A Study and Analysis of Ambient Air Quality Monitoring and Controlling for Nagpur

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Abstract**—** An effort is made in this study to determine the Nagpur Zone's ambient air quality. The current study project primarily considers two pollution criteria: respirable suspended particulate matter and suspended particulate matter. The selection was conducted at nine monitoring locations, three for each residential, business, and industrial zone in the Nagpur region, throughout the winter months of December and January and the summer months of March and April. Each monitoring location has a 24-hour sampling period. The average RSPM concentration in residential, commercial, and industrial locations over the winter and summer seasons did not above the NAAQS requirements, according to analytical data.

. Taking into account the average RSPM concentrations for all three sites once again, it was discovered that the residential area falls within the excellent category (AQI) for both the winter and summer seasons, ranging between 0 and 50 µg/m3, whereas the commercial area comes under the industrial area is classified as being in the excellent category during the summer and the moderate category during the winter, with variations between 51-100 µg/m3. However, summertime Particulate Matter concentrations are lower than wintertime Particulate Matter concentrations because of strong wind speeds that dilute airborne contaminants.

Keywords**—** Air Quality Index, SPM, RSPM, and National Ambient Air Quality

I. Introduction

Most metropolitan locations have complicated air quality issues because of fugitive and line emissions, among other source contributions. A country's economic status deteriorates when air pollution causes long-term productivity decreases. As a result, cutting air pollution is crucial to sustainable development since it enhances our quality of life, protects the environment, and reduces the risk of sickness. There are several sources of anthropogenic air pollution emissions, including construction, farming, burning of garbage, moving sources, and commercial establishments. Every day, the sources and the emissions get more and more convoluted. India's ambient air monitoring program has provided guidance to policy makers; nonetheless, the issue is complicated by QA/QC shortcomings in data collection, interpretation, and general monitoring. In order to address the issue of air pollution nationwide in a comprehensive way, the Central Government launched the National Clean Air Programme (NCAP), a long-term, time-bound national strategy with targets to achieve 20% to 30% reduction in Particulate Matter concentrations by 2024, using 2017 as the base year for concentration comparisons. Based on the Air Quality data from 2014–2018, 122 non-attainment cities have been identified nationwide under NCAP. The Government of Maharashtra (GoM) and the Maharashtra Pollution Control Board (MPCB) want research on source allocation and emission inventories for all of the state's non-attainment towns. Action plans tailored to each city are required to reduce air pollution. These plans should address a variety of issues, such as raising public awareness, reducing industry and automobile emissions, and fortifying the monitoring system. The responsibility for regularly supervising the execution of the city-specific action plans will fall to committees at the Central and State levels, namely the Steering Committee, Monitoring Committee, and Implementation Committee.

Objectives • Measuring baseline particle matter pollution in various city locations, such as hotspots and kerb sites.

• A list of every kind of emission coming from the city.

• To carry out a particulate matter source apportionment study.
• An action plan for reducing air pollution

II. NEED OF THE STUDY

The current study looks at the sources' contribution to aerosol mass, which is crucial for creating strategies that effectively manage issues related to aerosols. In addition to PM, an inventory of additional contaminants and their sources is required to determine the site of production. When formulating strategy and initiating an action plan, every implementing body should take pollutants of all origins into full consideration. Source complexity and its effect on receptors are related to factors including strength, temperature, atmospheric changes, height of release, and meteorology. It is necessary to develop strategies for sector-specific pollution based on solid and convincing scientific data. Numerous methodologies, including emission inventory, dispersion modeling, receptor modeling, and cost-effectiveness analysis of various choices, can be used to extract these data.

III. LITERATURE REVIEW

According to S.TikheShruti et al. (2013), Two soft computing algorithms, Artificial Neural Network (ANN) and Genetic Programming (GP), were used by Pune, Maharashtra, which is ranked second on the list of polluted cities in India, to predict future concentration levels of air pollutants, such as oxides of sulfur (SOx), oxides of nitrogen (NOx), and respirable suspended particulate matter (RSPM), over the period of 2005 to 2011. Using hourly average data values of the concentration of pollutants over more than seven years, they have developed a total of six models, three for each of the ANN and GP algorithms. The GP approach outperforms the ANN algorithm between these two methods.

