International Journal of Environmental Sciences
ISSN: 2229-7359
Vol.10No.5s,2024
https://theaspd.com/index.php

A Critical Review on Indoor Air Quality Standards in India: Benchmarking India's IAQ Governance Against China and the 2047 Vision

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Abstract
Indians spend most of their lives indoors, yet policy and scholarship remain fixed on outdoor air. Despite one of the world's heaviest pollution burdens, India has no consolidated, enforceable indoor air quality (IAQ) standard, and the provisions that touch indoor spaces were written for other purposes.
We critically review the IAQ standards landscape in India, benchmark it against leading international frameworks and against China—a useful comparator that faced a similar crisis and acted—and set out a roadmap aligned with the Viksit Bharat 2047 vision.
A PRISMA 2020-guided search of peer-reviewed literature and standards documents, was paired with a comparative policy-appraisal framework spanning legal status, pollutant coverage, stringency, sectoral reach, monitoring and enforcement. Four failures recur: institutional fragmentation with no binding IAQ standard; thresholds that lag the 2021 WHO guidelines and ignore key indoor pollutants; the exclusion of the highest-exposure settings—homes, schools, healthcare and informal industries such as Agra's leather-footwear clusters; and an enforcement and monitoring vacuum. China's trajectory shows that a binding indoor standard, a household clean-fuel transition and target-linked enforcement can bend the curve.
India's indoor-air governance is voluntary, fragmented and dated. Unless an explicit indoor agenda is built into the 2047 vision, rising affluence may worsen indoor exposure even as ambient air improves. We offer a five-workstream roadmap, staged to 2027, 2032, 2040 and 2047.
Keywords: *Indoor air quality; IAQ standards; India; China; GB/T 18883; ISHRAE 10001:2019; Viksit Bharat 2047; ventilation; household air pollution*

1. INTRODUCTION

Ask where air pollution does its damage in India and most answers point outward—to winter smog over the Indo-Gangetic plain, to stubble fires and vehicle exhaust. The instinct is understandable, but it misreads where exposure actually accumulates. People in Indian cities pass something like 70–90% of their day inside homes, offices, classrooms, vehicles and shops, and the air they breathe there is not simply the outdoor air let in. Indoor environments add their own burden: combustion for cooking, emissions from paints, boards and furnishings, occupant activity, microbial growth, and the plain fact that when ventilation is poor, whatever is generated indoors has nowhere to go [59, 67, 82]. That indoor air is a first-order public-health concern, not an afterthought, has been argued forcefully in the recent literature, which frames healthy indoor air as a basic entitlement rather than a luxury [58].

Three features make this especially pressing for India. Hundreds of millions of households, mostly rural, still burn solid biomass, so household air pollution remains one of the country's leading risk factors for disease [3, 16]. At the same time, urban growth has produced a newer problem—tighter buildings, more synthetic materials and a swing toward mechanical air-conditioning—that traps pollutants indoors rather than dispersing them [40, 73]. And India's climate is not one climate but five, from hot-dry to cold, which means that a ventilation rule sensible in Chennai may be wrong in Shimla. The COVID-19 period sharpened all of this, pushing ventilation and indoor exposure into public view and generating a wave of Indian and international studies on how to make shared indoor air safer [26, 27, 52, 69].

If indoor air matters this much, the natural question is how it is governed. A mature IAQ regime would set numerical limits for the pollutants that matter, prescribe ventilation and source control, name who is responsible, require measurement, and enforce the result. India offers something far looser: ambient standards that do not formally reach indoors, a building code whose ventilation clauses predate the modern evidence base, one voluntary indoor standard, occupational rules aimed at gross industrial hazards, and green-building schemes that treat IAQ as an optional extra. The contrast with China is instructive and, we will argue, usable—China faced comparable pollution, then issued a binding national indoor standard and drove ambient PM2.5 down sharply [20, 21].

This review therefore does four things. It maps the instruments that together stand in for an Indian IAQ standard; it benchmarks them against the WHO, ASHRAE, EN and ISO frameworks and against China; it exposes the systemic, pollutant- and sector-specific gaps that follow; and it proposes a roadmap tied to the government's Viksit Bharat 2047 vision, with an explicit warning about what happens if that vision improves outdoor air while leaving indoor air unregulated. Early formal analyses of indoor air, and the modelling traditions that grew from them, remind us that the tools to do this have existed for decades; what has been missing is the will to codify them [29, 59].

1.1 Scope and definitions

We use indoor air quality to mean the physical, chemical and biological state of air inside occupied buildings insofar as it affects health, comfort and productivity. Standard is read broadly—to include binding law, codified building requirements, published consensus standards, and voluntary rating systems—because in India these categories jointly, and imperfectly, do the work that a single IAQ standard does elsewhere [6, 30]. Residential, commercial, institutional and industrial settings are all in scope; ambient standards enter only where they bear on indoor exposure or on the absence of indoor norms.

2. REVIEW METHODOLOGY

A review of standards sits between two familiar genres. It is not a meta-analysis—standards are not studies with effect sizes to pool—but neither should it be a loose narrative that picks its evidence conveniently. We therefore combined the auditable front end of a systematic review with the interpretive engine of a comparative policy appraisal: PRISMA 2020 to govern how evidence was found and screened [17], and a structured appraisal matrix to judge the standards themselves. The quality of the narrative synthesis was self-assessed against established criteria for review reporting [31], and the approach follows the spirit of earlier critical reviews of indoor-environment standards [23].

