



Received: 22-01-2026
Accepted: 02-03-2026

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Evaluation of the Awareness of Health Risks Associated with Air Pollution among the Elderly in Sunderland, United Kingdom

¹ Christabel Ihedike, ² Judith Eberhardt, ³ Jonathan Ling

¹ Public Health School of Psychology, Faculty of Health and Wellbeing, University of Sunderland, England

² School of Social Sciences, Humanities & Law Teesside University, England

³ Darlington Council Independent Researcher, Darlington, England

DOI: <https://doi.org/10.62225/2583049X.2026.6.2.5967>

Corresponding Author: Christabel Ihedike

Abstract

Air pollution is a global problem, with its health impact disproportionately affecting certain age groups, including the elderly. It is a complex issue driven by human activities, and addressing it requires a strong focus on health literacy and risk communication. Understanding public awareness of air pollution exposure and its health consequences is essential for developing effective interventions. This study aimed to evaluate awareness of the health risks associated with air pollution among the elderly in Sunderland, United Kingdom. A total of 420 participants were recruited, and their responses to questionnaires were collected and analysed using a Chi-square test. The results showed an

awareness index of 0.8, indicating that participants were generally aware of the health risks associated with air pollution in the study area. Several factors influenced awareness among older people. The Chi-square test was highly significant ($p < 0.01$), and the Pseudo R-square value of 0.731 indicated that the explanatory variables accounted for 73.1% of the variation in awareness levels. However, less than half of the sample was fully aware of the health risks posed by air pollution. Enhancing public awareness and promoting exposure-reduction strategies could help protect the elderly and individuals with respiratory diseases.

Keywords: Awareness, Air Pollution Effect, Health Risk. Elderly

Introduction

Air pollution is a significant risk factor for the onset and exacerbation of various health conditions, including lung cancer, cardiovascular disease, respiratory illness, and reduced life expectancy (Cohen *et al.*, 2017; de Bont *et al.*, 2022; Ihedike, Mooney, & Ling, 2023) [3, 5, 11]. Associations between cardiovascular diseases, hospital visits, and exposure to air pollutants such as particulate matter (PM_{2.5}), carbon monoxide, nitrogen dioxide, and sulphur dioxide have been well-documented (Brauer *et al.*, 2021; de Bont *et al.*, 2022; Ihedike *et al.*, 2024; WHO, 2024) [1, 5, 10, 28]. Global estimates suggest that nearly 20% of all cardiovascular diseases can be attributed to air pollution exposure (Brauer *et al.*, 2021) [1]. Research has shown that long-term exposure to air pollutants can lead to a reduced life expectancy, with risks of respiratory diseases, lung cancer, and cardiovascular conditions (Brauer *et al.*, 2021; Ihedike *et al.*, 2023) [1, 11].

Despite various approaches employed by Department for Environment, Food & Rural Affairs (DEFRA), UK Health Security Agency (UKHSA) and Environment Agency (EA) (air quality agencies) to communicate the health risks of air pollution, little is known about the extent and effectiveness of these efforts. Studies have identified the media as a key source of communication about air pollution (Cisneros *et al.*, 2017; Ramírez *et al.*, 2019 [21]). However, a recent content analysis of wildfire-related air pollution press releases and public complaints found that both were poorly aligned with actual air pollution data (Cisneros & Schweizer, 2018) [2]. This discrepancy suggests that misperceptions about air pollution risks persist among both the media and the public. While standards exist for the effective communication of air pollution risks, the extent to which these are followed by official organisations is unclear. For example, the UK Department for Environment Food & Rural Affairs (DEFRA) has published guidelines for effectively communicating environmental risks. These guidelines include using websites with diverse data visualisation tools, engaging local news media, officials, and schools, and tailoring information to the specific needs of sensitive populations, such as the elderly (Public Health England, 2018; DEFRA, 2024) [19, 27]. DEFRA's

recommendations are consistent with what is known about best practices in risk communication, which also emphasise the need for tailored messaging and dissemination strategies to reach diverse and multiple populations, along with specific and actionable information (Public Health England, 2018; Ramirez *et al.*, 2019, DEFRA, 2024) [19, 21, 27]. Despite such recommendations, there is little research on effective communication strategies or their influence on awareness (Giorgini *et al.*, 2017 [9], Ganesh & Smith, 2017; Gao *et al.* 2018 [7], Holtgrewe *et al.*, 2024).

