OPEN ACCESS

Environmental exposure and risk of death by suicide, attempted suicide and suicide ideation: a systematic review and meta-analysis

Sophie Marie Jones, Leandro Garcia, Claire L Cleland, Niamh O'Kane, Emma Ross, Ruth F Hunter

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/jech-2025-225491).

Centre for Public Health, Queen's University Belfast, Belfast, UK

Correspondence to
Dr Sophie Marie Jones; sophie.jones@qub.ac.uk and Professor Ruth F Hunter; ruth.hunter@qub.ac.uk

Received 18 November 2025
Accepted 7 July 2026

ABSTRACT

Background The impact of environmental exposure on suicide risk is poorly understood. We investigated the relationship between four environmental exposures—air, noise, light and water pollution—and the risk of death by suicide, attempted suicide and suicide ideation.

Methods We searched three electronic databases for empirical studies (2010–2024) investigating the relationship between environmental exposures and death by suicide, attempted suicide or suicide ideation. Random effect meta-analyses and narrative synthesis were performed. Risk of bias was assessed with the Newcastle Ottawa Scale.

Results This review included 45 studies, 29 in the meta-analysis and 16 in the narrative review. Short-term exposure to PM2.5 (n=13 studies, OR 1.0139, 95% CI 1.0001 to 1.0279) and PM10 (n=7 studies, OR 1.0100, 95% CI 1.0007 to 1.0195), and long-term exposure to PM2.5 (n=6 studies, OR 1.5254, 95% CI 1.1351 to 2.0481) and NO_2 (n=7 studies, OR 1.3173, 95% CI 1.0641 to 1.6308) had statistically significant positive associations with risk of suicide, attempted suicide and suicide ideation. The narrative review found potential positive associations for other air pollutants (including SO_2 and O_3) and noise pollution. Meta-analysis was not possible for water and light pollution; however, narrative review findings showed conflicting and unclear results.

Conclusion This meta-analysis shows statistically significant positive associations between short-term exposure to PM2.5 and PM10, long-term exposure to PM2.5 and NO_2, and risk of death by suicide, attempted suicide and suicide ideation. The narrative review also suggests that positive associations exist for other air pollutants and for noise pollution. The results highlight the importance of considering environmental exposures as modifiable risk factors in suicide prevention.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Suicide prevention can be viewed from a public health perspective due to the interplay of individual, biological and contextual factors. However, the role of the environment and its impact on suicide risk is often overlooked. This systematic review and meta-analysis aim to examine the relationship between environmental exposures and risk of death by suicide, attempted suicide and suicide ideation.

WHAT THIS STUDY ADDS

⇒ Pooled effect sizes showed that short-term exposure to PM2.5 and PM10, and long-term exposure to PM2.5 and NO_2, has statistically significant associations with death by suicide, attempted suicide and suicide ideation, in addition to narrative synthesis which demonstrated positive associations for other air pollutants and noise pollution. These results underscore the critical need to consider environmental exposures as modifiable risk factors within suicide prevention frameworks

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This systematic review and meta-analysis offer evidence of the role different environmental exposures may play in death by suicide and suicidal behaviours. Our results emphasise the importance of understanding the role that the environment plays in shaping death by suicide, attempted suicide and suicide ideation which can contribute to helping prevention efforts in interventions, policy and practice.

Check for updates

To cite: Jones SM, Garcia L, Cleland CL, *et al*. *J Epidemiol Community Health* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/jech-2025-225491

INTRODUCTION

Each year, over 720 000 people die by suicide globally[1] and these figures are likely to be under-reported.[1] In response, the WHO developed a Mental Health Action Plan to reduce the global suicide rate by one-third between 2013 and 2030.[2] Suicide rate is also included in the United Nations' Sustainable Development Goals as an indicator for target 3.4 of reducing premature mortality from non-communicable diseases by one-third by 2030, through prevention, treatment, and promotion of mental health and well-being.[3]

While there is no one single cause for suicide, reasons have been described as multifaceted and include several individual and biological factors[4 5] in addition to wider cultural and social factors.[6 7] These factors, in turn, are common targets for interventions to prevent suicides, with particular emphasis on clinical solutions, delivered by healthcare professionals in the mental health workforce.[8] However, these efforts often focus solely at the level of the individual, with a recent *Lancet Public Health* series demonstrating the need for a public health approach to suicide prevention.[8] It argued that individuals do not exist in a vacuum; their health is influenced

by multiple contextual factors, including social determinants, explaining 'the circumstances in which people grow, live, work, and age, and the systems put in place to deal with illness are the conditions in which people live and die, and are in turn, shaped by political, social economic forces'.[8 9] In this article, we further extend the application of a public health lens to suicide prevention to explore environmental exposures which can play a role in shaping risk factors for death by suicide, attempted suicide and suicide ideation, thereby adding to the recent commissioned series on preventing suicide.

The effect of environmental exposures such as air, noise and light pollution are well documented in the context of mental health outcomes such as depression or anxiety.[10] However, the role between these environmental exposures and risk of death by suicide, attempted suicide and suicide ideation is less well understood. A recent meta-analysis[11] focusing on air pollution exposure (particulate matter, PM) and associations with depression, anxiety, bipolar disorder, psychosis and suicide risk (n=25 studies), found evidence to suggest that short-term exposure to PM10 (0 to 2 days lag period) was positively associated with death by suicide (risk ratio (RR) 1.02, 95% CI 1.00 to 1.03). However, while this is suggestive evidence of a relationship between air pollution and suicide, the authors highlight the lack of studies investigating the effect of longer-term exposure and argue the need for more evidence to understand the relationship fully.

A separate review conducted by Hadad *et al*,[12] focusing on the impact noise pollution, particularly traffic noise, has on mental health conditions, highlighted several studies which demonstrated negative relationships with depression, anxiety and suicide.[13–16] Similarly, when looking at water pollution, a study focusing on the mental health risks and resilience among pollution-exposed adolescents reported air and water pollution exposure was associated with elevated symptoms of depression, generalised anxiety among other mental health conditions.[17] Additionally, a separate review looking at the effect of outdoor artificial light at night found an increased prevalence of depressive symptoms and suicidal behaviours.[18] However, when it comes to investigating environmental exposures and suicide behaviour, several limitations are noted due to heterogeneity of study design and environment measures,[19] and by the risk of residual and confounding factors,[11] which may in part explain the lack of evidence examining the relationship between environmental exposures and suicide behaviour.

