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Different Paths to Clean Air

Global Insights for India's Reform Agenda

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INTRODUCTION

Poor ambient air quality in India has been a long-standing public policy issue, perpetuating a public health crisis. An under-capacitated, poorly equipped, and under-funded environmental regulatory regime lies at the heart of this complex air pollution problem. Previous works have examined their capacities, constraints, and performance in isolation to understand why frontline environmental regulators in India struggle to meet their mandate. This issue brief aims to place these analyses in the context of global comparators with a view to analysing and learning from diverse air quality regimes, and charting a roadmap to build a capable and forward-looking environmental regulatory regime in India.

Indian environmental regulators were constituted under the Water (Prevention and Control of Pollution) Act in 1974.[1] The Central Pollution Control Board (CPCB) is the apex regulator operating at the national level with the primary functions of national programme design, guideline development, and standard-setting. State Pollution Control Boards (SPCBs) and Pollution Control Committees (PCCs) operate within States and Union Territories, respectively, and are tasked with the implementation of pollution control programmes and regulating industrial emissions and effluents, among a range of other responsibilities. Originally created to regulate water pollution, their responsibilities were later expanded to include air and other types of pollution under the Air (Prevention and Control of Pollution) Act, 1981, and the Environment (Protection) Act, 1986.[2] Within the domain of air quality management, these regulators are tasked with setting ambient air quality standards, monitoring ambient air quality, regulating industrial air pollution, and implementing the National Clean Air Programme (NCAP) and other measures that improve air quality.[3]

Since their creation over 50 years ago, India has experienced high levels of economic, industrial, and population growth. For context, India has seen an almost 8-fold increase in GDP and a 17-fold increase in its industrial output since 1975, along with a growth in its population of about 130% in the same time period.[4] This has coincided with an increase in the types and sources of environmental pollution, and consequently, the responsibilities of SPCBs. Today, SPCBs and PCCs are the frontline agencies that are charged with regulating a wide variety of environmental challenges, including air, water and noise pollution, and also managing various kinds of waste (such as plastics, biomedical, and hazardous waste).

Aerial view of smog in Delhi. Credit: Annanya Mahajan, SFC

This significant increase in their workload has not been accompanied by a commensurate increase in internal capacity. Several studies over the last three decades carried out by governments, academia, and civil society have highlighted serious shortcomings – these regulators have been found to be lacking in technical knowledge, staffing capacity, infrastructure, and funds.[5]

Several performance evaluations and government audits of these regulators have articulated a clear need for institutional reform.[6] Arguments in favour of institutional reform have largely focused on plugging gaps in capacity and infrastructure that were in many cases gauged based on prevailing conditions over two decades ago. The question, however, is whether reform that focuses solely on plugging these manpower and infrastructure gaps would be sufficient in accounting not just for past and current challenges, but also challenges that are likely to emerge in the coming decades. The ability of these agencies to adapt to these emergent challenges will be an essential component in their necessary evolution.

To this end, a dual approach is essential: the first approach, more inward-looking in scope, involves understanding the duties assigned to SPCBs and assessing their effectiveness in performing them. This approach is best used for studying the *de facto* versus *de jure* status of these regulators, and has been the default approach followed in many previous research publications and audits.[7]

The second, a complementary approach – broader and outward-looking in scope – involves going beyond the domestic context in an attempt to learn from others' experiences and contexts to inform our own. Air pollution is not a new issue, and decades of work elsewhere on regulatory reform and policy development can aid us in leapfrogging some of the growing pains associated with understanding and implementing policy to address what are emergent challenges for India.

This is the approach we take in this brief. We study environmental regulatory regimes from Brazil, China, Germany, Mexico, Poland, South Korea, and the USA to better understand how these countries address their varied air pollution challenges. These countries were chosen to be somewhat comparable and relevant to India, and the group is therefore a mix of countries with large economies, a history of dealing with high air pollution, rapid industrialisation coupled with high GDP growth, and belonging to both the Global North and the South. The varied source profiles, regulatory institutions, history of air pollution policymaking, and differing governance regimes (unitary versus federal) in these countries also present differing approaches that could inform Indian policymaking on air quality. It is also important to note here that historically, international environmental regulatory expertise has supported Indian environmental regulators since their inception, and this effort carries forward that legacy.[8]

The disparate nature of air quality regulation and governance across countries makes direct comparison between countries difficult. As a result, for this brief, we have chosen to highlight specific trends and examples that offer useful insights worth considering for application in the Indian context. With this brief as a foundation, we hope to dig deeper into the regulatory regimes of these countries in order to obtain further insights in future publications.