Awareness of health risks is essential for individuals to make informed decisions about healthy living. Although studies have been conducted on the health risks of air pollution, none have specifically examined awareness of these risks among the elderly (Manisalidis *et al.*, 2020) [14]. This research was conducted in Sunderland, a city located in Northeast England. Sunderland was selected as the focus of this study due to its recent industrial and urban development, which contributed significantly to local air pollution levels. Despite these recent developments and environmental factors, little research has investigated public awareness of air pollution's health impacts in this area. Therefore, this study aimed to examine the awareness of health risks associated with air pollution among the elderly population in Sunderland. Understanding their awareness is crucial, as older adults are particularly vulnerable to the adverse health effects of air pollution, and improving their knowledge could lead to better self-protection measures and advocacy for cleaner air policies. Additionally, increasing awareness among the older population may encourage broader community engagement and policy changes that benefit public health.

Method

The city of Sunderland is home to a diverse range of ethnic communities and languages. The sample consisted of volunteered elderly individuals (aged 60 and above) living in the Sunderland area.

The questionnaire used in this study was designed to gather comprehensive information about the awareness, of elderly individuals (aged 60 and above) residing in Sunderland on health risks associated with air pollution. Given the city's diverse ethnic composition, the questionnaire was structured to capture a broad range of demographic, and social factors relevant to the study.

This quantitative study used a structured questionnaire to examine awareness of health risks associated with air pollution, among elderly individuals (60+) in Sunderland's diverse ethnic communities. The questionnaire was developed based on existing literature and input from the research team.

A pilot test with 15 participants ensured clarity and relevance, leading to minor adjustments. The final questionnaire included closed and Likert-scale questions across key areas: demographics, awareness, health risk associated with air pollution. Data were scored using quantitative scales, applied to all responses. The calculated sample size was 384.

Sampling

A total of 650 questionnaires were distributed. The questionnaire included questions on demography, such as age, gender, education level, and existing health conditions, to provide context for analysing responses. It also assessed

awareness of the health risks associated with air quality by exploring participants' knowledge of pollution sources, its impact on respiratory and cardiovascular health, and their perception of personal vulnerability. Additionally, the questionnaire investigated behaviours related to air pollution exposure, such as time spent outdoors, and engagement with public health information on air quality. The questionnaire, designed to be completed in 10 minutes, aimed to efficiently gather insights into participants' demographic details, and awareness of air pollution risks.

The questionnaires were distributed at churches, community centres, shopping areas and bus stations. Of the distributed questionnaires, 420 were correctly completed and included in the analysis. All respondents provided written informed consent before completing the questionnaire. Also, to avoid duplication of information one researcher collected all the data. Data collection took place over a four month period.

Data analysis

The data were analysed using the Statistical Package for the Social Sciences (SPSS), version 28. A Chi-square (χ^2) test was conducted to assess associations, as all variables were categorical. The significance level was set at 0.05.

Ethics statement

This study was conducted according to the ethical principles of the university. The study was approved by the Institutional Review Board of the University of Sunderland (ethical approval number 023044).

Participants were introduced to the study and issued each with the participant information sheet and those that showed interest were given consent form. Only that signed the consent form were recruited to participate and were reminded that they can withdraw without excuse.

Results

Table 1 presents demographic data on ethnicity, gender, education, and age distribution within the sample. The largest ethnic group was Asian (38.1%), followed by White-British (34.3%), African (25.7%), and Afro-Caribbean (1.9%). Male participants accounted for 53.6% of the sample, while females made up 46.4%. The highest percentage of respondents (48.6%) had a secondary school education, while 45.0% held a bachelor's degree, and only 6.4% had a postgraduate degree. The majority of participants (48.6%) were aged 66–70 years, followed by 44.3% in the 60–65 age group. The smallest age group was 71–88 years, comprising only 7.1% of the sample. Also Less than half of the respondents were aware of the health risks associated with air pollution.

