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Impact of Urbanization on Air Quality in Sonbhadra District: Source, Trend and Health Implications

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Abstract
Sonbhadra District, which has been dubbed the "energy capital" of Uttar Pradesh, is experiencing a rapid decline based in air quality as a result of fast urbanization & coal-based industrialization. The study primarily focuses on the pollution sources and thermal power plants (Obra, Anpara) responsible for PM10, SO2, and NOx emissions released through fly ash, to mention dust from mining operations and vehicles as well. It forecasts the patterns till 2024 and points out PM10/PM2.5 (e.g., 104 µg/m³ at Robertsganj) as the leading pollutant, a persistent "Poor" AQI, and summer months as the most affected period. The health impacts consist of a 55-60% occurrence of respiratory problems, 60-66% cases of eye irritation, and the risks linked to PTEs (Hg, As) and fluorosis for those living near industrial areas. The adoption of control measures such as the regulation of fly ash disposal, the extension of monitoring, and the use of renewable energy is crucial. Comprehensive urban planning can counteract the upward trend, thus safeguarding public health during the development process.
Keywords: *Urbanization, Air Quality, Thermal Plants, PM2.5, Health Risks*

I. Introduction

Sonbhadra District, covering 6,905 square kilometers in the southeastern region of Uttar Pradesh, India, illustrates the intricate relationship between fast urbanization, industrial growth, and environmental deterioration. Situated at the base of the Vindhya Range and next to Madhya Pradesh and Chhattisgarh, this mineral-abundant area—frequently referred to as the "energy capital of India"—has experienced significant transformation since the post-independence period [1]. The environment, characterized by deep woods, rivers such as the Son and Rihand, and extensive coal reserves, previously sustained a primarily agrarian and tribal populace. Strategic industrial investments have prompted demographic changes, transforming rural areas into semi-urban industrial centers. This introduction outlines the district's urbanization path, highlighting its inseparable connection to the decline in air quality due to emissions from thermal power plants [2].

Census statistics have revealed a certain noticeable population growth, which is one of the reasons for the increase nature of in the pace of urbanization. In 2001, Sonbhadra had around 1.46 million living people, with a literacy rate of about 55%, and a rural-urban ratio of almost 85:15 [3]. This number, by the next census in 2011, was already 1.862 million, showing the growth rate for the decade at 27.27%, which was higher than the average for Uttar Pradesh of 20.2%. Places like Robertsganj (district headquarters), Renukoot, and Obra were the ones that received the prime share of this growth, attracting migrant workers from Bihar, Jharkhand, and even nearby states. The National Commission on Population trends and state urban development plans have predicted that by 2024 the population might even reach 2.4 million, thanks to the availability of industrial employment. This is visible in the land use changes too: remote sensing data from NRSC, for instance, shows a 15-20% increase in built-up areas between 2000 and 2020, encroaching upon forests and agricultural fields. The urbanization rate, which was 16.88% in 2011, is now expected to go beyond 25% by 2024, due to the uncontrolled suburban growth around industrial corridors that are causing the influx of people [4].

The urbanization process is mainly attributed to the development of thermal power stations using coal as the primary fuel, which led to the positioning of Sonbhadra within the Indian Singrauli-Sonbhadra energy cluster, one of the world's largest energy hubs. Key power plants amongst others are the NTPC Rihand Super Thermal Power Station which has a capacity of 3,000 MW, NTPC Anpara with 2,630 MW, Obra thermal plant with 1,000 MW, and Anpara B with 1,500 MW along with the captive plants meant for aluminum smelters like Hindalco situated in Renukoot. The aforementioned plants have been operational since the 1970s and as a result, they generate a huge amount of fly ash which is estimated to be around 10-12 million tons per year for the entire district of Sonbhadra due to the burning of coal. Fly ash which has PM10 and PM2.5 as its components gets released from the power plants and covers the nearby areas. Satellite measurements such as TROPOMI have detected NOx hotspots that are specifically aligned with the power plants' emissions and this in turn, creates more photochemical haze. Urbanization adds to the problem; the growing traffic jams on NH-39 and the roads leading to industries cause an increase in the emission of hydrocarbons and carbon monoxide while the activities of stone crushers and coal mining (e.g., Northern Coalfields Ltd.) contribute to the dust in the atmosphere. Studies link this situation with increased AQI levels, and in most cases, they exceed the NAAQS limits, and PM2.5 levels are 2-3 times the national average during the winter months.

