Hazelwood
HEALTH STUDY

Volume 1

Hazelwood Health Study:

10 Year Review

Version 1.1

19 September 2024

Contents

i. Foreword

This is the 1st volume, from a set of three, submitted to the Victorian Department of Health in fulfillment of the Hazelwood Health Study's 42nd contractual milestone. Combined, the three volumes represent an overview of the Hazelwood Health Study's activities and findings in the ten years since the Study's inception on 30 October 2014.

Volume 1. Hazelwood Health Study: 10 Year Review is the primary report, providing an overview of the background to the Study, research questions and further information requested by the Department of Health, governance structure, research streams and methods, key findings, community engagement activities, and the influence of Study findings on policy and practice.

Volume 2. Hazelwood Health Study: 10 Year Review Summary is a high-level summary of the details provided in Volume 1.

Volume 3. Hazelwood Health Study: 10 Year Review Appendices contains all of the Appendices referred to in Volumes 1 and 2, including a list of all previously completed contractual milestones, governance committee memberships, the Study's Outputs Directory, all lay language Research Summaries and the Study's 2023 Community Flyer.

This work was funded by the Victorian Department of Health. The findings represent the views of the authors and not the views of the Department.

The Hazelwood mine fire, February 2014
Photo courtesy of Keith Pakenham, Country Fire Authority Victoria, Australia

ii. Document History

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vii. Abbreviations

μg/m³	Micrograms (one-millionth of a gram) per cubic meter
μm	Micron (thousandth of a millimetre)
ABS	Australian Bureau of Statistics
AEDC	Australian Early Development Census
AIHW	Australian Institute of Health and Welfare
Air NEPM	Ambient Air Quality National Environment Protection Measure
CAC	Community Advisory Committee
CCAM	Conformal Cubic Atmospheric Model
CD-RISC2	Connor-Davidson Resilience Scale
CFA	Country Fire Authority
CI	Confidence interval
CIMT	Carotid intima-media thickness
CO	Carbon monoxide
COPD	Chronic obstructive pulmonary disease
COVID-19	Coronavirus Disease 2019
CRG	Clinical Reference Group
CRIES-13	13-item Children's Revised Impact of Events Scale
CRP	C-reactive protein
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTM	Chemical transport model
CVD	Cardiovascular disease
CVDL	Centre for Victorian Data Linkage
CWI	Community Wellbeing Index
DSSI-11	Duke Social Support Index
ECG	Electrocardiograph
ELF	Latrobe Early Life Follow-up Study
ECRHS	European Community Respiratory Health Survey
EMV	Emergency Management Victoria
EPA	Environment Protection Authority
EQ-5D-5L	EuroQol Group measure of health status
ETS	Environmental tobacco smoke
FeNO	Fractional exhaled nitric oxide (marker of lung inflammation)
FEV_1	Forced expiratory volume in one second
FMD	Flow mediated dilatation (measure of endothelial function)
FOT	Forced oscillation technique
FVC	Forced vital capacity

GDM	Gestational diabetes mellitus
GP	General Practitioner
GPHN	Gippsland Primary Health Network
GREMPC	Gippsland Regional Emergency Management Planning Committee
HbA_{1c}	Glycosylated Haemoglobin (marker of blood glucose control)
HHS	Hazelwood Health Study
HMFI	Hazelwood Mine Fire Inquiry
HR	Hazard Ratio
hsCRP	High sensitivity C-reactive protein
ICD-10-AM	The International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification
IES-R	Impact of Events Scale Revised
IHD	Ischaemic heart disease (also known as coronary artery disease)
IRR	Incidence rate ratio
IRSAD	Index of Relative Socio-economic Advantage and Disadvantage
K10	Kessler 10-item General Psychological Distress Scale
LHA	Latrobe Health Assembly
LTE-Q	List of Traumatic Experiences Questionnaire
MAC	Ministerial Advisory Committee
MBS	Medicare Benefits Schedule
MBW	Multiple breath washout test
MEMPC	Municipal Emergency Management Committee
MRH	Monash Rural Health
NAPLAN	National Assessment Program - Literacy and Numeracy
NDI	National Death Index
NEPM	National Environment Protection Measure
NO_2	Nitrogen dioxide
NT-pro-BNP	N-terminal pro B-type natriuretic peptide
O_3	Ozone
OR	Odds ratio
PAR	Participatory action research
PBS	Pharmaceutical Benefits Scheme
PHIDU	Public Health Information Development Unit
PHQ-15	Patient Health Questionnaire
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 micrometres (thousandths of a millimetre) or less
PM_{10}	Particulate matter with an aerodynamic diameter of 10 micrometres or less
PMG	Project Management Group

ppm	Parts per million
PR	Prevalence ratio
PSC	Project Steering Committee
PTSD	Posttraumatic Stress Disorder
PWV	Pulse wave velocity (measure of blood vessel stiffness)
R1	Round 1
R2	Round 2
R3	Round 3
RI	Further requested information
RQ	Research question
RR	Relative risk
SA1	Statistical Area Level 1
SA3	Statistical Area level 3
SARS-CoV-2	Severe-acute-respiratory-syndrome-related coronavirus 2 (also known as COVID-19)
SD	Standard deviation
SEC	State Electricity Commission
SEHQ	School Entrant Health Questionnaire
SEIFA	Socio-Economic Indexes for Areas
SF	Short Form
SIR	Standard Incidence Ratio
SO_2	Sulphur dioxide
SPHPM	School of Public Health & Preventive Medicine
SRG	Scientific Reference Group
TAPM	The Air Pollution Model
T_LCO	Carbon monoxide transfer factor
VACAR	Victorian Ambulance Cardiac Arrest Registry
VACIS	Victorian Ambulance Clinical Information System
VAED	Victorian Admitted Episodes Data
VCR	Victorian Cancer Registry
VEC	Victorian Electoral Commission
VEMD	Victorian Emergency Minimum Dataset
VGCCC	Victorian Gambling and Casino Control Commission
VPDC	Victorian Perinatal Data Collection
VPHS	Victorian Population Health Survey
WHO	World Health Organization