Despite these limitations, there is growing recognition of the pathways that may link environmental exposures to suicide behaviour. For example, air pollution and water pollution have been suggested as having neurological implications (eg, through chronic inflammation and neurotoxicity, which has a negative impact on brain function and consequently affects mood and stress resilience).[20] Similarly, noise and light pollution have been suggested as increasing stress levels due to circadian rhythm disruptions,[12 21] whereas air pollen has been linked with exacerbating allergies, which has a negative impact on inflammation and mental health.[22] It is through these interconnected biological, psychological and social mechanisms that environmental exposures may shape suicide behaviour.

Recognising the growing interest in environmental factors influencing suicide risk, we conducted a systematic review and meta-analysis examining the relationship between environmental exposures and suicidal behaviour, and assessed whether specific exposure types (eg, air pollutants) and sociodemographic factors (eg, sex, socioeconomic status) varied this risk.

METHODS

Search strategy and selection criteria

We conducted a systematic review to determine the association between four environmental exposures—air, noise, light and water pollution—and deaths by suicide and suicide behaviour (including suicidal ideation and suicide attempts). Three electronic databases (Medline, PsycInfo and Embase) were searched (by SJ) in April 2024 with limits placed on human studies only, English language and date of publication (January 2010–April 2024). The search strategy was developed by the research team (experts in the field of public and planetary health, suicide prevention and urban environments) to include search terms relating to the environmental exposures of interest. Search terms were then piloted and refined by members of the research team (SJ, CC, RH). The finalised search strategy can be found in online supplemental material 3, along with inclusion and exclusion criteria.

We defined our outcome variables as follows: death by suicide as intentionally taking one's own life[23]; attempted suicide as intentional self-harm with the objective of suicide[23]; and suicidal ideation as thinking about ending one's life.[23] Additionally, some studies included deaths coded as 'undetermined intent', which we also included in our review if the study was applicable. The independent exposures of interest for this review were air pollution (eg, particulate matter), water pollution (eg, arsenic in water), noise pollution (eg, traffic noise) and light pollution (eg, artificial light at night).

Following the search of electronic databases, all records were imported into Covidence (https://www.covidence.org/) and were independently screened by two members of the research team (SJ and CC), both with previous review experience. Where discrepancies could not be resolved, a third reviewer was consulted (RH).

The study protocol was registered with PROSPERO (CRD42024557190) and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[24] (checklist reported as online supplemental material 4). Following the search and screening phase, the research team decided to focus this article on negative biological, psychological and social mechanisms linking environmental exposures to suicidal behaviour, with a separate paper addressing how natural environments influence physical, psychological, economic and social well-being.

Data analysis

Once the selection of studies was complete, the following data were extracted (by SJ): authors, year of publication, study design, country of study, population, outcomes and exposures investigated, outcome and exposure measures, data source, period of study, effect measure and size and adjusted variables. Data extraction was verified for accuracy by two additional reviewers (CC, NOK). Any additional missing fields were marked in the extraction sheet as unknown.

Risk of bias for each study was independently completed by two members of the research team (SJ, CC). After an initial assessment of 15 studies, the agreement rate was 97%. All discrepancies were resolved by a third reviewer (RH). A modified version of the Newcastle-Ottawa Scale[25] was used for this assessment and was modified to assess the risk of bias of cross-sectional studies appropriately, informed by a previous study[26 27] (online supplemental material 5).

Meta-analysis

Having met the inclusion criteria, each study was considered either for a narrative synthesis or for the meta-analysis. To be

included for the meta-analysis, each study had to provide an effect size (ES) and its confidence interval. The primary outcome of interest was death by suicide, attempted suicide and suicidal ideation. Due to the rarity of the outcome, hazard (HR), odds (OR) and relative risk (RR) ratios were considered to approximate to the OR which was considered the primary ES.[28] Most studies reported ES on a continuous scale. These interquartile ranges (IQRs) varied much between studies, making it necessary to standardise to the proportional change in risk per one unit of exposure variable, according to the formula exp(ln(ES)/IQR). ES also required adjustment where necessary on harmonising measurement units, for example, parts per billion were converted to micrograms per cubic metre ($\mu g/m^3$). If any data outlined above were missing or not in quantitative format (eg, effect sizes), then authors were contacted for this information. In total, 10 authorship teams were contacted, of which five responded with the data required for meta-analysis. When authors did not respond and data were presented as figures, a data estimation tool (https://plotdigitizer.com/) was used to estimate quantitative data. These figures were further confirmed by the author of the paper themselves, or otherwise manually by three reviewers (SJ, CC, NOK).

Meta-analysis was conducted by each main exposure type group (air pollution and noise pollution), and by more specific exposure groups (such as PM10 in air pollution) if studies were available. Where possible, exposure was analysed according to duration groups (short-term exposure defined as <6 months and long-term exposure defined as >6 months), as previously published meta-analyses highlighted the limited understanding of longer-term (ie, >6 months) air pollution exposure on death by suicide and attempted suicide and suicide ideation outcomes. For the short-term outcomes, a 0–3 day time lag effect of air pollution exposure was analysed.

Analysis was conducted following guidance from the Cochrane handbook for systematic reviews.[28] To run the meta-analysis, random-effect models were fitted using R (version 4.4.2) based on evidence from the χ^2 heterogeneity test and the I^2 statistic, using the most fully adjusted ES available from each study. The main result of the meta-analysis was the pooled ESs taken to represent the OR of outcome with its 95% confidence interval (95% CI). Sensitivity analysis was performed by excluding studies with a score <6 for the risk of bias assessment and restricting to a single outcome.

RESULTS

Following de-duplication, we identified 6585 studies from database searches. Title and abstract screening resulted in 287 studies selected for full-text review, with 45 studies meeting all criteria for inclusion and 29 eligible for inclusion in the meta-analysis (figure 1). In total, 242 studies were excluded (online supplemental material 6). Further study characteristics, including an overview of main results, are highlighted in online supplemental material 1.