Smog over the Yamuna river in the National Capital Region. Credit: Annanya Mahajan, SFC

Table 1: Sampling parameters for the 7 countries.
Source: Authors' Compilation[9]

COUNTRIES	GDP (Billion USD ,2022)	AVERAGE ANNUAL AMBIENT $PM_{2.5}$ CONCENTRATION ($\mu g/m^3$, 2023)	POPULATION IN MILLIONS (2023)	RATIONALE FOR SELECTION
BRAZIL	1,920	13.9	211	Major developing economy from the Global South
CHINA	17,963	32.6	1,423	Major economy with history of high air pollution and rapid industrialisation
GERMANY	4,082	7.8	85	Largest EU economy with large-scale industrialisation
INDIA	3,417	47.1	1,438	Baseline
MEXICO	1,465	17	130	Developing economy with history of high air pollution, similar geography and airshed issues
POLAND	688	12.9	39	Developing economy with air pollution issues stemming from similar energy sources
SOUTH KOREA	1,674	25.9	52	Major developed economy with history of rapid industrialisation
USA	25,440	8.6	343	Major developed economy with long history of air pollution management

ANALYSIS

1. Science plays a fundamental role in establishing strict, health-based air quality standards.

The primary marker to gauge air quality management is the ambient air quality levels of a country. Therefore, regardless of the contextual factors such as the level of background pollution, an air quality regulatory regime must start by developing science-backed ambient air quality standards, in order to determine acceptable levels of air quality exposure for its citizens and ensure that ambient air quality remains at healthy levels.

As a result, air quality standards vary across countries. However, what is clear is that air quality is a significant concern even for countries with much lower ambient air quality levels than India. This is reflected in their ambient air quality standards and also their average ambient air pollution concentrations. Two of these eight countries (as shown in Figure 1) have set $PM_{2.5}$ standards that meet the World Health Organisation (WHO) interim target level-4 (annual average ambient levels of 10 $\mu g/m^3$) — which is the penultimate level before the WHO Air Quality Guidelines level of 5 $\mu g/m^3$. The USA maintains a 9 $\mu g/m^3$ annual standard for $PM_{2.5}$, averaged over 3 years. In China, $PM_{2.5}$ standards vary by first-class (nature reserves and other specially protected areas), and second-class (general commercial and residential areas) zones, mandating annual $PM_{2.5}$ standards at 15 $\mu g/m^3$

and 35 μg/m^3, respectively.[10] Germany and Poland have their $PM_{2.5}$ standards set at 25 μg/m^3 and 20 μg/m^3 respectively. Both countries are on the path to meet the European Union (EU) guideline of 10 μg/m^3 by 2030. India is the only country where its ambient air quality standards do not meet any current WHO interim target levels.