1 Introduction

During a period of extreme weather conditions in February 2014, bushfire embers ignited a series of small fires in the Hazelwood open-cut brown coal mine located in the Latrobe Valley, a rural area containing small towns in the State of Victoria, Australia. These rapidly spread and the resulting coal fire burned for more than six weeks. The low buoyancy of the smoke plume led to dense smoke levels, particularly in the adjacent town of Morwell.[1] There was limited research on emission factors from open-cut coal mine fires, and few precedents upon which to base public health protection messages or to assess adverse health effects.[2] There were gaps in the evidence available for the health impacts of poor air quality for time periods of weeks to months. Most evidence at that time had been based upon short-term (days) or long-term ambient smoke exposure (years to decades) but not medium term exposure (weeks to months).[2]

On 21 March 2014 the Victorian State Government appointed a Board of Inquiry into the Hazelwood Coal Mine Fire (HMFI). The Inquiry heard that the Latrobe Valley community, particularly those in Morwell, reported a variety of physical symptoms including sore and stinging eyes, coughing, shortness of breath, headaches, chest pain, fatigue, mouth ulcers, blood noses and rashes.[3]

The Victorian Department of Health determined that it was important to learn from the fire by monitoring long-term health effects. The Department consulted with the local community in May 2014 to inform the development of key research questions and then released a Request for Tender for "A long term study into potential health effects from the Hazelwood coal mine fire" (tender number: Health C3478"). The HMFI affirmed the proposed long-term health study as a useful predictive tool to assist with understanding future risks, and to prevent or reduce the chances of adverse health effects arising from similar situations in future.[3] The tender was awarded to a Monash University-led research consortium including the University of Tasmania Menzies Institute for Medical Research, Federation University, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the University of Adelaide. Since then, the team has expanded to include collaborators from the University of Newcastle, James Cook University, the University of Melbourne, Alfred Health Respiratory Medicine and Environment Protection Authority (EPA), Victoria.

The resulting Hazelwood Health Study (HHS) commenced on 30 October 2014 and is currently in the final year of an initial ten-year Agreement with the Department of Health. This report, titled "Volume 1 Hazelwood Health Study: 10 Year Review" has been prepared in fulfillment of the Study's 42nd contractual milestone to deliver a 10th annual report to the Department by 19 September 2024. For a complete list of the Study's contractual milestones see Volume 3 Appendix 1.

This report has been structured so as to provide:

- the research questions, and further requested information, that were provided in the Department's Request for Tender (Health C3478);
- a description of the project management governance structure;

- brief description of the HHS research streams which were set up in response to the research questions and further requested information;
- an overview of participant eligibility, recruitment and data collection methods;
- an overview of the main HHS findings;
- a brief description of community engagement and dissemination activities; and
- a description of the influence that the HHS findings have had on public health-related policy and practice.

The Hazelwood mine fire, February 2014
Photo courtesy of Keith Pakenham, Country Fire Authority Victoria, Australia

2 Hazelwood Health Study research questions and further requested information

The following research questions (RQ) and further requested information (RI) were provided in the Request for Tender (Health C3478) issued by the Victorian Department of Health in June 2014.

RQ 1

Is there evidence that people in general, and susceptible sub-populations in particular, who were exposed to emissions from the Hazelwood fire, compared with otherwise similar people who were not exposed to emissions from the fire, *currently* have clinical or sub-clinical cardiovascular or, respiratory conditions that could be associated with clinically important adverse health consequences in the future?

RQ 2

Is there evidence that people in general, and susceptible sub-populations in particular, who were exposed to emissions from the Hazelwood fire, compared with otherwise similar people who were not exposed to emissions from the fire, *over time develop* clinical or sub-clinical cardiovascular or respiratory conditions that could be associated with clinically important adverse health consequences in the future?

RQ 3

Is there evidence of any difference in birth weight of babies born to mothers exposed to emissions from the Hazelwood fire, compared to babies born to otherwise similar mothers who were not exposed to emissions from the fire?

RQ 4

Is there evidence that people in general and susceptible sub-populations in particular (including children) who were exposed to emissions from the Hazelwood fire, compared with otherwise similar people who were not exposed to emissions from the fire, have a higher prevalence and persistence of psychological distress?

RQ 5

What sociodemographic factors and exposure levels are associated with higher levels and persistence of psychological distress?

RQ 6

Is there evidence that people who were exposed to emissions from the Hazelwood fire, compared with otherwise similar people who were not exposed to emissions from the fire, have a higher incidence of malignant disease (cancer) over a prolonged period of follow-up?

RI 1 and 2

What key pollutants relevant to the scope of this long-term study are based on the extensive air monitoring dataset available from environment protection and emergency service sources for air samples collected at the mine boundary and into the local community? How will exposure be assessed?

RI 3

What comparator populations might be suitable?

RI 4

Other questions important to consider? Here we specified:
Child development; Impact on older people; and Impact on community wellbeing and community rebuilding efforts.

The Morwell Centenary Rose Garden

3 Governance

The Hazelwood Health Study adopted a project management governance structure to establish clear policies and procedures, delineate decision-making processes, ensure accountability, build transparency, manage risk and reduce the likelihood of errors that could derail the project and maximise the implementation of best practice. The Study governance structure has included:

Research leadership and direction groups

- Project Steering Committee
- Project Management Group

Key advisory groups

- Clinical Reference Group
- Community Advisory Committee
- Latrobe Health Assembly Hazelwood Health Study Sub-committee
- Gippsland Primary Health Network
- Scientific Reference Group

Department of Health oversight

- Hazelwood Long term Health Study Contract Committee
- Ministerial Advisory Committee

3.1 Research leadership and direction groups

3.1.1 Project Steering Committee

The Project Steering Committee (PSC) is made up of the leaders of each of the Study's research streams and provides overall strategic advice for the Study.

The function of the PSC is to take responsibility for the research issues associated with the Study. The PSC is also responsible for approving budgetary strategy, defining and realising benefits, and monitoring risks, quality and timeliness. The roles of the PSC are to:

- take on responsibility for the Study's feasibility, research streams and achievement of outcomes;
- provide overall strategic guidance for the Study;
- ensure probity;
- ensure the Study's scope aligns with the requirements of the stakeholder groups;
- provide those directly involved in the Study with guidance on research issues;

- ensure effort and expenditure are appropriate to stakeholder expectations;
- address any issue or risk that has major implications for the Study;
- keep the Study scope under control as emergent issues force changes to be considered;
- reconcile differences in opinion and approach, and resolve disputes arising from them;
- endorse the project plan and major documents relating to the Study;
- endorse major equipment requests where the value exceeds $10,000;
- sign off on the completion of each phase of the Study including the deliverables;
- provide advice on the communication of information about the Study; and
- take on responsibility for any 'political' issues associated with the Study.