The dynamic between the arrival of people and the emissions from industries shows a negative loop: the process of urbanization increases the number of workers near the sources of pollution and this way the exposure is kept. This forms the base for discussing specific pollution sources, their trends, and health impacts in the following sections. To tackle this relationship further, it is necessary to have unified overall policy measures that bring together urban planning and emission controls process to ensure good air quality in Sonbhadra while working towards its development objectives.

1. Urbanization Overview

The urbanization of Sonbhadra District is a clear indication that the area which was once covered with forests and inhabited by tribes has quickly turned into an industrial center due to the progress made in the energy sector. The study looks into the populationbooms, changes in location, and the factors of growth, drawing attention to their role in air pollution through increased emissions and land alterations [5].

2. Population Density and Urban Share

Sonbhadra is a district that occupies an area of 6,905 km². Its population density has been rising from 212 people per km² in the year 2001 to nearly 270 per km² by the year 2011 which signifies increased human occupancy. The Census 2011 data has been the basis for this remark. It is, at the same time, pointing out the uneven distribution: on the one hand, the rural blocks like Dudhi and Robertsganj are indeed having lower densities of 150-200/km², and on the other hand, the urban-industrial regions are already over one thousand per km². In the year 2011, urban population accounted for 16.88% of the total population, mainly residing in statutory towns like Robertsganj (district headquarters, population of about 40,000), Renukoot (approximately 50,000), Obra (around 40,000), and Shakti Nagar [6]. These hubs which are situated around thermal power plants draw the workforce consisting of skilled and unskilled labor from Bihar, Jharkhand, and eastern Uttar Pradesh. According to the 2024 census forecast, urban population will account for about 25-30%, largely due to peri-urban sprawl and industrial township development. The increase in population density is making the air pollution problem worse: higher population areas have more PM2.5 exposure as the residential areas get closer to the smoke coming out from the nearby industries. Medical surveys conducted in the area indicate that the places with the highest population density have a 20-30% increase in respiratory problems and that the people living in those areas are more likely to inhale pollutants than others.

Industrial Migration and Built-Up Expansion

NRSC's satellite assessments propose that the shift of industries has transformed Sonbhadra, which resulted in the increased built-up areas by 15-25% during the period of 2000-2020, and this is quite similar to the urban sprawling of Dehradun. So, the people migrating here to the mines of Northern Coalfields Limited and electricity-generating plants would eventually be around 100. The majorities of these new residents have ended up forming small settlements around NTPC Rihand, Anpara, and Hindalco. Along with the people, the housing, roadways and NH-39 logistic hubs for workers came "at the cost" of converting 5-7% of the forest/agriculture area into urban space, particularly [7]. Bumping up by 2-4°C, the surface temp of the areas showed the same pattern as that of Dehradun urbanization-induced increasing temp zones which were trapping pollutants and thus elevating ozone at ground level. With the rise of dust resuspension and vehicle emissions, a 10% rise in non-permeable surfaces would correspondingly cause a 15-20% increase in PM10. The Robertsganj-Renukoot corridor has been highlighted as one of the main areas of growth where the industrial routes, as indicated by remote sensing data, separate the green cover and reduce the pollution sinks, such as forests. This situation worsens the mining-related emissions, both directly and indirectly, via coal dust (2-3 million tons/year) and stack emissions; hence, the ambient air quality remains poor (AQI in 100-200 range) continuously.

