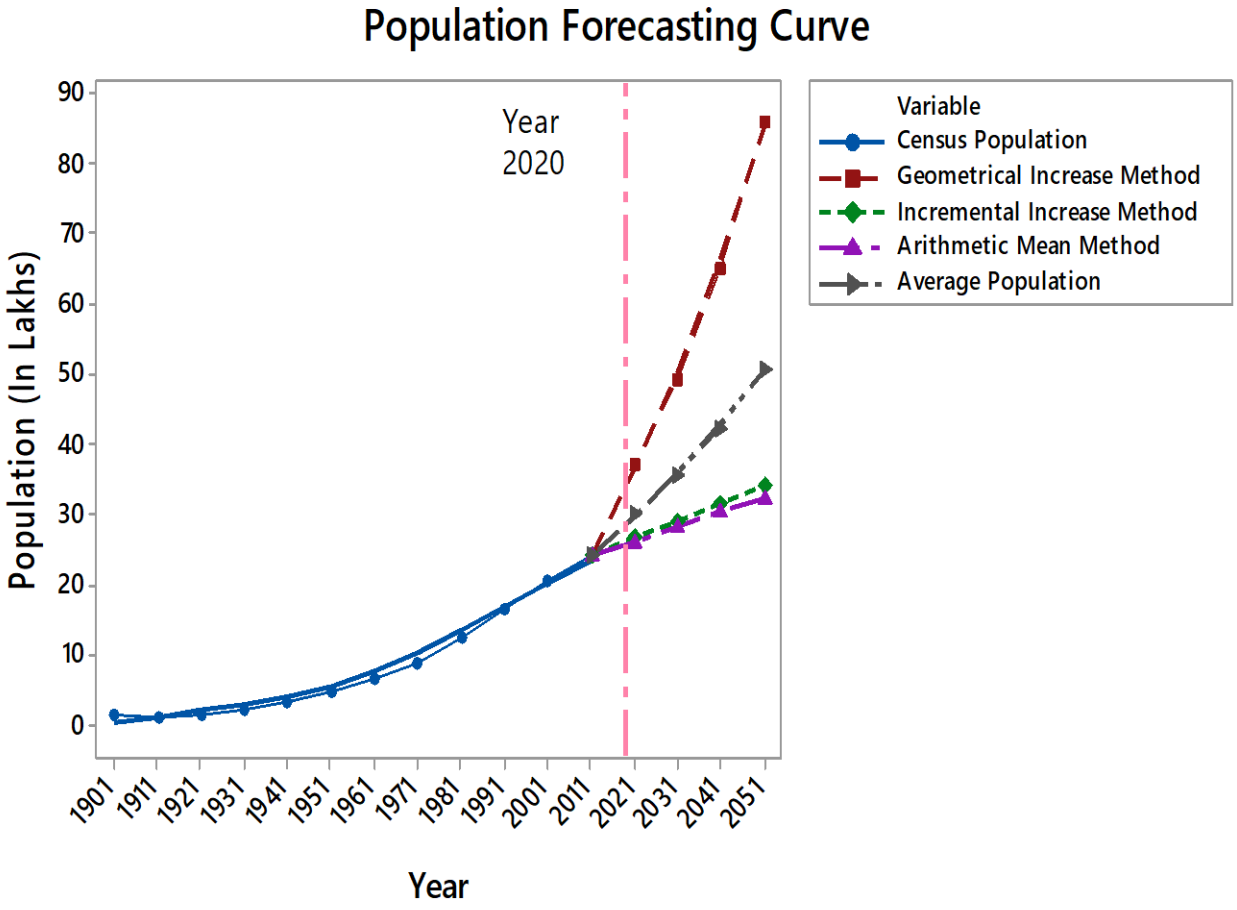


Figure 9.4: Population Forecasting of Nagpur city

9.4 Pillars of Nagpur Economy

9.4.1 Trade and commerce

9.4.1.1 MIHAN

MIHAN is an acronym expands as 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 location of Nagpur, which is center of the country and to develop an integrated industrial, commercial, and transport hub. The project sprawls over an area of 4,354 hectares that houses Special Economic Zone (SEZ), air cargo terminal, rail terminal, and a road terminal. The major components and their highlights are presented in **Figure 9.5.**

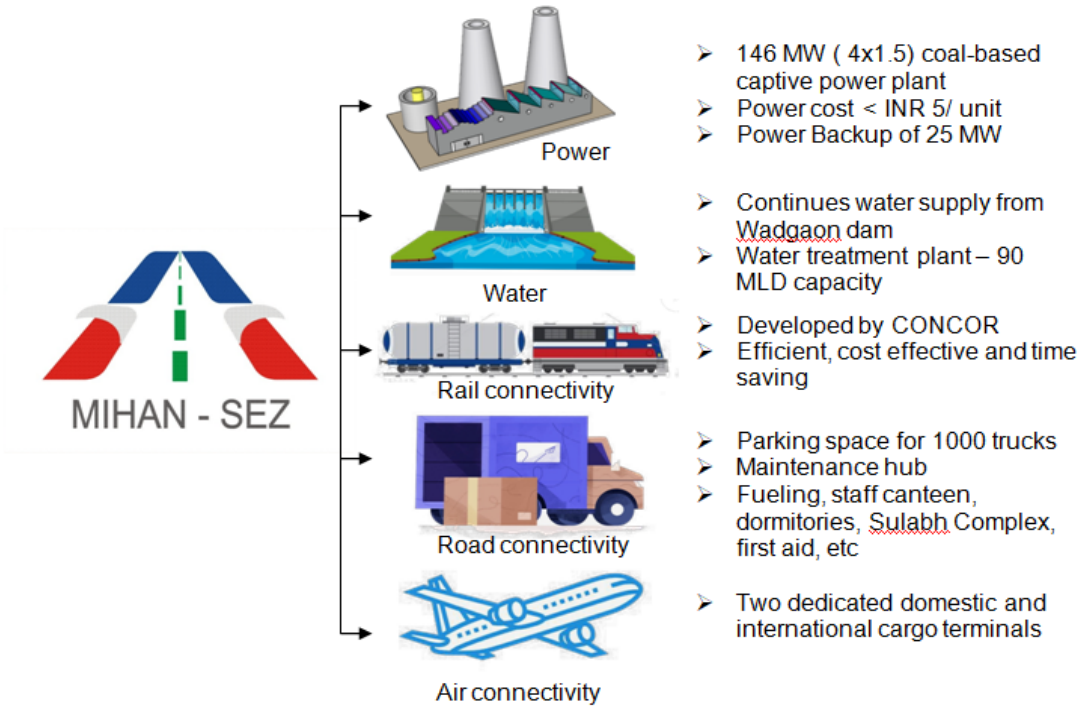


Figure 9.5: Components of MIHAN

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 INR 2,581/- Crores and expected investment by the private investor will be INR 20,000 Crores. MIHAN project will generate employment for over 4.5 lakhs youth of Nagpur region over next 10 years (Mihan SEZ, 2020).

9.4.1.2 Startups and New businesses

Nagpur is also a hub on new startups with intensive initiatives taken by the center and state governments. Some of the Nagpur based startups are discussed below:-

Panino has recreated the art of sandwich making and is one the indigenous restaurant chain competing with international giants Macdonalds, Subways etc. With 10 serving outlets in city Panino is a popular name among the city residents. It provides employment to over 150 people.

Figure 9.6: Startups of Nagpur

Another success story is Kichadiwala, started from a stall at Nagpur traffic park with a cost of INR 70,000 to a full fledged business start up. The start up is successful and has generated INR 57 lakhs revenue and employs 54 people.

9.4.2 Transportation

Commuting facilities are the backbone of a metropolitan. 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. Nagpur railway station is being in operation since 1867.

Nagpur Mahanagar Parivahan Limited (NMPL) operates with fleet of 487 buses to carter in-city travel of 160,000 passengers daily. Aviation of the city is backed by Dr. Babasaheb Ambedkar International Airport, with over 1400 aircrafts flying over the Nagpur airspace. The airport has three domestic and two international airlines offering flights to ten cities.

The road network of the city measured as 1907 km and has unique four-layer transport system which include (from bottom to top) a roadway, railway bridge, flyover and elevated metro, shown in **Figure 9.7**.

Figure 9.7: First of its class 4-layer transport system

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.

9.4.2.1 Nagpur Metro

Nagpur metro is the 13th metro railway system of the country (**Figure 9.8**), and is the greenest one with 65% of its electricity requirement meeting from solar energy. It will have 38 stations , 2 depots and a fleet of 69 metro cars. The cost of this project is estimated at 8,680 crore.

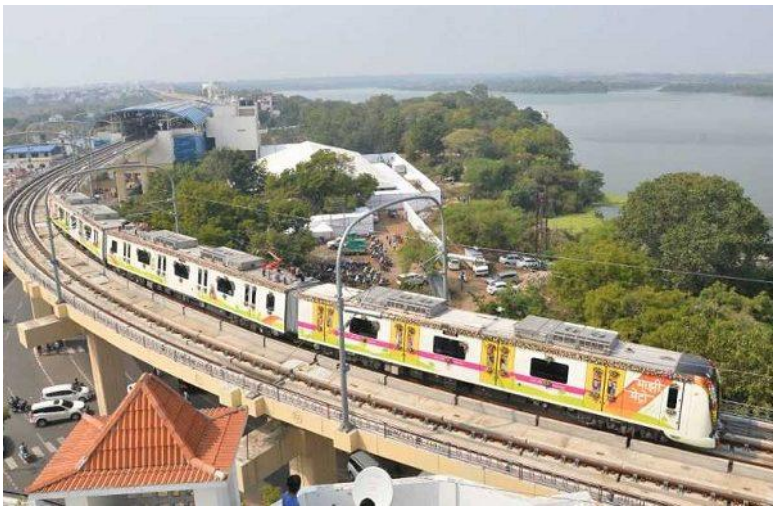


Figure 9.8 Aqua line of Nagpur Metro

9.4.2.2 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.

9.4.2.3 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 has come up with the ambitious super expressway project named Maharashtra Samruddhi Mahamarg which will cut short travel time between two cities nearly half of the earlier. As, it enables to travel from Nagpur to Mumbai and vice versa within 8 hours. Ease of connectivity with the business capital of country, Mumbai will bring prosperity to the Nagpur region and will links MIHAN to the country's largest container port – JNPT. The project costs around INR 55,000 and stretches up to 701 km. The highway will include over 50 flyovers, over 24 interchanges, more than 5 tunnels, more than 400 vehicular and over 300 pedestrian underpasses at strategic locations.

9.4.2.4 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.

During January, 2019 to January, 2020 the airport has witnessed average footfall of 2,52,185 flyers (Airports Council International, 2020). The operational statistics of flyers flown from Nagpur airport during 2019-20 is presented in **Figure 9.9.**

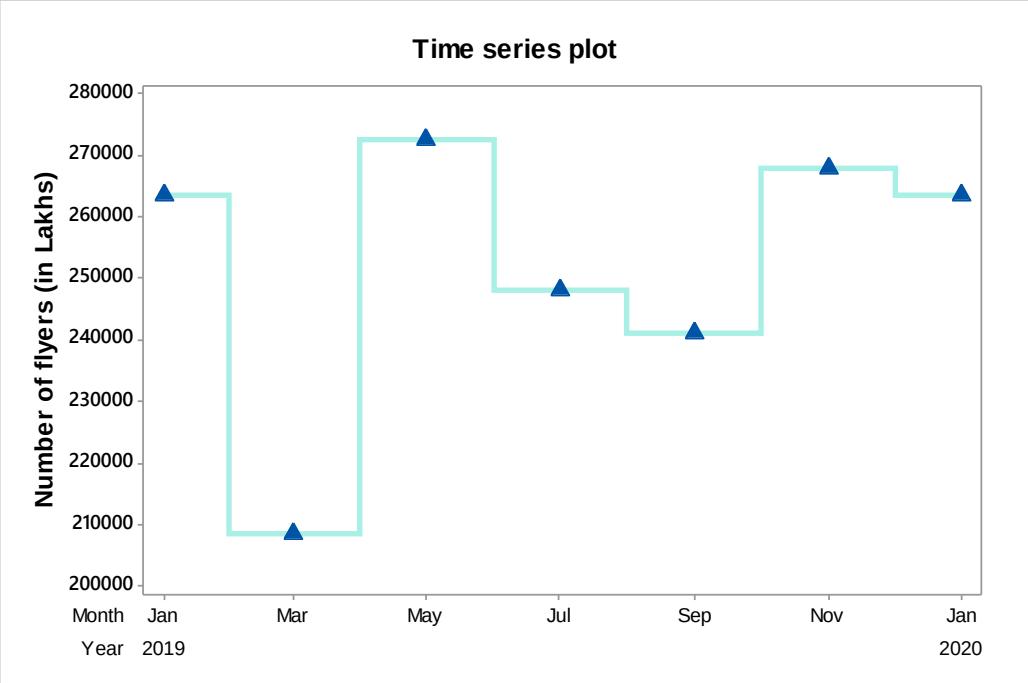


Figure 9.9 Flyers profile of Nagpur Airport (Jan 2019 - Jan 2020)

Nagpur airport is set to be integrated with a SEZ under MIHAN project. The existing runway is to be extended by 200m 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.

