DOI: 10.54254/2753-8818/110/2025.AU22958

Characteristics of Air Pollution and Health Risk Assessment in China

Chengyin Huang

Institute of Guangdong Pharmaceutical University, Zhongshan, China
2747489429@qq.com

Abstract: As the world's largest developing country, China faces a severe and growing air pollution challenge. This paper reviews the current research status on the characteristics of air pollution and health risk assessment in China, comparing and analyzing various methodologies while emphasizing the importance of addressing data gaps and enhancing public health awareness. A comprehensive analysis of relevant studies reveals the distinct characteristics of air pollution in China, its associated health risks, and the urgency for policy interventions. The study also highlights limitations of the existing Air Quality Index (AQI), including its computational complexity, neglect of certain pollutants, and the predominant focus on single or few cities, specific timeframes, or isolated pollution events, which results in a lack of systematic nationwide data. To improve the accuracy of air pollution monitoring and assessment, effective policy measures must be implemented. This study proposes the adoption of health-based indices, such as the Air Quality Health Index (AHQI) and Health Risk Air Quality Index (HAQI), to better characterize air pollution and validate correlations between epidemiological data and AHQI/HAQI values. Additionally, raising public health awareness is critical, as active public participation can drive environmental protection and the adoption of green, eco-friendly lifestyles.

Keywords: Air pollution, health risks, AQI, AHQI

1. Introduction

Based on statistics from the National Bureau of Statistics, since the initiation of reform and opening-up policies, China's economy has experienced remarkable growth, with its annual Gross Domestic Product (GDP) surpassing 100 trillion yuan in 2022. Nevertheless, during this period of rapid development, the nation's atmospheric environment has encountered severe challenges to public health, primarily due to high population density, increasing vehicle numbers, and swift urbanization. Prolonged exposure to air pollution can significantly affect critical organs and systems, including the heart, brain, kidneys, urinary system, and respiratory system [1]. Consequently, addressing and mitigating air pollution has become an increasingly pressing concern. Among various pollutants, fine particulate matter (PM2.5) poses the most significant threat to human health. Due to their minuscule size (less than 2.5 micrometers in diameter), these particles can infiltrate deep into the lungs, enter the bloodstream, and are strongly linked to numerous diseases, such as cardiovascular conditions, respiratory ailments, and cancer [2-3]. Although China has made notable progress in combating air pollution, substantial efforts remain necessary.

This research aims to investigate the approaches for further reducing air pollution and evaluate the three key strategies that can be pursued collaboratively. Firstly, fostering the high-quality development of green energy is essential. This involves expanding the adoption of renewable energy sources and decreasing the share of coal power within the total installed capacity. However, achieving this transition demands considerable financial investment and cutting-edge technology, requiring time for gradual implementation.

Secondly, industrial emissions have emerged as a primary contributor to air pollution during the rapid industrialization phase. Strengthening comprehensive regulatory measures is crucial to continuously diminish pollutant emissions, such as sulfur dioxide, nitrogen oxides, and particulate matter, from industrial activities. Additionally, controlling carbon dioxide emissions from key industries like steel and construction materials is vital for enhancing air quality and promoting green and sustainable industrial development.

Lastly, managing vehicle exhaust emissions, particularly from high-emission vehicles like diesel-powered heavy trucks, is of utmost importance. Establishing multiple monitoring stations on busy roads and targeting outdated diesel vehicles that frequently emit black smoke can play a pivotal role in reducing air pollution levels.

2. Current research progress

Current research on atmospheric pollution primarily relies on analyzing data from operational air quality monitoring stations. These national environmental monitoring stations collect daily average mass concentrations of pollutants, including SO_2, NO_2, PM_{10}, CO_2, and O_3, which are then processed to assess daily air quality conditions. The Air Quality Index (AQI) serves as a comprehensive indicator representing the health impacts of various atmospheric pollutants while maintaining both temporal and spatial representativeness. Most existing studies on atmospheric pollution characteristics and health risks utilize AQI calculations to determine pollution levels, temporal variations, and spatial distribution patterns.

