Risk Assessment for Environmental Health in Adelaide Based on Weather, Air Pollution and Population Health Outcomes

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List of Abbreviations

µm	Micrometre (micron) = 10^{-6} metres
ABS	Australian Bureau of Statistics
ARF	Acute renal failure
AQI	Air quality index
CBD	Central business district
CI	Confidence interval
CNS	Central nervous system
CO	Carbon monoxide
CO_2	Carbon dioxide
COPD	Chronic obstructive pulmonary disease
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CVD	Cardiovascular disease
ED	Hospital emergency department
EPA	Environment Protection Authority
ICD	International classification of diseases
IHD	Ischaemic heart disease
IPCC	Intergovernmental Panel on Climate Change
m^3	Cubic metre
MBD	Mental and behavioural disorders
MI	Myocardial infarction
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NO_2	Nitrogen dioxide
NO_x	Nitrous oxides
NPI	National Pollutant Inventory
O_3	Ozone
^oC	Degree Celsius
PM	Particulate matter
PM_{10}	Particles with an equivalent aerodynamic diameter ≤ 10 µm

$PM_{2.5}$	Particles with an equivalent aerodynamic diameter ≤ 2.5 µm
ppb	Parts per billion
ppm	Parts per million
SA	South Australia
SAAS	South Australian Ambulance Service
SES	State Emergency Service
SO2	Sulphur dioxide
TEOM	Tapered Element Oscillating Microbalance
U.S.	United States of America
WHO	World Health Organization

Abstract

Background

The progression of climate change may have wide ranging and varied implications for population health. Climatologists predict increases in heatwaves, droughts and bushfires for Australia, with health consequences including a potential rise in heat-related illnesses and adverse effects from increases in some air pollutants. Epidemiological evidence of the impact of temperature extremes and air pollution on morbidity and mortality at the local level is essential to identify site specific characteristics of vulnerable sub-populations and in projections of future scenarios. This study aimed to assess the impact of weather and air pollution on population health outcomes in Adelaide, and to inform decision makers on likely health impacts of climate change.

Method

Health outcome, meteorological and air quality data for periods of up to 12 years were used to assess the environmental health impact of heatwaves and air pollution on morbidity in Adelaide. The first part of the study investigated the impact of heatwaves, defined as being three or more consecutive days of maximum temperatures 35^{o}C or above, on hospital admissions, ambulance callouts and emergency department visits using a case series approach. Spatial analytical techniques were used to identify regions at increased risk in the metropolitan area. The second part of the study investigated, using case-crossover analysis, the effect of air pollution on cardiovascular and respiratory health outcomes. Finally, an evidence based environmental health risk assessment for Adelaide was formulated using a climate change perspective.

Results

Heatwaves have a noticeable effect on population health in Adelaide. Findings showed ambulance callouts increased by 3.6% during heatwaves in Adelaide, with

some industrial and disadvantaged suburbs identified as heat-sensitive regions of the metropolitan area. Persons with mental and behavioural disorders were found to be susceptible to heat extremes with hospitalisations increasing by 7.3% during heatwaves compared to non-heatwave periods. Hospital admissions for renal disease and acute renal failure were increased by 10.0% and 25.5% respectively during heatwaves and heat-related presentations at emergency departments increased almost 3-fold compared to non-heatwave periods in the warm season. Despite Adelaide's air quality comparing well with cities elsewhere, airborne particulate matter had a noticeable effect on health, more so in the cool season, with a 4.5% increase in cardiovascular hospitalisations associated with an increase of 10 $\mu g/m^3$ in fine particles.

Conclusion

Mounting evidence points towards a continued rise in global temperatures and more intense and frequent heatwaves. Findings from this study suggest that in the absence of adaptation and acclimatisation of the local population, there may be a disproportionate increase in heatwave-related morbidity; however the effect on air pollution-related morbidity is less clear. In a warming climate the adverse cardiovascular health effects of air pollution observed in the cool season in Adelaide may decrease, but overall may be modified by the health impacts of increased exposure to bushfire smoke and dust.

Policy Implications

Findings from this study have helped inform policies for extreme heat emergency plans for South Australia and may be of interest to the government and non-government sectors concerned with formulating local and national air quality guidelines.

