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Impact of environmental pollution on acne: a systematic review

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Abstract

In an increasingly urbanized world, environmental pollution is recognized for its adverse effects on both systemic and skin health. While its role in conditions such as atopic dermatitis and psoriasis is well documented, its impact on acne vulgaris remains less clear. This review aims to evaluate existing literature examining the association between environmental pollutants – such as particulate matter (PM_{2.5}, PM₁₀), nitrogen oxides (NO₂, NO_x) and traffic-related emissions – and the development, severity or exacerbation of acne. A systematic search of peer-reviewed English-language studies published between 2010 and 2025 was conducted using PubMed. Search terms included 'air pollution', 'particulate matter', 'PM_{2.5}', 'PM₁₀', 'NO₂', 'NO_x', 'environmental pollution', 'traffic pollution', 'acne' and 'acne vulgaris'. Studies were included if they investigated the relationship between environmental pollutants and acne in human populations. Of the 27 studies identified, 17 met inclusion criteria. Systematic reviews were also incorporated to provide broader context. Several studies demonstrated significant associations between pollutant exposure and acne exacerbation. A time-series study in China involving 71 625 outpatient visits found that each 10 µg m⁻³ increase in SO₂ and NO₂ correlated with 1.02% and 2.13% increases in acne-related visits, respectively. Other studies appear to show pollutants being associated with increased sebum production and reduction of antioxidants. Proposed mechanisms include oxidative stress, microbiome disruption and follicular hyperkeratinization. However, study heterogeneity, lack of diversity and limited control for confounders limit generalizability. Longitudinal research is needed to clarify pollution's role in acne and inform targeted prevention strategies.

Acne vulgaris is a common and burdensome skin condition, particularly affecting adolescents and young adults. Emerging evidence suggests air pollution may contribute to the development or exacerbation of acne vulgaris. Environmental pollutants such as particulate matter (PM), nitrogen oxides (NO_x) and polycyclic aromatic hydrocarbons (PAHs) have been shown to promote oxidative stress and inflammation which in turn can impair skin barrier function and potentially alter the cutaneous microbiome, all of which may be implicated in acne pathogenesis.¹ While some studies have investigated the relationship between pollution and acne exacerbation, findings remain limited and often do not account for confounding variables. This systematic review aims to evaluate the current literature on the relationship between environmental pollution and acne outcomes.

Materials and methods

Study design

This systematic review was conducted following the PRISMA 2020 guidelines.² The review protocol was registered in PROSPERO (CRD420251134623).

Eligibility criteria

Studies were included if they met the following criteria:

- Population: humans of any age or sex.
- Exposure: environmental pollution, including but not limited to PM, NO_x, sulfur dioxide, carbon monoxide and PAHs.
- Outcomes: acne vulgaris development, severity, sebum excretion rates (SERs), antioxidant levels, outpatient visits or acne-related symptoms.
- Study design: observational (cross-sectional, cohort, time-series), experimental or preclinical studies assessing pollutant exposure in relation to acne outcomes.
- Language: English-language studies.
- Time frame: studies published between 2010 and 2025.

Studies were excluded if they did not report acne outcomes or were case reports, conference abstracts or reviews lacking original data.

Search strategy

A systematic search of PubMed was conducted to identify relevant peer-reviewed studies. The search