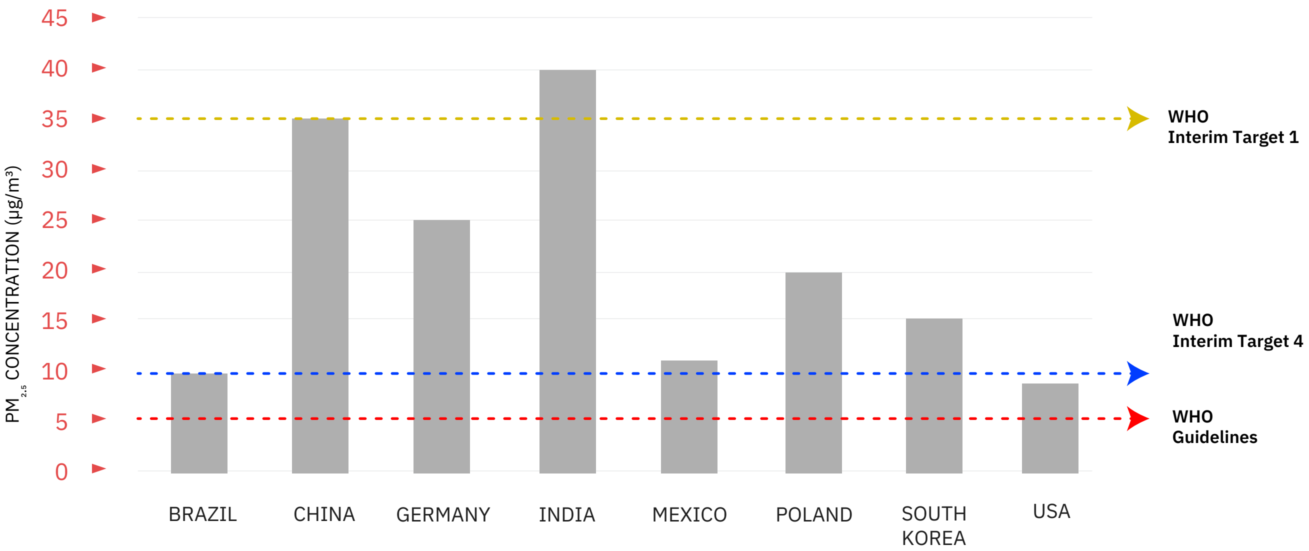


Figure 1: Comparison of national standards for annual average ambient $PM_{2.5}$ concentration (μg/m^3).
Source: Authors' Compilation[11]

How these standards are set and revised also varies across country contexts with one common foundational principle – the centrality of evidence on health impacts. In the USA, for example, the Environmental Protection Agency's (US-EPA) Clean Air Scientific Advisory Committee (CASAC) is mandated to carry out a robust, multi-stage review of the current science for each pollutant every five years.[12] China follows no defined periodicity, but has updated its air quality standards to include new pollutants with each revision with a view to bringing them in line with global guidelines and health evidence.[13] China's current ambient quality standards were issued back in 2012, but are due for a revision soon.[14] With respect to Germany and Poland, as members of the EU, they are required to meet the European Commission's directives on ambient air quality that are underpinned by extensive impact assessment reports, stakeholder consultations, and strengthening provisions for monitoring, modelling, and plan development.[15] Across all country contexts, however, scientific evidence on pollutants and health outcomes plays a crucial role in determining what are acceptable levels of exposure to air pollution.

India has currently not revised its National Ambient Air Quality Standards (NAAQS) since 2009, with a review of these standards commissioned in 2021 yet to report on its findings. The 2009 review was also not available in the public domain with the standards notified through the Gazette, rendering any analysis of the science that went into the decision-making process impossible to determine.[16]

2. Strong focus on $PM_{2.5}$ reductions through top-down or bottom-up approaches depending on country contexts

The importance of $PM_{2.5}$ control is well understood in the air quality and health literature, and global regulatory regimes reflect the same. The connection between $PM_{2.5}$ and serious health risks to populations, including cardiovascular, pulmonary, metabolic, neurological, and maternal/neonatal issues, is well-established, and the prioritisation of $PM_{2.5}$ points to the centrality of public health in policies on air pollution reduction.[17] In addition to being emitted directly, $PM_{2.5}$ can also form in the atmosphere through chemical reactions involving gaseous pollutants like ammonia, sulphates and nitrates, resulting in secondary particles that can add to the ambient concentration.[18] Because $PM_{2.5}$ integrates contributions from both primary emissions and secondary formation, it generally serves as a good overall marker for ambient air quality, making its control central to effective air pollution management.

The importance of $PM_{2.5}$ manifests in policy directives across countries. Despite starting at a high baseline (Figure 2), China has been able to bring about a sharp decline in ambient air pollution levels. A recent paper has attributed this reduction to two key policy initiatives: disclosure of real-time air quality information leading to public awareness, and inclusion of pollution reduction in the performance evaluation framework of local officials.[19] Between 2003 and 2023, Germany and Poland — both part of the EU — have managed a 51% reduction. This is thanks to the gradual tightening of the EU's air quality standards, primarily through its Ambient Air Quality Directives.[20]

