AIR POLLUTION AND HEALTH IN INDIA

A review of epidemiological evidence

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CREA

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Authors

Dr. Manojkumar N, Analyst, CREA

Dr. Niveditha Muruganandam, Consultant, CREA

Mr. Monish Raj, Consultant, CREA

Dr. Priyadharshini Babu, Assistant Professor, Centre for Disaster Mitigation and Management, Vellore Institute of Technology, Vellore, India

Dr. Vigneswari Aravindalochanan, Assistant Professor, Department of Epidemiology, The Tamilnadu Dr. MGR Medical University, Chennai, India

Contributor

Nandikesh Sivalingam, Director and Co-founder, CREA

Editor

Jonathan Seidman, Communications Specialist, CREA

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Summary

- **Strong overall evidence of adverse health associations**: Of the 184 epidemiological studies reviewed (1975–2025), 169 (91.8%) reported at least one positive association between air pollution exposure and a health outcome.
- **Government-supported research**: The vast majority of scientific projects in India are supported by central ministries and public institutions—including Ministry of Environment, Forest and Climate Change (MoEFCC), Ministry of Health and Family Welfare (MoHFW), Indian Council of Medical Research (ICMR), Central Pollution Control Board (CPCB), All India Institute of Medical Sciences (AIIMS), Department of Science and Technology (DST), University Grants Commission (UGC) and Council of Scientific and Industrial Research (CSIR). Government-backed research naturally makes up the bulk of the epidemiological evidence in India, with 44 of 46 government-funded and 77 of 81 government-affiliated studies documenting clear adverse health impacts.
- **Range of health outcomes**: Mortality was assessed across 16 studies. Among the disease outcomes, respiratory diseases were the most frequently studied (86 studies), followed by cardiovascular diseases (11 studies). Other studies examined diabetes, pregnancy-related complications, low birth weight and impaired child growth, neoplasms, haematological disorders, neurocognitive and mental health disorders, metabolic disorders, sleep disorders, ocular diseases, chronic kidney and bone diseases, and morbidity.
- **Geographical coverage**: Studies covered 18 states and Union Territories, alongside national and multi-state research. Delhi had the highest number of studies (26), followed by Punjab (13), Maharashtra and Uttar Pradesh (11 each), West Bengal (10), Tamil Nadu (9), Karnataka (8) and Telangana (7).
- **Rural health evidence**: 38 of the 40 studies covering rural populations reported at least one adverse health association.
- **Multiple exposure settings**: Studies examined ambient, household, indoor and occupational air pollution, covering exposures from outdoor sources, cooking and heating fuels, indoor environments and workplaces.
- **Evidence across multiple pollutants**: Studies investigated particulate matter and its components, including black carbon, organic carbon and heavy metals, alongside gaseous pollutants such as nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3) and carbon monoxide (CO), and volatile organic compounds (VOCs).

Introduction

Air pollution is no longer just an environmental concern in India; it is a primary determinant of public health, as millions face chronic exposure outdoors, at home, and at work. Health risks include respiratory, cardiovascular, and metabolic diseases and vary by pollutant type, exposure concentration, and duration (WHO, 2026).

Evaluating these health impacts is essential because of India's large, growing population, rapid urbanisation, industrial growth, and complex emission profiles. Over the past 50 years, health research has grown significantly and provided valuable insights into environmental health risks. However, published studies vary widely in methodology, scope, and exposure assessment tools, ranging from stationary monitoring stations to satellite imagery and chemical transport models. Consequently, it is often hard to compare findings across studies. Localised research rarely reflects national population risks, and critical pollutants or health outcomes remain understudied.

To address these gaps, this brief synthesises 184 published epidemiological studies on air pollution and human health in India from 1975 to 2025. It examines how this body of evidence has evolved, including exposure settings, monitoring approaches, geographic distribution, institutional involvement, and funding landscapes, and highlights key exposure-health associations to inform evidence-based policy and future research priorities.

Methodology

CREA searched Scopus, Web of Science, and PubMed for peer-reviewed English-language studies on air pollution and health in India published between 1975 and March 2025, and reported the review according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 (Page et al., 2022). The search combined three sets of terms. First, air pollutants — ambient, indoor and household exposure to particulate matter (PM_1, $PM_{2.5}$, PM_{10}), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), black carbon, organic carbon, volatile organic compounds (VOCs) and heavy metals. Second, health outcomes — mortality, morbidity, hospital admissions, respiratory and cardiovascular diseases, cancer, diabetes and eye conditions. Third, epidemiological study designs.

Studies were included if they examined populations in India, used an epidemiological design, assessed exposure by measurement, modelling, or a proxy such as household fuel type, and reported an association with a health outcome. We excluded reviews, editorials, protocols, animal and in vitro studies, and non-peer-reviewed reports. We also excluded studies that estimated attributable deaths or illness using relative risks from other populations and multi-country studies that provided no separate estimate for India.

Two reviewers independently screened the 6,114 retrieved records in Rayyan and resolved disagreements through discussion. After removing duplicates and screening titles, 1,129 records remained, and citation searching added 38. Abstract screening of the 1,167 records reduced them to 252 for full-text review; of these, 184 met the criteria, 51 were excluded, and 17 could not be retrieved (Figure 1).

Each study was classified by the direction of its reported associations (see Study findings). Study quality and risk of bias were not formally assessed.

