



# Delving into the Impacts of Air Pollution on Sex, Health, Environment, and Pollution-related Policies in Nepal: A Scoping Review

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## ABSTRACT

**Background:** Air pollution poses a serious threat to public health as it contributes to a high prevalence of non-communicable diseases (NCDs) such as respiratory illness and cardiovascular diseases. This scoping review aimed to provide an overview of the impacts of air pollution on sex, health, and the environment, with a brief highlight on pollution-related policies in Nepal. It reviews the environmental effects of air pollution and existing policies for controlling air pollution.

**Methods:** This review followed the five-stage methodological framework outlined by Arksey and O'Malley and was reported by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews. A comprehensive search was conducted across databases, including Frontiers, Google Scholar, and PubMed, using keywords related to air pollution, its impact, and policies. A total of 104 were initially identified, with 12 meeting the inclusion criteria.

**Results:** The review synthesizes the findings from studies conducted between 2018 and 2024, indicating that women, particularly involved in cooking with biomass fuels, face higher exposure to harmful pollutants, leading to serious health outcomes like chronic obstructive pulmonary disease (COPD), eye disorders, and adverse pregnancy outcomes. The studies revealed that the concentration of particulate matter (PM<sub>2.5</sub>) has often exceeded World Health Organization guidelines, and indoor and outdoor air pollution negatively impact environmental health and human wellbeing.

**Conclusion:** The study underscores the urgent need for targeted interventions and policy measures to mitigate air pollution and protect vulnerable populations, particularly women, in Nepal. Further research is essential to address existing gaps for different sexes and inform effective public health strategies.

**Keywords:** air pollution; health impact; sex; Nepal.

## BACKGROUND

Air pollution has long been considered a silent killer, causing various chronic and infectious diseases (1–3). In Nepal, the commonest diseases like respiratory illness, allergy, and eye infection, and chronic diseases like lung cancer, chronic obstructive pulmonary disease (COPD), Ischaemic Heart Disease (IHD), and stroke are present at an alarming rate (4). Non-communicable Diseases (NCDs) have been the primary cause of human

death, accounting for 60% of deaths. Of NCDs, cardiovascular diseases have caused a maximum death of 22% followed by chronic respiratory diseases 13%, cancer 8%, and other NCDs 14%. Premature (between the ages of 30 and 70 years) mortality due to NCDs is 22% (4).

Outdoor pollution primarily stems from vehicular emissions and industrial activities, while indoor pollution results from using solid fuels for cooking and heating (5–6). Air pollution is

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associated with various diseases, particularly respiratory and cardiovascular conditions. PM<sub>2.5</sub> exposure can lead to lung cancer, chronic bronchitis, and respiratory symptoms. In addition, there is a correlation between PM<sub>2.5</sub> levels and increased mortality from all causes (7).

Not only human health, but the effect on the environment is also quite sensitive. According to a study, air pollution significantly contributes to a range of environmental issues, including climate change and the degradation of air quality (5-6). Due to this, women are more vulnerable to the effects of air pollution than men (8) as women are primarily involved in daily cooking (9), which exposes them to household air pollution with increased risk of the consequent health outcomes (10-12).

The sex disparity in exposure to air pollution is closely linked to socioeconomic factors such as income and employment status (13). A study found that the women who earn more were more likely to use clean fuel, while those having less than USD 900 annually were likely to use biomass fuel. In business, those involved in Government were expected to use clean fuel, unlike farmers, labourers, and homemakers, who were likelier to use biomass fuel (9).

Solid fuels, particularly biomass fuel, are still in an era of rapid technological advancements. A study revealed that out of 415 women who performed cooking, only 23 used a smokeless stove, 43 used LPG gases, and most used firewood, cow dung, straw, and leaves (10). The result showed that the participants, who came in contact with all the fuels, have impact on their respiratory health. In addition, outdoor air pollution has also been proven to have a much greater effect on women, as a study evinced the presence of biomarkers more in female traffic police officers than in males, due to the outdoor air pollution in Kathmandu, Nepal (14).

