CalSPEC
California State Policy Evidence Consortium

Near-Roadway Indoor Air Pollution: Assessing Health Effects and Mitigation Strategies

Appendix D1. Mitigation Detailed Methods

This appendix provides details on the literature search ad evaluation methods including:

1) A literature search guide developed by the CalSPEC team to inform the librarian's literature search on mitigation strategies to reduce near-roadway indoor air pollution.
2) The librarian's search strategy
3) Diagrams outlining the process for screening articles to include in the evidence synthesis of source, ambient, and exposure control strategies.

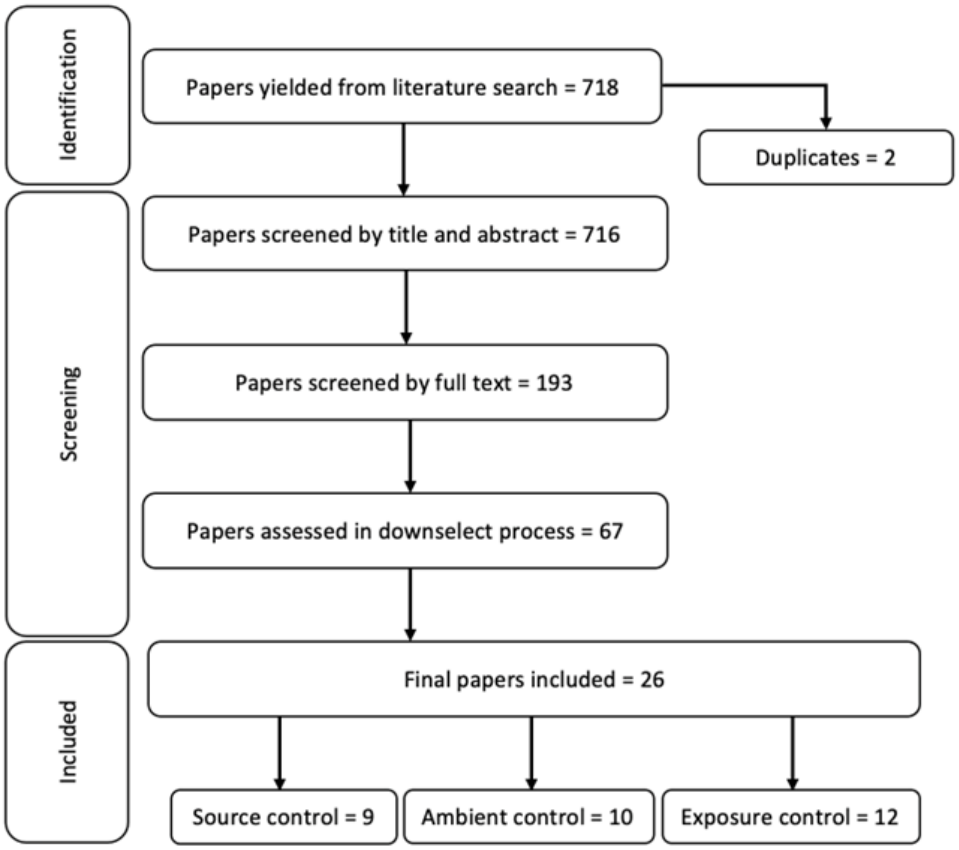
Mitigation Literature Search and Evaluation Methods

In brief, working with a research librarian, CalSPEC used keywords to search relevant databases to identify systematic and narrative review articles assessing the effectiveness or cost-effectiveness of source, ambient, and indoor exposure control strategies. Two reviewers independently screened the studies first by title and abstract and then by full text to assess eligibility. Inclusion criteria included reviews available in the public domain, focused on mitigation, producing synthesized effects, written in English, and published in 2010 or later. Papers providing general background or analytical methods, focused solely on health effects, incorporating extraneous topics (such as microbial pollutants), or unrelated to residences, schools, or offices were excluded.

