



Review Article



The Most Important Laws and Plans to Reduce Air Pollution Caused by PM, SO₂, NO₂, and VOC Pollutants in Iran and Other Countries: A Systematic Review Study

Nima Aali¹ , Hamid Abdi^{2*} ¹Department of Law, Faculty of Law, Maragheh Branch, Islamic Azad University, Maragheh, Iran²Department of Civil Engineering, Water and Environment, Faculty of Civil Engineering, Water and Environment, Shahid Beheshti University, Tehran, Iran**Article history:**

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***Corresponding author:**

Hamid Abdi,

Email: hamid.abdi64@gmail.com**Abstract**

According to the WHO report, 9 out of 10 people worldwide breathe air with high levels of pollutants, and every year, air pollution causes the premature death of more than 7 million people. To identify relevant literature, keywords such as air pollution, strategies, international laws, mitigation, regulation, reduction, national, international, urban, cities, traffic, vehicle, emission, particulate matter, SO₂, NO₂, VOC, air quality, standards, management, policies, policy implementation, outdoor air, ambient air, and mitigation measures were used to search the Scopus and PubMed databases. The review period covered studies published from 2010 to 2023. The results of studies show that most countries adopt successful air pollution control measures from other nations. The majority of the world's most polluted cities are located in China and India; this study primarily examined the air pollution situation in these countries. Furthermore, the air pollution status and mitigation programs implemented in England (especially London), the United States, the European Union, Japan, South Korea, Brazil, South Africa, and Australia—countries with successful experiences in reducing air pollution—were also discussed. The results demonstrate that these plans have a remarkable capacity to prevent the harmful effects of air pollution and mitigate climate change.

Keywords: Air pollution, Review, Law, Plan, Control strategies

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Introduction

Access to clean air, safe food, and safe drinking water plays a crucial role in determining human health.¹⁻⁴ According to a World Health Organization (WHO) report, 9 out of 10 people worldwide breathe air containing high levels of pollutants. Each year, air pollution causes the premature death of more than 7 million people. Moreover, over 80% of people living in urban areas with air quality monitoring stations are exposed to air pollution levels that exceed WHO guidelines. Middle-income countries, in particular, experience the highest exposure to both indoor and outdoor air pollution.^{5,6} Besides, statistics from the Greenpeace Institute show that among 3,000 cities with available air pollution data, 64% exceed the permissible limits for PM_{2.5} particles. According to the report, all cities in the Middle East, 99% of cities in Southeast Asia, and 89% of cities in East Asia have pollutant levels above the WHO threshold.⁷ Today, more than half of the world's population lives in urban areas. This trend is expected to

continue, with projections indicating that in regions such as the European Union, over 75% of the total population will reside in urban areas.⁸

The most common and important air pollutants especially in urban areas are referred to as standard pollutants and include particulate matter (PM), nitrogen dioxide (NO₂), carbon monoxide (CO), sulfur dioxide (SO₂), tropospheric ozone (O₃), and volatile organic compounds (VOCs).^{9,10} A major contributor to the rise in these pollutants is rapid urbanization, which has led to significant changes in land use and land cover. The expansion of cities, coupled with the increase in vehicles and industrial activities in and around urban areas, is one of the primary causes of deteriorating air quality in many cities.^{5,11} Air pollutants are linked to a wide range of diseases and health complications. Exposure to polluted air has been associated with premature birth, low birth weight, and various neurodevelopmental disorders in children. These effects include impaired brain development, reduced IQ, memory deficits, depression,



anxiety, and behavioral issues.¹² Moreover, air pollution is a contributing factor to numerous other health problems, such as cardiovascular diseases, asthma, lung cancer, and reduced life expectancy.^{10,13,14} Meta-analyses of air pollutants including PM, gaseous pollutants, toxic metals, and endocrine-disrupting chemicals have established strong associations between these compounds and cardiovascular diseases.¹⁵