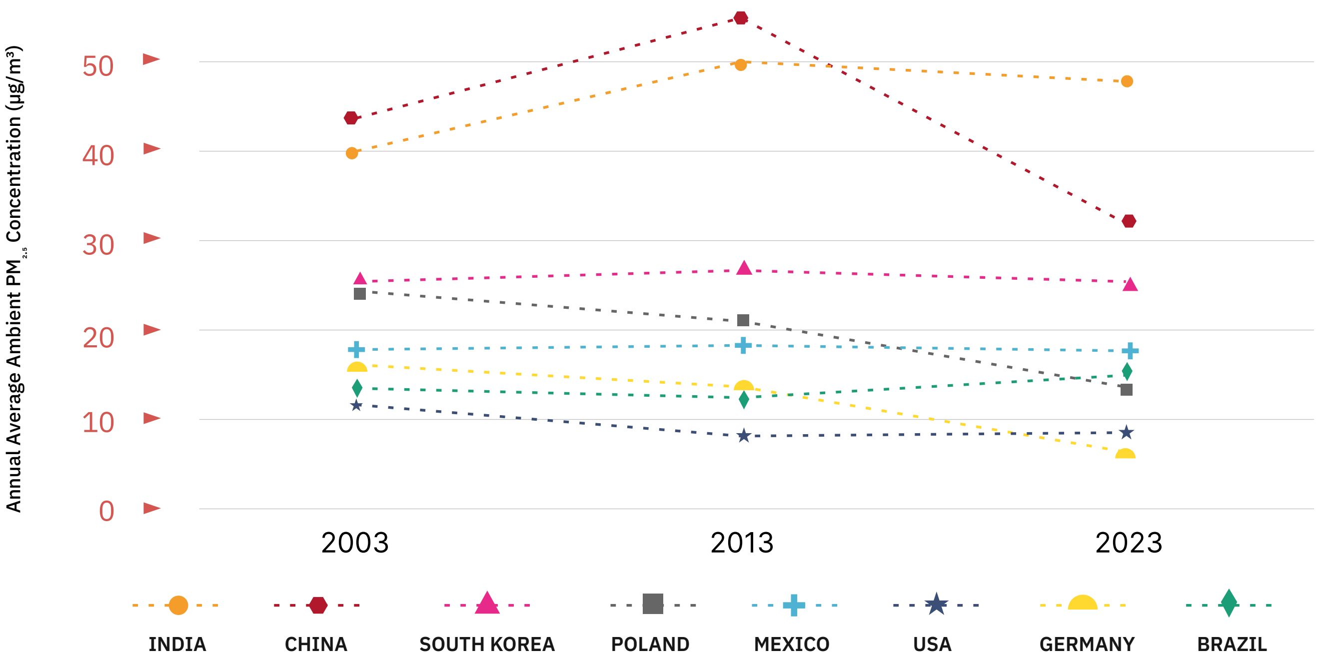


Figure 2: Comparison of average annual ambient $PM_{2.5}$ concentrations[I] across countries in 2003, 2013, and 2023. Source: Authors' Compilation[21]

[I] Satellite-derived measurements were used for comparability across countries

Additionally, the EU Clean Air Policy and the National Emission Reduction Commitments Directive (2016/2284/EU) both work in tandem to oversee the implementation of air quality standards within set deadlines through cross-sectoral interventions targeting emissions from transport, industry, and agriculture.[22] Ambient levels of $PM_{2.5}$ concentrations in India remain much higher than this set of comparator countries, even after two decades of policy action.

Depending on national context, the diffusion of programmes and policies have either been top-down or bottom-up. In the cases of China, Poland, and South Korea, strict regional targets have been set to supplement national goals. In China, the third Air Pollution Control Plan has mandated a reduction of $PM_{2.5}$ by 20% and 15% in the Beijing-Tianjin-Hebei and the Fenwei Plain area, respectively.[23] In South Korea, Seoul has devised a roadmap to reduce $PM_{2.5}$ levels in the city, with a directive to meet international standards by 2030, cutting down $PM_{2.5}$ levels to 13 µg/m³ by then.[24] Poland has set limits for NO_2 (a precursor to $PM_{2.5}$) reduction in its second-largest city, Krakow, by 50% by 2026.[25] For $PM_{2.5}$ reduction specifically, Krakow introduced a complete ban on coal and wood combustion for household heating in 2019.[26] Similarly, the NCAP in India is a top-down scheme that seeks to build up city-level capacity with financial support from the union government. On the other hand, in Mexico, state-level programmes have inspired a federal programme: the Megalopolis ProAire 2021-2030 mandates a 36.4% reduction of $PM_{2.5}$, and a 23.7% reduction of PM_{10} by 2030.[27] It also aims to prevent at least 6,000 deaths in the year 2030, with over 4,800 preventable deaths related to $PM_{2.5}$.