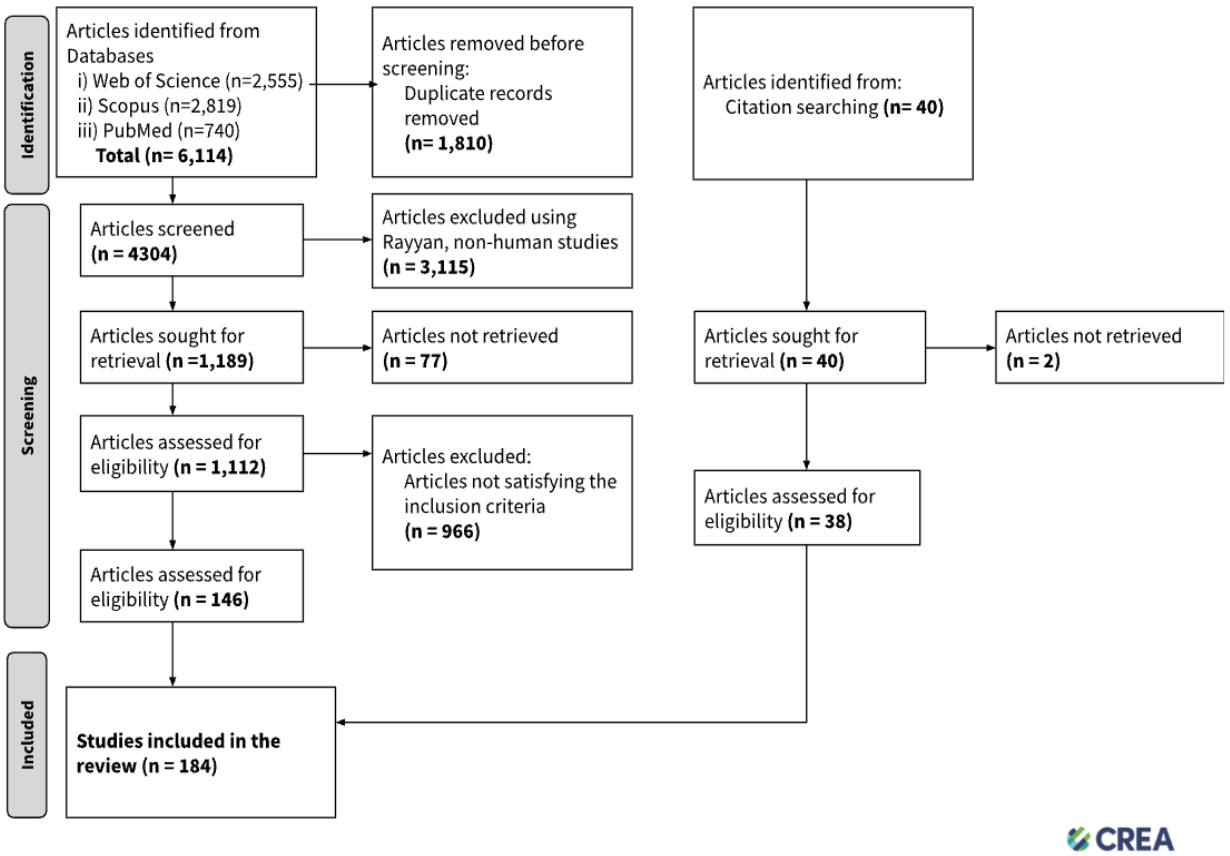


Figure 1 — Flow diagram outlining the identification, screening, and inclusion process for articles selected in this review.

Study findings

Air pollution linked to adverse health effects in most studies

The 184 studies were classified according to the direction and statistical significance of the reported associations between air pollution exposure and health outcomes. We classified studies based on reported effect estimates and statistical evidence, including p-values and confidence intervals, where available, along with the authors' reported findings. Positive findings indicated statistically significant associations with adverse health outcomes, while negative findings indicated statistically significant associations in the opposite direction. Null findings referred to statistically non-significant associations. We interpreted the direction of each association in the context of the health outcome and the exposure examined. Studies reporting different directions or levels of statistical significance across multiple pollutants, exposures or health outcomes were assigned multiple classifications. Where statistical information was insufficient to independently assess significance, the classification relied on the reported study findings.

The largest group, 99 studies (53.8%), reported both positive and null findings. This means that these studies identified an association between at least one exposure and a health outcome, but did not find a statistically significant association for every comparison examined. A further 63 studies (34.2%) reported only positive findings. Together, these two groups account for 162 of the 184 studies (88%), which reported at least one positive association between an air pollution exposure and a health outcome.

By comparison, 11 studies (6.0%) reported only null findings. These studies did not identify a statistically significant association for the exposure–outcome comparisons examined. The remaining studies reported associations in different directions or combinations of results: one study (0.5%) reported positive and negative findings, six (3.3%) reported positive, negative and null findings, and two (1.1%) reported negative and null findings.

Two additional studies (1.1%) were classified as favourable + null findings. These examined outcomes following the phase-out of leaded petrol and the use of improved cookstoves, reporting favourable changes in some health-related burdens (technically considered a negative association in the context of the study), alongside non-significant results.

Overall, 92% of the reviewed studies reported at least one positive association between air pollution exposure and a health outcome. This indicates that the relationship between air pollution and health impacts is a prominent finding in the reviewed Indian evidence. Null results in some studies do not cancel out associations found for other pollutants or health outcomes. Findings can differ depending on the exposure, population, duration of exposure and health measure examined.

Study findings with respect to health outcomes

Respiratory diseases were the most commonly studied health burden, accounting for 86 of the 184 studies (47% of the total reviewed literature). Of the 86 studies, inferences from 81 showed at least one positive association with the observed health outcome. Only positive associations were found in 23 studies, and the inferences from the several studies reported that higher exposure to particulate matter, household biomass or solid fuels, cooking smoke, traffic-related pollution, and other exposures was associated with reduced lung function, respiratory symptoms, asthma, tuberculosis, respiratory hospital admissions, or other respiratory problems. At the same time, many respiratory studies were classified as positive + null (54 studies). Here, some studies found significant associations for $PM_{2.5}$, PM_{10}, CO, NO_2, and SO_2, while some other pollutants related to respiratory comparison in the same studies were not significant. Similar mixed findings were observed in studies that considered cooking fuels and biomass exposure, and lung function showed 'positive + negative + null' (four studies) associations. A smaller number of respiratory studies were classified as null (five studies), where the exposure showed no statistically significant association with the respiratory outcome.

A total of 28 studies examined **multiple diseases;** of these, 25 studies showed at least one positive association with the health outcomes studied. A total of 12 studies showed only positive associations. These studies reported health effects across multiple outcomes, including respiratory, cardiovascular, ocular, diabetes, childbirth, pregnancy, toxicological disorder, and nutritional outcomes. Some of these studies associated biomass and household air pollution exposure with several adverse health conditions. At the same time, 12 multiple-disease studies showed positive + null findings because some outcomes were significantly associated with exposure while others were not. Two studies reported null significance, whereas one study showed 'positive + negative + null': $PM_{2.5}$ and NO_2 were positively associated with childhood stunting, while SO_2 was negatively associated, and other pollutants were not significant. Only one study evaluating an improved cookstove intervention reported favourable + null findings. Eye irritation symptoms decreased

following the intervention, while changes in blood pressure were not statistically significant.