PSC members are listed in Volume 3 Appendix 2 of this report series.

3.1.2 Project Management Group

The function of the Project Management group (PMG) is to operationalise the Project Plan and manage the project toward the successful delivery of all outputs. The PMG's responsibilities include:

- overseeing the smooth day-to-day running of the Study;
- facilitating relationships between the collaborating institutions;
- coordinating, reporting to and, where applicable, minuting the PSC and advisory group meetings;
- ensuring continuity and balance across all elements of the Study;
- monitoring the project plan and making recommendations about change and further development;
- monitoring the project risk register and making recommendations as required;
- monitoring all financial transactions and preparing annual budgets;
- managing and coordinating key activities occurring across the lifetime of the project;
- negotiating agreements with sub-contractors;
- monitoring quality control across all activities;
- facilitating staff performance development;
- overseeing compliance with all regulatory and ethical guidelines as required by the relevant Human Research Ethics Committees and the Monash University School of Public Health and Preventive Medicine Research Governance Office;

- reviewing all Study outputs before delivery to the Department of Health;
- tracking and maintaining a directory of all Study outputs and citations;
- monitoring and updating the HHS website (https://hazelwoodhealthstudy.org.au/);
- coordinating, hosting and presenting at annual community briefings;
- monitoring the community's response, expectations and/or concerns about the Study;
- coordinating annual Study-wide staff retreats for the purpose of maximising cohesion and cross-collaboration between research streams;
- with the support of the PSC, drafting and delivering all Interim Reports, Annual Reports and Contract Reviews as per the milestone schedule in the Head Agreement with the Department of Health;
- ensuring adherence to all other contractual obligations included in the Head Agreement with the Department of Health;
- reporting to the Department of Health Hazelwood Long term Health Study Contract Committee; and
- responding to communications and requests from the Department of Health and other governing or regulatory bodies.*

*The PMG invested considerable and, perhaps, unexpected resources responding to a number of external reviews, particularly in the early years of the Study's tenure. This included an audit of the Study's scope, content, methodology, governance and reporting, recommended by the 2nd HMFI in 2015, and undertaken by Deloitte Access Economics in 2016. Also, in 2016, the PMG responded to all of the requirements of two Privacy Impact Assessments; one ordered by the Victorian Electoral Commissioner, the other by the Victorian Commissioner for Privacy and Data Protection. These were followed by a 2017/2018 review undertaken by the, then, newly established Hazelwood Mine Fire Long Term Health Study Ministerial Advisory Committee (MAC; see section 3.3.2). That review, in turn, led to the Minister of Health's request that the PMG undertake a strategic overview of the Study, advise the Department on what the overall Study findings meant for the health of the Latrobe Valley community and the future scope of the Study, and submit a revised project plan in July 2019. The resulting 69-page 2019 Strategic Overview and Revised Project Plan, prepared by the PMG in collaboration with the PSC, involved extensive community engagement and consultation activities over a five-month period, a critical overview of governance and communications processes, an evaluation of all Study findings relative to the research questions in the original tender and a presentation of new, improved research protocols.

PMG members are listed in Volume 3 Appendix 2 of this report series.

3.2 Key advisory groups

Advisory groups for the Hazelwood Health Study were first established in March 2015. Initially these included a Scientific Reference Group, Clinical Reference Group, and a Community Advisory Committee, before a restructure replaced the clinical and community groups with existing networks to the Latrobe Health Assembly and the Gippsland Primary Health Network. The advisory groups have played key roles in the Study, particularly in the early years when the researchers and advisory groups worked in partnership to co-design the research activities.

Via these groups, the Study has received invaluable support from local community members and representatives of health and community service providers, clinicians and local government. The insights provided by those with lived experience and specialised knowledge have significantly enriched the Study and ensured its success.

3.2.1 Scientific Reference Group

The Scientific Reference Group (SRG) was established in 2015 and comprises experts in various scientific disciplines relevant to the Study who provide input into the Study directions. These include, but are not limited to toxicology, respiratory medicine, cardiology, psychiatry, socio-demography, biostatistics, oncology etc. The role of the SRG is to:

- assist the academic leads and stream leaders develop their research plans;
- monitor the progress of the Study's research activities;
- provide the academic leads and stream leaders with ongoing advice;
- review protocols and adherence;
- function as a data monitoring and safety board in the event of adverse responses or complaints;
- consider proposals for new research activities or streams;
- identify potential new collaborations; and
- provide guidance on the annual review of research activity.

SRG members are listed in Volume 3 Appendix 2 of this report series.

3.2.2 Clinical Reference Group

The Clinical Reference Group (CRG) was responsible for providing advice to the PSC about the clinical aspects of the Hazelwood Health Study (HHS) from 2015 through to 2020. The role of the CRG was to provide clinically-relevant guidance at all stages of the Study including:

- documentation provided to Study participants;
- promotional material;

- clinical fieldwork;
- dissemination plans for Study findings;
- documentation to promote Study findings to the community;
- any issue or risk that had major clinical implications for the Study;
- clinical pathways for abnormal results;
- reviewing individual abnormal results;
- linkage of relevant local healthcare data; and
- dissemination of findings to key health and related professional outlets, organisations and agencies.

CRG members are listed in Volume 3 Appendix 2 of this report series.

3.2.3 Community Advisory Committee

The Community Advisory Committee (CAC) was the Hazelwood Health Study's primary community-based advisory body until 2020. The CAC was established to ensure that the Study heard directly from, and worked in partnership with, Latrobe Valley community members, health and community service providers and local government in undertaking the research program, and ultimately to improve health services and health outcomes for the local community.

In early 2015, a call for expressions of interest for community membership for the CAC was promoted through various methods, including media interviews, an advertisement in the Community Notices section of the Latrobe Valley Express newspaper and through media coverage during the opening of the local Study office. Initially three community representatives were appointed as members of the CAC. Further community members from the Latrobe Valley and Sale communities joined the CAC over time. Organisational members were nominated for CAC by the Gippsland Regional Office of the Department of Health, local health service care providers, local authorities, and Federation University.