2.1. Pollution severity assessment

The assessment process involves first calculating individual AQI values for each pollutant and then comparing these values to identify the dominant pollutant with the highest concentration. The final AQI value representing overall air quality is determined by this highest individual pollutant AQI.

$$AQI_i = \frac{AQI_i - AQI_{i,j-1}}{m_{i,j} - m_{i,j-1}} \times \left(m_i - m_{i,j-1}\right) + AQI_{i,j-1}, j > 1$$

$$AQI_i = AQI_{i,1} \frac{m_i}{m_{i,1}} \text{ when } j = 1$$

$$AQI = \max\left(AQI_1, AQI_2, \ldots, AQI_n\right), n = 1,2, \ldots ,6 \quad (1)$$

The final air quality assessment is determined by comparing these values against the classification criteria in Table 1. This method provides an intuitive and straightforward evaluation of how air quality impacts human health.

Table 1: Air Quality Index (AQI) representation [4]

Air Quality Index (AQI)	Level	**Category**	**Health Implications**
0~50	Level 1	Excellent	Minimal impact
51~100	Level 2	Good	Air quality is acceptable; however, some pollutants may slightly affect a

DOI: 10.54254/2753-8818/110/2025.AU22958

Table 1: (continued).

			very small number of exceptionally sensitive individuals.
101~150	Level 3	Lightly Polluted	Mild aggravation and irritation symptoms may occur in susceptible groups.
151~200	Level 4	Moderately Polluted	Further symptom aggravation in susceptible groups; possible effects on cardiovascular and respiratory systems in healthy individuals
201~300	Level 5	Heavily Polluted	Significant symptom worsening in cardiopulmonary patients; reduced exercise tolerance with widespread symptoms in the healthy population
>300	Level 6	Severely Polluted	Severe symptoms apparent; reduced exercise capacity in healthy individuals with potential early onset of certain diseases

2.2. Temporal variation characteristics

According to Table 2, northern cities like those in the Beijing-Tianjin-Hebei region experience increased pollutant emissions during winter heating seasons, coupled with relatively poor atmospheric dispersion conditions, leading to elevated AQI levels. Conversely, higher summer temperatures and improved atmospheric dispersion result in lower AQI readings. Thus, northern cities exhibit a distinct "high in autumn/winter, low in spring/summer" pattern [5]. Southern cities display similar seasonal variations, though less pronounced. For instance, the Pearl River Delta region shows relatively poorer air quality in winter and better conditions in summer, but with smaller seasonal fluctuations compared to northern cities [6]. Nationally, major Chinese cities demonstrate peak AQI in winter and lowest levels in summer, with monthly averages following a U-shaped trend—highest in January/December and lowest in August/September.

Table 2: Seasonal average variation of AQI of several parts in China in 2014–2016 [7]

Region	**Spring**	**Summer**	**Autumn**	**Winter**
Northeast China	71.22	63.27	71.13	83.84
North China	96.77	85.44	90.81	118.39
Central China	88.60	71.58	84.91	129.18
East China	81.57	70.80	76.84	100.88
South China	59.42	49.85	63.05	78.27
Northwest China	113.15	79.06	81.36	108.45
Southwest China	75.06	60.05	61.93	82.73

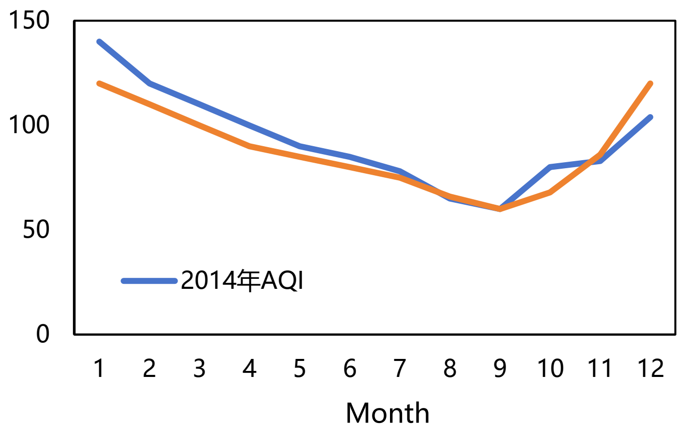

Figure 1: 2014-2015 China AQI [8]