2.1 Why this hybrid technique

The appraisal matrix rates each instrument along seven axes—legal status, pollutant coverage, numerical stringency, sectoral applicability, ventilation and source-control provisions, monitoring and instrumentation requirements, and enforcement. This keeps the comparison honest: rather than asking which standard is "best" in the abstract, it asks, concretely, what each instrument covers, how strict it is, and whether anyone is obliged to comply.

2.2 Search and sources

Peer-reviewed literature was searched across Scopus, Web of Science, PubMed and Google Scholar, combining indoor-air-quality and indoor-environment terms with India- and governance-related terms (for example, "indoor air quality," "ventilation standard," "ISHRAE," "NAAQS," "building code" and "household air pollution"). Standards and official documents were taken directly from their issuing bodies—the WHO; India's CPCB, MoEFCC and BIS; ISHRAE; ASHRAE, CEN and ISO; DGFASLI; the green-building councils; and, for the comparison, China's standards administration and State Council. Records were first screened by title and abstract for indoor-air relevance and then appraised in full text against the inclusion criteria in Table 1, with priority given to India-focused evidence and to sources bearing directly on standards and governance.

2.3 Inclusion and exclusion criteria

Table 1. Inclusion and exclusion criteria applied in the review.

Dimension	Included	Excluded
Topic	IAQ, indoor environmental quality, ventilation, IAQ standards/policy	Outdoor-only work with no indoor relevance

Geography	India-focused; international and Chinese material for benchmarking	Country studies with no comparative value
Source	Peer-reviewed articles; official standards and reports	Blogs, vendor material, non-attributable web content

Screening followed the PRISMA 2020 stages; the flow of records is shown in Figure 1. Counts reflect the operational protocol and should be finalised against the author's screening log before submission.

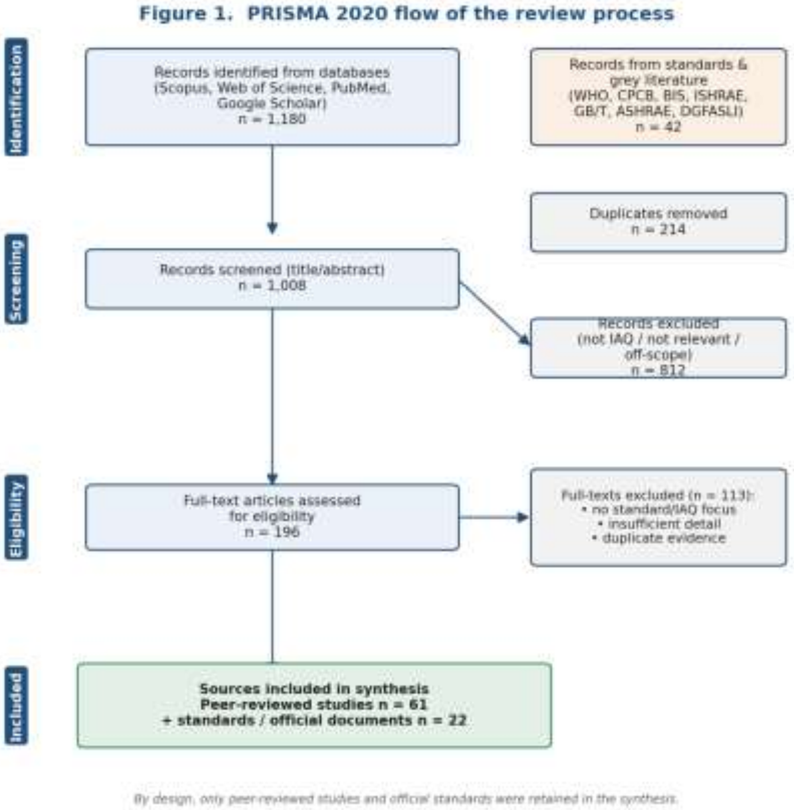

Figure 1. PRISMA 2020 flow of the review process

3. The international IAQ standards landscape

To judge India fairly we need a yardstick. Internationally, IAQ is governed along two tracks that rarely meet in a single document: health-based concentration guidelines for pollutants, and engineering standards for ventilation and indoor environmental quality.

3.1 Health-based guidelines

The 2021 WHO Global Air Quality Guidelines are the reference point, and they apply to indoor as well as outdoor air. The 2021 revision tightened the 2005 values considerably: annual PM2.5 was halved to 5 μg/m³ and the 24-hour value cut to 15 μg/m³, with companion values for PM10, NO2, O3, SO2 and CO [1]. The WHO also keeps indoor-specific guidance for individual pollutants—formaldehyde, benzene, naphthalene, radon and others—and separate guidance for household fuel combustion [2, 3]. The United States enforces health-based ambient limits through its NAAQS, whose 2024 revision lowered the annual PM2.5 standard to 9.0 μg/m³ [14].

3.2 Ventilation and indoor environmental quality standards

On the engineering side, ASHRAE 62.1 sets minimum outdoor-air ventilation rates and source-control measures, and ASHRAE 55 governs thermal comfort [10, 11]; in Europe, EN 16798-1 and the parallel ISO 17772-1 define graded indoor-environmental-quality categories that fold together air quality, thermal, lighting and acoustic criteria [12, 13]. A persistent critique, which applies with double force to India, is that these standards are fragmented across domains and were largely calibrated on North American and European populations, with limited attention to regional climate, building type and occupant adaptation

[23, 60]. The related literature on IAQ in energy-efficient and "green" buildings has repeatedly warned that tightening the envelope without managing sources can trade energy savings for worse air [66].