Our sample countries' focus on $PM_{2.5}$ is in contrast with India's lack of a reduction target for this crucial pollutant. While India has ambient air quality standards for $PM_{2.5}$, the NCAP focuses only on PM_{10} reduction in 131 non-attainment cities, seeking to improve annual average ambient PM_{10} levels by 40% (with 2017 as a base year) or meet the NAAQS for PM_{10} by 2026.[28] This has led to cities focusing disproportionately on managing dust, a key source of PM_{10} but far less harmful than $PM_{2.5}$.[29]

3. Large increases in monitoring capacity alone may not necessarily yield spatial and temporal representativeness.

A spatially and temporally representative air quality monitoring network serves as the bedrock for effective air quality management. It allows regulators to identify pollutant sources, address highly polluted areas, and also enables tracking progress over time. India has a larger monitoring network than five of the seven sample countries, with 1,566 stations nationwide. China[II] (1,766 monitors) and the US (4,821 monitors) are the only countries with more air monitoring stations.[30]

[II] Data for China's monitoring capacity is with the authors and may be made available on request.

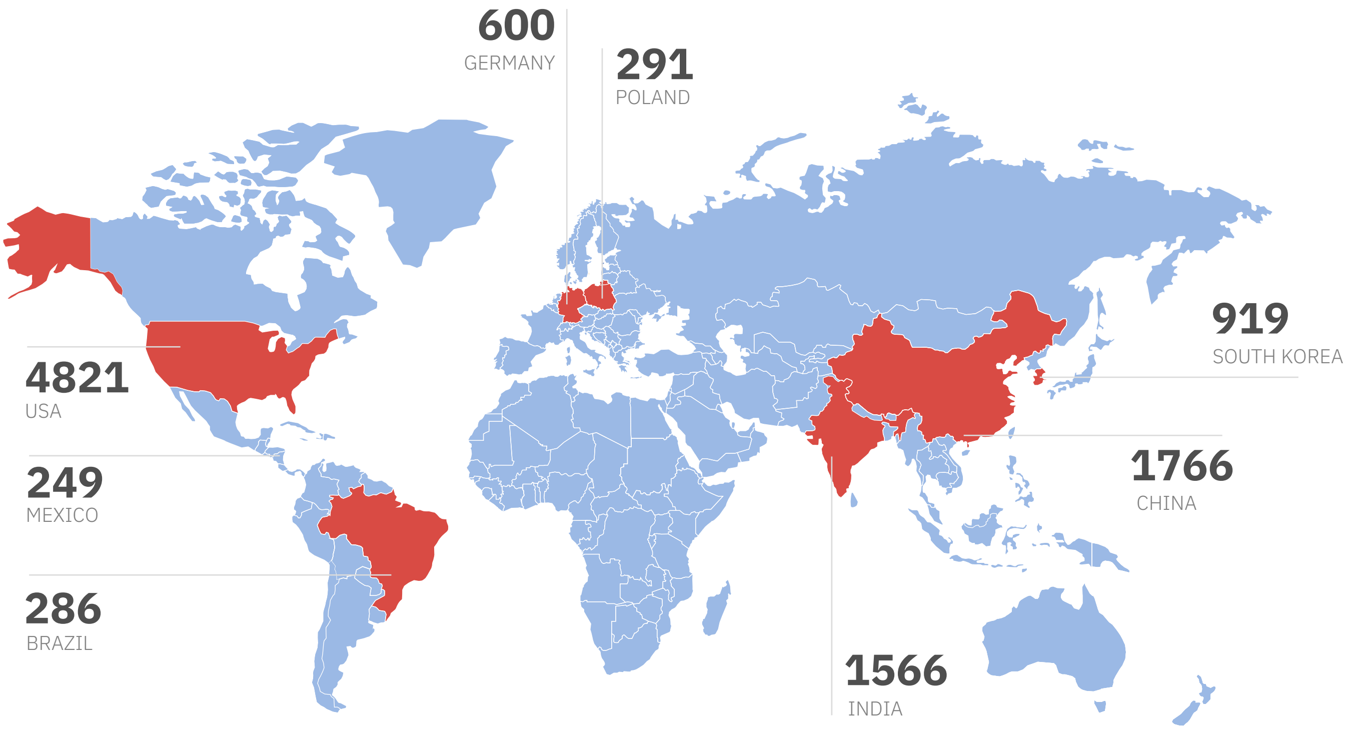


Figure 3: Total number of monitoring stations.
Source: Authors' Compilation[31]

However, it is not just the total number of air quality monitors that determines the effectiveness of a country's monitoring system. In order to accurately capture what people are breathing an effective monitoring network should be able to encompass both the population and the geographical area adequately. According to a 2023 report, nearly 50% of India's population lives outside the maximum radius of the air quality monitoring system, of both real-time and manual monitors.[32] The existing monitoring network covers only 12% of the 4,041 cities and towns listed in the 2011 census.[33] India's Guidelines for Ambient Air Quality Monitoring (the most recent publicly available version is from 2003) lists pollutant-wise guidelines for the density of population-weighted monitoring stations in urban areas.[34] For Suspended Particulate Matter, in an urban area with a population greater than 5 million, a minimum of 12 ambient air quality monitoring stations is required.