Decadal Growth from Census Data

Census in the year 2011 has reported a remarkable population growth of 27.27%, that is, the population increased by more than 4,00,000 people from 2001 to 2011 mainly due to the mining and power incidents. The total number of people went up from 1.460 million in 2001 to 1.862 million in 2011, out of which 22% were Scheduled Tribes and the incoming of migrants had a direct impact on ten thermal power stations with a total capacity of about 10,000 MW. The change in Robertsganj tehsil was 35%, and among the reasons were the improvements in the administration and the services related to energy projects. The trends for the period after 2011 based on NFHS-5 and state statistics indicate a yearly population growth of 2-2.5% that might reach 2.4 million by the year 2024. The UDAN and industrial corridors are among the initiatives behind this growth. On the other hand, the annual mining output is more than 50 million tons of coal and the power sector alone is contributing over 50,000 jobs directly and thus supporting the population increase, but the rough and smoky roads are also their by-products, as the urbanized areas are experiencing 30-50% higher NOx and PM levels than rural baselines [8].

The same situation is observed in Singrauli, a neighboring district, through comparative studies, and thus the tokes of the expansion are characterized by sectoral booms resulting in 2-3 times the national AQI exceedances. This growth poses a threat to air quality, as larger laborpopulations consume more energy, thus, the cycles of emissions and health-related issues, such as asthma (prevalence of 12-15% in industrial areas), continue to be active.

In the case of Sonbhadra, the rate of urbanization is closely linked to the demographic dynamism and the environmental crisis, which also lays the groundwork for the forthcoming sections that will discuss pollution sources.

3. Pollution Sources

In Sonbhadra District, the major source of air pollution is its energy-centered industrialization and, in this regard, coal-dependency is the main culprit of emission being urbanization. This segment investigates the sources which are major, secondary, and specific to hotspots, through the monitoring data of 2024 in order to reveal their shares in PM10, PM2.5, SO2, NOx, and heavy metals, which often surpass NAAQS limits [9].

Principal Sources: Coal-Fired Thermal Power Stations

The pollution profile of Sonbhadra is mainly marked by coal-fired thermal power plants which disperse heavy PM10, SO2, NOx, and mercury into the environment through burning and fugitive emissions. The main plants consist of the Obra Thermal Power Station (1,000 MW), Anpara A/B (4,130 MW combined), NTPC Rihand (3,000 MW), and NTPC Singrauli (2,000 MW next to it) that together consume an annual amount of coal of about 50 million tons and cause about 10-12 million tons of fly ash to be produced as a result. The emissions from the chimney create PM10/PM2.5 of 50-100 µg/m³ being spread downwind while the sulfur dioxide released (200-500 kg/MWh) and nitrogen oxides produced (400-600 kg/MWh) can be regarded as the main factors leading to acid rain and smog [10]. Mercury, which is being liberated from high-sulfur coal (0.1-0.3 ppm), is getting trapped by wet scavenge and, thus, the soil contamination of 0.5-2 mg/kg around Rihand is taking place due to accumulation. Fly ash, the main fugitive source, is being released from unlined ponds and open storage like Obra's 3-million-ton ash pond which is giving rise to the emission of the respirable silica-laden particles during monsoons, increasing the ambient PM2.5 levels by 30-50 µg/m³ within 10 km distance.

The CPCB's 2023 National Ambient Air Quality Status Report indicates the presence of sulfur dioxide (15-25 µg/m³ annual averages) at the Robertsganj station as a direct consequence of the insufficient application of scrubbers, with only 20% of the FGD being modernized by 2024. Regulatory scrutiny after 2020 decreased the SO2 emissions by 15-20% at the plants that complied like Anpara B; though, the issue of particulate matter and nitrogen oxides still continues, as the SAMEER reports for 2024 indicate that there has been 40-60% noncompliance with NAAQS during the winter inversions.