Cardiovascular diseases were examined in 11 studies, of which 10 studies showed at least one positive association. Three studies showed positive-only associations, particularly for $PM_{2.5}$ and cardiovascular indicators, such as higher $PM_{2.5}$ exposure, which was associated with higher blood pressure, hypertension, atherosclerosis and arterial stiffness in these studies. However, seven studies also reported positive + null findings. For example, $PM_{2.5}$ showed significant associations with some blood-pressure measures and cardiovascular outcomes, while other exposure-related gaseous pollutants or outcome measures were not significant. However, for similar pollutants, one study showed a negative or null association with systolic and diastolic blood pressure, respectively.

Mortality due to air pollution exposure was observed in 16 studies. In that, all 16 studies showed at least one positive association with examined health outcomes. A total of six (positive) published articles reported higher mortality associated with $PM_{2.5}$ exposure. However, mortality findings were not always consistent across all age groups, locations or pollutants. Some studies reported significant associations for the overall population but null findings for particular age groups or exposure periods. Therefore, we classified nine mortality studies as positive + null rather than positive alone. One study observed positive + negative results, showing a positive association with mortality during solid fuel use and a negative association during the shift to cookstove use.

For ten studies of **birth outcomes and child growth**, eight showed at least one positive association; among them, findings were mainly positive in three studies and positive + null in the five studies. Studies reported associations between air pollution or household-fuel exposure and outcomes such as low birth weight, newborn head circumference and length measurements, stunting and child growth. Two studies showed null significance to exposures such as $PM_{2.5}$, CO and black carbon.

Among the seven studies on **neurocognitive disorders**, four showed only positive associations, and three showed positive + null associations. Household biomass solid fuel exposure was the main pollution focus in six of seven studies, and one study identified $PM_{2.5}$ as the only pollutant.

Of the five **morbidity** studies, three reported positive associations with heavy metal exposure (1) and particulate matter (2). Meanwhile, the remaining two studies on fuel exposure sources showed null (1) and positive + null (1) associations.

Neoplasm had four studies, all classified under the exposure-based assessment; two showed positive + null results, one was null, and one showed positive + negative + null findings.

Three studies considered health-related burdens such as **hematologic disorders**, showing two positive associations with $PM_{2.5}$ and one positive + null association with household solid fuel exposure. Another three studies examined **ocular diseases**, two of them focusing on cataract development related to cooking fuel exposure. One study reported positive findings (senile cataract: usually develops above age 50), while the other reported a combination of positive and null findings (cataract) and the similar positive + null findings reported in another eye's tear-film abnormalities study related to gaseous pollutant exposure.

Pregnancy-related studies were comparatively few (two studies), and the available findings showed positive associations with $PM_{2.5}$ and household biofuel exposure. These included associations with maternal outcomes (preeclampsia/ eclampsia) and other pregnancy-related health effects.

Two studies examined **diabetes:** one considered PM_{10}, while the other investigated $PM_{2.5}$ along with black carbon. Their findings were classified as positive + null and negative + null, respectively.

Similarly, **mental disorders** were examined in two studies, and the inferences showed a positive association for 'depression' with household cooking exposure in one study, while the other reported similar positive findings for 'attention-deficit hyperactivity disorder' due to PM_{10} exposure.

A total of five articles were considered in **other** categories due to the unique health burdens assessed, such as metabolic disorders ($PM_{2.5}$; positive + null), sleep disorder ($PM_{2.5}$; positive), chronic kidney disorder (PM and gaseous pollutants; positive), and bone diseases ($PM_{2.5}$ and black carbon; positive + null). Finally, one study examining blood lead levels in children following the phase-out of leaded petrol reported favourable + null findings, with blood lead levels declining after the policy change, reflecting an improvement (favourable) in the **toxicological disorder** while also showing null significance to other factors.

