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"ASSESSMENT OF THE IMPACTS OF AIR POLLUTION IN SATNA, MADHYA PRADESH: A COMPREHENSIVE ANALYSIS"

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ABSTRACT

This review paper investigates the adverse impacts of air pollution on the environment and public health in Satna, Madhya Pradesh. Satna, an industrial city, has been grappling with escalating levels of air pollutants due to rapid urbanization and industrialization. This paper aims to synthesize existing literature to comprehend the extent of air pollution, its sources, and its consequences on the local ecosystem and human health. Various studies, reports, and data sources are analysed to provide insights into the pollutants prevalent in the region, including particulate matter (PM), sulphur dioxide (SO2), nitrogen dioxide (NO2), and volatile organic compounds (VOCs). Furthermore, the review examines the socio-economic factors contributing to air pollution and evaluates current policies and measures undertaken to mitigate its adverse effects. Recommendations for future research and strategies for effective pollution control and management are also discussed.

Keywords: Air Pollution, Satna, Madhya Pradesh, Particulate Matter, Sulphur Dioxide, Nitrogen Dioxide, VOCs, Health Impacts, Pollution Control

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1. INTRODUCTION

Air pollution remains a pressing environmental concern for humanity. According to the World Health Organization (WHO) in 2016, more than 90% of the global population is exposed to air quality that falls short of WHO guidelines. that 55% of the world's population faced increasing concentrations of PM2.5 between 2010 and 2016, with notable regional disparities. While North America and Europe experienced decreasing trends, central and south Asia saw rising concentrations. WHO's 2016 evaluation attributed approximately 7 million premature deaths worldwide in 2012 to air pollution exposure from both outdoor and indoor anthropogenic sources. The WHO's updated air quality guidelines in 2021 underscore the urgent need to reduce air pollution emissions and enhance air quality on a global scale.

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The major sources of these regulated pollutants vary. For example, in New Delhi, residential, transport and industrial sectors are the major sources of PM2.5 (Sahu et al., 2011).

Few studies in India, tried to analyse air quality using AQI in cities. Sahu and Kota, Aerosol and Air Quality Research, 17: 588–597, 2017 589For example, Sharma et al. (2003) used Indian NAAQS and health standards by the US, for suspended particulate matter (SPM), CO, NO2, O3, SO2, and PM10 to estimate AQI in an Indian city. Bhaskar and Mehta (2010) used the US method to estimate AQI at thirteen different sites in Ahmadabad city in India, and observed strong seasonal effects on AQI. Banerjee and Srivastava (2011) estimated AQI proposed by Rao and Rao (1979),

Satna, a city located in the central Indian state of Madhya Pradesh, has experienced rapid urbanization and industrial growth over the past few decades. As a result, it has faced significant challenges related to air pollution. The combination of industrial activities, vehicular emissions, biomass burning, and urban expansion has led to deteriorating air quality in the region. This introduction provides an overview of the air pollution situation in Satna, highlighting its causes, impacts, and implications for public health and the environment.

Cohen et al. (2005) observed that the relationship between relative risk and cardiopulmonary diseases, lung cancer, and acute respiratory infections in children was linear between PM2.5 concentrations of 7.5 $\mu g\ m^{-3}$ to 50 $\mu g\ m^{-3}$, and flattened thereafter.

2. SOURCES AND EMISSIONS OF AIR POLLUTANT

Air pollutants originate from various sources, both natural and anthropogenic, contributing to environmental degradation and adverse health effects. transport sector is the major source of CO and NOx (Aneja et al., 2001); and industries are major source for SO2 (Sadavarte and Venkataraman, 2014).

The time series Poisson regression models are widely used to analyse the relation between pollutant concentrations and mortality (Dholakia et al., 2014). The Poisson model used in this study, represented using (Bhaskaran et al., 2013; Imai et al., 2015).

