EFFECTIVENESS OF AIR FILTRATION IN PROTECTING WORKER CARDIOVASCULAR HEALTH : A NARRATIVE REVIEW

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ABSTRAK
Polusi udara dianggap sebagai salah satu bahaya lingkungan terbesar yang menyebabkan penyakit kardiovaskular, dan jumlah kontaminan di sebagian besar lingkungan kerja mungkin jauh lebih tinggi daripada yang direkomendasikan oleh Organisasi Kesehatan Dunia (WHO). Pencegahan penting untuk melindungi pekerja dan meningkatkan kesehatan jantung. Tinjauan naratif ini berfokus pada studi tentang intervensi penyaringan udara pada pekerja yang terpapar polusi udara dan dampaknya terhadap hasil kardiovaskular. Ditemukan empat penelitian yang menilai pengaruh sistem penyaringan udara dalam menghilangkan polutan di tempat kerja dan, lebih jauh lagi, meningkatkan tindakan kardiovaskular. Hasil ini konsisten dengan temuan bahwa pengurangan paparan partikel dan gas melalui penyaringan bermanfaat bagi kesehatan jantung. Tinjauan tersebut menyimpulkan bahwa penerapan teknik penyaringan udara di lingkungan kerja tertutup dapat mengurangi paparan zat dan gas berbahaya, yang secara signifikan akan mempengaruhi perubahan indikator sistem kardiovaskular seperti tekanan darah, dan detak jantung. Temuan ini memiliki konsekuensi nyata terhadap kesehatan kerja, khususnya dalam hal pencegahan penyakit kardiovaskular. Namun demikian, penelitian baru dibenarkan untuk memperluas basis bukti agar mencakup kelompok pekerja berisiko tinggi lainnya.

Kata kunci : kesehatan jantung, paparan kerja, penyaringan udara, polusi udara

ABSTRACT
Air pollution is considered one of the greatest environmental hazards for cardiovascular diseases, and the amount of contaminants in most working environments may be much higher than that recommended by the World Health Organization (WHO). Prevention is important to protect workers and enhance heart health. This narrative review focuses on studies of air filtration interventions in workers exposed to polluted air and their impact on cardiovascular outcomes. Four studies were found that assessed the effect of air filtration systems in eliminating pollutants in the workplace and, by extension, enhancing cardiovascular measures. These results were consistent with the finding that the reduction of exposure to particulate matter and gases by filtration was beneficial to heart health. The review concluded that the application of air filtration techniques in closed working environments can reduce exposure to dangerous substances and gases, which will significantly affect changes in the indicators of the cardiovascular system such as blood pressure, and heart rate. The findings have explicit consequences for occupational health, particularly in terms of cardiovascular disease prevention. Nevertheless, new studies are justified to expand the evidence base to include other high-risk groups of workers.

Keywords *: air filtration, air pollution, occupational exposure, cardiovascular health*

INTRODUCTION

Air pollution is considered one of the greatest environmental hazards associated with cardiovascular diseases (Hu et al., 2024; Khoshakhlagh et al., 2024; Scimeca et al., 2024). Ambient air pollution caused 4.2 million deaths worldwide for various diseases, and 70% of these deaths were caused by CVDs, with ischemic Heart Disease (IHD) and stroke (Miller et al., 2024). The pollutant that most often harms cardiovascular health is Particulate Matter 2.5 ($PM_{2.5}$) (Henning, 2024; Miller et al., 2024). Pollutants cause inflammation and oxidative damage to the lungs, releasing mediators into the circulation, causing systemic adverse effects on the cardiovascular system and resulting in various disorders, including narrowing and

hardening of the arteries and a decrease in the ability of blood vessels to relax (Brauer et al., 2021; Münzel et al., 2025). Furthermore, long-term exposure can accelerate the growth and development of atherosclerosis and increase the vulnerability of atherosclerotic plaques, thus increasing the risk of developing cardiovascular disease or triggering an acute event such as a heart attack or stroke (Brauer et al., 2021; Lv et al., 2025; Urbanowicz, 2025). Air pollution plays a very significant role in exacerbating cardiovascular disease, leading to increased prevalence, mortality, and associated healthcare costs (Khoshakhlagh et al., 2024; Kim et al., 2020; Mannucci et al., 2019).