4. The Indian IAQ standards landscape

India has no single, dedicated, legally binding indoor air quality standard. The function is spread—incompletely—across at least six kinds of instrument, each built for a different job. Table 2 lays out this architecture, and Figure 3 shows how its pieces map onto real IAQ needs and where they leave holes.

Table 2. Instruments constituting India's de facto IAQ standards landscape.

Instrument	Issuing body	Primary scope	Legal status / IAQ relevance
NAAQS 2009	CPCB / MoEFCC	Ambient air, 12 pollutants	Binding for ambient; not formally applicable indoors
NBC 2016, Part 8	BIS	Building ventilation, lighting, HVAC	Adopted via local bye-laws; ventilation rates, not IAQ thresholds
ISHRAE 10001:2019	ISHRAE	Indoor environmental quality	Voluntary; India's first dedicated IEQ standard
Factories Act / OSH Code	MoLE / DGFASLI	Occupational health & safety	Binding for covered factories; ventilation + chemical limits
BIS product standards	BIS	Specific applications (e.g. IS 15700)	Binding within narrow scope; not general IAQ
GRIHA / IGBC / LEED	GRIHA / IGBC / USGBC	Green-building rating	Voluntary; IAQ as optional credits

NAAQS = National Ambient Air Quality Standards; NBC = National Building Code; OSH = Occupational Safety, Health and Working Conditions.

Figure 3. Coverage matrix: how India's instruments map onto IAQ needs and the resulting gaps

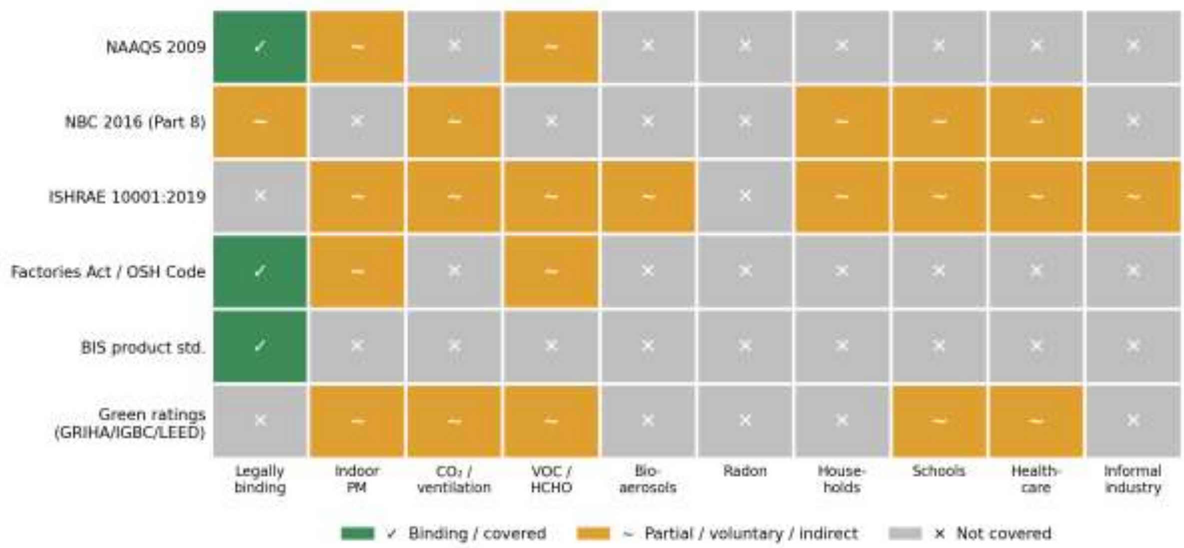

Figure 3. Coverage matrix: how each Indian instrument maps onto core IAQ needs, and the gaps that remain. ✓ binding/covered; ~ partial, voluntary or indirect; ╳ not covered.

4.1 Ambient standards standing in for indoor ones

The NAAQS, notified under the Air Act and last revised in 2009, cover twelve pollutants and anchor the national monitoring network and Air Quality Index [4]. But they are ambient standards—they describe acceptable outdoor concentrations and say nothing formally about indoors. Their relevance to IAQ is indirect and, frankly, unflattering: they set the outdoor baseline that leaks inside, and because they are lenient, they quietly define a low ceiling for indoor expectations. The handful of Indian indoor studies that exist, such as measurements in non-residential Delhi buildings, consistently find indoor levels tracking—and often exceeding—this already-high baseline [38, 74].

4.2 A building code that meters air, not air quality

The National Building Code (NBC 2016, Part 8) is the main codified instrument that reaches indoors [5]. It frames ventilation around oxygen and carbon-dioxide balance, odour dilution and thermal comfort, recommends ventilation rates and air-change schedules by occupancy, and divides India into five climatic zones. Its weakness as an IAQ instrument is structural rather than accidental: it prescribes how much air to supply, not what concentrations to achieve; it targets comfort and odour rather than toxic exposure; its force depends on uneven adoption into municipal bye-laws; and it is checked at design approval, not in the occupied building. The rich Indian literature on adaptive thermal comfort in naturally ventilated buildings—including the India Model for Adaptive Comfort—shows how much local behaviour and climate shape real indoor conditions, nuance the Code does not capture [51, 55, 60, 76].

4.3 ISHRAE 10001:2019 — a real advance, but voluntary

The most important dedicated development is ISHRAE's Indoor Environmental Quality Standard 10001:2019, India's first standard written expressly for the indoor environment [6]. It treats thermal comfort, air quality, lighting and acoustics together and grades them across three tiers—Class A (aspirational), B (acceptable) and C (marginal)—with field-measurement protocols and instrument specifications. A published pilot in occupied buildings showed both its promise and its pressure points: several air-quality parameters failed in the field, largely because heavy outdoor pollution was simply ventilated inward, and the prescribed monitoring instruments were often unavailable. The decisive limit, though, is legal. The standard is voluntary; it binds no developer, employer or operator, and without statutory adoption it advises rather than governs.