All 45 studies were conducted with the general population (online supplemental material 1). All ages were included in the review (online supplemental material 1), in addition to male- or female-only studies.

In summary, 16 studies employed a case-crossover design, 10 cross-sectional, six ecological, six cohort, six time-series analysis and one panel study.

Eleven studies were conducted in European countries, including Belgium (n=2), Spain (n=2), Italy (n=2), Denmark (n=1), Switzerland (n=1), Poland (n=1), Hungary (n=1), and the United Kingdom (n=1). One additional study was conducted across multiple European countries including Denmark, Sweden, France, Netherlands, Germany and Austria. Ten studies were conducted in North America, including the United States (n=8) Canada (n=1), and Mexico (n=1). Eight studies were conducted in in South Korea, seven in China, three in Taiwan, three in Japan, and one in Colombia. Additionally, one multi-country study was conducted across South Korea, Japan, and Taiwan.

Thirty-three studies investigated death by suicide, seven investigated suicidal ideation and five investigated attempted suicide. Thirty-eight studies examined air pollution exposures, three examined water pollution, three examined noise pollution and one study examined light pollution.

The risk of bias assessment for each study can be found in online supplemental material 7. In the assessment, the majority of studies scored 5 (n=24), followed by 12 studies scoring 6, four studies scoring 7, two studies scoring 8, two studies scoring 4, and one study scoring 2 .

Air pollution exposure

Of the 38 studies examining air pollution, 26 were included in the meta-analysis, analysed by specific pollutants: PM2.5 (n=19 studies), PM10 (n=11 studies), SO_2 (n=7 studies), NO_2 (n=15 studies), O_3 (n=10 studies) and CO (n=3 studies). Meta-analysis results for air pollution can be found in figures 2 and 3, and a summary of results are presented below, with narrative review findings reported in online supplemental material 2.

For each 10 $\mu g/m^3$ increase in PM2.5 (n=13 studies), the pooled OR was 1.0139 (95% CI 1.0001 to 1.0279, p=0.0484, I^2=99.9%) at <6 months of exposure. At >6 months, per 10 $\mu g/m^3$ increase in PM2.5 (n=6 studies), the pooled OR was 1.5254 (95% CI 1.1351 to 2.0481, p=0.0050, I^2=78.8%). This suggests a statistically significant increase in the risk of death by suicide and attempted suicide and suicide ideation for both short- and long-term exposure to PM2.5.

For each 10 $\mu g/m^3$ increase in PM10 exposure (n=7 studies), the pooled OR was 1.0100 (95% CI 1.0007 to 1.0195, p=0.036, I^2=81.2%) at <6 months of exposure. At >6 months, per 10 $\mu g/m^3$ increase in PM10 (n=4 studies), the pooled OR was 1.7062 (95% CI 0.8509 to 3.4212, p=0.1323, I^2=98%). This suggests a statistically significant increase in risk of death by suicide and attempted suicide and suicide ideation for short-term exposure to PM10, but not for long-term exposure.

For each 10 part per billion (ppb) increase in SO_2 exposure (n=4 studies), the pooled OR was 0.9804 (95% CI 0.8945 to 1.0746, p=0.6724, I^2=88.3%) at <6 months of exposure. At >6 months, per 10 ppb increase of SO_2 (n=3 studies), the pooled OR was 2.1945 (95% CI 0.8179 to 5.8881, p=0.1186, I^2=82.1%). These results suggest a lack of evidence for an association between SO_2 exposure and risk of death by suicide and attempted suicide and suicide ideation.

For a 10 ppb increase in NO_2 exposure (n=8 studies), the pooled OR was 1.0047 (95% CI 0.9883 to 1.0212, p=0.5782, I^2 = 65.7%) at <6 months of exposure. At >6 months, per 10 ppb increase in NO_2 exposure (n=7 studies), the pooled OR was 1.3173 (95% CI 1.0641 to 1.6308, p=0.0114, I^2=92.4%). This suggests a lack of evidence for an association between short-term exposure to NO_2 and the risk of death by suicide and attempted suicide and suicide ideation, but a statistically significant risk for long-term exposure.

For a 10 ppb increase in short-term exposure to O_3 (n=10 studies), the pooled OR was 1.1649 (95% CI 0.9213 to 1.4730, p=0.2023, I^2=99.8%), suggesting a lack of evidence for the

