

# Critical Analysis of Emergency Plans for Critical Air Pollution Episodes: A Global Perspective

Aline L. N. Guarieiro<sup>1</sup>, Luciana M. B. Ventura<sup>2</sup>, Eduardo dos S. Fontoura<sup>3</sup>, Lilian L. N. Guarieiro<sup>4,5\*</sup>

<sup>1</sup>IA2YOU, São José dos Campos, Brazil

<sup>2</sup>Instituto Estadual do Ambiente (INEA), Saúde, Brazil

<sup>3</sup>Eduardo Fontoura Consultoria Ambiental, Mata de São João, Brazil

<sup>4</sup>Universidade SENAI CIMATEC, Salvador, Brazil

<sup>5</sup>INCT de Energia e Ambiente, Salvador, BA, Brazil

Email: alinelefol@gmail.com, engenlu@gmail.com, eduardo.fontoura@uol.com.br, \*lilianguarieiro@gmail.com

**How to cite this paper:** Guarieiro, A. L. N., Ventura, L. M. B., Fontoura, E. S., & Guarieiro, L. L. N. (2025). Critical Analysis of Emergency Plans for Critical Air Pollution Episodes: A Global Perspective. *Open Journal of Political Science*, 15, 725-747.

<https://doi.org/10.4236/ojps.2025.153040>

**Received:** June 15, 2025

**Accepted:** July 28, 2025

**Published:** July 31, 2025

Copyright © 2025 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

## Abstract

Air pollution is a critical environmental issue affecting cities across all continents, compromising public health and the quality of life for millions of people. It is driven by factors such as uncontrolled urban growth, accelerated industrialization, and increasing vehicle emissions, which together contribute to deteriorating air quality. The frequency and severity of critical air pollution episodes (CAPE) have risen, underscoring the need for emergency plans to mitigate health impacts. This article aims to analyze key emergency plans adopted globally, focusing on countries and cities considered references in addressing CAPE across the Northern, Central, and Southern Hemispheres. The findings reveal significant diversity in emergency plan approaches, shaped by each region's legislative, technological, and socioeconomic contexts. Countries in the Northern Hemisphere employ robust strategies supported by advanced technologies and integrated policies. In the Central Hemisphere, efforts focus on adapting plans to challenging urban environments, while the Southern Hemisphere faces the ongoing challenge of implementing comprehensive policies. Developing effective emergency plans requires not only adapting successful practices but also continuous commitment to innovation, evaluation, and integration. This synthesis contributes to identifying best practices and strategies, enabling other regions to create coordinated and effective CAPE plans to mitigate health impacts associated with these events.

## Keywords

Air Quality, Exposure to Atmospheric Pollutants, Particulate Matter, Risk Mitigation, Public Health

## 1. Introduction

Air pollution is one of the most critical environmental and public health challenges faced globally. Scientific studies consistently demonstrate the relationship between exposure to atmospheric pollutants and a wide range of health issues (Liu & Ma, 2025; Zhang et al., 2025). Martins et al. (2012) emphasize that inhalation of fine particulate matter is significantly associated with an increased risk of respiratory and cardiovascular diseases. Similarly, (Shin et al., 2021) identified a direct correlation between air pollution and the exacerbation of chronic respiratory conditions, such as asthma and chronic obstructive pulmonary disease (COPD). Maung et al. (2022) further highlight that prolonged exposure to high pollutant levels can cause irreversible health damage, particularly in vulnerable populations such as children and the elderly. The World Health Organization (WHO) estimates that air pollution is responsible for approximately 7 million premature deaths annually, underscoring the severity of the issue. These deaths are often attributed to diseases such as stroke, lung cancer, and acute respiratory infections, emphasizing the urgent need for effective interventions to reduce public exposure to dangerous pollutant levels (World Health Organization, 2021). In addition to global air pollution challenges, critical air pollution episodes (CAPE) have become increasingly frequent across continents, significantly impacting urban populations' quality of life. CAPE occurs when pollutant concentrations exceed established thresholds, posing significant risks to human health and the environment. These events are often exacerbated by adverse meteorological conditions, such as temperature inversions, which hinder pollutant dispersion, or by intensified anthropogenic emissions from sources such as vehicular traffic and industrial activities (da Silva et al., 2020).

CAPE has severe and immediate impacts on human health, exacerbating respiratory and cardiovascular diseases and increasing premature mortality (Lee, Kim, & Lee, 2014). Given this alarming scenario, implementing emergency plans to address CAPE has become a priority for many cities worldwide. Emergency plans play a crucial role in coordinating actions across different sectors and government levels, enabling a more effective and integrated response (Khalid & Okitasari, 2023).

For instance, Santiago, Chile, frequently experiences high pollution levels, necessitating the implementation of emergency measures to protect public health (Barraza et al., 2017). Similarly, Mexico and China have adopted rigorous strategies to mitigate the adverse health impacts of CAPE (Alola et al., 2023). In Beijing, China, severe pollution episodes have prompted policies such as strict emission controls and temporary industrial activity restrictions as part of emergency plans (Imran Tajammul, 2023).

In Brazil, São Paulo recorded the worst air quality globally for three consecutive days in September 2024 (Brazil Reports, 2024). However, unlike the aforementioned countries, São Paulo lacks an emergency plan for such episodes, necessitating reactive measures without prior planning.

Regions such as Paris, California, and Australia have developed emergency

plans due to the recurrence of CAPE, aiming not only to mitigate immediate damage but also to effectively communicate risks to the public (Imran Tajammul, 2023). In Paris, CAPE often results from Saharan dust transport, while in California, frequent summer wildfires lead to pollution peaks, requiring swift and coordinated responses (Masri, Jin, & Wu, 2022). In Australia, events such as dust storms and wildfires have driven the development of robust emergency plans, including health resource mobilization and coordination with emergency services to minimize public health impacts (Paton-Walsh et al., 2019).

The recurrence of CAPE worldwide underscores the urgent need for effective emergency plans. These plans are essential for mitigating immediate health impacts and ensuring clear and timely communication with the public. According to (Vardoulakis et al., 2020), accurate and timely communication enables individuals to take appropriate protective measures during CAPE, such as adhering to health recommendations and avoiding affected areas.

Considering the increasing frequency of CAPE in various cities worldwide, this article aims to explore emergency plans adopted in countries and cities recognized as references in addressing these episodes across the Northern, Central, and Southern Hemispheres. By analyzing their strategies, other regions can develop their own emergency plans, mitigate health impacts and promote a more effective and coordinated response.

## 2. Methodology

### 2.1. Approach and Selection Criteria

This study adopts a qualitative, exploratory, and comparative approach aimed at analyzing emergency plans for CAPE (critical air pollution episodes) developed in cities/countries across the Northern, Central, and Southern Hemispheres. The analysis also considers local social, economic, and climatological aspects, as these factors have a strong correlation with the behavior of atmospheric pollutants and, consequently, with the measures to be implemented during critical episodes and scenarios. The selection of plans was based on a review of scientific and institutional databases, including Scopus, Web of Science, Google Scholar, governmental repositories, and technical reports published up to December 2024. Included documents comprised of normative acts, official reports, scientific articles, and legal guidelines that presented specific emergency plans for CAPE. The selection prioritized countries with recognized air quality monitoring frameworks and well-established or developing public policies to address critical air pollution episodes. **Table 1** presents the countries selected for analysis.

### 2.2. Information and Evaluation Criteria for Emergency Plans

To assess the similarities and specific features of the Emergency Plans for CAPE studied, several key elements were selected for analysis, including: 1) Monitored pollutants; 2) The types of monitoring adopted; 3) The definition of alert levels; 4) Criteria for alert activation; 5) Action plans (AP); 6) The responsibility for de-

fining and activating AP. This methodological approach enables an in-depth and comparative analysis of the Emergency Plans for CAPE, providing a critical perspective on the effectiveness of these plans across different socioeconomic and structural contexts.