9.5 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 couple of years key national level institutions such as AIIMS, IIM, IIIT and NLU were established in the city. Apart from it, prestigious private universities like Symbosis International University has

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 ambiguous 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 collages 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 school Nagpur region has best Student- Teacher Ratio (STR) in the state at 29.4 and 27.5 respectively. A comparative graph covering all regions of state of Maharashtra, containing total number of schools and STR for three year period for 2015 to 2018 is represented in the **Figure 9.10**.

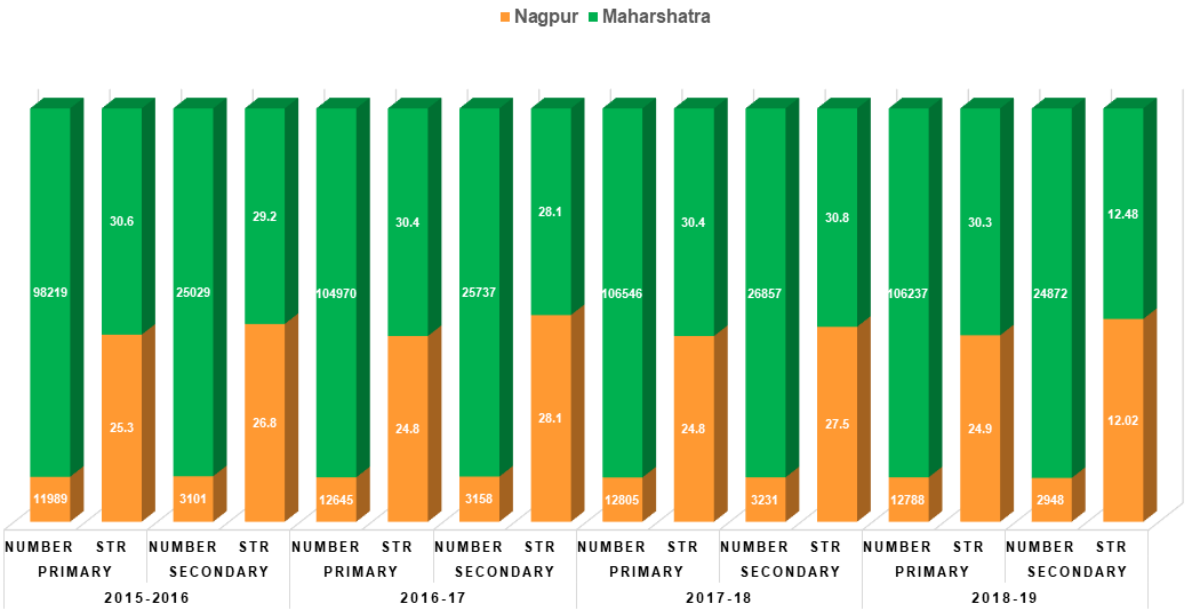


Figure 9.10 Comparative study of number of primary and secondary schools with respective STR for Nagpur and Maharashtra

9.6 Key indicators

9.6.1 Human development Index (HDI)

HDI, measures the quality of life of the citizens on basis of their life expectancy, education, and per capita income. It was developed by economist Mahbub ul Haq, 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 by Shinge, (2020) in Economic survey of Maharashtra, HDI of Nagpur is 0.786 where as the Mumbai holds the tag of city with best HDI in the state at 0.814. However, Nagpur's HDI is higher than the state's average 0.752. **Figure 9.11** represents the HDI of the cities of Maharashtra with more than 20 lakhs population as per census 2011.

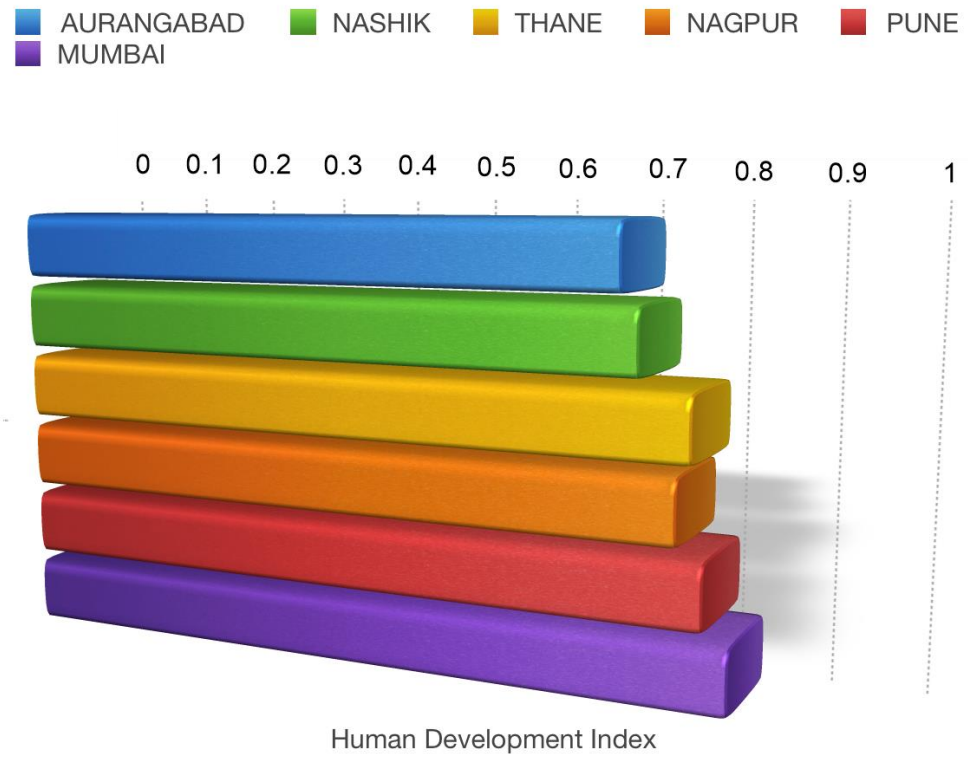


Figure 9.11 HDI of cities of Maharashtra with population >20 lakhs (Census, 2011)

9.6.2 New Business registrations

In India 95% of the business establishments are come under small and medium enterprise sector. Thereby serves as the backbone of the country's economy. To identify, regularize, and promote micro, small, and medium enterprises, the GoIhas launched Udyog Adhaar. The registrations of Udoyog Aadhar done in region directly indicate the state of trade and commerce of that region. In Maharashtra Nagpur stood fourth in the Udyog Adhaar enrolment and

succeeded by Mumbai, Konkan and Pune in the timeframe of nearly four years from October, 2015 to March, 2019. Also Nagpur has received 8.2% of the total investment made in the state, accounting INR 13,141 crores (Shinge, 2020).

9.6.3 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.

The real GVA of Nagpur and Nagpur Division (Wardha, Bhandara, Gondia, Chandrapur, Gadchiroli, and Nagpur) is presented in the Figure. 10 from the year 2011 to 2019.

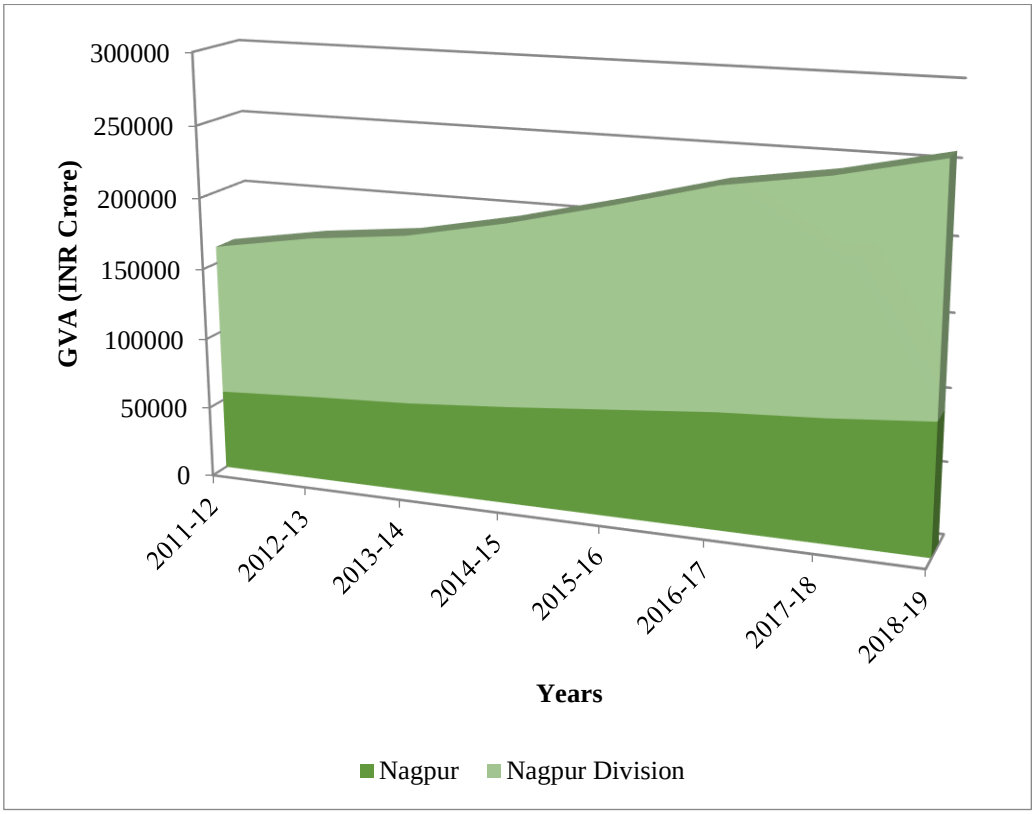


Figure 9.12: GVA of Nagpur and Nagpur division (2011 - 19)

9.7 Summary & Conclusions

Being located exactly of 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 will adds up the educational profile of the city.

Nagpur is a home for successful business ventures such as Haldirams, Dinshaws, Biadyanath, to name a few, and successful start ups as well, like Panino and Khichdiwala. 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.

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CHAPTER 10:
RECOMMENDATION AND ACTION PLAN

ESR-2019-2020

10.1 Climate Change

To address the global challenge called climate change, an unprecedented level of cooperation is necessary, on both global and local levels. Leading the fight against climate change at the local level would be the modern city as they are the most vulnerable to the effects of climate change. With the urban population expected to increase by 66% by 2050, adding 2.5 billion people to the urban population (World Economic Forum, 2016), along with climate change, the modern cities of the 21st century will face severe stress on several critical services.
Potential stressors include an increase in surface and ocean temperatures, higher frequency and intensity of extreme events, rising of sea levels, melting of glaciers, shifting of agricultural patterns, pressure on food and water security, and effects on human health. IPCC's AR5 report says that due to certain anthropogenic activities, these changes are already underway. All this makes the planning for the future a highly complex and raises questions on when, who, and how should mitigation and adaptation plans start to counter the potential impacts of climate change. With this in mind, a modern city would be the most suitable platform in the fight against climate change, and the same is true to the city of Nagpur.

Temperature and Energy Consumption

The study shows that, as seen in fig.2.2, in the last two decades (2000-2019), the annual average temperature shows an increasing trend and similar trend was observed for extreme heat events for period between 2000-19, as seen in fig 2.3. Further, the decadal investigation indicates that the incidence of high heat days and nights (HHDN) is on the rise especially in the monsoon season (June-Sept), as seen in fig 2.4.

The rise in the ambient temperature of Nagpur city will have a direct impact on the demand for cooling services, especially for monsoon season when the climate will be both hot and humid. The increasing trend in cooling degrees days, as seen in fig 2.8, indicates high-energy demand for cooling building. This analysis shows that Nagpur is headed towards a hotter climate with more extreme heat events, which would require high energy and water consumption to maintain the indoor thermal comfort.

Precipitation

The analysis of 50 years meteorological data (1970-2019), indicates that the annual mean rainfall for Nagpur city has not in last five decades (fig 2.5). However, the same cannot be said when we investigate the season rainfall pattern. The investigation of decadal rainfall shows that

there is drastic reduction of rainfall during the post-monsoon and winter seasons (fig 2.6). This reduction could affect the productivity of Rabi crops cultivated in the region. Further, table 2.1 shows that wheat productivity has a negative correlation with rainfall, so heavy rains during the summer could further reduce the yield of wheat crop.

Even though the magnitude of rainfall during the southwest monsoon has increased but the number of rain days for the decade of 2010-19 has reduced (fig 2.7). This indicates that the intensity of the southwest monsoon has increased with a large volume of rainfall taking place in fewer days. This kind of intense rainfall can stress the urban infrastructure and services and lead to urban flooding.

Recommendations

The present study on the climate variability of Nagpur city for over 50 years (1970-2019) indicates that climate-related changes are happening in the city, and its impacts are being felt in terms of extreme weather events, energy consumption, and food/water security issues. This section would delineate some action points that can be taken to understand further the impact of climate change on various city-wise wide sectors and provides certain recommendations.