Furthermore, multiple studies have shown that both indoor and outdoor air pollution contribute to an increase in chronic kidney diseases. The kidneys, which serve as the body's primary detoxifying organs, can be affected directly through the bloodstream or indirectly via molecular and physiological disruptions in other organs and tissues.¹⁶ As polluted air infiltrates indoor environments, it increases people's vulnerability to respiratory infections and other health conditions.¹⁰ Different countries have adopted specific air quality standards based on their environmental conditions and public health priorities. This study aims to review and evaluate the key regulations and strategies for reducing air pollution caused by PM, SO₂, NO₂, and VOC in Iran and other countries. Table 1 presents national air quality standards from selected countries, along with WHO guidelines.

Materials and Methods

The current study was a systematic review aimed at examining international laws, programs, and effective measures to control and reduce the main pollutants, including PM, NO₂, SO₂, and VOCs. The study employed a structured search strategy using the PICO framework: Population (P): Urban areas in various countries, Intervention (I): Laws, programs, and measures to reduce air pollution, Comparison (C): Different regulatory approaches and their effectiveness, Outcome (O): Reduction in levels of PM, NO₂, SO₂, and VOCs.

To find relevant articles, we used keywords such as air pollution, strategies, international laws, mitigation,

regulation, reduction, national, international, urban, cities, city, traffic, vehicle, emission, particulate matter, SO₂, NO₂, VOC, air quality, standards, management, policies, policy implementation, outdoor air, ambient air, and mitigation measures in the search section of Scopus, PubMed, and Google Scholar databases. The review covered studies published from 2010 to 2023. The review included studies published between 2010 and 2023. The inclusion criteria were as follows: 1. Articles written in English, 2. Full-text availability and peer-reviewed status, 3. Publication date between 2010 and 2023, 4. Reporting of outcomes and impacts of implemented programs and measures, 5. Focus on at least one of the target pollutants addressed in this review, 6. Relevance to environmental (outdoor) air pollution, and 7. Coverage of national programs (e.g., in China, India, England, Canada, and the United States) or transnational initiatives (e.g., the European Union and similar organizations). In addition, exclusion criteria included failure to meet the above selection criteria, studies focused on indoor air pollution, and clinical research. Figure 1 shows the PRISMA flowchart illustrating the article selection process.

Results and Discussion

The results indicated that many countries imitate successful strategies from other nations to combat air pollution. Currently, most of the world's most polluted cities are located in China and India. This study examined the air pollution situation in these two countries. Moreover, it explored air quality conditions and mitigation programs in several other nations and regions that have achieved notable success in reducing air pollution, including England (particularly London), the United States, the European Union, Japan, South Korea, Brazil, South Africa, and Australia. India is home to 22 of the 30 most polluted cities globally. In response, the Indian government has launched a national plan to tackle air pollution in 100 cities. The goal is to reduce pollution

Table 1. Comparison of Pollutant Standards in Some Countries With WHO Guidelines

Pollutant	Averaging Time	India	China	European Union	United States	United States ^a	WHO
PM ₁₀	Annually	60	40	40	-	-	20
	24-hour	100	50	50	150	150	50
PM _{2.5}	Annually	40	15	25	15	15	5
	24-hour	60	35	-	35	35	25
SO ₂	Annually	50	20	-	-	-	-
	24-hour	80	50	125	-	-	20
	1hour	-	150	350	75 (ppb)	196	-
NO ₂	Annually	40	40	40	53 (ppb)	107	40
	24-hour	80	80	-	-	-	-
	1hour	-	200	200	100 (ppb)	203	200
CO	24-hour	-	4000	-	-	-	-
	8-hour	2000	-	10000	9 (ppb)	11,100	-
	1 hour	4000	10000	-	35 (ppb)	43,170	30,000
Ozone (O ₃)	8-hour	100	100	120	0.075 (ppm)	159	100
	1 hour	180	160	-	-	-	-
Reference		17	18	17	19		20

All the values are in µg/m³, except for those with units listed in brackets.

