

Air Quality Legislation in Australia and Canada—A Review

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Abstract: Air pollution is a pervasive global issue affecting human health, ecosystems, and the environment. This paper reviews the evolution and implementation of air quality legislation in Australia and Canada, providing a comparative analysis of their approaches to managing air pollution. Both countries have established robust legal frameworks to address air quality issues, involving governmental policies, regulatory mechanisms, and collaborative efforts among stakeholders. Australia began its air quality regulation at the state level in the 1950s, evolving into a national framework with the National Environment Protection Measure for Ambient Air Quality in 1998. In contrast, Canada centralized its efforts with the Clean Air Act in 1971, complemented by the National Air Pollution Surveillance program. Key findings reveal that, while both nations have achieved significant improvements in air quality, challenges remain in addressing the broader impacts of air pollution, such as climate change and health-related economic burdens. Australia's air quality standards are generally more stringent than Canada's for particulate matter but more relaxed for sulfur dioxide, nitrogen dioxide, and ozone. Both countries employ advanced air quality monitoring and reporting systems, with Australia's Air Quality Index and Canada's Air Quality Health Index providing critical public health information. The study highlights the need for continuous improvement and a more integrated approach to air quality management. By examining the legislative and regulatory landscapes of Australia and Canada, this paper offers valuable insights for other countries striving to enhance their air quality governance and mitigate the adverse effects of air pollution on a global scale.

Keywords: air quality policy; air quality management; air protection



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1. Introduction

The visible effects of environmental degradation, resulting from human activities such as deforestation, urbanization, industrialization, climate change, and resource overexploitation, became evident as early as the 1960s. However, global attention remained largely indifferent until these impacts began to affect powerful nations [1]. The roots of contemporary air pollution awareness can be traced back to the environmental movements of the 1970s, an essential decade that marked a turning point in public consciousness regarding environmental degradation. Landmark events, such as the first Earth Day [2] in 1970 and the publication of influential works like Rachel Carson's "Silent Spring", stimulated public support for environmental protection [3].

The issue of air pollution and its extensive impact on both flora and fauna, as well as human health, is widely recognized [4,5]. The direct consequences encompass a myriad of health ailments, ranging from cardiovascular [6] and neurological disorders [7] to respiratory issues [8]. Moreover, air pollution has been linked to declines in animal populations [9], alterations in algae activity [10], soil degradation [11], and the emission of greenhouse gases, all of which contribute to ozone depletion. Given the pervasive nature of air pollution, its mitigation has become a paramount task for environmental conservation institutions. Improving air quality is crucial because it profoundly influences all facets of the natural world, including human health and biodiversity.

Despite their membership in the Commonwealth and shared challenges and interests, comparative studies between these nations are scarce. Limited comparative examination exists, except for Michael Jeffery's work [12], which focused on a single province from each nation. This paper will focus on the environmental policies and measures implemented by these two prominent nations, Australia and Canada, to address the issue of ambient air pollution. These countries, which are ranked fifth and seventh in terms of global land area, respectively, possess expansive territories that amplify the significance of their actions in combating climate change and air pollution on a global scale. Several similarities and differences between Australia and Canada are discussed below to provide a rationale for this comparative analysis.

Both Canada and Australia are high-income, industrialized nations with well-established environmental policies. However, Canada and Australia differ significantly in terms of geography, climate, and population density. Canada, with its vast geography and varying climate conditions, experiences different types of air quality issues across its provinces and territories. For example, urban areas like Toronto and Vancouver face challenges related to transportation emissions, while rural regions may struggle with agricultural runoff and industrial pollution. Australia, on the other hand, contends with a different set of challenges, including the effects of climate change, bushfires, and dust storms, which can significantly impact air quality.

Both Australia and Canada experience periods of hot, dry weather, which can lead to an increased risk of wildfires. In Australia, summer months bring extreme heat, while in Canada, especially in the western provinces, particularly in British Columbia and Alberta, summer and fall bring high temperatures and dry conditions conducive to wildfires. These produce significant amounts of smoke, which can affect air quality and public health over vast areas, even far from the fire's source. This gives rise to respiratory issues, particularly for vulnerable populations. It also causes significant property damage, loss of infrastructure, and displacement of residents [13].

The recent bushfire crisis highlighted the vulnerabilities of Australian cities to poor air quality, prompting urgent discussions about the effectiveness of existing policies. By examining how each country addresses its specific challenges, our study can identify best practices and lessons learned that can inform policy improvements.

Canada and Australia both operate under federal systems of governance, which inherently influence how environmental policies are developed and implemented. In both countries, authority over air quality management is divided between federal, provincial, or territorial governments (in Canada) and state governments (in Australia). This multi-layered governance structure allows for the examination of how various levels of government coordinate their efforts to address air pollution. Despite their similarities, Canada and Australia face unique environmental challenges that necessitate tailored approaches to air pollution management. This comparison will allow us to explore how two similar governance structures (federal systems) have evolved their air quality management strategies differently. Understanding these distinctions provides valuable lessons for other developed nations with diverse environmental contexts.

Canada and Australia have relatively low population densities compared to developing countries like China and India; however, both countries have developed sophisticated air quality monitoring, legislation, and public health systems. Their approaches to air quality governance, particularly their integration of public health indices (e.g., Canada's AQHI and Australia's AQI), can offer transferable insights for developing countries, especially regarding public engagement, data transparency, and air quality monitoring systems. These governance mechanisms can serve as a model for more populous developing countries seeking to refine their air quality strategies. We believe the core principles of air quality management—such as stakeholder engagement, cross-jurisdictional collaboration, and adaptive legislative frameworks—are applicable across different contexts. The purpose of narrowing the focus on Canada and Australia is to analyze how these principles have been successfully implemented in two diverse yet well-regulated environments. Other nations,

even those with higher population densities, can learn from these adaptive approaches to enhance their own policy frameworks.

Both Canada and Australia play active roles in international environmental agreements, which is significant within the Commonwealth context. Their experiences can be valuable for other Commonwealth nations that share similar governance structures but may lack the resources to implement robust air quality policies. Highlighting these countries' contributions to international frameworks on air quality can offer a broader perspective on how global cooperation influences national policies (Figure 1).