Table 10.1: Salient Features of Key Recommendations made under Climate Change Mitigation

S. No.	Recommendations	Salient Features
1.	City-Wide GHG emission inventory and accounting	For any city to take proper and effective action on mitigating climate change, useful and robust data on greenhouse gas emissions (GHG) from the city is required. Therefore, any climate change action plans begin with the development of a robust GHG emission inventory. This would highlight the GHG emissions from various sectors of the city and devise appropriate action plans. The GHG emission inventory can be classified into three main parts (Kean Fong *et al.*, 2014) : ***1. Introduction to Reporting an accounting, Delineating inventory boundary and scope – wise definition*** ***2. Sector-wise accounting, sourcing of data and emission factor calculations***

		3. ***The setting of mitigation goals and performance tracking*** Further, the GHG emissions for any source can be classified into the following sectors 1. ***Stationary Energy*** 2. ***Transportation*** 3. ***Waste*** 4. ***Industrial processes and product use*** 5. ***Agriculture, forestry and other land use*** The inventory would help cities in the development of robust data on GHG emissions by various sectors, as specified above. Also, it would provide a baseline for track performance in the reduction of GHG emissions.
2.	Climate Vulnerability Index	For combating the effects of climate change, it is essential to understand which all communities, cities services, and other sectors are vulnerable to the impacts of climate change. Climate vulnerability Index can be calculated based on three indices and their relationship with the effects of climate change. The three sub-indices are as follows (NMSHE and India, 2018; Salas and Araya, 2018) 1. ***Exposure*** 2. ***Sensitivity*** 3. ***Adaptive Capacity*** The development of a climate-based vulnerability index for the city would provide the planners and policymakers, a blueprint for climate-adaptive a focussed city development plan.
3.	Development of Climate Resilience Plan	Using the GHG emission inventory and Climate Vulnerability Index, the different vulnerable zones/sectors can be identified, and sector/zone specific adaptive climate action plans can be formulated for implementation. Examples of sector-specific action plans: 1. Decarbonization of towns and cities

		2. Strengthen the adaptive capacity 3. Increasing energy efficiency, use of renewables and improving access to energy

10.2 Water Environment

Old and corroded water distribution systems (WDS) show frequent pipe breaks and leakages. This results in significant loss of treated drinking water and revenue loss. Therefore, it becomes impossible for the utilities to maintain the network up to the mark and meet its expected performance. This leads to the decision of operating the network with Intermittent Supply instead of Continuous one i.e. 24/7 water supply. Such intermittent systems are highly prone to contaminant intrusion due to negative pressure in pipes during non-supply hours. In many cities Non-revenue water (NRW) ranges from 30 to 60%. This includes Water loss due to leakage (real loss) approximately 14 to 20%. The influx of contaminants across pipe walls, through breaks and via cross connections frequently results into outbreak of waterborne diseases like gastroenteritis, jaundice, typhoid etc.

Commendable efforts to regain river status to Nag river from Nag *Nullah* is undertaken by NMC every year during pre-monsoon season which includes dredging and silt removal. CSIR -NEERI has been monitoring NAG river for Environmental Status Report . However the Water quality of Nag river is highly polluted and steps to prevent sewage ingress into inland water bodies are be taken on high priority . Comparative charts of Chemical Oxygen Demand and Biochemical Oxygen Demand , which are measure of the organic and biodegradable organic content , respectively; of Nag , Pilli and Pora rivers are given in the Figure 1 and 2 below :

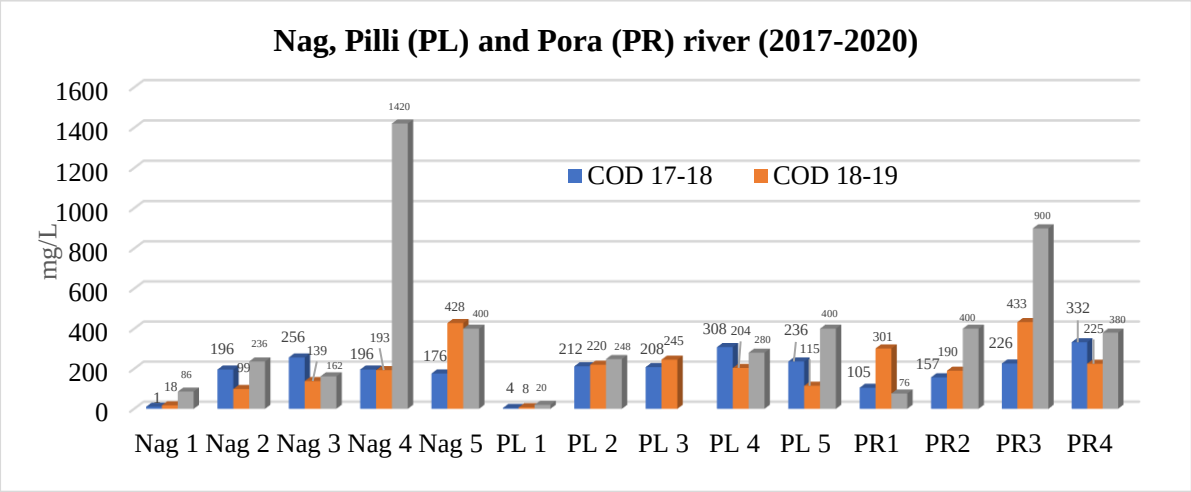

Figure 10.1: Comparative Chemical Oxygen Demand

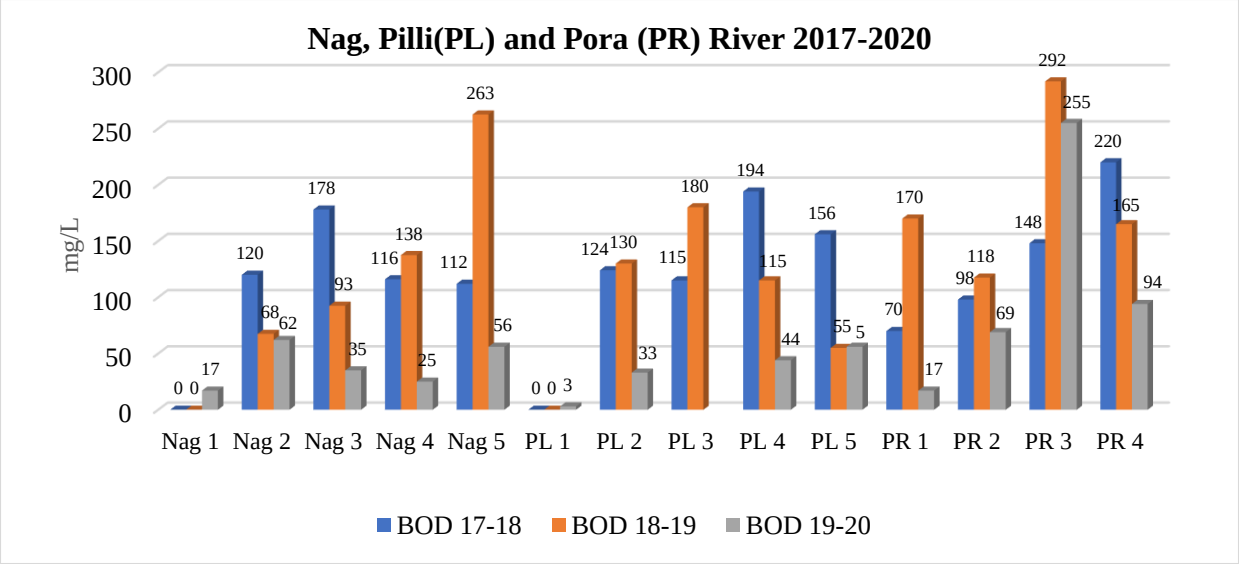

Figure 10.2: Comparative Biochemical Oxygen Demand

It is clearly observed that the rivers waters except at Location Pilli 1 fall in CPCB class E i.e. fit for irrigation industrial use and controlled waste.

Groundwater

Due the changes in the precipitation and temperature pattern, to maintain the agricultural produce, the tapping of groundwater is one the most important methods for bridging this gap. For Ground water level studies vs rainfall, study shows a low negative trend correlation as seen in Chapter 2.0. This indicates that even if the rainfall is high, the GWL decreases. This can be attributed to two factors 1). No proper groundwater recharge and 2) High extraction/exploitation of GWL.

Recommendations

- A network of observations should be set up for monitoring the groundwater quality (major cations-anions, trace elements) in pre-monsoon (May) and post-monsoon (November) seasons. The monitoring wells should be in the vicinity of the landfill site at Bhandewadi and the Industrial clusters at Hingna.
- Piezo metres should be set up in the Industrial cluster at Hingna and groundwater level should be monitored at least in pre-monsoon (May) and Post-monsoon (November) for long term water level scenario.

- There is scope for further development of groundwater resource in the city. However, a detailed groundwater budgeting based on the recent data should be carried out and the quantum of groundwater which can be developed should be worked out.

Water supply

With the use Software Like RISK-PiNET2.0 developed by CSIR-NEERI; the condition of water pipes can be assessed to develop rehabilitation plan. This software has been tested in Hanuman Nagar pilot study area in Nagpur. Using this software, a strategic network management program can be developed for the water supply network of Nagpur city. This can reduce a significant component of NRW which is real or technical loss and improve the network by giving returns every-year in addition to health benefits.

Rivers

As per suggestion in ESR 2018-2019, it is recommended to follow the interventions given therein:

- Sewer connections to households and slums to prevent sewage from entering Nag, Pilli and Pora Rivers.
- Hospitals built along these rivers to maintain their own STP.
- Mobilization of Nag river Improvement plan through NMC and Smart City authorities should be expedited
- Decentralized treatment options for townships and small cluster settlements to prevent the expenditure of carrying sewage to a centralised system.
- In situ drain treatment to prevent flow of untreated sewage from non-point sources of pollution
- Treated sewage kiosks can be maintained for sale of polished treated sewage
- Nagpur city ESR 2017-2018, 2018-2019 reported in detail the condition of inland surface bodies within the Municipal Corporation . Since the scenario has not improved as evident from Figures 10.1& 10.2 it is reiterated that prevention of sewage from entering the rivers or in situ treatment are the options available for rejuvenation of these surface water bodies of Nagpur city.

- Buffer zones and green belt development along the banks of river to protect the water quality

- Demarcation of boundaries to protect the areas of rivers and lakes to preventing the encroachments
- Rain water harvesting mandatory to every registered structure under NMC/NIT's jurisdictions may be policed and recorded alongwith annual precipitation to study effect on recharge of groundwater through the years .
- Creation of groundwater hydrology maps and groundwater models to understand the amount of surface runoff entering the groundwater aquifers.
- Proper drainage systems should be provided in buildings to avoid sewage influx with groundwater.

Lakes

- Ensuring protection by appropriate aesthetic shoreline development / embankment on all sides of lake to prevent silt inflow from surrounding areas. Design for development of peripheral wetland to Intercept and arrest the nutrients inflow into the Futala and Naik lake
- Mass awareness programs for cooperation from citizens regarding indiscriminate throwing of nirmalaya / garbage / food waste into Naik talav Futala , Gandhisagar Sakkardhara lakes
- Social awareness on importance of maintaining lake ecosystem
- Employing prevention and/or reduction in non-point source of pollution and nutrient inflow into the lakes from water shed by in-situ treatment techniques

Activities to be undertaken

- Creating earning source from lake ecosystem e.g. Fish, Aquatic plants etc
- Provision of adequate number of toilets and dustbins to prevent waste disposal in all the lake
- Determining the morphometry of the lake to be created & slope stabilization in Futala lake
- Periodical cleaning of all the lakes
- Lakes like Naik talao are on the verge of dying and needs immediate cleaning and rejuvenation plans for implementation and action

- Unhygienic human activities like urination, defecation, bathing washing to be prevented in the vicinity of the lake
- Wandering of stray animals to be prevented in the vicinity of the Futala lake

10.3 Urban green spaces (UGS) and Ecosystem Services (ES) for Green Infrastructure (GI) planning in Nagpur

The provision of open space and public green and blue spaces as a public asset in urban areas, can minimize the negative impacts of climate variability and vulnerability, especially since Nagpur falls in the high temperature belt of the country. For implementation of an urban resilient framework, there is growing need to create green and open spaces so as to maintain the sustainability of socio-cultural, economic, and ecosystem services flow. Based on the survey that was carried from Feb-mid March, 2020 to understand citizens' response to public Urban Green Spaces (UGS) and key Ecosystem Services (ES) a total 1050 respondents from 100 wards participated and based on that following recommendations are made:

- Along with taking participatory survey results to understand demand supply gap it is also necessary to understand the wards in different color grades of green, orange and red their available spaces, built up area density and population for better planning of GI that also follows recommendations of URDPFI guidelines (MoUD, 2015 a, b and c).
- Focusing on avenue plantations should be priority in the city especially in orange and red zones to enhance connectivity and develop corridors to connect UGS. Avenue plantation is an important landscape approach to maximize outputs and enhance green spaces. Especially avenue plantations can help address and reduce impacts of air pollution and heat islands.
- There are many wards in city center that are dense and do not have sufficient space for avenue plantations or creating green parks the idea of plantation will not effective there and instead alternate measures like developing vertical garden on metro pillars, flyover pillars and under the bridges should be planned. Road dividers can be efficiently used for raising healthy plants to reduce air pollution and heat island impacts using hardy and tolerant fast growing preferably native species. This can also be followed at ward level roads by making it compulsory for each road in the city premises.
- 19 Red zones are the most sensitive zones and numbers will be much more not less than at least 35-40 wards if survey is completed for all wards. These wards and residents are already having huge gap in terms of access and availability to UGS. NMC needs to

make a 10 year monitoring and review plan where NEERI can be involved for understanding and identifying locations for plantations, developing vertical GI along with Natural Infrastructure (NI).

