PROJECT AIRVIEW–WHITE PAPER

Decoding Bhubaneswar's Air Quality **with Hyperlocal Data**

Towards Cleaner Air

#MoBhubaneswarMoAir

FOREWORD

This white paper on air pollution in Bhubaneswar City brings to light the critical environmental issues affecting the city today. Aurassure, using its own Hyperlocal Air Quality monitoring network in the city of Bhubaneswar provides a comprehensive analysis of its air quality & identifies the pollution hotspots & suggests steps to address this challenge. The report presents a thorough examination of the impact of air pollution on the surrounding environment, including short-term and long-term effects. The document also highlights the policies and regulations that have been put in place and those that are currently under consideration to address this issue effectively.

#MoBhubaneswarMoAir, where 'Mo' signifies 'My' in the local language of Odisha, reflects the pride and ownership that the people of Bhubaneswar have towards their city and its air quality. It represents a collective commitment and responsibility to safeguarding and improving the air we breathe. Overall, this white paper serves as a valuable resource to inspire action and promote awareness toward improving the air quality in the city for a healthier and more sustainable future.

ACKNOWLEDGMENT

Our sincere thanks to

- CRUT (Capital Region Urban Transport) for their invaluable assistance in allowing us to install air quality monitoring devices in their buses. This collaboration has enabled us to capture real-time air quality data from different parts of the city and enhance our understanding of the hyperlocal variations in air pollution levels.
- STPI-Bhubaneswar for providing us with the necessary space and infrastructure to install two of our stationary air quality monitoring devices. Their support has been instrumental in expanding the coverage of our monitoring network and gathering comprehensive data for analysis.
- Odisha State Pollution Control Board (OSPCB) for their collaboration and support of our project in a significant way. Their expertise and role as the primary air quality regulatory body in the region have greatly contributed to the accuracy and reliability of our findings.
- Sneha Mahalingam, Research scholar, Kumaraguru College of Technology, Anna University, for her invaluable contributions to data analysis and research. Her expertise and content have significant contributions to this whitepaper that enhanced the quality and depth of our research findings.
- Google LLC, Our esteemed technology partner, and sponsor. Their unwavering support and collaboration have played a pivotal role in the success of the "Hyperlocal Air Quality Monitoring Network for Bhubaneswar" project. Their expertise and resources have enabled us to implement state-of-the-art monitoring solutions and gather valuable insights into the air quality of the city.
- Ms. Prarthana Borah, Our esteemed mentor, for her invaluable guidance and expertise. Her mentorship has been instrumental in enhancing the quality and depth of our research findings, and we are deeply honored to have had the opportunity to work under her guidance.
- Last but not least, we would like to express our deep appreciation to all the dedicated members of the Aurassure team whose tireless efforts have been instrumental in completing this project successfully.

It is with the collective efforts and collaboration of these esteemed partners, stakeholders, and team members that we have achieved this significant milestone, and we look forward to continuing our mission of improving air quality and promoting a sustainable future for Bhubaneswar and beyond.

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INTRODUCTION

BHUBANESWAR CITY

Bhubaneswar, a rapidly developing Tier 2 smart city located along the eastern coast of India, has experienced remarkable growth and development in recent years. With a population of over 880K residents growing at a rate of 3% [1] each year and covering an expansive urban area of approximately 186 square kilometres, the city has been actively expanding its infrastructure to accommodate its growing population. In response to this, Bhubaneswar has implemented a range of transportation systems, including numerous buses that provide reliable and convenient means of transportation for commuters both within the city and beyond. To ensure seamless connectivity throughout its expanding urban areas, Wi-Fi Access points have also been installed at various strategic locations around town which act as essential points connecting people with services. These innovative technologies are playing an instrumental role in enabling sustainable economic growth while simultaneously providing unparalleled convenience for residents.

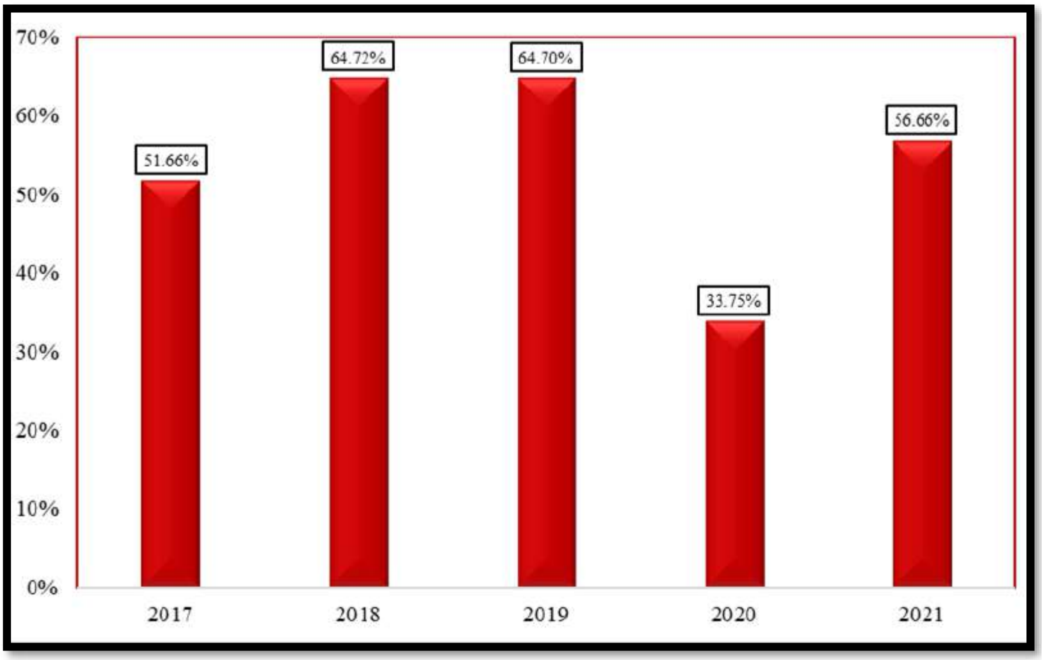


Figure 1 Percentage of PM_{10} Exceeding the NAAQS limit.

Despite the city's impressive progress, there has been no significant improvement in air quality which has raised concerns among its residents.

Figure 1 depicts the % concentration of Particulate Matter (PM_{10}), over the National Ambient Air Quality Standards (NAAQS) Annual Limit over the years in Bhubaneswar

City. According to data, rapid urbanisation and industrial expansion have contributed to worsening air quality in Bhubaneswar. As a result, residents have been exposed to high levels of pollution, which can cause respiratory problems and other illnesses over time.

To address this issue, it is crucial for the city to implement effective measures aimed at reducing emissions from various sources. This will require collaboration among local authorities, industries, and the community to identify sustainable solutions that will not only improve air quality but also promote economic growth and prosperity. The following sections of this whitepaper provide a comprehensive analysis of the air quality data collected in Bhubaneswar over the past year, as well as an overview of the measures that have been taken thus far to combat air pollution in the city.

OBJECTIVES

In this section, we aim to provide a comprehensive outlook on our objectives and strategy for achieving cleaner air in the city of Bhubaneswar. We strongly believe that by endorsing specific action plans geared towards controlling air pollution and establishing an effective monitoring network, we can achieve tangible results for the benefit of all residents. Our commitment to implementing these measures demonstrates our unwavering dedication to improving the quality of life in our community through sustainable environmental practices.

In this section, we present a comprehensive overview of the data gathered by Aurassure, providing valuable insights into the air pollution situation in the city of Bhubaneswar. Our primary focus is to present the data as evidence of the pollution levels and trends. We believe that by showcasing the data and its correlations, we can contribute to informed decision-making and support policies that have a positive impact on air quality.

Our objective is to provide a factual account of the changes observed in air pollution levels over time and establish a clear connection between these changes and potential policy interventions. By highlighting the data-driven evidence of the effectiveness of certain policies, we aim to encourage support for initiatives that have shown positive outcomes.

Our commitment is to provide reliable data and analysis to foster a collaborative approach towards achieving cleaner air in Bhubaneswar, working in partnership with government agencies, community organisations, and other relevant stakeholders.

EMISSION REDUCTION OBJECTIVES

The reduction of emissions in Bhubaneswar City is a crucial objective that requires an in-depth approach. The focus lies on the criteria for air pollutants, which include PM2.5, PM10, NO_2, CO_2, and SO_2. The implementation of this initiative aims to ensure compliance with National Ambient Air Quality Standards (NAAQS) - by reducing pollution levels across sustained periods where at least 98% compliance is achieved annually as mandated by the Air Act (1981). To achieve these goals effectively, low-cost sensors have been installed strategically throughout various locations within the city to closely monitor pollution levels. To gain greater insight into the effectiveness of such measures over longer durations would entail analysing trends related to ambient concentration through various timeframes; assessing baseline concentrations against required reductions aligned with national standards for ambient air quality controls set out under NAAQS guidelines. Such stringent monitoring targets are essential for preventing instances marked by high-pollution surges and creating conditions for healthier living environments.

AIR QUALITY MONITORING NETWORK

We have implemented an extensive air quality monitoring network consisting of around 50 monitoring stations strategically placed across various regions of Bhubaneswar. Our network incorporates both stationary and mobile approaches to capture accurate data from diverse locations throughout the city. We understand that effective management of air pollution can only be achieved by identifying high-pollution zones and tracking trends over time. Therefore, our network provides us with vital information to direct targeted actions toward mitigating harmful emissions into the environment.