Some primary sources of air pollutants include:

1) **Industrial Activities:** Factories, power plants, refineries, and manufacturing processes emit pollutants such as sulphur dioxide (SO2), nitrogen oxides (NOx), particulate matter (PM), volatile organic compounds (VOCs), and heavy metals.
2) **Transportation:** Vehicles, including cars, trucks, airplanes, ships, and trains, emit pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), volatile organic compounds (VOCs), and hydrocarbons.
3) **Agricultural Practices:** Agricultural activities such as livestock farming, crop burning, and the use of fertilizers and pesticides release pollutants such as ammonia (NH3), methane (CH4), nitrous oxide (N2O), and particulate matter (PM).
4) **Residential Heating and Cooking:** Burning of wood, coal, charcoal, and other solid fuels for heating and cooking purposes releases pollutants such as carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NOx), and sulphur dioxide (SO2).
5) **Waste Management:** Landfills, open burning of waste, and waste incineration contribute to air pollution through the release of methane (CH4), carbon monoxide (CO), volatile organic compounds (VOCs), and particulate matter (PM).
6) **Natural Sources:** Volcanic eruptions, wildfires, dust storms, and biological processes (such as plant emissions and microbial activities) are natural sources of air pollutants, releasing particulate matter (PM), sulphur dioxide (SO2), nitrogen oxides (NOx), methane (CH4), and other compounds into the atmosphere.

Efforts to mitigate air pollution involve implementing regulations and technological advancements to reduce emissions from these sources, promoting cleaner energy alternatives, improving fuel efficiency standards, and adopting sustainable agricultural and waste management practices. Additionally, raising awareness and encouraging individual and collective actions to reduce pollution can play a significant role in improving air quality and protecting public health and the environment.

3. OBJECTIVE THE STUDY

a. To ascertain the ambient air quality of Satna

3.1. STUDY ARE

Satna, a comprehensive study area situated in the heart of Madhya Pradesh, India, has been subject to extensive research on air pollution due to its diverse industrial and vehicular activities. The city contends with a myriad of pollutants stemming from industrial emissions, vehicular exhaust, and other human activities. Geographical and meteorological factors in Satna exacerbate the issue, resulting in the formation of localized pollution hotspots. Moreover, the city's expanding population and rapid urbanization further exacerbate air quality degradation. Therefore, understanding the dynamics of air pollution in Satna is crucial for formulating effective mitigation measures to protect public health and the environment. Researchers are diligently analysing and monitoring various factors influencing air quality in Satna to pave the way for sustainable development and ensure cleaner air for its residents.

Totally we have located 3 places in Satna district, from which we have taken sources of air quality.

Along with this, a lot of information has also been provided by the pollution control board.