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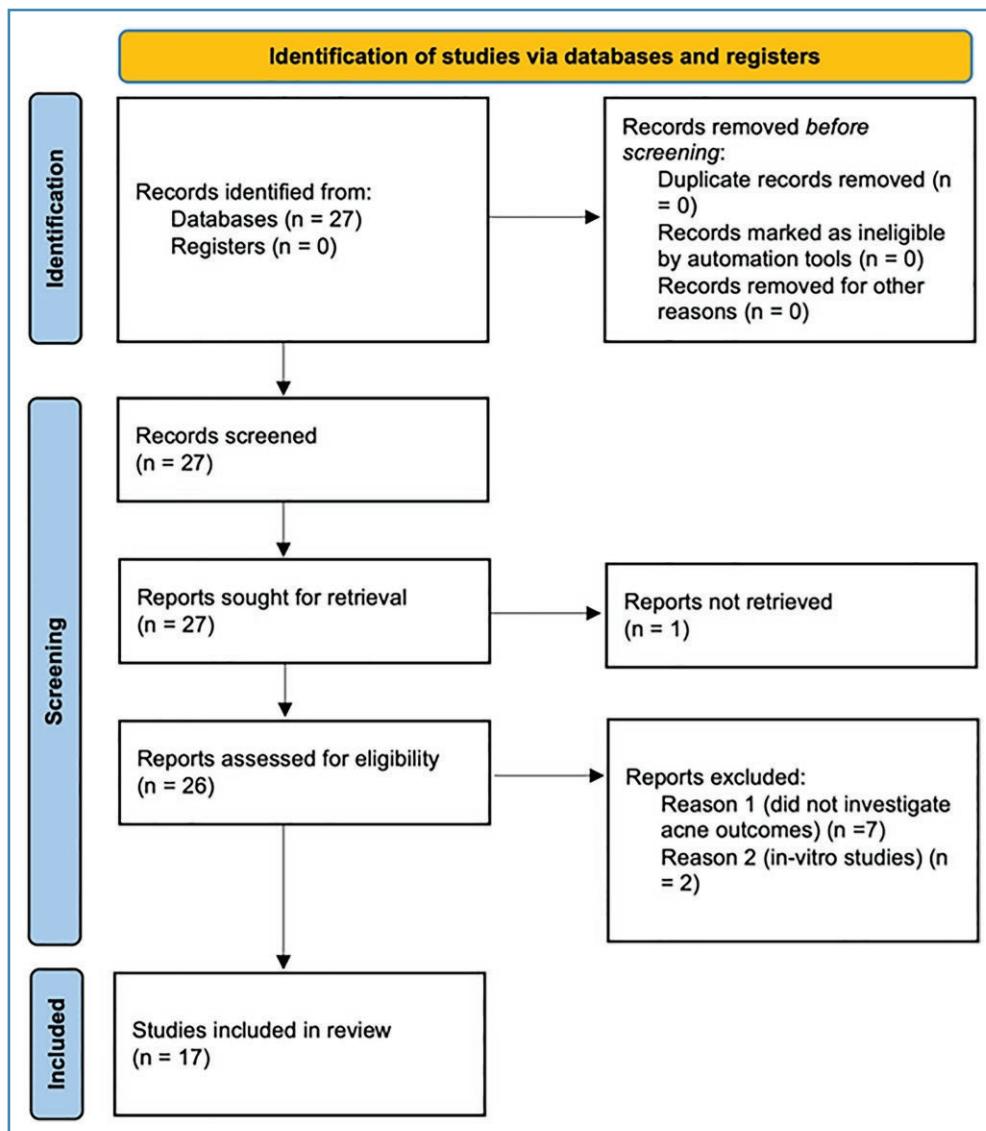


Figure 1 PRISMA flow diagram of the study.

strategy combined controlled vocabulary (Medical Subject Headings) terms and free-text keywords relating to environmental pollution and acne. Search terms included 'air pollution', 'particulate matter', 'PM_{2.5}', 'PM₁₀', 'NO₂', 'NO_x', 'environmental pollution', 'traffic pollution', 'acne' and 'acne vulgaris'.

Study selection

Two independent reviewers screened titles and abstracts for eligibility, resolving any discrepancies through consensus with a third reviewer. A schematic presentation of the record selection process is outlined in the PRISMA flow diagram (Figure 1).

Data extraction

Data were independently extracted by one reviewer and checked by another reviewer using a standardized form. Extracted information included:

- Study characteristics: author, year, country, study design, sample size, population characteristics.
- Exposure assessment: type and measurement of pollutants, exposure duration.
- Acne outcomes: severity measurements, clinical assessments, sebum excretion, antioxidant levels, outpatient visits.
- Key findings and effect estimates: odds ratios, relative risks or correlation coefficients, where available.

Risk of bias assessment

Risk of bias was assessed independently by two reviewers using the Newcastle-Ottawa Scale. Disagreements were resolved by consensus.