The US-EPA classifies monitoring site representativeness into six spatial scales, from micro to national scale, to reflect the spatial extent over which pollutant concentrations can be considered relatively uniform.[35] For all pollutants, including $PM_{2.5}$, a population-weighted metric is used to ensure accurate exposure assessment.

In metropolitan areas with over 1 million people, three monitoring stations are required if the recent 3-year average $PM_{2.5}$ level is at least 85% of the NAAQS limit. Similarly, the EU's guidelines (Directive (EU) 2024/2881) recommend the minimum number of sampling points for fixed measurements depending on a zone population. For example, for $PM_{2.5}$, the Directives recommend between 2 stations for less than 1 million population and 8 stations for more than 6 million population.[36] It is also important to note that these are indicative densities, and actual monitoring density in a location may change depending on context-specific factors such as differences in meteorology, geography and population densities.[37]

A monitoring network with wide coverage is essential for countries with a large rural population, such as India. Household combustion sources, along with biomass and coal burning, are major sources of air pollution that are prevalent in rural areas but are not captured by monitoring networks. Hence, enhancing the spatial extent of monitoring systems to rural areas is essential for improving exposure assessments and designing more equitable air quality management strategies.

4. Indian regulators are comparatively resource-poor

Smog filled streets of Delhi during winters. Credit: Pexels

Well-funded regulators can discharge their duties smoothly by having adequate levels of staffing and infrastructure. Secure, untied funding from governments also fosters regulatory independence, by reducing the reliance on alternate sources of funding (such as industrial permit fees), which may potentially lead to conflicts of interest.

We looked at the most recent budget numbers of the central pollution control agencies in India and the USA, while also looking at the budget numbers of the wealthiest states (by GDP) in the two countries: Maharashtra and California.

India's CPCB, for the year 2025-2026, has been allocated a budget of INR 126 crores (USD 61.6 million in 2024 purchasing power parity or PPP terms).[38] Contrasted with the 2025-2026 budget of the Maharashtra Pollution Control Board (MPCB) of INR 469.2 crores (USD 229.4 million in 2024 PPP terms), the CPCB's budget is a little more than a quarter of the MPCB.[39]

In the USA, the Office of Air and Radiation of the Environmental Protection Agency is charged with implementing clean air programmes nationally and regionally. The 2025 Budget of the U.S. Government has earmarked USD 1.5 billion for the Office of Air and Radiation.[40] The California Air Resources Board (CARB) has proposed a budget of USD 1.2 billion for FY2025-2026, which is more than 5 times the budget of the MPCB in PPP terms.[41]

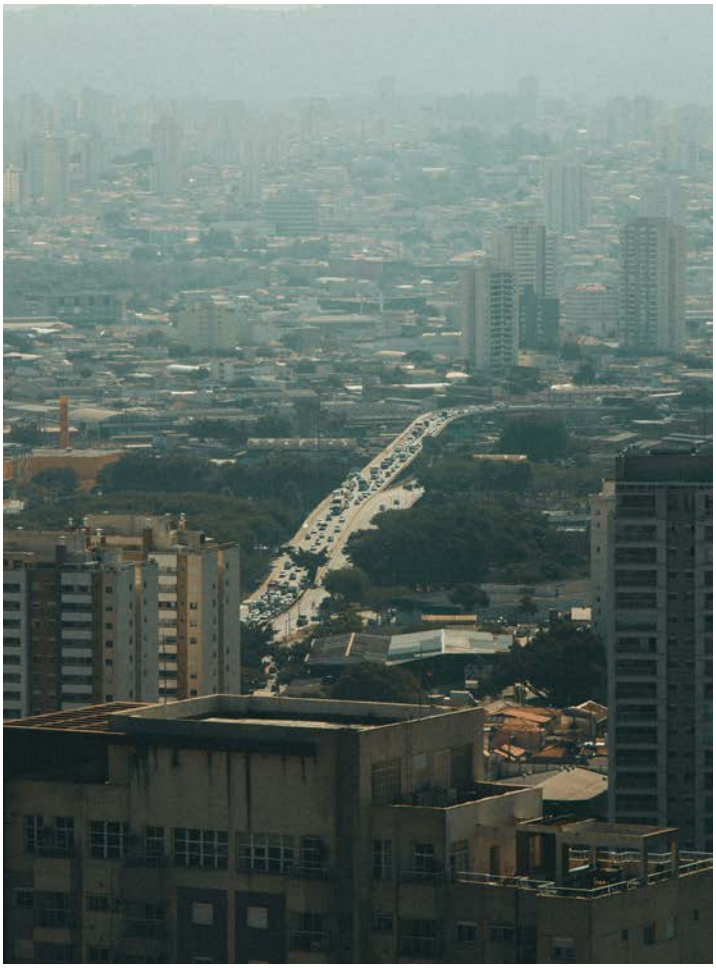
India's pollution control boards are also heavily understaffed.[42] Even with limited data regarding staff strength in regulators in the sampled countries, when compared to the US and China, India's staffing numbers are much smaller — as of 2024, out of 12,016 sanctioned posts for the SPCBs and PCCs combined, only 5,941 positions were occupied.[43] The CPCB has a staff strength of 504 out of a sanctioned maximum of 603.[44] As of 2024, the US EPA had a staff size of 17,202 permanent employees and 1,540 ad hoc employees. Of the 17,000 permanent staff, 7,172 are employed as technical staff, comprising environmental protection specialists, environmental engineers, and general physical scientists.[45]