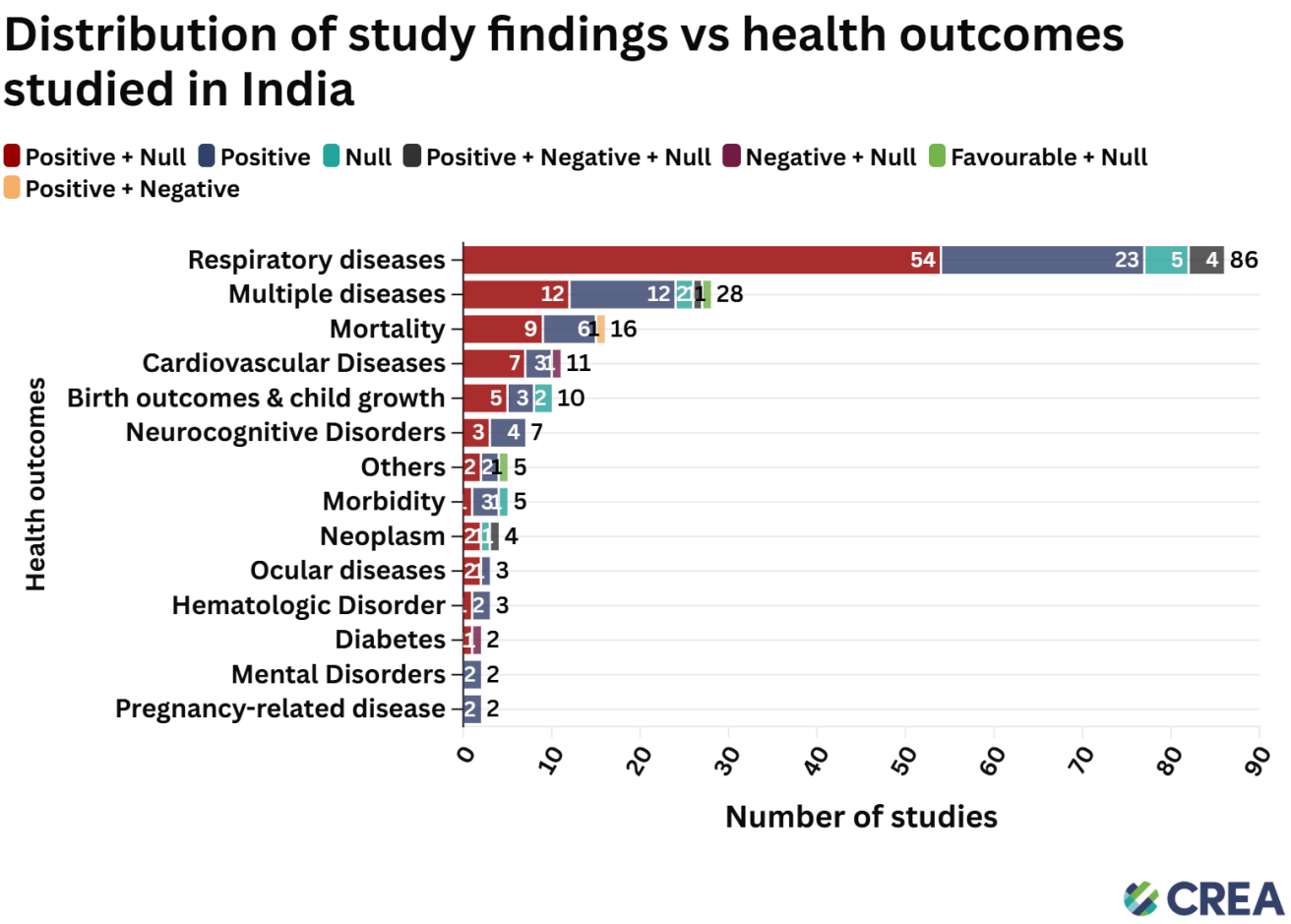


Figure 2 — Health burden-wise distribution of study findings

Descriptive analysis

Geographic distribution of air-pollution studies in India

The geographic distribution of the 184 studies shows that research has been conducted at national (all-India), multi-state and individual-state levels (Figure 3). Studies covering all of India formed the largest category, with 43 studies (23.3%). Delhi was the most frequently studied location, with 26 studies (14.1%) focusing on the national capital, followed by multi-state studies — 24 (13%).

Among studies focused on individual states, Punjab had the highest representation, with 13 studies (7%). Maharashtra and Uttar Pradesh each accounted for 11 studies (each 5.9%), followed by West Bengal with 10 (5.4%), Tamil Nadu with nine (4.8%) and Karnataka with eight (4.3%). Telangana accounted for seven (3.8%) studies, while Haryana and Rajasthan

had three (1.6%) each . Madhya Pradesh was represented by two (1%) studies. Assam, Chandigarh, Gujarat, Kerala, Ladakh, Mizoram and Odisha each had only one (0.5%) study in this review count. Seven (3.8%) studies examined air pollution across multiple countries, including India.

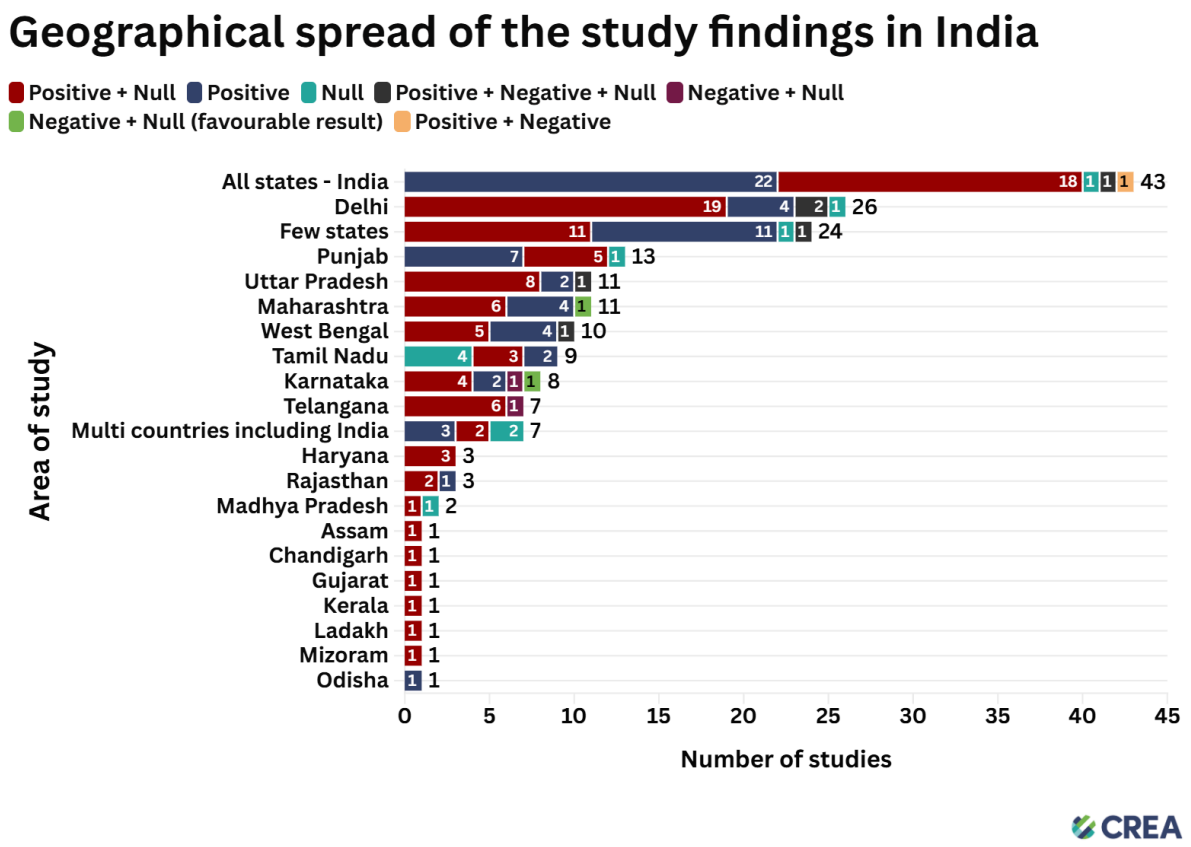


Figure 3 — Geographical spread of the study findings in India

Year-wise distribution and study design characteristics

The number of epidemiological studies examining the health effects of air pollution in India has increased substantially over time, with nearly two-thirds of the 184 studies included in this review published between 2016 and 2025 (Figure 4). Publication numbers rose from seven studies in 2001–2005 to 18 in 2006–2010 and 32 in 2011–2015. This upward trend continued in the subsequent decade, with 52 studies published in 2016–2020 and 65 in 2021–2025, together accounting for 117 studies (63.6%) of the total.