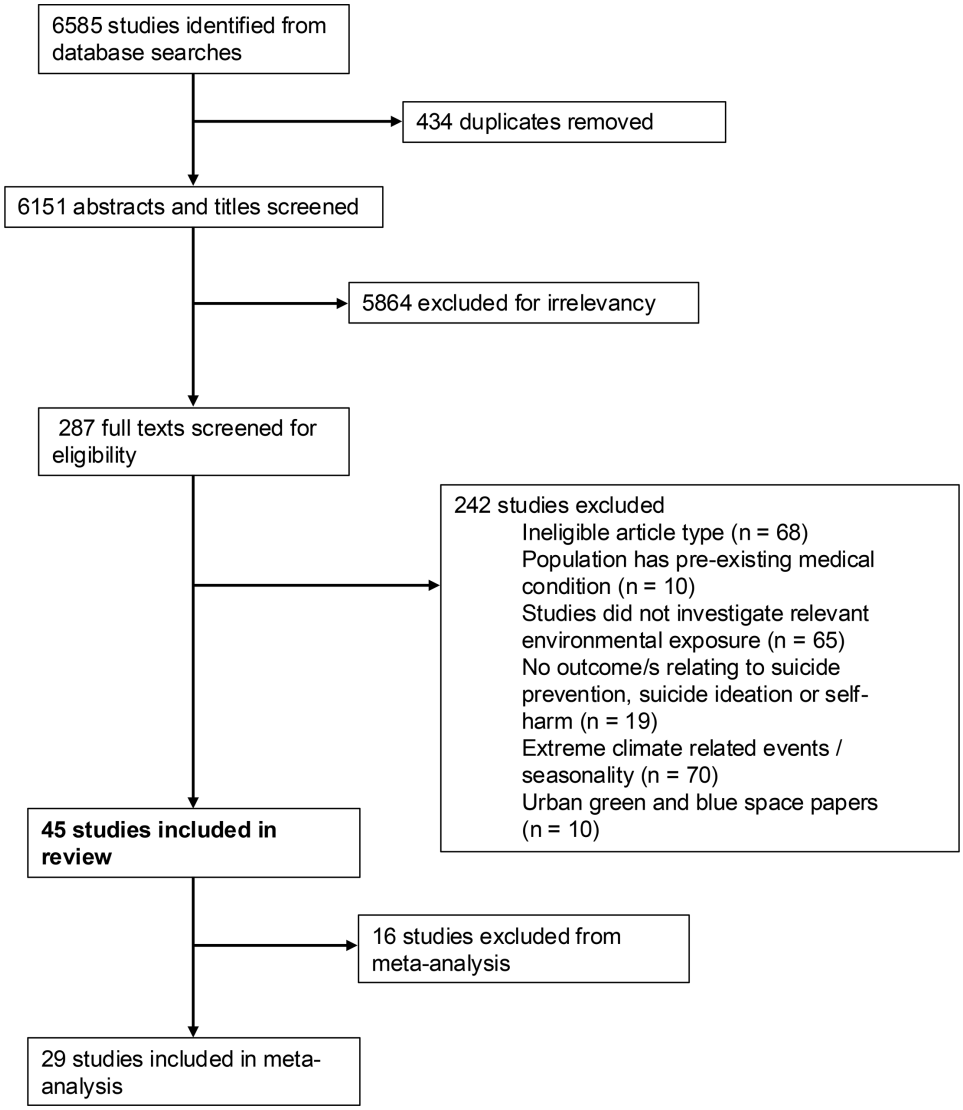

Figure 1 PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

increase in the risk of death by suicide and attempted suicide and suicide ideation. There were not enough studies investigating long-term exposure for a meta-analysis.

For short-term CO exposure (n=3 studies), the pooled OR was 1.2591 (95% CI 0.3547 to 4.4701, p=0.0212, I^2=81.2%) for each 10 part per million increase, suggesting a lack of evidence for the increase in the risk of suicide and attempted suicide and suicide ideation. Meta-analysis for long-term exposure was not possible due to lack of studies.

Noise pollution

All three studies investigating noise pollution and death by suicide and attempted suicide and suicide ideation risk were included in the meta-analysis. Results can be found in figure 4, and show a pooled OR of 1.1213 (95% CI 0.9646 to 1.3034, p=0.1361, I^2=84.1%) for each 1 dB increase in noise. These results suggest a lack of evidence for the increase in risk of death by suicide and attempted suicide and suicide ideation.

Water pollution

Meta-analysis for water pollution was not possible due to heterogeneity between outcome measures, meaning harmonisation across studies was not possible. Results from the narrative review are reported in the online supplemental material 2; in summary, findings suggest an inconsistent relationship.

Light pollution

Meta-analysis was also not possible for light pollution and deaths by suicide and attempted suicide and suicide ideation due to the small number of studies available (n<2). The narrative review is reported in online supplemental material 2 and, in summary, suggests a positive result.

Sub-group and sensitivity analyses

Subgroup analyses by gender are shown in online supplemental material 8. Overall, no significant differences were observed between men and women. Sensitivity analysis for the meta-analyses can be found in online supplemental material 9). While exploring the risk of bias alone (removing studies with a score <6), sensitivity analysis results revealed that only short-term NO_2 exposure and long-term PM2.5 exposure remained statistically significant (OR 0.9561, 95% CI 0.9266 to 0.9865, p=0.0049 for short-term NO_2; OR 1.5316, 95% CI 1.1063 to 2.2120, p=0.0102 for long-term PM2.5). When exploring the risk of bias and single outcomes (removing studies with a score <3 along with one measure of suicide risk (ie, only death by