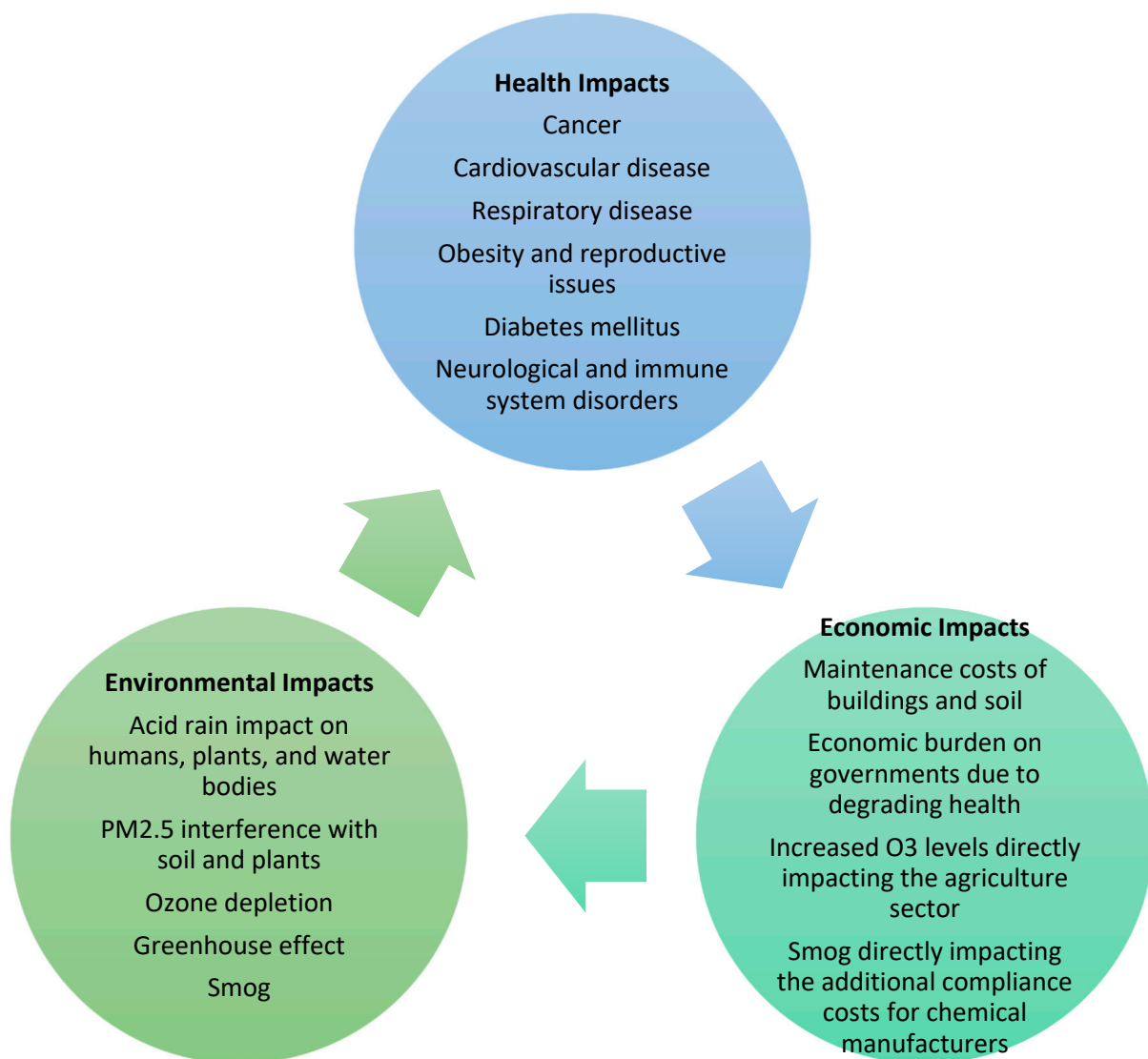


Figure 1. Impact of air pollution on other elements of the environment.

2. Important International Air Quality Legislation

Following the 1952 London smog, which resulted in approximately 12,000 premature deaths [14], the Clean Air Act was introduced in the United Kingdom in 1956 [15]. Initially, the focus was primarily on the health risks associated with air pollution, which led to the widespread adoption of more dispersed chimneys to reduce their impacts [16]. By the late 1960s, Swedish research found that atmospheric pollution acidifies rivers, threatening the survival of aquatic organisms and reducing crop yields and forest growth rates [17]. Subsequently, international research into the consequences of air pollution, such as acid rain [18], ground-level ozone [19], and nitrogen deposition [20], broadened the scope of attention to encompass the broader ecosystem.

With the increase in international awareness of the transboundary nature of air pollution and its impacts on both human health and ecosystems, the Convention on Long-Range Transboundary Air Pollution (LRTAP) was established in 1979, providing a regional framework for Europe, North America, and Russia, and former East Bloc countries to reduce transboundary air pollution [21]. This agreement currently has 51 parties and 8 protocols. In addition to limiting emissions of sulfur compounds, nitrogen oxides, and volatile organic compounds, it also includes heavy metals, particulate matter, and black carbon. This collective effort has reduced emissions of a range of harmful substances by 40% to 80% and has contributed to the development of international environmental law.

Compared to the Long-Range Transboundary Air Pollution (LRTAP) Convention, the Montreal Protocol, established in 1987, shifted its focus to protecting the ozone layer [22]. The objective was to reduce and ultimately eliminate the production and consumption of substances harmful to the ozone layer, such as hydrochlorofluorocarbons (HCFCs), which are primarily used in refrigeration, air conditioning, and foam applications. This protocol represents the first universal approval from both developed and developing countries in United Nations history and is acclaimed as the most successful international agreement. It has led to the gradual phase-out of nearly 100 harmful ozone-depleting substances in production and consumption worldwide and is expected to restore stratospheric ozone to pre-Antarctic ozone hole levels by the middle of this century [23].

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was established, focusing on addressing global warming and climate change and stabilizing greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system [24]. Since its entry into force in 1994, the Convention has established principles for action based on the differentiated responsibilities of countries. For example, the 43 countries listed in Annex I (e.g., the US, the EU, and Australia, most of which are developed countries) were required to reduce their national emissions back to 1990 levels by the year 2000. However, most countries did not achieve this target [25].

Subsequently, the 1997 Kyoto Protocol was adopted as an annexed agreement to the UNFCCC, providing legally binding emission targets for Annex I countries and promoting cooperation between developed and developing countries. Nevertheless, the Kyoto Protocol primarily placed emission reduction responsibilities on developed countries without requiring specific commitments from developing countries, such as China and India, leading some developed countries to perceive the protocol as unfair [26]. In 2001, the United States withdrew from the agreement [27]. Overall, due to economic, political, and technological challenges, emission reduction efforts have lagged behind planned targets.

Another subsidiary agreement of the UNFCCC is the Paris Agreement, which was adopted in 2015 and represents the latest achievement of the United Nations climate change negotiations [28]. The Paris Agreement sets a long-term temperature goal of maintaining the global average temperature increase to well below 2 °C and pursuing efforts to limit this temperature to 1.5 °C above the preindustrial level [29]. The emission reduction commitments made under the agreement are expected to reduce air pollution on a global scale [30]. As of 2022, the UNFCCC has 198 parties.