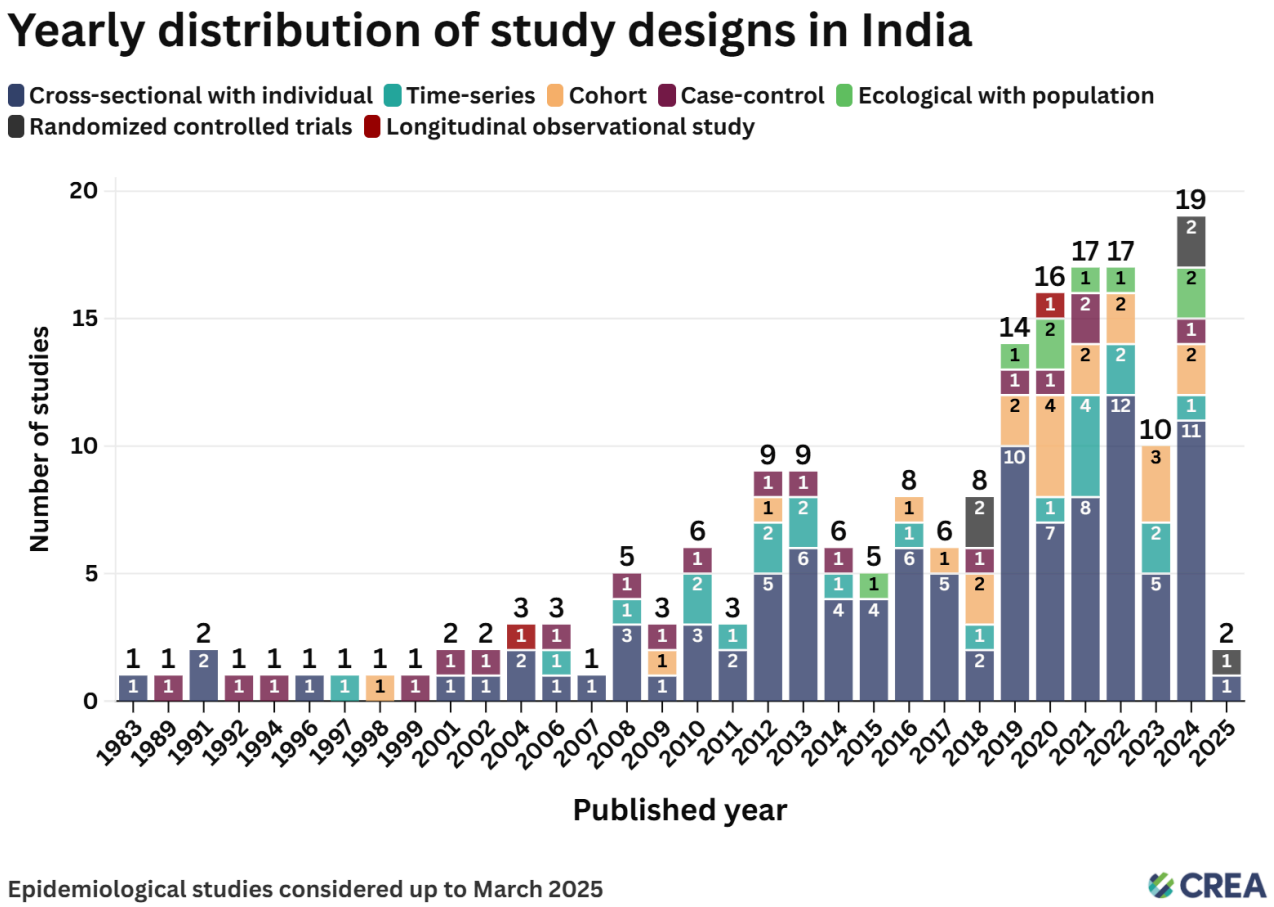


Figure 4 — Year-wise distribution of India epidemiological studies and their respective study designs

Cross-sectional studies involving individuals were the most common research design, accounting for 105 studies (57.1%). Time-series studies and cohort studies accounted for 23 (12.5%) and 22 (12.0%) studies, respectively, followed by case-control studies (19; 10.3%). Since 2018, more investigation has been done on ecological studies using population-level data (eight; 4.3%), randomized controlled trials (five; 2.7%), and longitudinal observational studies (two; 1.1%).

The predominance of cross-sectional studies indicates that much of the reviewed evidence assesses exposure and health outcomes at a particular point in time, while fewer studies use designs that follow individuals over time.