Scientific evidence shows that ambient air pollution is associated with morbidity and mortality (Bont et al., 2022). Rapid urban growth is a major factor in increasing exposure to air pollution (Domínguez et al., 2024). Cities are the epicenter of air pollution and air pollution-related diseases, where concentrations of fine particles $PM_{2.5}$ are influenced by local sources, such as motor vehicle traffic and local fuel combustion (Domínguez et al., 2024; Jandacka et al., 2024; Pongpiachan et al., 2025). This exposure poses a health risk, with 84% of the population exposed to PM2.5 concentrations above the WHO guideline (10 µg/m³) (Khomenko et al., 2021). The relationship between environmental pollutants and cardiovascular health has been extensively studied, but targeted interventions to reduce workplace exposure remain underexplored (Ohlander et al., 2020). Occupational exposure to chemicals and biological agents continues to contribute significantly to the disease burden of the workforce worldwide (Domínguez et al., 2024). However, a systematic review of occupational intervention studies spanning six decades (1960–2019) concluded that the number of intervention studies remains low (Ohlander et al., 2020).

High-Efficiency Particulate Air (HEPA) filters are a personal-level intervention to mitigate 56% of $PM_{2.5}$ concentrations (Xia et al., 2021). Furthermore, intervention studies have demonstrated a significant reduction in Systolic Blood Pressure (SBP), with a pooled mean difference of −2.28 mmHg or a 2.01% decrease (Liu et al., 2022). While the benefits of air filtration have been reported in the general population, including unexposed workers, evidence in workers in actual work environments is limited (Xia et al., 2021). Based on previously identified gaps and our current knowledge of the effect of air pollution on workers' cardiovascular health, this narrative review aimed to assess the effectiveness of air filtration in mitigating the adverse effects of air pollution on cardiovascular health in workers or occupational settings.

METHODS

This study employed a narrative review approach to analyze current evidence of the effect of air filtration on occupational pollution and its effect on cardiovascular health. A narrative review was selected because the topic involves multidisciplinary perspectives ranging from occupational health, environmental science, engineering controls, and cardiovascular health, which require flexible integration· This approach allows broader conceptual exploration and identification of thematic relationships among study designs, populations, and workplace settings. We searched for original research articles in the Pub Med and ScienceDirect databases using the following Boolean search terms: "occupational air pollution" or "occupational air quality, "air purification" or "air filtration" and "cardiovascular health" or "heart health". Initial screening of studies for inclusion was based on reading abstracts from the papers retrieved from the database searches and determining (a) if workers were participants in the study, (b) if the study used air filtration or air purification to reduce air pollution, and (c) if the study had any type of cardiovascular health outcome. The exclusions criteria are (a) if article not full text, (b) if article close access (c) if article was published more than10 years ago.

Figure 1 shows that 649 studies were retrieved from the publication database, of which 30 were from PubMed and 619 from ScienceDirect. After merging and duplicating of articles, 154 studies remained. After applying the inclusion and exclusion criteria describe above, four studies were included and reviewed.