**Table 1.** Countries considered for the analysis of emergency plans.

Hemisphere	Selected Countries
Northern	United States of America (USA); France; United Kingdom and China.
Central	Mexico; Colombia e India
Southern	Chile, Brazil e Austrália.

### 3. Results and Discussion

The synthesis of information contributed to the identification of best practices and strategies that can be applied in other regions, aiming to improve public environmental policies and promote environmental justice (Hoelting et al., 2024).

#### 3.1. Key Focus Areas in Emergency Plans

Emergency Plans for Episodes of Critical Air Pollution are designed as environmental management tools to mitigate adverse impacts on human health, particularly among vulnerable groups, and to reduce negative effects on ecosystems (Deryugina, Moore, & Tol, 2021). Although approaches vary depending on geographic and socioeconomic contexts, emergency plans generally share structural similarities and some key aspects, which are outlined in Table 2.

These fundamental aspects make emergency plans for CAPE essential tools in managing environmental crises, enabling rapid and coordinated responses that help mitigate the negative impacts of air pollution on human health and the environment.

#### 3.2. Comparative Study of Key Aspects of Emergency Plans

Despite their geographic and socioeconomic differences, the emergency plans for CAPE analyzed in this study serve as key references, as they share the common goal of finding effective and coordinated ways to mitigate air pollution-related harm. Emergency plans must define responsibilities for setting and activating alerts, specify the actions to be taken at each alert level, outline the responses during critical episodes, and detail the measures to be adopted, among other elements.

To illustrate this, Tables 3(a)-(c) presents a comparative analysis of the main measures implemented in the emergency plans developed for countries in the Northern, Central, and Southern Hemispheres.

These plans comprise a set of coordinated actions and preventive measures activated when pollutant concentrations and/or Air Quality Indices (AQI) indicate the approach or onset of a critical episode (Braga et al., 2001). Among the

**Table 2.** Key aspects of emergency plans for CAPE.

Key Aspects	Description
Continuous Air Quality Monitoring	A cornerstone of these plans is the establishment of an atmospheric monitoring network capable of providing real-time data on pollutant concentrations. This monitoring is essential for quickly detecting critical episodes and informing the population and relevant authorities (Gouveia & Mendes, 2004).
Classification of Pollution Levels	The plans often employ a classification system for pollution levels, establishing various alert levels corresponding to the severity of the situation. These levels are determined based on air quality indices and the concentration of specific pollutants, such as fine particulate matter (PM <sub>2.5</sub> ), sulfur dioxide (SO <sub>2</sub> ), and ozone (O <sub>3</sub> ) (Companhia Ambiental do Estado de São Paulo (CETESB, 2020)). Each alert level triggers a specific set of mitigation measures.
Mitigation Measures	Depending on the alert level, emergency plans outline actions to reduce population exposure to pollutants. Common measures include: Traffic Restrictions: Implementation of vehicle rotation systems or limitations on the circulation of high-polluting vehicles (Gouveia & Mendes, 2004). Reduction of Industrial Activities: Temporary suspension of operations in industrial sectors that significantly contribute to air pollution (Companhia Ambiental do Estado de São Paulo (CETESB, 2020)). Promotion of Sustainable Transportation: Encouraging the use of public transportation or non-motorized means of transport, such as bicycles (Braga et al., 2001).
Guidance for the Population	Dissemination of recommendations for the population to adopt behaviors that minimize exposure, such as avoiding outdoor physical activities during pollution peaks (Braga et al., 2001).
Effective Communication	Communication plays a crucial role in these plans. It is essential to disseminate information about air quality and necessary measures clearly and promptly. This is often achieved through multiple communication channels, including radio, television, internet, and mobile applications (Gouveia & Mendes, 2004).
Interinstitutional Collaboration	The effectiveness of emergency plans depends on coordinated efforts among different levels of government, health agencies, environmental organizations, and civil society. This collaboration ensures the efficient implementation of measures and the availability of necessary resources (Braga et al., 2001).

analyzed Northern Hemisphere countries, it is observed that the United States and China use the Regional Air Quality Index (RAQI) as a reference for activating emergency plans during critical air pollution events (CAPE). In contrast, France and the United Kingdom adopt pollutant concentration thresholds defined in their national legislations to trigger these plans, with country-specific parameters. Implemented practices include public advisory alerts about unhealthy air conditions, the activation of action days when RAQI reaches critical levels, and mitigation measures accompanied by intensified public communication efforts (United

States Environmental Protection Agency, EPA, 2024). In France, actions range from voluntary measures to mandatory restrictions, such as traffic limitations and industrial activity suspensions in severe cases (Atmo France, 2024). The United Kingdom, in turn, applies public health recommendations and potential restrictions in areas with high pollution levels (Department FOR Environment (DEFRA, 2024)). In China, the “Red Alert” is activated for the most critical pollution levels, involving strict restrictions and orders to reduce industrial emissions (Ministry of Ecology and Environment of the People’s Republic of China, 2024). All four countries conduct automatic pollutant monitoring, with daily public disclosure of RAQI levels. Responsibility for implementing CAPE emergency plans generally lies with the federal government, supported by state and municipal agencies.

In the analyzed Central Hemisphere countries, there is unanimity in the use of the Regional Air Quality Index (RAQI) as a reference for activating emergency plans during critical air pollution events (CAPE). The implemented practices are also similar, with a focus on actions such as traffic restrictions, particularly in urban areas, suspension of industrial activities, and increased enforcement and restrictive measures according to the severity of the alert. All three countries conduct automatic pollutant monitoring, with daily public disclosure of RAQI levels. Responsibility for implementing CAPE emergency plans is generally shared among federal, state, and local governments.

**Table 3.** (a) Key aspects of emergency plans for CAPE in northern hemisphere countries; (b) Key aspects of emergency plans for CAPE in central hemisphere countries; (c) Fundamental aspects of emergency plans for CAPE in southern hemisphere countries.

(a)				
Factors	USA <sup>a</sup>	France <sup>b</sup>	United Kingdom <sup>c</sup>	China <sup>d</sup>
Definition of Alert Levels	The USA uses the AQI with six alert levels: Good (0 - 50), Moderate (51 - 100), Unhealthy for Sensitive Groups (101 - 150), Unhealthy (151 - 200), Very Unhealthy (201 - 300), and Hazardous (301 - 500).	France employs four alert levels based on the Air Quality Index: Level 1 (Moderate), Level 2 (High), Level 3 (Very High), Level 4 (Critical).	The UK adopts a ten-level alert system in its AQI, ranging from 1 (Low) to 10 (Very High).	China also uses the AQI with six levels: Good (0 - 50), Moderate (51 - 100), Light (101 - 150), Moderate (151 - 200), Severe (201 - 300), and Hazardous (>300).
Types of Alerts	Advisory Alerts: Inform the population about predicted unhealthy air conditions. Action Days: Activated when AQI reaches hazardous levels; include mitigation measures and intensified public communication.	Alerte Pollution: Levels 1 and 2 trigger voluntary measures; Levels 3 and 4 activate mandatory measures such as traffic restrictions and suspension of industrial activities.	Health Alerts: Correspond to high AQI levels (7 - 10) and include public health recommendations and possible restrictions in critical areas.	Color Alerts: Yellow, Orange, Red, and Purple Alerts indicate increasing pollution severity, with corresponding measures. “Red Alerts” are activated for the highest levels and include strict restrictions and industrial emission reduction orders.