S1 – Civil line Area

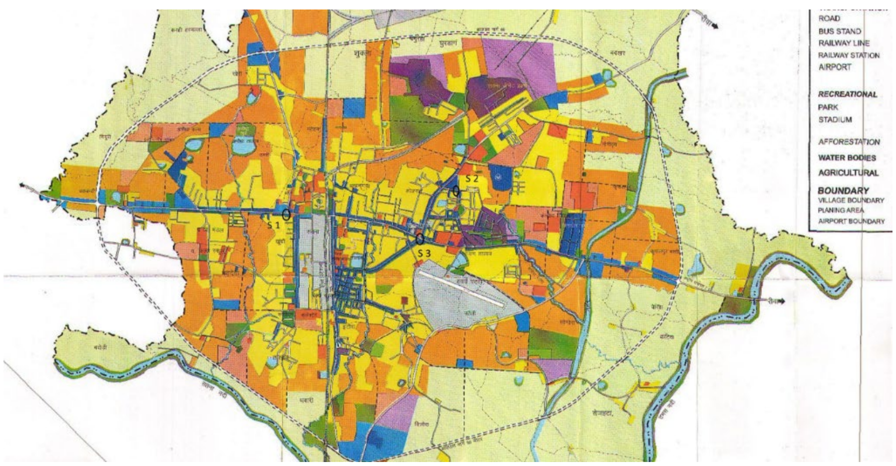
S2 – Bandhavgarh Colony Area

S3 – Semaria Chauraha Area

S3 – Dhawari Area

S4 – Sherganj Area

Table 1



Source Google Map India

3.2. INDUSTRIAL EXPANSION

Satna has emerged as a prominent industrial hub, with various industries such as cement manufacturing, thermal power plants, and chemical factories operating in the region. While these industries contribute to economic growth and employment opportunities, they also release a substantial number of pollutants into the atmosphere. Emissions from industrial sources include particulate matter, sulphur dioxide, nitrogen oxides, and volatile organic compounds, among others, which significantly contribute to air pollution.

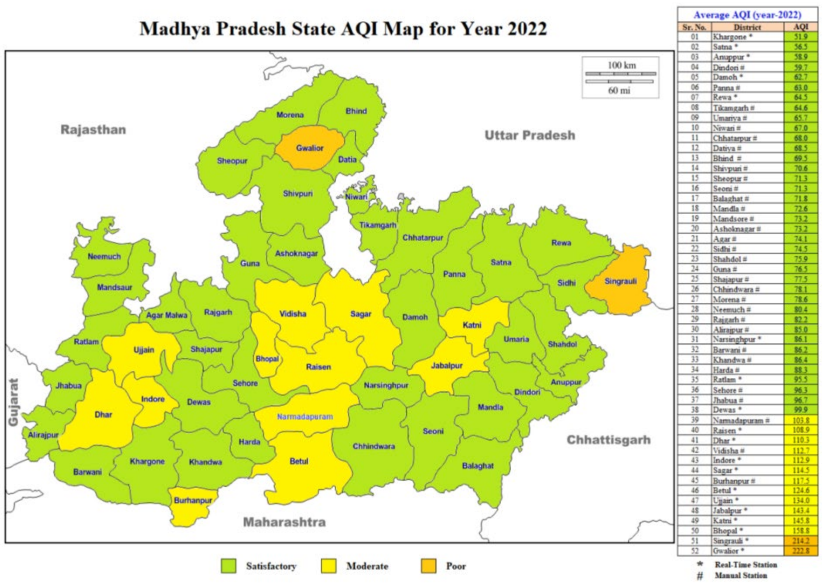
3.3. VEHICULAR EMISSIONS:

The proliferation of vehicles on the streets of Satna has worsened the city's air pollution. Inadequately serviced vehicles, obsolete emission control regulations, and ineffective traffic supervision all play a role in elevating levels of harmful exhaust emissions, especially in urban zones. The combustion of fossil fuels in vehicles emits pollutants like carbon monoxide, nitrogen oxides, and hydrocarbons, exacerbating the decline in air purity.

3.4. BIOMASS BURNIN

In the rural regions surrounding Satna, agricultural practices frequently entail the burning of crop residues and biomass, especially after the harvest season. This practice results in the emission of substantial quantities of particulate matter and other detrimental pollutants, thereby exacerbating air pollution on a regional scale. Additionally, the prevalent utilization of biomass for cooking and heating purposes in both rural and urban settings further compound the issue.