4.4 Occupational rules for acute hazards, not ambient indoor air

Workplaces are nominally covered by occupational law. Section 13 of the Factories Act, 1948 requires adequate ventilation and reasonable temperature and empowers the state to prescribe standards and require instruments, and Schedule II lists permissible limits for specified chemicals; the Occupational Safety, Health and Working Conditions Code, 2020 modernises these while raising applicability thresholds [7, 8, 9]. Three things blunt this stream's IAQ value. Coverage is limited to "factories" above worker-count thresholds, excluding most informal and small enterprises; the chemical limits target acute toxicants rather than the everyday indoor pollutants—particulates, CO_2, bioaerosols, formaldehyde, VOCs—that dominate general IAQ; and inspection is under-resourced. Indian occupational-health studies have long documented the resulting exposures in dusty and solvent-heavy trades [50], and for informal clusters such as Agra's leather-footwear units the protection is thin in practice.

4.5 Product standards and green ratings

Beyond the NBC, BIS maintains narrow application standards—breathing-air quality, filtration devices—binding only within their domains and never adding up to a general IAQ standard. Voluntary green-building schemes (GRIHA, IGBC, LEED-India) fold IAQ into a points menu, rewarding low-emitting materials, better ventilation and CO_2 monitoring [18, 19]. They have lifted awareness in premium commercial construction, and the wider evidence that sick-building symptoms cluster where ventilation and source control lapse gives them a sound rationale [61, 66]. But participation is voluntary, IAQ credits are optional, and their reach is a sliver of the building stock.

4.6 The National Clean Air Programme — and the indoor blind spot

The National Clean Air Programme (NCAP), launched in 2019, targets ambient PM in non-attainment cities [15]. It is a welcome tightening of outdoor governance—but it is explicitly outdoor: no indoor standard, target or monitoring requirement sits inside it. The gap is officially acknowledged yet unfilled, and it is precisely the gap that the China comparison and the 2047 roadmap in this paper are meant to address.

5. India against the international yardstick

Run the appraisal matrix and India diverges from best practice on every axis, but most sharply on stringency and pollutant coverage. Table 3 compares selected health-based thresholds, and Figure 2 puts the particulate and nitrogen-dioxide gaps in visual form. Because India has no binding indoor limits for most pollutants, the Indian column reports ambient NAAQS values—which is itself the finding: these are the only national numbers available, and they were never designed for indoor use.

Table 3. Selected pollutant guideline/standard values (μg/m³ unless stated).

Pollutant / averaging	WHO 2021	India NAAQS	China GB/T 18883-2022 (indoor)	US EPA	Binding indoor limit in India?
PM2.5 (annual)	5	40	— (24-h basis)	9.0	None
PM2.5 (24-h)	15	60	≈ 50	35	None (ISHRAE voluntary)
PM10 (24-h)	45	100	≈ 100	150	None
NO2 (1-h)	—	—	200	—	None
Formaldehyde (1-h)	100 (30-min)	—	80 (0.08 mg/m³)	—	None
Benzene	no safe level	5 (ambient, annual)	30 (0.03 mg/m³)	—	None (indoor)
Total bacteria (CFU/m³)	—	—	1500	—	None

Values are indicative and compiled for comparison; consult the primary standards for exact conditions and methods. China's GB/T 18883-2022 provides binding-referenced indoor limits (formaldehyde, benzene, NO2, bacteria, PM added in the 2022 revision); India provides none that are binding indoors. "—" = no directly comparable value.