As of 2018, China's Ministry of Environment and Ecology had 500 employees, but the Environment Protection Bureaus that are spread across China had approximately 60,000 employees, working on air quality monitoring, inspection and research at regional levels.[46] Staff strength is a key determinant for the effectiveness of an environmental regulator, especially one tasked with managing multiple environmental challenges, as is the case in India. Low staffing levels therefore have a crippling effect on air quality regulation.

5. Airshed-level governance is gaining importance and requires nested governance

Given the dispersed nature of air pollution, regulators and regulations restricted to political boundaries are largely ineffective. Instead, governance at the level of an airshed — the typical circulatory region for a body of air — has gained prominence worldwide. The Commission for Air Quality Management (CAQM) is an Indian airshed-level regulatory body, with its jurisdiction including the National Capital Territory of Delhi and its adjoining areas.[47] The CAQM plays the role of coordinating actions across the SPCBs of the demarcated region and the Delhi Pollution Control Committee. There are some examples of airshed-level governance in other countries. Within our sample, China, Mexico, and South Korea have been able to demarcate and manage airsheds.

China's Beijing-Tianjin-Hebei region, encompassing Beijing and 12 other cities with a cumulative population exceeding 110 million, is recognised as the country's most heavily polluted urban area.[48] To address this, a multi-tiered regulatory framework was established, integrating central, regional, and municipal authorities. The region adopted the Air Pollution Prevention and Control Action Plan, which targeted a 25% reduction in $PM_{2.5}$ concentrations between 2012 and 2017.[49] This was to be achieved through stringent caps on coal burning, tighter industrial emissions controls, and a transition to cleaner energy sources. The implementation of these air quality improvement measures has yielded substantial reductions in air pollution-linked mortality. Between 2013 and 2017, premature deaths associated with short-term $PM_{2.5}$ exposure in the Beijing-Tianjin-Hebei region declined from 24,700 to 17,500 annually, and declined further to 13,500 by 2020. Despite hurdles such as the transport of pollutants back into the airshed from industries shifted to areas just out of it, the programme has largely been effective.[50]



Aerial view of a city in smog in Brazil. Credits: Pexels

In South Korea, the Seoul, Incheon, and Gyeonggi-do region was designated as a single airshed in 2003 to address severe air pollution. The region's regulatory framework is anchored by the Clean Air Conservation Act and the National Fine Dust Reduction Plan, which mandate joint action across city and provincial governments.[51]

Key measures include an emissions cap-and-trade system for key pollutants, restrictions on vehicles, seasonal fine dust management, and substantial investment in transport emissions reduction. Since delineating the airshed, $PM_{2.5}$ levels have declined by 40% between 2015 and 2023, although only 27% of monitoring sites met the strict national $PM_{2.5}$ annual standard in 2022.[52]