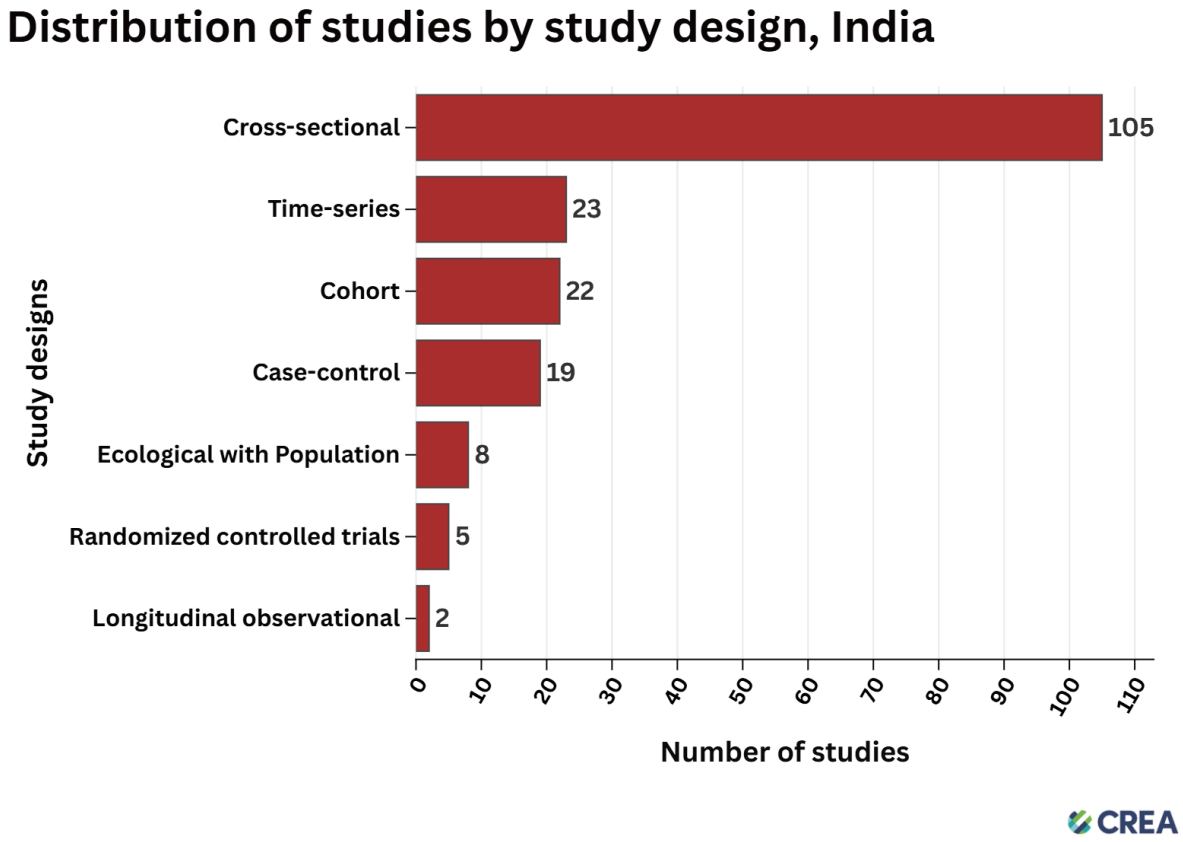


Figure 5 — Distribution of epidemiological study designs

Exposure settings

Ambient air pollution was the most frequently studied exposure setting, covered in 76 of the 184 studies (41.3%). Household air pollution, mainly associated with the use of fuels for cooking, heating and lighting, was examined in 53 studies (28.8%). Five studies (2.7%) examined indoor air pollution alone, including exposure related to smoking and indoor environments such as homes, schools, offices and workplaces. Another 25 studies (13.6%) investigated both household and indoor air pollution, while 15 (8.2%) examined both ambient and household exposure. Six studies (3.3%) focused on occupational exposure, and two studies (1.1%) investigated both ambient and indoor air pollution, while another two (1.1%) examined all three settings: ambient, household and indoor air pollution (Figure 6).

Overall, the reviewed studies covered a range of air pollution exposure settings, including ambient, indoor (excluding household) , household and occupational environments. This

range of evidence provides a broader understanding of the different contexts in which air pollution exposure and its associated health effects have been investigated in India.

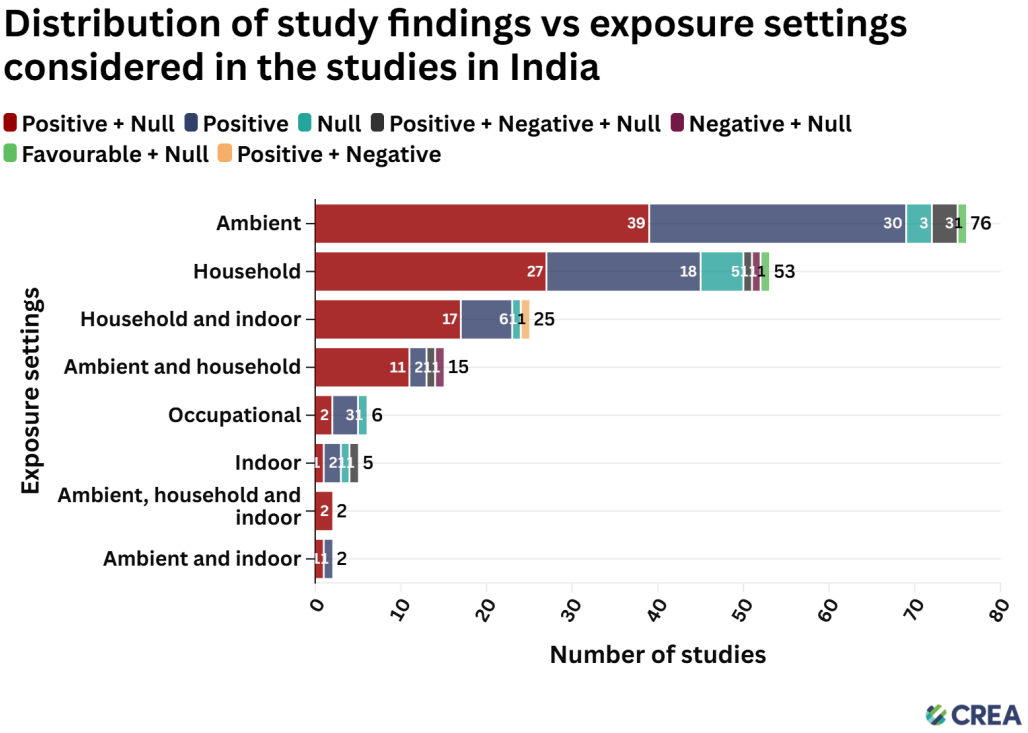


Figure 6 — Exposure settings-wise distribution of study findings

Type of pollutants studied

The reviewed studies assessed air pollution exposure using a range of approaches, including fuel-use indicators and measurements of specific pollutants (Figure 7). Fuel- or exposure-focused studies formed the largest category, accounting for 60 studies (32.6%). These studies examined health outcomes in relation to household fuel use or other exposure characteristics, rather than focusing on a specific measured pollutant.