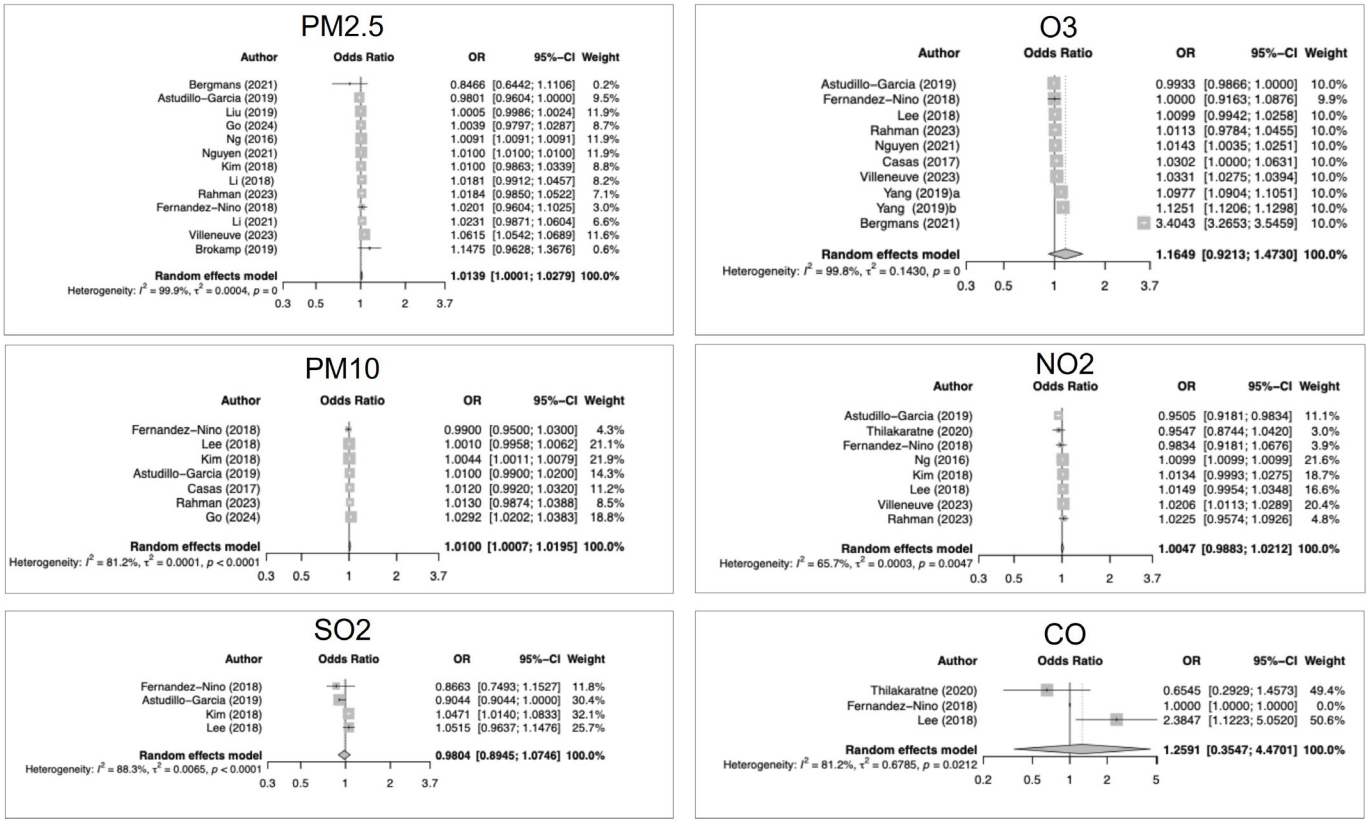

Figure 2 Forest plot showing the OR of death by suicide and attempted suicide and suicide ideation following short-term (<6 months) exposure to air pollution for six pollutants. Each pollutant is shown per 10 units of increase (μg/m^3 for PM2.5, PM10; parts per billion (ppb) for SO_2, O_3, NO_2; and parts per million (ppm) for CO). PM, particulate matter.

suicide or suicide ideation)), sensitivity analysis results revealed that only short-term NO_2 remained statistically significant (OR 0.9561, 95% CI 0.9266 to 0.9865, p=0.0049).

DISCUSSION

This systematic review and meta-analysis investigated the relationship between four environmental exposures and risk of death by suicide, attempted suicide and suicide ideation. Results from the meta-analysis found statistically significant associations for short-term exposure to PM2.5 and PM10, and long-term exposure to PM2.5 and NO_2. Results for the other pollutants were not statistically significant at a level of p<0.05. Sensitivity analysis revealed that, when focusing on risk of bias, only short-term NO_2 exposure and long-term PM2.5 exposure remained statistically significant, and when focusing on risk of bias and single outcomes, only short-term NO_2 exposure remained statistically significant.

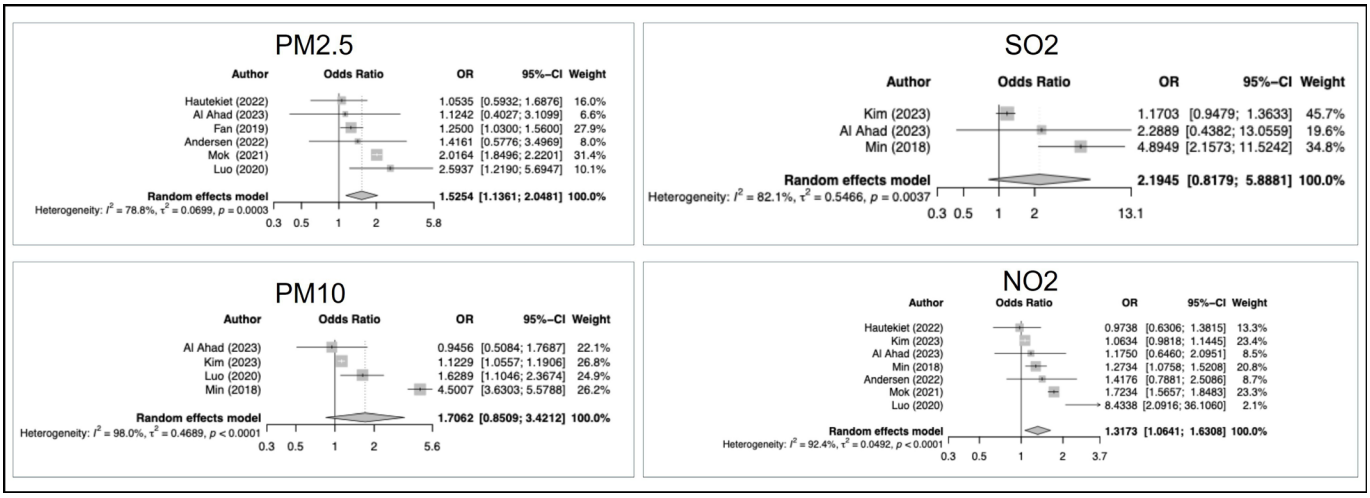

Figure 3 Forest plot showing the OR of death by suicide and attempted suicide and suicide ideation following long-term (>6 months) exposure to air pollution for four pollutants. Each pollutant is shown per 10 units of increase (μg/m^3 for PM2.5, PM10; parts per billion (ppb) for SO_2, O_3, NO_2; and parts per million (ppm) for CO). PM, particulate matter.