According to The Central Pollution Control Board's classification system, cities with criteria pollutant levels surpassing standards by 1.5 times annually are considered critically polluted. By implementing this advanced Hyper-Local Air Quality Monitoring Network, we have an unparalleled opportunity to monitor atmospheric conditions more closely, identify hotspots where pollutants regularly exceed acceptable limits, and take proactive measures toward reducing their occurrence significantly. This approach helps us in promoting healthier environments for all inhabitants of Bhubaneswar.

EMISSION INVENTORY

An emission inventory is made up of different parts that help us understand the types and extent of pollutants being released into the air. The first part is identifying the pollutants, which include harmful substances like sulphur dioxide, nitrogen oxides, particulate matter (PM), carbon dioxide, and volatile organic compounds (VOCs). The second part is determining the sources of these pollutants. This includes activities like transportation, industrial operations, and agricultural practices that can release harmful chemicals into the air [2]. Finally, the inventory measures the number of pollutants being released by each source, using scientific methods.

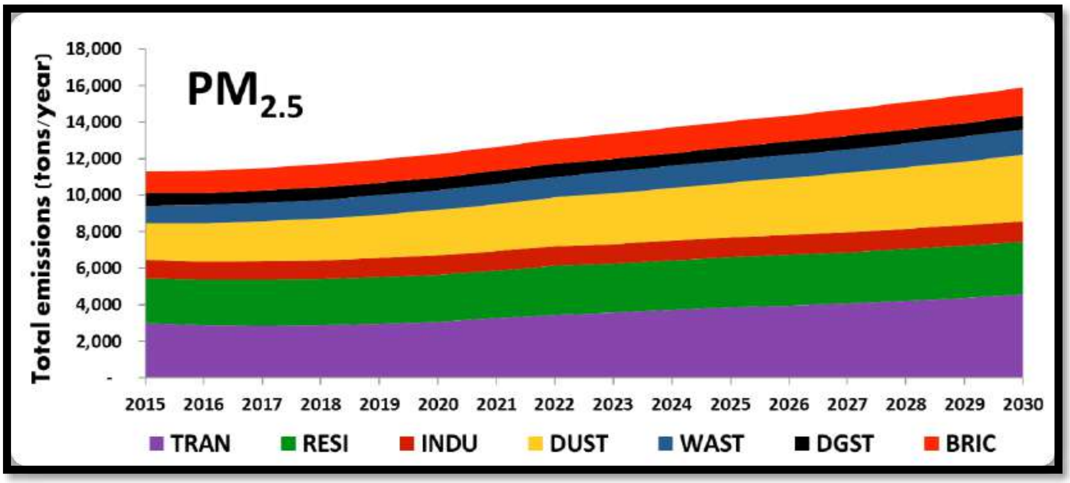


Figure 2. Estimated emissions of Bhubaneswar (tons/year)

TRAN *= Transport emissions from road, rail, aviation, and shipping (for coastal cities)*
RESI *= Residential emissions from cooking, heating, and lighting activities*
INDU *= Industrial emissions from small, medium, and heavy industries (including power generation)*
DUST *= Dust emissions from road re-suspension and construction activities.*
WAST *= Open waste burning emissions*
DGST *= Diesel generator set emissions*
BRIC *= Brick kiln emissions (not included in the industrial emissions)*

Using the most recent emission inventory data from an independent think tank, urban Emissions dedicated to studying emissions in Bhubaneswar, we were able to identify the primary sources of air pollution in Bhubaneswar city as shown in Figures 3,4,5,6. The insightful dataset unequivocally highlights that dust particles and vehicular sources are the primary precursors responsible for PM_{10}, $PM_{2.5}$, and NO_2 emissions [3]. Precisely speaking, it reveals that dust particles contribute significantly more towards PM_{10} emissions while transportation is found to be the main cause behind increased levels of hazardous $PM_{2.5}$ emissions. Figure 6 prominently illustrates how vehicular sector activities play a crucial role in polluting this city. Furthermore, industrial activity, transportation & Diesel Generators have been identified as being accountable for the high NO_2 pollution levels observed in Bhubaneswar.

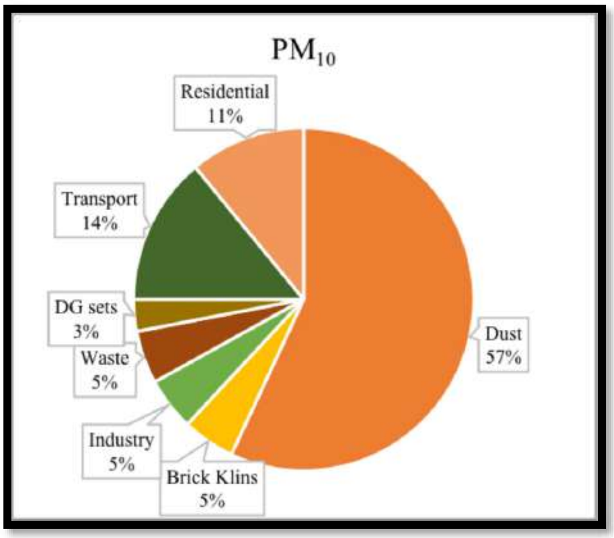


Figure 3 Contribution of PM10

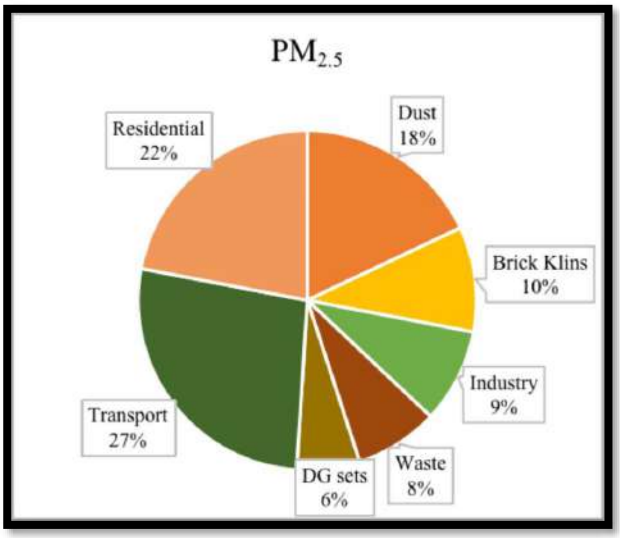


Figure 4 Contribution of PM2.5

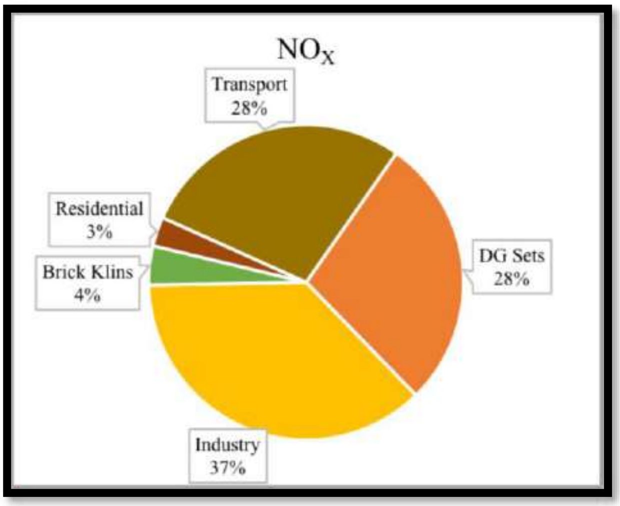


Figure 5 Contribution of NOx

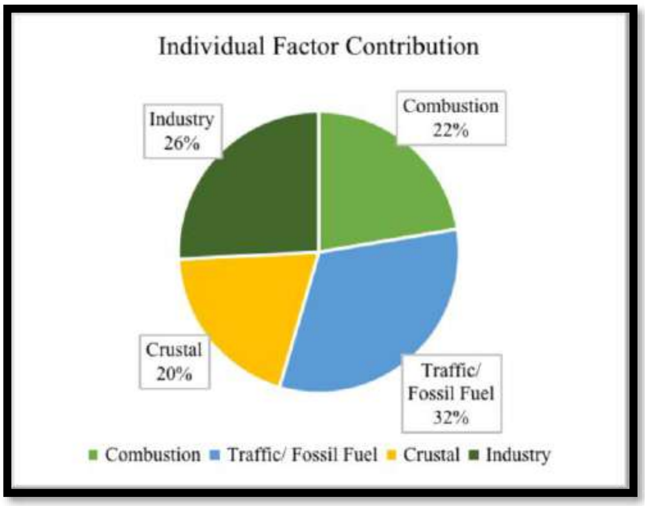


Figure 6 Wintertime Source contribution to PM2.5

Additionally, research conducted in Bhubaneswar reveals that the city's winter PM2.5 concentrations range from 101-142 μg m-3, which is on par with other developing cities worldwide. This highlights the urgent need for effective measures to reduce air pollution and its negative impacts on health and the environment. Positive Matrix Factorization analysis shows that vehicular sources are the largest contributor at 32%, followed closely by industrial sources at 26% as shown in Figure 6. Additionally, combustion activities account for a considerable share of contribution towards $PM_{2.5}$ mass (22%), along with crustal sources (20%). Notably, vehicular emissions account for 14% of the overall proportion of PM2.5 mass in Bhubaneswar. [4]

DATA ANALYSIS

NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

The Central Pollution Control Board (CPCB) has set National Ambient Air Quality Standards (NAAQS) that are applicable throughout India. These standards aim to regulate air pollution levels, which can impact both human health and the environment. The CPCB has established these standards based on scientific studies and research that analyse the concentration levels of pollutants in the air, the duration of exposure to pollutants, and the health risks associated with long-term exposure to pollutants.