Study Screening and Selection

Of 718 articles identified through the database search, 193 underwent full-text screening and 67 were selected for preliminary review. In the end, 26 articles (9 assessing source control strategies, 10 ambient control, and 12 indoor exposure control) were selected for inclusion based on their use of empirical data (systematic review or data synthesis) or unique contributions (coverage of interventions not touched upon in the systematic reviews and/or focus on cost-effectiveness) **(Figure 1).**

Figure 1. Overall study selection* diagram.
*(*Some papers covered multiple categories of source, ambient, and exposure control.)*



Assessing the Weight of Evidence

CalSPEC assessed near-roadway air pollution (NRIAP) mitigation strategies based on the overall **weight of evidence** available for each strategy. The weight of evidence was assessed by considering the following factors:

- **The quality of the body of evidence**. CalSPEC relied on the review articles to assess the quality of evidence derived from primary studies, including consideration of potential biases, limitations, and study design (e.g., short vs. long term, revealed vs. stated outcomes, laboratory experiments vs. computer simulations vs. real world intervention results).
- **Direction of effect estimates**. CalSPEC considered the direction and magnitude of effects reported in the literature. Consistently positive results would receive greater weight than conflicting results.
- **Confidence in the effect estimates**. CalSPEC considered the number of available primary studies and the diversity of the methods used (e.g., laboratory experiments, computer simulations, and real-world intervention results) to assess confidence in the effect estimates.

In addition to these factors, CalSPEC sometimes considered other compelling attributes of the data in assigning a weight of evidence grade. For example, while sufficient data were collected through

diverse methods, they could be concentrated in non-U.S. counties, where results might be less applicable to U.S. settings.

Based on these factors, CalSPEC rated the evidence as sufficient, moderate, suggestive, or insufficient **(Table 1).**

Table 1. Evidence rating levels and definitions

Evidence Level	Definition and Criteria
Sufficient	At least 3 primary studies suggest an effect based on observed via diverse settings and/or methods; mostly absent of known confounding factors or biases (>50% of the primary studies).
Moderate	At least 3 primary studies suggest an effect, but downgraded due to reasons such as: (1) lack of diversity of the methods or experimental approaches used to estimate the effects (e.g., effects were based entirely on model simulations rather than field measurements); (2) potential confounding effects and biases in >50% of the studies; or (3) limited generalizability related to the study time period or location/population.
Insufficient	There is a paucity of evidence of effect due to a lack of studies (<3 primary studies referenced across all the included review articles) or inconsistent or weak effects (e.g., substantial directional inconsistency and/or non-statistically significant outcomes).

Cost and Cost Effectiveness Assessment

The cost of mitigation strategies is sparsely reported in the literature. CalSPEC found 16 relevant cost-related review articles that met inclusion criteria. Each included qualitative and subjective cost assessments, mostly regarding the cost and complexity of *implementation.* Additional details are provided under the findings and in **Appendix E**.

Search Guide

Overall useful keywords: traffic-related air pollutants, near-road pollution, road proximity, roadside pollution, near-road monitoring, mitigation strategies, intervention, air pollution exposure, indoor exposure, indoor air quality, on-road emissions, vehicular emissions, vehicle emissions, urban air quality, exposure assessment, exposure reduction, monetary impact values, benefit and cost, health benefit

1) To what extent have specific mitigation strategies been effective in reducing near-roadway indoor air pollution?
    a. Source control: reduce the amount of primary and precursor emissions related to traffic.

i. Reducing vehicle miles traveled: telecommuting, increasing use of public transit, increasing active mode such as biking or walking; sustainable travel behavior

ii. **Additional keywords:** mobile source control, emissions control, public transportation

Levy, Jonathan I., Susan L. Greco, Steven J. Melly, and Neha Mukhi. 2009. "Evaluating Efficiency-Equality Tradeoffs for Mobile Source Control Strategies in an Urban Area." *Risk Analysis* 29 (1): 34–47. https://doi.org/10.1111/j.1539-6924.2008.01119.x.

