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Abstract

The objective of this article is to systematically review and assess what is known about the impacts of climate change on aeroallergens and other naturally derived particulates, and the associated human health impacts, and to examine responses to these in Australia, focusing on adaptation. Prior research was searched using several general and discipline-specific research databases. The review concludes that whereas there is little original research on the impacts of climate change on aeroallergens and other naturally derived particulates in Australia, or the human health consequences of these, research from overseas suggests that these impacts may be adverse and of considerable magnitude. More research is required to assess the impacts of climate change on these airborne particles and associated diseases in Australia and other parts of the Asia-Pacific. There are important policy implications of this review. There is a need for enhanced monitoring of the atmospheric environment and associated health conditions in Australia. Education about climate change and human health in general, and air quality and related diseases specifically, is required for the community, health professionals, and others. Improvements are needed in the preparedness of infrastructure, such as health care facilities and early warning systems, particularly for aeroallergens, and all of these adaptive policy responses require further research.

Keywords

adaptation, aeroallergen, bushfire smoke, climate change, dust, human health, impacts

Introduction

Climate change affects many physical, biological, and human systems. Impacts of climate change on human health can be both direct, for example, via the impacts of increases in temperature or changes in severe meteorological events on heat-related disease and physical injury; or indirect,

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via the impacts of climate change on aspects of the physical and human environments that are associated with disease. The impacts of climate change on human health via aeroallergens and other naturally derived particulates are an example of the latter.

Aeroallergens are particles of airborne allergen from living organisms such as plants, fungi and animals, with common examples including pollen grains, mould spores, and allergens from house dust mites, cockroaches, cats, and dogs. Aeroallergen concentrations are partly dependant on atmospheric conditions. For example, many allergen-producing organisms are weather and climate sensitive. Diseases associated with aeroallergens include asthma and allergic rhinitis (commonly known as hay fever).

Naturally derived particles originate from environmental, rather than human, sources, with most naturally derived dust generated by bushfires, dust storms, and volcanic eruptions. Whereas the latter is rare in Australia (although proximity to major active volcanoes in the Pacific region means it cannot be discounted), bushfires and dust storms are common throughout Australia. Dust storms tend to originate in arid regions, with particle loads rich in crustal elements that can be transported vast distances from source. Likewise, bushfires can affect air quality far from the fire itself. Bushfires, however, produce vast amounts of both particulate and gaseous pollutants, in addition to extreme heat and destructive force. These natural events tend to have dramatic, short-term impacts on air quality and have been widely linked with adverse health impacts here and overseas.

Although bushfires may also be generated by human activity, for the purposes of this discussion, bushfires are considered to be “natural” events, as the pollutants produced and the associated health impacts are the same, whether the fire was deliberately lit or naturally ignited.

Although several reviews and assessments have been produced at the international scale on the impacts of climate change on aeroallergens,¹⁻⁴ and dust and bushfire emissions,² to date there have been no such examinations at the Australian national or sub-national level. This lack of knowledge about potential impacts significantly limits Australia’s ability to develop appropriate adaptation policy in this area.

This article reviews and assesses what is known about the impacts of climate change on aeroallergens and other naturally derived particulates, and the associated human health impacts. It also examines responses to these impacts, focusing on adaptation in Australia.

Methods

Prior research was searched using several general and discipline-specific research databases. The former included “ISI Web of Knowledge/Science” (Thomson Reuters), and the latter included “Ovid MEDLINE” (Ovid Technologies, Inc), “BIOSIS Previews” (Ovid Technologies, Inc), and “Meteorological and Geostrophysical Abstracts” (ProQuest CSA illumina). The 3 discipline-specific research databases were selected to cover the 3 broad areas (health and medicine, biological sciences, and climate science, respectively) of the multidisciplinary subject. These research databases were searched using combinations of a range of keywords and phrases, such as “Australia,” “pollen,” “mould spore,” “allergen,” “dust,” and so on. To restrict the temporal scope of the review, and ensure adequate coverage of recent literature, only literature from the year 2000 to present (April 2010), that is, approximately the past decade, was reviewed.

Discussion

Impacts of Climate Change on Aeroallergens and Other Natural Particulates

Very little is known about the impacts of climate change on aeroallergens for Australia. Unlike some other regions and countries, such as Europe, North America, and Japan, there are no long-term

records of aeroallergens (specifically pollen) for Australia. It is therefore not possible to use observational data to examine the impacts that recent warming and other changes in climate in Australia may have had. Nevertheless, based on knowledge about the impacts of climate change on aeroallergens from observational and experimental research elsewhere, there is potential for increased pollen production,⁵⁻⁸ lengthening of the pollen season,⁹⁻¹² increased pollen allergenicity,¹³ and changes in the range and distribution of some plant species¹⁴ to have already occurred and to continue in the future. These impacts have largely been associated with increases in atmospheric temperature and/or carbon dioxide concentrations.