## Continued

Action Plan	Measures include traffic restrictions, industrial activity suspensions, and recommendations to stay indoors. "Action Days" focus on specific activities to reduce emissions.	Measures vary from public recommendations (initial levels) to mandatory actions (higher levels), such as vehicle rotation and limits on industrial emissions.	Includes traffic restrictions, encouragement of public transport use, and public health campaigns during Health Alerts.	Includes industrial activity suspensions, vehicle rotation, and public awareness campaigns to reduce vehicle use, particularly during "Red Alerts".
Monitoring	Continuous monitoring by the Environmental Protection Agency (EPA), with real-time data available to the public.	Monitoring conducted by the Atmo France network, covering the entire territory, with daily updated data.	Monitoring by the Department for Environment, Food & Rural Affairs (DEFRA) through a national network, with continuous updates.	Monitoring by the Ministry of Ecology and Environment, with an extensive network in urban areas, providing daily accessible data.
Responsibility	Shared responsibility between the EPA, state, and local governments, coordinating responses during critical episodes.	Implementation led by the French government and local authorities, coordinated by the Ministry of Ecological Transition.	Responsibility divided between DEFRA and local authorities, with central government coordination during critical episodes.	Centralized responsibility within the federal government (Ministry of Ecology and Environment), with support from local governments in implementing measures.
Current Legislation	Clean Air Act: Regulates air quality and establishes standards for pollution control, including critical episodes. First enacted in 1963, with significant amendments in 1990.	Arrêté of March 26, 2014: Defines alert levels and emergency measures for critical air pollution episodes.	Air Quality Standards Regulations-2010: Establishes air quality standards and guidelines for critical episodes, based on EU legislation.	Air Pollution Prevention and Control Action Plan-2013: Defines guidelines and actions for managing critical pollution episodes.

<sup>a</sup>(United States Environmental Protection Agency, EPA, 2024); <sup>b</sup>(Atmo France, 2024);

<sup>c</sup>(Department for Environment, DEFRA, 2024); <sup>d</sup>(Ministry of Ecology and Environment of the People's Republic of China, 2024).

(b)

Factors	Mexico <sup>a</sup>	Colombia <sup>b</sup>	India <sup>c</sup>
Definition of Alert Levels	Mexico uses the AQI (Índice Metropolitano de la Calidad del Aire - IMECA) with five levels: Buena (0 - 50), Regular (51 - 100), Mala (101 - 150), Muy Mala (151 - 200), and Extremadamente Mala (>200).	Colombia adopts the Air Quality Index with six levels: Bueno (0 - 50), Moderado (51 - 100), Dañino para Grupos Sensibles (101 - 150), Dañino (151 - 200), Muy Dañino (201 - 300), and Peligroso (>300).	India uses the Air Quality Index (AQI) with six levels: Good (0 - 50), Satisfactory (51 - 100), Moderate (101 - 200), Poor (201 - 300), Very Poor (301 - 400), and Severe (>400).

**Continued**

Types of Alerts	Contingency Ambiental Phases I and II: Phase I is activated when IMECA levels exceed 150. Phase II occurs when levels surpass 200, triggering stricter measures.	Air Quality Level Alerts: Progressive emissions restrictions as AQI increases. Alerts include Yellow, Orange, Red, Purple, and Brown levels to indicate rising severity.	Advisory Alerts: Include population recommendations and industrial restrictions when AQI reaches harmful levels, particularly Poor and above.
Action Plan	Includes traffic restrictions, particularly in urban areas, and suspension of industrial activities. During Phase II, stricter measures such as vehicle rotation are implemented.	Measures include traffic restrictions, suspension of polluting industrial activities, and recommendations to stay indoors. Actions intensify with alert severity.	Includes vehicle rotation, strict restrictions in industrial and construction sectors, and public awareness campaigns to reduce emissions.
Monitoring	Continuous monitoring by the Atmospheric Monitoring System (SIMAT), covering Mexico City and metropolitan areas. Real-time data is available.	Monitoring conducted by the Institute of Hydrology, Meteorology, and Environmental Studies (IDEAM), covering major cities and urban areas. Data is regularly updated.	Monitoring conducted by the Central Pollution Control Board (CPCB) through the National Air Quality Monitoring Programme (NAMQP), with an extensive network of stations in urban areas.
Responsibility	Responsibility is shared between federal, state, and local governments, with the Ministry of Environment coordinating actions during critical episodes.	Implementation is coordinated by IDEAM, with support from local authorities and the Ministry of Environment. Specific actions are executed by local and municipal governments.	Responsibility is centralized within the CPCB, with coordination between state pollution control agencies and local authorities to implement measures.
Current Legislation	Norma Oficial Mexicana NOM-172-SEMARNAT-2019: Establishes criteria for activating atmospheric environmental contingencies and implementing measures to protect public health and the environment (2019).	Resolución 2254 de 2017: Regulates air quality management and protocols for addressing air pollution episodes based on the National AQI (2017) ( <a href="#">Ministerio de Ambiente y Desarrollo Sostenible, 2017</a> ).	National AQI Guidelines: Standards established by CPCB for monitoring and managing critical air pollution episodes, including specific measures to protect public health (2014).

<sup>a</sup>(Government of Mexico, 2024); (Instituto de Hidrología, IDEAM, 2024); <sup>c</sup>(Central Pollution Control Board, CPCB, 2025).

(c)

Factors	Chile <sup>a</sup>	Brazil <sup>b</sup>	Australia <sup>c</sup>
Definition of Alert Levels	Chile employs three main alert levels: Alert, Pre-emergency, and Emergency, based on pollutant concentrations such as PM <sub>2.5</sub> and PM <sub>10</sub> .	Brazil adopts three alert levels: Level 1 (attention), Level 2 (alert), and Level 3 (emergency), based on air quality standards for pollutants such as PM <sub>2.5</sub> , PM <sub>10</sub> , and O <sub>3</sub> .	Australia uses the AQI system with five categories: Good (0 - 33), Fair (34 - 66), Poor (67 - 99), Very Poor (100 - 149), and Hazardous (150+), focusing primarily on PM <sub>2.5</sub> and O <sub>3</sub> .

## Continued

Types of Alerts	Environmental Alert, Pre-emergency Alert, and Environmental Emergency: Activated based on pollution levels, with different measures for each stage.	Alerts Level 1, 2, and 3: Triggered based on standards established by CONAMA Resolution 491/2018, focusing on public health protection.	Advisory Alerts: Issued when AQI reaches harmful levels, particularly in the Very Poor and Hazardous categories. They include recommendations and potential restrictions.
Action Plan	Includes restrictions on vehicle traffic, suspension of industrial and school activities, and incentives for public transportation. During Environmental Emergencies, stricter measures, such as complete restriction of certain activities, are implemented.	There is no current nationwide Action Plan in Brazil, except for São Paulo state, which has an outdated plan from 1988.	Includes restrictions on outdoor activities, industrial sector limitations, and recommendations to the population to reduce exposure to pollutants.
Monitoring	Continuous monitoring is conducted by the Red de Monitoreo del Ministerio del Medio Ambiente (SINCA), with real-time data for various cities, particularly Santiago.	Monitoring is conducted by the National Institute of Meteorology (INMET) and state agencies, with public data available through the National Air Quality Information System (SisAr).	Monitoring is conducted by the Bureau of Meteorology (BoM) in collaboration with state agencies, with publicly available data.
Responsibility	The Ministry of the Environment is responsible, with support from regional governments for implementing and enforcing measures during critical episodes.	Responsibility is shared among the Ministry of the Environment, state environmental agencies, and CONAMA, which coordinates actions during critical episodes.	Responsibility is divided between the National Environment Protection Council (NEPC) and state agencies, with the federal government coordinating responses.
Current Legislation	Atmospheric Prevention and Decontamination Plan (PPDA), published in 2016.	CONAMA Resolution No. 491/2018, published in 2018.	National Environment Protection Measure for Ambient Air Quality.