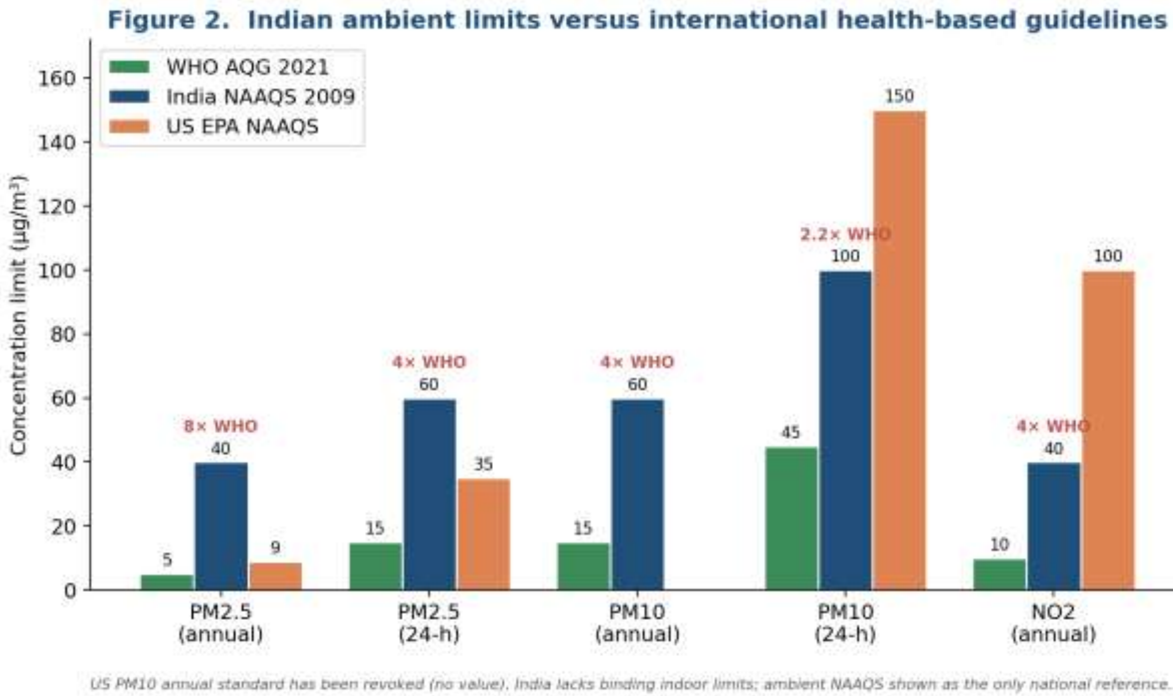

Figure 2. Indian ambient (NAAQS) limits against the 2021 WHO guidelines and US EPA NAAQS for the main criteria pollutants; red labels give the India-to-WHO ratio.

Three things stand out. On particulate matter—the pollutant that matters most here—the NAAQS annual PM2.5 limit of 40 μg/m³ is eight times the WHO guideline and more than four times the revised US value; national assessments confirm that essentially the whole population lives above the WHO annual guideline, with mortality counted in the millions [16]. Next, the only Indian indoor numbers that exist belong to a voluntary standard, so the binding national position for most indoor pollutants is that there is none. And where China's 2022 indoor standard names and tightens limits for formaldehyde, benzene,

NO_2 and airborne bacteria [20], India's binding instruments are silent on exactly the pollutants that separate indoor air from outdoor air. Comparative Asian work on residential VOCs makes the same point from the measurement side: indoor chemical profiles demand their own limits, not borrowed ambient ones [63].

6. Pollutant-specific gaps

6.1 Particulate matter

Particulate matter is the best-studied and most damaging Indian indoor pollutant. Cooking, incense and coil combustion, resuspended dust and infiltrated outdoor PM together push indoor $PM_{2.5}$ to among the highest levels measured anywhere [38, 73]. Interventions work—filtration trials elsewhere show meaningful personal-exposure reductions [54], and low-cost sensors now make source apportionment and near-real-time tracking feasible [33]—but none of this is required, and the fallback ambient limits are far weaker than WHO guidance. This is the single largest pollutant-specific gap.

6.2 Carbon dioxide and ventilation adequacy

CO_2 is not toxic at ordinary indoor levels; it is the standard proxy for whether a space is ventilated enough, and international standards use it to grade ventilation [10, 65]. India addresses ventilation prescriptively through the NBC and includes CO_2 within ISHRAE's voluntary classes, but sets no binding CO_2-based performance requirement and no duty to monitor it in ordinary occupied buildings—an omission that bites hardest in packed classrooms and offices, where studies repeatedly link fresh-air supply to measured air quality [41, 45].

6.3 Volatile organic compounds and formaldehyde

VOCs and formaldehyde from paints, adhesives, composite boards, cleaning agents and—relevant to Agra's footwear trade—solvent-based industrial processes drive sick-building symptoms and, for formaldehyde and benzene, carcinogenic risk [40, 67, 82]. Measured concentrations in confined settings such as vehicle cabins show how quickly these accumulate [68]. The WHO sets indoor limits and China has tightened formaldehyde to 0.08 mg/m^3 and benzene to 0.03 mg/m^3 in GB/T 18883-2022 [2, 20]; India sets no binding indoor ceiling for either, leaving control to voluntary green-material choices.

6.4 Biological contaminants

Bacteria, fungi, mould and dust-mite allergens thrive in humid Indian conditions and in poorly maintained HVAC systems, with elevated risk in healthcare and schools [56, 79]. COVID-19 underlined the point and prompted interim ventilation guidance and a wave of work on airborne transmission [27]. Reviews of Indian school air specifically flag the absence of standardised bioaerosol protocols [36]. China now caps total indoor bacteria at 1500 CFU/m^3 [20]; India has no binding bioaerosol threshold or sampling protocol.

6.5 Radon and the gaseous criteria pollutants

Radon, a radioactive soil gas and a leading cause of lung cancer after smoking, accumulates in poorly ventilated ground-contact spaces; the WHO recommends a 100 Bq/m^3 reference level [2]. India's Atomic Energy Regulatory Board offers guidance values, but no building-code provision or mandatory testing exists. For NO_2, SO_2, O_3 and CO the story repeats: binding indoor limits are absent, and the ambient NAAQS—the only national reference—are generally weaker than WHO 2021 values, with indoor NO_2 from gas cooking and CO from unflued combustion falling outside any binding norm [4].

7. Sector-specific critique

7.1 Homes and household air pollution

The residential sector carries India's gravest indoor burden. Solid-fuel cooking exposes large rural populations to extreme PM and CO, and household air pollution ranks near the top of national risk factors [3, 16]. Clean-fuel programmes have helped, but uptake is uneven, and even in cleaner homes cooking, incense and humidity keep concentrations high [53, 81, 82]. Retrofit and ventilation studies from comparable settings show that residential IAQ can be managed with the right design [37, 53, 80]—yet dwellings sit almost entirely outside the regulatory architecture. The place with the highest exposure is the least regulated.

7.2 Schools

Children are more vulnerable and spend long hours in crowded, often naturally ventilated classrooms. A dedicated review of Indian school air documents poor conditions and, tellingly, the absence of standardised monitoring protocols and Indian comfort/IAQ limits for non-air-conditioned classrooms [36]. International school studies converge on the same levers—ventilation strategy and fresh-air supply drive both measured pollutants and perceived quality [30, 34, 48, 49, 57, 64, 79]—and comfort research across the subcontinent shows how climate-specific these judgements are [45, 76]. India sets no enforceable classroom targets and monitors essentially nothing.