The impact of air pollution on public health is significant and is influenced by various socioeconomic factors (13). Addressing air pollution is crucial to improving public health outcomes in Nepal. Thus, this scoping review aimed to provide a comprehensive understanding of the sex-specific health impacts of air pollution in Nepal, including environmental effects, and to review and critique policy frameworks for controlling air pollution.

## METHODS

This scoping review was conducted using a five-stage methodological framework outlined by Arksey and O'Malley and reported by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines. This

framework has been widely adopted and later refined by the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines, which aim to enhance transparency and consistency in the reporting of scoping reviews. The PRISMA-ScR provides a checklist that complements Arksey and O'Malley's approach by ensuring comprehensive and standardized reporting (15).

This review outlines a systematic approach to exploring the health implications of air pollution, with a focus on Sex, Health, Environment, and pollution-related policies.

## Study selection

The articles published between 2018 and 2024 were included in the study to ensure the inclusion of recent and relevant data that reflects the current trends, practices, or developments in the field. The studies related to the impact of air pollution (indoor and outdoor) on sex, environment, overall health, burden of disease, and pollution-related policies were included. Only full-text articles in the English language were included. The different study designs, such as Randomized controlled trials, experimental studies, and interventions, were avoided. The unpublished documents, letters, conference papers, and reviews were also excluded.

## Literature Search

The relevant studies were searched using Frontiers, Google Scholar, and PubMed databases. The search was carried out using keywords such as "air pollution and health", "impact of air pollution", "air pollution and sex", "air pollution and burden of diseases", and "air pollution policies". The last search in all databases and registers was done on Aug 15, 2024. The four reviewers screened titles, abstracts, and full texts separately. The disagreements regarding the study selection were resolved by discussion between the reviewers.

## Data extraction, processing, and reporting

The process followed a systematic approach using the PRISMA framework to ensure rigorously selected final articles. The review focused on sex, health, environment, and pollution-related policies concerning air pollution. Keywords relevant to the study were then identified and critically analyzed. Information under these themes was extracted from the selected articles, ensuring consistency and relevance to the research focus. Lastly, the results were synthesized, including integrating findings from the extracted data into a comprehensive overview of the subject matter. This process ensured a structured and detailed literature analysis concerning air pollution impacts across different dimensions.