iii. Zero emission/clean vehicles, alternative fuel vehicles

iv. **Additional keywords:** electric vehicles, environmental benefits, urban exposures, urban design

Holland, Stephen P., Erin T. Mansur, Nicholas Z. Muller, and Andrew J. Yates. 2019. "Distributional Effects of Air Pollution from Electric Vehicle Adoption." *Journal of the Association of Environmental and Resource Economists* 6 (S1): S65–94. https://doi.org/10.1086/701188.

Yu, Haofei, and Amy L. Stuart. 2017. "Impacts of Compact Growth and Electric Vehicles on Future Air Quality and Urban Exposures May Be Mixed." *Science of The Total Environment* 576 (January): 148–58. https://doi.org/10.1016/j.scitotenv.2016.10.079.

v. Emissions control, vehicle emission standards, fuel standards

vi. **Additional keywords:** exposure modeling, exposure assessment, mobile source emission control, vehicular emissions

Moutinho, Jennifer L., Donghai Liang, Rachel Golan, Stefanie E. Sarnat, Rodney Weber, Jeremy A. Sarnat, and Armistead G. Russell. 2020. "Near-Road Vehicle Emissions Air Quality Monitoring for Exposure Modeling." *Atmospheric Environment* 224 (March): 117318. https://doi.org/10.1016/j.atmosenv.2020.117318.

vii. Mitigations for brake and tire wear particles

viii. **Additional keywords:** resuspended dust, road dust, brake and tire wear particles

Askariyeh, Mohammad Hashem, Madhusudhan Venugopal, Haneen Khreis, Andrew Birt, and Josias Zietsman. 2020. "Near-Road Traffic-Related Air Pollution: Resuspended PM2.5 from Highways and Arterials." *International Journal of Environmental Research and Public Health* 17 (8): 2851. https://doi.org/10.3390/ijerph17082851.

ix. Traffic management and congestion reduction, such as land use/street network strategies to reduce traffic, and congestion pricing)

x. **Additional keywords:** traffic management strategies, traffic demand management, freeways, urban green space

Bigazzi, A.Y., Rouleau, M., 2017. Can traffic management strategies improve urban air quality? A review of the evidence. Journal of Transport & Health 7, 111–124. https://doi.org/10.1016/j.jth.2017.08.001

Patterson, R.F., Harley, R.A., 2019. Effects of Freeway Rerouting and Boulevard Replacement on Air Pollution Exposure and Neighborhood Attributes. International Journal of Environmental Research and Public Health 16, 4072. https://doi.org/10.3390/ijerph16214072

b. Ambient control: reduce ambient/outdoor concentration of traffic related pollutants arriving at the receptor buildings.

    i. For example, barriers (e.g., vegetation, sound walls)

    ii. **Additional keywords:** vegetation barriers, green infrastructure, sound walls, combination barriers; pollution dispersion

Baldauf, R., 2020. Air pollution mitigation through vegetation barriers and green space, in: Traffic-Related Air Pollution. pp. 437–453. https://doi.org/10.1016/B978-0-12-818122-5.00017-X

Ranasinghe, Dilhara, Eon S. Lee, Yifang Zhu, Isis Frausto-Vicencio, Wonsik Choi, Wu Sun, Steve Mara, Ulrike Seibt, and Suzanne E. Paulson. 2019. "Effectiveness of Vegetation and Sound Wall-Vegetation Combination Barriers on Pollution Dispersion from Freeways under Early Morning Conditions." *Science of The Total Environment* 658 (March): 1549–58. https://doi.org/10.1016/j.scitotenv.2018.12.159.

    iii. Strategic siting of sensitive receptors, e.g. according to road proximity to ensure enough atmospheric dilution

    iv. **Additional keywords:** near-road pollutant concentrations, model concentration gradients