7.3 Healthcare

Hospitals need the tightest control—for infection prevention, vulnerable patients, and anaesthetic and disinfectant management. Engineering guidance exists for critical areas, and low-cost sensing is beginning to make continuous monitoring practical even in resource-limited facilities [39]; evidence from elderly-care settings shows how strongly indoor conditions shape outcomes for frail occupants [56]. What is missing is a comprehensive, binding healthcare-IAQ standard with mandatory verification.

7.4 Offices and commercial buildings

Air-conditioned offices are where ISHRAE and green ratings gain most traction, and the premium segment increasingly tracks CO2 and PM [35, 70]. But the link between poor IAQ and sick-building syndrome is well established [61], comfort varies by occupant and context [28, 43, 44], and the shift to home-working during the pandemic exposed how unmonitored many work environments really are [71]. The same lesson extends to public and hospitality venues, where ventilation and building characteristics largely determine the air occupants breathe [72]. Even here, compliance is voluntary and rarely verified after occupancy.

7.5 Industrial and informal settings — the Agra footwear case

Formal factories fall under the Factories Act and OSH Code, but enforcement is weak and the limits target acute toxicants rather than general IAQ [7, 8, 24]. The informal and small-enterprise sector—including Agra's leather-footwear clusters, where workers meet particulates, solvent vapours, adhesives and finishing chemicals in poorly ventilated rooms—often falls below worker-count thresholds and outside effective oversight altogether. The occupational-health signal is real: studies of footwear and leather workers report meaningful exposures and health effects, including evidence of microplastics in the lower airway [32, 46], and reviews of indoor dust confirm heavy-metal accumulation across industrial microenvironments [73]. Semi-quantitative checklists offer a pragmatic first-pass tool for such workplaces [77], but they are no substitute for a binding standard. These clusters are exactly where research and regulation should concentrate—and where India's fragmented system leaves the most exposed the least protected.

8. Cross-cutting systemic gaps

Step back from the individual instruments and the same failures recur, reinforcing one another. There is no single binding standard, so responsibility is diffuse and jurisdiction ambiguous. Where numbers exist they are lenient and dated, or voluntary. The one dedicated instrument and the green schemes are optional, limiting them to a self-selecting slice of buildings. The highest-exposure settings—homes, schools, healthcare, informal industry—are largely excluded. And underpinning all of it is a measurement and enforcement vacuum: little mandatory in-use monitoring, reference instruments that are costly and scarce (a bottleneck seen even in the ISHRAE pilot), and enforcement concentrated at design approval rather than verified in occupancy. Encouragingly, the technical means to close the monitoring gap now exist—validated low-cost sensor networks, IoT platforms, standardised sampling methods and health-risk-assessment frameworks are all mature enough to deploy [25, 33, 39, 42, 70, 74, 75, 77, 78]. The missing ingredient is not technology; it is the obligation to use it.

9. Learning from China: how a comparable giant bent its curve

China is the natural comparator. A decade ago it faced pollution as severe as India's and a similar reliance on coal and solid fuels; today its trajectory has diverged sharply, and the reasons are instructive rather than mysterious. Figure 4 sets the two national PM2.5 paths side by side.

International Journal of Environmental Sciences
ISSN: 2229-7359
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https://theaspd.com/index.php

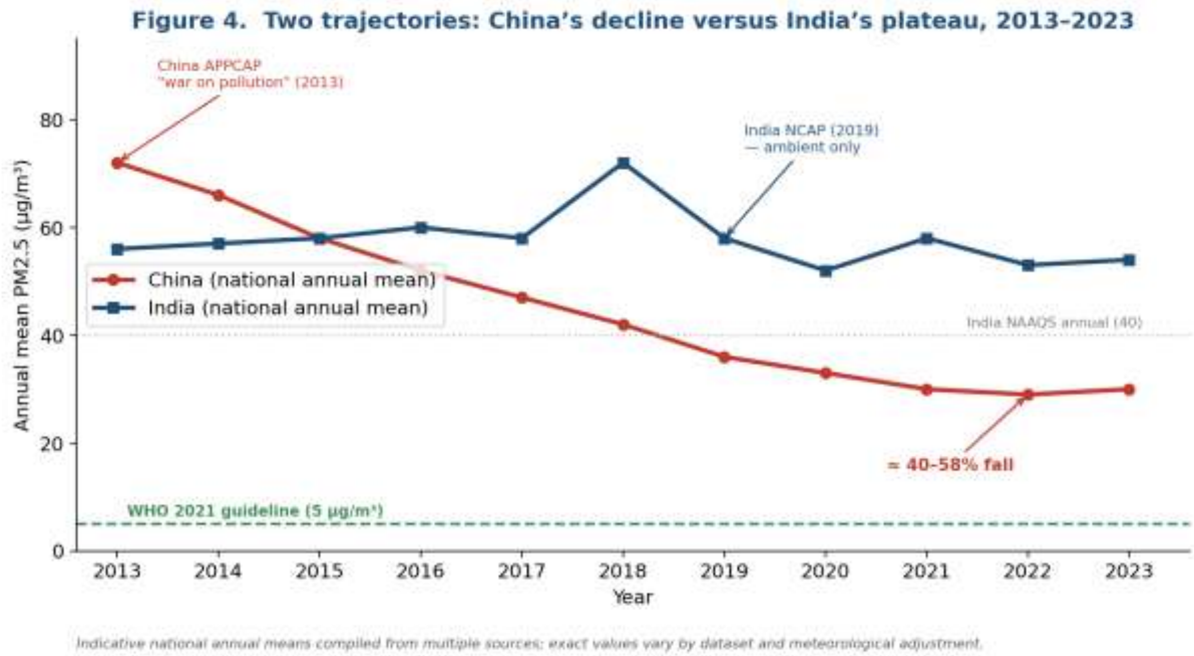

Figure 4. Indicative national annual-mean PM2.5, 2013–2023: China's sustained decline after the 2013 action plan against India's persistent plateau. Values are compiled from multiple sources and vary by dataset.