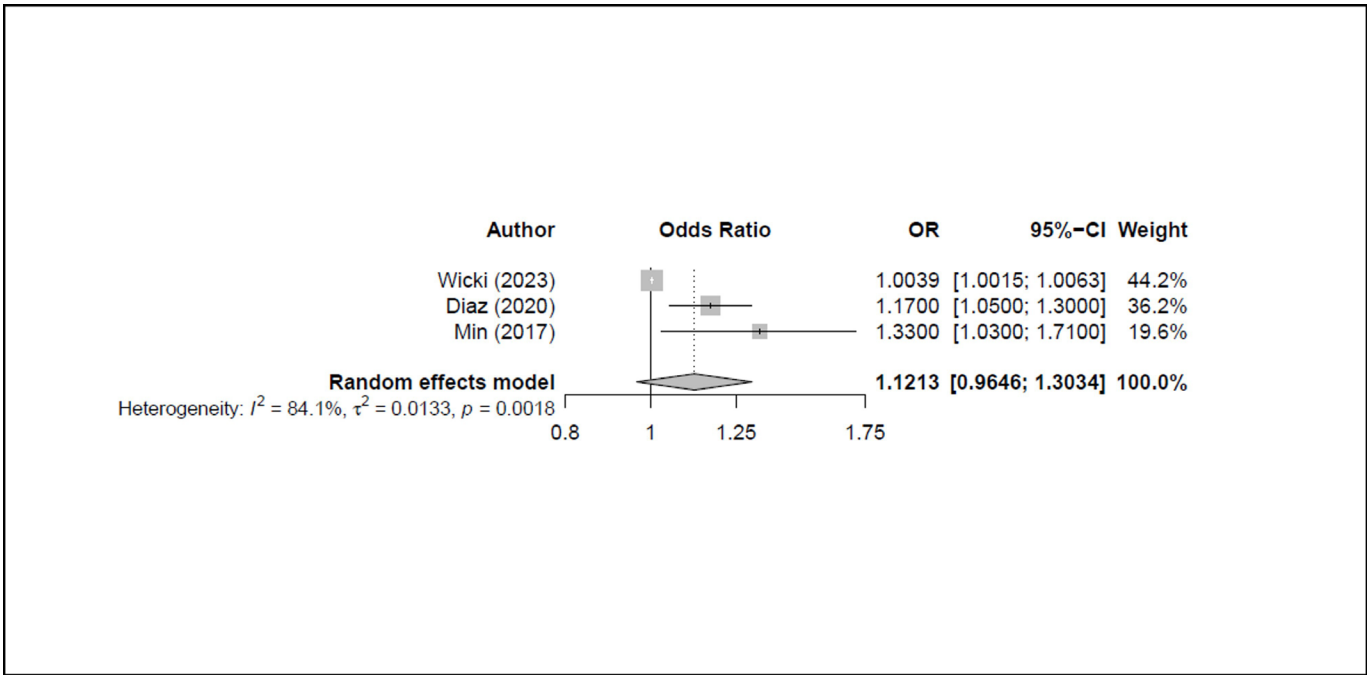

Figure 4 Forest plot showing the OR of death by suicide and attempted suicide and suicide ideation following exposure to noise pollution. Results are shown per 1 dB increase in road traffic noise.

These results were also complemented by a narrative synthesis, which found positive associations between exposure to PM2.5 and death by suicide[29–31]; PM10 and death by suicide[30–32]; PM10 and suicidal ideation[33]; NO2 and deaths by suicide[29 31 34]; and NO2 and suicidal ideation.[33] The narrative review also showed further positive associations between O_3 and death by suicide[32 35] and SO_2 and death by suicide.[29 35] These latter findings were different from the results observed in the meta-analysis, but this discrepancy is similar to previously published systematic reviews and meta-analyses,[11 20 36] which also found mixed findings between specific pollutants. The sub-analysis for males and females did not find significant differences between groups.

For noise exposure, while the results from the meta-analysis were not statistically significant, they do suggest a small positive relationship, which is consistent with previously published work conducted by Hahad *et al*,[12] who reported positive associations for nighttime, road traffic and railway noise, but reported weaker associations for aircraft noise.

While meta-analysis was not possible for water pollution, the narrative review synthesis found an inconsistent relationship.[37 38] These results are consistent with a similar previously published review looking at arsenic in water,[39] which also reported conflicting and inconsistent results when looking at the association between arsenic and suicide rates.

Lastly, findings from the narrative review synthesis suggested a positive association for light pollution.[40] While only one study was included in this review, a similar review focusing on affective disorders (including suicidal behaviour) also reported that outdoor artificial light at night is associated with suicidal behaviour.[18]

From the above data, we report evidence of statistically significant positive relationships between short-term exposure to two pollutants (PM2.5 and PM10) and long-term exposure to two pollutants (PM2.5 and NO_2), and the risk of death by suicide and attempted suicide and suicide ideation. The narrative review also suggests that potential positive associations may exist for other air pollutants and noise pollution. However, evidence was inconclusive for the potential role of light and water pollution.

These findings contribute to a broader understanding of the role environmental exposures play in suicide risk. They align with the conceptual model proposed by Pirkis *et al*,[10] which emphasises the influence of contextual factors on health and, consequently, suicide risk. Within this framework, the environmental exposures examined in this paper could be considered additional risk factors, particularly as they represent potential targets for universal interventions (eg, reductions in PM2.5, traffic-related noise mitigation).

Several pathways may explain these associations. For example, air pollution including PM2.5, PM10, NO_2, O_3 and water pollution (ie, water polluted with arsenic, lead, lithium or nitrate) have been linked to neurological effects, including chronic inflammation and neurotoxicity, which can impair brain function and influence mood and stress resilience,[17 20] while traffic and other environmental noise (ie, aircraft) and light pollution (namely outdoor artificial light at night) have been suggested to elevate stress levels through circadian rhythm disruption.[12 18] Each of these pathways consequently could lead to an increase in suicide risk due to changes in mood and behaviour.

Several pathways may explain these associations. Air and water pollution have been linked to neurological effects, including chronic inflammation and neurotoxicity, which can impair brain function and influence mood and stress resilience.[13] Noise and light pollution may elevate stress levels through circadian rhythm disruption.[12 18] Additionally, exposure to air pollen has been associated with exacerbated allergic responses, which can increase inflammation and negatively affect mental health. These results offer further understanding of the important role the environment plays in death by suicide risk and attempted suicide and suicide ideation. The findings directly link to the conceptual model highlighted by Pirkis *et al*,[10] that contextual factors have a significant influence on health and consequently suicide risk. As such, the exposures in this paper could be acknowledged in

Pirkis and colleagues' model as an additional risk factor, given the various environmental exposures could be recognised as targets through universal interventions (eg, PM2.5 reductions, noise traffic reduction targets).

This systematic review and meta-analysis is the first to synthesise evidence on multiple environmental exposures and their association with suicide risk. It expands current knowledge about the link between air, noise, light and water pollution and suicide. The study's strength lies in its comprehensive search, standardised data extraction and meta-analysis.