Secondary Sources: Mining Dust, Stone Crushing Operations, Automotive Emissions

The urbanizing corridors of thermal power plants are mainly affected by secondary anthropogenic sources such as mining dust, stone crushers, and automobile emissions. Norther Coalfields Limited (NCL) extracts around 50 to 60 million tons of coal from the Dudhi and Singrauli coalfields each year, thus producing 2 to 3 million tons of fugitive dust from overburden disposal and transport roads. PM10 emissions due to blasting and crushing could range between 200 and 500 µg/m³ at the source, spreading a distance of 20 to 50 km under the influence of wind. More than 500 stone crushers along NH-39 and beside Rihand River take care of quartzite with the releasing of crystalline silica (10-20% of total suspended particulate matter), while 1–2 million tons of dust loading annually indicated by 2022 UPPCB inventories are formed on account of these activities in the region [11].

Emissions from vehicles in areas like Renukoot and Robertsganj, which are expanding metropolitan regions, are very high, where NH-39/135BG has over 50,000 heavy trucks and 100,000 two-wheelers that emit hydrocarbons, carbon monoxide, and black carbon; the transition to a BS-IV fleet by 2024 has led to a 25% reduction in carbon monoxide, but the size of the particulate matter resulting from tire and road wear is still 15-30 µg/m³. The various sources have a mutually beneficial relationship: mining trucks blow dust off the ash-covered roads, while crushers cause TSPM levels in summer to rise to 300 µg/m³. One of the main contributors to urban expansion—i.e. 20% increase in built-up areas from 2015 to 2024, has caused a further increase in the tram density coinciding with AQI jumps of 15%-25% as echoed in UPPCB's 2024 real-time data. The biomass burnt in over 200 brick kilns is responsible for the rise of organic and elemental carbon, of which organic particulate matter constitutes 30%-40% of the total emissions.

NOx Hotspots from Coal Clusters: TROPOMI Data from 2018 to 2024

Satellite data from TROPOMI (Sentinel-5P) shows the presence of large amounts of NOx emissions in the coal mining area of Sonbhadra-Singrauli that will last until the year 2024 with tropospheric columns exceeding the range of 10-15 × 10^15 molecules/cm². The Rihand-Anpara baseline, set for 2018-2019, marked the location as the largest NOx emitter in Asia, with an annual release of 500-700 Gg of NOx that was due to unwatered coal stacks and very low stack heights of about 150-200 meters. The longitudinal trends have shown a decrease in emissions of about 5-10% due to FGD/SCR pilots, which were carried out in 2021; nevertheless, the predictions for 2023-2024 show winter peaks of 20-30 x 10^15 as a result of the increased generation capacity of 15,000 MW. A spatial study has pointed out the area of Obra-Renukoot as another hotspot (with 8-12 × 10^15) where the urban NOx emissions from diesel generators and traffic are happening together with the industrial plumes thus facilitating the O3 generation which is at 50-80 ppb during the day [12].

The comparison of data from the years 2020 to 2024 shows that per-MW NOx emissions of Sonbhadra are 2-3 times higher than those of Delhi and Mumbai due to the low-efficiency operation of its plants (32-35%). Ground validation using CPCB/ARAI monitors reports surface NOx levels of 25-45 µg/m³ (averages for 2024), which are higher than the annual limit of 40 µg/m³. The NOx hotspots in the area contribute to the formation of regional haze; moreover, the transfer of the vole downwind extends to Varanasi (100 km east) and during this period of westerly winds, PM2.5 levels get a 10-20% increase.

4. Air Quality Trends

Air quality trends in Sonbhadra show that the problem with the dominance of particulate matter resulting from industrial discharges is still very much present. This can be proved by the data coming from CPCB, UPPCB, and satellite monitors up to the year 2024, which has revealed that there were constant exceedances with the exception of brief improvements [13]. This method links together the data from various sources (e.g. station records, bulletins, and forecasts) and compares the patterns of the data over time with urbanization and seasonal influences.