Karner, A.A., Eisinger, D.S., Niemeier, D.A., 2010. Near-Roadway Air Quality: Synthesizing the Findings from Real-World Data. Environmental Science & Technology 44, 5334–5344. https://doi.org/10.1021/es100008x

    v. Urban planning and built environment design (e.g. building height and layout)

    vi. **Additional keywords:** urban design, urban planning, building design measures, development, traffic control, urban street canyon, vehicle emission dispersion

County of Los Angeles. 2019. "Public Health Recommendations to Minimize the Health Effects of Air Pollution Associated with Development Near Freeways and High-Volume Roads." Accessed June 2, 2023. http://www.publichealth.lacounty.gov/place/docs/DPH%20Recommendations%20to%20Minimize%20Health%20Effects%20of%20Air%20Pollution%20Near%20Freeways_Final_March%202019.pdf.

Huang, Y., Lei, C., Liu, C.-H., Perez, P., Forehead, H., Kong, S., Zhou, J.L., 2021. A review of strategies for mitigating roadside air pollution in urban street canyons. Environmental Pollution 280. https://doi.org/10.1016/j.envpol.2021.116971

c. Indoor pollution and exposure control: reduce indoor concentration experienced by the residents, for given outdoor concentrations.

    i. Building envelope control (e.g. reducing uncontrollable air leakage, filtering incoming ventilation air, and locating air intake to limit inflow of outdoor pollutants)

    ii. **Additional keywords:** building envelopes, green infrastructure, ventilation, outdoor interventions

Abhijith, K. V., Prashant Kumar, John Gallagher, Aonghus McNabola, Richard Baldauf, Francesco Pilla, Brian Broderick, Silvana Di Sabatino, and Beatrice Pulvirenti. 2017. "Air Pollution Abatement Performances of Green Infrastructure in Open Road and Built-up Street Canyon Environments – A Review." *Atmospheric Environment* 162 (August): 71–86. https://doi.org/10.1016/j.atmosenv.2017.05.014.

Abhijith, K. V., Vina Kukadia, and Prashant Kumar. 2022. "Investigation of Air Pollution Mitigation Measures, Ventilation, and Indoor Air Quality at Three Schools in London." *Atmospheric Environment* 289 (November): 119303. https://doi.org/10.1016/j.atmosenv.2022.119303.

    iii. Indoor removal by upgrading heating and air conditioning filters and use portable air cleaners

    iv. **Additional keywords:** air purifiers, exposure reduction, exposure intervention, HVAC

Rawat, Nidhi, and Prashant Kumar. 2023. "Interventions for Improving Indoor and Outdoor Air Quality in and around Schools." *Science of The Total Environment* 858 (February): 159813. https://doi.org/10.1016/j.scitotenv.2022.159813.

    v. Strategies to clean the air at personal rather than building level or room level controls

    vi. **Additional keywords:** personal strategies, personal exposure, air cleaner, public policy

Carlsten, Christopher, Sundeep Salvi, Gary W. K. Wong, and Kian Fan Chung. 2020. "Personal Strategies to Minimise Effects of Air Pollution on Respiratory Health: Advice for Providers, Patients and the Public." *European Respiratory Journal* 55 (6). https://doi.org/10.1183/13993003.02056-2019.

Rajagopalan, Sanjay, Michael Brauer, Aruni Bhatnagar, Deepak L. Bhatt, Jeffrey R. Brook, Wei Huang, Thomas Münzel, et al. 2020. "Personal-Level Protective Actions Against Particulate Matter Air Pollution Exposure: A Scientific Statement From the American Heart Association." *Circulation* 142 (23): e411–31. https://doi.org/10.1161/CIR.0000000000000931.