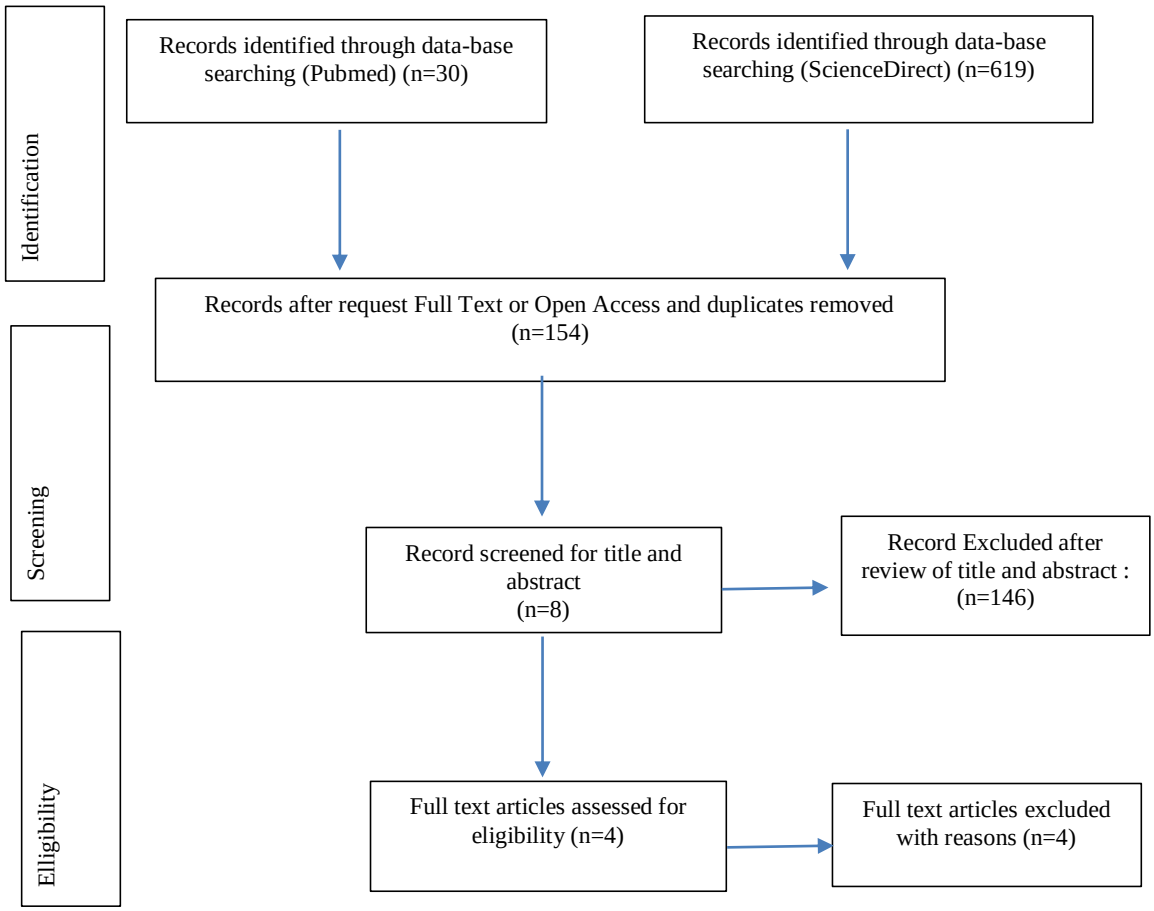

Figure 1. Flow Diagram Of Inclusion And Exclusion Criteria At Each Phase Of The Data Mining Process Leading To The Final Work

RESULT

Tabel 1. Summary Of Characteristic Of Air Filtration Intervention Studies in Narrative Review

Study	Study Subject	Interventions	Study Design	Statistical Method	Contaminant Type	Effect on Cardiovascular Health
Chuang et al., 2017	200 healthy homemakers	Air Filtration (True air conditioner filter - Filtrete™ A/C Filter, 80% efficiency) vs. Control Intervention (False air conditioner	Long-term Randomized Crossover	Mixed-effects models, paired t-tests, and between-group t-tests were used.	PM2.5 and Total Volatile Organic Compounds (VOCs)	lowering blood pressure (SBP, DBP)