Table 1. Summary of included articles

| Topic                                                                                                                                                                                  | Study Design and Study settings                                            | Author and Year of Publication | Outcomes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Women's Ideas about the Health Effects of Household Air Pollution, Developed through Focus Group Discussions and Artwork in Southern Nepal                                             | Focus group discussion<br>Urban and peri-urban areas                       | (Devakumar et al., 2018)       | Effects related to eye and respiratory system reported                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Roadside Exposure and Inflammation Biomarkers among Cohort of Traffic Police in Kathmandu, Nepal                                                                                       | Cohort study<br>Urban area                                                 | (Shakya et al., 2019)          | No significant association between 24 hr PM 2.5 average with analyzed biomarkers. Inflammation and vascular injury marker concentration higher in females                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Linking weather and health outcomes: Examining the potential influences of weather factors and particulate matter pollution on adverse pregnancy outcomes in the Kavre district, Nepal | Cohort study<br>Rural area                                                 | (Tiwari et al., 2024)          | Disruption of physiology and anatomy of placenta and umbilical cords reported                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Prevalence of Biomass Use and its Effect on the Respiratory Health of Women Residing in Eastern Terai Region of Nepal                                                                  | Descriptive Cross-section study<br>Rural area, eastern terai region        | (P. Adhikari et al., 2023)     | Cough (14.7%), Phlegm (9.9%) reported                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Effect of exposure to biomass smoke from cooking fuel types and eye disorders in women from hilly and plain regions of Nepal                                                           | Community based cross section study<br>Rural area, hilly and plain regions | (Patel et al., 2022)           | Cataract (39%), 1.9% blind in right eye and 2.6% blind in left eye                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Prevalence of Chronic Obstructive Pulmonary Disease and its Associated Factors in Nepal: Findings from a Community-based Household Survey                                              | Cross sectional household survey<br>Semi urban area                        | (T. B. Adhikari et al., 2020)  | COPD 8.5% (95% CI: 7.1-10.0) on gold criteria, 5.4% (95% CI: 4.2-6.6) on LLN criteria                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Gaseous Air Pollutants and Respirable Crystalline Silica Inside and Outside Homes at Brick Kilns in Bhaktapur, Kathmandu Valley, Nepal                                                 | Cross sectional study<br>Urban area                                        | (Beard et al., 2022)           | Positive association between the variable how long lived in house and SiO <sub>2</sub> (quartz) concentrations, which may reflect sustained take-home exposure to SiO <sub>2</sub> (quartz) over time                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Assessment of Health Impact of PM <sub>2.5</sub> Exposure by Using WRF-Chem Model in Kathmandu Valley, Nepal                                                                           | Cross sectional study<br>Urban area                                        | (Tuladhar et al., 2021)        | Due to PM 2.5 exposure 19 people could die because of lung cancer and 175 people could die because of other diseases                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Personal Exposure to Fine Particulate Air Pollution among Brick Workers in Nepal                                                                                                       | Cross sectional observational study<br>Urban area                          | (Johnston et al., 2023)        | The overall geometric mean (GM) PM <sub>2.5</sub> exposure was 116 µg/m <sup>3</sup> (95% CI: 94.03–143.42). PM <sub>2.5</sub> levels varied significantly across job roles. Administrative staff had the lowest exposure (GM: 47.92 µg/m <sup>3</sup> ), while firemen, green brick hand molders, and top loaders had significantly higher exposures (around 159–163 µg/m <sup>3</sup> ). Firemen also had higher exposure than green brick machine molders, and hand molders had significantly higher exposure than machine molders. Frontline production workers experienced substantially greater PM <sub>2.5</sub> exposure compared to administrative staff |
| Air-Quality Assessment of On-Site Brick-Kiln Worker Housing in Bhaktapur, Nepal: Chemical Speciation of Indoor and Outdoor PM <sub>2.5</sub> Pollution                                 | Cross –Sectional study<br>Urban areas                                      | (Thygerson et al., 2019)       | Geometric mean PM <sub>2.5</sub> = 184.65 g/m <sup>3</sup> (95% CI: 134.70, 253.12 g/m <sup>3</sup> ). PM <sub>2.5</sub> concentrations differed by kiln number (p = 0.009). Kiln number was significantly associated with 16 of 29 (55%) air pollutant.                                                                                                                                                                                                                                                                                                                                                                                                          |
| Assessment of Factors Associated with Indoor Air Pollution using Multinomial Logistic Regression: A Case Study of Barbardiya Municipality                                              | Cross section study<br>Rural area                                          | (Bhandari & Shrestha, 2021)    | Fitted model predicted that the odds ratio of socio-economic variables like Ethnicity: Tharu community relative to Bhramin/Chhetri community = 2.5 (95% CI: 1.08 -5.78), household head's education level: illiterate relative to literate was 8.21 (95% CI: 3.30-59.54), family's monthly income: ≤ NRs 30000 relative to > NRs 30000 was 2.38 (95% CI: 1.10-5.16) considering high with respect to low IAP                                                                                                                                                                                                                                                      |

The findings of the articles are presented in the following themes:

## RESULTS

A total of 104 were found upon an initial search. After filtering the articles, 19 duplicates were detected and removed. 85 articles were screened, which led us to exclude 37 articles that did not meet our inclusion criteria, and 17 articles were further excluded for not having full text. Out of 31 articles, 19 articles were further excluded. A total of 12 finalised based on the inclusion criteria defined by the team.