Tran, Phuong T. M., Max G. Adam, Kwok Wai Tham, Stefano Schiavon, Jovan Pantelic, Paul F. Linden, Eleni Sofianopoulou, S. Chandra Sekhar, David Kok Wai Cheong, and Rajasekhar Balasubramanian. 2021. "Assessment and Mitigation of Personal Exposure to Particulate Air Pollution in Cities: An Exploratory Study." *Sustainable Cities and Society* 72 (September): 103052. https://doi.org/10.1016/j.scs.2021.103052.

vii. Strategies to provide cooling so occupants don't have to rely on open windows

viii. **Additional keywords:** sensor technology, ventilation technology, pollutant control, thermal comfort

Schieweck, Alexandra, Erik Uhde, Tunga Salthammer, Lea C. Salthammer, Lidia Morawska, Mandana Mazaheri, and Prashant Kumar. 2018. "Smart Homes and the Control of Indoor Air Quality." *Renewable and Sustainable Energy Reviews* 94 (October): 705–18. https://doi.org/10.1016/j.rser.2018.05.057.

ix. Respirators for sensitive individuals

x. **Additional keywords:** face masks, N95 respirators, mask design, filtration efficiency

Cherrie, John W., Andrew Apsley, Hilary Cowie, Susanne Steinle, William Mueller, Chun Lin, Claire J. Horwell, Anne Sleeuwenhoek, and Miranda Loh. 2018. "Effectiveness of Face Masks Used to Protect Beijing Residents against Particulate Air Pollution." *Occupational and Environmental Medicine* 75 (6): 446–52. https://doi.org/10.1136/oemed-2017-104765.

Morishita, Masako, Lu Wang, Kelly Speth, Nina Zhou, Robert L Bard, Fengyao Li, Jeffrey R Brook, Sanjay Rajagopalan, and Robert D Brook. 2019. "Acute Blood Pressure and Cardiovascular Effects of Near-Roadway Exposures With and Without N95 Respirators." *American Journal of Hypertension* 32 (11): 1054–65. https://doi.org/10.1093/ajh/hpz113.

xi. The role of indoor and outdoor monitoring as a tool to inform and educate the public and provide actionable information for building operators

xii. **Additional keywords:** air quality alert, advanced warnings, communication, education, environmental monitoring, forecasting

Kelly, Frank J., Gary W. Fuller, Heather A. Walton, and Julia C. Fussell. 2012. "Monitoring Air Pollution: Use of Early Warning Systems for Public Health." *Respirology* 17 (1): 7–19. https://doi.org/10.1111/j.1440-1843.2011.02065.x.

2) What is the relative cost effectiveness of these strategies?

   a. Costs: including upfront costs and maintenance costs if applicable; Benefits: Health benefit from individual strategies

b. **Additional keywords:** cost effectiveness, health benefits, air quality benefits, economic benefits, low-cost impermeable solid structures, low-cost sensing technology, mortality impacts, sick building syndrome

Fisk, W.J., Black, D., Brunner, G., 2011. Benefits and costs of improved IEQ in U.S. offices. Indoor Air 21, 357–367. https://doi.org/10.1111/j.1600-0668.2011.00719.x

Hashad, K., B. Yang, R.W. Baldauf, P. Deshmukh, V. Isakov, and K.M. Zhang. 2020. "Enhancing the Local Air Quality Benefits of Roadside Green Infrastructure Using Low-Cost, Impermeable, Solid Structures (LISS)." *Science of the Total Environment* 717. https://doi.org/10.1016/j.scitotenv.2020.137136.

Jeanjean, A. P. R., J. Gallagher, P. S. Monks, and R. J. Leigh. 2017. "Ranking Current and Prospective NO2 Pollution Mitigation Strategies: An Environmental and Economic Modelling Investigation in Oxford Street, London." *Environmental Pollution* 225 (June): 587–97. https://doi.org/10.1016/j.envpol.2017.03.027.