Table 1: Participants' demographic characteristics

		Frequency	Percent
Ethnicity	Asian	160	38.1
	White-British	144	34.3
	African	108	25.7
	Afro-Caribbean	8	1.9
Gender	Male	225	53.6
	Female	195	46.4
Education	Secondary school	204	48.6
	Bachelor's degree	189	45.0
	Postgraduate degree	27	6.4
Age	66-70	204	48.6
	60-65	186	44.3
	71-88	30	7.1

Table 2 presents the results of the regression analysis examining factors influencing awareness of the health impacts of air pollution. The awareness index was measured at 0.8, indicating a moderate level of awareness among participants in the study area. The Pseudo R-square value of 0.731 demonstrated that the predictor variables accounted for 73.1% of the variance in awareness levels. Among the predictor variables, marital status had the strongest and most significant impact on awareness ($t = 11.303, p < 0.001$). Years of awareness and age showed positive but weakly significant effects ($t = 1.651, p < 0.05$ and $t = 1.562, p < 0.05$, respectively). Education was weakly significant and had a negative effect ($t = -1.587, p < 0.05$), suggesting that lower education levels may be associated with reduced awareness.

Table 2: Regression analysis of factors influencing awareness of air pollution health risks

Variables	Coefficient	t-value
Constant	13.785	0.995
Years of air pollution awareness	0.279	1.651*
Age	0.154	1.562*
Marital status	5.923	11.303***
Education	-1.769	-1.587*
χ^2		0.728
Log-likelihood		15.298
Pseudo (R^2)		0.731

Table 3 presents the distribution of awareness levels of various health risks associated with air pollution among older adults in Sunderland. The findings indicate that 90% of respondents were aware of the risk of respiratory diseases, while 10% were not. Awareness of lung infections was slightly lower, with 84.55% of respondents recognizing the risk, while 15.45% were unaware. Cardiovascular diseases were identified as a risk by 72.27% of respondents, whereas 27.73% were not aware of this connection. However, awareness of other health risks was significantly lower. Only 11.82% of respondents recognized the risk of neurological problems associated with air pollution, with 88.18% unaware of this impact. Similarly, 21.82% acknowledged the risk of cancer, while 78.18% were not aware.

Awareness of other conditions was even more limited. Only 24.55% of respondents were aware of the risk of eye or skin allergies, while 75.45% were not. Additionally, awareness of immune system disturbances (0.91%), infertility (0.45%), fatigue (0%), and depression (0%) were virtually nonexistent. The overall awareness index was calculated 50.94% indicating a moderate level of awareness among participants. This means that, on average, about half of the respondents are aware of the health risks.

Table 3: Distribution of awareness levels of health risks among older people

Health risk	Aware	% Aware	Not Aware	% Not Aware
Respiratory diseases	198	90	22	10
Lung infections	186	84.55	34	15.45
Cardiovascular diseases	159	72.27	61	27.73
Eye/ Skin allergy	54	24.55	166	75.45
Cancer	48	21.82	172	78.18
Neurological disorders	26	11.82	194	88.18
Immune system disturbances	2		0	0.91

Infertility	1		0	0.45	0
Fatigue	0		0	0	0
Depression	0		0	0	0
Awareness Index (AI)	50.94%				

Discussion

This study evaluated the awareness of health risks associated with air pollution among the elderly in Sunderland, UK. Air pollution is a well-documented risk factor for numerous health problems, making awareness among vulnerable populations, such as the elderly, crucial. The results of this study indicated that a significant proportion of the sample were aware of the health risks associated with air pollution. However, less than half of the participants believed that respiratory or heart diseases could be worsened or caused by air pollution. Additionally, more than a quarter of participants were unsure about the necessary steps to reduce exposure to air pollution. These findings highlight the need for targeted efforts to improve awareness of the health impacts of air pollution and promote strategies to mitigate exposure.

The findings of this study are consistent with those of a study conducted in London (Smith *et al.*, 2024) [25] focused on vulnerable populations, including older adults, to understand their lived experiences related to air pollution. The study emphasised the need for targeted educational interventions to improve environmental health literacy among older adults, enabling them to make informed decisions to protect their health. Similarly Schulte & Hudson (2023) [22], explored sociodemographic patterns in accessing air quality information channels and how this correlates with the adoption of protective behaviours. The research highlighted that older adults may face challenges in accessing digital platforms that provide air quality information, potentially limiting their ability to take preventive measures against air pollution exposure. Also a research conducted in the inner-city areas of Lambeth and Southwark revealed that older residents are less likely to prioritise environmental issues, including air quality, compared to younger populations. Despite being disproportionately affected by air pollution—linked to heart failure, strokes, cognitive decline, and lung cancer—only 9% of older individuals viewed the environment as a significant concern. This suggests a gap in awareness regarding the health risks posed by air pollution among the older Population (Impact on Urban health, 2020) [12] Their observations align with the findings of the present study, which showed that awareness was closely associated with individuals’ level of education.

