Decoding AQI: The Real-Time Signal of Our Environmental Emergency

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1. Introduction

Globally, climate change has become one of the major visible concerns in both developing and developed countries. Climate change has many direct and indirect impacts on many species and has the capability to set the rules of survival and existence of every species. Humans are not an exception to the hazardous effects of climate change. One of the latest concerns is that climate change has led to the trapping of pollutants inside the atmosphere, leading to huge air pollution, which has risen alarmingly in recent times. Environmental crisis such as hazardous waste disposal, air and water pollution, limited resources, and more have become significant concerns in the current era (Ahmed et al., 2024). Public health is very fragile and particularly vulnerable to the change in quality of air we breathe which is heavily influenced by air pollution in emerging countries as well as major metropolitan cities across the India. One of the major reasons for the alarm rise in the pollutants is the excessive usage of resources like coal, electricity, over extrapolation of ground resources and population growth might be one of the reasons as suggested by (Gupta et.al.2020). The AQI is a crucial metric for monitoring air quality and provides information on the level of air pollution and its potential health risks. Primarily there are three AQI forecasting metrics used to calculate quality in three scenarios based on the air pollutants data, Monthly average Nitrogen dioxide (NO_2), Sulfur dioxide (SO_2), Oxygen (O_3), and Particle matter ($PM_{2.5}$) Ground-level ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide.

AQI is an index for reporting daily or hourly air quality, summarizing complex pollution data into a single value that the public can easily understand. Regulatory agencies (e.g., US EPA, SAFAR in India) define breakpoint ranges for each pollutant; the overall AQI is usually the maximum of the pollutant-specific index values for that period. AQI links pollutant levels to short-term health risk, helping people know when air is unhealthy and whether to limit outdoor activity, especially for sensitive groups like children, the elderly, and people with asthma or heart disease. Governments use AQI data to give health advisories, emergency responses (e.g., wildfire smoke), and to evaluate and communicate the effectiveness of air quality regulations and urban planning measures (www.airnow.gov). High AQI values correlate with increased risks of respiratory and cardiovascular problems, hospital admissions, premature mortality, and can also affect cognitive function and mental health over time. Continuous AQI-based monitoring supports sustainable development by guiding policies to reduce emissions, improve urban air quality, and protect vulnerable populations, thereby improving life expectancy. (Khaiwal *et al.*,2024)

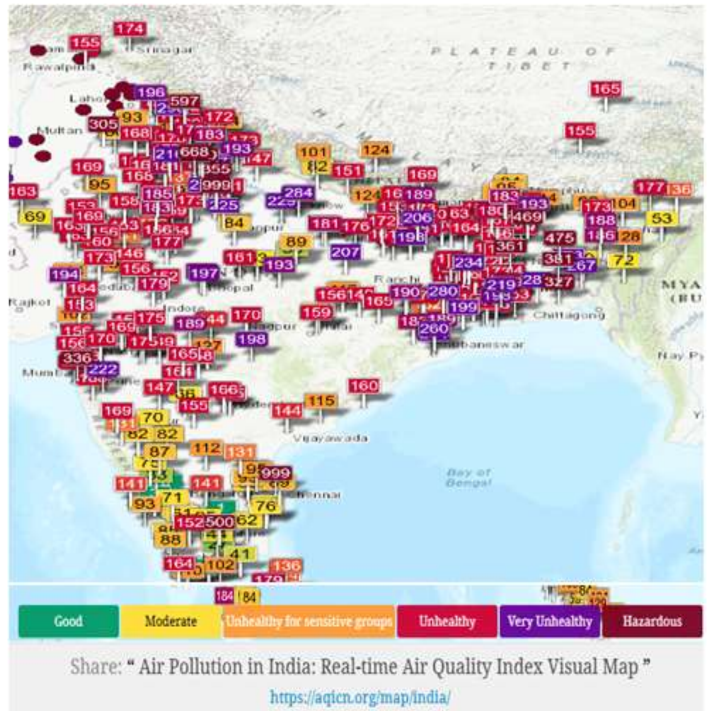

Fig. 1. AQI across the India on 03-12-25 (*https://aqicn.org/map/India/*)

2. How to read the Air Quality Index (AQI)

An Air Quality Index (AQI) is a number used by government agencies to measure the air pollution levels and communicate it to the population. As the AQI increases, it means that a large percentage of the population will experience severe adverse health effects. The measurement of the AQI requires an air monitor and an air pollutant concentration over a specified averaging period. The results are grouped into ranges, and each range is assigned a descriptor, a color code and a standardized public health advisory. (indiatoday.in)

The pollution sources in India and in most Asian countries are numerous and incompletely understood. In Delhi, for example, it comes mostly from light and heavy duty vehicle traffic emissions, road dust, and solid fuel combustion for heating and cooking, biomass, waste burning, thermal power plants, diesel generators, construction and small-scale local industries. That's why each country has to have their own AQI values.

The National Air Quality Index Standard (NAQI) in India was launched by the Ministry for Environment, Forests & Climate Change, on 17 September 2014. The initiative constitutes part of the Government's mission to introduce the "culture of cleanliness", as the air pollution has been a huge concern in the country, especially in urban areas. The National Air Monitoring Program (NAMP), that covers 240 cities in the country, has been operated by the Central Pollution Control Board (CPCB) and developed by the Indian Institute of Technology, Kanpur (IIT), providing data in public domain, on real time basis. You can access it by clicking here.