Prevalence of PM10 Over NO2/SO2; Recurring "Poor" Air Quality Index

Research consistently names pm10 as the major polluter in Sonbhadra, with its concentrations surpassing those of no2 and so2, and consequently the AQI ratings usually falling within the ranges of "Poor" (101-200) to "Very Poor" (201-300) based on the 2024 research. The ground-level assessments, which include studies performed by UPPCB and CPCB, show annual PM10 mean values of 120 to 180 µg/m³ (which is 2-3 times the NAAQS of 60 µg/m³) due to fly ash and dust, but in the case of nitrogen dioxide the levels vary from 15 to 30 µg/m³ (below the 40 µg/m³ limit) and for sulfur dioxide from 10 to 20 µg/m³ as a consequence of FGD retrofits. To illustrate, the statistics collected by the MoEF in 2024 and real-time systems show that the PM10: PM2.5: NO2 ratios are around 3:2:1, where PM10 accounts for 70-80% of days with the poor air quality index (AQI) [14].

The AQI episodes hit the highest point in the winter of 2024 when the level of 198 (Unhealthy) at the Sonbhadra stations was with PM10 and 180µg/ m³, thus bringing about a stark contrast with significantly lowered levels of gaseous pollutants. Similar clusters such as Singrauli validate this ranking by declaring that the fugitive sources are mostly to blame for PM in the light of the 25% urban growth. According to AirPollution.io's forecasts for 2024, the poor ratings (AQI 150-250) will continue, and these point out the benefits of thermal-mining synergy over point-source emissions.

CPCB Stations: PM2.5 concentration around 104 µg/m³; Historical increase associated with urbanization

The Robertsganj monitoring site of the Central Pollution Control Board (CPCB) is showing extremely high PM2.5 levels that are unhealthy, estimating around 104 µg/m³ as the annual average (2020-2024), which is over 20 times the recommended limit by WHO and more than India's intermediate target of 40 µg/m³, with the historical upwards trend reflecting the urbanization process. The continuous tracking done since 2018 points to an increase of 20-30% during the decade: the initial levels of about 70-80 µg/m³ in 2019-2020 went up to 100-120µg/m³ by 2023-2024, which is in line with a 15% growth in urbanization and an increase in coal handling to 55 million tons per year. The high concentrations recorded over 24 hours reached 177-208 µg/m³ (e.g., 2024 winter inversions), classifying as Unhealthy (AQI 150-200) [14].

The distribution of air quality shows that the industry is affecting the air quality in the surrounding areas: the monitoring stations close to Rihand/Anpara have 1.5-2 times higher Pm2.5 levels compared to rural areas, which in turn is related to the urban growth caused by migrants. The analysis of data from CPCB NAAQS reports shows that land-use changes (for example, loss of forests by 5-7%) were responsible for 40% of the increase, which leads to more resuspension of dust. In 2024, the annual averages during the monsoon months were around 90-110 µg/m³ but they peaked 2-3 times higher during the dry season, pointing to a long-term problem in case of no green belts established around the city.

Bulletins from 2015 to 2023: Escalating Particulate Alerts and Summer Peaks

The bulletins published by CPCB and UPPCB, which cover the period from 2015 to 2023, show an upward trend in particulate alarms, especially in the summer months (March to June) when wind was weak and open burning took place. The initial reports covering the years 2015-2018 showed that there were annually about 50-100 exceedance days for PM10 (mean 140 µg/m³), which then increased to 120-150 days in 2020-2023 due to additional emissions from the COVID recovery [15].

During the summer season of 2022-2023, the PM2.5 alerts were in the range of 150 to 250 µg/m³ (AQI 200-400), which was mainly due to the mining dust and improper ash management in temperatures over 40°C. Reports from the National AQMS point to a 25% rise in the number of days with moderate to severe pollution (AQI > 100) and this situation continued through May and June when PM10 levels reached around 200-300 µg/m³ because of natural crustal resuspension. Bulletins associated this with urbanization: the industrial expansion after 2015, like that of Anpara, quintupled summer TSPM. The 2023 summaries revealed that project management was responsible for 60% of the alarms, and hence it was necessary to enforce the controls.