The NAAQS standards, shown in Table 1 below, serve as a crucial benchmark to ensure that atmospheric conditions remain conducive to sustaining life on Earth, while also addressing concerns related to air pollution and its impact on human health and well-being. It is essential to uphold these standards with the utmost diligence to maintain optimal levels of air quality across the country.

TABLE 1 NATIONAL AMBIENT AIR QUALITY STANDARDS

National Air Quality standards

Pollutants (m3)	**Time Weighted Average**	**NAAQS 16th Nov 2009**	
		Concentration in ambient air (µg/m³)	
		Industrial, Residential, Rural & other areas	Ecologically sensitive Area
Sulphur Dioxide (SO_2) µg/m³	Annual	50	20
	24 hours	80	80
Nitrogen Dioxide (NO_2) µg/m³	Annual	40	30
	24 hours	80	80
Particulate Matter (Size <10µm) or	Annual	60	60
PM_{10} in µg/m³	24 hours	100	100
Particulate Matter (Size <2.5µm) or	Annual	40	40
$PM_{2.5}$ in µg/m³	24 hours	60	60
Ozone (O_3) in µg/m³	Annual	100	100
	24 hours	180	180
Lead (Pb) in µg/m³	Annual	0.5	0.5
	24 hours	1	1
Carbon Monoxide (CO) in mg/m³	Annual	2	2
	24 hours	4	4
Ammonia (NH_3) in µg/m³	Annual	100	100
	24 hours	400	400
Benzene (C_6H_6) in µg/m³	Annual	5	5
Benzo(a)Pyrene (BaP) - particulate phase only in µg/m³	Annual	1	1
Arsenic (As) ng /m³	Annual	6	6
Nickel (Ni) ng/m³	Annual	20	20

GOVERNMENT INTERVENTIONS

India's Ministry of Environment, Forests and Climate Change (MoEF&CC) has launched the National Clean Air Program (NCAP) with the intention of achieving National Ambient Air Quality Standards (NAAQS). The NCAP is a long-term plan that focuses on both preventive and curative measures to reduce air pollution in the country. It aims to reduce PM (Particulate Matter) pollution by 20-30 % in at least

102 cities by 2024 [5]. It also includes measures such as increased air quality monitoring, setting emission standards for various industries, improving public transport, and promoting clean technologies. In addition, the program focuses on public awareness and participation in reducing air pollution. The NCAP is a step in the right direction to tackle air pollution and improve air quality in India.

To improve solid waste management and reduce relative emissions, the Indian government has implemented various initiatives under the Swachh Bharat Mission (SBM). These include Pradhan Mantri Ujjwala Yojana (PMUY) and Unnat Chulha Abhiyan (UCA), which aim to promote the application of cleaner fuels and better cooking stoves. In addition, the National Electricity Mobility Mission Plan (NEMMP) will be implemented to promote zero-emission vehicles. In addition, the implementation of BS VI (Bharat Stage Emission Standards) fuel will be accelerated to further support the transition to cleaner energy sources. BS VI fuel's sulphur content is 80% lower than in BS IV [6]

With the pressing need to tackle air pollution and improve air quality in Bhubaneswar, Odisha we have taken the initiative to monitor various parameters of air quality in the city and provide it to the government bodies with actionable insights.

HYPERLOCAL AIR QUALITY MEASUREMENT

Aurassure firmly believes in the transformative power of Hyperlocal Air Quality measurement using low-cost environmental sensors in establishing an effective decision support system for promoting sustainability amidst the ever-changing urbanisation landscape. Our state-of-the-art technology offers end-to-end solutions including IoT-based sensor devices and cloud-based platforms to facilitate air quality monitoring.

We have implemented a dense hyperlocal air quality monitoring network in Bhubaneswar City. The network comprises 50 advanced sensors that continuously gather detailed, minute-by-minute data on air quality across various locations throughout the city as demonstrated in figure 7.

These devices measure an array of airborne pollutants, including PM10, PM2.5, CO_2, VOCs, SO_2, and NO_2, as well as temperature and humidity levels, providing essential insights into how atmospheric conditions contribute to Air Pollution. These innovative sensors operate utilising cutting-edge 4G LTE technology, which seamlessly transmits crucial data to cloud servers where further analysis is done using Google tools like Bigquery, Looker studio, and Vertex AI.

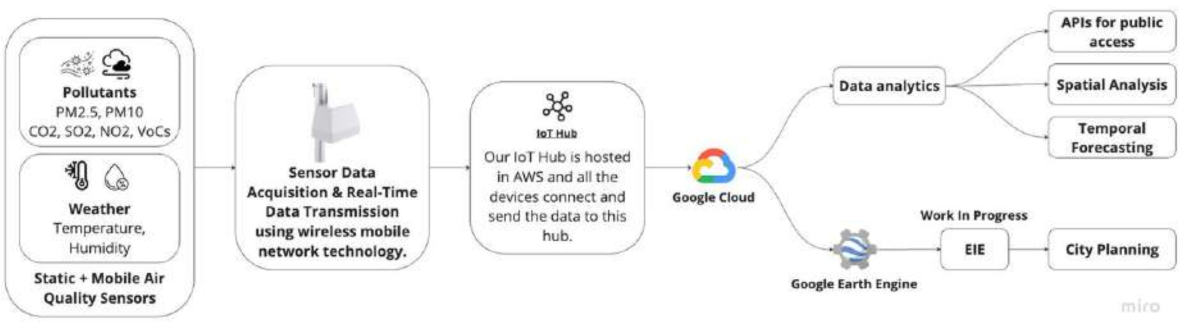


Figure 7 Architecture

Our monitoring network includes both stationary and mobile approaches to capture accurate data from diverse locations throughout the city. We are proud to have the support of esteemed organizations such as the Capital Region Urban Transport (CRUT) and the Software Technology Parks of India (STPI) in setting up the network. We have installed 20 stationary sensor devices strategically with 1 device in every 5 square kilometres of the city to create a hyperlocal monitoring network to capture fine-grained air quality data.

With the help of CRUT, we were able to set up 30 mobile sensor devices on public Mo Buses across the city to capture real-time air quality data. STPI has supported us in setting up a few stationary sensor devices. Furthermore, we are pleased to have the support of the Odisha State Pollution Control Board (OSPCB) in validating our air quality monitoring initiatives, as we work towards our goal of mitigating air

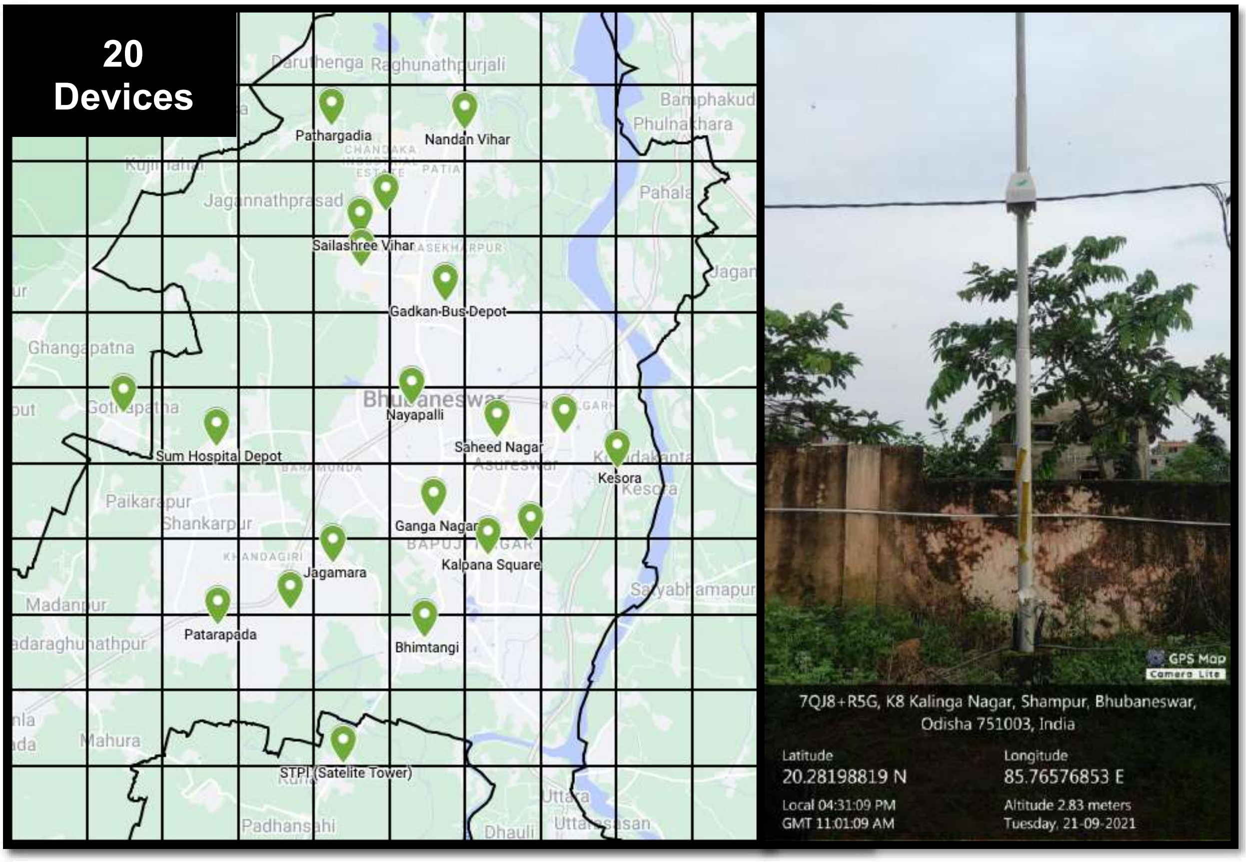


Figure 8a Locations of static monitoring

pollution in the city of Bhubaneswar.