^a Numbers have been converted to µg/m³ for comparison.

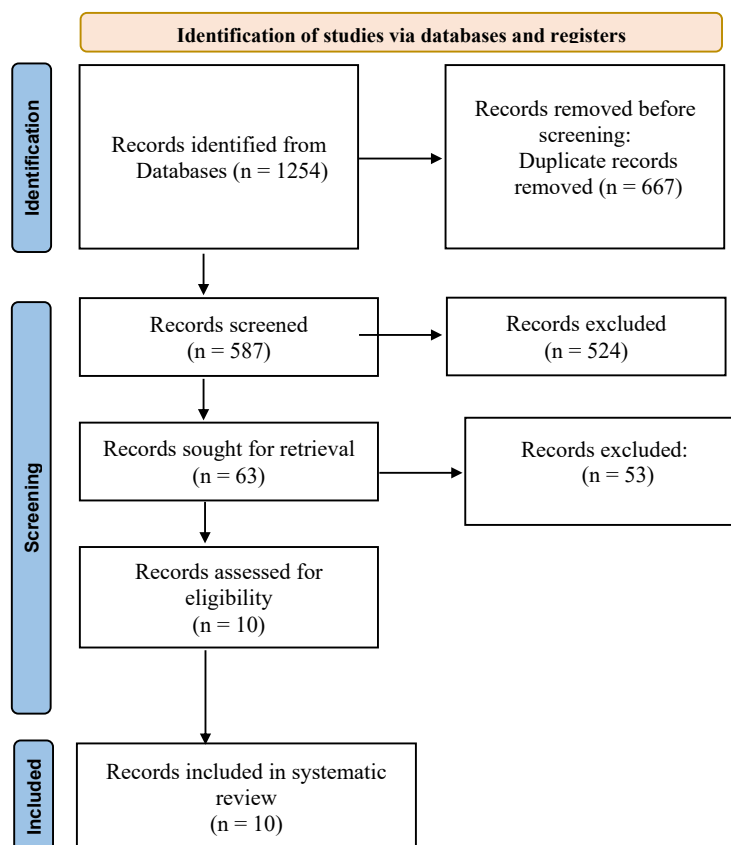


Figure 1. The PRISMA Flowchart of the Article Selection Process

levels by 53% in the first three years and by 50% over the subsequent five years. This five-year program began in 2019 and prioritizes cities based on pollutant levels, particularly NO_2 , $\text{PM}_{2.5}$, and PM_{10} . Key components of the program include expanding the air quality monitoring network, establishing meteorological information systems, licensing air pollution monitoring and research institutions, implementing air quality forecasting systems, strengthening enforcement mechanisms, increasing public awareness, and introducing daily traffic restrictions. Local authorities in each city are expected to work in coordination with state pollution control boards. A central objective of the initiative is to implement proven measures that have been effective in other countries. Table 2 refers to the retained studies based on the inclusion and exclusion criteria.

The Clean Air Campaign for Delhi is one of India's initiatives aimed at improving air quality in various cities. This campaign was launched on February 10, 2019 to identify sources of air pollution. As a part of the executive body of the campaign, 70 teams were sent across Delhi to find the sources of air pollution. These teams were granted legal authority to fine individuals or entities violating environmental regulations. Key areas of enforcement include vehicle emissions, industrial pollution, dust management, traffic control, and emissions from construction and demolition activities. In addition, expanding green space coverage is part of municipal action plans.³³ India's national standard for CO is more stringent