Simultaneously, nations worldwide began implementing air quality legislation to address local air pollution concerns. These legislations often reference guidelines provided by the World Health Organization (WHO) as scientific benchmarks. A summary of the air pollution concentration limits in mainstream regions is provided below (Table 1).

Table 1. Ambient air quality standards in key countries and regions.

Ambient Air Pollutant	Averaging Period	WHO	Australia	Canada	China	EU	UK	US
CO (mg/m ³)	15 min	100	-	-	-	-	-	-
	1 h	35	-	-	10	-	-	40.1
	8 h	10	10.3	-	-	10	10	10.3
	24 h	4	-	-	4	-	-	-
NO ₂ (ug/m ³)	1 h	200	150.4	112.8	200	-	200	188
	24 h	25	-	-	80	200	-	-
	annual	10	28.2	31.96	40	40	40	-
O ₃ (ug/m ³)	1 h	-	-	-	200	-	-	-
	8 h	100	127.4	121.52	160	120	100	137.2
	6 months	60	-	-	-	-	-	-
SO ₂ (ug/m ³)	10 min	500	-	-	-	-	-	-
	15 min	-	-	-	-	-	266	-
	1 h	-	262	183.4	500	350	350	196.5
	24 h	40	-	-	150	125	125	-
	annual	-	52.4	13.1	60	-	-	-
Pb (ug/m ³)	3 months	-	-	-	1	-	-	0.15
	annual	0.5	-	-	0.5	0.5	0.25	-
PM ₁₀ (ug/m ³)	24 h	45	50	-	150	50	50	150
	annual	15	25	-	70	40	18	-
PM _{2.5} (ug/m ³)	24 h	15	25	27	75	-	-	35
	annual	5	8	8.8	35	20	10	12
Polycyclic Aromatic Hydrocarbons (expressed as concentration of Benzo(a)pyrene) (ng/m ³)	24 h	-	-	-	2.5	-	-	-
	annual	0.12	-	-	1	1	0.25	-
Benzene (ug/m ³)	annual	-	-	-	-	5	3.25	-
As (ng/m ³)	annual	6.6	-	-	-	6	-	-
Cd (ng/m ³)	annual	5	-	-	-	5	-	-
Ni (ng/m ³)	annual	25	-	-	-	20	-	-

In the above table, Arsenic (As), Cadmium (Cd), and Nickel (Ni) are ubiquitous pollutants present in the atmosphere. The main sources of these heavy metals are industrial processes, electricity generation, and fuel combustion.

These air quality limits vary in stringency and format, with options including hourly or daily averages, and are often updated periodically based on evolving scientific understanding and pollution control. While legislation and standards may differ, the collective aim remains to safeguard both human health and the environment from the adverse effects of air pollution.

However, a robust air quality governance framework involves not only setting standards but also requiring institutional frameworks, including air quality monitoring systems

and mechanisms for institutional responsibility and enforcement. Given the similarity between Australia and Canada in terms of air pollution challenges, this paper compares the policies and institutions that govern air pollution in these two countries.

3. Development of Air Quality Legislation in Australia

3.1. A Brief History of Australian Legislation

While historical efforts to regulate air pollution trace back to the fourteenth century, the modern acknowledgment of the magnitude of this challenge has only recently emerged. Early legislative endeavors predominantly targeted the prohibition of dark smoke and offensive odors, with governmental bodies assuming responsibility for overseeing and restricting activities that could generate public nuisances or endanger public health.

Australia's push for legislation addressing air pollution commenced in 1957 with the introduction of the Clean Air Act in Victoria. Drawing inspiration from British precedents, particularly the 1957 Clean Air Act of the United Kingdom, Australia's legislation closely mirrored industrial provisions. Subsequently, the enactment of the Clean Air Act in New South Wales in 1961 reflected the findings of a Smoke Abatement Committee established in 1955, aligning legislative developments with committee recommendations. Queensland and Western Australia followed suit, adopting legislation largely akin to that of New South Wales, while South Australia incorporated amendments of a more general nature into its Health Act. Tasmania, conversely, lacked specific clean air legislation, although some regulatory mechanisms existed within the framework of the Public Health Act and the Local Government Act [31].

The Commonwealth started active engagement in air quality regulation only after the establishment of the Senate Select Committee on Air Pollution in April 1968. Even so, the Commonwealth's role was merely to encourage, coordinate, and complement state programs through financial assistance, research initiatives, and the dissemination of information. It was as late as 1998 that the Commonwealth government took charge of and began participating in regulatory decision-making to protect human health and wellbeing.

Since then, developments in Australia's regulatory landscape have been part of a global trend toward implementing sophisticated legislative frameworks aimed at preventing and mitigating environmental pollution while promoting the conservation of natural resources. On 26 June 1998, Australia implemented its inaugural National Environment Protection Measure for Ambient Air Quality, commonly known as the Air NEPM (DCCEEW, 2022). This policy established national benchmarks for six criteria air pollutants: carbon monoxide (CO), ozone (O₃), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), lead, and particulate matter (PM₁₀). The standards delineated within the Air NEPM held legal force across all tiers of Australian governance [32]. Subsequently, the NEPM was amended in 2003 to incorporate advisory reporting standards pertaining to finer particulate matter, specifically PM_{2.5} [33].

The National Environmental Protection Council (NEPC) conducted a review of the National Environment Protection Measure for Ambient Air Quality (NEPM) in 2011, marking the first comprehensive assessment since its inception in 1998. The findings from this review highlighted significant health implications associated with prevailing levels of air pollution in Australian urban areas. The existing standards fell short of ensuring adequate protection of human health. Consequently, the review proposed 23 recommendations for reform, aiming to address these deficiencies. These recommendations were slated for prioritization and response through the formulation of the National Plan for Clean Air (NPCA) by the Council of Australian Governments Standing Council on Environment and Water (SCEW), with an intended delivery date in 2014. However, by the end of 2016, the Clean Air Plan had not materialized [34].

Subsequently, in December 2015, the NEPC resolved to amend the AAQ NEPM, effectuated in February 2016, with strengthened national standards for PM_{2.5} and PM₁₀. Further enhancements to standards for ozone, nitrogen dioxide, and sulfur dioxide were adopted in May 2021.

In April 2014, the Commonwealth Environment Minister Greg Hunt proposed the development of a National Clean Air Agreement (NCAA) to address air quality challenges comprehensively. On 15 December 2015, the NCAA was enacted, serving as a foundational framework for national cooperation on air quality issues. This agreement aims to achieve health, environmental, and economic benefits through collaborative efforts between industry and government at various levels [35].