According to Archontoula Chaloulakou et al. (2003), the study used multiple linear regression (MLR) and artificial neural network (ANN) methods to anticipate the PM10 concentration for the Greek city of Athens over a two-year period. "The dataset is divided into three unequal subsets before applying input to ANN; two thirds of the available records or cases are in the training dataset, and the remaining cases are equally divided into the validation and test sets." This study also included a comparison between ANN and MLR, which shows that ANN performs better than MLR. This study suggests that, when correctly trained, artificial neural networks (ANNs) may provide acceptable prediction solutions or outcomes as needed.

According to Yusef Omi-Khaniabadi et al. (2016), the main objective of this study is to ascertain the association or connection between health consequences, such as the mortality rate from cardiovascular diseases over the years 2014 and 2015 for Kermanshah, Iran, and air pollutants, such as PM10, NO2, and O3. They used the AirQ program, which was suggested by the WHO, for this. 188 premature deaths from cardiovascular disease have been connected to PM10, 33 to NO2, and 83 to O3.The results of the study indicate that for every 10µ/m3 increase in PM10, NO2, and O3 concentration levels, the mortality risk would increase by 1.066, 1.012, and 1.020, respectively.

According to R. Gunasekaran et al. (2012), This study's main objective is to monitor the air quality at Salem Swadeswari College in Tamil Nadu between April 2011 and March 2011. Because the yearly average concentrations of pollutants including sulfur dioxide, nitrogen oxides, and suspended particle matter are within the range of national regulations, it has been shown that there are no severe pollution concerns in this area. The annual average concentration of pollutant PM10, however, is a little higher than the national standard limits. The same year's monthly 24-hour average PM10 concentration was higher above the national standard level, with the exception of July through October.

HeidarMaleki (et al.2019) forecasted the hourly concentration values for the ambient air pollutants NO2, SO2, PM10, PM2.5, CO, and O3 for the stations in Ahvaz, Iran (the world's most polluted city), Behdasht, Havashenasi, and MohiteZist. For the four air quality monitoring sites in Ahvaz listed above, they have also calculated and estimated the Air Quality Health Index (AQHI) and Air Quality Index (AQI). For the period of August 2009 to August 2010, they employed an Artificial Neural Network (ANN) machine learning method to forecast the hourly concentration of air pollutants and the two air quality indices, AQI and AQHI. Factors including air pollution concentration, time, date, and meteorological information are input into ANN algorithms.

AMBIENT AIR QUALITY

Continuous Ambient Air Quality Monitoring Station (CAAQMS) At GPO Civil Lines in Nagpur, MPCB runs a Continuous Ambient Air Quality Monitoring Station (CAAQMS). At various sample frequency, a number of metrics, including PM10, PM2.5, SO2, NO2, Ozone (O3), CO, Benzene, Ethyl Benzene, m, p-Xylene, and Toluene, are being monitored. Figure shows the 24 hourly AAQ for each of these metrics for a particular month. It is evident that for every parameter, the percentage of missing data ranges from 0% to 20%. The percentage of exceedances for PM2.5 and benzene concentration is also found to be high, followed by NO2 and PM10 concentrations.

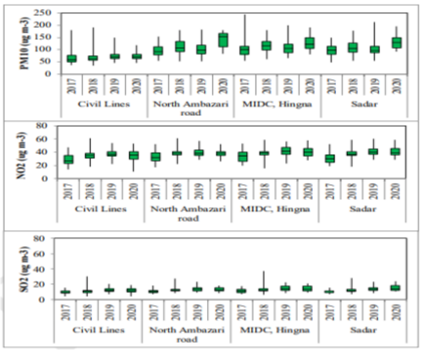

Figure : SO2, NO2 and PM10 Concentration During 2017-2020 (till March) at Few Locations in Nagpur (Data Source: www.mpcb.gov.in)