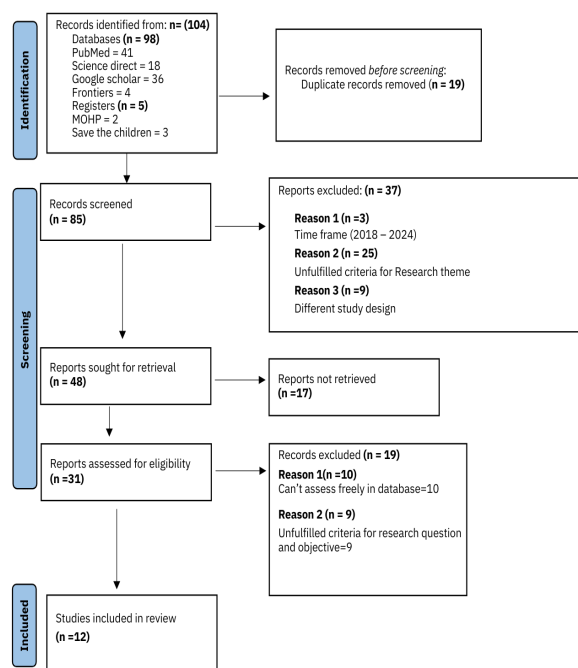


Figure 1. PRISMA flow diagram of the selection process.

### Impact of air pollution on sex

Air pollution has adverse effects on both sexes, but the effects can differ. One study found that the prevalence of COPD was higher in men (10.9%) than in women (6.4%) when assessed by GOLD criteria, since men are more likely to work in the outer environment and have higher pollution exposure (8). In contrast, women are more affected by indoor air pollution from cooking with biomass fuel (8,20), leading to heightened risks of respiratory illnesses and other health complications, therefore, women are affected by indoor air pollution, as households using biomass fuel for cooking face up to 3.8 times higher pollution levels (18). In contrast, also with regards to the outer environment, another study had concluded that the higher concentration of eight biomarkers(SAA,IL-2, IL-4,IL-6, IL-10, IL-12, IL-13, IFN- $\gamma$ ) were reported in the females due to roadside exposure (14).

### Impact of air pollution on health

Air pollution is associated with various diseases, especially respiratory and cardiovascular conditions. A study revealed that COPD prevalence ranges from 1.67% to 14.3%, highlighting it as a leading cause

of global morbidity and mortality, with chronic respiratory diseases causing 10% of all deaths (22). A study mentioned that women suffered from respiratory problems mainly along with cough, wheezing, phlegm, breathlessness, and chest illness(10); however, the other studies reported that eye problems (cataracts and risk was over threefold higher in women using biomass fuel) had affected the women more than respiratory diseases (9,16). Therefore, the studies carried out in epidemiology, medicine, and physics indicate that PM<sub>2.5</sub> may induce adverse pregnancy outcomes through interference with placental and umbilical cord functions, inducing oxidative stress, inflammation, blood coagulation changes, and hypertension (17).

In Nepal, A review of studies in Nepal reported that Non-Communicable Diseases (NCDs) account for 60% of deaths, with cardiovascular diseases causing 22%, chronic respiratory diseases 13%, cancer 8%, and other NCDs 14%, while premature mortality (ages 30–70) due to NCDs is 22%; respiratory illnesses, allergies, eye infections, and chronic conditions like lung cancer, COPD, ischemic heart disease, and stroke are alarmingly prevalent, particularly among brick workers who face high rates of COPD and other respiratory issues (4,19,21). The other study identified an 8.5% prevalence of COPD, pointing to a substantial public health challenge (8). A study revealed that 19 deaths were related to lung cancer and 175 to all other causes due to PM 2.5 exposure in Kathmandu valley (7). The studies mentioned that PM<sub>2.5</sub> exposure was linked to over four million deaths and significant disability-adjusted life years (DALYs) lost (21).

### Impact of Air pollution on the environment

The study reported that vehicular emissions, industrial activities, unplanned road expansion, and residential combustion are the leading causes of air pollution (7). Air pollution impacts the environment by degrading air quality, driving climate change, and causing public health issues (22). A study conducted in southern Nepal reported that while cooking using biomass fuel, a foul odour is noted, producing a large amount of dust, affecting the quality of the environment (16). A study showed that the average outdoor PM<sub>2.5</sub> concentration across the four brick kilns was 186.52  $\mu\text{g}/\text{m}^3$ . The PM 2.5 concentrations were found to be over detection limits than WHO guidelines (20), revealing that outdoor air quality exceeds World Health Organization guidelines (4), leading to broader environmental issues such as climate change and ecosystem degradation (20).