A study by Omanga *et al.* (2014) [17] highlighted participants’ awareness of the health impacts of air pollution and found that awareness levels were linked to education, a finding that aligns with the results of this study. Similarly, Dowling *et al.* (2024) [4] examined levels of awareness and reported that less than half of U.S. adults recognize air pollution as a health risk. These studies demonstrate a critical gap in awareness of air pollution’s health risks among adults, including the elderly (Ge *et al.*, 2024) [8]. Thus, this study’s findings partially align with prior research. For example, So *et al.* (2024) found that long-term exposure to pollutants is associated with an increased risk of dementia in older individuals. This underscores the significant health implications of environmental factors on the elderly, particularly due to low levels of awareness. Previous studies

have highlighted two key factors that influence air quality awareness. Results from a media campaign on air pollution showed that perception of personal risk significantly influences how individuals seek information, with those facing respiratory health challenges being more likely to seek out air quality information compared to those with cardiovascular disease (Egondi, *et al.*, 2013; Wang, & Cao, 2024) [6, 27]. Another study found increased air quality awareness in areas with a reported Air Quality Index, even in areas where the index did not exceed a moderate categorisation (Mirabelli, Belt, & Damon, 2020) [16].

These studies highlight a significant gap in awareness and understanding of air pollution's health risks among the elderly in the UK. Addressing this issue requires targeted educational initiatives to improve environmental health literacy, ensuring that older populations are informed and can take appropriate measures to protect their health (Panagioti, *et al.*, 2018; Wang & Cao, 2024) [18, 27]. Collectively, these studies highlight a gap between awareness of air pollution health risks and actions taken to reduce exposure.

Studies collectively highlight the challenges faced by older adults in the UK regarding access to information and awareness of health risks associated with air pollution (Panagioti, *et al.*, 2018 [18]; Ramires *et al.*, 2019; Wang, & Cao, 2024 [27]; So, *et al.*, 2024). Our findings suggest that individuals with limited education had lower levels of knowledge about the health risks associated with air pollution. Previous studies, however, have shown that a lack of awareness of these health risks can double the health impacts of air pollution (Holtgrewe *et al.*, 2024; Ge *et al.*, 2024 [8]). Interventions addressing this gap could be strengthened by efforts not only to improve air pollution awareness but also to identify and promote practical strategies for reducing air pollution exposure (Sofia *et al.*, 2020) [23].

Strengths and Limitations

This study is the first to develop a quantified awareness index to measure the level of understanding about the health risks of air pollution among older residents. The study identified influential factors that shape awareness levels, offering critical insights on air pollution varying awareness, personal experience and health impact and media exposure and information access for targeted public health interventions. Additionally, the research provides a baseline understanding of awareness levels, which can guide future efforts to address gaps in knowledge and develop region-specific strategies for mitigating health risks.

However, several limitations should be considered. The reliance on self-reported data for demographic characteristics introduces the potential for misclassification and recall bias. For instance, participants may have forgotten prior exposure to information about air pollution. Furthermore, the study's cross-sectional design limits the ability to establish causal relationships between demographic factors and awareness levels.

Future research should address these limitations by employing longitudinal study designs to explore how awareness evolves over time and its impact on health behaviours. Efforts should also be made to validate self-reported demographic data through independent verification methods. Additionally, expanding the scope of the study to include diverse regions, Traditional media (Television,

radio, Newspapers and Magazine) which remains a primary source of news and health information for older adults and younger groups could enhance generalisability and provide a more comprehensive understanding of awareness levels and their determinants. Although beyond the scope of the present study, future research should focus on developing and evaluating the effectiveness of tailored communication strategies in improving awareness and reducing exposure to air pollution in vulnerable populations.

Conclusion

Exposure to air pollution is a modifiable risk factor for various health problems. By reducing exposure, individuals can take proactive steps to protect their health.