Observational research has also shown long-term trends of *Alternaria* mould spores in Derby, United Kingdom.¹⁵ From the early 1970s to the late 1990s, spore concentrations increased and the spore season started earlier and increased in duration, trends that were associated with increases in local temperature. Recent experimental research has shown that elevated atmospheric carbon dioxide concentrations amplify *Alternaria alternata* sporulation and total antigen production.¹⁶

There is, however, a reasonable amount of research on the current relationships between aeroallergens and weather and climate here in Australia. Recent studies of relationships between pollen and meteorological factors, for example, have been conducted in Brisbane,^{17,18} Darwin,¹⁹ Melbourne,²⁰ Sydney,^{21,22} and rural New South Wales.²³ Similarly, recent studies of relationships between mould spores and meteorological factors have been conducted in Sydney,²⁴ and the rural areas of Wagga Wagga and Moree.²⁵ Although the combination of taxa and meteorological factors studied varies from study to study, and results are, to some extent, location specific, associations are often found with temperature, precipitation, rainfall, relative humidity, dew point temperature, wind speed, wind direction, sunshine hours, air pressure, and evaporation. As such, these studies also suggest that climate change, both past and future, would influence aeroallergen concentrations. Potential impacts of climate change on aeroallergens should also be considered in the context of extreme meteorological events, which are projected to increase in frequency and/or severity in the future. One example is the association between asthma epidemics and thunderstorms in Australia, resulting from the explosive release of highly allergenic rye grass pollen starch granules on contact with water.²³ Another example is the prolific growth of mould in New Orleans dwellings damaged by Hurricane Katrina.²⁶

Relationships also exist between indoor allergens, such as mould and house dust mite, and climate. Recent Australian studies of house dust mite and climate, particularly relative humidity, include the studies by van den Bemt et al.²⁷ and Crisafulli et al.²⁸ The latter, for example, found that house dust mite allergen concentrations in children's beds in Sydney fluctuate approximately 2-fold to 3-fold on an annual cycle, partly determined by relative humidity, with peaks in late autumn and minima in summer.²⁸ Although there are clear links between indoor and outdoor climate, impacts of climate change on indoor allergens have received very little consideration in Australia, other parts of the Asia-Pacific, and elsewhere. A recent and substantial exception to this is the report prepared for the US Environmental Protection Agency on public health consequences and cost of climate change impacts on indoor environments,²⁹ which considers indoor allergens, particularly indoor mould. One of the key points of the report is that "increased relative humidity from climate change will increase the moisture content of materials indoors and thus increase the risk for mold growth," and that "these conditions will be exacerbated by heavy periodic rainfalls that will likely stress the ability of buildings of all types to adequately manage excess water flow."²⁹

The most substantial climate change-related increases in particulate levels are likely to result from the projected increase in frequency and intensity of dust storms and bushfires. Climate change is projected to increase the frequency and severity of drought periods, decreasing vegetation cover, soil moisture and particle cohesion, and creating dust storm events that can travel huge distances from source and affect major urban centers across Australia. Previous years of

drought have already produced more frequent severe dust events, affecting major cities, including Adelaide, Brisbane, Melbourne, and Sydney. Far greater research is required on the potential impacts of climate change on naturally derived particulates.

Impacts of Changes in Aeroallergens and Other Natural Particulates on Health

The aeroallergen-related diseases of greatest concern are the allergic respiratory diseases such as allergic asthma and allergic rhinitis. A number of studies in Australia have examined the links between not only climate and allergens, but also those between climate and asthma. There is potential for climate change to have already had impacts on diseases such as asthma and allergic rhinitis in Australia, via the impacts on aeroallergens discussed previously,^{30,31} and it is anticipated that impacts on these diseases will increase with ongoing climate change.