To understand how the AQI works, you just have to know the six range categories (Good, Satisfactory, Moderately Polluted, Poor, Very Poor, and Severe) (Table.1) and check the associated health impacts. Solutions should be taken based on the AQI Category and the pollutant associated to it, as follows (aqi.in/blog)

Table.1. AQI categories and health impact on individuals

AQI value	Category	Color	Health Impact
0–50	Good	Green	Satisfactory; little or no risk to health.
51–100	Satisfactory	Yellow	Acceptable; minor breathing discomfort for sensitive individuals.
101–200	Moderate	Orange	Breathing discomfort for those with lung, asthma, or heart diseases.
201–300	Poor	Red	Breathing discomfort for most people with prolonged exposure.
301–400	Very Poor	Purple	Serious health effects from prolonged exposure; public is more likely to be affected.
401–500	Severe	Maroon	Health alert: emergency conditions, with everyone likely to be affected.

(**Source**: https://www.aqi.in/blog/en-in/aqi/)

If you check the Indian NAQI, you are going to realize that the Particulate Matter (PM) pollution ranks the worst among the other pollutants.

3. India initiatives to reduce Air pollution and maintain AQI

The plan was introduced in 2017 by the Ministry of Environment, Forests & Climate Change (MoEF&CC) and is implemented by the Commission for Air Quality Management (CAQM). The Graded Response Action Plan (GRAP) is a set of guidelines and measures to reduce air pollution. (Bhuyan *et al.*,2025)

GRAP working principle

1. Forecast-Based Action: Actions for higher pollution levels can be initiated in advance if forecasts predict worsening air quality. The India Meteorological Department (IMD) and weather experts provide daily AQI updates to guide decisions.

2. Escalation of Actions: Restrictions from earlier stages are carried over to higher stages. For example, if Stage III is triggered, Stage I and II actions also remain in effect.

3. Authority Coordination: Several agencies, such as the Municipal Corporation of Delhi (MCD), Delhi Pollution Control Committee (DPCC), and traffic police, are responsible for implementing GRAP measures.

Table.2. Actions to be taken to combat air pollution under each stage according to GRAP

Grade	Quality	Action
Stage I	Poor AQI (201–300)	Construction activities must control dust by using covered vehicles and sprinkling water on roads. Open burning of waste is strictly prohibited. Regular sweeping and cleaning of roads are mandated.
Stage II	Very Poor AQI (301–400):	Increased use of anti-smog guns and water sprinkling. Stricter monitoring of vehicle emissions; fines for visible smoke emissions. Parking fees may be raised to discourage private vehicle use. Industries must switch to approved, cleaner fuels.
Stage III	Severe AQI (401–450)	Ban on most construction and demolition activities except critical public infrastructure projects. Closure of brick kilns, stone crushers, and hot mix plants. Stopping non-essential trucks from entering Delhi. Encouragement of remote working and use of public transport.
Stage IV	Hazardous AQI(>450)	Complete ban on entry of non-essential trucks. Restrictions on diesel-operated vehicles unless

		they meet high emission standards. Closure of schools and non-essential offices; work-from-home policies encouraged. Consideration of vehicle odd–even rules to reduce traffic

(**Source**: Horn et al., 2024; Ansari and Quaff, 2025; Kumar et al., 2025)

Similarly, some of the case studies in India like, Data-driven analysis and predictive modeling of hourly Air Quality Index (AQI) using deep learning techniques: a case study of Azamgarh, India (Ansari et al., 2025) and the Prediction of Air Quality Index (AQI) using machine learning-based tree models a case study of Gurugram City, India indicates that, In order to measure hourly particulate matter (PM2.5, PM10), gaseous concentrations (NO2, SO2), and meteorological parameters (temperature, relative humidity, wind direction, wind speed, and UV radiation), a total of 8760 data points were gathered between July 2022 and June 2023. The estimated annual mean hourly AQI was 123, indicating moderate pollution, with higher AQI values in the winter than in the summer. The estimated annual mean hourly AQI was 123, indicating moderate pollution, with higher AQI values in the winter than in the summer. We used a MANOVA to ascertain the statistical significance of changes in PM2.5, PM10, SO2, and NO2 at several time scales, including hourly, daily, weekly, and monthly. Every temporal scale examined by MANOVA showed significant differences in pollutants, with $p < 0.001$ for hourly, daily, weekly, and monthly. An ANOVA revealed that there were extremely significant changes every day ($F = 170.7$, $p < 0.001$), every week ($F = 2270$, $p < 0.001$), and every month ($F = 2215$, $p < 0.001$) Moreover, the AQI varied significantly over the day and night, as shown by t-tests, with the night time mean (135) significantly higher than the day time mean (111) ($t = -11.906$, $p < 0.001$). (Kumar et al.,2025) The hourly AQI was predicted using six deep learning models: Transformer, Gated Recurrent Units (GRU), Convolutional Neural Network (CNN), Feed forward Neural Network (FNN), Long Short-Term Memory (LSTM), and Multi-Layer Perceptron (MLP). The FNN performed better than the other models, with the lowest MAE of 2.89, the lowest RMSE of 4.99, and the greatest R-squared value of 0.9971 with a reasonable processing time of 28 s. A Taylor diagram was used to show how well the models performed in comparison. Sensitivity analysis revealed that PM2.5, NO2 and SO2 have the greatest effects on FNN model forecasts. Machine learning based M5P-based model exhibits superior predictive accuracy compared to other models in testing stage, achieving a maximum coefficient of correlation (CC) value of 0.8287. The mean absolute error (MAE) is also recorded at 33.6908, while the root mean square error (RMSE) is 45.1823.These findings suggest that FNN has the potential to significantly enhance AQI forecasts and be helpful in developing complex, fine-scale air pollution forecasting models.

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