Data synthesis

Given the heterogeneity of study designs, pollutant measures and acne outcomes, a narrative synthesis was

conducted. Key findings were summarized in tables and text according to pollutant type, exposure assessment method and acne outcome. Where feasible, trends across studies were highlighted and inconsistencies were discussed. Quantitative meta-analysis was not performed due to substantial methodological and outcome variability.

Results

Environmental pollutants

Recent attention has focused upon the adverse effects of environmental pollution upon health and disease states. Environmental pollutants are harmful substances present in the air, water and soil, which can be both naturally forming and anthropogenic. Commonly studied pollutants include PM, NO_x and PAHs, and many are monitored by national agencies. PM is classified by size: $\text{PM}_{2.5}$ refers to fine particles with a diameter of $\leq 2.5 \mu\text{m}$, while PM_{10} includes slightly larger particles up to $10 \mu\text{m}$. These particles mainly emanate from traffic emissions, industrial activity and domestic fuel burning.³ NO_x , comprising both nitrous oxide (NO) and nitrogen dioxide (NO_2), are reactive gases predominantly released by power plants and vehicle exhausts, while PAHs are organic compounds generated during incomplete combustion of organic materials such as coal, oil and wood.⁴

Beyond their well-established roles in cardiovascular and respiratory diseases, including increased risk of heart disease, strokes and chronic lung conditions,⁵ these pollutants have also been implicated in various dermatological conditions.^{6–11}

Preclinical studies

Emerging evidence from preclinical and experimental studies suggest that pollutants may disrupt skin barrier function, increase oxidative stress (through generation of reactive oxygen species and depletion of antioxidants), promote inflammation, alter the cutaneous microbiome and stimulate sebum production – all mechanisms that plausibly contribute to acne development and exacerbation.^{6–11}

A multi-omics observational study examined the effect of chronic exposure to pollution, gauged by PAH and metabolite levels in hair, upon clinical signs, including acne, pigmentation and wrinkles.¹² This study demonstrated the PAH exposure was associated with alterations in the cutaneous microbiome and metabolic profiles, which could contribute to the development and exacerbation of acne by compromising skin barrier function.

A separate *in vitro* study simulated acne-like inflammation by stimulating neonatal human keratinocytes stimulated with *Cutibacterium acnes* or *Staphylococcus aureus* peptidoglycan.¹³ Whilst exposure to the bacteria induced inflammation, additional exposure to PM further increased expression of proinflammatory cytokines [interleukin (IL)-1 α , IL-1 β , IL-6, IL-8, tumour necrosis factor- α], cyclooxygenase-2 protein, Toll-like receptor 4 and phosphorylation of nuclear factor- κ B. Taken together, these findings suggest that PM exposure may worsen acne by accentuated microbial-induced inflammation.

Epidemiological association between air pollution and acne

While study designs and pollutant measurements varied, several studies support the association of exposure to ambient air pollution and poorer acne outcomes. Most studies employed the use of cross-sectional or longitudinal methods and utilized environmental monitoring data or satellite-derived estimates of pollutant exposure. Acne severity was typically assessed using dermatological grading scales or patient-reported outcomes. Table 1 summarizes all relevant studies investigating the association between air pollution and acne.

Sebum excretion and antioxidant levels

A recent systematic review¹⁹ of 80 studies with sample sizes ranging from 50 to 2472004 participants, examined factors influencing acne development and severity. Of the 80 studies, 8 explored the relationship between acne and natural environmental factors, including air pollution. One of the cited clinical studies²³ investigated the link between environmental pollution and acne by comparing 189 patients (96 from a highly polluted district of Mexico City and 93 from a less polluted district). Following clinical evaluation by dermatologists, it was found that patients from the less polluted district had a significantly lower SER compared with those from the more polluted district, with mean values of 64 and 100, respectively ($P < 0.001$). Additionally, a decrease in skin antioxidants was observed. Participants from the highly polluted district had significantly lower levels of both squalene (42.7 vs. 76.6; $P < 0.001$) and vitamin E (36.2 vs. 391.1; $P < 0.001$) compared with those from the less polluted district.