The present study revealed significant gaps in awareness among elderly residents in Sunderland. These results highlight the need for targeted educational initiatives to improve awareness of air pollution's health risks and to promote practical actions for reducing exposure. Empowering elderly individuals with knowledge about air quality and its effects on health is essential for encouraging behaviour change and reducing the burden of air pollution-related health problems. Increasing individual awareness and public involvement could be powerful tools in achieving better air quality. The present findings highlight key areas for mitigating pollution risks as environmental policies evolve. Future efforts should prioritise enhancing public knowledge as well as implementing actionable strategies to reduce exposure, ensuring long-term improvements in both air quality and public health.

References

1. Brauer M, Casadei B, Harrington RA, Kovacs R, Sliwa K, WHF Air Pollution Expert Group. Taking a stand against air pollution - the impact on cardiovascular disease. *European Heart Journal*. 2021; 42(15):1460-1463. Doi: <https://doi.org/10.1093/eurheartj/ehaa1025>
2. Cisneros R, Schweizer DW. The efficacy of news releases, news reports, and public nuisance complaints for determining smoke impacts to air quality from wildland fire. *Air Quality, Atmosphere and Health*. 2018; 11(4):423-429. Doi: 10.1007/s11869-018-0545-
3. Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, *et al.* Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: An analysis of data from the Global Burden of Diseases Study 2015. *Lancet (London, England)*. 2017; 389(10082):1907-1918. Doi: [https://doi.org/10.1016/S0140-6736\(17\)30505-6](https://doi.org/10.1016/S0140-6736(17)30505-6)
4. Dowling T, Pennington F, Wall H, Maria C, Mirabelli M. Air Quality Perceptions, Awareness, and Associated Behaviors Among U.S. Adults with and Without Heart Disease, *AJPM Focus*. 2024; 3(4):100249. ISSN: 2773-0654. Doi: <https://doi.org/10.1016/j.focus.2024.100249>
5. De Bont J, Jaganathan S, Dahlquist M, Persson Å, Stafoggia M, Ljungman P. Ambient air pollution and cardiovascular diseases: An umbrella review of systematic reviews and meta-analyses. *Journal of Internal Medicine*. 2022; 291(6):779-800. Doi: <https://doi.org/10.1111/joim.13467>
6. Egondi T, Kyobutungi C, Ng N, Muindi K, Oti S, Vijver SVD, *et al.* Community Perceptions of Air Pollution and Related Health Risks in Nairobi Slums. *International Journal of Environmental Research and*