Notwithstanding of this study's strengths, the findings of this review should be interpreted in the light of its limitations. First, assumptions were made to conduct the meta-analysis, such as grouping together suicide outcomes, due to the small number of studies available on each respective outcome. This decision was deemed appropriate given the limited understanding of how environmental exposures are linked with the risk of death by suicide and attempted suicide and suicide ideation, and mechanistically, the hypothesised pathways are similar for each pollutant on each outcome. Additionally, while we ran meta-analyses for exposures with >2 studies, it is suggested that meta-analyses with <10 comparisons should be interpreted with caution due to reduced power.[28]

Next, results of the meta-analysis are reported with high levels of heterogeneity. While this has been commonly reported when investigating environmental exposures due to the variability in study design and environmental measures,[19] we did include an investigation of the sources of heterogeneity using a sensitivity analysis to account for the different outcomes and differing qualities of studies. After excluding studies with higher risk of bias, and keeping single outcomes (ie, just death by suicide), levels of heterogeneity were lower. However, only one exposure (short-term NO_2) showed a statistically significant relationship. Additionally, due to risk of bias scores with within studies being <6, it was not possible to do a sensitivity analysis for noise pollution.

Similarly, in the meta-analysis different effect measures (OR, HR, RR) were pooled together under the assumption that the outcome of interest (suicide) was rare. While this approach is commonly used in meta-analysis of rare events,[28] it may introduce some heterogeneity or bias which should be acknowledged.

While this systematic review and meta-analysis offers evidence regarding the association between environmental exposures and risk of death by suicide and attempted suicide and suicide ideation, the potential role of some exposures (ie, noise, light and water pollution) remains unclear. Therefore, further research is needed to understand the nature of the relationship for these exposures, and the possible mechanisms underpinning the relationships. This would also be beneficial from a practice and policy perspective as part of wider efforts for suicide prevention.

Another area for future research is to understand how other sociodemographic indicators, such as age or levels of deprivation, interact with these exposures, especially in terms of understanding how inequalities (such as living in a more deprived area) may exacerbate the influences of these exposures.

An additional priority for research is understanding the influence of simultaneous environmental exposures, and how these cumulatively affect the risk of death by suicide and attempted suicide and suicide ideation. This is an important gap to address given that most exposures (ie, traffic pollution, air pollution, artificial light and water pollution) do not exist in isolation, and their health effects are likely to interact with each other.

Finally, this study also has several implications from a practice and policy standpoint. In unison with the *Lancet* commissioned series,[41] calling for a public health lens to suicide prevention, policies should integrate mental health outcomes into environmental regulations, urban planning and surveillance systems. Addressing these links also highlights issues of environmental justice, as marginalised communities often face disproportionate exposure and limited access to mental health support. Overall, recognising environmental determinants of suicide risk supports a more holistic, preventive approach that connects environmental protection with mental health promotion.

CONCLUSION

Our systematic review and meta-analysis provide evidence examining the association between environmental exposures and risk of death by suicide and attempted suicide and suicide ideation. The evidence from the meta-analysis suggests statistically significant positive associations between short-term exposure to PM2.5 and PM10, long-term exposure to PM2.5 and NO_2, and risk of death by suicide and attempted suicide and suicide ideation. The narrative review also suggests that positive associations exist for other air pollutants and noise pollution. However, evidence for light and water pollution is inconclusive. Further research should investigate the cumulative effect of these environmental exposures to better understand the role environment plays in shaping death by suicide and attempted suicide and suicide ideation risk. These findings bring to attention the critical importance of recognising environmental exposures as modifiable risk factors within suicide prevention efforts. Integrating environmental health into mental health policy, through cross-sectoral collaboration, pollution reduction strategies and targeted public health interventions, could play a vital role in reducing suicide risk and improving overall population mental well-being.

Acknowledgements The authors would like to thank and acknowledge Dr Finian Bannon and Dr John Busby for their statistical advice and guidance in the analysis.

Contributors SJ and RH were responsible for the study concept, methodology, design, interpretation of findings and are the study guarantors. SJ and CC screened the abstracts and full texts for the review and did the risk of bias assessment. SJ, CC and NOK extracted the data and completed data checking. SJ and LG performed the data analysis and produced the figures. SJ wrote the manuscript, and RH, LG, CC, NOK and ER contributed equally to the review and editing. All authors had full access to all data in the study and had full responsibility for the decision to submit for publication.

Funding The authors would like to acknowledge funding from a UK Prevention Research Partnership grant (MR/V049704/1) awarded to GroundsWell (an interdisciplinary consortium involving researchers, policy, implementers and communities led by Queen's University Belfast, University of Edinburgh and University of Liverpool in partnership with Cranfield University, University of Exeter, University of Glasgow, University of Lancaster and Liverpool John Moores University) and the UKRI Queens's University Belfast 2022-2026 ADR UK Programme ES/W010240/1. The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

ORCID iDs
Sophie Marie Jones https://orcid.org/0000-0001-5757-7343
Leandro Garcia https://orcid.org/0000-0001-5947-2617
Emma Ross https://orcid.org/0000-0002-0541-8647
Ruth F Hunter https://orcid.org/0000-0001-7315-0382