CAC members provided advice and support in a broad range of areas relevant to the Study's research program and objectives, including:

- community perspectives in proposed new research/clinical/engagement activities, plans and projects as presented by the Study's stream leads;
- recruitment protocols, recruitment strategies and messaging for the Schools Study, Adult and Child Development Surveys, and thus maximising the enrolment of Study participants;
- the selection of Sale as a comparison community for the Adult Survey;
- engagement and communication issues including the optimal communications plan;

- promoting participation in the Study, ensuring the Study was widely known to people in its catchment;
- monitoring of the effectiveness of the Study's communication processes;
- strategies for reaching non-responders and underrepresented groups;
- receiving updates and providing feedback on Study findings;
- evaluating the impact of the Study in the region;
- input into the 2019 Strategic Overview and Revised Project Plan;
- promoting Study activities and the dissemination of Study findings through their networks, supporting effective communication and amplifying research messages.

CAC members are listed in Volume 3 Appendix 2 of this report series.

Community supporters and Hazelwood Health Study team members, 2016

3.2.4 Latrobe Health Assembly Hazelwood Health Study Sub-committee

As part of a 2019 Strategic Overview and Revised Project Plan (a requirement of the MAC; see section 3.3.2), a review of the governance structure took place, where it was agreed that it would be preferable to embed the Study's community and clinical input into existing networks, with wider connections across the region. On the basis of this, discussions commenced with the Latrobe Health Assembly (LHA). The LHA is a community-led organisation that seeks to positively shape and facilitate new ways of working to improve health and wellness in Latrobe. The majority of LHA members are from the community, with a diverse representation from various locations, professions, demographics and connections to communities and groups

In early 2021, the LHA board supported a proposal from the HHS team for the Assembly to take on the role of providing community input into the Study in place of the CAC, through the establishment of a dedicated Sub-committee. The LHA Hazelwood Health Study Sub-committee was specifically tasked with meeting researchers on a regular basis to provide input on Study directions and research findings and consider local implications. Existing community representatives on the CAC were invited to continue to contribute to the Study through membership of the LHA Hazelwood Health Study Sub-committee, with three members taking up the invitation.

The purpose of the LHA's HHS Sub-committee is to ensure the Study heard directly from, and worked in partnership with, Latrobe City community members, health and community service providers and local government in undertaking the research program and ultimately improving health services and health outcomes for the local community.

The objectives of the LHA HHS Sub-committee are to:

- discuss and advise on community perspectives on proposed new research/clinical/engagement activities, plans and projects as presented by the Study's research leads;
- ensure the Study was widely known to people in its catchment and the wider Gippsland region;
- provide advice and feedback to the PSC and PMG on engagement and communication issues;
- act as a conduit to local and state government, service providers and other key stakeholders regarding the translation of HHS findings into practice locally and more broadly;
- assist in identifying new research and collaborative opportunities, building on the HHS research program and targeting the future health and wellbeing of the community; and
- undertake any other activities that contributed to the realisation of the Study objectives.

The LHA HHS Sub-committee holds meetings approximately three times per year.

LHA HHS Sub-committee members are listed in Volume 3 Appendix 2 of this report series.

3.2.5 Gippsland Primary Health Network

Since 2021, clinical engagement activities have been integrated with the work of the Gippsland Primary Health Network (GPHN), including its three regional clinical councils. The Study also accessed clinical leads in relevant disciplines at Latrobe Regional Hospital and Central Gippsland Health Service (Sale).

The GPHN and the Hazelwood Health Study signed a memorandum of understanding, agreeing to work collaboratively as follows:

- Hazelwood Health Study research activities to be included as part of the agenda for the Latrobe/Baw Baw GPHN Sub-regional Clinical Council for meetings held in February, May and August.

- Hazelwood Health Study to provide project information for inclusion in the agenda documents, including details of research activities and findings of relevance to the GPHN.
- A GPHN team member will present the item for advice on behalf of the Hazelwood PMG and will highlight areas where feedback and advice are required from Clinical Council advisors.
- GPHN team members agree to collaborate with HHS members to identify collaborative opportunities of value to both organisations and the community.

3.3 Department of Health oversight

3.3.1 Hazelwood Long term Health Study Contract Committee

Administered fully by the Department of Health, the Hazelwood Long term Health Study Contract Committee has required the PMG to attend regular meetings and provide updates since the Study's inception in 2014. The Contract Committee met as frequently as monthly in the early years of the Study, extending out to quarterly from 2017 onwards and twice-yearly from 2023. Typical agenda items include reports on Study progress, highlights, directions, issues, dissemination of findings and community engagement.

3.3.2 Ministerial Advisory Committee

The Ministerial Advisory Committee (MAC) was established in July 2017 in response to a recommendation by the 2nd HMFI. The MAC's purpose was to provide advice to the Minister for Health on the Hazelwood Mine Fire Long Term Health Study. The MAC was tasked with undertaking a review of the Study streams and the scope of work that was specified in the Agreement with the Department of Health. This review was carried out to identify any departures from the agreed scope of work during implementation, risks to the ongoing quality implementation of the Study and what those may have meant for the overall Study.

The PMG provided substantial documentation to the MAC upon their request. As described in section 3.1.2, the MAC's advice to the Minister included the recommendations that the Study undertake a strategic overview and submit a revised project plan. At that time, the MAC also recommended that the Study expand community representation on the CAC, clinical representation on the CRG, ensure additional independent oversight of the SRG and enhance communication with the LHA, Latrobe Health Advocate and the GPHN; all of which was acted upon by the Study team The MAC was discontinued in 2019.

4 Overview of the Hazelwood Health Study research streams

To address the research questions and further requested information, the HHS set up several distinct research streams. An overview of each stream's aims and methods is provided below and a timeline, demonstrating each stream's key data collection activities, is in section 4.11.

4.1 Exposure Assessment

CSIRO Oceans & Atmosphere was subcontracted to conduct in-depth modelling of air quality data.