Table 2



Sr. No.	District	AQI
01	Khargone *	51.9
02	Satna *	56.5
03	Anuppur *	58.9
04	Dindori #	59.7
05	Damoh *	62.7
06	Panna #	63.0
07	Rewa *	64.5
08	Tikamgarh #	64.6
09	Umariya #	65.7
10	Niwari #	67.0
11	Chhatarpur #	68.0
12	Datiya #	68.5
13	Bhind #	69.5
14	Shivpuri #	70.6
15	Sheopur #	71.3
16	Seoni #	71.3
17	Balaghat #	71.8
18	Mandla #	72.6
19	Mandsore #	73.2
20	Ashoknagar #	73.2
21	Agar #	74.1
22	Sidhi #	74.5
23	Shahdol #	75.9
24	Guna #	76.5
25	Shajapur #	77.5
26	Chhindwara #	78.1
27	Morena #	78.6
28	Neemuch #	80.4
29	Rajgarh #	82.2
30	Alirajpur #	85.0
31	Narsinghpur *	86.1
32	Barwani #	86.2
33	Khandwa #	86.4
34	Harda #	88.3
35	Ratlam *	95.5
36	Sehore #	96.3
37	Jhabua #	96.7
38	Dewas *	99.9
39	Narmadapuram #	103.8
40	Raisen *	108.9
41	Dhar *	110.3
42	Vidisha #	112.7
43	Indore *	112.9
44	Sagar *	114.5
45	Burhanpur #	117.5
46	Betul *	124.6
47	Ujjain *	134.0
48	Jabalpur *	143.4
49	Katni *	145.8
50	Bhopal *	158.8
51	Singrauli *	214.2
52	Gwalior *	222.8

3.5. TOPOGRAPHICAL AND METEOROLOGICAL FACTORS:

The geographical location and meteorological conditions of Satna also influence its air quality. Situated in a basin surrounded by hills, Satna experiences limited air circulation, which can lead to the accumulation of pollutants in the atmosphere. Additionally, factors such as temperature inversions and atmospheric stability can exacerbate pollution levels by trapping pollutants close to the ground.

3.6. HEALTH IMPACTS

The deteriorating air quality in Satna poses significant health risks to its residents. Exposure to air pollutants such as particulate matter, sulphur dioxide, and nitrogen dioxide is associated with respiratory diseases, cardiovascular ailments, and other health complications. Vulnerable populations such as children, the elderly, and individuals with pre-existing health conditions are particularly susceptible to the adverse effects of air pollution.

In light of these challenges, addressing air pollution in Satna requires coordinated efforts from government authorities, industries, communities, and other stakeholders. Implementing stringent emission control measures, promoting sustainable transportation options, and raising awareness about the importance of air quality are essential steps towards improving the environmental and public health conditions in the city.

3.7. AIR QUALITY INDEX

Table 3

Revised National Ambient Air Quality Standards (NAAQS)
[NAAQS Notification dated 18th November, 2009]

S. No.	Pollutants	Time Weighted Average	Concentration in Ambient Air: Industrial, Residential, Rural and other Areas	Concentration in Ambient Air: Ecologically Sensitive Area (notified by Central Government)	Methods of Measurement
1	Sulphur Dioxide (SO_2), µg/m^3	Annual*	50	20	1. Improved West and Gaeke 2. Ultraviolet Fluorescence
		24 Hours**	80	80	
2	Nitrogen Dioxide (NO_2), µg/m^3	Annual*	40	30	1. Modified Jacob & Hochheiser 2. Chemiluminescence
		24 Hours**	80	80	
3	Particulate Matter (Size <10µm) or PM_{10} µg/m^3	Annual*	60	60	1. Gravimetric 2. TEOM 3. Beta attenuation
		24 Hours**	100	100	
4	Particulate Matter (Size <2.5 µm) or $PM_{2.5}$ µg/m^3	Annual*	40	40	1. Gravimetric 2. TEOM 3. Beta attenuation
		24 Hours **	60	60	
5	Ozone (O_3), µg/m^3	8 hours**	100	100	1. UV photometric 2. Chemiluminescence 3. Chemical Method
		1 hours **	180	180	
6	Lead (Pb), µg/m^3	Annual *	0.50	0.50	1. AAS/ICP Method after sampling using EPM 2000 or equivalent filter paper 2. ED-XRF using Teflon filter
		24 Hour**	1.0	1.0	
7	Carbon Monoxide (CO), mg/m^3	8 Hours **	02	02	Non dispersive Infra Red (NDIR) Spectroscopy
		1 Hour**	04	04	
8	Ammonia (NH_3), µg/m^3	Annual*	100	100	1. Chemiluminescence 2. Indophernol blue method
		24 Hour**	400	400	
9	Benzene (C_6H_6), µg/m^3	Annual *	05	05	1. Gas chromatography based continuous analyzer 2. Adsorption and Desorption followed by GC analysis
10	Benzo(a)Pyrene (BaP)- particulate phase only, ng/m^3	Annual*	01	01	Solvent extraction followed by HPLC/GC analysis
11	Arsenic (As), ng/m^3	Annual*	06	06	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel (Ni), ng/m^3	Annual*	20	20	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper

** Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform interval.** 24 hourly 08 hourly or 01 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 investigation.

Source Central pollution control board New Delhi

4. MATERIAL AND METHOD: -

The determination of the Air Quality Index (AQI) involves several steps in the material and methods section:

Data Collection: Gathering data on pollutant concentrations from monitoring stations in the Satna region. This includes pollutants such as PM10 (particulate matter with a diameter of 10 micrometres or less), PM2.5 (particulate matter with a diameter of 2.5 micrometres or less), NO2 (nitrogen dioxide), and SO2 (sulphur dioxide).

1) **Standard Values:** Identifying the standard values set for each pollutant by relevant regulatory bodies or environmental agencies.
2) **Calculation of Pollutant Ratios:** Calculating the ratio of the concentration of each pollutant to its respective standard value. This involves dividing the concentration of each pollutant by its standard value.
3) **Arithmetic Mean Calculation:** Computing the arithmetic mean of the ratios obtained in the previous step. This provides an overall indication of air quality based on multiple pollutants.
4) **AQI Index Determination:** Multiplying the arithmetic mean by 100 to derive the AQI index. This index serves as a quantitative measure of the overall air quality in the region.
5) **Comparison with Rating Scale:** Comparing the calculated AQI with a predefined rating scale. This scale categorizes air quality into different levels (e.g., good, moderate, unhealthy) based on specific AQI ranges.
6) **Individual Pollutant AQI Calculation:** For each pollutant, calculating its individual AQI using a specific formula tailored to that pollutant. These formulas typically involve mathematical relationships between pollutant concentrations and their health effects.

By following these steps, researchers can accurately determine the AQI for the Satna region, providing valuable insights into air quality conditions and potential health risks associated with air pollution.

Method I: involves the calculation of the Air Quality Index (AQI) by computing the arithmetic mean of pollutant concentrations relative to their respective standard values, including PM10, PM2.5, NO2, and SO2. This average is subsequently multiplied by 100 to derive the AQI index. The resulting AQI is then compared with a predefined rating scale as per the study by Kaushik et al. (2006).

Method II: In this method, the (AQI) is determined by computing the geometric mean of the ratios between the concentration of pollutants (such as PM10, PM2.5, NO2, and SO2) and their respective standard values. Subsequently, the AQI obtained is compared against a rating scale for evaluation, as outlined by Ravikumar et al. in 2014.

Method III: The Oak Ridge National Air Quality Index (ORNAQI) serves the purpose of comparatively ranking the overall status of air quality. Over all AQI was estimated by the following mathematical equation developed by the Oak Ridge National Laboratory (ORNL), USA Air quality Index then measured and compared with relative ORAQI values (Bhuyan et al. 2010)