In April 2018, federal, state, and territory Environment Ministers endorsed a work plan for 2018–2020 to specify roles, responsibilities, and timelines for implementing actions outlined in the NCAA (NEPC, 2019b). A commitment was made to conduct formal reviews of the work plan every two years to ensure relevance and accountability for delivery. The latest work plan for the National Clean Air Agreement for 2021–2023 was released on 10 May 2022.

To support national air quality policy and programs aligned with the NCAA and its work plan, a National Air Quality Technical Advisory Group (NATAG) was established in 2018. NATAG provides guidance and advice to the Air Project Management Group, which is composed of representatives from the Australian Government and each state and territory, to achieve national air quality objectives [36]. Table 2 lists the enactment of air quality legislation in Australia in chronological order.

Table 2. Australian national air quality legislation in chronological order.

Australian Air Quality Legislation	Year Enacted
Senate Select Committee formed	1968
National Environment Protection Council Act	1994
National Environment Protection Measure (NEPM)	1998
Review of NEPM	2011
AAQ NEPM amended	2016
National Clean Air Agreement	2015
Air Project Management Group	2015
National Clean Air Agreement 2018–2020 Work Plan	2018
National Air Quality Technical Advisory Group (NAQTAG)	2018
National Clean Air Agreement 2021–2023 Work Plan	2022

3.2. National Regulatory Agencies for Air Quality in Australia

At the national level in Australia, key agencies such as the Department of Climate Change, Energy, the Environment and Water (DCCEEW) and the National Environment Protection Council (NEPC) play pivotal roles in shaping air quality management policies and strategies [37].

The NEPC, established under the National Environment Protection Council Act in 1994, is tasked with two primary functions: the formulation of National Environment Protection Measures (NEPMs) and the evaluation and reporting of the implementation and effectiveness of these measures across participating jurisdictions. NEPMs serve as overarching protocols for monitoring and reporting air quality, as well as guiding interventions and strategies to combat air pollution.

On the other hand, the DCCEEW serves as the Commonwealth jurisdictional environmental agency, with a primary focus on administering legislation related to air quality management and reporting. It collaborates with states and territories to uphold and enhance Australia's air quality standards. Additionally, the DCCEEW supports air quality research through initiatives such as the National Environment Science Program and offers policy advice on air quality matters to the Australian government as needed.

Furthermore, the Department of Infrastructure, Transport, Regional Development, Communications and the Arts assumes responsibility for policy and standard development concerning vehicle safety, emissions, vehicle noise, and fuel consumption labeling. It oversees the administration of Australian Design Rules (ADRs), which are national standards governing vehicle safety, antitheft measures, and emissions. Additionally, this department provides input on fuel quality issues, manages environmental criteria for fuel tax credits for heavy diesel vehicle operators, and hosts and manages the Green Vehicle Guide website, which provides information on environmentally friendly vehicles. Table 3 presents the national framework for air quality in Australia in a tabular form.

Table 3. Australian national framework for air quality policy.

Framework/Agreements	Administering Body
National Environment Protection (Ambient Air Quality) Measure	National Environment Protection Council (NEPC)
National Environment Protection (Pollutant Inventory) Measure	National Environment Protection Council (NEPC)
National Clean Air Agreement	Department of Climate Change, Energy, the Environment and Water (https://www.dcceew.gov.au/) (accessed on 3 October 2024)
Australian Design Rules	Department of Infrastructure, Transport, Regional Development, Communications and the Arts
Green Vehicle Guide	Department of Infrastructure, Transport, Regional Development, Communications and the Arts

3.3. State Regulatory Agencies on Air Quality in Australia

In Australia, the federal government assumes responsibility for national standards and the regulation of imports concerning air quality-related matters, while individual states and territories are tasked with managing air quality within their respective jurisdictions. These regional entities enact laws and strategies to address pollution, particularly from industrial sources, and report against national ambient air quality standards aimed at safeguarding public health.

Victoria led Australia's air quality regulation by establishing the Victorian Clean Air Act of 1958, which targeted both gaseous and particulate pollution from industrial sources [31]. The Environment Protection Authority (EPA) Victoria took over regulatory duties in 1970, with a focus on mitigating the harmful effects of pollution and waste on human health and the environment. In 2021, the EPA underwent a transformation to modernize its framework, emphasizing a prevention-based approach to environmental protection.

Similarly, New South Wales (NSW) enacted the Clean Air Act in 1961 following recommendations from the Smoke Abatement Committee. The NSW Environment Protection Authority (EPA) was established in 1991 as an independent agency, with a focus on enhancing air quality through a comprehensive legislative and programmatic framework. NSW boasts the most extensive air quality monitoring network in Australia, guided by national health-based standards [38].

Queensland and Western Australia (WA) adopted Clean Air Acts resembling NSW's legislation, with administration centralized under their respective air pollution councils. Queensland's Environmental Protection Agency (EPA) oversees air quality management [39], while WA's Department of Water and Environment Regulation operates an air quality monitoring network [40]. Both states adhere to the National Environment Protection (Ambient Air Quality) Measure.

South Australia introduced its Clean Air Act in 1984, mandating controls on domestic incineration and integrating air quality assessments into planning decisions. The Environment Protection Act of 1993 streamlined regulatory frameworks, with the Envi-

Environment Protection Authority (EPA) playing a pivotal role in enforcing environmental regulations [41].

Tasmania's Environment Protection Authority (EPA) administers the Environmental Management and Pollution Control Act of 1994, overseeing environmental regulation. The Environmental Protection Policy (Air Quality) of 2004 provides a strategic framework for managing emissions.

Overall, state- and territory-level agencies such as the EPA play crucial roles in implementing air quality regulations, working alongside federal agencies to ensure comprehensive air quality management across Australia.

4. Development of Air Quality Legislation in Canada

4.1. A Brief History of Canadian Legislation

Canada's approach to air quality management has undergone significant evolution, driven by advances in scientific understanding, heightened public awareness, and the necessity for policy interventions. A notable incident highlighting the severity of air pollution in Canada occurred during the "Gray Cup smog" of November 1962. This smog event, lasting five days, resulted in a marked increase in hospital admissions in southern Ontario and necessitated the postponement of a football game in Toronto due to severely impaired visibility [42]. Atmospheric conditions during the prolonged Arctic winter, such as light winds and temperature inversions, exacerbate the accumulation of air pollutants from more southerly regions. Another critical environmental challenge was the battle against acid rain, which became a pressing concern in the late 1970s and early 1980s.