- In 44 orange zones planning should be to identify locations appropriate for plantation and vertical gardens, monitoring of remaining UGS for effective conservation and restoration. Special effort should be to identify the reasons behind deterioration of quality and quantity of green spaces and by avoiding them a 5-year plan should be prepared that should be reviewed and monitored every year. These wards need improvement in UGS in next 5 years so, that they don't turn up as additional red wards in next 5 years.
- In 50 green zones focus should be to reduce interferences in UGS, avoiding any kind of encroachment or felling and promoting additional plantations. Most of the parks don`t have sufficient trees regular monitoring for understanding tree density should be a compulsory activity for garden department of NMC involving district forest department and citizen science approaches where NEERI can partner and provide scientific training and support.

10.4 Solid Waste Management

At present, mixed waste is usually collected and sent to the dump-sites/waste to energy (WtE) plants/compost plants. Effective system of waste segregation is required at appropriate stages i.e. source of waste generation, collection, transportation, processing and disposal.

The owners and occupiers of premises within the Municipal Area shall segregate waste under three categories as per the SWM Rules, 2016:

- Organic or bio-degradable wastes (called wet waste)
- Recyclable or non-biodegradable wastes (called dry waste)
- Domestic hazardous wastes

The Local Authorities may consider providing, for one time, one bin for wet waste and one bin for dry waste storage to individual specially to the low income groups and slums lying within the Municipal Area.

Sanitary waste, as defined under the SWM Rules, 2016, generated at the household level shall be wrapped in paper and handed over separately to waste collector every day in areas where segregation is already happening. It's a high time to commence it in other areas as well.

Incentivize segregation at source: In order to push and encourage on-source segregation, local authorities may consider creating system for incentives, which may not be necessarily through any financial means or products. Incentives may be like awarding and recognizing the households by giving certificates, by publishing their names on respective websites or reduction in property tax etc.

The local Authorities may initiate a roadmap for taking steps to strengthen segregation, collection, transportation and processing and should include the followings:

- Enforcement of segregation of waste
- Ward by ward mapping and coverage to ensure segregation at source
- Building awareness of households
- Distribution of bins
- Monitoring of progress to achieve the desired objectives
- Ensuring compliances from bulk generators
- Ensuring compliances from street vendors
- Creating infrastructure to collect segregated waste
- Training of waste collectors
- Ensuring compliances over processing of segregated streams

The authorities should adopt decentralized technologies such as biomethanisation, composting etc and may encourage generator to treat wet waste at source and may consider creating systems for incentives, which may not be necessarily through any financial means or products but to recognize the best performing community or household and publishing their names on respective websites or in the society.

Local authorities shall prepare a timely plan for remediation and bio-mining of the existing dumpsites.

Local Authorities shall penalize households for non-segregation

Devise a system/App: Local Authorities shall develop an application or a system to address complaints and to spot-check the black spots removal in the city. They shall create a system wherein any person can post a picture and the municipality shall clear the posted black spot in a fixed time. If that task is not done, then the same shall be notified to the higher officer. This shall also help in rating the efficiency of the municipality in solving grievances.

10.5 Environmental Externalities Evaluation due to the Pollution from Bhandewadi Dumping Yard, Nagpur

Valuation of environmental externalities has been done using national and international approaches recommended for assessment. The framework developed by CSIR-NEERI to evaluate environmental externalities has been used extensively deriving knowledge from the methodologies developed by the United Nations and US EPA. Externalities are evaluated for air, water (leachate) and greenhouse gas emissions from the dumpling yard at Bhandwari. Given the limited data availability and the analysis following insights can be looked into future:

- Leachate, although causing less damages as considered to be contaminating only the soil can contaminate water bodies at a later stage. The damage value should be considered as conservative and should be used to collect and treat the leachate.
- It is evident that GHGs emissions are major component of environmental damages. They can be controlled with application of biogas extraction system on a stabilised dumpsite. This will help reduce the damages.
- The booming activity is a welcome step for the dumpsite and will not only help in recycling but also reduce above damages. It will be worthwhile to estimate the positive externalities of biomining activity at a later stage when sufficient data is available.

10.6 Air Environment

The following specific recommendations to control air pollution in the city can be prioritized.

- Ambient air quality is being monitored in Nagpur by several agencies namely MPCB, CPCB through NEERI and VNIT.
- Only one CAAQMS station is being operated by MPCB stationed at Civil Lines (near GPO). All other monitoring is carried out by manual monitoring, which is spread across the city.
- It is desired that one monitoring station be set up in the downwind side of two major thermal power plants namely Koradi and Khaparkheda so that the impact of power plant emission can be assessed.
- Influence of lockdown on ambient air quality in the city is significant, which suggests the significant contribution from traffic emissions and construction activity. The remaining contribution is by the power plants that mainly contribute when the wind

direction is towards the city. KTPS and KHTPS therefore need to strictly follow the emission norms and adopt control options as per the National Clean Air Programme.

- It is important to understand the contribution from the nearby areas and also the regional contribution. Air shed of the area need to be identified so as to account for the emissions sources.
- To mitigate the emissions from house hold combustion activities, slum population, within the city need to be encouraged to shift to LPG. Hotels and restaurants need to strictly use LPG.
- Buses in the city are observed to emit substantial visible smoke. Heavily emitting public vehicles and old buses need to be identified and phased out. Alternative fuel based buses should be introduced in phases. Periodic monitoring and regular maintenance of bus fleet needs to be ensured.
- Open burning although banned is still happening in the local / residential areas and needs strict enforcement of the law.
- Slums areas need to be visited and proper guidance on solid waste management may be given to the residents through public awareness programmes.

CHAPTER - 11

CITIZEN'S CORNER

AS THEY SPEAK……

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The contents of this section are solely the views of the authors. CSIR-NEERI does not agree or disagree nor do we endorse the matter. This section has been included solely to add a voice to citizens participating in environmental awareness.

Industrialisation of Vidarbha – The Restricting Elements

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Economic development of Vidarbha has been the objective of the Vidarbha Economic Development Council (VED), a Nagpur-based NGO that has as its vision and mission the prosperity of Vidarbha.

Industrialisation forms an integral part of economic development, but, unfortunately, Vidarbha hasn't attracted large investments consistently. Even incentives which were granted by the state government have not produced the desired results. Maharashtra announced the Package Scheme of Incentives in September, 2019 granting additional incentives to Vidarbha, Marathwada, Ratnagiri, Sindhudurg & Dhule the outcomes of which are yet to be seen.

At VED, we tried to analyse the reasons why Vidarbha hasn't been able to attract industry, and came up with a few important reasons - restricting elements - that contribute to this lacuna.

Western Maharashtra, historically, has attracted industrial investment due to its proximity to the port. Such industrial investment and the virtue of location advantage leads to concentration of activities. Industrial activity leads to creation of employment opportunities and consequentially greater consumption levels and higher demand for goods. This phenomenon has led to concentration of industrial activity in Mumbai/Pune. The benefits accrue to the surrounding towns as well.

World over, coastal regions have attracted maximum investments, India being no exception. Therefore, cities like Chennai and Mumbai have led port based industrial development with NCR also tagging along. Clusters of Sectors like Auto, pharmaceuticals, steel, textiles and many more are located in these regions.

Source : Representation in Business world

Please note: Map not factual. Meant only for purpose of showing corridirs

The government's focus on port led industrial development led to development of industrial corridors like Delhi-Mumbai (DMIC) funded by the Japanese government, similarly Mumbai-Bengaluru, Chennai-Vizag and Amritsar-Kolkata. The National Industrial Corridor Development and Implementation Trust (NICDIT) was constituted on 22.12.2016 under the Ministry of Commerce and Industry to implement the industrial corridors project. In November 2019, the government of India notified the implementation of the above corridors, leaving a yawning gap in central India, with Vidarbha being totally left out, again contributing to the lack of interest shown by industrialists.

The government's focus on above industrial corridors works out well for port-based places like Chennai, Mumbai, and Gujarat, these being port-cities themselves, having ports, or being close to the ports, which lowers export and import costs, and achieves a better balance for industry, once again making a bedevilled Vidarbha's land-locked centrality a disadvantage.

While being the centre of India gives Vidarbha certain advantages, simultaneously it brings with it a few major disadvantages as well. Firstly, it is away from high consumption centres like Bangalore, Chennai, Delhi, NCR, Pune, Mumbai, and Gujarat. It stands to reason that with the markets being in these distant places industry is unlikely to come here, considering the high logistics costs. Industrial facilities generally are concentrated either near their consumers or raw material sources.

Vidarbha is mineral-rich, but these, as well as other industries, are beleaguered by the great forest wealth of Vidarbha, for the necessary conservation of which, environmental clearances are not come by easily, thereby restricting development.

The government (Co-operation, Marketing and Textile Department, Government of Maharashtra) on its part has taken pro-active steps in addressing these issues by announcing State Textile Policy 2018-2023 in February, 2018 to offset the additional cost burden as indicated above. The textile industries at Nandgaonpeth in Amravati is a classic example of how the state government can attract investments with implementation of the right policy and creating appropriate infrastructure.

The Hyderabad Nagpur industrial corridor as announced by the Telangana Government through its arm The Telangana State Industrial Infrastructure Corporation Limited and Maharashtra Samruddhi Mahamarg being constructed by the Maharashtra State Road Development Corporation connecting Mumbai and Nagpur will create the right infrastructure to attract industrial investment in the 20 odd industrial areas planned alongside it.

Let’s hope that the infrastructure development reduces cost for industry and links it cost effectively to the industrial hotspots of the country. It is only then that large corporates will find this region attractive for investments.

Vibrant Start up Ecosystem In Nagpur

-By Poonam Khandelwal

Poonam is CA by profession. She is regional partner for Venture Catalysts, India's 1st Integrated Incubator & Leading Early Stage Startup Investor (#7 Globally). Poonam is also Market Development Partner for Venture Catalysts and working on expansion of Vcats to 100 cities in India. Poonam is an angel investor with 15 startups investments. She also operates a 30 seater incubation centre in Nagpur. She is chairperson of Vidarbha Industries Association's Entrepreneurship Forum.

Maharashtra has a vibrant start up ecosystem, with a total of 2,787 start ups registered in the state, out of over 14,565 under the government's start up-centric programmes. It was ranked first in terms of the number of start ups registered with the Department For Promotion Of Industry And Internal Trade (DPIIT) in 2018.

Though Mumbai dominates as the primary start up hub within Maharashtra, the state's progressive policy and regulatory environment have led to the emergence of many regional start up hubs in cities such as Pune, Thane, Nashik, Aurangabad, Nagpur, and Solapur.

Among these cities, Nagpur was awarded the Smart City status in September 2016 and is a major commercial and logistics hub in central India, thanks to its proximity to the Andhra Pradesh, Telangana and Madhya Pradesh state lines. In fact, the city has undergone tremendous economic development and urbanisation in the past few decades. Riding on this growth, it ranks 15 in India and 339 globally, based on the strength of its start up ecosystem.

With the government and local ecosystem stakeholders taking a keen interest in the city's start up economy, Nagpur is well on its way to becoming a flourishing start up hub.

According to secondary research by **Data Labs**, the total funding of the Nagpur-based start-ups from 2014 to the end of the first quarter of 2019 was $442,091 across 8 deals. Nagpur is now home to over 170 start-ups.

Housing Scheme and Slums Development in Nagpur

Mrs Leena Buddhe
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Centre for Sustainable Development, established in the year 2004 started working in the slums of the city mainly to cater to the long pending demand of "Patta rights" (Land tenure rights) of the slum dwellers. Having studied the slum situation of the city , CFSD was part of the preparation of the urban slum data bank.

There are 459 slums in the city with encroachment on lands of government , private, NMC and NIT and some slums encroachment on lands reserved for other purposes like, public utility, play ground, green belt, zhudpi jungles etc. In Nagpur almost all the slums have good infrastructure development and once they get the infrastructure, slum dwellers start building their own houses not waiting for the governments housing scheme.