Figure 8b Mobile Monitoring Stations

Key Metrics

# of Data Points Collected = 40 Mn+ over a period of 16 months
Sensor Network Area Coverage = 186 sq km
# of People residing in the area covered = 1.2 Mn

AIR QUALITY TRENDS AND PATTERN - STATISTICAL ANALYSIS

The following section will discuss the annual, seasonal, and monthly trends of PM_{10}, $PM_{2.5}$, and NO_2 concentrations monitored across various locations in Bhubaneswar City during Nov 2021 - Mar 2023.

PM_{10} - ANNUAL AVERAGE

The annual average PM_{10} concentration was monitored at twenty locations across Bhubaneswar City, and the recorded values are presented in Figure 9. Among the locations monitored, Bhimatangi, Infocity, Kalpana Square, Lakshmi Sagar, Patarpada, Pathargadia, Saheed Nagar, and Sailshree Vihar adhere to the national ambient air quality standards, indicating safe levels of air quality in those areas. However, the following locations, in particular, had higher concentrations: Dumduma (65.16 ± 47.64 µg m^{-3}), Ganga Nagar (60.99 ± 55.84 µg m^{-3}), Jagamara (76.41 ± 58.86 µg m^{-3}), Nandan Vihar (61.82± 50.61 µg m^{-3}), Nayapalli (64.62± 54.44 µg m^{-3}), Niladri Vihar (57.05 ± 52.84 µg m^{-3}), Rasulgarh (60.97 ± 48.14 µg m^{-3}), STPI Satellite tower (70.17 ± 50.21 µg m^{-3}), Sum Hospital (80.34 ± 54.62 µg m^{-3})

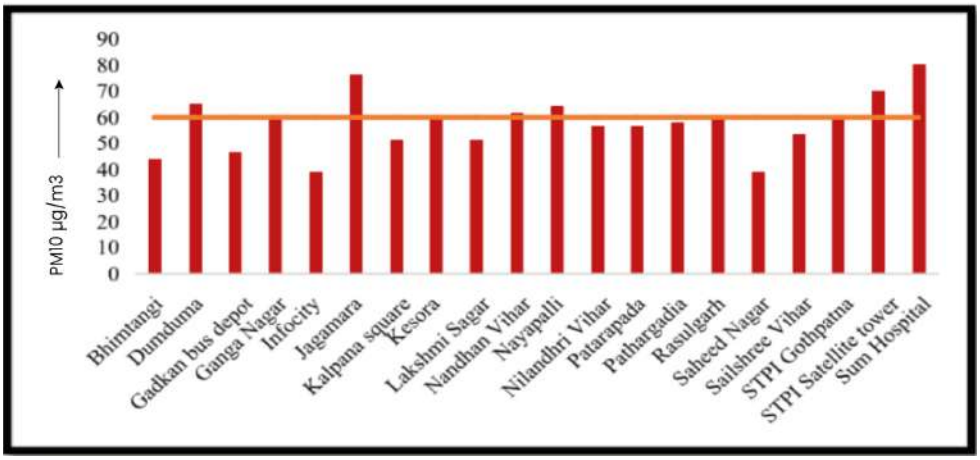


Figure 9 Annual Average of PM_{10} concentration

respectively. The concentration varies a lot due to variations in temperature, humidity, and rainfall throughout the year. This highlights that addressing the issue of high pollutant levels in these areas can have positive health implications for the residents living there.

PM_{10} - SEASONAL TREND

Analysis of the seasonal Trend in PM_{10} concentrations revealed that winter levels were significantly higher than summer, monsoon, and post-monsoon. The data shows that during the winter months, almost all static monitoring sites experienced high concentrations of PM_{10}, above the National Air Quality Standards (NAAQS) of 60 µg m^{-3} as represented in Figure 10. In contrast, other seasons showed a decrease in concentrations of PM_{10} relative to winter – specifically, summer decreased by 68%, followed by monsoon by 85% and post-monsoon by 43%. The analysis of individual contributions to PM_{10} pollution showed that summers accounted for about 21%, while both monsoons accounted for approximately one-quarter of each (i.e., 27%), however, there was a significant difference observed between them. Post-monsoons appeared relatively cleaner, as they only contributed about 14% to total concentration compared to highly polluted winters, which caused the utmost pollution.

One of the main causes of the increase in PM_{10} during winter is temperature inversion, where a layer of warmer air traps cooler air at the surface, preventing pollutants from dispersing. This causes a higher concentration of pollutants to accumulate in the air. As temperatures drop during the winter, this inversion condition often becomes more pronounced, resulting in higher levels of PM_{10}.

The burning of fossil fuels, wood, and waste for heating in winter also exacerbates the problem, releasing more pollutants into the air. On cold winter days, the combination of temperature inversion and the burning of fossil fuels can cause PM_{10} levels to exceed the recommended threshold limit. Unfavourable weather patterns, such as stagnant air and low wind speeds, can trap pollutants and prevent them from dispersing. These factors combine to make air pollution a significant health concern during the winter months in Bhubaneswar.