Table : Statistical Summary of CAAQMS Data at Civil Lines, Nagpur

Parameter	Average ± SD	95th Percentile	Max	Missing values(%)	% of Exceedances	CPCB Standard
PM$_{10}$ (□g/m^3)	68.8 ± 28.3	121.8	161.5	6.4	56.4	60
PM$_{2.5}$ (□g/m^3)	35.0 ± 17.5	68.2	95.9	5.8	35.5	40
NO$_2$ (□g/m^3)	43.5 ± 19.2	68.0	220.6	20	56.7	40
SO$_2$ (□g/m^3)	7.4 ± 8.0	22.2	56.7	5.5	0.3	50
CO (□g/m^3)	741.6 ± 43.0	1460.0	2710.0	0	0.8	2000*
NH$_3$ (□g/m^3)	24.7 ± 11.0	43.9	83.0	20	--	100
O$_3$ (□g/m^3)	37.2 ± 43.6	136.1	180.4	11.2	14.9	100*
Benzene (□g/m^3)	4.4 ±2.9	10.1	16.1	5.8	32.1	5
Ethyl Benzene (□g/m^3)	3.7 ± 4.1	11.8	24.1	10.9	--	--
m, p-Xylene (□g/m^3)	5.1 ± 5.8	15.6	32.2	17.4	--	--
Toluene (□g/m^3)	10.2 ± 7.2	23.6	38.6	5.8	--	--

The concentrations of PM10 and PM2.5 are found to be lower during the monsoon months and greater from November to February. Except for September, when NH3 concentrations are seen to be rather high, SO2 and NH3 concentrations are found to be lower throughout the monsoon months. While NO2 concentration is found to be greater in October through April, NO concentration is found to be higher in November through January. As might be predicted, April and May, when there is often strong solar insolation, see increased ozone concentrations. The content of CO is greater from October to May, whereas that of benzene and ethylbenzene is higher from November to January. From April to March, a declining monthly trend in m, p, Xylene, and Toluene was seen.