than the WHO guidelines. Also, the national standards for NO_2 , SO_2 , and O_3 are almost equal to the WHO guideline values, those for PM_{10} and $\text{PM}_{2.5}$ are significantly higher. One of the main contributors to Delhi's air pollution is the increase in motor vehicle use, driven by urbanization and population growth. This problem also exists for the other 39 polluted cities in India, which have a population between 1.5 and 17 million people. Among these, 30 cities have a population density exceeding 100 people per hectare, and at least 30% of households own motorcycles. In 19 cities, 10% of households own four-wheeled vehicles. While most cities are fueled by liquid gas (LPG), most households use other fuel types, such as biomass, kerosene, and coal. Besides, from the 20 cities in question, at least 30% of households use non-LPG stoves. Frequent power outages in winter and summer have increased the use of home generators in cities. Furthermore, in most of the small cities of India, fewer studies have been done on air pollution. Common mitigation strategies, such as expanding public transportation, imposing pollution taxes, and mandating cleaner fuels, have often failed to yield substantial results.⁶ The Global Burden of Disease (GBD) assessment has ranked air pollution among India's top 10 risk factors. The study estimates that air pollution in India causes 695 000 premature deaths and 18.2 million healthy life years lost due to $\text{PM}_{2.5}$ and O_3 air pollution. Among the risk factors, outdoor air pollution ranks 5th in mortality and 7th in overall disease burden in India.⁴ A study by Purohit et al, conducted in 2019, focused on

Table 2. The Retained Studies Based on the Inclusion and Exclusion Criteria

Region/Country	Air Pollution Control Plan	Effectiveness	Key Achievements	Challenges	Reference
United States	Clean Air Act (CAA), EPA regulations	Significant reductions in pollutants such as SO ₂ , NO _x , and particulate matter (PM _{2.5})	SO ₂ : 90% reduction in SO ₂ levels from 1970 to 2020. NO _x : 50% reduction in NO _x levels since the 1990s. PM _{2.5} : 40% reduction in PM _{2.5} levels since 2000. Lead: Nearly eliminated from air. Improved visibility in national parks.	Emerging issues with ozone levels, methane emissions; new challenges with climate change.	21
European Union	European Air Quality Standards, National Air Quality Plans	Reduction in PM _{2.5} , NO ₂ , and SO ₂ levels; improvements in air quality across member states	PM _{2.5} : Average annual PM _{2.5} levels have decreased by 20% from 2005 to 2019 NO ₂ : 30% reduction in NO ₂ levels from 2010 to 2019. SO ₂ : Significant reductions due to stricter emission limits. Enhanced air quality monitoring network.	Variation in implementation and enforcement across countries; some cities still exceed air quality limits.	22
China	Air Pollution Prevention and Control Action Plan, 13th Five-Year Plan	Significant reductions in PM _{2.5} levels in major cities; increased use of clean energy	PM _{2.5} : Beijing saw a 40% reduction in PM _{2.5} levels from 2013 to 2020. Coal Consumption: Reduced by approximately 10% in major urban areas. Renewable Energy: Investment in wind and solar power increased significantly Enhanced vehicle emission standards.	Continued high levels of pollutants in some areas; ongoing industrial emissions; enforcement challenges.	23
India	National Clean Air Program (NCAP)	Gradual improvement in air quality in some cities; increased awareness and regulations	- City Improvements: Reduction in PM _{2.5} levels in cities like Delhi and Mumbai Monitoring: Establishment of a national air quality monitoring network. Regulations: Stricter vehicle emission standards and industrial regulations. Awareness: Increased public awareness and advocacy.	Persistent high pollution levels; regulatory enforcement issues; challenges in low-income and rural areas.	7
Japan	Air Pollution Control Law, various local initiatives	Effective reduction in SO ₂ , NO _x , and PM _{2.5} ; good air quality management practices	SO ₂ and NO _x : Substantial reductions due to strict regulations. PM _{2.5} : Improved air quality, especially in urban areas. Air Quality Monitoring: Comprehensive network and real-time reporting. Clean Technology: Advanced pollution control technologies in industry.	Ongoing concerns with urban traffic emissions; balancing industrial growth with environmental regulations.	24
South Korea	National Ambient Air Quality Standards, Clean Air Act	Significant improvements in air quality; reductions in NO ₂ and PM _{2.5} levels	NO ₂ : Significant reduction in NO ₂ levels in urban areas. PM _{2.5} : Reduction of PM _{2.5} levels in major cities. Emission Controls: Implementation of stringent emission controls for vehicles and industry. Public Transport: Expansion of clean public transportation.	Challenges with fine particulate pollution; continued industrial and vehicular emissions.	25
Brazil	National Policy on Climate Change, state-level initiatives	Progress in urban areas with improved air quality; some reductions in deforestation-related emissions	Urban Air Quality: Improvements in air quality in major cities like São Paulo Deforestation: Some reductions in emissions related to deforestation Renewable Energy: Increase in the use of biofuels and hydropower Public Initiatives: Growth in environmental awareness and activism.	Inconsistent enforcement of regulations; rural air pollution issues; challenges with industrial pollution.	26
South Africa	National Environmental Management: Air Quality Act	Improvement in air quality in certain regions; introduction of stricter regulations	Regulations: Implementation of stricter emission limits for industries. Monitoring: Improved air quality monitoring and data collection Public Health: Increased focus on public health and air quality Emission Reductions: Notable reductions in emissions in some urban areas.	High levels of industrial pollution; challenges with regulatory enforcement; economic constraints.	27
Australia	National Clean Air Agreement, various state-level measures	Significant reductions in air pollutants, especially in major cities	Pollutants: Reduction in levels of major pollutants like PM _{2.5} and NO ₂ . Clean Air Zones: Creation of low-emission zones in cities. Regulations: Stringent air quality standards and emission controls. Public Awareness: High levels of public awareness and engagement.	Urban air pollution from vehicles and industry; challenges with balancing development and environmental protection.	28
Iran (Tehran)	Tehran Air Pollution Control Plan	reduce traffic volume and air pollutants	Increase the length of the designed cycling routes to reduce traffic volume	Lack of coordination between organizations to increase the efficiency of air pollution reduction projects	29, 30