4.1.1 Aims

This stream aimed to:

- identify key pollutants relevant to health impacts;
- analyse differences in pollutant concentrations measured across Morwell during smoke-impacted and non-smoke impacted periods (e.g., mine fire-related versus background ambient air quality in the Latrobe Valley);
- compare pollutant concentrations, measured at Morwell, to other urban sites within the Latrobe Valley and Victoria and assess the impact of the mine fire on ambient air quality; and
- provide exposure fields for smoke-related particulate matter with an aerodynamic diameter of 2.5 microns (thousandths of a millimetre; μm) or less ($PM_{2.5}$) across Morwell and the greater Latrobe Valley.

The Hazelwood mine fire, February 2014
Photo courtesy of Keith Pakenham, Country Fire Authority Victoria, Australia

4.1.2 Methods

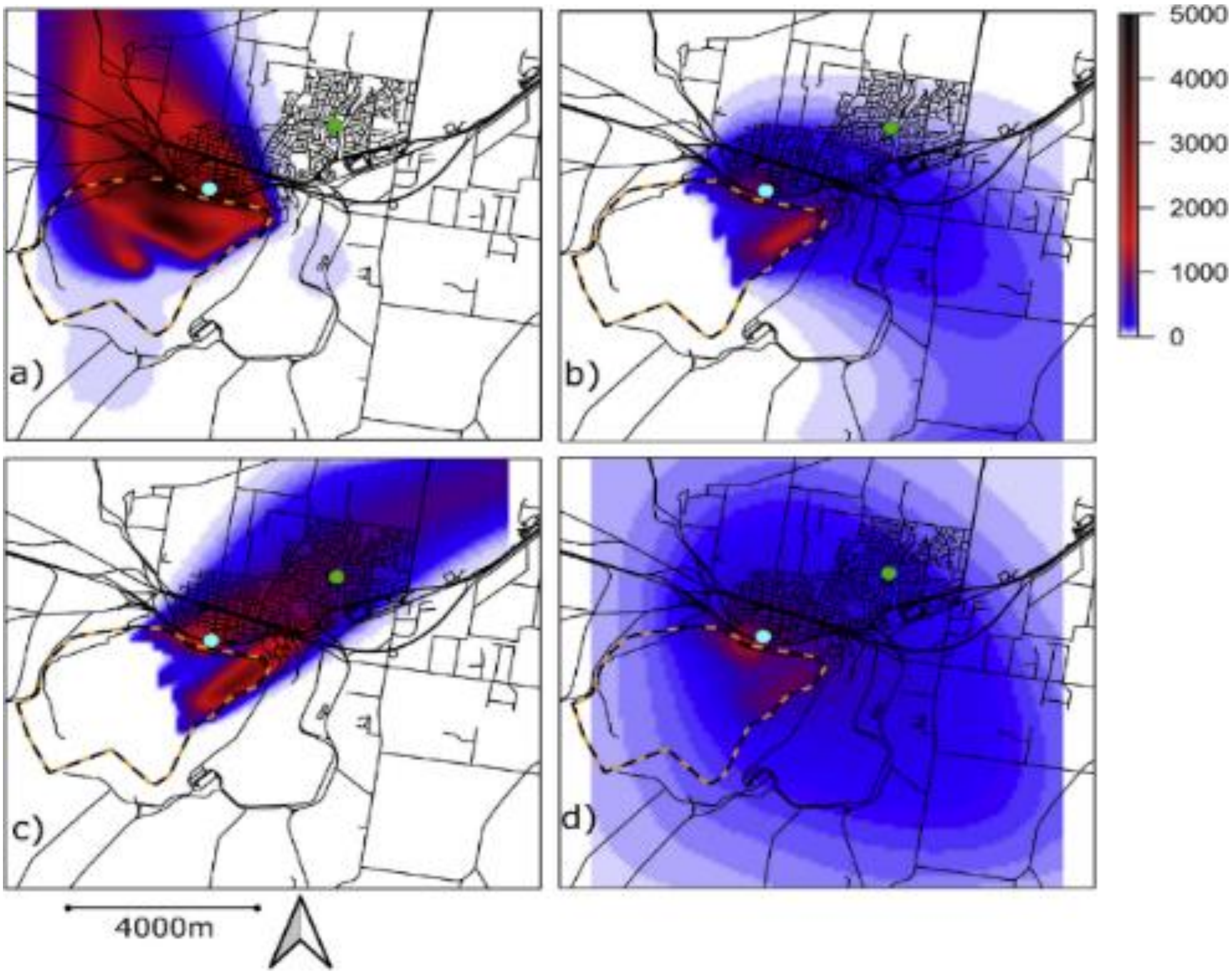
In order to describe the pollutants emitted from the Hazelwood mine fire, CSIRO initially evaluated air quality measurements made during the fire by its own researchers and also those of EPA Victoria and Country Fire Authority (CFA) Victoria. Pollutants measured include particles smaller than 10 µm (PM_{10}) and smaller than 2.5 µm ($PM_{2.5}$), carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), volatile organic compounds (e.g., benzene and formaldehyde), polycyclic aromatic hydrocarbons (e.g., benzo(a)pyrene), dioxins and metals.[1] Chemical analyses were conducted on filter samples to calculate particle composition and size distribution. To get a better understanding of the combustion process, emission ratios for PM, benzene or formaldehyde were calculated relative to the known (measured) CO emission rate. Meteorological data provided hourly temperature, wind speed and wind direction. Comparisons were made with other bushfire and peat fire events to further identify the unique air pollution composition of the Hazelwood mine fire event.[1, 4]

To compare pollutant concentrations at Morwell to other urban sites within the Latrobe Valley, and to provide exposure fields for $PM_{2.5}$ across the region, mine fire-related $PM_{2.5}$ concentrations were retrospectively modelled by CSIRO using The Air Pollution Model (TAPM v4.0.5),[5, 6] combined with a chemical transport model (CTM).[7] TAPM is a fine-scale air pollution model without chemistry and the CTM is a broader scale model that includes atmospheric chemistry. Both were driven by a separate downscaled weather model, the Conformal Cubic Atmospheric Model (CCAM).[8] Modelled data were used due to a paucity of air quality monitoring at the time of the fire. In particular, no data were available for the first 10 days of the fire in the residential areas of Morwell closest to the mine, when exposure levels were likely at their highest.[1, 7]