A complementary clinical study conducted in Shanghai²⁴ investigated similar associations by comparing 159 participants – 79 patients with higher exposure to pollution and 80 patients with lower exposure. Industrialized countries such as China provide a valuable setting to investigate the relationship between air pollution and acne, given the consistently high concentration of PMs. However, unlike the Mexico City study, there was no statistically significant difference in SER between the groups, with mean values of 67 and 61 in the highly and less polluted areas, respectively. It is worth noting that SER values tend to be lower in Chinese populations when compared with Black and White American populations,²⁵ which may partially explain this observation. Nonetheless, with regards to antioxidant levels, a similar trend to that observed in the Mexico City study was reported, with a significant decrease in squalene levels among those with higher pollution exposure ($P < 0.05$).

Outpatient visits

A time-series study conducted in Xi'an China¹⁶ examining 71 625 outpatient visits for acne found that for every $10 \mu\text{g m}^{-3}$ rise in SO_2 and NO_2 concentrations, outpatient visits increased at lag 0 by 1.02% [95% confidence interval (CI) 0.16–1.88] and 2.13% (95% CI 0.98–3.28), respectively, with positive associations for both male and female participants. Here, 'lag 0' refers to the effects of exposure on the same day as the outpatient visit, whereas longer lag periods

Table 1 Summary of studies investigating the association between environmental pollution and acne outcomes

Study	Sample size (n)	Study design	Country	Pollutants measured	Exposure measurement	Acne outcomes	Summary of results
Chen 2024 ¹⁴	4325	Cross-sectional study	China	PM _{2.5} , PM ₁₀ , O ₃ , SO ₂ , NO ₂ , CO	AQMS	Machine learning model	Study investigated relationship between air pollution and skin sensitivity in patients with acne. This study revealed nonlinear relationships between secondary sensitive skin and PM (PM _{2.5} , PM ₁₀), O ₃ , SO ₂ , NO ₂ and CO. The risk of secondary sensitive skin rises with PM _{2.5} concentrations, sharply increasing after 40 µg m ⁻³ . Fluctuations were observed with PM ₁₀ and NO ₂ , while high SO ₂ levels significantly impacted the occurrence of sensitive skin. However, CO seemed to be a protective factor
Paik 2024 ¹	128 – across the population of 7 major Korean cities	Narrative review		PM			This narrative review comprises epidemiological studies investigating the association between PM and skin conditions. Four studies specifically examined the association between PM and acne. PM exposure was linked to increased acne outpatient visits. However, these results were not consistent amongst all four studies, with one cross-sectional study reporting no significant associations between PM and acne
Jin 2024 ⁹		Narrative review		PAHs			In this study, the relationship between PAHs and acne was studied. PAHs were implicated in the development of chloracne via several proinflammatory pathways and increase in sebum production
Gu 2024 ¹⁰		Narrative review		Various pollutants			Air pollution was implicated in the development of acne. Specifically, exposure to PAHs and O ₃ were linked to an increase in proinflammatory mediators which lead to the development of acne
Belzer 2023 ¹¹		Narrative review		PAHs, PM _{2.5} , PM ₁₀ , NO ₂			Air pollution exposure was linked with acne and other skin conditions such as atopic dermatitis, psoriasis and pigmentary disorders
Isler 2023 ⁶		Narrative review		PAHs, NO ₂			This review demonstrated that exposure to pollutants such as PAHs and NO ₂ triggered changes to skin microbiome, which promotes the development of acne
Li 2022 ¹⁵	120842	Time-series analysis	China	PM _{2.5}	EMC	Acne outpatient visits	This study demonstrated positive associations between PM _{2.5} concentrations and acne outpatient visits. Specifically, a 10 µg m ⁻³ increase in PM _{2.5} concentrations was associated with a 1.71% (95% CI 1.06–2.36) increase in acne outpatient visits over a 0–7-day lag period. Stratified analyses revealed that the effects of PM _{2.5} were more significant in individuals aged 25 years or over compared with those under 25 years, 2.26% (95% CI 1.37–3.15) and 1.24% (95% CI 0.38–2.10), respectively. However, there were no significant gender-based differences observed
Li 2022 ¹⁶	71 625 outpatient visits	Time-series analysis	China	PM ₁₀ , SO ₂ , NO ₂	EMC	Acne outpatient visits	A 10 µg m ⁻³ rise in SO ₂ and NO ₂ concentrations were linked to increased acne outpatient visits at lag zero, 1.02% (95% CI 0.16–1.88) and 2.13% (95% CI 0.98–3.28), respectively, with positive associations for both male and female participants. The effect of PM ₁₀ was statistically significant for adults over 30 years, with every 10 µg m ⁻³ rise at lag 0–3 corresponding to 0.46% (95% CI 0.08–0.84%) increase of acne visits. However, no statistical difference was found between different gender and age subgroups when comparing SO ₂ and NO ₂

