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Narrative Review

The role of imaging in the diagnosis of potential air pollution related illness: A narrative review

A. Taylor [a], P. Lockwood [b, *]

[a] Radiology Department, St George's University Hospitals NHS Foundation Trust, Blackshaw Rd, London, United Kingdom
[b] Department of Radiography, School of Allied Health Professions, Faculty of Medicine, Health and Social Care, Canterbury Christ Church University, Kent, United Kingdom

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ABSTRACT

Introduction: The World Health Organization (WHO) emphasizes the global issue of poor air quality, largely attributed to the release of pollutants by human activity. In a significant development, air pollution was officially recorded as a cause of death in the UK for the first time in 2021, prompting the creation of the Clean Air Bill and campaigns to reduce emissions. In light of these developments, this paper aims to map available literature on air pollution-related illnesses, with a specific focus on the role of radiographic imaging in their diagnosis.
Method: A scoping review was conducted using the Scopus, Trip Medical Database, and CINAHL databases. Key terms such as "air pollution" and "imaging" and inclusion and exclusion criteria were applied. A critiquing framework assessed the quality, rigor, and transparency of research. Data from each study was extracted and extrapolated into a thematic matrix to display the results.
Results: A review of ten papers comprising four systematic reviews, four cohort studies, and two longitudinal studies found nine different pollutants implicated in various diseases. Seven papers focused on brain pathological changes, two on lung function, and one on cardiovascular changes. Eight studies used Magnetic Resonance Imaging (MRI), and two used Computed Tomography (CT) scans.
Conclusion: The findings revealed nine different air pollutants were mentioned across a range of CT and MRI imaging modalities in the studies. Dementia was the most referenced illness. The results suggest that air pollution-related illnesses will continue to pose a significant health risk, impacting the general population and the clinical work of the radiography profession.
Implications for practice: Given the diverse effects of air pollutants on health, it is important radiographers are educated on how patient's history may influence imaging findings.

Introduction

Air Pollution is a universally acknowledged cause of morbidity and death.[1] Human activity, particularly in urban areas, has led to the release of particulates and hazardous gases into the air.[2] In 2021, the World Health Organization[1] (WHO) announced that 99% of the world's population breathes air that does not meet their guidelines for good air quality, emphasising the effect this can have on the population's health. In the United Kingdom (UK), the correlation between high levels of air pollutants and health became poignant when, in 2021, 'exposure to air pollution' was recorded on a death certificate as a cause of death for the first time.[3] Subsequently, this prompted the creation of the Clean Air (Human Rights) Bill,[4] intended to protect the right to breathe clean air, and the increase of various campaigns to promote the lowering of emissions.[5]

Thus, the effect of these substances when inhaled into the body is the subject of much ongoing discourse and research within medical and public health spheres. In medicine[6,7] and nursing,[8,9] there are ongoing discussions regarding the conditions that can be exacerbated or caused by air pollutants and the extent to which healthcare professionals are educated on these topics. As registered healthcare professionals, radiographers are required by the Health and Care Professions Council (HCPC),[10] Allied Health Professions Federation[11] (AHPF), and governmental policies[12,13] to promote health and prevent ill health. Other health risks such as obesity[14] and smoking[15] are discussed in publications aimed at educating the radiography workforce with this intent. However, there is currently a dearth of literature aimed at radiographers regarding air pollution. This makes it difficult for radiographers to execute

* Corresponding author. School of Allied Health Professions, Faculty of Medicine, Health and Social Care, Canterbury Christ Church University, Kent, United Kingdom.
E-mail address: paul.lockwood@canterbury.ac.uk (P. Lockwood).

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evidence-based practice regarding this topic. Thus, research into air pollution and its associated health risks, are important to understand the extent radiographic practice can assist in diagnosing air pollution-related pathologies. The aims of this scoping review are to map the available research on air pollution-related illnesses that include radiographic imaging in its diagnosis.

Method

A scoping review methodology[16] was used to identify literature utilising the databases: Scopus, Trip Medical Database, and the Cumulative Index to Nursing and Allied Health Literature (CINAHL). These databases were chosen due to the collated valid research literature in the medical and healthcare sphere and thus were reliable to search for relevant papers. This search did not require ethical approval as all the literature considered was published in the public domain.[17]

Inclusion and exclusion criteria were established (Table 1) to avoid deviance from the search terms. Boolean operators and medical subject heading (MeSH) terms were employed as this is advised to aid an advanced search of the databases and to ensure the criteria are followed.[18] The key terms "air pollution" AND (imaging OR "Computed Tomography" OR CT OR X-ray OR "Magnetic Resonance Imaging" OR MRI) were searched for in the title and abstract in each database alongside the specified date range.