<sup>a</sup>(Ministerio del Medio Ambiente, MMA, 2024); <sup>b</sup>(Conselho Nacional do Meio Ambiente, CONAMA, 2025); <sup>c</sup>(National Environment Protection Council, NEPC, 2024).

In the Southern Hemisphere, we analyzed only Chile and Australia, as Brazil does not currently have updated legislation at the time of this review. Analyzing these two countries, it is observed that Australia follows more up-to-date standards, employing the RAQI as a reference for activating emergency plans during critical air pollution events (CAPE). In contrast, Chile uses three alert levels based on pollutant concentrations. The implemented practices are also similar, with measures such as restrictions on outdoor activities, limitations on industrial sectors, and recommendations to the population to reduce exposure to pollutants. Both Australia and Chile conduct automatic pollutant monitoring, with daily pub-

lic disclosure of RAQI levels. The responsibility for implementing emergency plans for CAPE generally falls to environmental protection agencies, supported by regional governments.

Despite regional and contextual variations, emergency plans for CAPE are generally based on scientific studies correlating air pollutant exposure with adverse health effects, particularly in vulnerable populations such as children, the elderly, and individuals with chronic respiratory diseases (Saldiva; Braga, 2001). A critical criterion in implementing CAPE emergency plans is the definition of levels and activation criteria for the plans based on the types of alerts. **Tables 4(a)-(c)** present the alert levels and activation criteria adopted in the emergency plans developed for countries in the Northern, Central, and Southern Hemispheres.

**Table 4.** (a) Alert levels and activation criteria for CAPE emergency plans in northern hemisphere countries; (b) alert levels and activation criteria for CAPE emergency plans in central hemisphere countries; (c) Alert levels and activation criteria for CAPE emergency plans in southern hemisphere countries.

(a)			
Country	Alert Level	Alert Activation Criteria	Monitored Pollutants
USA <sup>a</sup>	Good (0 - 50), Moderate (51 - 100), Unhealthy for Sensitive Groups (101 - 150), Unhealthy (151 - 200), Very Unhealthy (201 - 300), Hazardous (301 - 500).	Activation based on the AQI, which considers average pollutant concentrations over 24-hour periods, with specific criteria for each level.	PM <sub>2.5</sub> , PM <sub>10</sub> , O <sub>3</sub> , NO <sub>2</sub> , CO, SO <sub>2</sub> .
France <sup>b</sup>	Level 1 (Moderate), Level 2 (High), Level 3 (Very High), Level 4 (Critical).	Criteria based on the average concentration of pollutants, particularly PM <sub>10</sub> and O <sub>3</sub> , over 24 hours, with specific actions for each alert level.	PM <sub>10</sub> , PM <sub>2.5</sub> , O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> .
United Kingdom <sup>c</sup>	1 - 3 (Low), 4 - 6 (Moderate), 7 - 9 (High), 10 (Very High).	Activation based on the AQI, using 1-hour averages for O <sub>3</sub> and NO <sub>2</sub> , 24-hour averages for PM <sub>2.5</sub> and PM <sub>10</sub> , and 8-hour averages for CO.	PM <sub>2.5</sub> , PM <sub>10</sub> , O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> , CO.
China <sup>d</sup>	Good (0 - 50), Moderate (51 - 100), Unhealthy for Sensitive Groups (101 - 150), Unhealthy (151 - 200), Very Unhealthy (201 - 300), Hazardous (>300).	Activation based on the AQI, which considers 24-hour averages for PM <sub>2.5</sub> and PM <sub>10</sub> , and 1-hour averages for O <sub>3</sub> and NO <sub>2</sub> .	PM <sub>2.5</sub> , PM <sub>10</sub> , O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> , CO.

<sup>a</sup>(United States Environmental Protection Agency, EPA, 2024); <sup>b</sup>(Atmo France, 2024);

<sup>c</sup>(Department for Environment, DEFRA, 2024); <sup>d</sup>(Ministry of Ecology and Environment of the People's Republic of China, 2024)

(b)			
Country	Alert Level	Alert Activation Criteria	Monitored Pollutants
Mexico <sup>a</sup>	Buena (0 - 50), Regular (51 - 100), Mala (101 - 150), Muy Mala (151 - 200), Extremadamente Mala (>200).	Activation based on the Metropolitan Air Quality Index (IMECA), with threshold values for daily or hourly average concentrations of each pollutant).	PM <sub>2.5</sub> , PM <sub>10</sub> , O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> , CO.

## Continued

Colombia <sup>b</sup>	Bueno (0 - 50), Moderado (51 - 100), Dañino para Grupos Sensibles (101 - 150), Dañino (151 - 200), Muy Dañino (201 - 300), Peligroso (>300).	Activation based on the National Air Quality Index (INCA), which uses 24-hour average concentrations for PM and 8-hour averages for O <sub>3</sub> , adjusted for each pollutant.	PM <sub>2.5</sub> , PM <sub>10</sub> , O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> .
India <sup>c</sup>	Good (0 - 50), Satisfactory (51 - 100), Moderate (101 - 200), Poor (201 - 300), Very Poor (301 - 400), Severe (>400).	Activation based on the National AQI, which considers 24-hour average concentrations for PM <sub>2.5</sub> , PM <sub>10</sub> , and 8-hour averages for O <sub>3</sub> , adjusted for each pollutant.	PM <sub>2.5</sub> , PM <sub>10</sub> , O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> , CO.

<sup>a</sup>(Government of Mexico, 2024); <sup>b</sup>(Instituto de Hidrología, IDEAM, 2024); <sup>c</sup>(Central Pollution Control Board, CPCB, 2025).

(c)			
Country	Alert Level	Alert Activation Criteria	Monitored Pollutants
Chile <sup>a</sup>	Alert, Pre-emergency, Emergency.	Activation based on the daily average concentration of pollutants such as PM <sub>2.5</sub> , PM <sub>10</sub> , and O <sub>3</sub> . For example, Alert is activated when PM <sub>2.5</sub> exceeds 80 µg/m <sup>3</sup> , Pre-emergency at PM <sub>2.5</sub> above 110 µg/m <sup>3</sup> , and Emergency at PM <sub>2.5</sub> above 170 µg/m <sup>3</sup> .	PM <sub>2.5</sub> , PM <sub>10</sub> , O <sub>3</sub> , CO, NO <sub>2</sub> , SO <sub>2</sub> .
Brazil <sup>b</sup>	Level 1 (Attention), Level 2 (Alert), Level 3 (Emergency).	Activation based on air quality standards from CONAMA Resolution No. 491/2018, considering 24-hour average concentrations for PM <sub>2.5</sub> and PM <sub>10</sub> , and 8-hour averages for O <sub>3</sub> . For example, Level 1 is activated when PM <sub>2.5</sub> is between 25 and 50 µg/m <sup>3</sup> , Level 2 between 50 and 75 µg/m <sup>3</sup> , and Level 3 above 75 µg/m <sup>3</sup> .	PM <sub>2.5</sub> , PM <sub>10</sub> , O <sub>3</sub> , CO, NO <sub>2</sub> , SO <sub>2</sub> .
Australia <sup>c</sup>	Good (0 - 33), Fair (34 - 66), Poor (67 - 99), Very Poor (100 - 149), Hazardous (150+).	Activation based on the AQI, using 1-hour averages for O <sub>3</sub> and NO <sub>2</sub> , and 24-hour averages for PM <sub>2.5</sub> and PM <sub>10</sub> . For example, Hazardous is activated when PM <sub>2.5</sub> exceeds 150 µg/m <sup>3</sup> .	PM <sub>2.5</sub> , PM <sub>10</sub> , O <sub>3</sub> , CO, NO <sub>2</sub> , SO <sub>2</sub> , Pb.