Evidence for adverse short-term and long-term health effects from exposure to particulate matter, especially fine particles, has increased in the last decade. Associations have been well documented both in Australia and overseas, and include increased hospitalizations and mortality for a range of respiratory and cardiovascular conditions. With climate change projected to increase concentrations of airborne particles, it is expected that respiratory and cardiovascular morbidity and mortality will also increase in Australia.³²

Measured increases in asthma severity and decreased lung function have been associated with the previous years of drought that have already produced more frequent severe dust events, affecting major cities, including Adelaide, Brisbane, Melbourne, and Sydney, referred to previously.^{33,34} Overseas studies have linked African, Asian, and North American dust events with increases in respiratory morbidity and mortality.³⁵⁻³⁹ Bushfires pose a more obvious threat to health, with large volumes of both particulate and gaseous pollutants produced, with adverse health impacts exacerbated by the presence of extreme heat from the flames. Some Australian studies have shown that bushfire smoke has been associated with increased asthma symptoms, respiratory medication use, and hospital admissions for asthma and other respiratory conditions,⁴⁰⁻⁴³ yet other studies have not found an association between bushfire smoke and various health outcomes.⁴⁴ More research is required on the potential impacts of climate change on naturally derived particulate associated morbidity and mortality.

Policy Implications

As for any potential adverse impact of climate change, the 2 basic policy options for the impacts of climate change on aeroallergens, other naturally derived particulates and related diseases, are mitigation and adaptation. Mitigation, as defined by the Intergovernmental Panel on Climate Change (IPCC), is “an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.”⁴⁵ Although mitigation efforts must continue, adaptation is also required as a result of inevitable climate change. Whereas mitigation focuses on greenhouse gas concentration reductions, adaptation in the context of climate change is simply defined as “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.”⁴⁵

Adaptation policy options for aeroallergens have been discussed and examined in a number of previous publications. Beggs¹ suggested that one adaptive strategy would be tighter management of a number of allergenic plant species. As an example, Beggs¹ suggested that “government authorities could consider more carefully which plant species are used in populated areas.” Rybníček and Jäger⁴⁶ discuss the use of such strategies to fight ragweed expansion in Europe.

More recently, Sofiev et al⁴⁷ have examined adaptation to climate change impacts on pollen and allergies from a biometeorological perspective.

Another adaptive strategy would be wider promotion of tips or measures for reducing pollen exposure, such as those outlined by the Australasian Society of Clinical Immunology and Allergy⁴⁸ and the National Asthma Council Australia.⁴⁹ Likewise, measures to reduce exposure to airborne dust or bushfire smoke are also highly desirable. There are currently no early warning systems in Australia that are specifically designed to warn of health risks from aeroallergens, bushfires, or dust storms. However, there are ad hoc air quality advisories produced by various local and national organizations, such as the National Asthma Council Australia and the state Environment Protection Authorities, during specific periods of diminished air quality. Further development, use, and dissemination of air quality warning systems in such circumstances are required.

There is a need for enhanced monitoring of the atmospheric environment⁵⁰ and associated health conditions on a regular and sustained basis, not only during periods of poor air quality. Education about climate change and human health in general, and air quality and related diseases in particular, is required for the community, health professionals, planners, and others. Improvements in preparedness of infrastructure, such as health care facilities, are needed. Improvements and/or developments in early warning systems, particularly for aeroallergens, and including the forecasting of relevant grass, weed, and tree pollen counts, may be of use to people with asthma with known pollen sensitivities. Finally, despite a growing body of evidence from overseas, there is little currently known about the potential impacts of climate change on aeroallergens, dust, and smoke in Australia, and all the adaptive policy responses we have described require further research.

Conclusion

Climate change is likely to have significant adverse impacts on aeroallergens and natural particulates and associated diseases in Australia and other parts of the Asia-Pacific. Although much more research on these climate change impacts is urgently required generally and particularly in Australia, at the same time, adaptation responses require development and implementation.

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Declaration of Conflicting Interests