Early initiatives predominantly targeted industrial emissions and urban pollution, culminating in the establishment of the Federal Clean Air Act in 1971 [43]. This Act empowered Environment Canada to regulate cases of significant health risks or to prevent violations of international agreements. The National Air Pollution Surveillance (NAPS) program, established in 1969, serves as the primary source of ambient air quality data in Canada. The NAPS program, which now consists of nearly 260 stations across 150 rural and urban communities, feeds into the Canada-Wide Air Quality Database (CWAQD). Managed by the Environment and Climate Change Canada (ECCC) in collaboration with provincial, territorial, and regional government networks, the NAPS is integral to various initiatives, including the Air Quality Health Index (AQHI), Canadian Environmental Sustainability Indicators (CESI), and the US-Canada Air Quality Agreement. Subsequent legislative advancements, such as the Canadian Environmental Protection Act (CEPA) of 1999 and the implementation of the Air Quality Management System (AQMS), have expanded regulatory jurisdiction and enhanced pollution control measures.

In response to Canada-US efforts to address acid rain, further authority was granted to the federal government in 1980 to regulate emissions that could harm individuals' health in another country. The 1985 Eastern Canada Acid Rain Program introduced a regional emissions cap for Canada's seven easternmost provinces, alongside individual provincial caps. The federal government played a pivotal role in facilitating intergovernmental cooperation, conducting research and monitoring, providing subsidies to support industrial pollution abatement, and engaging with the US to mitigate transboundary emission flows. These efforts culminated in the Canada-US Air Quality Agreement (AQA) in 1991.

The 1988 Canadian Environmental Protection Act (CEPA88) replaced the Clean Air Act, introducing the List of Toxic Substances to regulate health hazards, a provision that persists in today's CEPA. CEPA88, however, mandated that the Minister ensure that not all provinces were ready to implement similar requirements under their laws before federal intervention. This limitation was later lifted in the current CEPA, enacted in 1999 [44].

The years 2006–2007 witnessed significant regulatory proposals for federal involvement in air pollution regulation. In April 2006, Environment Canada issued a notice mandating pollution prevention plans for certain industrial facilities, with plans to introduce regulations by 2015. Additionally, in October 2006, the government published a Notice of Intent (NOI) to regulate climate change and air pollution, aiming to establish

emissions targets and regulate industrial emissions by the end of 2010. Subsequent actions in 2007 included the publication of a Regulatory Framework for Air Emissions, outlining plans for mandatory reduction targets, emission trading systems, and improvements in air quality and health, emphasizing federal action despite the importance of consultations with provinces and stakeholders [45].

Building upon the 2006 Notice of Intent (NOI), the government released the Regulatory Framework for Air Emissions in 2007, a significant milestone in Canadian environmental policy. This framework introduced the first-ever regulations imposing mandatory and enforceable reduction targets for greenhouse gases and air pollutants emitted by major industrial sources. It outlined plans for setting national and sectoral emission caps, establishing a domestic emission trading system, and anticipating improvements in air quality and public health resulting from these regulated emission reductions. While stressing the importance of consultations with provinces and stakeholders, the focus remained primarily on unilateral federal action. This initiative spurred intense federal–provincial engagement in air quality management, leading to the development of the Air Quality Management System (AQMS). Despite the initial plans outlined in the 2007 framework, the envisioned approach to industrial emission regulation did not materialize. Instead, the AQMS, developed collaboratively by industry representatives, health and environmental organizations, and federal, provincial, and territorial governments, gained traction. Implemented in October 2012, the AQMS prioritizes provincial regulation as the frontline, with federal oversight ensuring consistency through base-level industrial emission requirements (BLIERS). Recent policy initiatives under the AQMS include regulations on multisector air pollutants and volatile organic compounds (VOCs) from petroleum refining, aligning with ongoing calls for proactive federal involvement in air quality management, albeit within the collaborative framework of the AQMS.

Presently, Canada’s air quality policy is characterized by a multilevel governance framework in which federal, provincial, and municipal authorities collaborate to address a wide array of air pollution sources and associated challenges. It is noteworthy that Canada ranks among the countries with some of the lowest air pollution concentrations globally, according to the World Health Organization’s 2016 report (Table 4).

Table 4. Canadian national air quality legislation in chronological order.

Canadian Air Quality Legislation	Year Enacted
Clean Air Act	1971
Convention on Long Range Transboundary Air Pollution	1979
Leaded Gasoline Regulation Amended	1984
Canadian Environmental Protection Act Proclaimed	1988
Leaded Gasoline Regulation introduced	1990
Northern Contaminants Program	1991
Toxic Substances Management Policy and National Action Program on Climate Change	1995
Signed Rotterdam Convention	1998
Canadian Environmental Protection Act Passed, celebration of Clean Air Day Annually	1999
Canada–US Air Quality Agreement (Ozone Specific) signed	2000
Enforcement Branch created for Wildlife and pollution enforcement	2005

Table 4. *Cont.*

Canadian Air Quality Legislation	Year Enacted
Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations	2010
Ozone-depleting Substances and Halocarbon Alternatives Regulations	2016
Greenhouse Gas Pollution Pricing Act	2018
Healthy Environment and Healthy Economy Act introduced	2020

4.2. National Regulatory Agencies for Air Quality in Canada

Since the 1970s, Canadian national leaders have recognized the critical importance of air quality and have established various governmental bodies to address environmental issues. Environmental laws in Canada are administered at the federal, provincial, and municipal levels, with nongovernmental environmental agencies playing a significant role in their development and enforcement. The Environment and Climate Change Canada (ECCC), formerly known as Environment Canada (EC), is the federal department responsible for coordinating environmental policies and programs, as well as protecting and enhancing the natural environment and renewable resources [44].

Under the Canadian Constitution, environmental management is a shared responsibility between federal and provincial governments. Provinces primarily manage resource-related issues, including permitting industrial waste discharge, while the federal government oversees the regulation of toxic substances. The ECCC is instrumental in managing hazardous waste cleanup and oil spills and providing technical assistance both domestically and internationally. It also addresses international environmental issues, such as Canada–USA air agreements, and engages in international accords such as the Montreal and Kyoto Protocols, despite Canada’s withdrawal from the latter in 2011.

Provincially, each environment ministry handles environmental affairs, often through the Canadian Council of Ministers of the Environment (CCME), harmonizing and setting national standards. At the municipal level, cities such as Montreal and Greater Vancouver directly regulate sources of air pollution, whereas most municipalities focus on public awareness initiatives. Regional concerns vary, with Mississauga, Ontario, prioritizing air quality, and Halifax, Nova Scotia, focusing on wastewater management.

The Enforcement Branch of the ECCC ensures compliance with federal statutes, with enforcement officers appointed under section 217(3) of the Canadian Environmental Protection Act. These officers have the full authority of peace officers and are categorized as Environmental Enforcement or Wildlife Enforcement officers. Environmental Enforcement Officers oversee compliance with the Canadian Environmental Protection Act and pollution-related sections of the Fisheries Act, while Wildlife Enforcement Officers enforce the Migratory Birds Convention Act, Canada Wildlife Act, Species at Risk Act, and the Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act.