Slum improvement programmes:

1. Slum Improvement program (SIP): Slum areas that were declared/notified as slums were generally taken up to provide physical infrastructure work like laying of water pipe lines, sewer lines, storm water drains and roads.
2. The Low Cost Sanitation (LCS) was implemented in the slums to construct individual toilets for the slum dwellers wherein the slum dweller had to pay a contribution of Rs 365/-
3. The National Slum Development Programme (NSDP): This was a central government funded programme under which six basic infrastructure works (water, sewer, storm drain, road, street lights and garbage disposal) were done in the selected slums. An amount of Rs 1000 per person was allocated, out of which 800 and 200 was for physical and social infrastructure, respectively.
4. EWS layout: The was implemented by NIT for the economically weaker sections(EWS).These structures had a carpet area of 600 sq ft., which over the next few years went on reducing to 400 sq. ft
5. Low Income Group (LIG) scheme: This scheme was implemented by MHADA for the Low Income group families.

6. Lok Awas Yojana (LAY): it was a scheme for building houses of 300 sq ft. Total amount sanctioned was Rs 30,000 out of which 10,000 was beneficiary's contribution (5000 in the form of self-contribution and 5000 in the form of loan). The slum dweller had to construct his own Dwelling unit(DU). During implementation however, there were delays in payment instalments. The scheme was however scrapped as the amount was very less. One good example was in Panchsheel nagar as mentioned earlier which was implemented by the slum department by the deputy engineer Mr M P Kelkar. This scheme was being implemented by MHADA (Maharashtra Area Development Board)
7. VAMBAY: Valmiki Ambedkar Malin Wasti Awas Yojana was implemented in 2005. An amount of Rs 50,000 was sanctioned for construction of tenement upto 225 sq ft for slum dwellers. No contributions from beneficiaries had been taken under this scheme.
8. Durbal ghatak yojana: This programme is basically to provide infra woks in the slums and funds from this scheme are also used to maintenance and repairs of the existing infrastructure (both social and physical).
9. Dalit wasti Yojana: This programme is again to provide infrastructure works in the slums where there are 100% backward class people residing. The funds from this scheme are also used to maintenance and repairs of the existing infrastructure (both social and physical).
10. Basic services for Urban poor (BSUP) scheme: There are 446 slums in Nagpur city out of which 24 slums were selected for the BSUP-Insitu scheme . Eight DPRs were prepared and sanctioned by the GOI. Two DPRs were approved in November 2006 and Six DPRs were approved in February 2009. In these 8 DPRs of 24 slums, the SRA had proposed constructing 9829 DU units (with a budgetary sanction of 327.26 crore) . The GOI had sanctioned 5908 DU to be constructed. Although the scheme was explained to the slum dwellers, there was still resistance due to the following reasons:

The 269 sq ft carpet area being provided under the BSUP scheme was not adequate for their large family size

- Their existing plot size and housing structure is more than 269 sq ft
- Most of their existing structures are PUCCA
- There is no provision to give separate housing to the slum dwellers extended family (meaning married children)
- Under BSUP, the slum dwellers are being provided with flat scheme
- Their small-scale businesses and home business was being affected

In the general body meeting of the NMC (dated 29/08/2008) it was decided that consent of at least 60% of the slum dwellers had to be taken for the implementation of the scheme. The SRA faced problems to arrange for transit housing as most of the lands belonged to NIT and the lands that belonged to NMC were also not available.

Implementation of BSUP scheme in Nagpur: A revised proposal of a seven slums from the 23 selected slums and an addition of six new slums has been sanctioned for in-situ up-gradation targeting only kutcha structures and willing beneficiaries of semi-pucca structures has been approved. Five slums out of the 23 slums where work was in progress is still being continued with the same concept of in-situ redevelopment (flat scheme). A total number of 1556 DU were sanctioned to be constructed under the newly approved in-situ upgradation. Under the PPP model a total number of 1838 DU were sanctioned to be constructed in a relocation site at Nari, Nagpur.

11. Slum Rehabilitation Scheme (SRA) No programme was implemented of the pure SRA model of 50 % rehabilitation and 50% resale component!
12. Rajiv Awas Yojana (RAY): Nagpur had been selected as one of the pilot cities. Pilot socio economic survey's and Plane table surveys had been conducted in few slum pockets.

    We strongly believed in the integrated development of the slum and so were very actively involved in the BSUP scheme for the urban poor under the JNNURM project.

The political situation has been very crucial in the evolution of the "tenure rights program" in the slums. The first GR (Government Resolution) on tenure rights came out in July 2002. This was the first time that the government was actually talking about giving "Patta Rights" to the slum dwellers. But the conditions were pretty tough. So, although the intent was good, the implementation was difficult. Before this GR came in, there was a GR that every slum dweller was to obtain a photo pass . The Cut-off date of eligibility was 1.1.1995. Many slum dwellers came forward and started filling up the forms, however, there was no clarity about photo passes with the government department.

Eventually this process of giving photo passes passed away without much success, as it was not benefitting the slum dwellers to get "Patta Right"

Following this was the GR on the Tenure Rights of July 2002 which again held many promises but was difficult to implement as it had condition of formation of a Housing Co-operative society. No individual patta was being given, but the slum dwellers were expected to form a

“Housing Cooperative Society. This was a difficult task as there was no awareness amongst slum dwellers regarding this, they had no information about how to form a society and also there was illiteracy and lack of trust and faith between them which led to many conflicts.

Moreover there was also no clarity on how many societies could be formed in a slum and also the slum dwellers had no training on how to run the society. The other big challenge was to deposit the money collected by the members in cooperative banks which were not very reliable.

In April 2004, the Nazul department came up with a GR which talked about giving pattas to slum dwellers and the government recognised the importance Patta watap and gave specific instruction on implementation of the program. With this GR , an initiative was taken to implement this crucial program at Kamgaar Colony and Tukdoji nagar slum constituency which had 1200 households.

As per the provisions mentioned in the GR , the PTS map of the slum (kamgaar colony and tukdoji nagar) was to be approved by the Town planning department. Once this was done then the slum dwellers had to become members by paying the membership fee. Since most of the slum dwellers are not aware about the procedures, they end up paying more money to middle men in the slum as a result of which there is a lot of chaos and confusion.

The nazul department that was implementing the program was also confused on the procedures. The response from the slum dwellers to avail patta was also very less as getting a lease right was not enough as there was a demand for ownership rights. With all these challenges , the nazul department managed to give leasehold rights to about 165 slum dwellers only in the last 10 years and the process still continues.

The first meeting on *Patta watap* was in April 2016 and the rules were decided. Free Pattas would be given to people who belonged to the SC, ST, OBC and NT and also to the economically weaker section of the society. The first 500sq ft to be given absolutely free of cost. Pattas to be given up to 1500 sq. ft of land encroached by the slum dwellers. This took the shape of a GR in Jan 2017 and in this GR it was mentioned that the Pattas will be given to individuals but they were still expected to form a housing cooperative society within a year or two.

Since the pattas had to be given by the respective land owners, the first GR of NIT came out on 16th August 2016.

Eventually separate GR's came out for the revenue lands and also for the slums on NMC land and private land .

With Pattas in hand now , Slum dwellers are participating in the PMAY (Pradhan Mantri Awas Yojana) 4th Vertical where they can avail loan from banks at 6% interest to improve their houses.

Brief on SRA in Nagpur: The SRA was set up in Nagpur in the year 2006, with two officers on deputation from MHADA at a make shift office at NMC. The SRA was actually suppose to be an Authority which was to be set up to do complete planning of the slums of the city. The BSUP scheme was to be implemented at that time by NMC through a resolution passed in the general body meeting.

The SRA in Nagpur never really took off with in it's true spirit which was a scheme of 50% rehabilitation and 50% resale component. Today SRA still has a handful of officers on deputation and a handful of contractual staff implementing the PMAY scheme in Nagpur with very slow progress. A recent announcement by this government now wants to strengthen the SRA bodies and speed up the PMAY scheme.

Supplementary Data:
Status of wells in Nagpur City

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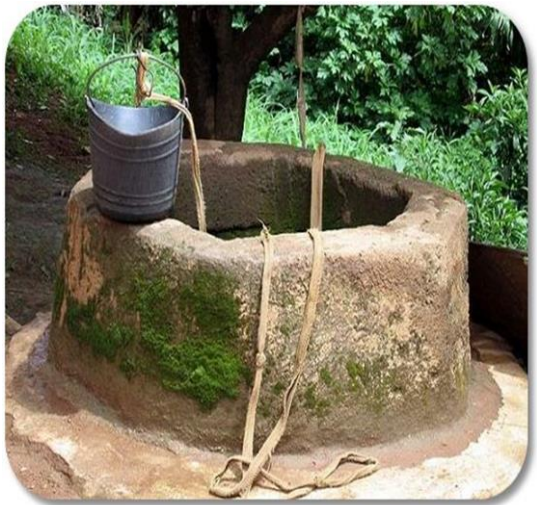
Mapping the Wells of Nagpur City

Groundwater has always been utilized to by the human race to supplement water demands; in many cases, it also serves as the sole source of potable water. Wells are extremely important to all societies. In many places wells provide a reliable and ample supply of water for home uses, irrigation, and industries. Where surface water is scarce, wells have always been tapped for water reserves. This report has mapped the wells of all ten zones of Nagpur city. The list of wells were supplied by NMC and ground survey of all was carried out to examine their current status. This report aims to raise awareness of maintaining ground water levels in the city which is best achieved by maintaining existing wells.

Wells are classified into different types, based on structure; viz, dug wells, drilled wells, etc. This report only chronicles the traditional dug wells and has not plotted drilled or bore wells. The oldest and most common kind of well is a water well, to access groundwater in underground aquifers. The well water is drawn up by a pump, or using containers, such as buckets, that are raised mechanically or by hand.



A traditional dug well that was a common sight in most homes, but now fast disappearing due to multi-rise buildings and urban space crunch.

The traditional dug wells are mostly replaced by drilled or bore wells that typically range from 3 to 18 meters (10–60 ft.) deep, but in some areas can go deeper than 900 meters (3,000 ft.).

Potable water in most urban locations is supplied by the municipality, which is more convenient and safe for use. However, dug wells are a very important source of increasing ground water levels of any city. With the realities of climate change and changing monsoon patterns, it is very crucial to maintain ground water levels to tide over harsh

periods, hence, this survey of current status has been carried out to help formulate a plan for revival of wells and water management in the city.

Methodology:

A list of wells recorded in the ten zones of Nagpur was collected from NMC. **666 wells are recorded at NMC.** A team from CSIR-NEERI visited all the wells and mapped their coordinates, took pictures and conducted a survey of people living near the said well. The questionnaires was simple, only designed to garner information of the existing status.

This survey was conducted to identify the actual condition of wells in Nagpur city. With the help of this questionnaire we aimed to understand the usage status of existing well and note their condition. This study will serve as a baseline to improve, govern, and prevent them for the betterment of human health and the environment. Location was plotted on google earth using plotting app Notecam.

Questionnaire for Survey of Wells of Nagpur City

Number of people = 5 for each well

Total number of wells = 666

✓ **Tick in front of the appropriate statement**

1. **For what purpose is the well water being used?**
   - I. Primary or Secondary purpose ☐
   - II. Drinking purpose ☐
   - III. Gardening purpose ☐
2. **Condition of Well at present?**
   - I. Well with proper covered Jali or net. ☐
   - II. Surrounded by a certain height wall from ground level. ☐
   - III. Any pipeline or tank install above well. ☐
3. **Why is the well not is use?**
   - I. Contaminated by solid waste. ☐
   - II. Contaminated by sewage waste. ☐
   - III. Covered by concrete or construction material ☐
4. **Location of Well at present?**
   - I. Open plot or area or ground. ☐
   - II. At open space or NMC garden. ☐
   - III. At clusters, surrounded by constructed houses or road. ☐

Results:

The zones of Nagpur are listed below. The table also indicates the number of wells in each zone and approximate depth of the water level available in respective zones

Sr. No.	ZONE	No. Of Wells	Approximate Water at Depth in the Wells (in meters)
1	Laxmi Nagar Zone	76 wells	3-8
2	Dharampeth Zone	73 wells	3-6
3	Hanuman Nagar Zone	71 wells	2-7
4	Dhantoli Zone	34 wells	3-9
5	Nehru Nagar Zone	91 wells	3-9
6	Gandhibagh Zone	78 wells	4-9
7	Satranjipura Zone	56 wells	3-7
8	Lakadganj Zone	67 wells	6-9
9	Ashi Nagar Zone	76 wells	3-11
10	Mangalwari Zone	44 wells	2-7
	Total	**666 wells**	

Detailed list of each well, zone wise, with picture of each is listed below

Results of survey have been mapped zone wise and are indicated below. Figure 1 demonstrates zone wise data of abandoned wells. The zones are colour coded to indicate numbers of abandoned wells, red being the highest indication of containing abandoned wells. Few wells are used for drinking water, which are graphically represented in each zone comapared to the abandoned ones in the form of histograms. The detailed numbers of the histogram are seen in Figure 2. Figure 3 shows the zone wise profile of abandoned wells and their reasons; i.e., contaminated with sewage or used as dumping points of solid waste