### Pollution-related Policies in Nepal

Air pollution is an issue in Nepal that affects public health and the environment. The Constitution of Nepal (2015) emphasizes the “right to clean and healthy environment, “establishing the framework for various

policies to improve air quality. The 15th Plan (2019/20-2023/24) targeted reducing PM 2.5 emissions from 53  $\mu\text{g}/\text{m}^3$  to 40  $\mu\text{g}/\text{m}^3$ , but required effective monitoring and implementation to achieve this. Although the policy lacks specific enforcement measures, the National Environment Policy (2019) aims to control pollution and promote greenery that ensures citizens' rights to a clean environment, which may hinder its effectiveness. The Kathmandu Valley Air Quality Management Action Plan (KVAQMAP, 2020) has outlined 135 actions to improve air quality in the valley, including declaration of public health emergencies. The 2019 National Health Policy highlights the need for a multi-action plan to address air pollution impacts, but it doesn't provide a specific indicator for monitoring. Similarly, the Urban Health Policy (2015) seeks to protect the citizens from adverse health factors in urban areas. Still, it lacks specific programs that address the control of air pollution, which undermines efforts in urban centers where air quality is a significant issue. The transportation policies, including the National Transport Policy (2007) and Environment-Friendly Vehicle and Transport Policy (2014), aim to promote sustainable transport and electric mobility. However, the absence of strict regulations limits their effectiveness. The Industrial Policy (2011) and Industrial Enterprises Act (2020) advocate for environmentally friendly practices, yet enforcement is often weak. While Nepal has established a comprehensive framework of policies to mitigate air pollution and its impacts on health and the environment, challenges such as inadequate enforcement, lack of specific action plans, and insufficient funding hinder their effectiveness. Strengthening implementation mechanisms, enhancing public awareness, and ensuring inter-sectoral coordination are essential to achieve desired outcomes in air quality improvement and public health protection.

## DISCUSSION

The impact of air pollution on sex was unequivocally found to be on women, especially those belonging to lower-income rural areas, where the use of biomass fuels for cooking is still persistent. They are suffering from respiratory diseases, eye problems, and pregnancy complications. Even though relevant policies exist, their enforcement is not robust. Prompt action through cleaner energy provision and awareness is essential to reduce the sexed impact of air pollution.

While social roles are at play, girls face more indoor and boys more outdoor pollution (28). A similar study in Bangladesh assessing the sex differences of household and ambient air pollution with child health found that solid fuel use is linked with respiratory illnesses primarily in girls. At the same time, boys are more affected by prenatal exposure to PM<sub>2.5</sub>, causing stunting (28). Another study in Kolkata, India, showed

that indoor air pollution (IAP) impacts women's health, particularly those who cook more indoors (29-30). A study from Sri Lanka also highlighted that air pollution predominantly affects women, particularly those who spend more time indoors, as they get exposed to indoor air pollutants from biomass cooking (32) consequent in both short-term issues such as eye irritation, dizziness (29-30) and long-term health issues mainly respiratory diseases such as pneumonia, chronic obstructive pulmonary disease (COPD), and asthma (33). Moreover, women are at risk of heart disease and complications during pregnancy, due to the harmful effects of air pollution (34). Economic constraints often prevent women from taking adequate measures to mitigate IAP, despite their awareness of its presence and health risk (31). A study conducted in rural Pakistan showed that the health expenses of households using biomass are almost 25% higher than those using LPG (35). Using traditional biomass has negatively impacted rural women's lives. Significant factors affecting the choice of fuels for cooking are household composition, education, income, access to electricity and LPG, and distance from the market (36). Clean energy and technologies, and empowerment through education and awareness, will help minimise the negative impacts of biomass fuels on women (35).

## CONCLUSION

This scoping review underscores the impact of air pollution on sex-specific health in Nepal, with women being disproportionately affected. The outdoor air pollution has affected both sexes, but due to exposure to indoor air pollution from biomass fuel, women are primarily at risk of respiratory and eye diseases. The study's findings highlighted an urgent need for interventions and legislative measures in Nepal to mitigate the impact of air pollution and protect the vulnerable populations, especially women. Further research is required to bridge existing knowledge gaps and to develop practical strategies to reduce the effect of air pollution on public health.

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## Conflict of Interest

The authors declare no conflict of interest.

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