the presence of numerous brick kilns in the Indo-Gangetic Plain. These kilns often use outdated technologies and burn a range of fuels, including biomass and coal. Additional contributors to air pollution include widespread coal use in state-run power plants (often near cities), limited air circulation due to geographical constraints in northern India, vehicular emissions, industrial activities, road dust, waste burning, and household fuel combustion.³¹ UrbanEmissions.info, an online database, collects real-time air pollution data from 342 monitoring stations across 127 cities, using satellite data to supplement ground-based readings. However, only a limited number of stations operate continuously, and many cannot measure all pollutants. Owing to limitations in data coverage and accuracy, 70% of studies are concentrated in five major cities—Delhi, Mumbai, Chennai, Kolkata, and Hyderabad—leaving other cities under-researched despite exceeding WHO air quality guidelines³³. Several solutions have successfully reduced SO₂ levels, including the adoption of cleaner fuels in urban areas, relocation of polluting industries, and modernization of coal and diesel facilities. However, these measures have been less effective in reducing PM₁₀, CO, and NO₂. Plans to reduce air pollution levels include several key strategies: legally switching the fuel of three-wheelers (rickshaws) to CNG and LPG; distributing Bharat Stage 5 emission standards (equivalent to Euro 5); increasing the number of CNG fuel stations in cities; managing intra-city travel by expanding the fleet of urban transport vehicles (buses); and establishing high-speed bus lines (BRT), modeled on the examples of Brazil and Colombia. Additional measures include implementing traffic restrictions for motorcyclists (as done in Singapore, London, and Sweden), imposing tariffs on parking spaces, and raising on-street parking fees. Environmental regulations targeting PM_{2.5} aim for a 30%–40% reduction. Other efforts include expanding the urban gas distribution network and transitioning to electricity instead of conventional fuels, upgrading brick kiln technologies near major cities, and replacing manual street sweeping with water sprinklers or vacuum trucks (given comparable costs). Finally, developing an optimal waste management system to prevent open burning of urban waste and expanding research on PM_{2.5} pollution are also among the proposed actions.⁷ Among the future programs and plans to reduce air pollution, the following measures can be highlighted: legally changing the fuel used in three-wheelers (rickshaws) to CNG and LPG; implementing the Bharat Stage 5 emission standard (equivalent to the Euro 5 standard); increasing the number of CNG fuel supply points in cities; and managing intra-city travel by expanding the fleet of urban transport vehicles (buses). Additional initiatives include establishing high-speed bus lines (BRT), modeled after those in Brazil and Colombia; imposing traffic restrictions for motorcycle riders (similar to policies in Singapore, London, and Sweden); and applying tariffs on parking spaces, including increasing current on-street parking