Statement

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Introduction

The influence of environmental stressors on human health has been of interest to researchers for decades. Due to metabolic homeostasis, the healthy human body generally adapts well to natural changes in the surrounding environment. However age, underlying illness, predisposition and social factors can limit adaptive capabilities, rendering individuals and populations susceptible to negative health outcomes associated with environmental exposures.

Since industrialisation, anthropogenic activities have contributed to increasing concentrations of atmospheric pollutants with history providing considerable evidence of their detrimental effect on health. Additionally climatologists claim the gradual build up of greenhouse gases in the atmosphere is contributing to changes in global weather patterns. Extreme weather events in the form of storms, floods, droughts, cold snaps and heatwaves, can have devastating short- and long-term health consequences for affected communities and susceptible individuals. Predictions of a climate change induced increase in some or all of these extreme events should be cause for great public health concern.

Whilst many epidemiological studies have been conducted to investigate the health impacts of air pollution and extreme weather, most have been undertaken in the major cities of North America and Europe. Many research groups, often collaboratively, have undertaken studies incorporating large study populations, some exposed to high levels of ambient air pollution or rare temperature extremes. Whilst evidence of environmental health impacts on a global scale is imperative and forms the basis for international guidelines, local evidence is also crucial to enable public health strategists to formulate targeted intervention strategies at the community level. With Australia's unique climate, lifestyle, demographics and geography, health responses may differ substantially from those in locations in the Northern Hemisphere.

The aim of this thesis was to characterise the public health impacts of extreme weather and air pollution in Adelaide, the capital city of the state of South Australia. The city has a temperate climate with long hot summers, mild winters and low rainfall. Heatwaves are common in Adelaide, with maximum temperatures above 35°C occurring on average 17 days per annum at present, with climate change scenarios predicting future increases in very hot days. Levels of air pollutants are generally relatively low although guideline exceedances do occur, often in association with bushfires or dust events. The impact on public health is yet to be assessed. A retrospective analysis of health outcomes associated with changes in ambient temperature and air quality was undertaken as part of this thesis, and susceptible subpopulations in Adelaide identified, thus providing an evidence base for an environmental health risk assessment, with implications for public health policy.

It should be noted that the terms “climate” and “weather” are often used interchangeably throughout the thesis, but generally “climate” refers to long term meteorological conditions, whereas “weather” refers to daily conditions or those over a period of several days.

The focus of the study was on conditions relevant to South Australia, and hence discussions and studies on the effects of extreme temperatures are limited to extreme heat, as very cold conditions are rare in Adelaide. Similarly, some pollutants in the Adelaide air shed are more prevalent than others which have decreased to low levels in the last few decades due to enforced regulations on vehicle design and industry emissions. The main pollutants of interest in this study were thus be particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide and ozone.

This thesis is formulated in four sections. Section I comprises two chapters, the first of which is a comprehensive literature review of international and Australian studies investigating the effects of weather and air pollution on human morbidity and mortality. Air pollutants are discussed in turn as well possible temperature-pollutant interactions, vulnerable populations, methodological issues concerned with various study designs, and gaps in current knowledge. The health impacts of climate change are addressed and whilst not the principal focus of the thesis, are a recurring theme in discussions of extreme heat and future scenarios. Section I concludes with a chapter outlining the aims and objectives of the study, research questions, framework of the study and methodologies used.

Section II comprising four chapters, provides details of studies investigating the health effects of heatwaves in Adelaide. Chapter 3 focuses on renal disease whilst Chapter 4, mental health morbidity and mortality during heatwaves. Chapters 5 and 6 seek to identify potentially heat-sensitive regions in the metropolitan area, incorporating spatial analysis into studies investigating the impact of extreme heat on ambulance callouts and syndromic surveillance of hospital emergency department visits.

The theme of Section III is air pollution in Adelaide. Chapter 7 summarises a study on the effect of air pollution on cardiorespiratory hospitalisations, whereas Chapter 8 investigates the complex interrelationships that can occur between individual air pollutants, and between temperature and air pollution.

Section IV combines the evidence gained from an extensive body of literature, together with results from studies undertaken within the candidature, to speculate on future scenarios. Chapter 9 uses a risk assessment framework to assess the future impact of the aforementioned environmental stressors on population health in Adelaide. Chapter 10 concludes the thesis with a general discussion and summary of the previous chapters highlighting the key findings, limitations, the public health significance of this work, policy implications and suggestions for future research.