Studies examining both particulate matter and gaseous pollutants formed the largest combined category, accounting for 45 studies (24.4%). $PM_{2.5}$ was investigated specifically in 32 studies (17.4%), four (2.2%) focused on PM_{10} alone, while 16 studies (8.7%) examined both PM_{10} and $PM_{2.5}$. Other studies focused on pollutant combinations, including $PM_{2.5}$ and black carbon (eight studies; 4.3%), $PM_{2.5}$ with black carbon and carbon monoxide (five

studies; 2.7%), and $PM_{2.5}$ with gaseous pollutants (four studies; 2.2%). Seven studies (3.8%) examined gaseous pollutants alone, while three (1.6%) investigated heavy metals.

Overall, the reviewed literature covered a range of exposure indicators and pollutants, with substantial attention to particulate matter, particularly $PM_{2.5}$, as well as studies examining multiple pollutants together.

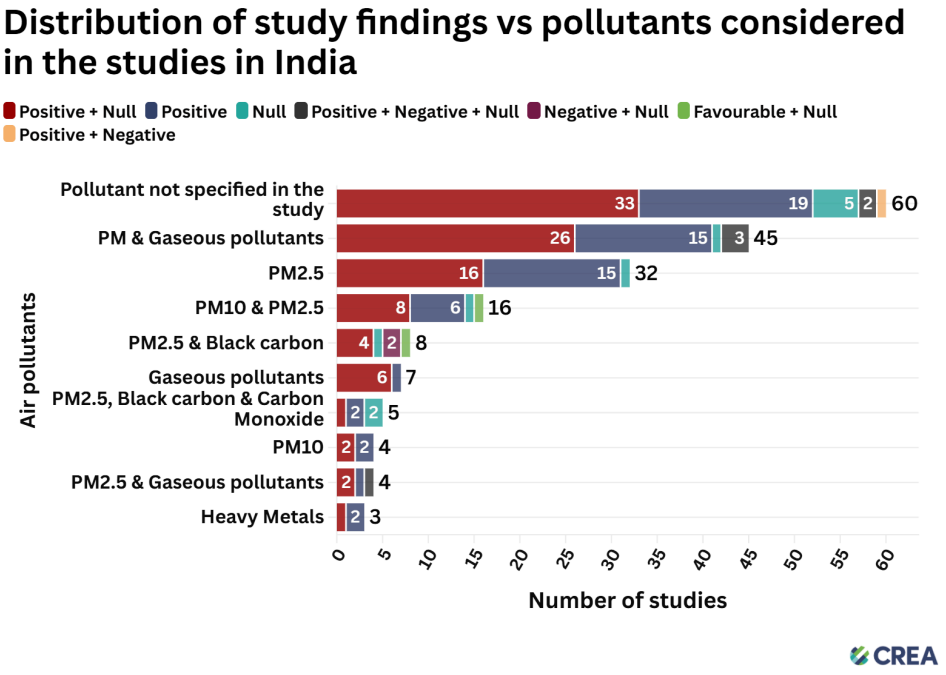


Figure 7 — Pollutant-wise distribution of study findingsAge groups considered

The age categories of exposed individuals are classified according to the Institute for Health Metrics and Evaluation (IHME), which includes neonatal (less than a year); under five; children (5–14 years); adolescent (10–19 years); young adult (20–25 years); adult (25–64 years); elder adults (65–80 years) and older adults (80 and above).

Adults were the most frequently represented age group in the reviewed studies, with 118 recorded occurrences. Adolescents accounted for 93 occurrences, followed by young adults (75), elderly adults (56), older adults (56), children (47), children under five years of age (40) and neonates (13). These findings indicate that the reviewed literature covered a broad range of age groups, although adults and adolescents featured most frequently in the studies.

Funding and institutional affiliations

Information about funding was not reported in 88 of the 184 studies (Figure 8). Among the studies that reported funding sources, 46 each were supported by government and foreign organisations, and four were funded by private institutions. Among the studies funded by the Indian government (46 studies), the Department of Science and Technology (DST) and the Indian Council of Medical Research (ICMR) each funded 12 studies. Other reported government funding sources included the Ministry of Environment and Forests (MoEFCC; six studies), the Council of Scientific and Industrial Research (CSIR; five studies) and the Central Pollution Control Board (CPCB; four studies). All India Institute of Medical Sciences (AIIMS), the Ministry of Health and Family Welfare (MoHFW), the University Grants Commission (UGC), King George's Medical University in Lucknow, the Directorate of Environment in Uttar Pradesh, and the Fulbright-Nehru Student Research Scholarship governed by the Ministry of External Affairs each funded a study. Another study listed "the Government of India with foreign agencies" as the funder.