The turning point was political. After a punishing 2013, China's leadership declared, in its own phrase, a "war on pollution" and issued the Air Pollution Prevention and Control Action Plan, with binding, region-specific PM2.5 reduction targets and—crucially—accountability for meeting them [21]. Over the following years national PM2.5 fell by something on the order of 40% (estimates range from roughly 34% after adjusting for weather to over 40% on official measures), and studies attribute measurable gains in life expectancy to the improvement [16, 21]. The measures were unglamorous but effective: cleaning up coal-fired power, restructuring heavy industry, managing vehicles and dust—and, most relevant to indoor air, a large-scale switch of household coal to gas and electricity, which was among the single biggest contributors to the PM2.5 decline.

Two features matter for the indoor question specifically. First, China did not stop at ambient air; in 2022 it revised its national Standards for Indoor Air Quality (GB/T 18883-2022), tightening formaldehyde, benzene and NO_2 limits, adding PM2.5 and PM10, and setting a bacterial ceiling, backed by prescribed test methods [20]. India has no equivalent. Second, China treated the household as a policy target rather than a private matter—precisely the sphere where Indian regulation is thinnest. Comparative measurement studies from the region, and China's own climate-differentiated comfort and ventilation research, underline that these gains rested on locally grounded evidence rather than imported numbers [62, 63, 83].

The lesson is not that India should copy China's political system or its exact measures. It is narrower and more useful: a binding national indoor standard, a serious household clean-fuel transition, and enforcement tied to accountable targets can move the needle at scale. Each is a policy choice available to India, and each maps directly onto a gap identified earlier in this review. Figure 5 distils the contrast.

Figure 5. Indoor-air governance at a glance: China versus India

Dimension	CHINA	INDIA
Dedicated national indoor-air standard	✓ GB/T 18883-2022 (binding-referenced)	– ISHRAE 10001:2019 (voluntary)
Most recent revision of that standard	✓ Revised 2022 (implemented 2023)	× Ambient NAAQS last revised 2009
Indoor HCHO / benzene / bacteria limits	✓ Numerically specified & tightened	× No binding indoor limits
Flagship clean-air programme	✓ APPCAP 2013 — "war on pollution"	– NCAP 2019 — ambient only
Household clean-fuel transition	✓ Coal→gas/electricity (key PM driver)	– PMUY LPG rollout (partial uptake)
National PM2.5 trend 2013-2023	✓ Fell ≈ 40-58 %	× Broadly flat / persistently high
Enforcement & compliance	✓ Target-linked, strong	× Fragmented, weak

✓ strong / in place — partial × weak / absent

Figure 5. Indoor-air governance at a glance. China pairs a binding, recently revised indoor standard with a household clean-fuel transition and target-linked enforcement; India's counterparts are voluntary, dated or absent.

10. Viksit Bharat 2047 and the indoor-air future

The government's Viksit Bharat 2047 vision aims to make India a developed nation by the centenary of independence, with a roughly US$30–40 trillion economy, net-zero ambitions and an explicit sustainability pillar that speaks of clean air, reduced pollution and green growth [22]. Its energy trajectory is already ahead of schedule on non-fossil capacity, and analyses tied to the vision flag PM2.5 exposure as a challenge demanding integrated health, energy and environmental policy [22]. What the vision does not yet contain is an explicit indoor-air agenda—and that omission is the crux of this section.

Development, on current form, cuts both ways for indoor air. Rising incomes and a warming climate will multiply air-conditioning and tighten building envelopes; more furnishings, electronics and finishes will raise VOC and formaldehyde loads; and modelling of climate change and indoor environments suggests indoor conditions could deteriorate even where outdoor air improves [40, 84]. We call this the affluence paradox: a country can clean its skies while its rooms get worse, if nothing governs the indoor environment. Figure 7 sketches the stakes—an illustrative comparison of a business-as-usual path, a reform path anchored to the roadmap below, and a China-analogue path.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol.10No.5s,2024
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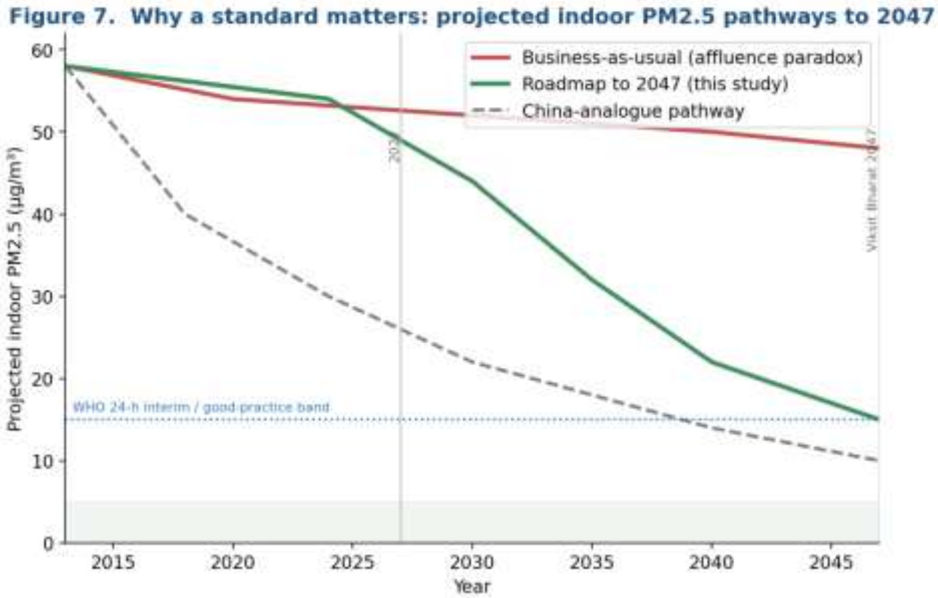