- Public Health. 2013; 10(10):4851-4868. Doi: <https://doi.org/10.3390/ijerph10104851>
7. Gao J, Hou H, Zhai Y, Woodward A, Vardoulakis S, Kovats S, *et al.* Greenhouse gas emissions reduction in different economic sectors: Mitigation measures, health co-benefits, knowledge gaps, and policy implications. *Environmental pollution* (Barking, Essex: 1987). 2018; 240:683-698. Doi: <https://doi.org/10.1016/j.envpol.2018.05.011>
 8. Ge Yan Lin, Oyu Tsogtbayar, Ser-Od Khuyagaa, Eelin Khurelbaatar, Jargalsaikhan Galsuren, Lauren Prox, *et al.* Interactive effects of air pollutants and viral exposure on daily influenza hospital visits in Mongolia, *Environmental Research*. 2024; 268. Doi: <https://doi.org/10.1016/j.envres.2024.120743>
 9. Giorgini P, Di Giosia P, Petrarca M, Lattanzio F, Stamerra CA, Ferri C. Climate Changes and Human Health: A Review of the Effect of Environmental Stressors on Cardiovascular Diseases Across Epidemiology and Biological Mechanisms. *Current Pharmaceutical Design*. 2017; 23(22):3247-3261. Doi: <https://doi.org/10.2174/1381612823666170317143248>
 10. Ihedike C, Mdegela M, Mooney JD, Ana GR, Ling J. Diurnal Effect of PM10 and NOX on Chronic Obstructive Pulmonary Disease and Asthma in Abuja Nigeria. *Global Multidisciplinary Journal*, 2024.
 11. Ihedike C, Mooney J, Ling J. The Effect of PM10 and NOx on COPD and Asthma Patients in Abuja Nigeria. *OAJRC Environmental Science*, 2023.
 12. Impact on Urban Health. Air pollution and older people. Air pollution and older people - Reports - Impact on Urban Health, 2020.
 13. Liu X, Zhu H, Hu Y, Feng S, Chu Y, Wu Y, *et al.* Public's Health Risk Awareness on Urban Air Pollution in Chinese Megacities: The Cases of Shanghai, Wuhan and Nanchang. *International Journal of Environmental Research and Public Health*. 2016; 13(9):845. Doi: <https://doi.org/10.3390/ijerph13090845>
 14. Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in Public Health*. 2020; 8:14. Doi: <https://doi.org/10.3389/fpubh.2020.00014>
 15. Mirabelli MC, Boehmer TK, Damon SA, Sircar KD, Wall HK, Yip FY, *et al.* Air quality awareness among U.S. Adults with respiratory and heart disease. *American Journal of Preventive Medicine*. 2018; 54(5):679-687. Doi: <https://doi.org/10.1016/j.amepre.2018.01.037>
 16. Mirabelli MC, Ebelt S, Damon SA. Air Quality Index and air quality awareness among adults in the United States. *Environmental Research*. 2020; 183:109185. Doi: <https://doi.org/10.1016/j.envres.2020.109185>
 17. Omanga E, Ulmer L, Berhane Z, Gatari M. Industrial air pollution in rural Kenya: Community awareness, risk perception and associations between risk variables. *BMC Public Health*. 2014; 14:377. Doi: <https://doi.org/10.1186/1471-2458-14-377>
 18. Panagioti M, Skevington SM, Hann M, Howells K, Blakemore A, Reeves D, *et al.* Effect of health literacy on the quality of life of older patients with long-term conditions: A large cohort study in UK general practice. *Quality of Life research: An International Journal of Quality of Life Aspects of Treatment, Care and Rehabilitation*. 2018; 27(5):1257-1268. Doi: <https://doi.org/10.1007/s11136-017-1775-2>
 19. Public Health England. Health matters: Air pollution - GOV.UK, 2018.
 20. Rajagopalan S, Landrigan PJ. Pollution and the heart. *The New England Journal of Medicine*. 2021; 385(20):1881-1892. Doi: <https://doi.org/10.1056/NEJMra2030281>
 21. Ramírez AS, Ramondt S, Van Bogart K, Perez-Zuniga R. Public awareness of air pollution and health threats: Challenges and opportunities for communication strategies to improve environmental health literacy. *Journal of Health Communication*. 2019; 24(1):75-83. Doi: <https://doi.org/10.1080/10810730.2019.1574320>
 22. Schulte K, Hudson B. A cross-sectional study of inequalities in digital air pollution information access and exposure reducing behaviour uptake in the UK, 2023. Doi: <https://doi.org/10.1016/j.envint.2023.108236>
 23. Sofia D, Gioiella F, Lo Trecchiano N, *et al.* Mitigation strategies for reducing air pollution. *Environ Sci Pollut Res*. 2020; 27:19226-19235. Doi: <https://doi.org/10.1007/s11356-020-08647-x>
 24. Shah AS, Langrish JP, Nair H, McAllister DA, Hunter AL, Donaldson K, *et al.* Global association of air pollution and heart failure: A systematic review and meta-analysis. *Lancet* (London, England). 2013; 382(9897):1039-1048. Doi: [https://doi.org/10.1016/S0140-6736\(13\)60898-3](https://doi.org/10.1016/S0140-6736(13)60898-3)
 25. Smith C, Drinkwater A, Modlich M, Van Der Horst D, Doherty R. IAQ and environmental health literacy: Lived experiences of vulnerable people. *Buildings and Cities*. 2024; 5(1):231-246. Doi: <https://doi.org/10.5334/bc.418>
 26. UK Department for Environment Food & Rural Affairs (DEFRA). Pollution forecast - Defra, UK, 2024.
 27. Wang C, Cao J. Air pollution, health status and public awareness of environmental problems in China. *Sci Rep*. 2024; 14:19861. Doi: <https://doi.org/10.1038/s41598-024-69992-2>
 28. World Health Organization. Air pollution. World Health Organization, 2024. https://www.who.int/health-topics/air-pollution#tab=tab_1
 29. Yin RK. Case study research: Design and methods (5th ed.). Thousand Oaks, CA: Sage, 2014.