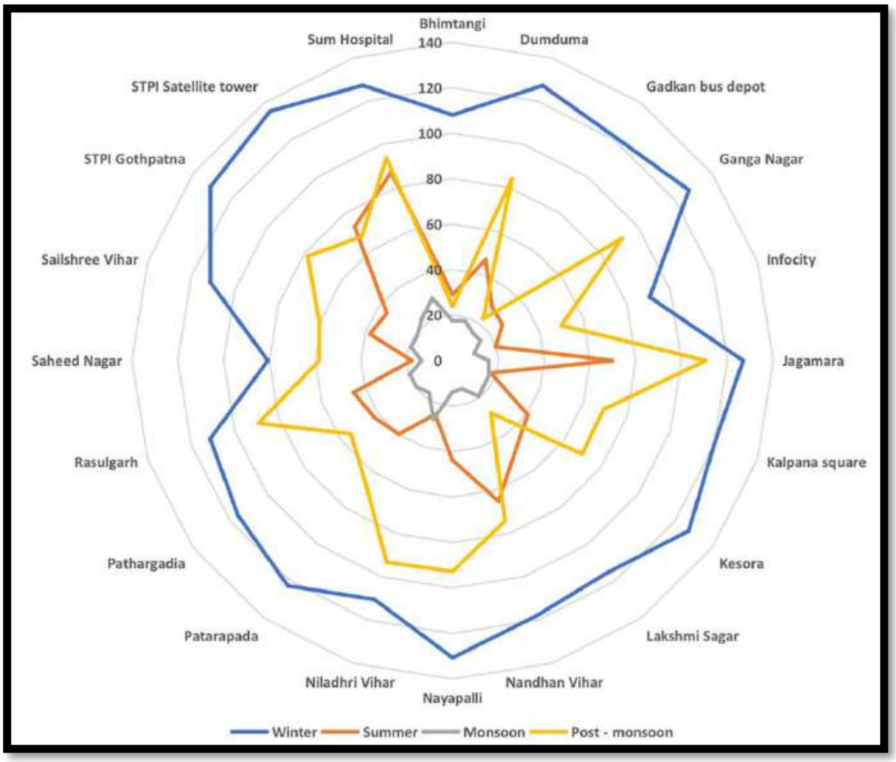


Figure 10 Seasonal variation of PM10 (µg/m3) concentration

PM_{10} – MONTHLY TREND

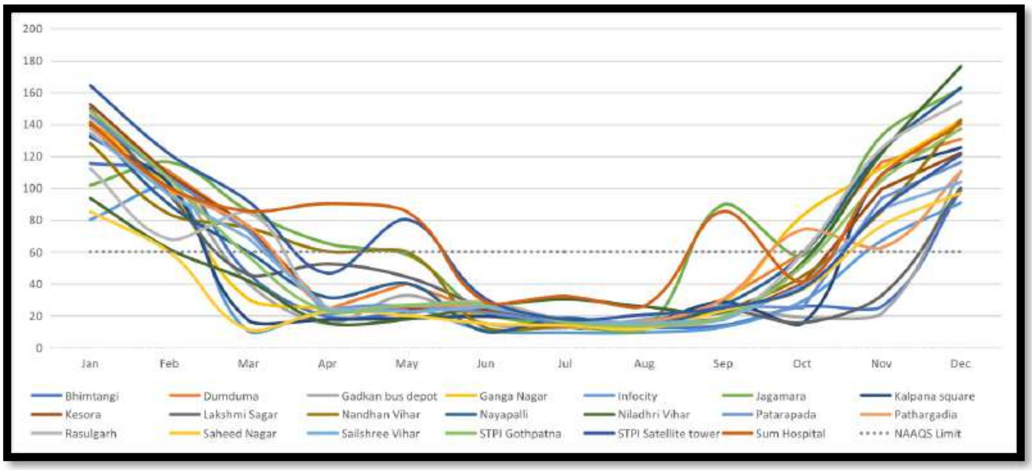


Figure 11 Monthly trend of PM_{10} (µg/m3) concentration

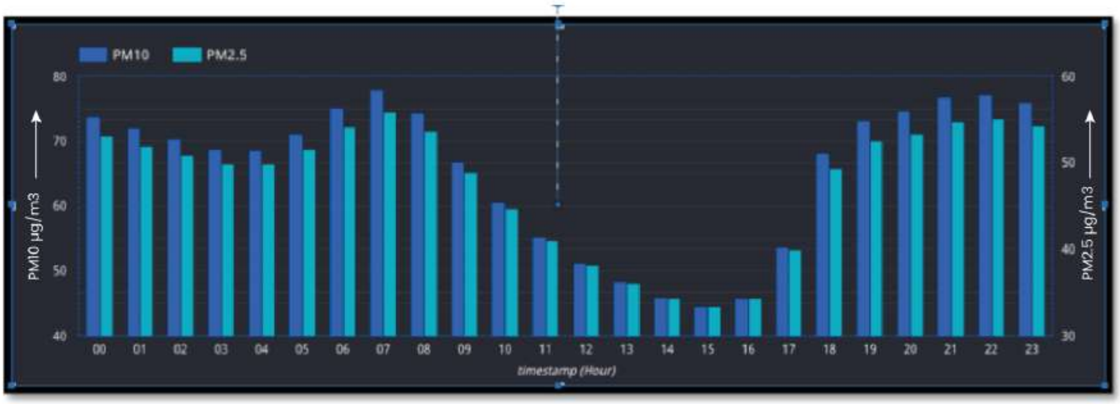
By analysing Figure 11, we can get a detailed understanding of the monthly trend in air quality for the year 2022. The data shows that the concentration of PM_{10} exceeded the 100 µg/m3 NAAQS at all static monitoring sites. In January, about 85%

of locations exceeded permissible limits, while in February, around 35% of locations showed a significant increase in pollutant levels. November and December also experienced moderate but concerning amounts of PM_{10}. However, from March to October, PM_{10} concentrations remained within acceptable limits at all static locations. According to the research conducted in Bhubaneswar city, the emission of PM_{10} is from major sources like Transport 17%, residential 15.9%, dust 20.8%, open waste 5.7%, DG sets 3.6%, and Brick kilns 4% [7].

Overall, this interpretation provides a deeper understanding of the complexity of environmental degradation caused by various factors affecting urban areas at different time intervals over several months. This observation indicates a likely seasonal trend in environmental factors influencing PM_{10} concentration levels in these regions and deserves further investigation into its impact on public health and safety measures in the future.

PM_{10} DIURNAL VARIATION

Changes in air pollutant levels over a day, also called Diurnal variation is a critical factor in understanding air quality. In the case of Bhubaneswar, several hotspots for PM_{10} concentration were identified, with Sum Hospital exhibiting the highest concentration levels. Despite an annual average of approximately 80.34 ± 54.62 μgm^{-3} as shown in Figure 12, a diurnal variation analysis revealed that during the morning and evening peak hours, there was a striking surge in concentration levels as compared to other time frames within the day. This phenomenon highlights the profound impact that vehicular emissions have on air quality, with the sizable quantities of coarse PM expelled by vehicles leading to elevated concentrations of pollutants during these crucial periods of high traffic activity.



The city of Bhubaneswar has experienced a significant rise in vehicular activity, as evidenced by the statistics presented in Figure 13. The impact of this surge on air

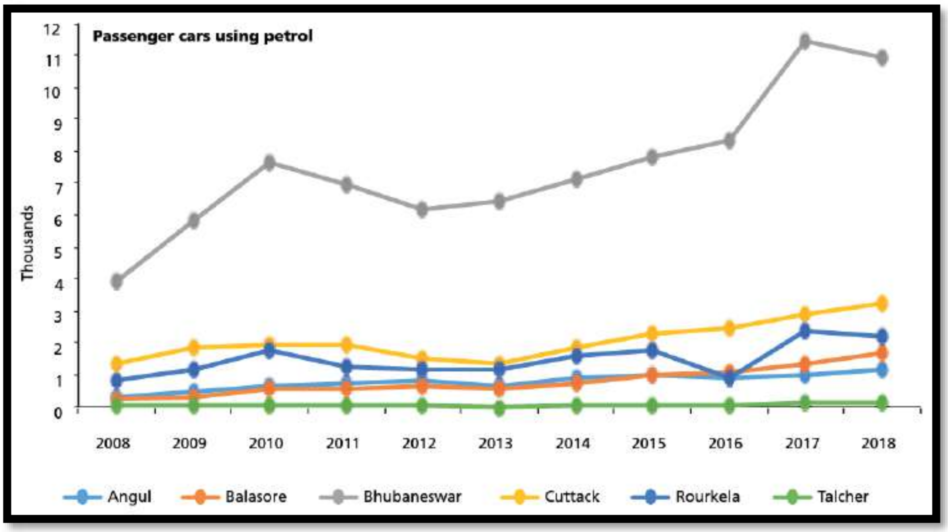


Figure 13 Passenger Petrol Cars [8]

pollution cannot be overstated, with particulate matter emissions being one of its major consequences.

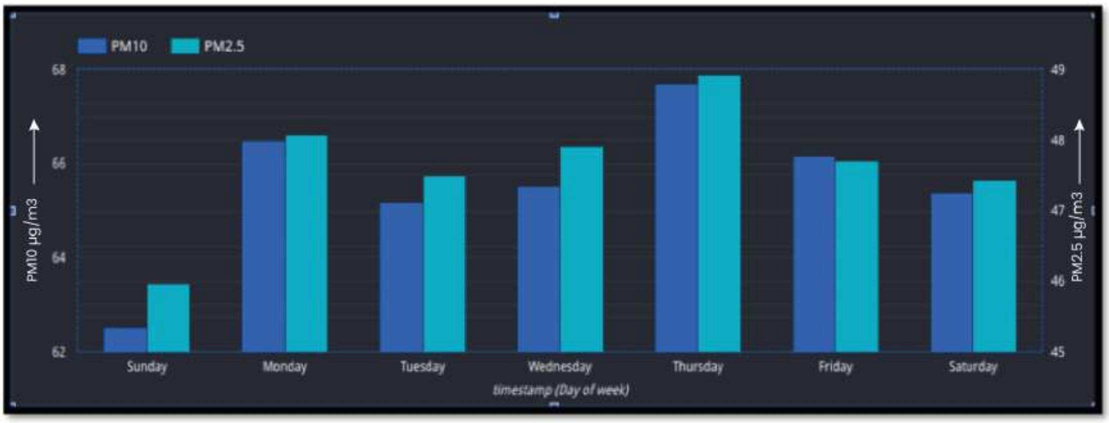


Figure 14 PM_{10} & $PM_{2.5}$ Day of week trend

According to the weekday and weekend analysis, it was found that during the weekdays, there was a rise in PM concentration in the atmosphere. During the weekends, it was comparatively lower. This indicates that the number of vehicles in circulation has a direct impact on the composition of pollutants in the atmosphere, which is why efforts should be made to reduce the number of vehicles in circulation to reduce the PM concentration.

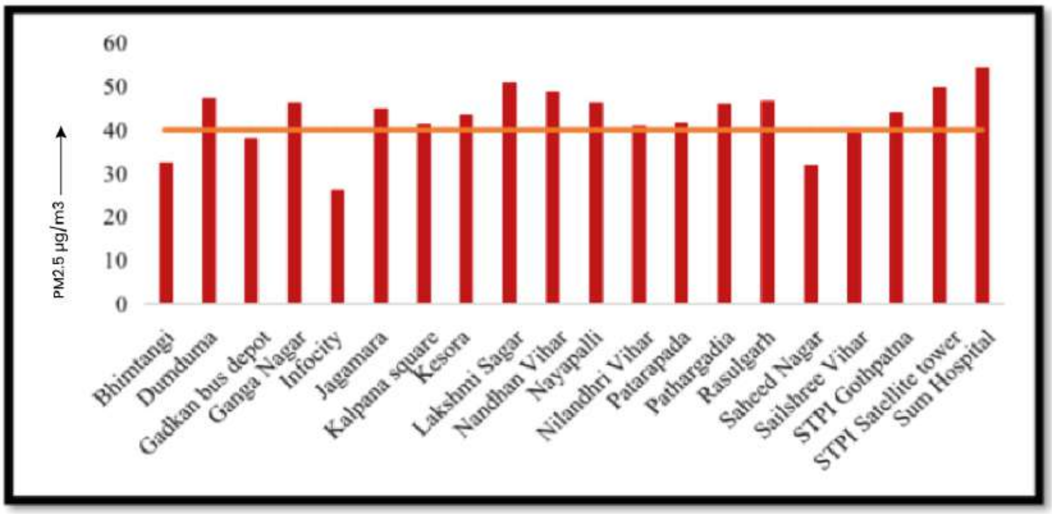


Figure 15 Annual Average of $PM_{2.5}$ concentration

$PM_{2.5}$ - ANNUAL AVERAGE

The annual average data of $PM_{2.5}$ as shown in Figure 15 highlights the need for immediate action to address the high levels of $PM_{2.5}$ in certain parts of the city. A concerning 75% of static monitoring locations have exceeded the NAAQS, as indicated in the figure. Upon closer examination, the concentration levels of $PM_{2.5}$ - a fine particulate matter that can penetrate deep into the lungs and cause respiratory problems - have revealed higher readings at various static monitoring sites. For instance, Dumduma, Ganga Nagar, Jagamara , Kalpana Square, Nandan Vihar, Nayapalli, Niladri Vihar, Patrapada, Pathargadia, Rasulgarh, STPI Gothapatna, STPI Satellite Tower, Sum Hospital. These levels are beyond the NAAQS limits, indicating that focused efforts are needed to reduce $PM_{2.5}$ in these areas.