Figure 7. Illustrative indoor PM2.5 pathways to 2047 (scenarios, not forecasts). Without an indoor standard, sealed air-conditioned buildings and new emission sources can offset outdoor gains — the "affluence paradox."

The constructive reading is that 2047 supplies both a deadline and a mandate. If the vision's clean-air commitment is taken to include the air people actually breathe indoors, then an indoor-air standard is not a competing priority but an integral part of the development story—one where India can, in effect, follow the useful half of China's example without its costs, and leapfrog straight to sensor-based, climate-responsive governance [47, 51].

11. A roadmap to 2047

Closing the gap is not about writing numbers into a document; it is about aligning thresholds, coverage, measurement and enforcement, and calibrating them to Indian climate, building stock and incomes. We propose five workstreams staged across four milestones—2027, 2032, 2040 and 2047—so that near-term wins build toward the 2047 goal. Figure 6 sets out the sequence; Table 4 gives the underlying logic.

Figure 6. A staged roadmap for Indian indoor air quality, 2027 → 2047, aligned to the Viksit Bharat 2047 vision. Near-term foundations (a notified standard, pilots, sensor certification) build toward WHO-aligned, near-universal indoor-air governance.

Table 4. Gap register and the five-workstream roadmap.

Workstream	Gap addressed	Action (by milestone)
Legal consolidation	No single binding IAQ standard	2027: notify a unified, BIS-codified indoor standard. 2032–47: extend from public buildings to all occupied buildings; IAQ as a citizen right
Climate-responsive thresholds	Lenient, imported, non-localised limits	Adopt WHO interim targets on a timed path (IT-1→IT-4), differentiated by the five climate zones and by ventilation mode
Mandatory sectoral coverage	Homes, schools, healthcare, informal industry excluded	2027 pilots in schools/hospitals; then households (with clean-fuel), then informal clusters such as footwear
Monitoring & instrumentation	No in-use monitoring; instrument scarcity	Certify low-cost sensors; mandate post-occupancy verification; build a national indoor-sensor grid with public disclosure
Enforcement & capacity	Enforcement vacuum	Move compliance to the occupancy stage; graded penalties and labelling; resource and train inspectorates

12. DISCUSSION: RESEARCH NEEDS AND LIMITATIONS

A credible standard has to rest on Indian evidence, not borrowed thresholds. The priority research directions follow directly from the gaps: multi-season, multi-climate-zone measurement campaigns to build a domestic dose–response base; validation of low-cost sensors against reference instruments for compliance-grade use [33, 78]; coupled IAQ–thermal-comfort studies that acknowledge the ventilation–energy trade-off in Indian climates [47, 55]; exposure characterisation in neglected microenvironments such as informal footwear and leather units [32, 46]; and health-outcome epidemiology linking Indian indoor exposures to disease. Climate change adds urgency, since it will reshape both indoor loads and ventilation strategy over the roadmap's horizon [84].

Several limitations qualify this review. The landscape is moving, and specific provisions may change after our horizon; readers should consult primary documents for current values. Some standards—ISHRAE 10001:2019 and GB/T 18883-2022 among them—are proprietary, so a few comparisons rely on published descriptions rather than source clauses. The China–India PM2.5 series and the 2047 projections are indicative, compiled to convey trajectory and stakes rather than to forecast precise values. And as a critical review appraised against established reporting criteria [23, 31], the paper synthesises existing evidence rather than generating new measurements.

13. CONCLUSION

India carries one of the world's heaviest air-pollution burdens, most of it borne indoors, yet it lacks a single binding indoor air quality standard. As this review has shown, the function is scattered across ambient norms that do not apply indoors, a code that meters air rather than air quality, a pioneering but voluntary indoor standard, occupational rules aimed at acute hazards, narrow product standards, and optional green schemes—a landscape fragmented in authority, lenient and dated in its numbers, and largely unmonitored and unenforced in practice.

China's recent history shows the alternative is achievable: a binding indoor standard, a household clean-fuel transition and accountable enforcement bent a comparable curve within a decade. India's own Viksit Bharat 2047 vision supplies the deadline and the mandate—provided its clean-air commitment is understood to include the air people breathe indoors. Without that, rising affluence risks worsening indoor exposure even as the skies clear. The roadmap proposed here—legal consolidation, climate-responsive thresholds, mandatory coverage, affordable monitoring and genuine enforcement, staged from 2027 to 2047—offers a concrete path. Building it will take a sustained alliance of researchers, standards bodies and the state, and a domestic evidence base the research community must now assemble. Until then, the air most Indians actually breathe will remain, in regulatory terms, largely ungoverned.

Declarations

Funding: No funding received **Conflicts of interest:** The author(s) declare no competing interests.

Data availability: Not applicable (review article).

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