Current Trends: AQI 40-61 indicates Good to Moderate levels, with occasional seasonal unhealthy surges

The year 2023-2024 showed that there was a bimodal pattern in the AQI which was from good to moderate (40-61) during the whole monsoon season (July-October, PM2.5 levels of 7-20 µg/m³ and a January 2026 proxy at 7.1 µg/m³) and at the same time there were seasonal peaks of very high (150-200+) levels of pollution during winter and summer. The real-time data (January 2026: AQI 40 Good, PM10 10 µg/m³) masked the peaks, for example, that of December 2024's 198 (PM2.5 177 µg/m³), which had 30-40 days of spikes annually. The predictions point to extremes of 208 µg/m³, as well as a 10-15% drop in gaseous pollutants due to the new regulations [16]. The urban factors of instability are caused by traffic and dust which lead to higher pollution levels during the off-season.

5. Health Implications

Respiratory Disorders, Ocular Irritation, and Pulmonary Incidence

In Sonbhadra, respiratory disorders are the main health issues affecting 55-60% of the people surveyed, with 60-66% suffering from ocular irritation and an increasing number of pulmonary diseases, especially among the occupationally exposed groups like traders, who deal with the hazards of inhaling smoke and dust. The prevalence of chronic bronchitis, asthma, and COPD in such industrial areas as Renukoot and Obra is reported through community-based studies as being 25-35%, which is 2-3 times the averages in Uttar Pradesh, mainly because of the long-term exposure to PM2.5/PM10 (annual means of 100-150 µg/m³) [17].

Over the 2018-2023 period, cross-sectional studies of more than 5,000 individuals have revealed a link between the exposure and the effects: the spatial relationship to thermal power plants comes with an increase of 40-50% in the odds ratios for wheezing and shortness of breath. Conjunctivitis and keratitis, which are part of the ocular irritation, are caused by alkaline fly ash droplets and SO2 damaging the tear glands, and coincide with the driest times of the year when the AQI is above 200, at which point ocular problems are at their worst. Merchants in the Robertsganj markets and those who work in dusty bazaars next to the NH-39 experience lung-related symptoms in 70-80% of cases and relate this to the 8-10 hours of daily exposure, while the rural controls show only 20-30% prevalence. Pulmonary function tests show a decline of 15-25% in FVC/FEV1 in people aged above 40, which parallels the development of silicosis due to exposure to mining dust.

Potentially Toxic Elements in Dust/Soil: Carcinogenic and Non-Carcinogenic Risks

The PTEs (Potentially Toxic Elements) like mercury (Hg) and arsenic (As), along with fly ash, dust, and soils, inhalation, ingestion, and cutaneous contact, cause considerable cancer and non-cancer risks plus hazard indices exceed acceptable limits in 60-70% of samples from industrial zones. The soil tests near Rihand and Anpara reveal mercury (1.2-5.5 mg/kg, 10-50 times of the background) and arsenic (15-45 mg/kg) levels which are coming from coal combustion residues that are already polluting plants and drinking water [18].

Airborne kingpins for PM2.5-bound PTEs: lifetime cancer risks (LCR) for Hg are up to 1.2 × 10^ {-4} next to ash ponds—outstripping the EPA's benchmark of 10^ {-6}—whereas as inhalation leads to 5-8 × 10^ {-5} risks, dependent on deposition rates during inversions. Non-cancerous (HI >1) conditions arise from long-term consumption of arsenic-tainted rice (0.5-2 mg/kg in irrigated areas), which impairs neurodevelopment and causes skin problems. Multimedia simulations suggest that 20-30% of the near population exceeds the harmless weekly intake limit for mercury (1.6 µg/kg body weight), linked with bioaccumulation in the fish from Rihand reservoir that increase the dietary exposure. Accretion of the city brings about risks: dust from construction activities will add 25-40% to the total particulate matter emissions and the impact will be higher on low-income people in informal settlements without any protective measures.

Fluorosis and Mercury Toxicity Adjacent to Flora; Skeletal Disorders in Communities

Coal-fired power plants are the major source of fluorosis and mercury poisoning due to the emissions, and it has been reported that the villages in the vicinity suffer from both skeletal and neurological abnormalities. The coal with a high fluoride content of 50-200 mg/kg releases fluoride into the atmosphere through volatilization at the rate of 5-15 $\mu g/m^3$, which subsequently gets deposited in tubers and tooth enamel; hence dental fluorosis develops with a high prevalence rate of 70-85% in children from the area of Obra/Renukoot and 25-40% in adults above 30 years of age suffering through skeletal fluorosis [19].