$PM_{2.5}$ - SEASONAL TREND

The concentration of $PM_{2.5}$ in Bhubaneswar shows a significant seasonal trend as highlighted in Figure 16. These observations regarding the seasonal trend of $PM_{2.5}$ are consistent with our analysis of PM_{10} in the previous section. During winter, when temperatures are low and combustion activity is high, $PM_{2.5}$ levels at all monitoring locations exceed NAAQS standards. However, as summer arrives, we see a promising decrease in $PM_{2.5}$ concentration with reductions up to 76%. Similarly, monsoon season exhibits an even greater improvement at 84%, while post-monsoon drops to around half its original amount reaching values up to only 54%

reduction when compared to winter measurements making it evident that seasonal trend plays an influential role in shaping $PM_{2.5}$ pollution patterns throughout the year.

During winter, the speed of wind plays an important role in dispersing air pollutants in the atmosphere. $PM_{2.5}$, being particles with an aerodynamic diameter size of 2.5 µm or less, highly lightweight, and very small in size, can easily accumulate in the air. Increased wind speed can help prevent such accumulation and improve air quality. However, colder temperatures can cause air pollutants to become more concentrated in the air due to the increased density of the air. Moreover, high humidity can trap pollution $PM_{2.5}$ in the air and they can remain suspended in the air for longer periods. Such minuscule particles can easily infiltrate an individual's lungs and result in numerous respiratory health issues specifically for children and

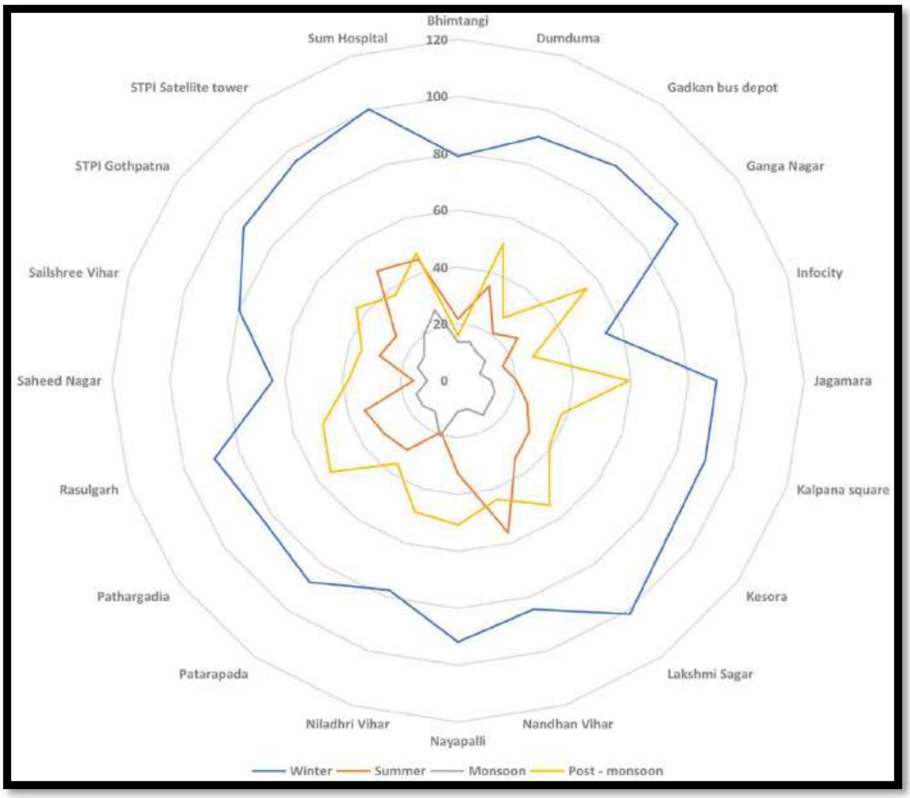


Figure 16 Seasonal trend of $PM_{2.5}$ (µg/m3) concentration

the elderly. This highlights the need for targeted measures to mitigate the impact of seasonal changes on air quality in the city.

$PM_{2.5}$ - MONTHLY TREND

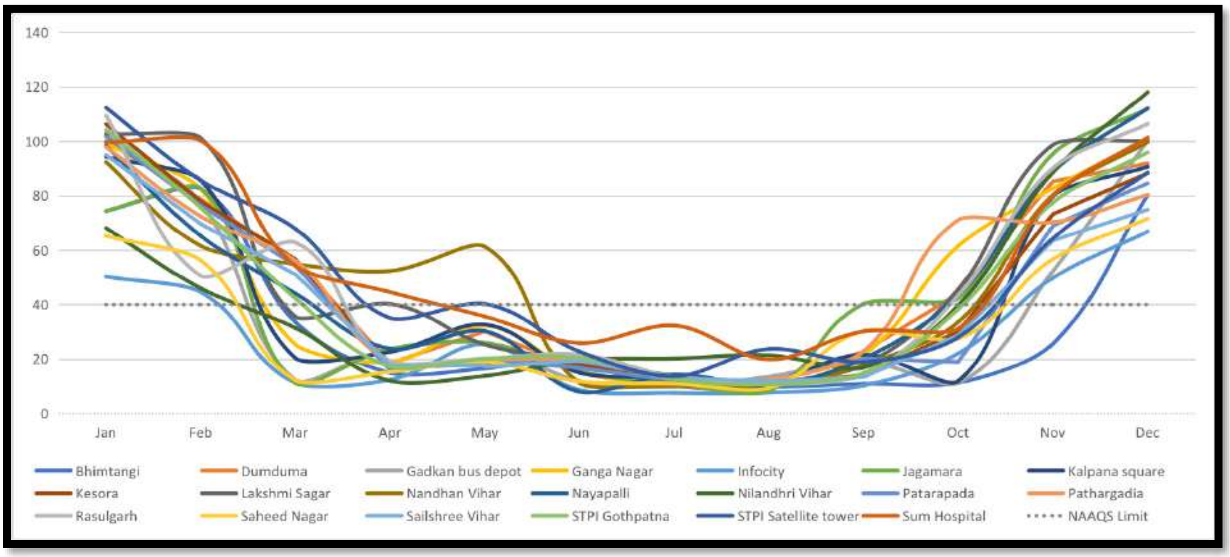


Figure 17 Monthly trend of PM2.5(µg/m3) concentration

Figure 17 shows $PM_{2.5}$ concentration levels throughout the year 2022, indicating that during January and December, 100% of static monitoring locations exceeded NAAQS of $PM_{2.5}$ concentration. In February and November, a high percentage 90% and 95%, respectively) also surpassed these limits; in March and October, only a small percentage (10%) failed to meet them. It is important to note that from April to September, there were no occurrences where $PM_{2.5}$ concentrations surpassed the NAAQS at any of the static monitoring sites - indicating a positive trend toward improved air quality during these months compared to other months.

NO_2 - ANNUAL AVERAGE

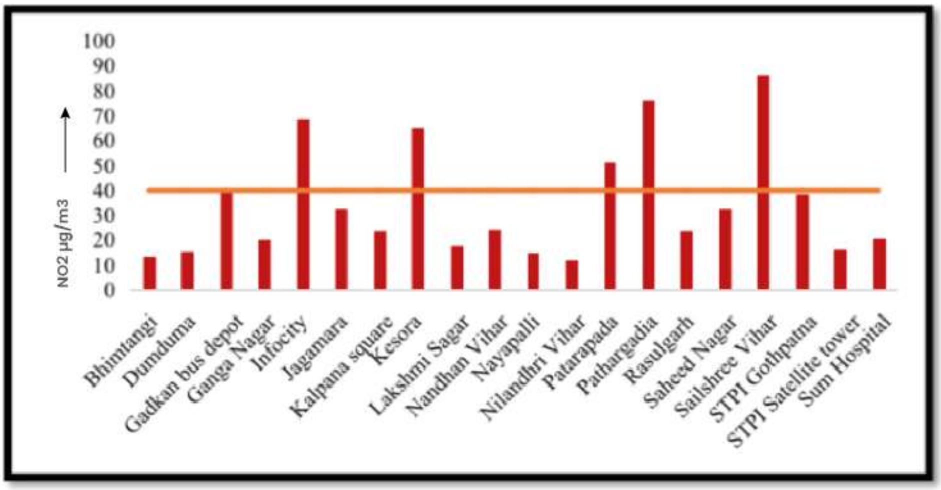


Figure 18 Annual Average of NO_2 concentration

Figure 18 offers a comprehensive overview of the annual average concentration levels of NO_2 in Bhubaneswar City at twenty distinct static monitoring locations. It is encouraging to observe that approximately 70% of these stations have successfully met the NAAQS limits. Five specific areas - Infocity, Kesora, Patrapada, Pathargadia, and Sailshree Vihar – stand out as having particularly high concentrations ranging from 51.41 ± 6.39 µg m-3 for Patrapada to 86.33 ± 3.70 µg m-3 for Sailshree Vihar: all well above acceptable limits. Most of these areas are surrounded by corporate offices, local businesses, traffic junctions, and other high-traffic locations. Therefore, it is evident that the primary cause of increased NO2 concentration in these areas is due to vehicle emissions from burning fossil fuels in combustion engines, which releases NO_2 into the environment.