2.3. Spatial distribution patterns

China's air pollution displays a general north-to-south decreasing gradient, where annual average AQI values progressively decline from high-latitude to low-latitude cities [9-10]. For example, in Henan Province, northern cities consistently show higher AQI than their southern counterparts, with values increasing along latitudinal gradients (most rapidly in central regions) [11]. The increase was attributed to rapid industrial and construction growth, the expansion of highly polluting tertiary industries, a coal-dominated energy structure, and winter heating practices [12]. For Beijing-Tianjin-Hebei cities, annual AQI averages demonstrate both spatial continuity across the region and clustering within sub-regions. This is primarily due to the region's unfavorable topographic and meteorological conditions for pollutant dispersion, coupled with its coal-dominated energy structure and concentration of heavy chemical industries in cities such as Qinhuangdao, Tangshan, Beijing, Langfang, Tianjin, and Baoding. Additionally, the impact of vehicle ownership exhibits an inverse growth pattern centered around the Beijing-Langfang-Tianjin corridor. Compared to the Pearl River Delta, the Beijing-Tianjin-Hebei (Jing-Jin-Ji) region relies heavily on energy-intensive industries—including cement, petrochemicals, steel, and thermal power—as economic pillars for most of its cities, resulting in significantly higher emissions of air pollutants.

Table 3: Annual AQI data of urban air quality in Henan province [13]

Region	2018	2019	2020	2021
Zhengzhou	96.42	111.83	98.92	95.75
Kaifeng	97.33	109.67	99.17	97.83
Luoyang	89.75	112.83	93.17	93.42
Pingdingshan	93.42	105.17	89.75	88.58
Anyang	110.08	124.83	113.58	105.08
Hebi	94.25	111.33	101.75	100.50
Xinxiang	97.08	102.25	94.67	100.08
Jiaozuo	98.33	114.92	101.83	99.75
Puyang	99.33	112.25	102.17	99.75
Xuchang	93.25	107.50	91.67	87.83
Luohe	91.67	107.92	93.92	91.42
Sanmenxia	84.75	99.25	88.17	90.83
Nanyang	92.42	106.92	89.58	88.00
Shangqiu	91.25	101.33	94.33	90.50
Xinyang	83.75	91.92	76.83	75.17
Zhoukou	92.17	103.83	91.33	85.75
Zhumadian	87.25	96.58	84.25	79.50
Jiyuan	89.83	114.25	94.00	101.42

Table 4: Proportion of days meeting air quality standards in key regions and 74 major monitored cities from representation [14]

Percentage of compliant days	Beijing-Tianjin-Hebei region	Yangtze River Delta region	Pearl River Delta region
2013	37.50%	64.20%	76.50%
2014	42.80%	69.50%	81.60%
2015	52%	72%	89.20%
2016	59.00%	77.50%	90.20%

DOI: 10.54254/2753-8818/110/2025.AU22958

3. Comparative analysis of indexes

3.1. Air Pollution Index (API) vs. Air Quality Index (AQI)

In previous studies, China utilized the Air Pollution Index (API) to evaluate the health impacts of daily air pollution. However, the API methodology exhibited significant limitations compared to the current AQI system. API is limited in pollutant coverage as it only monitors three pollutants (sulfur dioxide [SO_2], nitrogen dioxide [NO_2], and particulate matter [PM_{10}]), whereas AQI incorporates additional contaminants.

API is also insufficient when reflecting spatiotemporal resolution, providing weaker temporal and spatial representativeness for pollution characterization than AQI. API suffers from a simplistic classification framework with a merely rudimentary grading system with broad thresholds, failing to reflect nuanced health risk levels. AQI is more accurate, representative, and diverse compared to API.

Table 5: Air pollution index (API) representation [15]

Air Pollution Index (API)	Level	**Category**	**Health Impact Description**
0~50	Level 1	Excellent	No observable health effects
51~100	Level 2	Good	No significant health impact
101~200	Level 3	Lightly Polluted	Mild aggravation symptoms may appear in sensitive groups
201~300	Level 4	Moderately Polluted	Worsened symptoms in sensitive groups; the general population may experience discomfort.
>300	Level 5	Heavily Polluted	Heavy Pollution | Reduced exercise tolerance in healthy individuals; potential early onset of certain diseases

Comparative studies of air pollution index systems in Mainland China, Hong Kong (China), South Korea, and the United States revealed significant differences in the Chinese API system regarding pollution classification descriptions, spatiotemporal data representativeness, pollutant categories, and concentration thresholds for pollution grading [16]. More specifically, Hong Kong's adoption of the Air Quality Health Index (AQHI) has contributed to reduced hospitalization rates for hypertension diseases (HPD) and acute myocardial infarction (AMI) among elderly populations, while also helping to lower pediatric hospitalization rates, particularly for respiratory tract infections (RTI) and pneumonia [17]. In contrast, France developed the Pollution Air Quality Index (PAQI) with a seven-tier classification system, enabling more granular air quality assessments [18]. Meanwhile, China continues to use the Air Quality Index (AQI) for pollution level categorization.