fees. Furthermore, environmental regulations aiming to reduce PM_{2.5} concentrations by 30–40% are planned. Other strategies include expanding the urban gas distribution network and promoting the use of electricity instead of conventional fuels; upgrading brick kiln technologies around large cities; and replacing manual street sweeping with water sprinklers or vacuum trucks, given similar operational costs. Finally, the creation of an optimized waste management system to prevent the open burning of urban waste and expanded research on PM_{2.5} pollution are also among the proposed interventions.⁷

A study by Chen et al, performed in 2020, indicated that five of the thirty most polluted cities in the world are located in China. In recent years, China has made significant efforts to reduce air pollution, with a major turning point being the approval of a comprehensive action plan by the National Council of China in 2013. This plan outlined key air quality targets and included measures such as reducing dependence on coal, lowering industrial emissions, limiting the number of high-emission devices in certain cities, and promoting cleaner energy sources. When the program concluded in 2017, it was followed by a new three-year plan that expanded its scope to include more cities. As a result, studies have shown a decline in the GBD attributable to PM_{2.5} exposure in China. One study covering 74 Chinese cities found that annual PM_{2.5} concentrations decreased by one-third between 2013 and 2017. Additionally, the study reported a 54% reduction in SO₂ emissions and a 28% reduction in CO₂ emissions. However, despite these improvements, challenges remain. The annual population-weighted concentration of PM_{2.5} in China still exceeds WHO guidelines and remains above the interim target 1 (IT-1) of 35 µg/m³. Based on the 2017 GBD report, approximately 85 200 deaths in China were linked to PM_{2.5} exposure.³²

A lack of measures to address ozone exposure remains widespread in China. According to the GBD report, approximately 178 000 deaths from respiratory diseases are attributed to ozone exposure. Although air pollution in China remains higher than the global average, notable improvements in recent years have led to significant public health benefits. These improvements highlight the potential of well-designed air pollution management strategies to reduce emissions and rapidly enhance air quality. One of the key policies strictly implemented in China was a tax regulation introduced in 2008, which increased taxes on large vehicles and reduced them for smaller ones. Under this law, cars were taxed based on engine capacity: vehicles with engines larger than 4 liters were taxed at 40%, those with engines over 3 liters at 15–25%, and those under 1 liter at just 1–3%. Additional successful policies included limiting the number of new vehicle licenses issued annually and auctioning license plates in major cities such as Beijing, Shanghai, and Guangzhou. However, it should be noted that some of China's air pollution control strategies may not be applicable in Iran due to fundamental differences

in governance and administrative structure between the Chinese communist government and the Iranian system.^{8,9}