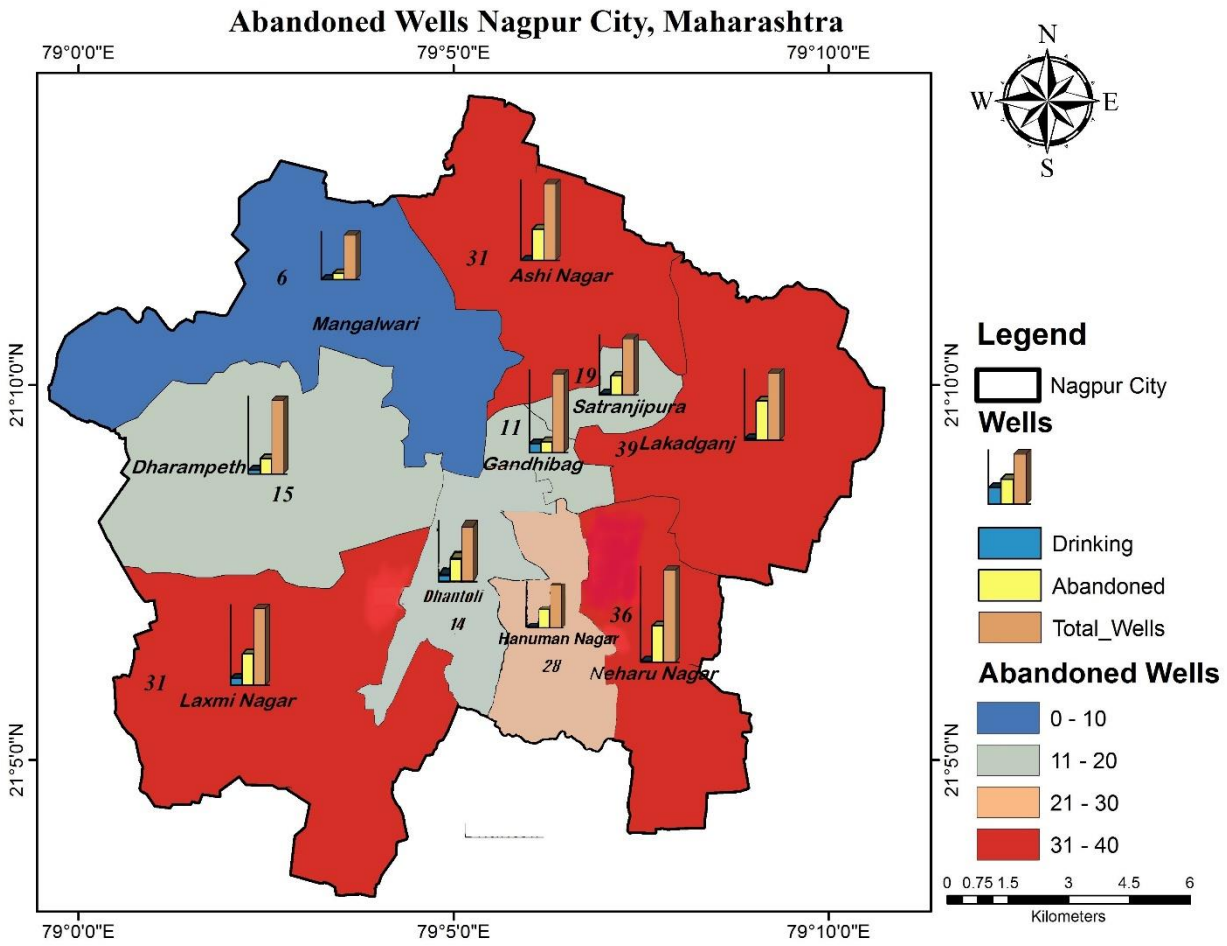


Figure 1: Demonstrating status of wells in each zone. The zones are colour codes as per number of abandoned wells. Red denotes zones which have the highest number of abandoned wells while blue zones have the least. The histograms in

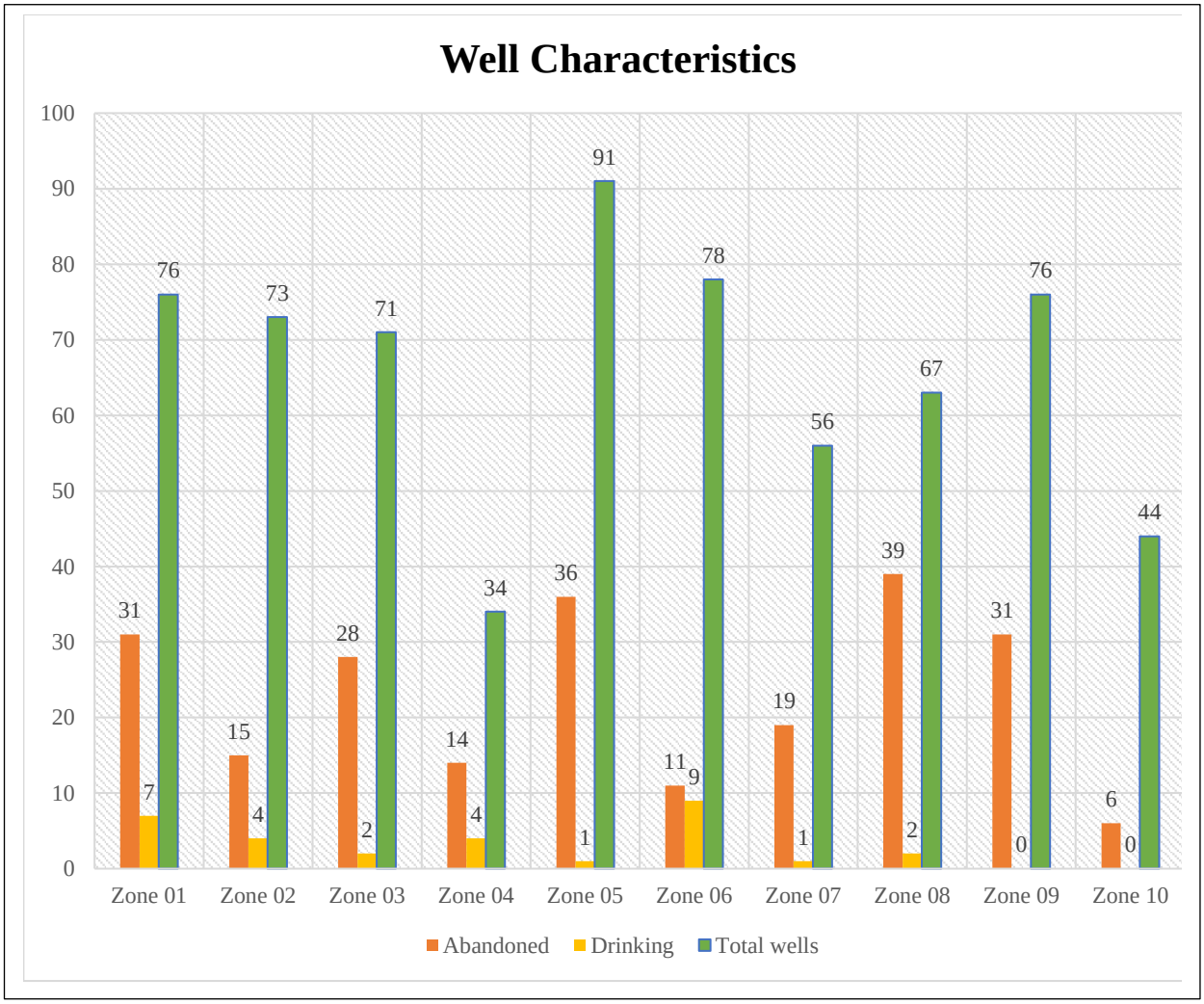


Figure 2: Data highlights the few wells used for drinking water purposes vs the abandoned wells. Wells used for secondary water purposes not indicated.

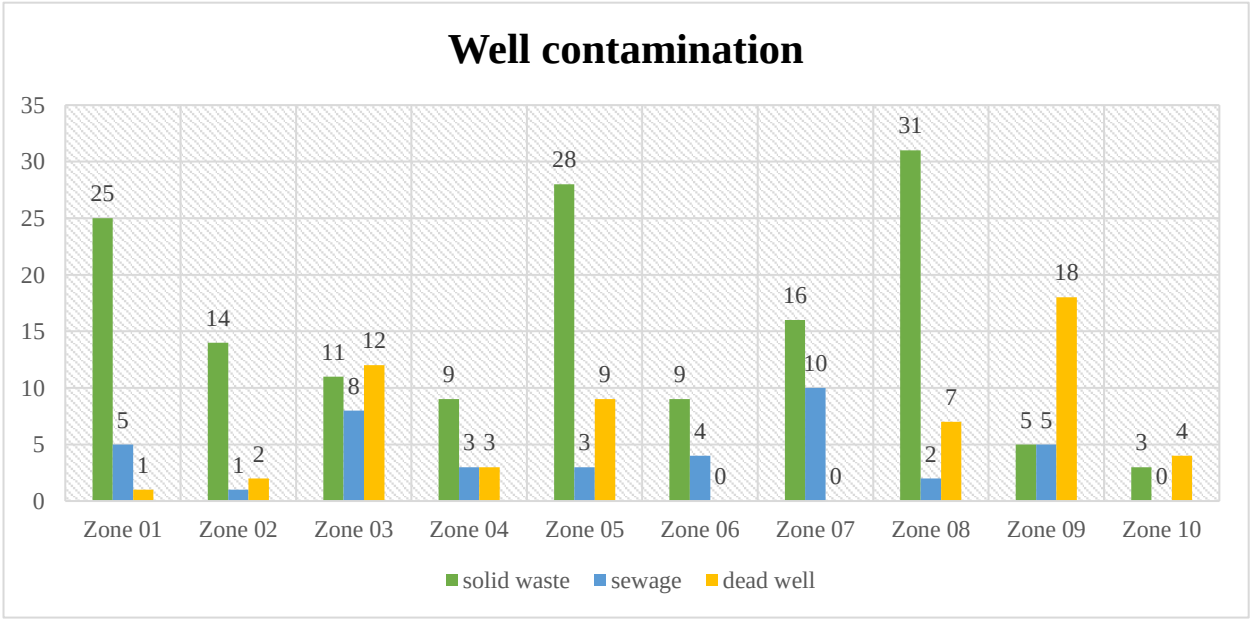
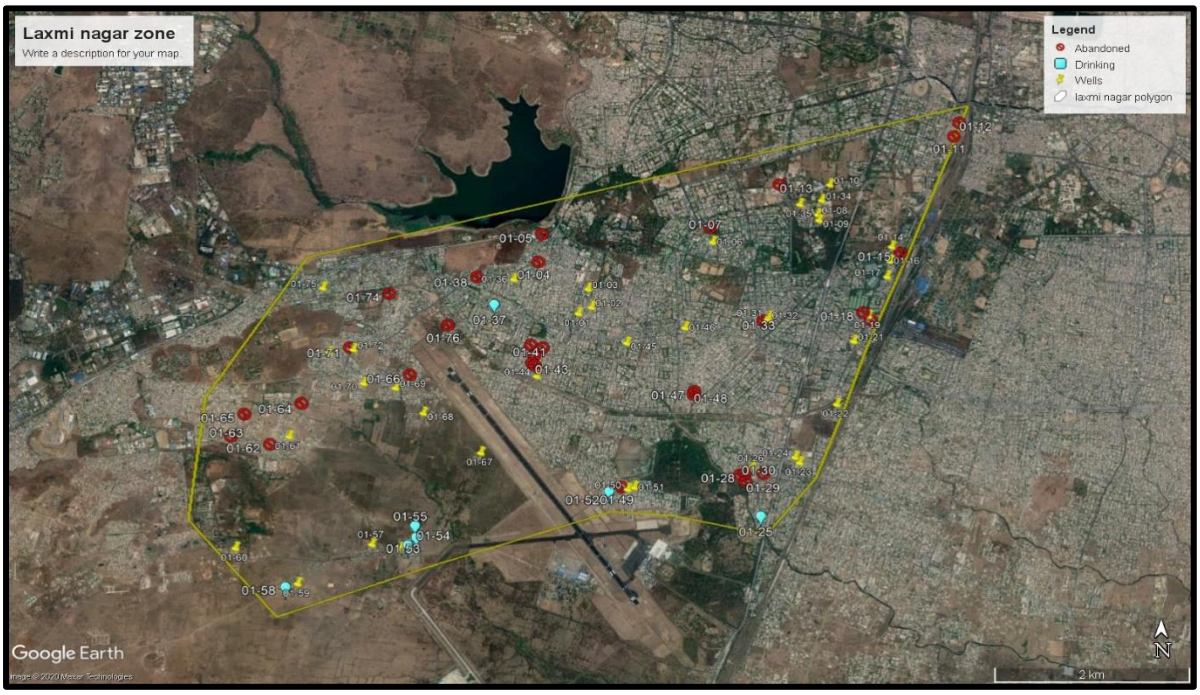
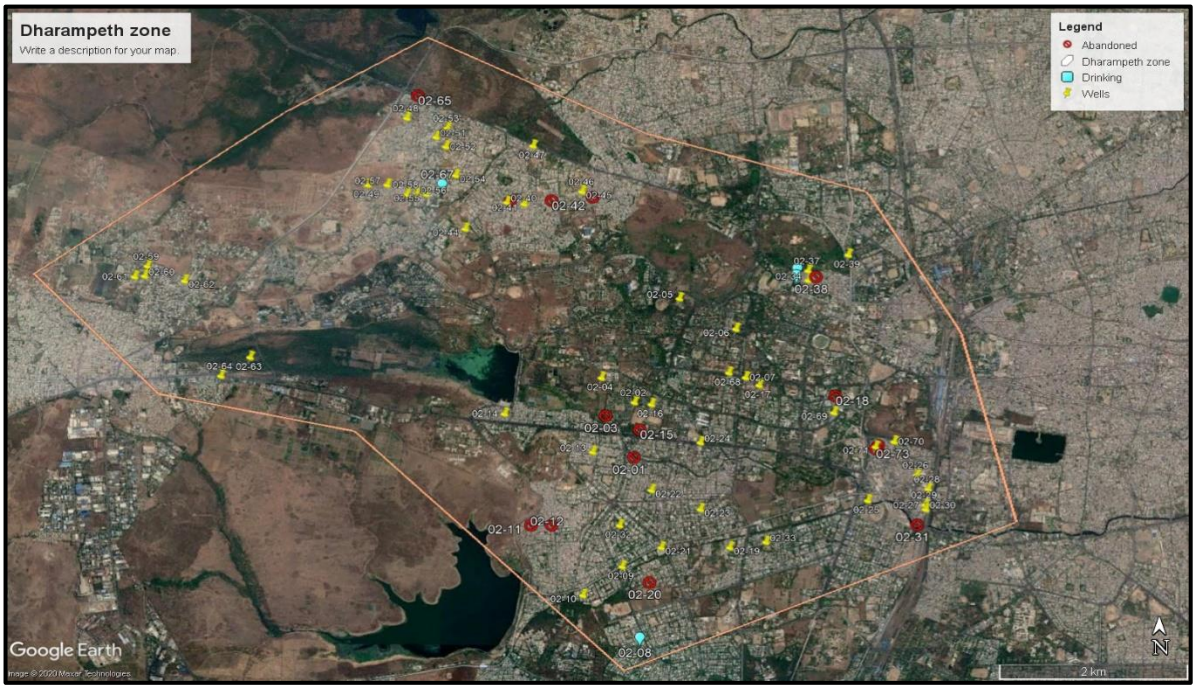
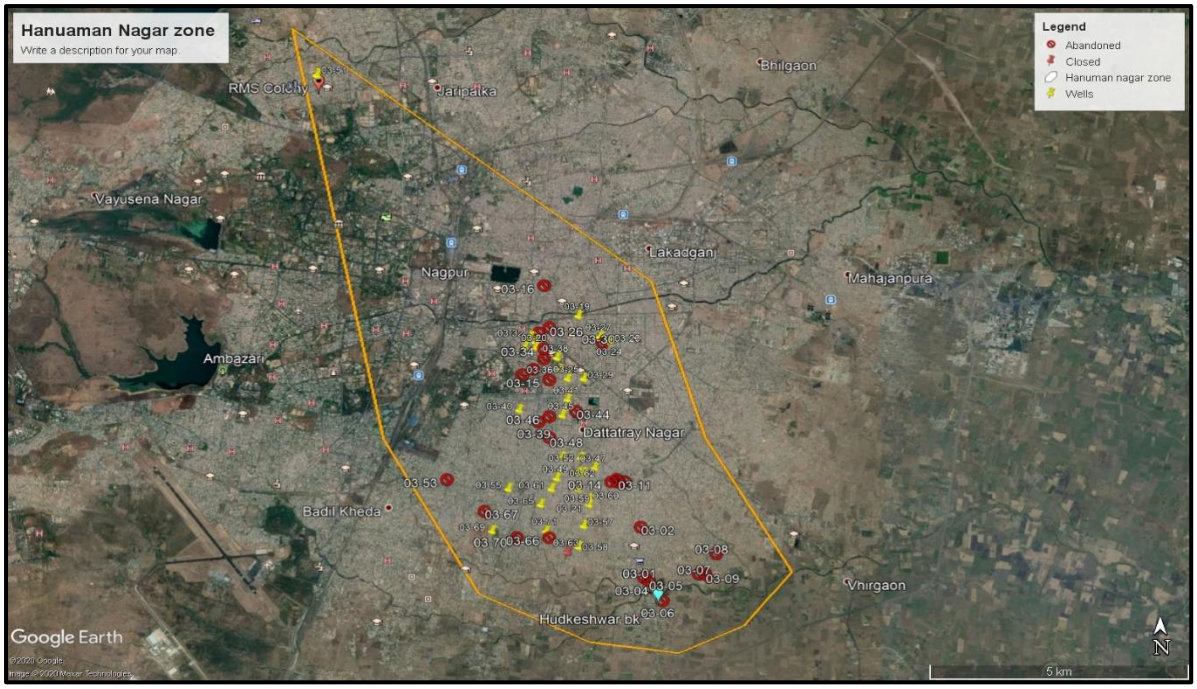