		filter - gauze, pore size > 10 μm)				
Chen et al., 2020	84 healthy Drivers	Control-mode (open windows, AC off, CO2 filtration off), Off-mode (AC on, false CO2 filtration), and On-mode (AC on, true CO2 filtration)	Repeated Measurements Intervention Study	Mixed-effects model, ANOVA, and Chi-squared test were used.	CO2, PM2.5, and Total Volatile Organic Compounds (TVOCs)	Decreased HR and BP.
Young et al., 2023	16 Normotensive Commuters	Filtered drive (Commercial cabin filter + HEPA + active carbon air purifier) vs. Unfiltered drives (Filters removed)	Randomized cross-over trial	effects model, adjusted for pre-drive levels, order, participant, and carryover.	Traffic-Related Air Pollution (TRAP), measured as Particle Number Count (PNC), PM2.5, and Black Carbon (BC)	increased blood pressure (SBP and DBP).
Mallach et al., 2023	48 Young Adult Commuters	Cabin Air Filtration (CAF) (Electrostatic air filter) vs. Placebo (Placebo air filter)	a randomized, double-blind	Linear mixed models with random intercepts for subject. Pollutant coefficients scaled to the IQR increases.	PM2.5, Black Carbon [BC], UFPs), BTEX, and Nitrogen Dioxide (NO2)	Reduced Heart Rate Variability (HRV).

As shown in table 1, three (75%) were randomized controlled studies, and one (25%) was a Repeated Measurements Intervention Study. The publication years of the studies ranged from 2015 to 2025, with 75% (n=3) published between 2020 and 2023.

Assessment of Air filtration Technologies in Occupational Setting

In this study, the assessment of air filtration technologies in occupational settings was primarily derived from studies in residential and mobile microenvironments, which often contain levels of pollutants relevant to work contexts. As shown in the table, studies focused on homemakers or healthy commuters/drivers, and the findings strongly suggest that air filtration methods included HEPA filters, activated carbon filters, electrostatic filters, and CO_2 filtration systems integrated into air conditioning (A/C) units. These finding were investigated through randomized cross-over designs or longitudinal intervention studies, ensuring the capability for within subject comparisons between filtered and unfiltered exposure phases. Active cabin air filtration systems reduce ultrafine particles (UFPs), $PM_{2.5}$, and black carbon (BC) by 28–32% (Mallach et al., 2023). During vehicle commutes air filtration reduced particle number counts by 86% (Young et al., 2023). Investigations into in-vehicle air quality revealed that air conditioning systems, both with the windows off and on, reduced PM2.5 levels compared to open windows (Chen et al., 2020). Another study of long-term home filtration using a high-efficiency A/C filter significantly reduced $PM_{2.5}$ and total volatile organic compound (VOC) levels (Chuang et al., 2017).

Cardiovascular Outcomes Associated with Air Filtration

The cardiovascular response to fine particulate matter PM_{25} has been extensively studied, revealing significant effects on blood pressure and markers of inflammation. In a long-term, household-based trial among housewives, air filtration reduced air pollution exposure and lowered markers of cardiovascular stress. Research showed that air filtration could lower systolic blood pressure by 3.75% and diastolic blood pressure by 2.66%. In addition air filtration has been associated with a reduction in inflammatory markers, such as high sensitivity-C-reactive protein (hs-CRP) by 4.58% and oxidative stress biomarkers like 8-hydroxy-2′-deoxyguanosine (8-OHdG) by 2.17% (Chuang et al., 2017).

In acute on-roadway exposure trials, filtration also yielded rapid results. Study observed that exposure to unfiltered traffic-related air pollution (TRAP) resulted in a net increase in blood pressure compared to filtered drives; adjusted mean DBP was 4.7 mmHg higher and SBP was 4.5 mmHg higher at one hour after the drive, and these effects that persisted up to 24 hours (DBP 3.8 mmHg higher) (Young et al., 2023). Increased $PM_{2.5}$ exposure during unfiltered "Control-mode" driving (windows open) was associated with a 9.8% increase in heart rate (HR) and a 4.9% increase in systolic blood pressure (SBP). Activating air conditioning (AC) systems with filtration eliminated the association between $PM_{2.5}$ exposure and cardiovascular biomarker. Meanwhile, increased CO_2 exposure caused significant decreases in heart measurements (a 16.6% decrease in HR, a 13.1% decrease in SBP, and a 14.2% decrease in DBP) and increased driver drowsiness, suggesting a physiological response to hypercapnia (Chen et al., 2020).