The title and abstract of the articles were then read, and articles that discussed links between air pollutants and at least one human illness were included in the study. Grey literature was excluded to reduce bias.[18] Any predictive papers or 'meta-predictions' were excluded as they were not predictions regarding radiography and strayed from the aims of the search. Once these were excluded, the full texts were screened against the Hek and Moule[19] method of critiquing literature to assess the quality, rigor and transparency of research to determine eligibility. The Hek and Moule[19] framework was chosen as it incorporates the critiquing of both qualitative and quantitative research to an equal standard. Additionally, a Preferred Reporting Items for Systematic Reviews and Meta-Analyses[20] (PRISMA) flow chart was used to record the search history. Data from each study was extracted, and common reoccurring themes and patterns were extrapolated into a thematic matrix to display the results.

Table 1
A table depicting the inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Articles published 2018–2023	Articles published pre-2018
Any age group	Not containing key search terms in Not referring to air pollution.
Containing key search terms	Grey Literature
Cohort studies, Longitudinal studies	Guidelines policies or Professional body documents.
Literature reviews	Not Peer Reviewed.
Published in English	Meta-Predictions
Any country of origin	

Results

The initial search yielded $n = 48$ papers across the three databases. Duplicates were removed, and the remaining articles were screened. After applying the exclusion criteria, ten papers were included in the review (Fig. 1). This included four systematic reviews, four cohort studies and two longitudinal studies (Table 2).

Nine different pollutants are implicated across the ten papers (Table 3). Seven papers focused on pathological changes to the brain,[21–27] 2 two focused on lung function[28,29] and one on cardiovascular changes.[30] In reference to the imaging implications of

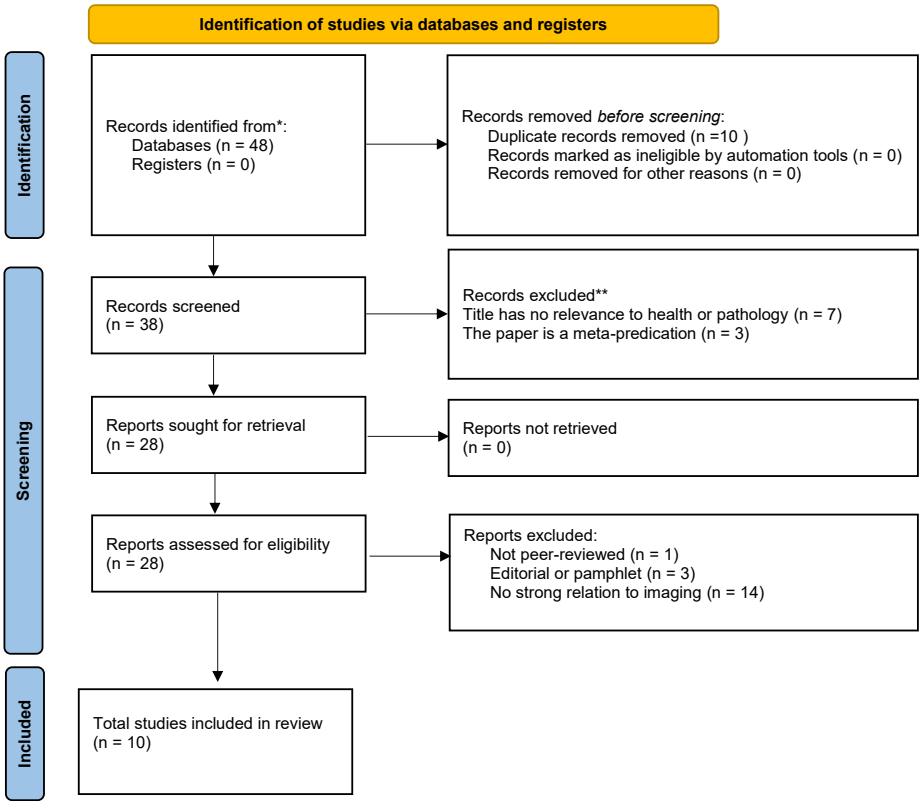

Figure 1. The PRISMA[18] chart for the literature search.

Table 2
Characteristics of the studies.