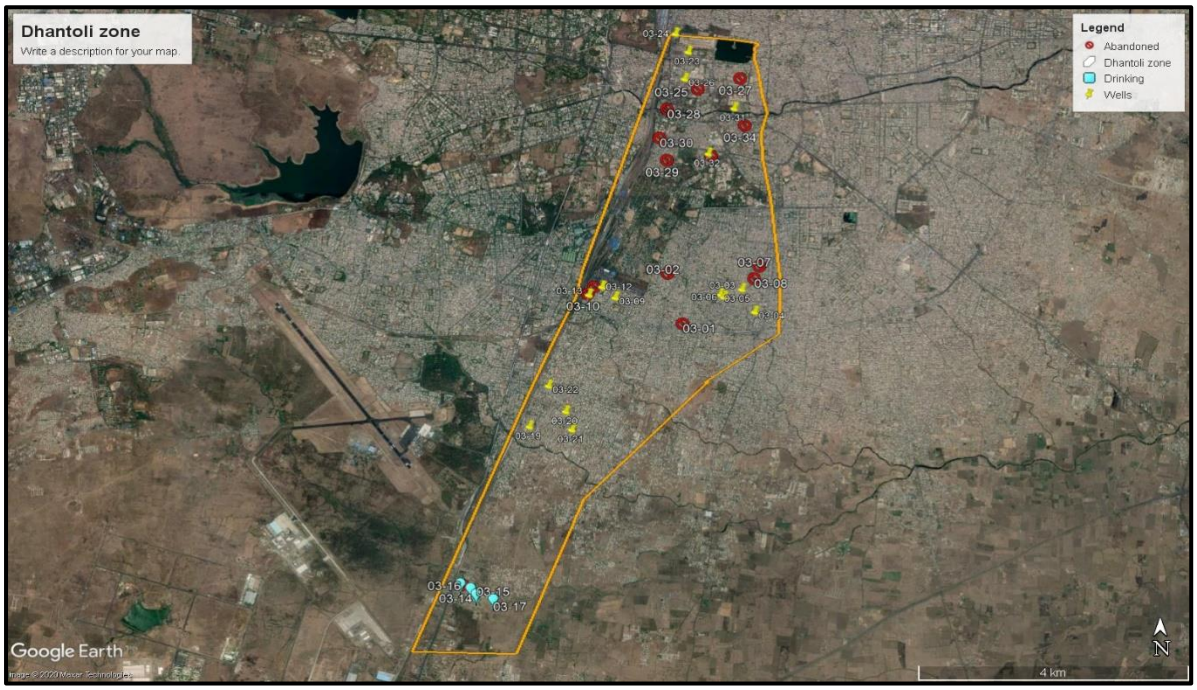
Figure 3: Zone wise chart demonstrating reason for abandoned wells

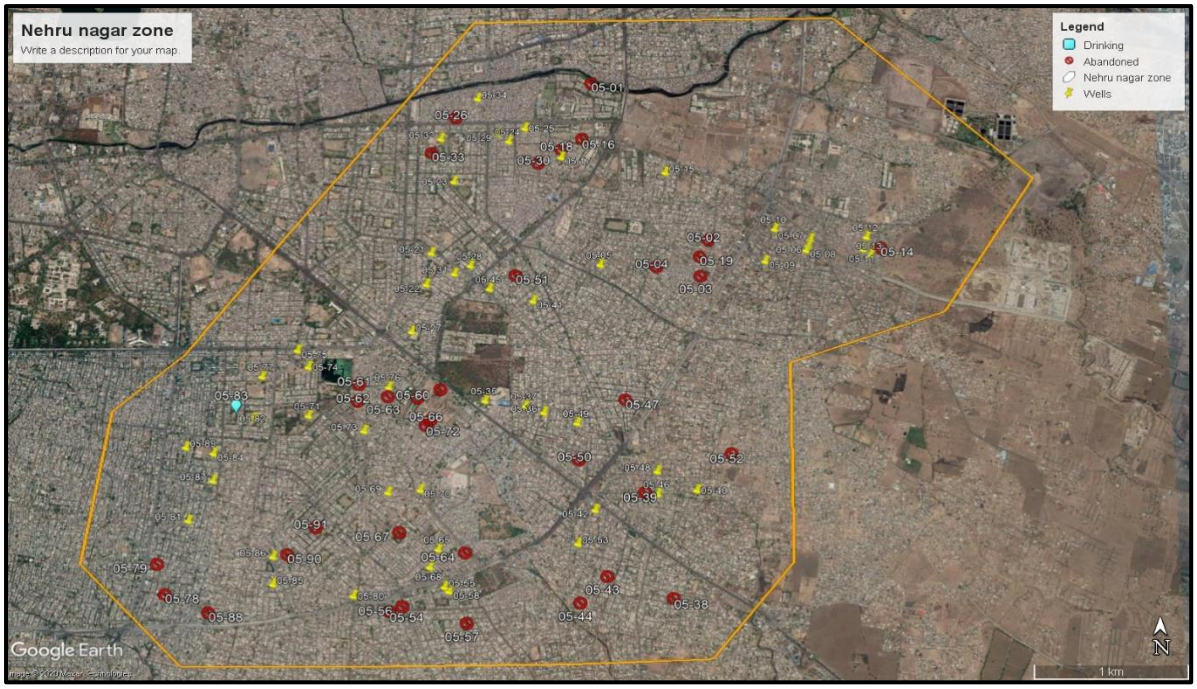
Each well has been mapped zone wise and plotted on google earth image to show placements. Zone wise figures are shown below.