When fossil fuels are burned, they release a range of pollutants including carbon dioxide, nitrogen oxides, and sulphur dioxide. Of these pollutants, nitrogen dioxide has the most significant effect on human health, as it is a major component of smog and has been linked to a range of respiratory and cardiovascular diseases. To effectively combat the detrimental effects of vehicular emissions on our environment, it is imperative that we encourage and promote alternative modes of transportation such as carpooling and public transit [9].

NO_2 SEASONAL TREND

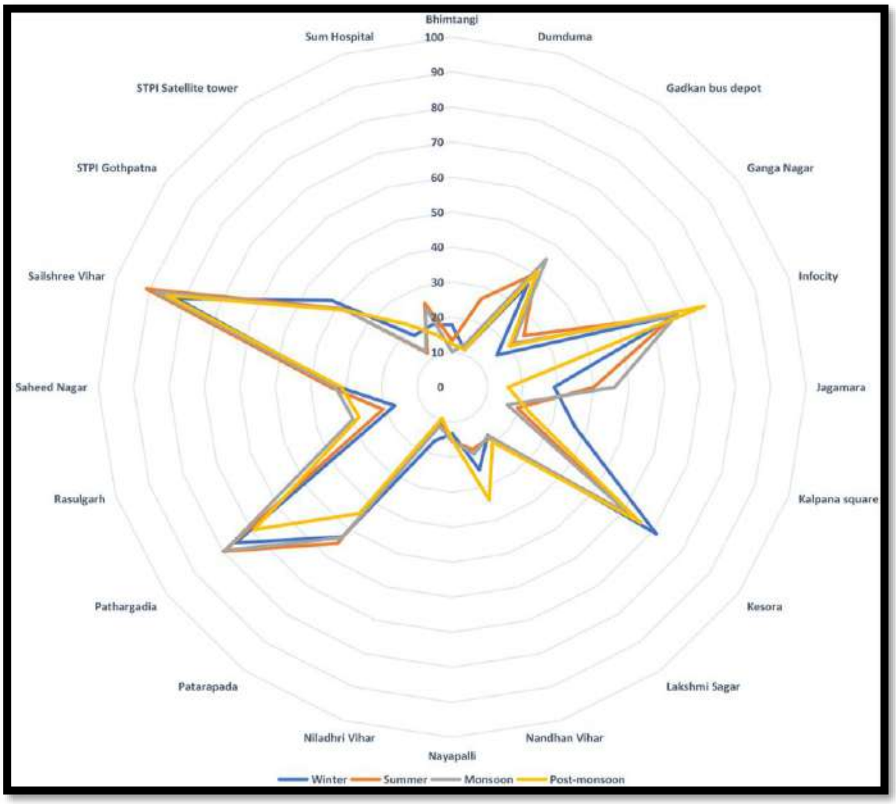


Figure 19 Seasonal trend of NO2 µg/m3 concentration

After careful observation and analysis of NO_2 levels at the stationary monitoring stations, it has been determined that there is no noticeable seasonal trend as shown in Figure 19. The data remained consistent despite weather patterns or other external factors [10]. This suggests that the environment being monitored is stable and cohesive, and it warrants further investigation for better comprehension.

NO_2 - MONTHLY TREND

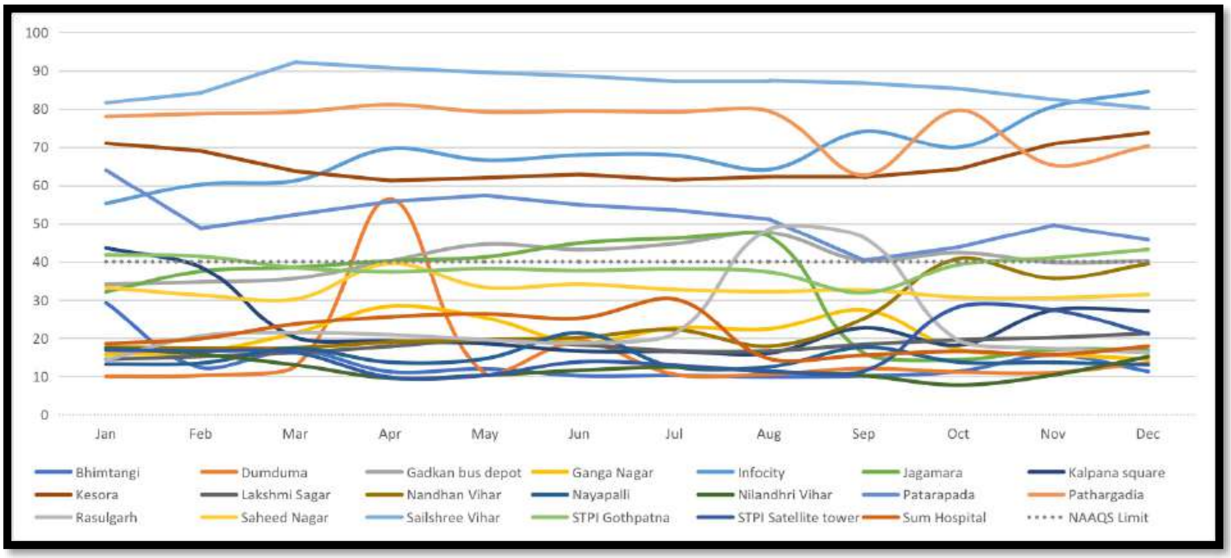


Figure 20 Monthly trend of NO2(µg/m3) concentration

The monthly analysis also showed that the NO_2 emission levels in the same areas namely Infocity, Kesora, Patarpada, Pathargadia, and Sailshree Vihar were considerably higher than those of other static monitoring stations as shown in Figure 20. The surpassing of Sailashree Vihar's NO_2 emission thresholds in the monthly trend is even higher, and it's vital to promptly address the matter before it intensifies.

POLLUTION HOTSPOTS

The concentration maps depicted in this analysis offer a detailed insight into the hotspots for PM_{10}, $PM_{2.5}$, and NO_2 during winter, spanning November, December, and January across two years 2021-22 and 2022-23. These months are known to pose significant health hazards due to heightened air pollution levels caused by factors such as weather patterns and vehicular emissions. The results of our study have identified several major locations that bear elevated concentrations of these harmful particles. The areas showing high levels of particulate matter include Sum Hospital Depot, Patarapada, Dumduma, Pathargadia, Gadkan bus depot, Ganga Nagar, Nayapalli, Sailashree Vihar, Kesora, and Rasulgarh; all densely populated regions where individuals face an increased risk of respiratory illnesses stemming from prolonged exposure to polluted air as shown in Figure 21, 22, 23. Our findings serve as a crucial call to action for policymakers and local authorities who must undertake measures aimed at reducing the impact on public health posed by increasing atmospheric pollution levels in these areas during wintertime - thereby ensuring healthier lives.

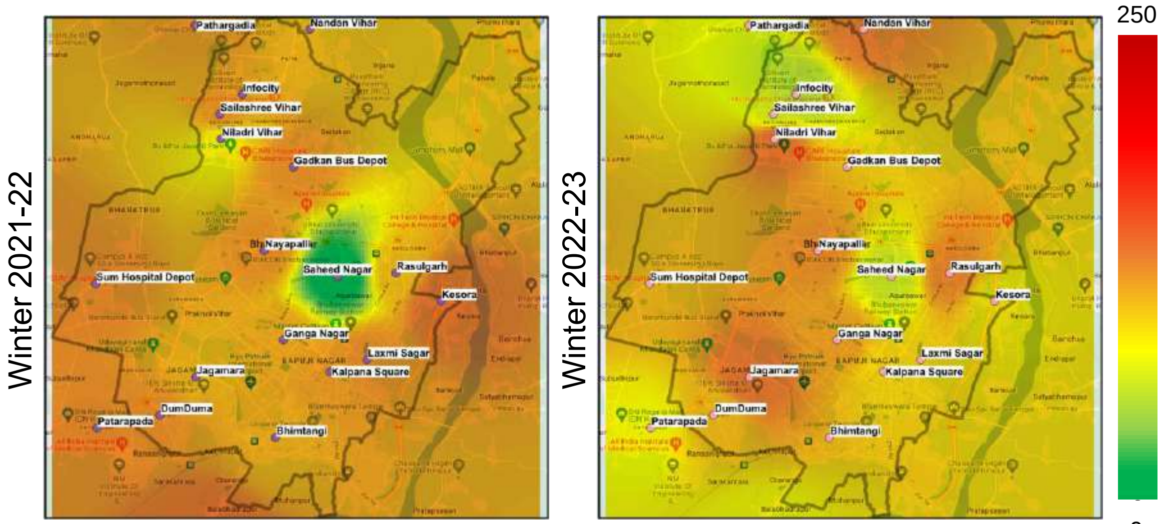


Figure 21 PM2.5 µg/m3 Concentration Maps
(Winter Average)