<sup>a</sup>(Ministerio del Medio Ambiente, MMA, 2024); <sup>b</sup>(Conselho Nacional do Meio Ambiente, CONAMA, 2025); <sup>c</sup>(National Environment Protection Council, NEPC, 2024).

Among the Northern Hemisphere countries analyzed, it is observed that they employ between four and six alert levels. The United States and China use 24-hour averages for PM<sub>2.5</sub> and PM<sub>10</sub>, and 1-hour averages for O<sub>3</sub> and NO<sub>2</sub> as criteria for activating emergency plans for CAPE. France applies the average concentration of pollutants, particularly PM<sub>10</sub> and O<sub>3</sub>, over a 24-hour period, with specific ac-

tions for each alert level. Meanwhile, the United Kingdom uses 1-hour averages for O<sub>3</sub> and NO<sub>2</sub>, 24-hour averages for PM<sub>2.5</sub> and PM<sub>10</sub>, and 8-hour averages for CO.

In the analyzed Central Hemisphere countries, five to six alert levels are observed. The alert activation criteria are based on 24-hour averages for PM<sub>2.5</sub> and PM<sub>10</sub>, and 8-hour averages for O<sub>3</sub>, adjusted for each pollutant, all of which are derived from the AQI. In countries in the Southern Hemisphere, alert levels range from 3 to 5, with activation criteria also based on the AQI in Australia, whereas Brazil and Chile rely on concentration thresholds. All these countries utilize a 1-hour average concentration for O<sub>3</sub> and NO<sub>2</sub>, and a 24-hour average for PM<sub>2.5</sub> and PM<sub>10</sub>. According to BRAGA et al. (2001), public health protection is the central priority in all plans, with specific guidelines aimed at reducing risks associated with exposure to high pollution levels.

In Tables 5(a)-(c) below, we evaluate the measures adopted by the studied countries during the activation of emergency response plans for CAPE. For all cases, we will discuss actions starting from level 3, when there is a significant health risk to the population.

**Table 5.** (a) Action Plans for each alert level outlined in Emergency Response Plans for CAPE in the Northern Hemisphere; (b) Action Plans for each alert level outlined in Emergency Response Plans for CAPE in the Central Hemisphere; (c) Action Plans for each alert level outlined in Emergency Response Plans for CAPE in the Southern Hemisphere.

(a)						
Country	Level 1	Level 2	Level 3	Level 4	Level 5	Responsibility and Implementation
USA	Intensified monitoring, recommendations for sensitive groups to avoid outdoor exertion.	Public advisories, voluntary restrictions on vehicle use, recommendations to reduce industrial activities.	Implementation of "Action Days," including vehicle use restrictions and increased industrial limitations.	Mandatory traffic restrictions, school closures, suspension of outdoor activities, further industrial emission reductions.	Partial or total evacuation of specific areas, suspension of all industrial activities, public health emergencies.	EPA in coordination with state and local governments, via State Implementation Plans (SIPs).
France		Continuous monitoring, public advisories, recommendations to use public transportation.	Vehicle use restrictions (rotation system), voluntary industrial activity limitations, educational campaigns.	Mandatory traffic restrictions, banning of highly polluting vehicles, enforced industrial limitations.	School and public area closures, severe restrictions on industrial activities, potential population confinement.	Ministry of Ecological Transition with the Police Prefecture and support from other government agencies.
United Kingdom	Monitoring, minimal public advisories, no mandatory actions.	Public advisories, encouragement to use public transport, recommendations to reduce emissions.	Vehicle restrictions in urban areas, greater focus on reducing industrial emissions, enhanced public advisories.	Mandatory traffic restrictions, school closures, severe limitations on industrial activities.	-	DEFRA in collaboration with local and regional governments, supported by public health agencies and security forces.

## Continued

China	Recommendations to reduce vehicle use, minimal public advisories.	Public advisories, voluntary industrial limitations, recommendations for sensitive groups to avoid outdoor exertion.	Vehicle restrictions (rotation system), mandatory limitations on industrial activities, reinforced public advisories.	Suspension of outdoor activities, school closures, severe industrial limitations.	Partial evacuation of affected areas, complete industrial shutdowns, confinement orders for the population.	Ministry of Ecology and Environment in coordination with national and regional authorities, with military and public health support.
(b)						
Country	Level 1	Level 2	Level 3	Level 4	Level 5	Responsibility and Implementation
Mexico	Recommendations to use public transportation, minimal public advisories.	Public advisories, recommendations to reduce vehicle use and avoid outdoor activities.	Voluntary vehicle use restrictions, industrial emissions limitations, educational campaigns.	Recommendations to use public transportation, minimal public advisories.	Mandatory traffic restrictions, suspension of industrial activities, school and public area closures.	SEDEMA in cooperation with state and local governments, with federal support if necessary.
Colombia	Minimal public advisories, recommendations for sensitive groups to avoid outdoor exertion.	Public advisories, voluntary restrictions on vehicle use, limitation of industrial activities in urban areas.	Mandatory traffic restrictions, increased industrial restrictions, recommendations to close schools.	Suspension of outdoor activities, severe industrial limitations, closure of schools and public areas.	Population confinement in severely affected areas, total suspension of industrial activities.	IDEAM in coordination with national and regional authorities, with emergency and public health support.
India	Recommendations to reduce vehicle use, minimal public advisories.	Public advisories, voluntary limitation of industrial activities, recommendations for sensitive groups to avoid outdoor activities.	Voluntary traffic restrictions, mandatory industrial emission limitations, educational campaigns.	Mandatory traffic restrictions, school closures, severe limitations on industrial activities.	Partial evacuation of affected areas, total suspension of industrial activities, confinement orders.	CPCB in coordination with national and state authorities, with emergency and public health support.
(c)						
Country	Level 1	Level 2	Level 3	Level 4	Level 5	Responsibility and Implementation
Chile		Recommendations for the population to avoid outdoor activities, encouragement to use public transportation, increased monitoring of mobile and stationary pollution sources.	Vehicle use restrictions, particularly in urban areas, suspension of industrial activities emitting high levels of pollutants, school closures.	Mandatory closure of schools and public areas, severe traffic restrictions, total prohibition of polluting industrial activities, partial confinement orders.		Ministry of the Environment (Ministerio del Medio Ambiente) with national, regional, and local coordination, including emergency measures enforcement (Ministerio del Medio Ambiente, MMA, 2024).

Continued

Brazil	In Brazil, states do not have specific emergency plans for CAPE, except for São Paulo, which has a very outdated plan (1988). CONAMA Resolution No. 491 of 2018 standardizes and provides guidance on the levels (attention, alert, and emergency); however, actions outlined in the plans are the responsibility of individual states.				Ministry of the Environment and CONAMA in coordination with state and municipal governments (Conselho Nacional do Meio Ambiente, CONAMA, 2025).
Australia	Recommendations to use public transportation, minimal public advisories.	Public advisories, voluntary limitation of industrial activities, recommendations for sensitive groups to avoid outdoor activities.	Voluntary traffic restrictions, mandatory industrial emission limitations, educational campaigns.	Mandatory traffic restrictions, school closures, severe limitations on industrial activities, partial confinement orders.	NEPC and state agencies in coordination with local governments, with support from emergency and public health services (National Environment Protection Council, NEPC, 2024).

Among the Northern Hemisphere countries analyzed, at level 3, the implementation of vehicle use restrictions is generally observed. However, there is no uniform approach regarding industrial emission sources. For instance, some countries, like France, voluntarily limit industrial emissions, while others, such as the USA and the United Kingdom, enforce industrial emission restrictions. In contrast, China mandates the limitation of industrial activities. In all cases, enhanced public advisories are issued.