5. RESULT AND DISCUSSIO

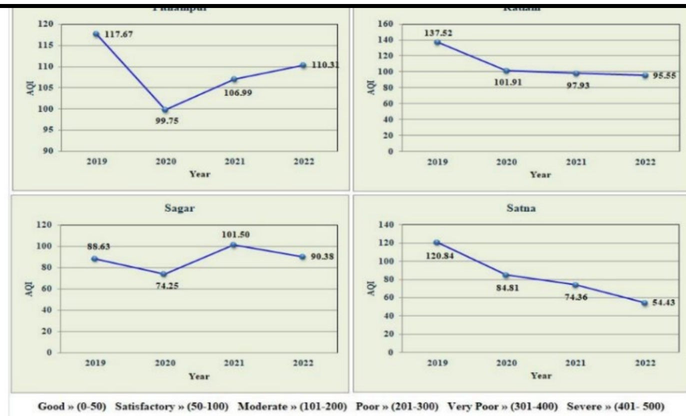
Table 4

S.N.	Name of Station	PM_{10} (μg/m³)	$PM_{2.5}$ (μg/m³)	SO_2 (μg/m³)	NO_x (μg/m³)
1	**S1**	118.36-11.52	52.56-6.71	10.83-1.04	13.01-1.32
2	**S2**	121.65-13.01	64.13-3.21	11.75-1.01	10.23-1.13
3	**S3**	208.17-23.01	78.41-4.03	14.16-0.86	23.76-01.17
4	**S4**	125.76-12.02	76.04-5.87	11.23-2.12	11.76-0.98
5	**S5**	56.12-4.13	26.19-2.13	2.11-0.76	6.17-1.10

1) **Particulate Matter (PM10):** PM10 concentrations were monitored at various stations with the assistance of RDS. The recorded PM10 levels ranged between 56.12 and 208.17 µg/m3 (as shown in Table 4). The lowest concentration, 56.12 µg/m3, was observed at S5 (Sher Ganj) residential area Along with this, there is also a farm-barn area here, well within acceptable limits. Conversely, the highest concentration, 208.17 µg/m3, was detected at Semaria Chauraha, attributed to heavy traffic and numerous small factories in the vicinity.
2) **Particulate Matter (PM2.5):** PM2.5 concentrations were assessed at five ambient air quality stations utilizing the ambient fine dust sampler control module. The recorded PM2.5 levels ranged between 26.19 and 64.13 µg/m3 (as depicted in Table 4). The lowest concentration, 26.19 µg/m3, was identified at S5 (Sherganj) residential area, remaining within acceptable limits. Conversely, the highest concentration, 64.13 µg/m3, was registered at S4 (Semaria Chauraha) commercial area, attributed to heavy traffic and the presence of numerous small factories.
3) **Oxide of Sulphur (Sox):** SOx levels were monitored at five ambient air quality stations using RDS. Sulphur dioxide (SO2) concentrations ranged from 2.13 to 14.16 µg/m3 (as detailed in Table 4). The lowest concentration, 2.13 µg/m3, was detected at S5 (Sherganj) area, while the highest concentration, 14.16 µg/m3, was recorded at S2 (Semaria Chauraha area).
4) **Nitrogen dioxide (NO2):** The concentration of NO2 ranged from 6.17 to 23.76 µg/m3 (as indicated in Table 4). The lowest concentration, 6.17 µg/m3, was observed at S5 (Sherganj) residential area, while the highest concentration, 23.76 µg/m3, was detected at Semaria Chauraha Area.

Satna city secured the top position among the monitored cities with annual average concentration of PM2.5 to be 18.2 ug/m3.

Table 5



Source Air quality Statistics 2022 MP pollution control board Bhopal

Satna, a city nestled in the heart of India, has recently emerged as a beacon of environmental consciousness, boasting a remarkable achievement in its air quality index (AQI) ranking. In a commendable feat, Satna has surged to the top 2 position in average air quality index ratings, signalling a remarkable improvement in its atmospheric conditions. This accomplishment underscores the concerted efforts undertaken by local authorities, residents, and various stakeholders to combat air pollution and prioritize sustainable practices. With a blend of stringent regulations, widespread awareness campaigns, and investments in green infrastructure, Satna has set a precedent for other cities striving to mitigate the adverse effects of pollution on public health and the environment. This remarkable progress not only enhances the quality of life for Satna's inhabitants but also serves as a testament to the power of collective action in safeguarding our planet's precious resources.