Endemic skeletal fluorosis shows genu valgum, kyphosis, and ligament calcification, and there are radiography studies that could support the same with the indication of 30-50% of abnormal bone density within 5 kilometres of the emission stacks. Those living in the vicinity of coal plants are affected by mercury toxicity through the vapor and methylation forms, so the population in 15-25% of the nearby villages exhibits tremors, cognitive impairments, and proteinuria, while the concentration of mercury in hair samples from Shakti Nagar (5-20 ppm) is higher than the WHO recommendation of 1 ppm and is related to prenatal neurotoxicity (IQ reductions of 5-10 points) [20].

The villages of Belwa and Pipri, which are located next to the breaches in the ash dykes, report that around 40% of the orthopedic appointments for "joint pains" are due to the F/Hg synergy. The longitudinal cohorts (2015-2024) reveal that the hospitalization rates for renal and osseous diseases are 2-3 times higher than for non-exposed tehsils, thus emphasizing the 10-20 km reach of the emission plumes.

6. Mitigation Strategies

Enforcement of Fly Ash Utilization

By the Ministry of Environment, Forest and Climate Change Company (MoEFCC) issued in 2021 changed the 2009 Fly Ash Rules among which one of the main notices is the complete utilization of fly ash at the thermal Power Plants (including Rihand and Anpara) by the production of bricks, cement, and the road base materials from ponded ash. Such measures led to compliance rates going up from 65% in 2019 to around 85-90% in 2024 through the use of both fines and incentives, and concurrently led to the reduction of about 30-40% in PM emissions coming from fugitive sources within the area around the Obra ash dykes. The district administrations conduct audits every three months, reclaiming 2 to 3 million tons a year for infrastructure, and thus, lessening soil pollution and immersion of particulates in the air.

Expansion of CPCB Monitoring

In 2024 the CPCB/UPPCB networks will cover more than 10 real-time stations (like Renukoot and Dudhi) instead of the initial 3 which will make it possible to conduct very detailed monitoring of air quality index (AQI) and activate alarms at the time of the sudden increase of PM. The use of satellites (TROPOMI and SNAP-4) not only provides the ground-based data but also helps the ground-based stations in locating the hot spots for focused inspections. The strengthening of the functionality of more than 50 local monitors will ensure the compliance with National ambient air quality standards and this will be translated into a 20% cut in exceedance days as a result of enforcement based on data.

Promotion of Renewable Energy

The conversion of 20-30% (e.g. 500 MW NTPC Rihand hybrid) of the 10 GW coal capacity in Sonbhadra to solar and wind by 2030 will lead to a drop of 50% in NOx/SO2 emissions. The establishment of green corridors around the Rihand reservoir which are taking advantage of 5.5 kWh/m^2 of sunshine will create 5,000 job opportunities and will be replacing 5 million tons of coal per year. The market-based incentives like SECI auctions will help in the faster adoption of such technologies, thereby supporting the development of eco-friendly urban areas.

II. Conclusion

The ongoing problem of air quality in Sonbhadra District, primarily being a result of urbanization and coal-dependent industrialization, is expected to get worse and to contribute to the increase of PM levels, hazardous air exposure, and a variety of respiratory and pulmonary health issues by the year 2024. The persistence of "Poor" AQI trends and PTE hazards necessitates an immediate and collaborative urban planning that will incorporate use of fly ash, enhancement of real-time monitoring, and renewable energy fast-tracking which will in turn lead to cutting off emission cycles. Without the kind of integrated policies that enforce restrictions on expansion while at the same time, offering environmental protection, health and nature would be at loss and the development of the district would be impeded. However, government cooperation at different levels can make it possible to restore air quality that is good for sustainability.

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