At level 4, school closures are recommended in the USA, the United Kingdom, and China, with mandatory traffic restrictions and severe limitations on industrial activities being universally implemented. Finally, at level 5, the actions become more stringent, including the evacuation of affected areas, total industrial shut-downs, and population confinement orders.

In the Central Hemisphere, countries respond at level 3 with voluntary traffic restrictions in Mexico and India, while Colombia enforces mandatory vehicle restrictions alongside industrial emission limitations. All these countries promote educational campaigns.

At level 4, mandatory traffic restrictions, school closures, and severe limitations on industrial activities are generally observed. At level 5, responses vary among the countries: in Mexico, measures include mandatory traffic restrictions, suspension of industrial activities, and closure of schools and public areas. In Colombia, actions escalate to population confinement in severely affected areas and total sus-

pension of industrial activities. In India, measures include partial evacuation of affected areas, total suspension of industrial activities, and confinement orders.

These plans are often structured to enable rapid adaptation to changing conditions during critical episodes, ensuring that measures are tailored to the specific situation in each region (Companhia Ambiental do Estado de São Paulo, CETESB, 2020).

In the Southern Hemisphere, it is observed that Chile and Australia follow similar practices to those of other countries at level 3. At level 4, measures include mandatory closure of schools and public areas, severe traffic restrictions, total prohibition of polluting industrial activities, and partial confinement orders.

Brazil, on the other hand, lacks a comprehensive emergency plan for CAPE, except for São Paulo, which has a very outdated plan (1988). The current Brazilian legislation, CONAMA Resolution No. 491 of 2018, standardizes and provides guidelines on the alert levels (attention, alert, and emergency), as outlined in the previous tables. However, the implementation of actions specified in these plans is the responsibility of the states, which largely lack such measures (Conselho Nacional do Meio Ambiente, CONAMA, 2025).

### 3.3. Effective Practices vs. Emission Sources

Throughout this analysis, the importance of identifying major emission sources becomes evident, as this is an essential step for the effectiveness of emergency plans aimed at mitigating critical air pollution episodes (CAPE). This approach enables prioritization of actions that directly target the largest contributors to pollution, optimizing resources and maximizing outcomes in terms of public health and environmental protection. Refer to best practices and guidelines according to emission sources in [Table 6](#).

Emission sources vary significantly across regions and economic sectors. For example, countries like China and India face challenges associated with coal-fired power plants, whereas in Europe, urban transportation pollution plays a predominant role (Rashkeev & Shomar, 2020; Vig, Ravindra, & Mor, 2023). In this context, measures such as requiring filters in power plants and expanding public transportation in urban areas, as mentioned in [Table 6](#), are essential to address these regional particularities. Accordingly, we have consolidated the most effective practices relative to emission sources in [Table 6](#).

### 3.4. Enforcement Mechanisms and Challenges in the Implementation of Emergency Measures

The effectiveness of emergency plans for critical air pollution episodes (CAPE) depends not only on the definition of alert levels and response protocols but also on the capacity to enforce measures such as industrial shutdowns and traffic restrictions. In the countries analyzed, enforcement is carried out through inter-agency coordination involving environmental authorities, public health agencies, municipal governments, and, in some cases, security forces (United States

**Table 6.** Summary of best practices and guidelines by emission source.

Sources	Agriculture	Residential Heating	Wildfires	Mining Industry	Steel Industry	Cement Industry	Petrochemical and Chemical Industries	Foundry Industry	Burning Practices	Urban Transport-Light Vehicles	Urban Transport-Heavy Vehicles	Industrial Plants	Coal-Fired Power Plants
<b>Suggested Actions During Critical Periods</b>													
Speed limit enforcement													
Increased inspections to ensure compliance													
Control of Volatile Organic Compounds (VOCs)													
Distribution of clean heating systems													
Expansion and subsidies for public transport in urban areas													
Requirement for particle control technologies													
Requirement for SO <sub>2</sub> and NO <sub>2</sub> control technologies													
Evacuation of vulnerable areas													
Strict enforcement													
Incentives for public transport use													
Incentives for bicycle use													
Incentives for practices that replace burning													
Incentives for electric and hybrid vehicles													
Limitation of high-impact polluting processes													
Temporary restrictions on circulation in critical areas													
Prevention and containment measures													
Use of low-emission alternative fuels													
Prohibition of agricultural burning													
Temporary prohibition of agricultural waste burning													
Temporary ban on firewood use													
Prohibition of heavy diesel vehicle circulation													
Promotion of practices minimizing ammonia emissions													
Temporary reduction of operations													
Vehicle circulation restrictions													
Restriction on solvent use and high-VOC-emission products													
Restriction on burning practices													
Reduction of ammonia-based fertilizer use													
Vehicle rotation system													
Alert system to inform the population about health risks													
Subsidies for low-impact heating systems													
Substitution of coal for natural gas													

Environmental Protection Agency, EPA, 2024; Atmo France, 2024; Ministry of Ecology and Environment of the People's Republic of China, 2024).

In China and France, such measures are legally mandated and centrally applied. In China, "Red Alerts" involve mandatory orders for industrial shutdowns and strict vehicle circulation restrictions, enforced by local authorities with the backing of the central government (Ministry of Ecology and Environment of the People's Republic of China, 2024). In France, the alert system is managed by the Police Prefecture, which is responsible for enforcing restrictions at alert levels 3 and 4 (Atmo France, 2024).

In the United States, enforcement responsibilities are decentralized and assigned to state and local agencies, following federal guidelines established by the Clean Air Act (United States Environmental Protection Agency, EPA, 2024). The so-called "Action Days" combine mandatory regulations with voluntary actions, which may limit their effectiveness depending on regional compliance and available local resources.

In Latin American and Global South countries such as Mexico, Colombia, and Chile, greater challenges to enforcement are observed. These include limited monitoring infrastructure, regional disparities in institutional capacity, and public resistance to mobility restrictions or industrial controls (Government of Mexico, 2024; IDEAM, 2024; Ministerio Del Medio Ambiente, MMA, 2024). In Santiago (Chile), enforcement is strict during critical episodes, while other regions show inconsistencies. In India, rapid urban growth and logistical challenges hinder the enforcement of measures such as vehicle rotation and industrial shutdowns (Central Pollution Control Board, CPCB, 2025).

Socioeconomic factors, such as dependence on individual transportation or informal labor, also limit adherence to restrictive measures. In Brazil, the absence of an updated national plan and the fragmentation of state-level legislation (e.g., CONAMA Resolution 491/2018) reduce the ability to implement coordinated actions during critical episodes (Conselho Nacional Do Meio Ambiente, CONAMA, 2025).

Therefore, although enforcement mechanisms vary, common challenges include: 1) Strengthening legal and institutional frameworks; 2) Coordination among different levels of government; 3) Public engagement and awareness. These elements are essential to improving the effectiveness of emergency plans to address CAPE.

### 3.5. Global Perspective on Emergency Plans for CAPE

In Northern Hemisphere countries, significant progress has been made in the formulation and implementation of emergency plans for critical air pollution episodes (CAPE). The United States stands out for the robustness of its legal framework, with the Clean Air Act (CAA) guiding both preventive and corrective measures. The use of the AQI by the EPA exemplifies how technology can aid in rapid decision-making. Despite notable reductions in regulated pollutants, re-

gional disparities—particularly in large urban areas like Los Angeles—continue to challenge the plan’s effectiveness (U.S. Environmental Protection Agency (EPA), 2023).

In Europe, France and the United Kingdom have adopted approaches that integrate legislation, monitoring, and direct action. France’s PRQA and London’s ULEZ have proven effective in reducing fine particles and nitrogen dioxide, respectively. However, limited public adherence in France and uneven implementation in the UK highlight that the effectiveness of policies depends on greater harmonization and public acceptance (Ministère de la Transition Écologique (MTE) & Department for Environment, 2023).