Kumar, Prashant, Lidia Morawska, Claudio Martani, George Biskos, Marina Neophytou, Silvana Di Sabatino, Margaret Bell, Leslie Norford, and Rex Britter. 2015. "The Rise of Low-Cost Sensing for Managing Air Pollution in Cities." *Environment International* 75 (February): 199–205. https://doi.org/10.1016/j.envint.2014.11.019.

Seppanen, Olli, and William Fisk. 2004. "A Model to Estimate the Cost Effectiveness of Indoor Environment Improvements in Office Work." Accessed June 2, 2023. https://www.osti.gov/servlets/purl/875736.

Wang, Haikun, Xiaojing He, Xinyu Liang, Ernani F. Choma, Yifan Liu, Li Shan, Haotian Zheng, et al. 2020. "Health Benefits of On-Road Transportation Pollution Control Programs in China." *Proceedings of the National Academy of Sciences* 117 (41): 25370–77. https://doi.org/10.1073/pnas.1921271117.

Full Search Strategy

The librarian used this full search strategy while conducting the literature search.

SCOPUS

(((INDEXTERMS ("Traffic-Related Pollution") OR TITLE-ABS-KEY ("Traffic-Related Pollution") OR TITLE-ABS-KEY ("pollution, traffic" OR "pollution, traffic-related" OR "pollution, vehicle" OR "traffic pollution" OR "traffic related pollution" OR "vehicle pollution") OR (INDEXTERMS ("Vehicle Emissions") OR TITLE-ABS-KEY ("Vehicle Emissions")) OR TITLE-ABS-KEY ("automobile exhaust" OR "diesel exhaust" OR "emission, vehicle" OR "emission, vehicular" OR "emissions, transportation" OR "emissions, vehicle" OR "emissions, vehicular" OR "engine exhaust" OR "exhaust, automobile" OR "exhaust, diesel" OR "exhaust, engine" OR "pollutants, traffic-related" OR "traffic related pollutants" OR "transportation emissions" OR "vehicle emission" OR "vehicle emissions" OR "vehicular emission" OR "vehicular emissions")) AND (TITLE-ABS-KEY (road OR roadway OR near-roadway OR interstate* OR highway* OR traffic))) AND (indoor OR in-door)) AND NOT (TITLE (china)) AND (LIMIT-TO (AFFILCOUNTRY , "United States")) AND (LIMIT-TO

(DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "dp") OR LIMIT-TO (DOCTYPE , "rp") OR LIMIT-TO (DOCTYPE , "ch")) AND (LIMIT-TO (EXACTKEYWORD , "Exhaust Gas") OR LIMIT-TO (EXACTKEYWORD , "Vehicle Emissions") OR LIMIT-TO (EXACTKEYWORD , "Motor Vehicle") OR LIMIT-TO (EXACTKEYWORD , "Vehicles") OR LIMIT-TO (EXACTKEYWORD , "Motor Vehicles") OR LIMIT-TO (EXACTKEYWORD , "Emission Control") OR LIMIT-TO (EXACTKEYWORD , "Roads And Streets") OR LIMIT-TO (EXACTKEYWORD , "Vehicle Emission") OR LIMIT-TO (EXACTKEYWORD , "Highway") OR LIMIT-TO (EXACTKEYWORD , "Traffic And Transport") OR LIMIT-TO (EXACTKEYWORD , "Diesel Fuel") OR LIMIT-TO (EXACTKEYWORD , "Diesel Engines") OR LIMIT-TO (EXACTKEYWORD , "Motor Vehicle Emissions") OR LIMIT-TO (EXACTKEYWORD , "United States"))

Link:
Click to run search
The above Jumpstart will only work for users who have access to this specific database.