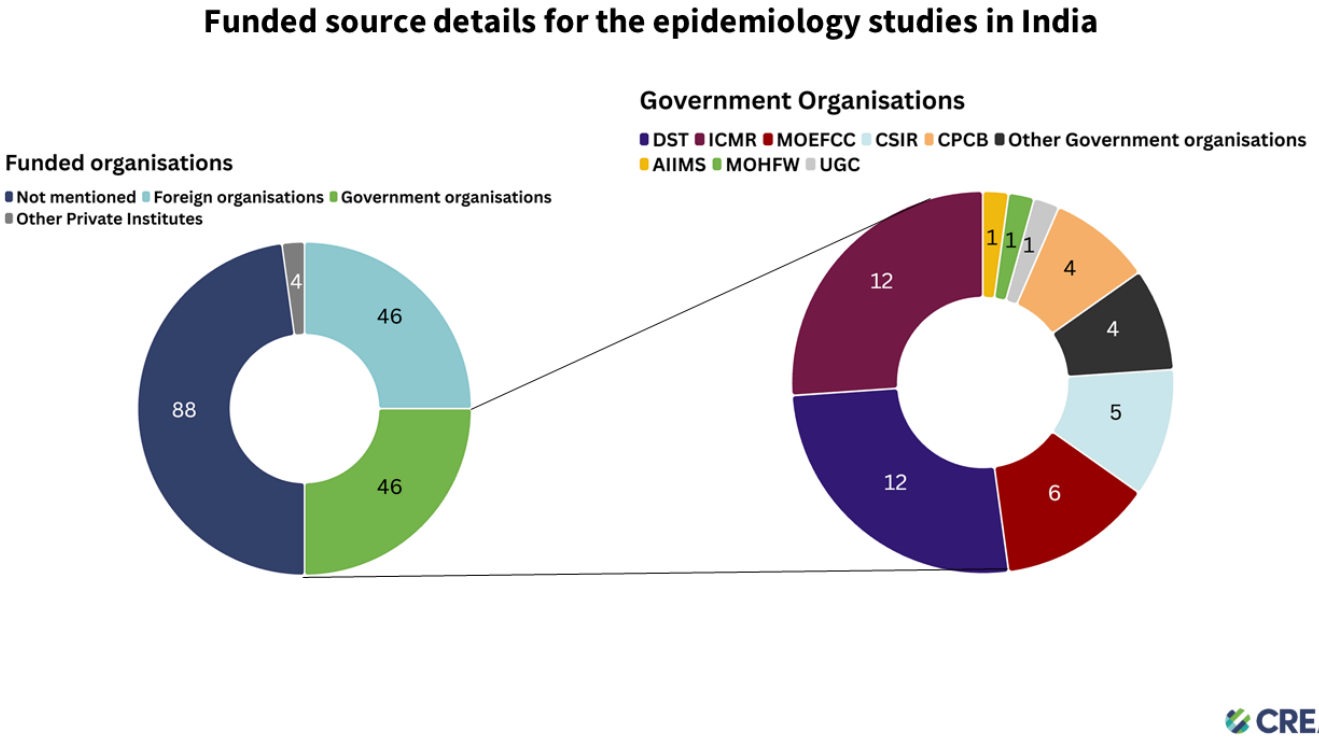


Figure 8 — Distribution of funding organisations for the research studies

Institutional affiliations showed substantial involvement of Indian and international research organisations (Figure 9). India–foreign collaborative institutions were associated

with 80 studies (43.5%), followed by Indian government institutions, which accounted for 58 studies (31.5%). These included Indian Institutes of Technology, AIIMS, ICMR institutions, CSIR institutes and other Central and state government institutions. Indian private institutions were affiliated with 14 studies (7.6%), including Sri Ramachandra Institute of Higher Education and Research in Chennai and St John's Medical College in Bengaluru. Government–private institutional collaborations accounted for 23 studies, while nine studies involved foreign institutions alone.

Overall, the findings indicate substantial international collaboration in epidemiological research on air pollution in India, alongside significant contributions from Indian government institutions. However, nearly half of the studies did not report funding information, limiting the assessment of financial support across the reviewed literature.

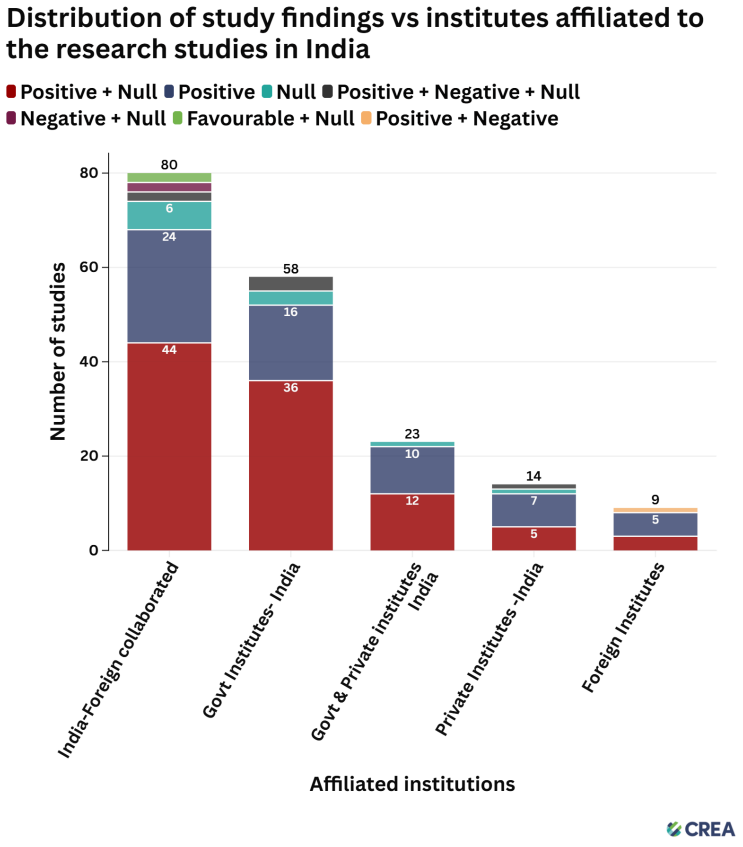


Figure 9 — Affiliated institutes category and its associated study findings

Policy priorities

The substantial body of epidemiological evidence linking air pollution exposure to adverse health outcomes reinforces the need to make exposure reduction a central objective of India's air pollution management policies. Reducing health risks requires lowering pollution concentrations across both ambient and indoor environments, rather than focusing on a single exposure setting or pollutant.

India's National Ambient Air Quality Standards (NAAQS), last revised in 2009, need to be updated to reflect current scientific evidence and public health considerations. This should be accompanied by expanded monitoring coverage through both Continuous Ambient Air Quality Monitoring Stations (CAAQMS) and Online Continuous Emission Monitoring Systems (OCEMS), to improve the assessment of ambient pollution levels and industrial emissions. Stronger ambient air quality standards must also be supported by stricter and enforceable emission standards for major pollution sources, including industries and thermal power plants. Clear, time-bound emission reduction targets should be established for individual sectors, with defined implementation timelines and effective compliance monitoring.

Equally important is reducing indoor air pollution by accelerating the transition away from solid fuels, including biomass, coal and dung, for household cooking and heating, while ensuring access to cleaner energy alternatives. Air pollution management must therefore adopt an integrated approach that addresses emissions across sectors and exposure settings. Ultimately, reducing population exposure to air pollution is essential to protecting public health and lowering the associated disease burden.

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