Among other successful efforts implemented in China to raise awareness about air pollution were the actions taken by the Chinese government during the 2008 Beijing Olympic Games. During this period, strict measures were enforced to ensure a “blue sky” for the games, including a 50% reduction in city traffic through odd-even license plate restrictions and the temporary shutdown of polluting industries near the city. These measures increased public awareness and demonstrated the necessity of both governmental and public commitment to achieving clean air. Similar regulations were also enforced during the military parade marking the 70th anniversary of China’s victory over Japan in World War II.¹⁰ In a review study, Menon and Sharma investigated nature-based solutions for reducing air pollution in Indian cities. Their findings highlighted the significant potential of these approaches to mitigate the harmful effects of both air pollution and climate change. The study also emphasized that low-income urban populations are particularly vulnerable to the adverse effects of air pollution and urban heat, and that implementing green solutions can help reduce the impacts in the residential areas of these groups.¹¹ In another review, Li et al examined local strategies for reducing air pollution and minimizing human exposure. Their study confirmed that outdoor air pollution is a major global issue with long-term health implications. They proposed several urban design interventions, including optimized building architecture, porous barriers, vegetated green walls and rooftops, and the application of theoretical modeling to better disperse urban pollutants.³³

Tehran, the capital of Iran, has a resident population of 8.7 million, which increases to 12.5 million during the day due to commuters. Ranked as the 19th most populated city in the world, Tehran is divided into 349 neighborhoods and covers an area of 620 square kilometers. The city’s weather conditions and topography significantly contribute to its poor air quality. Situated between 1,050 and 1800 meters above sea level and surrounded by the Alborz Mountains, Tehran’s geography traps polluted air within the city. Additionally, atmospheric anticyclones cause temperature inversions that prevent the dispersion of pollutants. Air pollution levels are typically lower in spring and summer; however, occasional dust storms at the end of spring and beginning of summer lead to sharp increases in PM particle concentrations and their associated health risks. Consequently, the long-term average concentration of

fine particulate matter consistently exceeds the annual standard across all 22 air pollution monitoring stations in the city.¹³

Studies on the disease burden caused by exposure to PM have shown that air pollution is responsible for over 7000 deaths and the loss of 100 000 years of life in Tehran. Additionally, the economic loss attributed to air pollution in 2017 was estimated at \$3 billion. Research has demonstrated that strategies to reduce pollutants can result in significant cost savings. One such strategy is the cycling project, initiated in 2014, aimed at reducing traffic volume from carbureted motorcycles as well as gasoline and diesel vehicles in Tehran. This project spans five years, with its goals summarized in the table below.¹⁵ Table 3 presents the objectives of Tehran’s five-year municipal development plan related to the cycling initiative.

The actions taken in 2015 include concluding contracts, using bicycle repair units, designing and printing smart cards for applicants, and building seven cycling routes.¹⁶

Conclusion

Surveys indicate that many countries adopt successful air pollution control measures from others. The majority of the world’s most polluted cities are found in China and India, and this study examined the air pollution status in these two countries. Moreover, the air pollution situation and mitigation programs in England—particularly London, which has demonstrated successful pollution reduction efforts—were also reviewed. Studies on the burden of disease caused by PM exposure reveal that air pollution in Tehran results in over 7000 deaths annually and a loss of 100 000 years of life. Furthermore, the estimated economic loss from air pollution in Tehran in 2017 was approximately 3 billion dollars. Evidence suggests that implementing pollutant reduction strategies can lead to substantial cost savings.

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Authors’ Contribution

Conceptualization: Nima Aali, Hamid Abdi.

Formal analysis: Nima Aali.

Investigation: Hamid Abdi.

Methodology: Nima Aali.

Project administration: Nima Aali, Hamid Abdi.

Software: Nima Aali.

Writing-original draft: Nima Aali.

Table 3. Objectives of the 5-Year Municipal Development Program for the Bicycle Plan in Tehran

Objective	Unit	Situation in 2013	Targeting				
			2014	2015	2016	2017	2018
The length of the designed cycling routes	Kilometer	282	350	400	450	550	600
The length of cycling routes under operation	Kilometer	215	278	307	337	366	395
Percentage of transportation by bicycle in intra-city trips	Percent	0.4	0.5	0.7	1	1.3	1.5
The number of cycling stations in operation	Number	198	285	350	415	480	545

Writing-review & editing: Nima Aali.

Competing Interests

The authors confirm that there is no competing interest in this research.

Ethical Approval

Not applicable.

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