While AQI offers intuitive understanding and has been widely adopted internationally, it suffers from computational complexity and often fails to account for the combined effects of multiple pollutants [19]. This limitation necessitates the introduction of novel methodologies—specifically the Health Risk Air Quality Index (HAQI) and Air Quality Health Index (AQHI)—to better examine the relationship between epidemiological patterns and air pollution.

3.2. Air Quality Health Index (AQHI)

The concept of AQHI was first proposed by Environment and Climate Change Canada and Health Canada [20]. Compared to AQI, AQHI provides a more comprehensive assessment of the combined health impacts of multiple air pollutants. It can also provide specific information on the impact of air pollutants in a particular region on human health and, at the same time, inform the public of the current air quality risk level to health, whether it is low risk, medium risk, or high risk. It is extremely applicable in the field of public health to provide health protection guidance for the

DOI: 10.54254/2753-8818/110/2025.AU22958

public and serves as a reference basis for formulating environmental protection policies in urban planning and environmental management. The index is constructed based on the total excess risk (ER) model developed by Cairncross et al. [21] and pollutant-specific regression coefficients.

The AQHI calculation involves three key steps: determining the excess risk (ERit) of disease-related medical visits attributable to individual pollutants, summing these pollutant-specific excess risks to obtain the total air quality-related excess risk (ERt), and normalizing the result by multiplying ERt by 10 and dividing by the maximum observed during the study period. ERt and AQHI can be calculated through Equation 2.

$$ER_{it} = [exp(\beta \times P_{it}) - 1] \times 100\%$$

$$\mathrm{AQHI} = 10 \times (\textstyle\sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{ER_{it}})/\mathrm{ER_{it(max)}} \quad (2)$$

In the formula, ERit represents the excess risk of disease-related medical visits attributable to pollutant i on day t, while Pit denotes the daily average mass concentration of pollutant i on day t. A practical application of this methodology can be observed in Shijiazhuang City's study on childhood respiratory diseases [22], which employed this approach to investigate the correlation between daily average pediatric respiratory illnesses and ambient air pollutant concentrations. Research in Tianjin has also shown that six types of air pollutants (SO_2, NO_2, CO, O_3, PM10, and PM2.5) all have a positive feedback effect on the number of medical visits made by the population. For every increase in the concentration of these pollutants by a certain amount, the total number of medical visits in the city will correspondingly rise [23].

3.3. Health risk Air Quality Index (HAQI)

To provide a more granular assessment of health risks associated with atmospheric pollution, numerous research teams have developed the HAQI methodology. This index is applicable to assess the health risks under the national atmospheric compound pollution conditions and evaluate specific pollution events or periods, thereby providing the public with more detailed air quality information. and it through the following computational process: First, determining the excess risk (ER) of pollutant i is equivalent to the total excess risk (ER total). Next, deriving the equivalent relative risk (RRi∗) Then, calculate the equivalent concentration. Ultimately, computing the HAQI value.

Compared to AQI, HAQI provides a more comprehensive assessment by integrating the health impacts of multiple pollutant concentrations, thereby delivering more accurate evaluations. Furthermore, HAQI can be compared with other air quality indices such as the Aggregate Air Quality Index (AAQI), offering valuable insights into the relative strengths and limitations of different indices in assessing both air quality and health risks.

While HAQI demonstrates significant potential, it currently faces several challenges: First, limited real-world applications. Second, existing data gaps in implementation. Third, absence of standardized calculation methodologies.

Despite these limitations, HAQI represents a promising research direction that may become a focal point for future atmospheric pollution studies, particularly in developing more health-relevant air quality metrics.

4. Conclusion

Through comprehensive pollutant research, distinct spatiotemporal distribution patterns and diverse methodologies for evaluating the health impacts of atmospheric pollution have been identified. Current studies predominantly focus on single-city analyses or short-term pollution events, revealing a critical lack of nationwide, systematic pollution databases [24–25].

China's air pollution control strategy must evolve from single-index assessments toward integrated health risk management. Taking Henan Province as a case study, research reveals inconsistencies in health effect assessments among the three air quality indices, with mismatched classification levels observed. Both the Health Air Quality Index (HAQI) and the Aggregate Air Quality Index (AAQI) consistently demonstrate higher values than the Air Quality Index (AQI), suggesting that the current AQI system may significantly underestimate the health risks posed by air pollution [26].