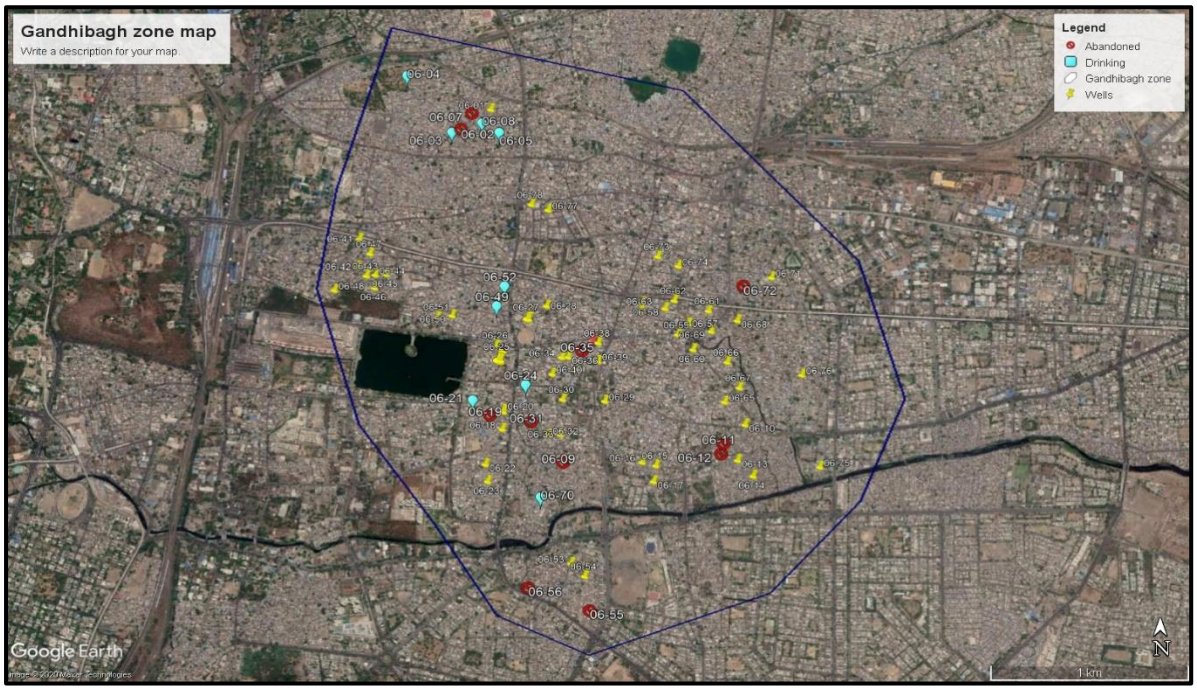


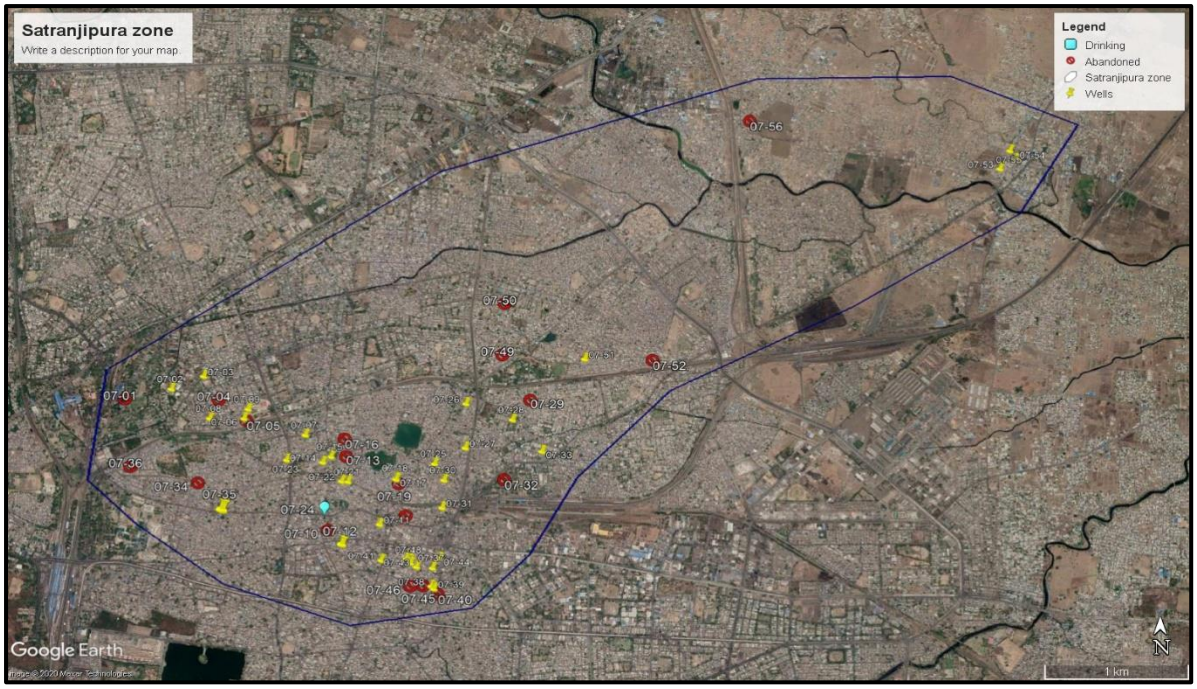


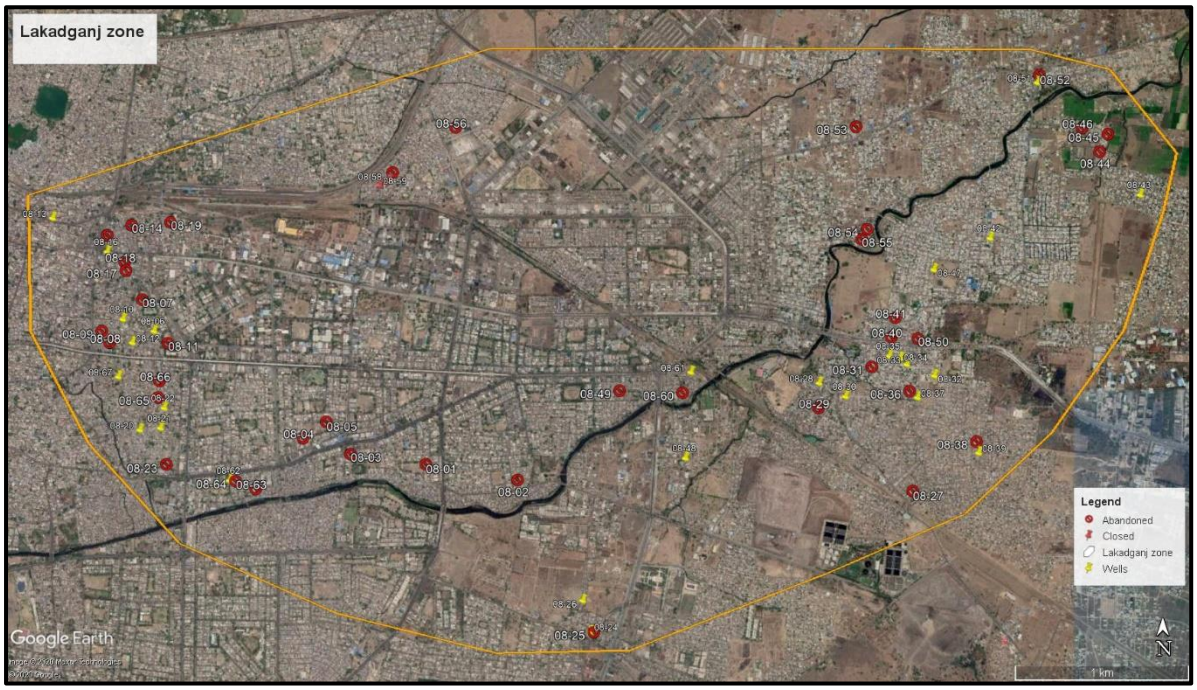

Hanuaman Nagar zone
Write a description for your map.
Legend
Abandoned
Closed
Hanuman nagar zone
Wells
RMS Colony
Jaripatka
Bhilgaon
Vayusena Nagar
Lakadganj
Nagpur
Mahajanpura
Ambazari
Dattatray Nagar
Badil Kheda
Vhirgaon
Hudkeshwar bk
Google Earth
5 km
N

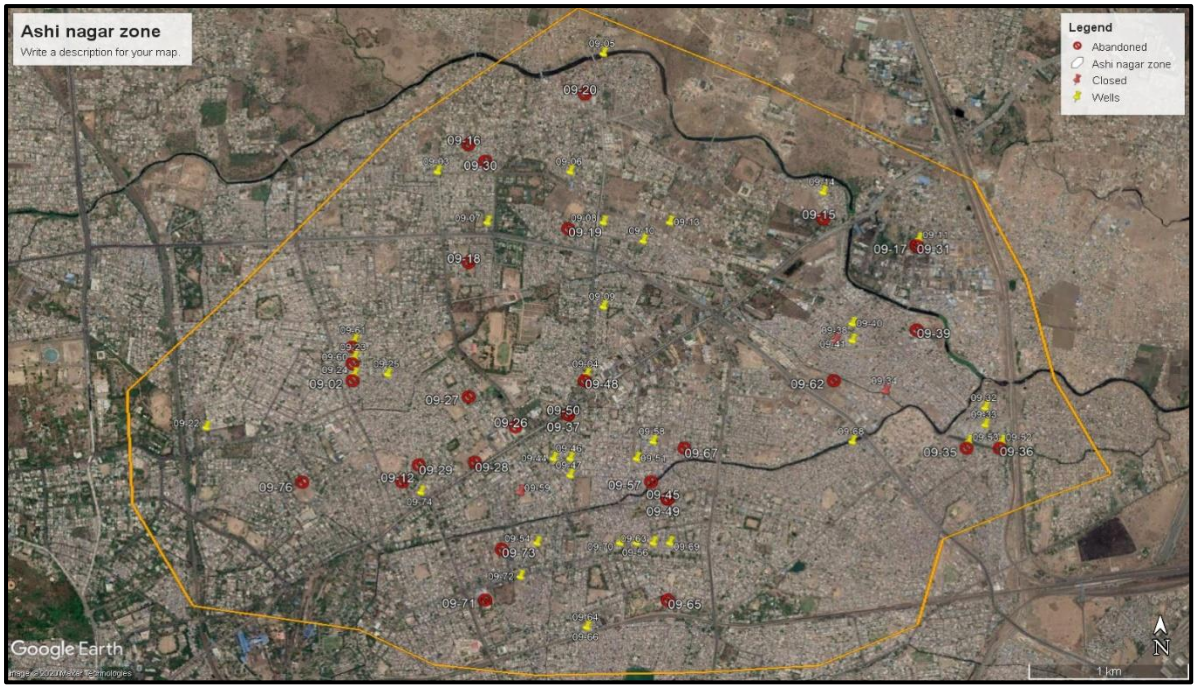

Dhantoli zone
Write a description for your map.
Legend
Abandoned
Dhantoli zone
Drinking
Wells
Google Earth
4 km
N

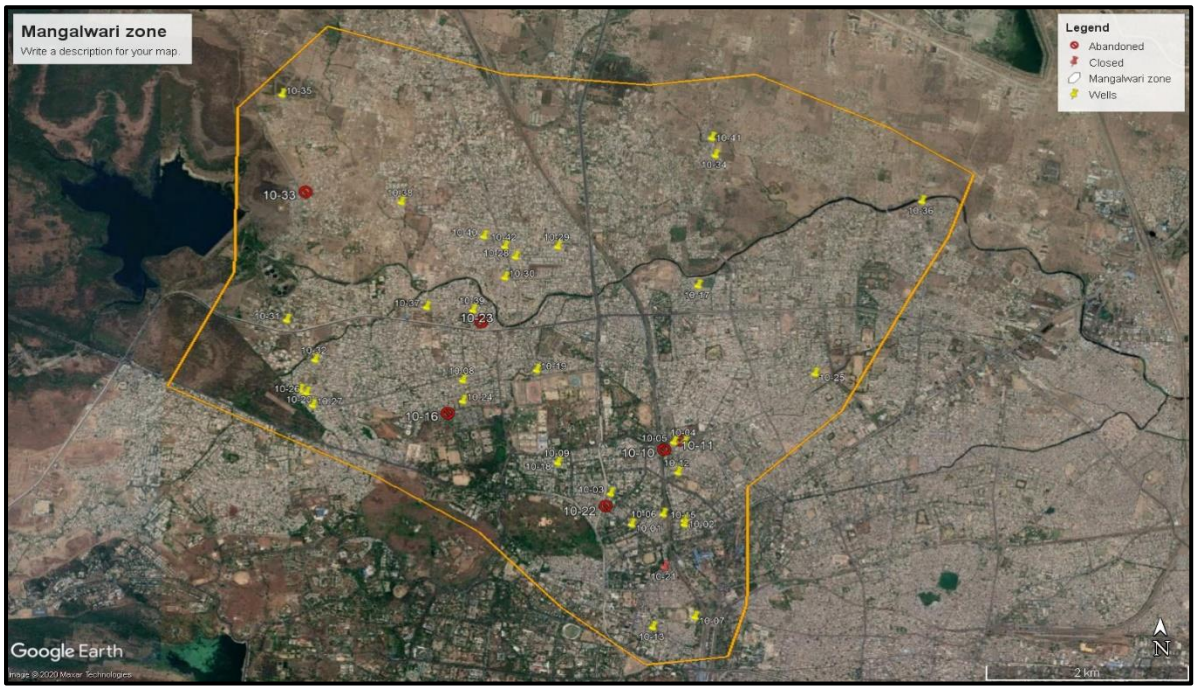

Nehru nagar zone
Write a description for your map
Legend
Drinking
Abandoned
Nehru nagar zone
Wells
Google Earth
1 km
N


Gandhibagh zone map
Write a description for your map
Legend
Abandoned
Drinking
Gandhibagh zone
Wells
Google Earth
1 km
N


Satranjipura zone
Write a description for your map
Legend
Drinking
Abandoned
Satranjipura zone
Wells
Google Earth
1 km
N


Lakadganj zone
Legend
Abandoned
Closed
Lakadganj zone
Wells
Google Earth
1 km
N


Ashi nagar zone
Write a description for your map.
Legend
Abandoned
Ashi nagar zone
Closed
Wells
09-20
09-16
09-30
09-15
09-19
09-18
09-17
09-31
09-39
09-62
09-48
09-27
09-50
09-26
09-37
09-67
09-12
09-29
09-28
09-76
09-57
09-45
09-49
09-73
09-71
09-65
09-35
09-36
Google Earth
1 km
N


Mangalwari zone
Write a description for your map.
Legend
Abandoned
Closed
Mangalwari zone
Wells
10-33
10-23
10-16
10-10
10-11
10-22
Google Earth
2 km
N

Conclusions:

Results indicate that approximately 50% or more of the wells are abandoned in each zone, the main cause being that they are dumped with solid waste with a few contaminated with sewage.

Wells are a natural storage for water and smart urban planning should include maintenance of them to increase ground water levels. Besides maintain ecosystem balance, these wells could be used for secondary purposes and lessen the load placed on fresh water .

TOTAL WELLS VISITED =666 NOS

TOTAL WELLS FOUND ABANDONED =230 NOS

TOTAL WELLS FOUND THAT WERE USED FOR DRINKING WATER =30 NOS

TOTAL WELLS FOUND CONTAMINATED WITH SEWAGE/ SOLID WASTE =36 NOS

Acknowledgements:

CSIR-NEERI wishes to acknowledge the help of Shri Baba Deshpande, Founder, Vruksha Samwadhan Samithi in helping with the study of mapping the wells.