(Completed)

Table 1 (Continued)

Study	Sample size (n)	Study design	Country	Pollutant measured	Exposure measurement	Acne outcomes	Summary of results	
Misra 2021 ¹²	134	Cross-sectional observational study	China	PAHs	AQMS	Dermatological clinical assessments	This study demonstrated that exposure to PAHs was associated with alterations in skin microbiota and metabolic profiles, which could compromise skin barrier functions and drive inflammation – changes contributing to the development and exacerbation of acne. However, direct causality between PAHs and acne was not established in this study	
El Haddad 2021 ¹⁷	372	Cross-sectional study	Lebanon	CO ₂ , CO, SO ₂ , NO ₂ and PM	AQMS	Patient-reported outcomes	Increased NO ₂ exposure was linked with a higher likelihood of developing acne (aOR 8.24). Working near a power plant also increased the risks of developing acne (aOR 3.07), as this was a source of pollutants, i.e. CO ₂ , CO, SO ₂ , NO ₂ and PM	
Abolhasani 2021 ¹⁸	22–252 799 outpatient visits	Narrative review	Various pollutants			Overview of air pollution effects on skin	This review included 103 studies. Many studies investigating the association between air pollution and acne reported significant associations with various pollutants and acne development and exacerbation. However, one Beijing study investigating the effect of air pollution on acne outpatient visits reported that increased SO ₂ levels were negatively associated with acne visits	
Yang 2020 ⁹	50–2472 0004	Systematic review		PM _{2.5} , PM ₁₀ , NO ₂	Patient-reported outcomes, acne prevalence	Review comprised 80 studies with a sample of 50–2472 004 patients. Two studies comparing more polluted areas with less polluted areas revealed reduced skin quality correlated with continued exposure to ambient air pollution. A Beijing study demonstrated a positive correlation between increase in PM _{2.5} , PM ₁₀ and NO ₂ concentrations and a rise in outpatient visits for acne vulgaris over the previous 2 years		
Passeron 2020 ²⁰		Narrative review		PM _{2.5} , PM ₁₀ , NO ₂	Overview of air pollution effects on skin	This review demonstrated that there were positive associations between air pollution and the development of acne. A Mexican study included in this review (n = 189) compared the facial skin of people living in a polluted city and subjects living in a less polluted city. This study demonstrated qualitative differences and increased sebum production in patients who lived in the polluted city compared with patients in the less polluted city		
Ali 2020 ⁸		Narrative review	Various pollutants	PM _{2.5} , PM ₁₀	Overview of air pollution effects on skin	This review demonstrated a relationship between pollutants and mechanisms which promote the development of acne such as inflammation, increased sebum production and oxidative stress		
Dong 2019 ²¹		Narrative review		PM _{2.5} , PM ₁₀	Overview of air pollution effects on skin	This study demonstrated associations between PM and acne, with long term PM exposure being reported to aggravate inflammatory skin conditions such as acne, atopic dermatitis and psoriasis. PM exposure was also associated with the development of skin cancer		
Liu 2018 ²²	59 325 outpatient visits	Time-series analysis	China	PM _{2.5} , PM ₁₀ , SO ₂ , NO ₂	EMC	Acne outpatient visits	Increased concentrations of PM _{2.5} , PM ₁₀ and NO ₂ were positively associated with increased acne outpatient visits over 2 years. However, an increase in SO ₂ concentrations showed negative correlation with acne outpatient visits in all test models used	
Puri 2017 ⁷		Narrative review		PAHs, PM, O ₃	Overview of air pollution effects on skin	Air pollution, particular PAH exposure was linked to the development of acneiform eruptions (chloracne), skin aging and pigmentation		

aOR, adjusted odds ratio; AQMS, Air Quality Monitoring Stations; CI, confidence interval; CO, carbon monoxide; CO₂, carbon dioxide; EMC, Environmental Monitoring Centre; NO₂, nitrogen dioxide; O₃, ozone; PAH, polycyclic aromatic hydrocarbon; PM, particulate matter (PM_{2.5}, PM₁₀); SO₂, sulfur dioxide.