Mexico City is an older example of using an airshed approach to reduce high levels of air pollution. In the 1980s, faced with unprecedented levels of ozone, lead, carbon monoxide and particulate matter, new legislation was introduced to reduce air pollution. The Valley of Mexico, which comprises Mexico City, the federal district of Mexico and the states of Morelos, Puebla, Tlaxcala and Hidalgo was delineated as an airshed. A coordinated action plan introduced in the 1990s, known as the Management Programme to Improve Air Quality (ProAire), is central to pollution control in this airshed. It made vehicle inspection obligatory, established a supply of unleaded petrol, introduced stricter vehicle emissions standards with the introduction of catalytic converters, and expanded the metro system.[53] Since its establishment, the airshed has achieved an approximately 50% reduction in key pollutants like ozone and particulate matter through vehicle restrictions, industrial controls, and public engagement. However, challenges remain, including traffic congestion and the persistence of $PM_{2.5}$ and PM_{10}, due to the region's geography and associated episodic high pollution

6. Accountability is a catalyst for sustained improvements in air quality

Regulatory bodies, even with their strict standards, long-term policies, or sectoral goals, may fall short in their duties if their ability to hold transgressors accountable is weak. Countries have developed their own accountability mechanisms, prompted by history, legal frameworks, and policy requirements.

India's approach to accountability is typically legal in nature, either through the State taking individual violators to court, through public interest litigations filed by individuals through the courts, or with the judicial system taking *suo motu* interest in and intervening to issue directions to the government that protect the environment and people. The Supreme Court in the Taj Trapezium Zone case directed industries close to the Taj Mahal to switch to cleaner fuel, and expected relocation of industries unable to make the switch.[54] The National Green Tribunal (NGT), India's environmental court, has been proactive in holding state governments accountable in cases of neglecting environmental damage. In 2022, the NGT fined the Uttar Pradesh government 120 crores for environmental violations.[55]

Recent amendments to India's environmental protections laws have sought to decriminalise offences and introduce monetary penalties in their place. These amendments, however, have not strengthened regulatory enforcement with loopholes allowing continued exploitation. However, capped at INR 15,00,000 (USD 17,029), the case for brushing environmental offences aside by 'polluting and paying' remains open to debate. Additionally, adjudicating officers appointed to levy monetary penalties have no clarity on what determines a case for financial penalties. The letter of the law speaks only of the "ease of living and doing business" in this regard, which implies a primacy given to choices furthering economic growth over protection of the health and environment.[56]
On the other hand, China's accountability mechanisms are baked into the bureaucratic incentive structure. One of the mechanisms employed for this purpose includes evaluating local officials' performance by integrating pollution reduction targets in the evaluation framework. This fosters a sense of personal accountability for officials who are entrusted with environmental protection by raising the stakes for them, leading to intentional and strengthened air quality action. Recently, the Chinese government has stated that accountability surpasses tenure in positions, and so retired bureaucrats and environmental officials would also be held accountable for engaging in environmental damage during their time in office.[57]

The US-EPA had until recently its Good Neighbour Provision under the Clean Air Act, wherein states were required to prevent transboundary air pollution and not adversely affect air quality in downwind states.[58] Incentivising states to maintain emissions within allowable limits to protect regional air quality, and using legal action against non-compliant states/sources fostered cooperative governance and a sense of shared responsibility and accountability. Alongside airshed-level governance, shared accountability across states ensured that air quality gains are achieved uniformly and sustainably. However, the Provision was stayed by the US Supreme Court in response to concerns raised by some states because it would increase costs and thus was unnecessary.[59]

CONCLUSION

Air pollution is a public health emergency in India, and achieving sustained reductions will require not just creative policymaking but crafting institutions that are capable of executing on their mandates. This brief is intended to serve as a starting point for conversations around what a future-ready form for national and sub-national air quality regulators in India looks like. Ongoing discourse around SPCB reform remains focused on plugging existing capacity and infrastructure gaps, and does not reflect the evolving nature of the air pollution challenge. India will continue to industrialise and urbanise rapidly, and gauging future needs based on past assessments will set them up for failure yet again. Simply fulfilling their work as envisioned decades earlier will not solve our ongoing air pollution crisis. Revitalising our environmental regulators will require foresight on best practices with respect to air quality management, tiered or nested governance and institutional structures that integrate local to national action, and policy instruments that recognise the spatially pervasive nature of the problem.

It is important to note that the diversity of sources and plurality of exposure pathways mean that India’s case is somewhat more complex than the comparator countries we have identified. Each, however, presents unique insights that, when amalgamated into a renewed vision of air quality governance and regulation in India, could prove useful guideposts in our quest for clean air.

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