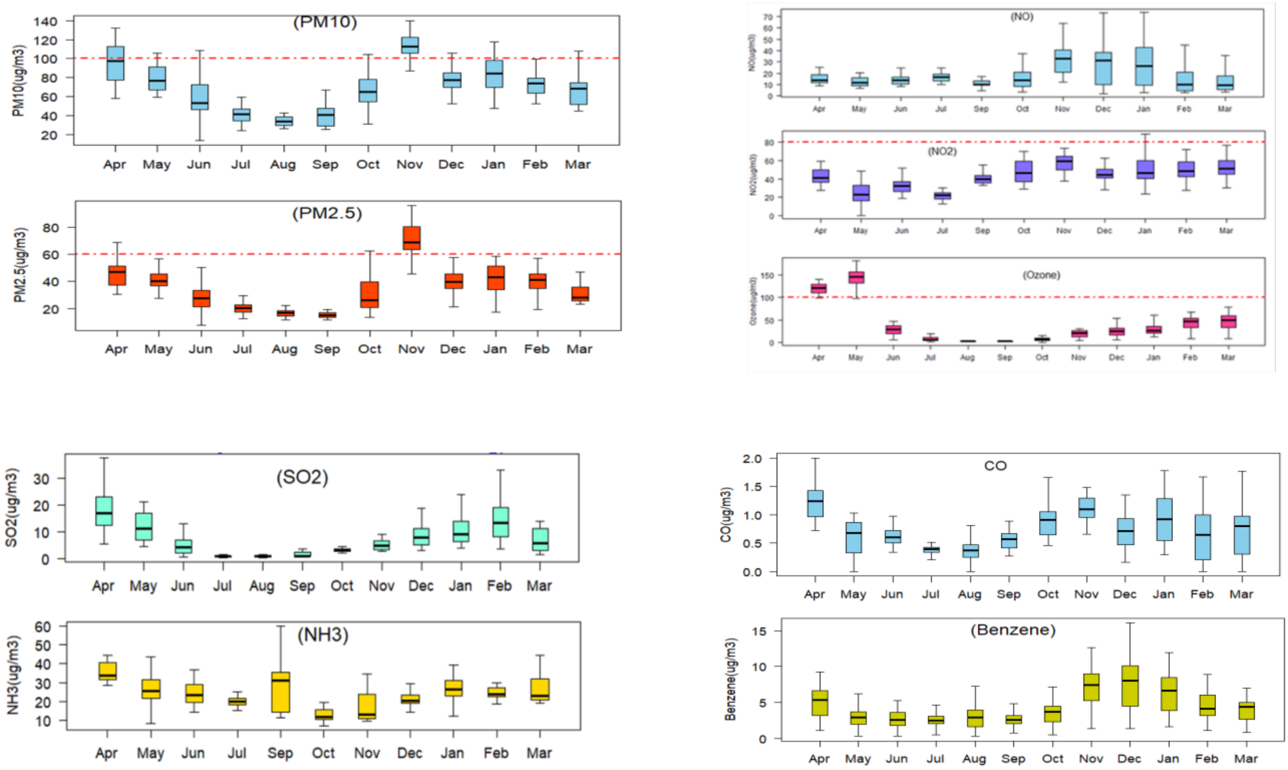

Figure 3.2-a,b,c : Monthly Variation of PM10 and PM2.5 Concentration , Monthly Variation of NO, NO2 and O3 Concentration, Monthly Variation of SO2 and NH3 Concentration, Monthly Variation of CO and Benzene Concentration during 2022-2023 at Civil Lines, Nagpur (CAAQMS Data Source: www.cpcb.nic.in)

IV. SOURCE DISPERSION MODELING

Dispersion modeling describes the atmospheric mechanisms that spread a pollutant released by one or more sources using mathematical formulae. To determine the influence of key sources on ambient air quality in the Nagpur region, air quality dispersion modeling has been done. Ground level concentration (GLC) of pollutants is calculated by creating an emission inventory for each pollutant and simulating its dispersion. The AERMOD Source Dispersion Modeling Tool has also been utilized to generate air quality scenarios for the whole city, accounting for emission loads from every grid. The goal of the current scenario model runs is to determine how pollutants disperse in response to local meteorological and emissions from all potential sources. Model runs also give information about additional sources that may have been taken into consideration earlier or about missing sources. In order to highlight the contributions and their unpredictability, scenarios for various times of year, places, and sources have been created. The results of the modeling experiment are displayed in tables and isopleths. Pollutant transportation and dispersion in the atmosphere are significantly influenced by meteorological factors. Hourly meteorological data is generated by WRF and analyzed, and AERMET is utilized to determine the vertical and surface profiles of meteorology.

The calculated air turbulence is utilized to calculate the horizontal and vertical dispersion coefficients (σx, σy) using the meteorological data. This research considers a meteorological domain with a radius of 25 km, including the entirety of Nagpur city on its east side grids.

In civil engineering, source dispersion modeling is an essential technique for forecasting the dispersal and spread of pollutants emitted from a variety of sources, including transportation emissions, industrial facilities, and unintentional chemical releases. It aids in evaluating the possible effects of these contaminants on the environment, human health, and air quality. Here's a summary of how it functions:

1. Understanding Sources: The first step in dispersion modeling is identifying the sources of pollutants. These could be point sources (e.g., smokestacks), line sources (e.g., highways), or area sources (e.g., urban areas with multiple pollution sources).

2.Emission Estimation: Once the sources are identified, engineers estimate the quantity and composition of pollutants emitted from each source over a specified time period. This involves factors such as emission rates, stack heights, wind speed, temperature, and atmospheric stability.

3. Meteorological Data: Meteorological information such as wind direction, speed, temperature, and atmospheric stability is crucial for the functioning of dispersion models. Pollutant transport and dispersion in the atmosphere are simulated using this data.

4. Model Selection: Dispersion models come in a variety of forms, from straightforward Gaussian models to intricate computational fluid dynamics (CFD) models. The kind of pollutants present, the complexity of the landscape, and the degree of precision needed for the evaluation all influence the model selection.

5. Model Inputs: Engineers input parameters such as emission rates, stack heights, release characteristics, meteorological data, and terrain information into the chosen dispersion model.

6. Simulation: Based on the supplied inputs, the dispersion model then approximates the motion of contaminants in the atmosphere. It considers variables including wind direction, atmospheric stability, the influence of topography, and the interaction of contaminants with the atmosphere.

7. Output Analysis: Engineers examine the results once the simulation is finished to determine the distribution and concentration of pollutants at different points downwind of the sources. This aids in comprehending the possible effects on human health and air quality.

8. Risk Assessment: Engineers can analyze the possible health and environmental concerns connected with the pollutants by using the findings of the dispersion modeling to inform their risk assessments. Making decisions and putting mitigation plans in place to lower emissions and safeguard the environment and public health depend on this knowledge.

All things considered, source dispersion modeling is essential for environmental impact assessments, urban planning, industrial permits, and emergency response plans because it offers important information about how pollutants are distributed in the atmosphere.