Environmental Enforcement Officers are equipped with batons and OC sprays, while Wildlife Enforcement Officers also carry firearms. Additionally, the minister can designate members of the Royal Canadian Mounted Police, fishery officers, park officers, customs officers, and provincial and territorial conservation officers as enforcement officers, granting them the powers vested in Department of Environment Officers [44].

4.3. State Regulatory Agencies for Air Quality in Canada

The Government of British Columbia engaged in consultations with various stakeholders, including the public, businesses, NGOs, and other interested parties, during the development of legislation. Local governments also have the authority to enact bylaws controlling emissions, such as backyard burning. Air quality management involves additional processes and legislation, including the environmental assessment process under the Environmental Assessment Act, which evaluates potential project impacts and develops measures to mitigate them. With the ongoing development of related regulations, the

government has enacted crucial acts and regulations to reduce greenhouse gas emissions and combat climate change. Airshed management planning, involving multiple government jurisdictions and stakeholders, is another key approach to addressing air pollution in British Columbia. This collaborative effort includes federal, provincial, regional, and municipal governments, alongside international joint organizations, responsible for making and enforcing laws, issuing permits, and setting standards (British Columbia, 2022). The federal government's role, defined by the Canadian Environmental Protection Act, covers emission sources beyond provincial authority, providing research support and advice to aid in strategy development. Provincially, British Columbia regulates pollution through legislation such as the Environmental Management Act, which addresses air quality and other environmental issues, with the authority to develop standards, regulate sources, and mandate airshed management plans. British Columbia also participates in Canada-wide standard development through the Canadian Council of Ministers of the Environment. Regional and municipal governments have the power to pass bylaws and regulate emissions, with Metro Vancouver delegated authority to manage air quality within its boundaries. International actions and agreements, such as the Montreal Protocol and the Canada–United States Air Quality Agreement, play a crucial role in addressing shared air quality management concerns [46].

As part of its provincial air quality management strategy aimed at preserving air quality and ensuring long-term sustainability, Manitoba has implemented various key programs and strategies. These include environmental licensing processes to assess and regulate industries and developments impacting air quality, ensuring that new facilities adhere to stringent environmental standards. The province conducts compliance monitoring and enforcement activities, requiring industries to perform air monitoring and sampling when necessary. Manitoba actively participates in setting air quality objectives and guidelines, collaboratively developing national criteria and establishing provincial standards. Through cooperation with Environment and Climate Change Canada, Manitoba conducts ambient air quality monitoring in selected urban and targeted areas. The province engages in national discussions and projects on air quality issues and provides accessible air quality information to the public in real time, including participation in the Canada Air Quality Health Index forecasting program, aiding individuals in making informed decisions to protect their health [47].

Ambient air quality objectives (AAQOs) play a vital role in Alberta's air quality management framework, serving to safeguard the health of residents and the environment. Alberta Environment and Parks (AEP) oversees the establishment and enforcement of these objectives, which are regularly compared to actual air quality measurements. AAQOs are utilized in various ways, including assessing compliance near major industrial emission sources, setting approval conditions for regulated facilities, evaluating construction proposals, guiding special air quality surveys, informing the public through an Air Quality Health Index, and reporting on the state of Alberta's atmospheric environment. Regular reviews ensure that AAQOs remain up to date, with new objectives developed as needed to address emerging concerns [48].

In 2012, ministers of the environment from all provinces and territories in Canada, excluding Quebec, reached an agreement to implement the National Air Quality Management System (AQMS) aimed at addressing cumulative air quality effects across the country. The AQMS sets the Canadian Ambient Air Quality Standards (CAAQS) for key air contaminants and provides a framework to maintain ambient air quality below these standards. Alberta has opted to fulfill its commitment to the AQMS through its regional planning process outlined in the Land Use Framework (LUF) and the Land Stewardship Act (LSA). The LUF divides the province into seven land-use planning regions, each requiring a regional plan that establishes objectives for economic, environmental, and social aspects, including air quality management strategies. These regional air quality management frameworks will align with the national AQMS objectives. Quebec does not implement the AQMS due to its federal industrial emission requirements duplicating Quebec's regulations; however,

Quebec is developing other components of the system. The Calgary Region Airshed Zone (CRAZ), situated within the South Saskatchewan Region, operates under the SSRP and manages air quality through its Particulate Matter and Ozone Management Plan, which is reviewed and updated every five years. With the introduction of the new CAAQS for nitrogen dioxide (NO₂), ozone (O₃), and fine particulate matter (PM_{2.5}) in 2020, Alberta will rely on the CRAZ and its members to ensure compliance with these standards in the region [49].

5. Comparison of Australia's Air Pollution Legislation and Policies with Those of Canada

The comparison between air protection policies in Australia and Canada reveals both similarities and differences. Both countries have established regulatory frameworks to control emissions from various sources, including industrial facilities and vehicles. These regulations typically involve emission standards, monitoring requirements, and enforcement mechanisms to ensure compliance. Additionally, both Australia and Canada have set emission reduction targets through legislation or international agreements, often accompanied by specific strategies and action plans to achieve them.

Despite slight differences in governance structures, both Australia and Canada prioritize the reduction of air pollution as a crucial element of their environmental policies. Strategies are tailored to target specific air pollutants known to adversely affect the environment and human health, with regulations aligned with guidelines from organizations such as the World Health Organization (WHO). Below are comparisons between the governance structure, policy, standards, initiatives, and stakeholder engagement in Canada and Australia.

5.1. Governance Structure and Responsibility Delineation

Canada operates under a clear multilevel governance structure where responsibilities for air quality management are delineated across federal, provincial, and municipal levels. The federal government, through Environment and Climate Change Canada (ECCC), oversees national standards and regulates toxic substances, while provinces manage resource-related issues and municipalities handle local air quality concerns. This structure allows each level of government to play a distinct and complementary role, ensuring that air quality regulations are tailored to local needs and conditions. Similarly, Australia has a federal system, but its approach centres on establishing national standards through the National Environment Protection Measures (NEPMs), which provide a consistent framework across the country. States and territories are then responsible for adapting and enforcing these standards based on local conditions. This model balances national consistency with regional flexibility, allowing states to tailor their regulations while maintaining a unified national standard.

5.2. Stakeholder Engagement

Canada's air quality policy development is characterized by extensive stakeholder engagement. The inclusion of a wide range of stakeholders—including the public, businesses, NGOs, and local governments—ensures that policies are well-rounded and widely accepted. This collaborative approach is essential for creating effective and equitable environmental legislation. Australia also emphasizes stakeholder engagement, particularly through the National Clean Air Agreement (NCAA), which fosters collaboration across all levels of government and with industry stakeholders. The NCAA's framework ensures that air quality management is consistent and aligned with national goals, while also accommodating input from diverse stakeholders, enhancing transparency and public participation.