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References

1. Beggs PJ. Impacts of climate change on aeroallergens: past and future. *Clin Exp Allergy*. 2004;34:1507-1513.

2. Confalonieri U, Menne B, Akhtar R, et al. Human health. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, eds. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press; 2007:391-431.
3. D'Amato G, Cecchi L. Effects of climate change on environmental factors in respiratory allergic diseases. *Clin Exp Allergy*. 2008;38:1264-1274.
4. Shea KM, Truckner RT, Weber RW, Peden DB. Climate change and allergic disease. *J Allergy Clin Immunol*. 2008;122:443-453.
5. Ziska LH, Caulfield FA. Rising CO₂ and pollen production of common ragweed (*Ambrosia artemisiifolia*), a known allergy-inducing species: implications for public health. *Aust J Plant Physiol*. 2000;27:893-898.
6. Rasmussen A. The effects of climate change on the birch pollen season in Denmark. *Aerobiologia*. 2002;18:253-265.
7. Wayne P, Foster S, Connolly J, Bazzaz F, Epstein P. Production of allergenic pollen by ragweed (*Ambrosia artemisiifolia* L.) is increased in CO₂-enriched atmospheres. *Ann Allergy Asthma Immunol*. 2002;88:279-282.
8. Ziska LH, Gebhard DE, Frenz DA, Faulkner S, Singer BD, Straka JG. Cities as harbingers of climate change: common ragweed, urbanization, and public health. *J Allergy Clin Immunol*. 2003;111:290-295.
9. Emberlin J, Detandt M, Gehrig R, Jaeger S, Noland N, Rantio-Lehtimäki A. Responses in the start of *Betula* (birch) pollen seasons to recent changes in spring temperatures across Europe. *Int J Biometeorol*. 2002;46:159-170.
10. Van Vliet AJH, Overeem A, De Groot RS, Jacobs AFG, Spieksma FTM. The influence of temperature and climate change on the timing of pollen release in the Netherlands. *Int J Climatol*. 2002;22:1757-1767.
11. Huynen M, Menne B. *Phenology and Human Health: Allergic Disorders*. Report of a WHO Meeting, Rome, Italy, January, 16-17, 2003. Health and Global Environmental Change, Series No. 1 (EUR/03/5036791 and EUR/02/5036813). Geneva, Switzerland: World Health Organization; 2003.
12. Menzel A, Sparks TH, Estrella N, et al. European phenological response to climate change matches the warming pattern. *Global Change Biol*. 2006;12:1969-1976.
13. Singer BD, Ziska LH, Frenz DA, Gebhard DE, Straka JG. Increasing Amb a 1 content in common ragweed (*Ambrosia artemisiifolia*) pollen as a function of rising atmospheric CO₂ concentration. *Funct Plant Biol*. 2005;32:667-670.
14. Intergovernmental Panel on Climate Change. Summary for policymakers. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, eds. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press; 2007:7-22.
15. Corden JM, Millington WM. The long-term trends and seasonal variation of the aeroallergen *Alternaria* in Derby, UK. *Aerobiologia*. 2001;17:127-136.
16. Wolf J, O'Neill NR, Rogers CA, Muilenberg ML, Ziska LH. Elevated atmospheric carbon dioxide concentrations amplify *Alternaria alternata* sporulation and total antigen production. *Environ Health Perspect*. 2010;118:1223-1228.
17. Green BJ, Yli-Panula E, Dettmann M, Rutherford S, Simpson R. Airborne *Pinus* pollen in the atmosphere of Brisbane, Australia and relationships with meteorological parameters. *Aerobiologia*. 2003;19:47-55.
18. Green BJ, Dettmann M. Quantitative trends in airborne loads of *Celtis sinensis* pollen and associations with meteorological variables in a subtropical Australian environment. *Ann Agric Environ Med*. 2004;11:297-302.
19. Stevenson J, Haberle SG, Johnston FH, Bowman DMJS. Seasonal distribution of pollen in the atmosphere of Darwin, tropical Australia: Preliminary results. *Grana*. 2007;46:34-42.