Database:
Ovid MEDLINE(R) ALL <1946 to May 25, 2023>

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2	exp Residence Characteristics/ or Residence Characteristics.mp. or (arrangement, living or arrangements, living or characteristic, residence or characteristics, residence or communities or community or domicile or domiciles or living arrangement or living arrangements	882,994

	or neighborhood or neighborhoods or residence characteristic or residence characteristics or residential selection or residential selections or selection, residential or selections, residential).mp.	
3	exp Motor Vehicles/ or Motor Vehicles.mp. or (buses or motor vehicle or motor vehicles or truck or trucks or vehicle, motor or vehicles, motor).mp.	42,658
4	1 and 2 and 3	151
5	(road or roadway or near-roadway or interstate or highway or traffic).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]	125,869
6	4 and 5	111
7	(united states or california).mp. or exp "united states"/ or exp california/	1,635,369
8	6 and 7	54

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(road or roadway or near-roadway or interstate or highway or traffic).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
4 and 5
(united states or california).mp. or exp "united states"/ or exp california/
6 and 7

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Cochrane Library
Search Name:
Date Run: 31/05/2023 14:31:50
Comment:

ID	Search	Hits
#1	traffic related air pollution	177
#2	indoor air pollution	545
#3	#1 AND #2	25

CABI Global Health

((indoor air pollution) AND (traffic related air pollution)) AND ("United States of America" OR "California")

Process for Screening Articles

Figure 2 and **Figure 3** outline the process of screening articles for source, ambient, and exposure control evidence synthesis.

Figure 2. Process to further screen articles for source control evidence synthesis

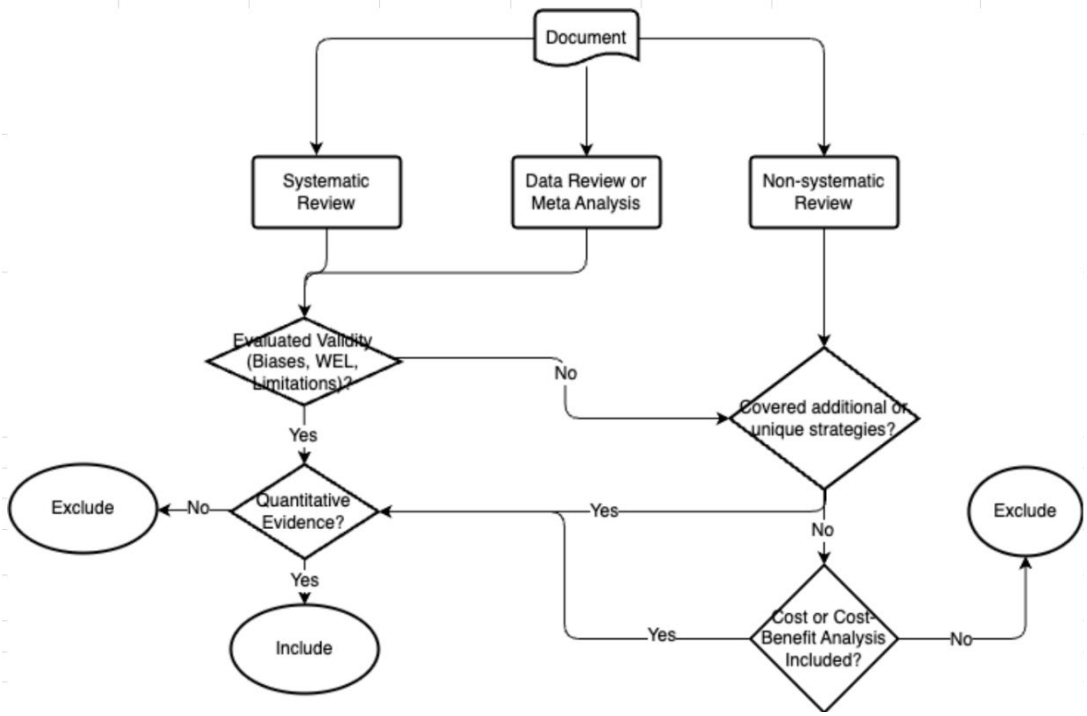

Figure 3. Process to further screen articles for ambient and indoor exposure control evidence synthesis.