5.3. National Frameworks and Standards

The National Air Quality Management System (AQMS) in Canada is a robust framework that sets Canadian Ambient Air Quality Standards (CAAQS) for key pollutants.

This system ensures that these standards are met through regionally tailored strategies, allowing provinces to address specific air quality issues while adhering to national benchmarks. Australia's national framework is underpinned by the NEPMs, which establish standards for key pollutants. The flexibility provided to states and territories to adapt these standards according to local conditions ensures that the regulations remain relevant and effective across diverse environments. This approach is reinforced by the regular review and amendment of these standards, ensuring alignment with the latest scientific evidence.

The key similarities are that both countries operate under a federal structure where national guidelines are enforced by local or regional authorities. Both have national air quality standards (NEPMs in Australia and CAAQS in Canada) that define acceptable levels of key pollutants. Public access to real-time air quality information and reporting is emphasized in both legal frameworks to keep citizens informed, while both countries have penalties and enforcement measures in place for industries and other polluters who fail to comply with air quality standards.

The key differences between the two countries are that Australia's regulatory approach is more centralized through NEPMs, while Canada's system allows more flexibility for provinces and territories to set additional or stricter standards. Canada's Air Quality Management System incorporates cross-border considerations due to its proximity to the United States, influencing how transboundary air pollution is regulated.

5.4. Types of Pollutants Measured

Canada focuses on monitoring five pollutants—SO₂, NO₂, PM_{2.5}, O₃, and VOCs—within its Canadian Ambient Air Quality Standards (CAAQS). In contrast, Australia's ambient air quality monitoring encompasses seven pollutants, namely SO₂, NO₂, PM_{2.5}, PM₁₀, O₃, CO, and lead, which occasionally exceed the recommendations set forth by the World Health Organization (WHO). Notably, while Australia's standards are generally more stringent than those of Canada for certain pollutants such as PM_{2.5}, they are more relaxed for SO₂, NO₂, and ozone (Boyd, 2006). Table 5 provides basic information on the maximum permissible levels of air quality indicators in both countries, reflecting their shared commitment to safeguarding air quality.

Table 5. Comparison of current air quality standards/guidelines between Australia and Canada.

Pollutant/Averaging Time	Australia (NEPM, 2021)	Canada (CAAQS, 2020)	WHO (2021)
SO₂	ppb	ppb	ppb
1 h mean	100	70	-
3 h mean	-	-	-
24 h mean	20	-	40
Annual mean	15	5	-
NO₂	ppb	ppb	ppb
1 h mean	80	60	-
3 h mean	-	-	-
24 h mean	-	-	25
Annual mean	15	17	10
PM₁₀	µg/m ³	-	µg/m ³
24 h mean	25	-	15
Annual mean	50	-	45
PM_{2.5}	µg/m ³	µg/m ³	µg/m ³
24 h mean	25	27	15
Annual mean	8	8.8	5

Table 5. *Cont.*

Pollutant/Averaging Time	Australia (NEPM, 2021)	Canada (CAAQS, 2020)	WHO (2021)
CO	ppm		ppm
8 h mean	9	-	-
1 h mean	-	-	-
24 h mean	-	-	4
Ozone	ppb	ppb	ppb
8 h mean	65	60	100
1 h mean	-	-	
Lead	$\mu\text{g}/\text{m}^3$		
Annual	0.5	-	-
NEPH or Visibility	10^{-4} m^{-1}		
1 h mean	$3 \times 10^{-4} \text{ m}^{-1}$ (300 Mm^{-1})	-	-

5.5. Air Quality Standards

Australia’s ambient air quality standards are derived from a comprehensive analysis of global scientific research on air quality and human health, incorporating standards from international bodies such as the WHO. Tailored to Australian conditions such as climate, geography, and demographics, these standards are established with consideration for Australians’ likely exposure to major air pollutants. Australia employs a singular air quality range, denoted as the “maximum acceptable concentration”, with limit values for key pollutants such as CO, SO₂, and NO₂ not to be exceeded more than once annually.

In contrast, Canada employs the CAAQS, which is structured with four management levels indicating the severity of pollutant presence in specific air zones. These levels prompt escalating air quality management actions as pollutant concentrations increase, ensuring that CAAQS are not misconstrued as thresholds to tolerate pollution but rather as targets necessitating proactive measures to maintain clean air zones (Environment and Climate Change, 2020).

5.6. Air Quality Assessment and Reporting

Canada adopts the Air Quality Health Index (AQHI) as a national tool to communicate health risks associated with air pollution. Developed by health and environmental experts, the AQHI assesses the combined health risks of ground-level ozone, PM_{2.5}, and NO₂ on a scale of 1 to 10+, reflecting the immediate health risk posed by the air pollution mixture. Unlike previous indices, the AQHI acknowledges that health effects can occur even at low pollution levels, providing a unified scale across the country [50].

The assessment and reporting of air quality in Australia are facilitated through the Air Quality Index (AQI), which is regulated by states under the guidelines of the National Environment Protection Measure for Ambient Air (NEPM). Despite variations in reporting methods among states, the AQI traditionally quantifies pollutant levels as a percentage of NEPM standards, with an AQI of 100 representing the national standard and values surpassing 100 indicating poor air quality. Post-2020, the AQI transitioned to the air quality category (AQC), introducing a revised health activity guide and reducing air quality categories from six to five, aligning with concentrations of criterion air pollutants and visibility standards.

5.7. Integration with Broader Environmental and Public Health Strategies

Air quality management in Canada is integrated with broader environmental and public health strategies, such as through the Canadian Environmental Protection Act (CEPA). This integration ensures that air quality is addressed within a wider context

of environmental sustainability and public health, linking air quality management with efforts to mitigate climate change, protect biodiversity, and improve public health outcomes. Similarly, Australia's air quality policies are embedded within broader environmental and public health frameworks, such as the National Environment Science Program and various environmental protection acts. This holistic approach ensures that air quality management is not treated in isolation but as part of a comprehensive strategy to protect the environment and public health.

5.8. Technical Advisory and Expert Support

While Canada does not have a single national advisory group like Australia's NATAG, it benefits from a range of scientific and technical bodies that provide guidance on air quality issues. The AQMS itself is a product of collaborative efforts between government, industry, and health organizations, ensuring that policies are science-driven and responsive to emerging challenges. In Australia, the National Air Quality Technical Advisory Group (NATAG) plays a crucial role in providing expert guidance and support for air quality initiatives. This group ensures that policies are informed by the latest scientific research and best practices, maintaining a science-driven approach to air quality management.