During travel, particulate matter (PM) exposure affects heart rate variability (HRV) and stress biomarkers. Furthermore, increased $PM_{2.5}$ correlated with a 28% increase in HRV, indicating increased parasympathetic activity, while ultrafine particles (UFP) were associated with an 18% increase in salivary cortisol, suggesting an acute stress response, particularly in women(Mallach et al., 2023). These studies show that air filtration reduces exposure to particulate pollutants and has a significant impact on cardiovascular health parameters by lowering blood pressure, oxidative stress, and systemic inflammation, as well as regulating autonomic balance.

DISCUSSION

Study showed that filtration has successfully lowered pollutant levels across residential and in-vehicle microenvironments. Studies have found a significant reduction in particle concentrations, such as an 86% reduction in PNC in commuters and a 28–32% reduction in UFP, PM2.5, and black carbon with cabin air filtration (Chen et al., 2020; Young et al., 2023). The use of air conditioning is associated with improved cardiovascular health, including lower blood pressure, reduced inflammatory biomarker levels, and oxidative stress (Bard et al., 2020; Chuang et al., 2017). However, exposure to traffic pollutants without filtration increases blood pressure and stress responses, whereas filtration systems can neutralize these effects and balance autonomic function (Chuang et al., 2017; Young et al., 2023). In the context of occupational health, especially for workers who spend a lot of time in vehicles or enclosed spaces, air filtration is an important engineering control measure. This review highlights air filtration as an efficient and cost-effective approach to lowering cardiovascular risk. Its success in reducing inflammation, oxidative stress, and blood pressure in domestic environments reinforces its potential for greater benefits when applied in the workplace.

This narrative review has some limitations. First, journals outside the PubMed and ScienceDirect databases may have been missed in our review, but we are confident that themes and gaps will be identified and maintained in future studies. Another limitation is that a meta-analysis could not be performed in this study because of the lack of eligible and comparable

journal articles. A major strength of this study is its focus on the effect of air filtration on pollution among workers on cardiovascular outcomes, an area where empirical research is still very limited. These findings highlight the importance of this study and emphasize the need for further investigations to expand the evidence based. Building on the strengths and limitations identified above, this review highlights the significance of air filtration as an occupational-health intervention. The findings of this review highlight an important but under-researched dimension of occupational health: the potential of air filtration systems as engineering controls to reduce the cardiovascular risks associated with airborne pollutants in indoor and mobile workspaces. In contrast to previous studies that predominantly focused on respiratory outcomes or environmental exposures in community settings (Canaday et al., 2025; Kaspersen et al., 2024), this review emphasizes cardiovascular pathways triggered by systemic inflammation, oxidative stress, and autonomic imbalance, positioning filtration-based interventions beyond improving comfort to achieve measurable clinical benefits.

From an occupational health and safety perspective, air filtration represents a hierarchy of hazard controls for reducing air pollution and improving cardiovascular health. Other implications of air filtration, such as increased productivity, reduced absenteeism, and prevention of long-term diseases, have not yet been explored in this study. Future investigations should include worker populations, direct exposure monitoring, and multifactorial cardiovascular outcomes to generate evidence-based policies that strengthen the occupational-health framework.

CONCLUSION

This narrative review study provides strong evidence that air filtration is effective in improving cardiovascular health by reducing dust particle levels, thereby reducing systemic inflammation, improving autonomic balance, and lowering blood pressure. Air filtration as a cost-effective engineering control and intervention also has direct implications for occupational health prevention strategies. Further research is needed to expand the scope of real-world work environments to high-risk worker populations.

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