As described by Johnson *et al.* (2019)[7] modelling was conducted at two spatial scales. Firstly, high-resolution near-field modelling with a spatial resolution of 100 m was undertaken for the 10×10 km^2 area around the coal mine and the town of Morwell. Maps of area burned, and estimated emission factors, were used to model hourly $PM_{2.5}$ emission rates. Emissions were dispersed using TAPM driven by CCAM-downscaled meteorology and were treated as tracer species, i.e., no secondary chemical reactions. Verification of the hourly modelled $PM_{2.5}$ concentrations, compared to available measured observations for the period 20 February–28 March 2014, found correlation coefficients of $r = 0.57$ close to the mine and $r = 0.37$, 3 km downwind of the mine.[4, 9] Modelled estimates were found to predict the correct magnitude, but the timing of the maxima was not always synchronised with measured observations.[4] However, throughout Hazelwood Health Study analyses of the effects of smoke exposure on health, the hourly model output was usually aggregated to daily mean concentrations, which would have improved the temporal reliability of the model.[7]

Secondly, regional modelling was conducted using the CTM driven by the CCAM-downscaled meteorology and incorporated full chemistry simulations.[4, 7, 9] The model incorporated a set of nested grids with resolutions ranging from 1 km close to Morwell, to 80 km at the national scale.

Two model runs were performed. The first included only background sources of $PM_{2.5}$ which incorporated all anthropogenic sources and active wildfires. The second also included $PM_{2.5}$ emissions from the coal mine fire. Subtracting one run from the other allowed mine fire-related concentrations, and non-mine fire background levels, to be calculated.[4, 9] As the coal mine fire burned continually over a number of weeks, the model not only simulated diffusion after the fire but innovative efforts were also made to account for the continuity of the fire. These included the use of aerial line-scan imagery to map the area of the mine burning each hour, the McArthur Forest Fire Danger Index[10] to modify the emission rates over time in response to changing weather conditions, and a dynamic plume rise model[4, 9] to vary the height of the emissions column in response to wind and area burning.[7] Examples of the modelled hourly-averaged near-surface mine fire-related $PM_{2.5}$ concentrations in micrograms per cubic meter (μg/m³), in and around Morwell on different days, are demonstrated in Figure 1.



(a) 10 February (0700–0800 h), (b) 15 February (1400–1500 h), (c) 15 February (1900–2000 h), and (d) 23 February (1400–1500 h). The dots are: green – eastern parts of Morwell, and light blue – southern parts of Morwell. Dashed black-orange line represents the coal mine boundary. The black lines represent roads and residential streets.

Figure 1 Modelled hourly-averaged near-surface $PM_{2.5}$ concentrations (μg/m³) in and around Morwell (Source: Luhar *et al.* 2020)[9]

4.2 Adult Survey

The Adult Survey is led by Monash University's School of Public Health and Preventive Medicine (SPHPM) and Monash Rural Health (MRH). Detailed methods have been described in several technical reports[4, 11-13] and scientific manuscripts.[9, 14, 15] A brief overview is provided here.

4.2.1 Aims

The Adult Survey's aims have been to:

- cross-sectionally investigate the health status of an exposed versus a comparison adult population using a baseline survey;
- compare the incidence rates of long-term health outcomes by linking survey respondents to administrative health datasets (see section 4.10.1);
- investigate the association between individual exposure level and risk of long-term health outcomes by using fine resolution exposure metrics developed by the Commonwealth Scientific and Industrial Research Organisation; CSIRO (see section 4.1);
- provide a baseline cohort (the Adult Survey cohort) from which the longitudinal Adult Psychological Impacts Stream (section 4.4), Respiratory Stream (section 4.8) and Cardiovascular Stream (section 4.7) participants could be recruited.[14]
- provide a baseline cohort which might be drawn upon to answer 'future' research questions not included at the time of the Department of Health's 2014 Request for Tender (Health C3478).

4.2.2 Eligible subjects

The Adult Survey exposed (study) group was defined as people who lived in Morwell and were aged 18 years or older on the 31st of March 2014. For the purpose of the Study, Morwell was defined as the area within the township boundary. The eligible comparison group were people aged 18 years or older on the 31st of March 2014, who lived within one of 16 selected Statistical Areas Level 1 (SA1s) within the town of Sale which had comparable median age, household size, Socio-Economic Indexes for Areas (SEIFA)[16] and population stability as Morwell. As indicated in Figure 2, and described in more detail in section 5.7.1, CSIRO modelling indicated that Morwell was by far the most exposed town and that Sale had little to no smoke exposure during the mine fire event.[4, 9]