5.9. Local and Regional Air Quality Management

Canadian provinces and municipalities play an active role in managing air quality at the local level. For example, British Columbia and Montreal have implemented localized regulations and public awareness campaigns tailored to their specific air quality challenges. This localized management is crucial in addressing region-specific pollution sources and ensuring public engagement. While Australia's states and territories have significant autonomy in implementing air quality standards, the focus on localized management is less pronounced compared to Canada. However, Australia's approach ensures that regional differences are considered, particularly through state-based regulations and localized monitoring efforts.

5.10. International Collaboration and Agreements

Canada is highly proactive in international environmental agreements, such as the Canada–United States Air Quality Agreement, which addresses transboundary air pollution. This international collaboration is vital for managing air quality in regions where pollution crosses borders, ensuring that Canada's air quality policies are aligned with global standards. Australia also engages in international collaboration, particularly in the Asia-Pacific region, to address transboundary air pollution issues. However, Australia's focus has been more on regional and national frameworks rather than on extensive international agreements like those between Canada and the United States.

5.11. Enforcement and Compliance Mechanisms

Canada has developed strong enforcement and compliance mechanisms, including specialized enforcement officers with the authority to ensure adherence to air quality regulations. These mechanisms are crucial for maintaining the integrity of air quality standards and ensuring that regulations are effectively enforced. Australia's enforcement mechanisms are also robust, with clear accountability measures under frameworks like the NCAA. The implementation of work plans and progress tracking ensures that policies are not only well-crafted but also effectively enforced, although the emphasis on specialized enforcement units is less pronounced compared to Canada (Table 6).

Table 6. A summary of national air quality framework and legal compliance structure for Australia and Canada.

Australia	Canada
<p>National Environment Protection Measures (NEPMs) The primary mechanism for air quality regulation is the Ambient Air Quality NEPM, which sets national standards for pollutants such as carbon monoxide, ozone, sulfur dioxide, nitrogen dioxide, lead, and particulate matter (PM₁₀ and PM_{2.5}). These standards apply across the country, and each state and territory is responsible for monitoring and reporting air quality to ensure compliance with these national benchmarks. The NEPM includes requirements for consistent monitoring, reporting, and public communication on air quality levels across Australia.</p>	<p>Canadian Environmental Protection Act (CEPA) CEPA gives the federal government authority to regulate substances that contribute to air pollution, including toxic substances and greenhouse gases. Under CEPA, regulations are set for pollutants like volatile organic compounds (VOCs), sulfur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter (PM). The Air Quality Management System (AQMS), developed collaboratively between federal, provincial, and territorial governments, provides a framework for managing air quality, including the establishment of air quality objectives for pollutants.</p>
<p>State and Territory Legislation Each state and territory in Australia has its own Environmental Protection Agency (EPA) responsible for enforcing air quality regulations based on both NEPM guidelines and local air quality laws. These state laws require industries to obtain licenses and permits to regulate emissions, ensuring that air pollution from industrial and commercial activities complies with standards. Penalties for non-compliance include fines, legal action, and requirements to implement remedial measures.</p>	<p>Provincial and Territorial Regulation Provinces and territories are responsible for implementing federal air quality standards and developing additional regulations tailored to local needs. Enforcement mechanisms include permits, emissions caps, and penalties for non-compliance. Industrial facilities must often undergo routine inspections and adhere to emission reporting requirements.</p>
<p>Monitoring and Public Reporting Each jurisdiction is responsible for monitoring ambient air quality. This data is reported to the public in real time and is also aggregated into annual reports that assess compliance with national standards. Regulatory bodies such as the EPAs enforce compliance through inspections, monitoring programs, and ensuring industries meet emission limits.</p>	<p>Monitoring and Public Reporting Environment and Climate Change Canada (ECCC) operates a national air quality monitoring network that collects data on air pollution and reports it to the public. Provinces and territories also maintain their own monitoring networks and produce air quality indices (AQI) to inform the public about local air quality conditions. Enforcement of regulations is conducted through regular inspections, emissions audits, and in cases of non-compliance, corrective actions or penalties are issued.</p>
<p>Public Health and Environmental Impact Local governments often develop additional measures that align with state and national policies to control sources of air pollution such as vehicle emissions, industrial emissions, and wood smoke. Specific projects, such as low-cost sensor networks or urban air quality improvement initiatives, may be implemented to address local air quality issues.</p>	<p>Public Health and Environmental Focus Local governments and non-governmental organizations (NGOs) often work in tandem with provincial and federal bodies to reduce air pollution in urban areas. Programs like AirCare in British Columbia (which tested vehicle emissions) and public awareness campaigns help reduce air pollution from vehicles, residential heating, and industrial activity.</p>

6. Conclusions

This review paper adds several new insights into the understanding of air quality legislation and its implementation by comparing Australia’s and Canada’s approaches. This nuanced comparison offers insights into the different regulatory priorities of the two nations, revealing that Australia’s air quality standards are generally more stringent for particulate matter (PM_{2.5} and PM₁₀) but more relaxed for pollutants like sulphur dioxide (SO₂), nitrogen dioxide (NO₂), and ozone compared to Canada.

The paper highlights the advanced air quality monitoring systems in both countries, with Australia using the Air Quality Index (AQI) and Canada employing the Air Quality Health Index (AQHI). These systems provide real-time public health information and are key tools in promoting public awareness and protection from air pollution.

Canada’s air quality policies are influenced by cross-border pollution, particularly from the United States, which adds a layer of complexity to its regulatory framework. In

contrast, Australia's approach is more regionally focused, reflecting fewer transboundary pollution challenges.

Both Australia and Canada have developed comprehensive air quality policy frameworks that reflect their unique governance structures and environmental contexts. Canada's approach is characterized by a clear delineation of responsibilities across government levels, extensive stakeholder engagement, and strong enforcement mechanisms. Australia, on the other hand, emphasizes national consistency with regional flexibility, regular review and updating of standards, and integration with broader environmental strategies. While each country has strengths that the other could learn from, both frameworks demonstrate a commitment to maintaining and improving air quality through innovative and collaborative approaches.

Further Research

The paper identifies a research gap regarding the economic ramifications of air pollution on human health but does not delve deeply into this aspect. Incorporating data or case studies on the economic costs of poor air quality (e.g., healthcare costs, lost productivity) would provide a more comprehensive understanding of the consequences of air pollution.

While the paper covers the legislative frameworks, it could benefit from a deeper exploration of the implementation challenges faced by both countries. This could include case studies of failed policies or regulations and how enforcement mechanisms could be strengthened. The paper could improve by discussing the role of emerging technologies such as low-cost sensors, satellite monitoring, and AI in enhancing air quality monitoring and management. This would provide a forward-looking perspective on the future of air quality governance.

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