Authors	Study Type	Country	Themes	Findings	Strengths	Limitations
Alemany et al., 2018[19]	Cohort study $n = 1,667$children	Spain	Brain development, Alzheimer's neurobehavior	The APOE allele gene potentially strengthens the link between air pollution and smaller brain caudate volume	Behavioural tests completed were computerised thus reducing examiner bias Prospective $n = 163$ MRI imaging	No replication study has shown the validity of the original study
Aung et al., 2018[28]	Cohort study $n = 3920$ adults	UK	Heart failure	Particulates < PM 2.5 and NO2 correlate with ventricular remodelling	Large cohort study Prospective $n = 3920$ MRI imaging	Estimated individual air pollution exposure
Balboni et al., 2021[20]	Systematic Literature Review n = 6 studies Adults and children	Global	Cognitive decline, dementia	The rate of hippocampal volume decrease increases alongside PM 2.5 even at lower PM 2.5 levels	Thorough analysis, clear graphs, and tables Retrospective $n = 34,692$ MRI imaging	Small literature search over big topic
Chambers et al., 2018[26]	Cohort study $n = 31$ adults	UK	Asthma, airway inflammation	There were no strong associations between high exposure and exacerbated symptoms. Women appeared more susceptible to air pollution exacerbating asthma symptoms then men	Personal air monitors meant data could be exact for each participant Prospective $n = 31$ Spirometry	Included a lot of rural areas
Chen et al., 2021[21]	Longitudinal Study $n = 1302$ adults	USA	Loss of brain volume, dementia	Women not adhering to the MIND dietary pattern with PM 2.5 exposure could be linked to lower volumes of white matter	Data correlated to other diet studies Retrospective $n = 1302$ MRI imaging	Brain volume was only measured once- could not predict a trend over time
de Prado Bert et al., 2018[22]	Systematic Literature Review $n = 11$ studies Adults and children	Global	Cognitive decline, dementia	Positive link between air pollution and cognitive decline. Promotes use of MRI for further studies	Retrospective $n = 4558$ MRI imaging *excluding Rat MRIs	Animal studies are included in the discussion
Herting et al., 2019[23]	Systematic Literature Review $n = 6$ studies Children	Global	Neurodevelopment	Pre- and post-natal exposure to pollutants effects can affect neuro development	Clear method, all articles in search are accounted for Retrospective $n = 1066$ MRI imaging	These are preliminary findings, and more research needs to be done. $n = 3$ studies used the sample data
Power et al., 2018[24]	Longitudinal Study $n = 1753$ Adults	USA	Cognitive decline, cerebrovascular disease, dementia	Little association between PMs and cerebrovascular disease. PM2.5 is associated with decreased frontal lobe volume	There were a large number of participants in the study Retrospective and Prospective $n = 1753$ MRI imaging	Mixed results from different locations
Rice et al., 2019[27]	Cohort study $n = 4464$ Adults	USA	Lung function	PM2.5 and O3 had an inconclusive association with interstitial lung disease but high carbon exposure associated with development and progression of the disease	Large number of participants. Retrospective $n = 2618$ Chest CT $n = 1846$ Cardiac CT	Rural areas monitored
Yuan et al., 2023[25]	Systematic Literature Review $n = 11$ studies Adults and children	Global	Cognitive decline, mild cognitive impairments	Highlights the damaging effects on children and the link between Demetia in the elderly and exposure to pollutants	Extensive search strategy Retrospective $n = 23,647$ MRI imaging	Meta-analysis not possible

Table 3
A table compiling the pollutants implicated in the literature search results.

Particulates Implicated	Number of Studies	Studies
Carbon Monoxide (CO)	1	de Prado Bert et al., 2018[22]
Copper (Cu)	1	Herting et al., 2019[23]
Elemental Carbon (EC)	4	Alemany et al., 2018[19]; de Prado Bert et al., 2018[22]; Herting et al., 2019[23]; Rice et al., 2019[27]
Coarse Particulate Matter ≤10 μm (PM_{10})	6	Aung et al., 2018[28]; Balboni et al., 2021[20]; de Prado Bert et al., 2018[22]; Herting et al., 2019[23]; Power et al., 2018[24]; Yuan et al., 2023[25]
Fine Particulate Matter ≤2.5 μm ($PM_{2.5}$)	8	Aung et al., 2018[28]; Balboni et al., 2021[20]; Chen et al., 2021[21]; de Prado Bert et al., 2018[22]; Herting et al., 2019[23]; Power et al., 2018[24]; Rice et al., 2019[27]; Yuan et al., 2023[25]
Nitrogen Dioxide (NO_2)	7	Alemany et al., 2018[19]; Aung et al., 2018[28]; Balboni et al., 2021[20]; Chambers et al., 2018[26]; de Prado Bert et al., 2018[22]; Herting et al., 2019[23]; Yuan et al., 2023[25]
Ozone (O_3)	2	Chambers et al., 2018[26]; Rice et al., 2019[27]
Polycyclic Aromatic Hydrocarbons (PAH)	2	Alemany et al., 2018[19]; Herting et al., 2019[23]
Sulfur Dioxide (SO_2)	2	de Prado Bert et al., 2018[22]; Yuan et al., 2023[25]