China, dealing with critical pollution levels, has implemented stringent measures, such as factory closures and traffic restrictions, resulting in significant reductions in PM<sub>2.5</sub>. However, the sustainability of these actions, given their economic impact, raises questions about the long-term viability of restrictive strategies (Ministry of Ecology and Environment of the People’s Republic of China, 2024).

In the Central Hemisphere, countries like Mexico, Colombia, and India exhibit significant variations in the scope and efficiency of their plans. Mexico’s Proaire combines real-time monitoring and restrictive measures but faces structural limitations, particularly in peripheral regions. This scenario reflects the challenge of universalizing policies in countries with pronounced regional disparities (Government of Mexico, 2024).

In contrast, Colombia has advanced with innovative systems, such as electric public transportation in Bogotá, which not only mitigates pollution but also promotes sustainable solutions. However, challenges related to intersectoral coordination limit the implementation of broader measures. India, facing extreme air pollution conditions, must balance its environmental regulations with economic growth, highlighting a recurring conflict in emerging economies (Ministère de la Transition Écologique (MTE) & Department for Environment, 2023).

Southern Hemisphere countries face significant challenges due to structural gaps and a lack of national coordination. In Brazil, CONAMA Resolution 491/2018 establishes air quality standards, but implementation remains limited, with local initiatives, such as those in São Paulo, still isolated. This reflects the lack of integration among states and the need for a consolidated national plan (Conselho Nacional do Meio Ambiente, CONAMA, 2025).

Conversely, Chile and Australia have shown progress in specific areas. Santiago enforces strict restrictions during critical episodes, while Australia implements robust measures based on the National Environment Protection Measure (NEPM), excelling in responding to events such as wildfires. Nonetheless, the recurrence of extreme weather events in Australia underscores the complexity of forecasting and planning effective actions (Ministerio del Medio Ambiente, MMA, 2024).

Overall, emergency plans for CAPE display a wide diversity of approaches, re-

flecting the legislative, technological, and socioeconomic realities of each country. Northern Hemisphere countries demonstrate more robust strategies, grounded in advanced technologies and integrated policies. In the Central Hemisphere, efforts are evident in adapting plans to challenging urban contexts, while the Southern Hemisphere struggles with the implementation of comprehensive policies.

Global results indicate that the combination of advanced monitoring, public engagement, and sustainable solutions—such as the electrification of public transport—are critical elements for the success of such plans. However, disparities in resources and capacities among countries highlight the need for greater international cooperation, technology transfers, and financial support to tackle the global challenges of air pollution.

The comparative analysis highlighted best practices and failures in air pollution control policies in regions like China, India, and Chile, comparing them to models adopted in developed countries such as the USA and Australia (Blackman, Li, & Liu, 2018).

According to Sun, Du, & Li (2021), this synthesis contributes to identifying best practices and strategies that can be applied in other regions, aiming to improve environmental public policies and promote environmental justice.

#### 4. Conclusion

The analysis of emergency plans for critical air pollution episodes (CAPE) across different regions worldwide highlights the importance of integrated strategies adapted to local realities to mitigate the impacts of air pollution on public health and the environment. Countries that have achieved greater success in managing these episodes share key practices that should be considered essential guidelines for the development and improvement of public policies.

Real-time monitoring of air pollution levels is a central element for rapid and effective responses. Systems like the USA's AQI demonstrate how advanced technologies can enable authorities to anticipate critical episodes and implement preventive actions. Moreover, clear communication protocols, using multiple channels to inform the population in an accessible manner, are indispensable for engaging citizens and promoting individual protective measures, especially for vulnerable groups such as children, the elderly, and individuals with respiratory diseases. In practical terms, restricting the use of private vehicles and promoting low-emission public transportation during high pollution periods have proven effective in regions like London and Santiago. Additionally, measures to temporarily suspend industrial activities and control burning practices, as adopted in China and Australia, illustrate the importance of directly addressing major emission sources during pollution peaks.

Another critical aspect is the need for robust interagency collaboration involving environmental agencies, transportation departments, health agencies, and various levels of government. Such coordination ensures integrated and effective responses, minimizing operational gaps and maximizing results. Following each

critical episode, systematic evaluations of the measures taken allow for adjustments and improvements, ensuring the continuous evolution of strategies.

Finally, building effective emergency plans requires not only adapting successful practices to local contexts but also a constant commitment to innovation, evaluation, and integration. By adopting these guidelines, countries can reduce the immediate impacts of air pollution while contributing to the creation of more resilient and healthier urban environments.

## Acknowledgements

This research was supported by Universidade SENAI CIMATEC and Scientific and Technological Development—CNPq, the National Agency for Petroleum, Natural Gas and Biofuels (ANP), the ANP Human Resources Program (PRH 27.1), and FINEP, program manager, national funds through the Brazilian Foundation for Science and Technology.

## Disclaimer/Publisher's Note

The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

- Alola, A. A., Muoneke, O. B., Okere, K. I., & Obekpa, H. O. (2023). Analysing the Co-Benefit of Environmental Tax Amidst Clean Energy Development in Europe's Largest Agrarian Economies. *Journal of Environmental Management*, *326*, Article ID: 116748. <https://doi.org/10.1016/j.jenvman.2022.116748>
- Atmo France (2024). *La qualité de l'air en France*.
- Barraza, F., Lambert, F., Jorquera, H., Villalobos, A. M., & Gallardo, L. (2017). Temporal Evolution of Main Ambient PM<sub>2.5</sub> Sources in Santiago, Chile, from 1998 to 2012. *Atmospheric Chemistry and Physics*, *17*, 10093-10107. <https://doi.org/10.5194/acp-17-10093-2017>
- Blackman, A., Li, Z., & Liu, A. A. (2018). Efficacy of Command-and-Control and Market-Based Environmental Regulation in Developing Countries. *Annual Review of Resource Economics*, *10*, 381-404. <https://doi.org/10.1146/annurev-resource-100517-023144>
- Braga, A. L. F., Saldiva, P. H. N., Pereira, L. A. A., Menezes, J. J. C., Conceição, G. M. S., Lin, C. A. et al. (2001). Health Effects of Air Pollution Exposure on Children and Adolescents in São Paulo, Brazil. *Pediatric Pulmonology*, *31*, 106-113. [https://doi.org/10.1002/1099-0496\(200102\)31:2<106::aid-ppul1017>3.0.co;2-m](https://doi.org/10.1002/1099-0496(200102)31:2<106::aid-ppul1017>3.0.co;2-m)
- Brazil Reports (2024). *Brazil Has World's Worst Air Quality This Week, Holds 75% of All Wild-Fires Burning in South America* (pp. 1).