REFERENCES

1 WHO Global Health Observatory. Suicide rate estimates, age-standardized, estimates by WHO region. 2024. Available: https://apps.who.int/gho/data/view.main.MHSUICIDEASDRREGv?lang=en [Accessed 3 Jun 2025].
2 WHO. *Comprehensive Mental Health Action Plan 2013–2030*. Geneva: World Health Organization, 2021.
3 Nations U. United nations sustainable development goals. 2015.
4 Levi-Belz Y, Gvion Y, Apter A. Editorial: The Psychology of Suicide: From Research Understandings to Intervention and Treatment. *Front Psychiatry* 2019;10:214.
5 Turecki G, Brent DA. Suicide and suicidal behaviour. *Lancet* 2016;387:1227–39.
6 Stack S. Contributing factors to suicide: political, social, cultural and economic. *Prev Med* 2021;152:106498.
7 Durkheim E. *Suicide: A Study in Sociology*. Routledge, 2005.
8 Hawton K, Pirkis J. Suicide prevention: reflections on progress over the past decade. *Lancet Psychiatry* 2024;11:472–80.
9 WHO Commission on Social Determinants of Health, World Health Organization. Closing the Gap in a Generation: Health Equity through Action on the Social Determinants of Health: Commission on Social Determinants of Health Final Report; World Health Organization; 2008.
10 Jimenez MP, DeVille NV, Elliott EG, *et al*. Associations between Nature Exposure and Health: A Review of the Evidence. *Int J Environ Res Public Health* 2021;18:4790.
11 Braithwaite I, Zhang S, Kirkbride JB, *et al*. Air Pollution (Particulate Matter) Exposure and Associations with Depression, Anxiety, Bipolar, Psychosis and Suicide Risk: A Systematic Review and Meta-Analysis. *Environ Health Perspect* 2019;127:126002.
12 Hahad O, Kuntic M, Al-Kindi S, *et al*. Noise and mental health: evidence, mechanisms, and consequences. *J Expo Sci Environ Epidemiol* 2025;35:16–23.
13 Dzhambov AM, Lercher P. Road Traffic Noise Exposure and Depression/Anxiety: An Updated Systematic Review and Meta-Analysis. *Int J Environ Res Public Health* 2019;16:4134.
14 Hegewald J, Schubert M, Freiberg A, *et al*. Traffic Noise and Mental Health: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health* 2020;17:6175.
15 Lan Y, Roberts H, Kwan MP, *et al*. Transportation noise exposure and anxiety: a systematic review and meta-analysis. *Environ Res* 2020;191:110118.
16 Generaal E, Timmermans EJ, Dekkers JE, *et al*. Not urbanization level but socioeconomic, physical and social neighbourhood characteristics are associated with presence and severity of depressive and anxiety disorders. *Psychol Med* 2019;49:149–61.
17 Theron LC, Abreu-Villaça Y, Augusto-Oliveira M, *et al*. A systematic review of the mental health risks and resilience among pollution-exposed adolescents. *J Psychiatr Res* 2022;146:55–66.
18 Menculini G, Cirimbilli F, Raspa V, *et al*. Insights into the Effect of Light Pollution on Mental Health: Focus on Affective Disorders—A Narrative Review. *Brain Sci* 2024;14:802.
19 Bolanis D, Vergunst F, Mavoa S, *et al*. Association between greenspace exposure and suicide-related outcomes across the lifespan: a systematic review. *Science of the Total Environment* 2024;906:167451.
20 Heo S, Lee W, Bell ML. Suicide and Associations with Air Pollution and Ambient Temperature: A Systematic Review and Meta-Analysis. *International Journal of Environmental Research and Public Health* 2021;18:7699.
21 Menculini G, Cirimbilli F, Raspa V, *et al*. Insights into the Effect of Light Pollution on Mental Health: Focus on Affective Disorders-A Narrative Review. *Brain Sci* 2024;14:802.
22 Ragguett RM, Cha DS, Subramaniapillai M, *et al*. Air pollution, aeroallergens and suicidality: a review of the effects of air pollution and aeroallergens on suicidal behavior and an exploration of possible mechanisms. *Rev Environ Health* 2017;32:343–59.
23 Nock MK, Borges G, Bromet EJ, *et al*. Suicide and suicidal behavior. *Epidemiol Rev* 2008;30:133:133–54:.
24 Page MJ, McKenzie JE, Bossuyt PM, *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.
25 Wells GA, Shea B, O'Connell D, *et al*. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses.
26 Patra J, Bhatia M, Suraweera W, *et al*. Exposure to second-hand smoke and the risk of tuberculosis in children and adults: a systematic review and meta-analysis of 18 observational studies. *PLoS Med* 2015;12:e1001835.
27 Forte AJ, Guliyeva G, McLeod H, *et al*. The Impact of Optimism on Cancer-Related and Postsurgical Cancer Pain: A Systematic Review. *J Pain Symptom Manage* 2022;63:e203–11.
28 Deeks JJ, Higgins JP, Altman DG, *et al*. Analysing data and undertaking meta-analyses. In: *Cochrane handbook for systematic reviews of interventions*. 2019: 241–84.
29 Bakian AV, Huber RS, Coon H, *et al*. Acute air pollution exposure and risk of suicide completion. *Am J Epidemiol* 2015;181:295–303.
30 Gładka A, Blachowski J, Rymaszewska J, *et al*. Investigating relationship between particulate matter air concentrations and suicides using geographic information system. *Psychology, Health & Medicine* 2022;27:2238–45.
31 Lin GZ, Li L, Song YF, *et al*. The impact of ambient air pollution on suicide mortality: a case-crossover study in Guangzhou, China. *Environ Health* 2016;15:90.
32 Kim Y, Myung W, Won HH, *et al*. Association between Air Pollution and Suicide in South Korea: A Nationwide Study. *PLoS One* 2015;10:e0117929.
33 Shin J, Park JY, Choi J. Long-term exposure to ambient air pollutants and mental health status: a nationwide population-based cross-sectional study. *PLoS One* 2018;13:e0195607.
34 Hidalgo-García D, Arco-Díaz J. Spatiotemporal analysis of the surface urban heat island (SUHI), air pollution and disease pattern: an applied study on the city of Granada (Spain). *Environ Sci Pollut Res* 2023;30:57617–37.
35 Yang AC, Tsai SJ, Huang NE. Decomposing the association of completed suicide with air pollution, weather, and unemployment data at different time scales. *J Affect Disord* 2011;129:275–81.
36 Davoudi M, Barjasteh-Askari F, Amini H, *et al*. Association of suicide with short-term exposure to air pollution at different lag times: A systematic review and meta-analysis. *Sci Total Environ* 2021;771:144882.
37 Rihmer Z, Hal M, Kapitány B, *et al*. Preliminary investigation of the possible association between arsenic levels in drinking water and suicide mortality. *J Affect Disord* 2015;182:23–5.
38 Whitaker CC, Cates ME, Cruthirds DL, *et al*. Association between concentrations of chromium in drinking water and mortality due to suicide in Alabama. *J Water Health* 2020;18:835–42.
39 Troiano G, Mercurio I, Melai P, *et al*. Suicide behaviour and arsenic levels in drinking water: a possible association?: A review of the literature about the effects of arsenic contamination in drinking water on suicides. *Egypt J Forensic Sci* 2017;7:2.
40 Min JY, Min KB. Outdoor light at night and the prevalence of depressive symptoms and suicidal behaviors: a cross-sectional study in a nationally representative sample of Korean adults. *J Affect Disord* 2018;227:199–205.
41 Pirkis J, Dandona R, Silverman M, *et al*. Preventing suicide: a public health approach to a global problem. *Lancet Public Health* 2024;9:e787–95.