Input Model

A full year of air quality modeling is conducted. The geographical distribution of various pollutant concentrations in ambient air is predicted using the Gaussian Dispersion Model (GDM). The model may be configured to handle either Cartesian or Polar coordinates; it can also simulate sources of point, area, and volume; it can take into account both dry and wet deposition; it can account for terrain adjustment; it can even design a downwash algorithm. The following information is needed as input for the model about source characteristics, climatic conditions, and receptor network:

(i) Source data: physical dimensions (stack height, position, and inner diameter), exit velocity, gas temperature, and the location and rate of pollutant emissions. The area source emission for Nagpur city is calculated as input to the model using the emission from various sources, such as roadside eateries, crematoria, bakeries, and cars, integrated in their respective grids.

(ii) Hourly meteorological data collected at hourly intervals using the weather research forecast (WRF) model during the simulation period, including wind speed, wind direction, ambient temperature, mixing height, and upper air data.

(iii) Co-ordinates of receptors, where the model would estimate the ground level concentration of pollutants.Emission Reduction Action Plan for Nagpur City

For dispersion modeling, a domain with a radius of 25 km is taken into consideration around the research area's center. In order to allow coverage of all the significant sites situated in and around key urban development centers, receptor locations within the research region were set up in a square grid pattern with a 500 m spacing between each site. A square grid layout was employed to disperse the area sources, and each grid made use of the available emission rate. The model makes use of hourly frequency distributions of processed AERMET data for wind speed, wind direction, ambient temperature, stability class, and mixing height. There are five pollutant parameters, the dispersion of which is to be simulated. The regulatory limit value of all these parameters and their emission rate are different New units of Koradi (660 MW) have taller stack height (275 m) and lesser emission (50 g/s) rate, however, old units have shorter stack height (90 m) and higher emission rate (200 g/s). This typical old power plant contributes to a very large extent towards the ground level PM10 and therefore emission control in these old units needs to be considered. Emission load calculated for one day is distributed for twelve day-time hours and night time emission are considered to be absent. Area source emission activity starts 8:00 AM to 8:00 PM. Vehicles do not ply at Nagpur at night so as to cause high levels of pollution like a metro city like Delhi. Presence of international flights, train and interstate bus services, invite large number of vehicles in metro city thereby requiring night time emission also. The emission rate of PM10 in area source is considered to vary diurnally

ACTION PLAN FOR CONTROL OF AIR POLLUTION

Civil engineering plays a crucial role in controlling air pollution through various infrastructure projects and sustainable design practices. Here are several ways civil engineering can contribute to air pollution control:

Green Infrastructure: Put green infrastructure ideas into practice, such bioswales, rain gardens, permeable pavements, and green roofs. By capturing and filtering pollutants from stormwater runoff, these features lessen the quantity of pollutants that are released into the atmosphere as a result of atmospheric deposition. Create and expand public transportation networks, such as light rail, buses, and trains, to promote modal shifts away from private automobiles. Air quality may be improved by reducing automobile emissions and traffic congestion through the provision of dependable and efficient public transit choices.

Active Transportation Infrastructure: Design pedestrian-friendly and bicycle-friendly infrastructure, such as sidewalks, bike lanes, and multi-use paths, to promote walking and cycling as alternative modes of transportation. Encouraging non-motorized transportation options helps reduce reliance on motor vehicles and decreases air pollution.

Traffic Management and Optimization Utilize civil engineering principles to design efficient traffic management systems, including traffic signal synchronization, intelligent transportation systems (ITS), and congestion pricing schemes. Optimizing traffic flow and reducing congestion can minimize vehicle idling and emissions, leading to improved air quality.

Industrial Pollution Control: Design and implement pollution control technologies for industrial facilities, including particulate control devices, scrubbers, and catalytic converters. Civil engineers can oversee the installation of these technologies to reduce emissions of harmful pollutants from industrial sources.