capture delayed or cumulative effects of exposure over several days. Interestingly, when comparing age subgroups, the effect of PM_{10} was statistically significant among adults over 30 years of age, with every $10\text{ }\mu\text{g m}^{-3}$ rise at lag 0–3 associated with a 0.46% (95% CI 0.08–0.84%) increase in acne visits. However, no significant trends were observed across age groups for SO_2 and NO_2 .

Another time-series study in Chongqing, China¹⁵ investigating the relationship between $PM_{2.5}$ exposure and acne outpatient visits ($n=120842$) demonstrated a positive association between higher $PM_{2.5}$ concentrations and increased outpatient visits. Specifically, a $10\text{ }\mu\text{g m}^{-3}$ rise in $PM_{2.5}$ concentrations was associated with a 1.71% increase in acne outpatient visits over a 0- to 7-day lag period (95% CI 1.06–2.36). Stratified analyses revealed that the impact of $PM_{2.5}$ was more pronounced in individuals over 25 years (2.26%; 95% CI 1.37–3.15) compared with those under 25 years of age (1.24%; 95% CI 0.38–2.10). However, no significant gender-based differences were observed.

A third time-series analysis,²² also examining acne outpatient visits in Beijing, China ($n=59325$), reported similar findings, with higher PM_{10} , $PM_{2.5}$ and NO_2 concentrations being positively associated with increased outpatient visits. Notably, increases in SO_2 concentrations appeared to have a protective effect, showing a negative correlation with acne outpatient visits across all test models.

Acne symptoms

A cross-sectional study across several regions in China investigated the relationship between air pollution and skin sensitivity secondary to acne (assessed by questionnaire).¹⁴ This study involved 4325 patients with acne and revealed nonlinear relationships between secondary sensitive skin and $PM_{2.5}$, PM_{10} , SO_2 , NO_2 and carbon monoxide (CO). The risk of developing secondary sensitive skin increased with rising $PM_{2.5}$ concentrations, with a sharp escalation observed above $40\text{ }\mu\text{g m}^{-3}$. Elevated SO_2 levels also significantly impacted the occurrence of sensitive skin, while PM_{10} and NO_2 showed fluctuating effects. Interestingly, CO seemed to be protective in this study.

A cross-sectional study involving 372 participants in Lebanon investigated the associations between pollutant exposure and the risk of developing acne.¹⁷ Increased exposure to NO_2 was significantly associated with a higher likelihood of developing acne [adjusted odds ratio (aOR) 8.24]. Additionally, participants working near a power plant – identified as a source of CO, SO_2 , NO_2 and PM – also showed an elevated risk of acne (aOR 3.07).

Overall, the evidence from the epidemiological studies indicates a potential link between increased exposure to air pollution and increased acne prevalence or severity. While findings report minor inconsistencies, likely due to differences in population demographics, study types and pollutant types, most studies support an association between exposure to pollutants such as $PM_{2.5}$, NO_2 and SO_2 and negative acne-related outcomes.

Discussion

This systematic review synthesizes emerging evidence suggesting a positive association between environmental

pollution and acne outcomes. Multiple epidemiological studies, particularly large-scale time-series studies conducted in China, consistently demonstrated that higher concentrations of airborne pollutants – especially $PM_{2.5}$, PM_{10} , NO_2 and SO_2 – were correlated with increased outpatient visits for acne. These findings are supported by observational and cross-sectional studies from diverse settings, including Mexico and Lebanon, further reinforcing the potential impact of pollutant exposure on acne severity, SER and skin antioxidant levels.