Similar findings have been documented in India, where studies confirm that HAQI provides a more comprehensive health risk evaluation compared to the National Ambient Air Quality Index (NAAQI). Analysis of index values during different periods surrounding the 2022 Diwali festival revealed consistently higher HAQI readings relative to AQI, highlighting elevated health risks during this period of intensified pollution [27].

This transformation requires enhanced monitoring systems through advanced networks to enable precise pollution classification using HAQI and AQHI methodologies while addressing data gaps. It also demands interdisciplinary innovation across environmental science, medical research, and data science to develop health-focused solutions, supported by science-driven policies prioritizing clean energy development, strict industrial SO_2 controls, and effective vehicle emission management [28-29].

By adopting this multidimensional approach, China can achieve more accurate health risk assessments and targeted pollution mitigation, ultimately advancing both environmental quality and public health outcomes.

References

[1] *Xia, X., Zhang, A., Liang, S., Qi, Q., Jiang, L., & Ye, Y. (2017). The association between air pollution and population health risk for respiratory infection: a case study of Shenzhen, China. International Journal of Environmental Research and Public Health, 14(9), 950. He, K., Huo, H., & Zhang, Q. (2002). Urban air pollution in China: current status, characteristics, and progress. Annual Review of Energy and the Environment, 27(1), 397-431.*

[2] *Yibing Li. (2016). A Brief Discussion on the Hazards and Governance of PM2.5 in Air Pollution. Science and Technology Innovation Herald, (28). (In Chinese)*

[3] *Thai-Ha Le, Youngho Chang, and Donghyun Park. (2021). Governance, Environmental Vulnerability, and PM2.5 Concentrations: International Evidence. The Energy Journal (6).*

[4] *Shuangquan Shen, Yue Du, Lijun Xu, et al. (2017). Analysis of spatiotemporal characteristics of urban air quality in China in 2015. Journal of Environment and Health, 34(3), 213-215, 282. (In Chinese)*

[5] *Xiangshu Yao, Wenji Zhao, Zhenyu Yang, Zejun Cao, and Dongchuan Wang. (2021). Spatio-temporal variation characteristics and causes analysis of air quality in the Beijing-Tianjin-Hebei urban agglomeration based on Ward system clustering. *Ecology and Environmental Sciences*.(In Chinese)*

[6] *Jianhua Cheng, Fayuan Li, Lulu Haoyang Jiao, and JiaoLingzhou Cui. (2023). Spatiotemporal Variation of Air Quality Index Characteristics in China's Major Cities During 2014-2020. Water, air, and soil pollution (5).*

[7] *Yanting Xu, Xingzhao Liu & Zhenbo Wang . (2019). Spatiotemporal distribution characteristics of urban air quality in China based on the AQI index. Journal of Guangxi Normal University (Natural Science Edition), 37(01), 187-196. doi:10.16088/j.issn.1001-6600.2019.01.022. (In Chinese)*

[8] *Xiaohong Liu & Keshen Jiang. (2018). Spatiotemporal variation and influencing factors of PM2.5 in Chinese cities: An empirical study based on 161 cities. The World of Survey and Research, (01), 25-34. doi:10.13778/j.cnki.11-3705/c.2018.01.004. (In Chinese)*

[9] *Pengfei Wang (2019). Analysis of Spatiotemporal Distribution Characteristics and Influencing Factors of Air Quality in Typical Cities in China [Master's Thesis]. Lanzhou University. Master. (In Chinese)*

[10] *Haitao Zhou, Yu-xian Yu, X. Gu, Yun Wu, and Mei Wang. (2020). Characteristics of Air Pollution and Their Relationship with Meteorological Parameters: Northern Versus Southern Cities of China. Atmosphere.*

[11] *Kai-guang Zhang, Ming-ting Ba, Hong-ling Meng, and Yan-min Sun. (2019). Spatial Distribution Characteristics and Evolution Pattern of Air Quality in Henan Province. Journal of Progressive Research in Mathematics.*

[12] *Yanjun Han, Xiaoming Chuai, Haixia Zhou & Chao Fan. (2020). Study on the interaction between air q uality and medical insurance investment in Henan Province. Reform and Opening-Up (Z1), 64-68. doi:10. 16653/j.cnki.32-1034/f.2020.001-002.017. (In Chinese)*