In Satna, the current Air Quality Index (AQI) reading of 54.4 falls within the "Satisfactory" category. This signifies that the overall air quality in the region is considered acceptable and poses minimal risk to public health. With an AQI in this range, the air is generally clean with low concentrations of pollutants, thus indicating favourable conditions for outdoor activities and everyday living.

However, while the air quality is deemed satisfactory overall, it's essential to remain vigilant, particularly for vulnerable individuals such as those with respiratory issues, young children, and the elderly. Even in satisfactory conditions, pollutants may still be present at levels that could cause health concerns for sensitive individuals if they are exposed for extended periods.

It's advisable for everyone, regardless of AQI level, to stay informed about local air quality conditions and take appropriate precautions when necessary. This may include minimizing outdoor activities during peak pollution hours, ensuring adequate ventilation indoors, and using air purifiers if available. Regular monitoring of air quality updates and following any health advisories issued by relevant authorities can help individuals make informed decisions to safeguard their well-being amidst changing environmental conditions.

Table 6

Ranking of Cities based on Average AQI : year-2022

City	AQI	Rank
Khargone	51.9	1
Satna	54.4	2
Maihar	58.5	3
Anuppur	58.9	4
Damoh	62.7	5
Rewa*	64.5	6
Narsinghpur	86.1	7
Ratlam	95.5	8
Dewas*	99.9	9
Mandideep	108.9	10
Pithampur	110.3	11
Indore	112.9	12

Source: - Air quality Statistics 2022 MP pollution control board Bhopal

6. CONCLUSION

The analysis of air pollution in Satna, Madhya Pradesh, highlights the pressing need for immediate action to address this critical issue. The findings underscore the detrimental effects of air pollution on both public health and the environment, necessitating concerted efforts from various stakeholders.

Satna city is a traditional city, along with the industrial hub, there is also a big cement factory which is harming the environment in some way or the other. The IQ level of Satna and its surrounding urban areas is increasing day by day, if we do not take steps to reduce air pollution then it is certain that a serious problem of air pollution will arise, which will affect people's health. But it will happen.

Health Impacts: The high levels of air pollutants, including particulate matter, sulphur dioxide, nitrogen dioxide, and volatile organic compounds, pose significant health risks to the residents of Satna. The documented increase in respiratory diseases, cardiovascular ailments, and related health issues emphasizes the urgency of mitigating air pollution to safeguard public health.

Environmental Degradation: Beyond its impact on human health, air pollution contributes to environmental degradation in Satna. Pollution from various sources contaminates the air, soil, and water, threatening biodiversity and ecosystem stability. Additionally, the emission of greenhouse gases exacerbates climate change, further endangering the environment and human well-being.

Economic Consequences: The economic ramifications of air pollution are substantial, affecting both individuals and the broader economy of Satna. The burden of healthcare costs associated with pollution-related illnesses weighs heavily on households and healthcare systems, while decreased agricultural productivity and tourism potential hinder economic growth and development.

Policy and Regulatory Measures: Addressing air pollution in Satna requires a multi-pronged approach involving stringent regulations, effective enforcement mechanisms, and proactive policy interventions. Government authorities must prioritize the implementation of emission standards, promote the adoption of clean technologies, and invest in sustainable urban planning to mitigate pollution levels.

Community Involvement: Engaging the local community is vital in combating air pollution effectively. Public awareness campaigns, educational initiatives, and citizen participation can foster a sense of responsibility and promote collective action towards reducing emissions, adopting sustainable practices, and advocating for cleaner air.

In conclusion, addressing the impact of air pollution in Satna demands collaborative efforts from government agencies, industries, civil society organizations, and individuals. By implementing comprehensive strategies to curb pollution levels, protect public health, and preserve the environment, Satna can aspire to achieve a healthier and more sustainable future for its residents.

CONFLICT OF INTERESTS

None.

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