Mechanistic pathways proposed by some studies provide plausible biological explanations for these associations. Pollutants such as PM and NO_2 may exacerbate acne through oxidative stress, inflammation, and disruption of the skin barrier and microbiome. The observational studies discussed suggest that increased pollution may be linked to higher SER and reduced antioxidant levels (vitamin E and squalene). This is particularly relevant, as these factors promote comedogenicity, oxidative stress and skin dysbiosis – all of which are key contributors to acne pathogenesis.²⁶

It is important to note that, while most studies showed positive associations, a few reported nonsignificant or protective effects, particularly with pollutants like CO or SO_2 in certain models. These findings may reflect real biological variation or methodological inconsistencies, warranting further investigations.

We acknowledge that limitations in the literature to date, namely heterogeneity in study design, pollutant measurement methods and acne outcomes assessments, limited comparability. Confounding variables such as individual pollutant exposure, diet, skincare practices and socioeconomic factors were often not accounted for. There was a paucity of geographic and ethnic diversity, which may limit the generalizability of findings, with most studies conducted in East Asia, with limited data from Western, African or other global populations. Cross-sectional designs make up a vast majority of the literature, limiting causal inferences. Longitudinal and interventional studies remain scarce.

This review underscores the need for future high-quality research to better define the causal relationship between air pollution and acne. Longitudinal studies with standardized pollution exposure assessment, acne outcome assessments and control for key confounders are crucial. Moreover, studies exploring vulnerable subgroups such as adolescents, individuals with pre-existing skin conditions and people living in heavily industrialized areas are needed to identify populations at greatest risk. Beyond acne, air pollution has also been implicated in the pathogenesis and exacerbation of other dermatological conditions including atopic dermatitis, skin ageing and psoriasis.^{27–29} Given this, future research could benefit from a broader dermatological perspective to fully grasp its impact on cutaneous health.

Implications for dermatologists

Recognition of air pollution as a potentially modifiable environmental risk factor for acne may help inform holistic patient care and urban health policy. For patients with recalcitrant acne, a brief environmental exposure history (e.g. proximity to heavy traffic or industrial areas) may

be relevant. The established links between occupational exposures and acne – such as polyhalogenated hydrocarbons causing chloracne,^{7,9} and coal tar or petrol derivatives contributing to occupational acne³⁰ – serve as a reminder that environmental factors can play a role in acne pathogenesis.

While the precise mechanisms by which common urban pollutants worsen acne remain incompletely understood, dermatologists may reasonably offer pragmatic skincare advice for patients in high-exposure settings (e.g. cyclists, roadside workers and outdoor labourers). These include twice-daily cleansing to putatively remove surface residues, use of a light noncomedogenic moisturizer to support the skin barrier, broad-spectrum sunscreen and considering antioxidant-containing products to offset some of oxidative stress induced by pollution.

Conclusion

This systematic review highlights a growing body of evidence supporting a link between environmental pollution and the development or exacerbation of acne. Although the findings are not entirely consistent across all studies, air pollution may act as an environmental trigger or aggravator of acne through oxidative stress, inflammation, and disruption of the skin barrier and microbiome.

However, limitations in study design, geographic scope and confounder control reduce the strength of current conclusions. As urbanization and environmental pollution continue to rise globally, it is increasingly important to understand how these exposures impact common skin conditions such as acne. Further high-quality, longitudinal and mechanistic research is needed to establish causality, identify high-risk groups and guide preventative strategies.

Incorporating environmental factors into dermatological assessments may support more personalized and comprehensive acne management. Ultimately, acknowledging pollution as a potential contributor to acne aligns with broader public health goals aimed at reducing environmental harm and promoting skin health.

Author contributions

Isobel R. Okeah (Methodology [lead], Writing—original draft [lead], Writing—review & editing [equal]), Usamah M. Afzal (Resources [equal], Supervision [supporting], Writing—review & editing [equal]) and Faisal R. Ali (Conceptualization [lead], Resources [equal], Supervision [lead], Writing—review & editing [equal])

Conflicts of interest

F.R.A. has received honoraria, sponsorship and speaker fees from L’Oreal, Galderma, Novartis, Leo Pharma, Incyte, Glenmark and Eli Lilly. No other conflicts are declared.

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Data availability

No new data were generated or analysed in support of this research.

Ethics statement

Not applicable.

Patient consent

Not applicable.

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