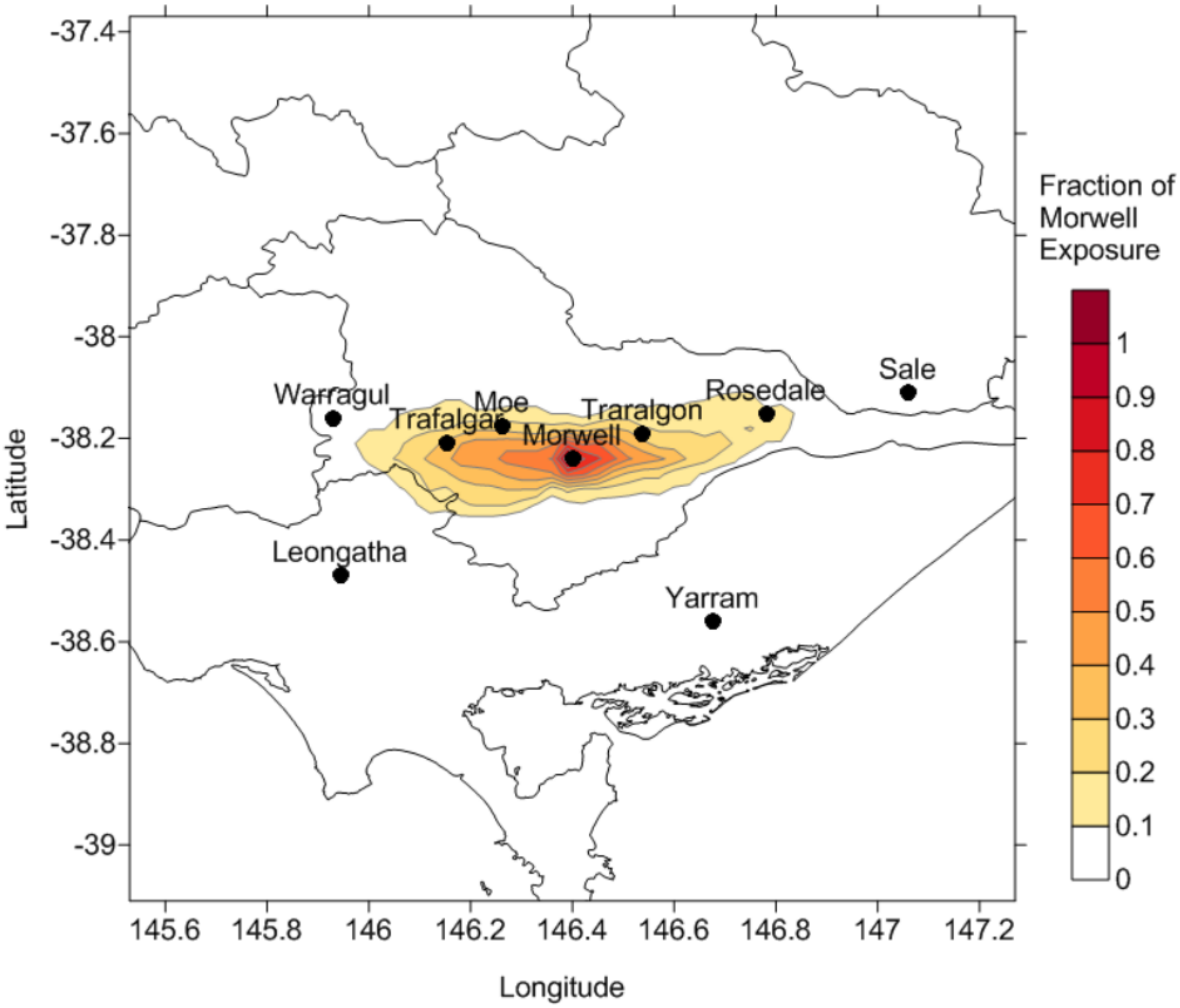


Figure 2 Modelled smoke exposure across the Latrobe Valley and parts of Gippsland during the Hazelwood mine fire period
(Source: Emmerson *et al.* 2016)[4]

The electoral roll maintained by the Victorian Electoral Commission (VEC) was determined to be the preferred sampling frame from which to identify eligible subjects, and their contact details, for the Adult Survey. This was because, with few exceptions, electoral registration was compulsory for Australian citizens aged 18 years or older.[17] The VEC identified 9,448 registered Morwell residents and 4,444 registered Sale residents.

4.2.3 Recruitment

Recruitment into the baseline Adult Survey cohort commenced in May 2016 and concluded in February 2017. Diverse strategies were utilised in the effort to contact and maximise recruitment of eligible adults from Morwell and Sale. These included personalised mail, follow-up phone calls where publicly listed numbers could be found, promotional fridge magnets (Figure 3), $20 gift vouchers as reimbursement, free catered public events (Figure 4), radio and print media, posters (Figure 5), website updates, attending community groups and events (Figure 6) and distributing flyers. Feedback was monitored in order to identify and address barriers to participation.

Figure 3 Promotional fridge magnets delivered across Morwell (left) and Sale (right)

Figure 4 Flyer promoting free catered events in public venues for Adult Survey participants

Figure 5 Example of a poster promoting Adult Survey questionnaire packs available in Sale

Figure 6 Hazelwood Health Study promotional stand at Morwell Pop-Up Park in April 2016

In total 4,056 adults, comprising 3,096 (33%) Morwell residents and 960 (23%) Sale residents, participated in the Adult Survey and became the HHS Adult Survey cohort. These recruitment rates were similar to, if not higher than, comparable studies.[18] However, sampling (selection) bias was a concern, where the health of participants might differ from the health of non-participants. A comparison of participants with community data, collected by the Australian Bureau of Statistics (ABS), indicated that women, and people aged over 50, were slightly overrepresented amongst participants. Importantly this occurred in both the Morwell and Sale groups which makes bias that might be caused by sex or age differences unlikely. To reduce the possibility of participation bias, the results were weighted by sex and age group. Furthermore, to minimise the effects of important health risk factors, multivariable methods were used to adjust for differences between the participating groups in factors such as education, employment, smoking, and alcohol use, as well as sex and age.

A brief refuser questionnaire, including self-reported health status, was completed by 20% of the refusers from Morwell and 15% from Sale. Results indicated that within each town, participants reported a similar health status to refusers. That finding reduced the likelihood that participation bias was affecting the observed differences in health between the two groups.[11]

4.2.4 Data collection

The baseline Adult Survey comprised a self-report survey which participants could complete online, by telephone interview or on paper. The survey included demographic indices, the single self-rated health item from the Short Form (SF) 12,[19, 20] doctor-diagnosed medical conditions, a modified version of the European Community Respiratory Health Survey (ECRHS),[21, 22] the Pekkanen asthma severity score,[23] the Impact of Events Scale-Revised (IES-R) which measured the three symptom clusters of posttraumatic stress (intrusive rumination, hyperarousal and avoidance behaviour) related to the mine fire,[24, 25] the Kessler-10 item (K10) general psychological distress scale,[26, 27] occupational exposures to dust, fumes, smoke, gas, vapour or mist, employment or volunteer roles in the emergency services, the Alcohol Use Disorders Identification Test-C (AUDIT-C)[28, 29] and pack years of cigarette smoking. Each participant's home address SA1 was used to generate an Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) score using data drawn from the 2016 Census.[16] The Survey also included year of construction of their home, main building material, type of roof and use of air conditioning.

As described in sections 4.1 and 5.1, spatially resolved hourly estimates of mine-fire related concentrations of airborne $PM_{2.5}$ were modelled by CSIRO based on air monitoring data, coal combustion and weather conditions.[1, 4, 9] Adult Survey participants completed time-location diaries with their home, work and any relocation addresses for each day and night of the mine fire period. In order to estimate each participant's mine-fire related $PM_{2.5}$ exposure level, their time-location diaries were blended with the modelled data.[14, 15]

Linkage of consenting Adult Survey participants to administrative health datasets was undertaken as part of the Hazelinks Stream and is described in section 4.10.1.