20. Erbas B, Chang J-H, Newbigin E, Dhamarge S. Modelling atmospheric concentrations of grass pollen using meteorological variables in Melbourne, Australia. *Int J Environ Health Res.* 2007;17: 361-368.
21. Stennett PJ, Beggs PJ. Pollen in the atmosphere of Sydney, Australia, and relationships with meteorological parameters. *Grana.* 2004;43:209-216.
22. Hart MA, de Dear R, Beggs PJ. A synoptic climatology of pollen concentrations during the six warmest months in Sydney, Australia. *Int J Biometeorol.* 2007;51:209-220.
23. Marks GB, Colquhoun JR, Girgis ST, et al. Thunderstorm outflows preceding epidemics of asthma during spring and summer. *Thorax.* 2001;56:468-471.
24. Stennett PJ, Beggs PJ. *Alternaria* spores in the atmosphere of Sydney, Australia, and relationships with meteorological factors. *Int J Biometeorol.* 2004;49:98-105.
25. Mitakakis TZ, Clift A, McGee PA. The effect of local cropping activities and weather on the airborne concentration of allergenic *Alternaria* spores in rural Australia. *Grana.* 2001;40:230-239.
26. Bloom E, Grimsley LF, Pehrson C, Lewis J, Larsson L. Molds and mycotoxins in dust from water-damaged homes in New Orleans after hurricane Katrina. *Indoor Air.* 2009;19:153-158.
27. Van Den Bemt L, De Vries MP, Van Knapen L, et al. Influence of mattress characteristics on house dust mite allergen concentration. *Clin Exp Allergy.* 2006;36:233-237.
28. Crisafulli D, Almqvist C, Marks G, Tovey E. Seasonal trends in house dust mite allergen in children's beds over a 7-year period. *Allergy.* 2007;62:1394-1400.
29. Mudarri D. *Public Health Consequences and Cost of Climate Change Impacts on Indoor Environments.* Report prepared for The Indoor Environments Division, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, DC, January 2010.
30. Beggs PJ, Bambrick HJ. Is the global rise of asthma an early impact of anthropogenic climate change? *Environ Health Perspect.* 2005;113:915-919.
31. Williams R. Climate change blamed for rise in hay fever. *Nature.* 2005;434:1059-1059.
32. Spickett JT, Brown HL, Rumchev K. Climate change and air quality: the potential impact on health. *Asia-Pac J Public Health.* 2010. In press.
33. Ekström M, McTainsh GH, Chappell A. Australian dust storms: temporal trends and relationships with synoptic pressure distributions (1960-99). *Int J Climatol.* 2004;24:1581-1599.
34. Chan Y-C, McTainsh G, Leys J, McGowan H, Tews K. Influence of the 23 October 2002 dust storm on the air quality of four Australian cities. *Water Air Soil Pollut.* 2005;164:329-348.
35. Kwon H-J, Cho S-H, Chun Y, Lagarde F, Pershagen G. Effects of the Asian dust events on daily mortality in Seoul, Korea. *Environ Res Section A.* 2002;90:1-5.
36. Chen Y-S, Sheen P-C, Chen E-R, Liu Y-K, Wu T-N, Yang C-Y. Effects of Asian dust storm events on daily mortality in Taipei, Taiwan. *Environ Res.* 2004;95:151-155.
37. Park JW, Lim YH, Kyung SY, et al. Effects of ambient particulate matter on peak expiratory flow rates and respiratory symptoms of asthmatics during Asian dust periods in Korea. *Respirology.* 2005;10:470-476.
38. Yang CY. Effects of Asian dust storm events on daily clinical visits for conjunctivitis in Taipei, Taiwan. *J Toxicol Environ Health A.* 2006;69:1673-1680.
39. Prospero JM, Blades E, Naidu R, Mathison G, Thani H, Lavoie MC. Relationship between African dust carried in the Atlantic trade winds and surges in pediatric asthma attendances in the Caribbean. *Int J Biometeorol.* 2008;52:823-832.
40. Johnston FH, Kavanagh AM, Bowman DMJS, Scott RK. Exposure to bushfire smoke and asthma: an ecological study. *Med J Aust.* 2002;176:535-538.
41. Chen L, Verrall K, Tong S. Air particulate pollution due to bushfires and respiratory hospital admissions in Brisbane, Australia. *Int J Environ Health Res.* 2006;16:181-191.
42. Johnston FH, Webby RJ, Pilotto LS, Bailie RS, Parry DL, Halpin SJ. Vegetation fires, particulate air pollution and asthma: A panel study in the Australian monsoon tropics. *Int J Environ Health Res.* 2006;16:391-404.

43. Tham R, Erbas B, Akram M, Dennekamp M, Abramson MJ. The impact of smoke on respiratory hospital outcomes during the 2002-2003 bushfire season, Victoria, Australia. *Respirology*. 2009;14:69-75.
44. Jalaludin B, Smith M, O'Toole B, Leeder S. Acute effects of bushfires on peak expiratory flow rates in children with wheeze: a time series analysis. *Aust N Z J Public Health*. 2000;24:174-177.
45. Intergovernmental Panel on Climate Change. Glossary. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, eds. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press; 2007:869-883.
46. Rybníček O, Jäger S. *Ambrosia* (ragweed) in Europe. *Allergy Clin Immunol Int*. 2001;13:60-66.
47. Sofiev M, Bousquet J, Linkosalo T, et al. Pollen, allergies and adaptation. In: Ebi KL, Burton I, McGregor GR, eds. *Biometeorology for Adaptation to Climate Variability and Change*. Heidelberg, Germany: Springer; 2009:75-106.
48. Australasian Society of Clinical Immunology and Allergy. Pollen allergy; 2007. http://www.allergy.org.au/aer/infobulletins/pollen_allergy.htm. Accessed July 24, 2009.
49. National Asthma Council Australia. Management—Allergen avoidance II; 2008. <http://www.nationalasthma.org.au/content/view/20/924/>. Accessed July 30, 2009.
50. Beggs PJ. Adaptation to impacts of climate change on aeroallergens and allergic respiratory diseases. *Int J Environ Res Public Health*. 2010;7:3006-3021.