these studies, eight used MRI,[21–27] two studies results were from CT scans[29,30] and one paper did not directly identify the imaging modality but discussed the clinical weight of this illness[28] (although, X-ray imaging would be in the diagnostic pathway). Chambers et al.,[28] were still included in the study as the discussed patient pathway would include diagnostic imaging.

Discussion

None of the research found directly discussed the impact air pollution-related diseases had on imaging departments. Rather, the links to clinical imaging can be identified when analysing the data collected in the research papers. Firstly, the largest proportion of studies in the literature review link air pollution with pathological changes in the brain. The research varied on exact brain area or pathological change but largely concluded on negative effects across various particulates. Most linked the changes to brain volume and function to dementia diagnosis, with air pollution as a contributing factor.[21,22,24,26,27] Notably, each of these studies used MRI scans to provide their data.[21–27] Although the purpose of MRI scans in research may differ from their clinical application, this can be seen to have a direct clinical correlation within the imaging department. Clinically, MRI is heavily implicated in dementia pathways to rule out alternate pathology and assess acute dementia.[31] Therefore, by acknowledging that MRI in the research that links air pollution to cognitive decline, it is possible to identify a link to clinical MRI.

Although Power et al.[26] found minimal effects of PMs on the development of cerebrovascular diseases that can lead to vascular dementia, this contradiction can be expected in such an exploratory field. Power et al.'s[26] study covered different locations with differing levels of urbanisation. As particulate matter is particularly prevalent near busy roads due to the output of soot or smoke from engine exhausts, PM levels are higher in busy cities.[2] The variation in geographical location within Power et al.'s[26] study may account for its deviation from the other papers in the review. Overall, the demographics that display links between cognitive decline and exposure to air pollution are far-reaching, suggesting that the patient groups that may be affected are multiple. Chen et al.[23] focuses on negative results in women, Yuan et al.[27] Herting et al.[25] and Alemany et al.[21] investigate the effects on children, while Yuan et al.[27] also gives an overview of a range of age demographics. Futhermore, these papers also note that the effects of air pollution are to be expected in the longer term, especially Herting et al.,[25] which investigated pre- and post-natal effects in infants. In 2022–23, the number of MRI scans completed in the NHS in England increased by 6.2%.[32] Meanwhile, MRI scans also have one of the longest waiting times between request and scan out of the imaging modalities in the NHS, with a median average of 20 days,[32] exemplifying the strain these services are already under. Although the research found in this review stresses the caveat of this being preliminary research and the future healthcare implications are still unclear,[25,26] the consensus of these eight papers[21–27,30] does suggest increased neurological impacts due to air pollution will be a long-term issue across a variety of demographics. Some researchers are already tentatively concluding that the additional dementia cases related to air pollution will place additional financial strain on the NHS, including the costs of scans.[33] Therefore, radiographers should be aware that the neurological impacts of air pollution on the population as a whole may increase their workload in the future.

Although, with less prominence in this review, the cardiovascular impact of air pollution is well accepted in healthcare. Coronary heart disease is recognised in the NHS Long Term Plan[34] as avoidable, with a predicted 50,000 deaths due to coronary disease being avoided if levels of $PM_{2.5}$ are reduced by 1 $\mu g/m^3$ by 2035.[34] Aung et al.[30] corroborates this in their research which found that higher concentrations of $PM_{2.5}$ and NO_2 were associated with biventricular enlargement and highlights higher $PM_{2.5}$ and NO_2 exposure increases risk of hospitalisation due to heart failure. Although the study is based on MRI scans, radiographers are involved in far more of the pathways involved in cardiovascular pathology.[35] Pathologies of this kind are imaged frequently through MRI, CT and as part of interventional procedures.[35] CT Coronary angiography, used to image cardiovascular disease, is even an area of advanced practice and specialisation for some radiographers,[36] further establishing the need for awareness within this domain. As the continued prevalence of high $PM_{2.5}$ levels in the air is linked to the development of coronary disease in England, it is plausible that these high pollutant levels shall also bolster the need for increased cardiac CT imaging as the NHS seeks to keep up with demand for these procedures.[32]