Major source of air pollution in Nagpur city is:

- Industrial Emission
- Vehicular emission Minor emission is from

- Road dust re-suspension Area Source
- Unmanaged Solid WastE

Table: Action Plan to Control Emissions from Various Sources

Control Option	Action	Responsible Agencies
Vehicular Emission		
Launch extensive drives against polluting vehiclesfor ensuring strict compliance	The RTO should have mobile PM and gaseous air pollution monitors, inspect polluting cars at random, and take strong measures to enforce mandatory maintenance. Since April 2017, all car manufacturers are currently required to adhere to the BS IV requirements.	RTO, Smart city NMC
Start educating the public about car emission reduction through lane discipline, adequate vehicle maintenance, and reducing the usage of personal automobiles. engine idling and stopping at junctions	NMC buses, display boards at various traffic intersections to be used for the advertisement	Traffic Engineer, NMC/Smartcity, Advertise Dept. NMC,MSRTC
Avoid parking your car in undesignated places. Finding locations where additional parking is needed and creating a parking facility	It is suggested to build parking lots at Dhantoli and along Ramdas Peth to Kanchipura Square in addition to the current NMC parking facilities. Similar parking structures will be built in other crowded locations.	Traffic Engineer, NMC DCP Traffic
Start the process of upgrading diesel automobiles with particle filters.	Making decisions on policies. Currently, auto rickshaws and light motor vehicles run on a mix of LPG and gasoline to some extent. In order to mitigate the effects of air pollution caused by public transportation vehicles, a gradual implementation of CNG, battery-operated systems, and E-rickshaws is planned for the future.	GoI, GoM, NEERI, IIT/VNIT
Prepare action plan to check fuel adulteration and random monitoring-of fuelquality data	Checking fuel adulteration with coordination of anti-adulteration cell which is a continuous process.	Residence Deputy Collector (RDC), Anti Adulteration Cell, RTO

V. CONCLUSIONS

It is discovered that the RSPM levels in both seasons are within the allowed range at every location. In both the summer and winter, the air quality at the residential site is good. Nonetheless, the wintertime air quality in the business area is good, and the summertime air quality is satisfactory. This variance results from the summertime dilution of airborne contaminants. Once more, the industrial area's air quality is acceptable in both the summer and the winter. Both seasons have distinct SPM and RSPM concentrations. Winter yields better outcomes than summer does. The wind-rose graphic unequivocally demonstrates how variations in wind direction and speed during the summer cause dilution and dispersion. of airborne contaminants. To determine the quantity of gaseous and particulate matter in the ambient air, other researchers have also conducted study in this area. The literature review reveals that many of the data that are currently available have concentrations that are above the new NAAQS norms or restrictions. As a result, it is crucial to continuously check the ambient air in order to prevent numerous health risks. The current study found that respirable suspended particulate matter (which is above the recommended standard set by the Central Pollution Control Board, i.e., 100 lg/m3), SO2, and NO2 as a result of various industries, construction activities, and vehicle emissions were the main pollutants that affected the quality of the air in the city. In an effort to stem the spread of the new Corona Virus, the Indian government implemented a lockdown on March 25, 2023, which was gradually lifted until December 2023. The unlocking phase of the lockdown began on June 1st, 2023. When compared to the pre-lockdown conditions (13, 37.5, and 115 lg/m3 for SO2, NO2, and RSPM, respectively), the average concentration of pollutants dropped significantly (5, 11 and 65 lg/m3 for SO2, NO2, and RSPM, respectively) as a result of the lockdown. Due to numerous vehicle activities, building projects, etc., the concentration of all pollutants increased once again in the reopening situation (9.25, 24.5, and 95.5 lg/m3 for SO2, NO2, and RSPM, respectively). The percentage decrease in the amount of pollutants during the lockdown state was as compared to the pre-lockdown conditions, for SO2, NO2, and RSPM, respectively, 59.26%, 66.59%, and 41.27%. Comparing the reopening situation to the lockdown state, the percentage increase for SO2, NO2, and RSPM was 73.86%, 94.52%, and 44.11%, respectively. The air quality indices reveal that during a lockdown, the quality of the air changes from MODERATE to SATISFACTIRY, and after a reopening, it again goes from SATISFACTIRY to MODERATE. These changes occur between 101-200 and 51-100, respectively. Due to the shutdown, there was less pollution in 2022 and 2023 when comparing the yearly average concentration of all pollutants with prior years. The majority of the year saw the closure of all manmade activity and enterprises due to lockdown because to first and second corona wave. .. Therefore, it may be said that transportation, industry, and human activity are the primary causes of the rise in environmental or air pollution. A CLEAN environment can be achieved by reducing environmental pollution to some extent if a lockdown is implemented in the region impacted by pollution.

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