- Central Pollution Control Board (CPCB) (2025). *National Air Quality Monitoring Programme (NAMP)*.
- Companhia Ambiental Do Estado de São Paulo (CETESB) (2020). *Relatórios de Qualidade do Ar-CETESB São Paulo*.
- Conselho Nacional Do Meio Ambiente (CONAMA) (2025). *Resolução Conama 491/2018—Padrões de Qualidade do Ar*.
- da Silva, I., de Almeida, D. S., Hashimoto, E. M., & Martins, L. D. (2020). Risk Assessment of Temperature and Air Pollutants on Hospitalizations for Mental and Behavioral Disorders in Curitiba, Brazil. *Environmental Health*, 19, Article No. 79.  
<https://doi.org/10.1186/s12940-020-00606-w>
- DEFRA-Department for Environment, Food & Rural Affairs (2024). *UK-AIR: Air Information Resource*.
- Deryugina, T., Moore, F., & Tol, R. S. J. (2021). Environmental Applications of the Coase Theorem. *Environmental Science & Policy*, 120, 81-88.  
<https://doi.org/10.1016/j.envsci.2021.03.001>
- Gouveia, N., & Mendes, F. M. (2004). Health Risks Associated with Air Pollution in São Paulo, Brazil. *Revista de Saúde Pública*, 38, 695-700.
- Government of Mexico (2024). *Índice Metropolitano de la Calidad del Aire (IMECA). Sistema de Monitoreo Atmosférico (SIMAT)*.
- Hoelting, K. R., Morse, J. W., Gould, R. K., Martinez, D. E., Hauptfeld, R. S., Cravens, A. E. et al. (2024). Opportunities for Improved Consideration of Cultural Benefits in Environmental Decision-Making. *Ecosystem Services*, 65, Article ID: 101587.  
<https://doi.org/10.1016/j.ecoser.2023.101587>
- IDEAM-Instituto de Hidrología, Meteorología y Estudios Ambientales (2024). *Sistema de Información de Calidad del Aire*.
- Imran Tajammul, K. (2017). Critical Review and Comparative Analysis of the Government of Punjab’s “Policy on Controlling Smog, 2017” with Counterpart Strategies in London, Beijing and Los Angeles. *Journal of Development Policy Research & Practice (JoDPRP)*, 7, 181-202. <https://doi.org/10.59926/jodprp.vol07/09>
- Khalid, A. M., & Okitasari, M. (2023). Enabling Effective Climate Action Plans at City Level: Insights from India’s Metropolitan Cities. *Sustainable Cities and Society*, 98, Article ID: 104812. <https://doi.org/10.1016/j.scs.2023.104812>
- Lee, B., Kim, B., & Lee, K. (2014). Air Pollution Exposure and Cardiovascular Disease. *Toxicological Research*, 30, 71-75. <https://doi.org/10.5487/tr.2014.30.2.071>
- Liu, Q., & Ma, C. (2025). Eco-Efficient Transition Pathways for Urban Transportation: A Case Study of Chengdu’s Decarbonization Initiatives. *Sustainability*, 17, Article No. 4949. <https://doi.org/10.3390/su17114949>
- Martins, L. D., da Silva Júnior, C. R., Solci, M. C., Pinto, J. P., Souza, D. Z., Vasconcellos, P. et al. (2012). Particle Emission from Heavy-Duty Engine Fuelled with Blended Diesel and Biodiesel. *Environmental Monitoring and Assessment*, 184, 2663-2676.  
<https://doi.org/10.1007/s10661-011-2142-3>
- Masri, S., Jin, Y., & Wu, J. (2022). Compound Risk of Air Pollution and Heat Days and the Influence of Wildfire by SES across California, 2018-2020: Implications for Environmental Justice in the Context of Climate Change. *Climate*, 10, Article No. 145.  
<https://doi.org/10.3390/cli10100145>
- Maung, T. Z., Bishop, J. E., Holt, E., Turner, A. M., & Pfrang, C. (2022). Indoor Air Pollution and the Health of Vulnerable Groups: A Systematic Review Focused on Particulate Matter (PM), Volatile Organic Compounds (VOCS) and Their Effects on Children and

- People with Pre-Existing Lung Disease. *International Journal of Environmental Research and Public Health*, 19, Article No. 8752. <https://doi.org/10.3390/ijerph19148752>
- Ministère De La Transition Écologique (MTE); Department for Environment, Food & Rural Affairs (2023). *Code de l'environnement*. <https://www.legifrance.gouv.fr>
- Ministerio de Ambiente y Desarrollo Sostenible (2017). *Resolución 2254 de 2017*.
- Ministerio del Medio Ambiente (MMA) (2024). *Ley 19.300 sobre Bases Generales del Medio Ambiente*.
- Ministry of Ecology and Environment of the People's Republic of China (2024). *Air Quality Index (AQI): A Guide to Air Quality and Your Health*. Air Quality Monitoring United States Environmental Protection Agency (EPA).
- National Environment Protection Council (NEPC) (2024). *National Environment Protection Measure for Ambient Air Quality (NEPM-AAQ)*.
- Paton-Walsh, C., Rayner, P., Simmons, J., Fiddes, S. L., Schofield, R., Bridgman, H. et al. (2019). A Clean Air Plan for Sydney: An Overview of the Special Issue on Air Quality in New South Wales. *Atmosphere*, 10, Article No. 774. <https://doi.org/10.3390/atmos10120774>
- Rashkeev, S. N., & Shomar, B. (2020). A Simple Reaction-Diffusion Model for Initial Stages of Biofouling in Reverse Osmosis Membranes. *Environmental Research*, 190, Article ID: 110000. <https://doi.org/10.1016/j.envres.2020.110000>
- Shin, S., Bai, L., Burnett, R. T., Kwong, J. C., Hystad, P., van Donkelaar, A. et al. (2021). Air Pollution as a Risk Factor for Incident Chronic Obstructive Pulmonary Disease and Asthma. a 15-Year Population-Based Cohort Study. *American Journal of Respiratory and Critical Care Medicine*, 203, 1138-1148. <https://doi.org/10.1164/rccm.201909-1744oc>
- Sun, L., Du, J., & Li, Y. (2021). A New Method for Dividing the Scopes and Priorities of Air Pollution Control Based on Environmental Justice. *Environmental Science and Pollution Research*, 28, 12858-12869. <https://doi.org/10.1007/s11356-020-11160-w>
- U.S. Environmental Protection Agency (EPA) (2023, February 28). *National Ambient Air Quality Standards (NAAQS)*. <https://www.epa.gov/naaqs>
- United States Environmental Protection Agency (EPA) (2024). *Clean Air Act Overview* (p. 1).
- Vardoulakis, S., Jalaludin, B. B., Morgan, G. G., Hanigan, I. C., & Johnston, F. H. (2020). Bushfire Smoke: Urgent Need for a National Health Protection Strategy. *Medical Journal of Australia*, 212, Article No. 349. <https://doi.org/10.5694/mja2.50511>
- Vig, N., Ravindra, K., & Mor, S. (2023). Environmental Impacts of Indian Coal Thermal Power Plants and Associated Human Health Risk to the Nearby Residential Communities: A Potential Review. *Chemosphere*, 341, Article ID: 140103. <https://doi.org/10.1016/j.chemosphere.2023.140103>
- World Health Organization (2021). *Air Pollution and Health: 7 Million Deaths Annually*. [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health)
- Zhang, H., Qian, W., Yang, S., Li, X., & Guo, S. (2025). Leveraging Environmental Information Disclosure for Sustainable Cities: Quasi-Experimental Evidence from China. *Sustainability*, 17, Article No. 4817. <https://doi.org/10.3390/su17114817>

---

## Abbreviations

The following abbreviations are used in this manuscript:

---

AP	Action plans
AQI	Air Quality Indices
Bom	Bureau of Meteorology
CAA	Clean Air Act
CAPE	Critical air pollution episodes
COPD	Chronic obstructive pulmonary disease
CPCB	Central Pollution Control Board
DEFRA	Department for Environment, Food & Rural Affairs
EPA	Environmental Protection Agency
IDEAM	Institute of Hydrology, Meteorology, and Environmental Studies
IMECA	Metropolitan Air Quality Index
INCA	National Air Quality Index
INMET	National Institute of Meteorology
NAMP	National Air Quality Monitoring Programme
NEPC	National Environment Protection Council
O <sub>3</sub>	Ozone
PM	Particulate matter
PPDA	Prevention and Decontamination Plan
RAQI	Regional Air Quality Index
SIMAT	Atmospheric Monitoring System
SINCA	Red de Monitoreo del Ministerio del Medio Ambiente
Sips	State Implementation Plans
Sisar	National Air Quality Information System
SO <sub>2</sub>	Sulfur dioxide
USA	United States of America
WHO	World Health Organization

---