The last significant anatomical area discussed within the review articles is the effect air pollution has on the pulmonary system. Chest X-rays are amongst the most common imaging requests in England, being the most common referral to imaging from General Practitioners.[32] Radiographers must understand the justification of the x-ray request in order to comply with their role as practitioners within the Ionising Radiation (Medical Exposure) Regulations.[37] However, in this search, the papers regarding pulmonary impacts had inconclusive evidence. Rice et al.[29] and Chambers et al.[28] are both inconclusive on the effects of O_3 on interstitial lung disease[29] (ILD) and the progression of asthma to chronic obstructive pulmonary disease (COPD).[28] Although the pathologies differ, with ILD affecting the lung tissue and COPD affecting the airways, both can result in coughs and shortness of breath.[38] This ultimately damages lung tissue and thus is referable to an X-ray as a justifiable request.[35] As a result, air pollution exposure again becomes relevant to patient history to radiographers. Interestingly, imaging for damage to the lungs caused by inhaled particulates is not a new concept; occupational lung disease has been imaged and researched frequently[39]; however, our findings show further research is required into the impact lesser researched pollutants have on lung function.

Additionally, an identifiable strength of Chambers et al.'s[28] paper, despite the inconclusive data, is that participants had personal air pollution monitors that tracked their individual air pollution, which was unique to this study. The concept of personalised knowledge of exposure history, rather than generalised to the population, is transferable to diagnostic imaging as this understanding enables holistic, individualised care. Therefore, although inconclusive, the papers regarding the pulmonary system found in this review highlight a key area of missing knowledge for the radiography workforce. By understanding the mechanisms of the diseases highlighted in the papers by Rice et al.[29] and Chambers et al.,[28] radiographers can provide informed and comprehensive care to their patients.

Regardless of the anatomical area, the findings propose that air pollution can be viewed as an additional health risk akin to smoking or obesity. Chen et al.'s[23] additionally proposed that unbalanced diets can accentuate the damages air pollution can contribute to cognitive decline. Meanwhile, Aung et al.'s[30] results showed that a history of smoking in combination with increased PM_{10} exposure had the highest association with increases in end-diastolic volume in the right ventricle – a potential precursor to heart failure.[40] Thus, air pollution is shown to work similarly to other health risks, where a combination of factors works in conjunction to contribute to ill health.[41] In radiography journals, health risks such as smoking or obesity are discussed as a cause of the patient's imaging referral[42] and as a source of stigma amongst staff.[43] Smoking and obesity are leading contributors to death in England,[44] and thus their prominence in health discussions is

proportional; however, as radiographers are now being encouraged to discuss health risks and lifestyle factors with patients,[45] it is important that radiographers understand the role air pollution has within the multi-faceted contributors to common comorbidities and general health. Therefore, the results of this literature review suggest that air pollution should be commonly included as another factor that influences the health of patients and how they present to the imaging department.

Recommendations for further research highlight the lack of literature regarding air pollution within radiography literature. It would be beneficial for future studies to complete a survey of radiographers' perceptions nationally of air pollution and how it affects their work. This would provide a starting point for more specific research topics and would continue the discussion on awareness of how air pollution will affect medical imaging.

Conclusion

The findings support the hypothesis that air pollution-related pathologies do and will continue to impact radiographic practice. The degree to which air pollution can affect patients' health is wide-reaching and complex, and thus, there is a continuously evolving discussion that will continue to impact healthcare in the future. However, as healthcare professionals responsible for providing the best possible care for our patients, radiographers should be aware of and educated on this growing discourse. Despite its limitations, this literature review contributed to this discussion by involving a radiography perspective and identifies multiple key areas for further research within radiography. There is a need to develop the topics in this literature review and to ensure radiographers are involved in research in this area to support evidence-based practice. Ultimately, this paper encourages the radiography profession to engage with their patient's care and diagnosis by educating themselves about air pollution as an additional health risk.

Conflict of interest statement

None.

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