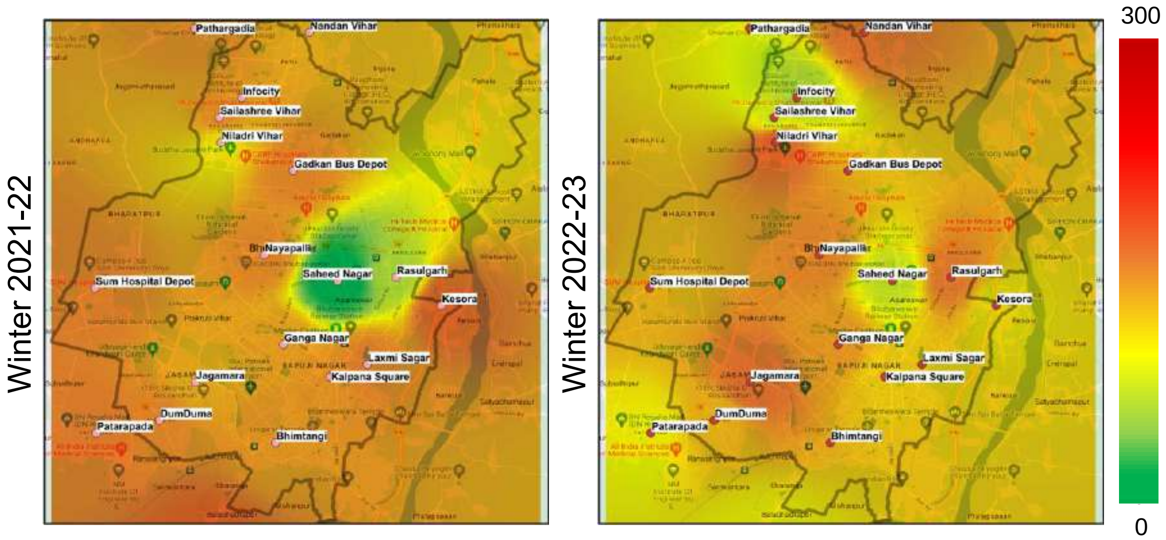


Figure 22 PM10 (µg/m3) Concentration Maps
(Winter Average)

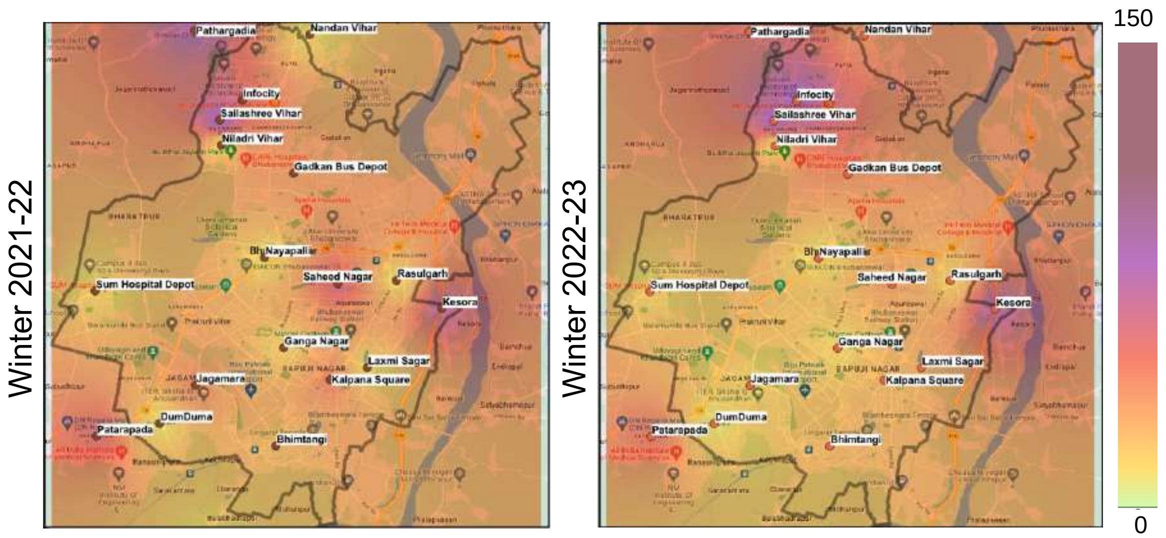


Figure 23 NO2 (µg/m3) Concentration Maps(Winter Average)

POLICY IMPACT ANALYSIS

The Bhubaneswar government has implemented several policies aimed at curbing air pollution in the city. This policy impact analysis evaluates the effectiveness of these policies by examining key indicators of air quality and pollution levels.

1. One of the primary policies implemented by the government is the introduction of new emissions standards [11]. This policy requires vehicles to meet specific emissions standards to be registered in the city. Data analysis shows that the introduction of these standards has had a positive impact on air quality. According to data from the Central Pollution Control Board, the annual average concentration of $PM_{2.5}$ in Bhubaneswar decreased by 12% from 2017 to 2019 [12], which could be attributed to the decrease in the number of vehicles with high emissions due to the new standards.
2. Another significant policy implemented by the government is the promotion of public transportation. Investments have been made in public transportation infrastructure, and incentives have been introduced to encourage the use of public transport, such as discounts on bus fares and the introduction of bicycle lanes [13]. Data analysis shows that this policy has also had a positive impact on air quality. The annual average concentration of PM_{10} decreased by 16% from 2017 to 2019 [12], which could be attributed to the decrease in the number of private vehicles on the roads due to the increased availability of public transportation.
3. The implementation of emissions-reducing technologies is another key policy implemented by the government. Technologies such as catalytic converters have been introduced to reduce emissions from vehicles [11]. The data analysis shows that this policy has also had a positive impact on air quality. According to data from the Central Pollution Control Board, the annual average concentration of NO_2 in Bhubaneswar decreased by 5% from 2017 to 2019 [12], which could be attributed to the implementation of such technologies.

Overall, the policies implemented by the Bhubaneswar government have had a positive impact on air quality in the city. The data analysis shows that the implementation of new emissions standards, the promotion of public transportation, and the implementation of emissions-reducing technologies have all contributed to the decrease in air pollution levels in Bhubaneswar.

However, it is essential to note that the impact analysis presented here is based on city-wide data and does not take into account the hyperlocal variations that exist within the city. Our hyperlocal network, which collects granular data on air pollution levels, can complement the city's monitoring efforts and provide more accurate insights into the impact of these policies on a local story. While the recent changes as observed from our network of sensors in air pollution levels in Q1 2022 vs 2023 as depicted in Fig. 24 indicate a slight increase in the annual average concentration of $PM_{2.5}$ and NO_2, and a slight decrease in PM_{10} levels could be attributed to the policies implemented by the government to reduce air pollution levels. However, this is preliminary. we are accumulating more data which can be used to validate and drive policy changes.

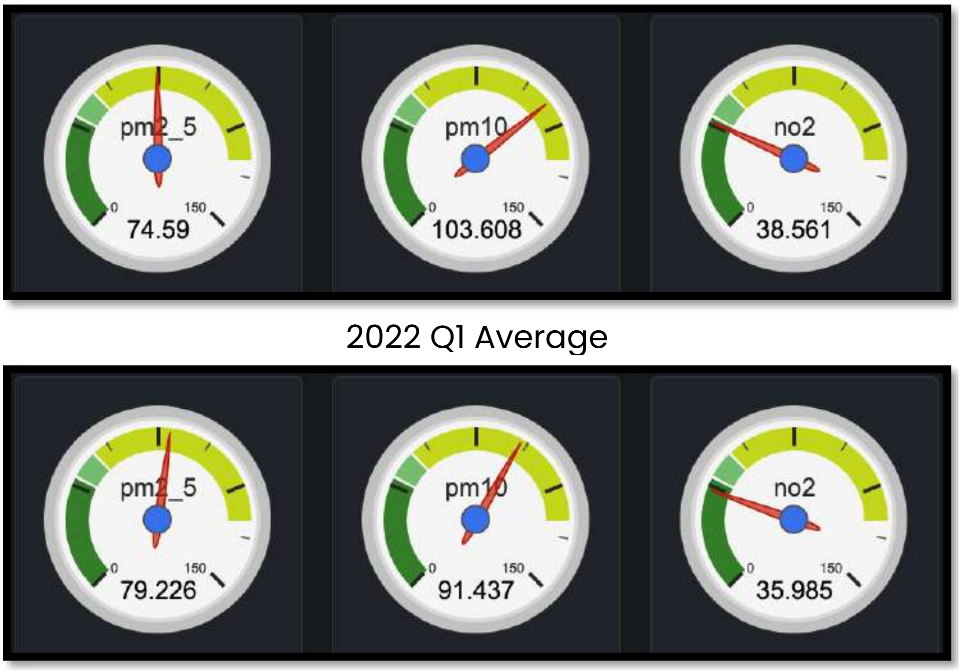


Figure 24

As we continue to gather more hyperlocal data over multiple years, it can help validate and boost further such initiatives in the right direction through the hyperlocal lens of the city. The data can also help identify areas where these policies may need to be strengthened or targeted to maximise their impact.

CONCLUSION

In conclusion, air pollution is a complex issue that requires a comprehensive approach to mitigation. Our whitepaper has shed light on the pressing issue of air pollution in Bhubaneswar, highlighting the need for a hyperlocal approach to monitoring air quality. Through our extensive sensor network, we have provided valuable insights into the state of air pollution in Bhubaneswar and analysed the impact of policy initiatives taken by the government. Our analysis shows that there is a need for more targeted interventions that address the sources of air pollution at a micro-level. By leveraging technology and data, we can empower individuals, policymakers, and other stakeholders to make informed decisions aimed at reducing the environmental impact of human activity. At Aurassure, we are committed to working towards a sustainable future and are proud to be at the forefront of leveraging technological advancements toward securing a healthier environment for generations to come.

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Aurassure empowers the governments and citizens with the real-time awareness of the environment, facilitating informed decisions and a healthy lifestyle.

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