[13] *An Wang, Yubo Zhang & Kairui Zheng. (2024). Spatiotemporal statistical analysis of air quality in Henan Province. Journal of Pingdingshan University, 39(5), 103-109. (In Chinese)*

[14] *Jie An. (2017). Research on air quality trends and spatial differences in the Beijing-Tianjin-Hebei urban agglomeration based on AQI (Master's thesis, Tianjin University of Finance and Economics). (In Chinese)*

[15] *Wenjie Li, Shihuang Zhang, Qingxian Gao, Lingmei Zhao & Zhaoyuan Zhou. (2012). Spatiotemporal distribution characteristics of the Air Pollution Index (API) and its relationship with meteorological factors in Beijing, Tianjin, and Shijiazhuang. Resources Science, 34(8), 1392-1400. (In Chinese)*

[16] *Yunrong Xiang, Yiqiang Zhang, Yinan Zhang, Qianqian Li, and Zunyu Chen. (2009). A Comparison of Air Pollution Index Systems between China and International Standards. Acta Scientiae Circumstantiae (8). (In Chinese)*

[17] *MASON, TG, Schooling, CM, RAN, J, Chan, K-P, and Tian, L. (2020). Does the AQHI reduce cardiovascular hospitalization in Hong Kong’s elderly population? Environment International.*

[18] *Francis Olawale Abulude (2020). Assessment of Air Quality using the Plume Air Quality Index Indicator (PAQI): Reference to five towns in Nigeria.*

[19] *Jie Liu (2015). A Study on the Spatiotemporal Variation Patterns of Air Pollutants and Evaluation-Prediction Models in Beijing [Doctoral Dissertation]. University of Science and Technology Beijing. (In Chinese)*

[20] *Stieb DM, Burnett RT, Smith-Doiron M, et al. A new multipollutant, no-threshold air quality health index based on short-term associations observed in daily time series analyses [J]. J Air Waste Manag Assoc, 2008, 58(3): 435-450. DOI: 10.3155/1047-3289.58.3.435.*

[21] *CAIRNCROSS, EUGENE K., JUANETTE, JOHN, and ZUNCKEL, M. A novel air pollution index based on the relative risk of daily mortality associated with short-term exposure to common air pollutants [J]. Atmospheric Environment, 2007, 41 (38): 8442-8454.*

[22] *Qu Yue, Zeng Fangting, Chen Fengge, Kang Hui, and Guan Mingyang. (2023). Development of an Air Quality Health Index for Childhood Respiratory Diseases in Shijiazhuang City. Journal of Environmental Hygiene, 13(01), 37-44. doi:10.13421/j.cnki.hjwsxzz.2023.01.005. (In Chinese)*

[23] *Min Zhang, Zhenlei Cui, Runxiang Gao & Wen Li. (2019). Establishment and application of the Air Qu ality Health Index (AQHI) in Tianjin. Acta Ecologica Sinica, 28(10), 2027-2034. doi:10.16258/j.cnki.1674-5906.2019.10.013.*

[24] *Yan Chen, Xu Xue, Jianxin Chen, et al. Characteristics of pollution in haze weather and its effect on health in Nanyang [J]. Meteorological Science and Technology, 2010, 38(6): 737-740, 820.*

[25] *Rong Xinang, Yu Xu, Jin Ou. Meta-analysis of the effects of ambient air pollution on allergic rhinitis among children. China Medical Herald, 2014, 11(15):109-113, 123.*

[26] *Fuzhen Shen. (2021). Spatiotemporal variations of atmospheric pollutant concentrations and the Air Quality Health Index (AQHI) in China.*

[27] *Buddhadev Ghosh, Harish Chandra Barman, and Pratap Kumar Padhy. (2024). Trends of air pollution variations during pre-Diwali, Diwali, and post-Diwali periods and health risk assessment using HAQI in India. Discover Environment (1).*

[28] *Jiming Hao, Zhen Cheng & Shuxiao Wang . (2012). Research on the Current Situation of Atmospheric Environmental Pollution and Prevention and Control Measures in China. Environmental Protection, (09), 17-20. doi:10.14026/j.cnki.0253-9705.2012.09.010. (In Chinese)*

[29] *Feng, L., & Liao, W. (2016). Legislation, plans, and policies for prevention and control of air pollution in China: achievements, challenges, and improvements. Journal of Cleaner Production, 112, 1549-1558.*