4.3 The Latrobe Early Life Follow-up Study

The Latrobe Early Life Follow-up (ELF) Study is led by the University of Tasmania's Menzies Institute for Medical Research. Detailed methods have been described in several technical reports[13, 30-35] and numerous scientific manuscripts.[7, 36-42] Only a brief overview is provided here.

4.3.1 Aims

The overall aim of the ELF Study is to investigate the potential impacts of exposure to smoke from the Hazelwood mine fire during pregnancy or early childhood on subsequent health and development of children in the Latrobe Valley.

Specific objectives include:

- Comparing perinatal outcomes, particularly foetal growth and maturity, for infants who were exposed, not exposed or minimally exposed to smoke from the Hazelwood mine fire.
- Comparing the frequency of parental reports of minor illnesses in infants, over a three-year period, for those exposed, not exposed or minimally exposed to smoke from the Hazelwood mine fire.
- Comparing respiratory and vascular function in children from 3 to 12 years of age, for those exposed, not exposed or minimally exposed to smoke from the Hazelwood mine fire.
- Assessing long-term indicators of health and development using an anonymised data linkage study comparing those areas exposed and those not exposed, or minimally exposed, to smoke from the Hazelwood mine fire.

Dale and Ash

4.3.2 Eligible subjects

The Latrobe ELF Study cohort includes children born from 1 March 2012 to 31 December 2015 in the Latrobe Valley, Victoria. As shown in Figure 7, this cohort includes those who were either *in utero* or in early childhood (defined as a child under the age of 2 years) during the mine fire air pollution event, or conceived after the event, to allow a gradient of exposures and developmental windows to be examined.

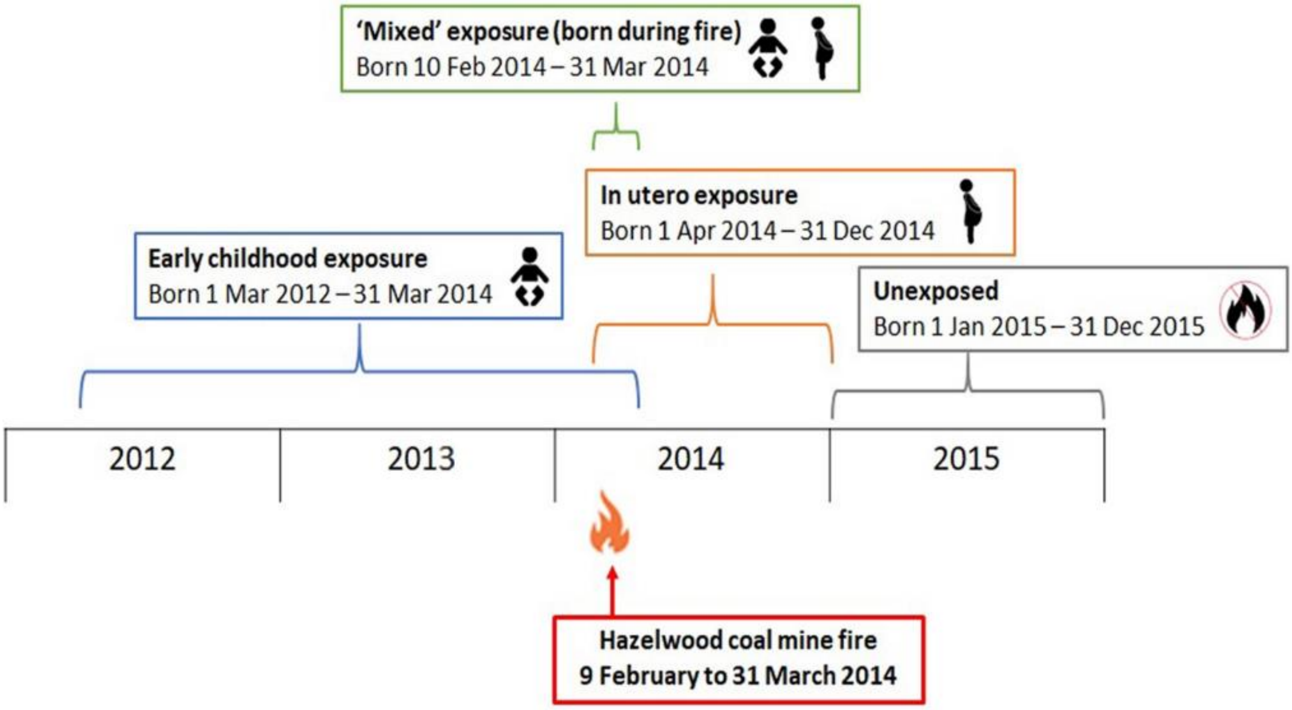


Figure 7 Latrobe ELF Study exposure groups by date of birth (Source: Melody *et al.* 2020)[38]

4.3.3 Recruitment

Two streams within the ELF cohort were established to answer the Study aims. These streams can be broadly classified into identified and de-identified cohorts, with differing recruitment methods.

4.3.3.1 Identified cohort

The Latrobe City Council's Maternal Child Health Service generated a nominal roll (list) of potentially eligible children who were known to their service, born between 1 March 2012 and 31 December 2015 and not identified as deceased by Births Deaths and Marriages Victoria. The Council sent approach letters to eligible families, with multiple options for opting out. After removal of the opt-outs and some duplicate records, and addition of a small number of eligible children not known to the Council, a population of 3,383 children were sent invitation packages by the ELF Study team to participate in an initial baseline survey.[13]

Baseline survey recruitment was conducted between March and December 2016. Completed baseline surveys were received from the families of 571 children which represented 43% of eligible Morwell families and 27% of eligible families from the broader Latrobe Valley.

Following the baseline survey, the identified cohort were invited into a number of sub-studies as demonstrated in Figure 8. From the 571 baseline participants, 213 were enrolled into Round 1 clinical testing (R1; 2017),167 into Round 2 clinical testing (R2; 2021) and 174 into Round 3 clinical testing (R3; 2023). Also, the parents of 289 children provided monthly symptom diaries and 331 consented to linkage with health and education datasets.

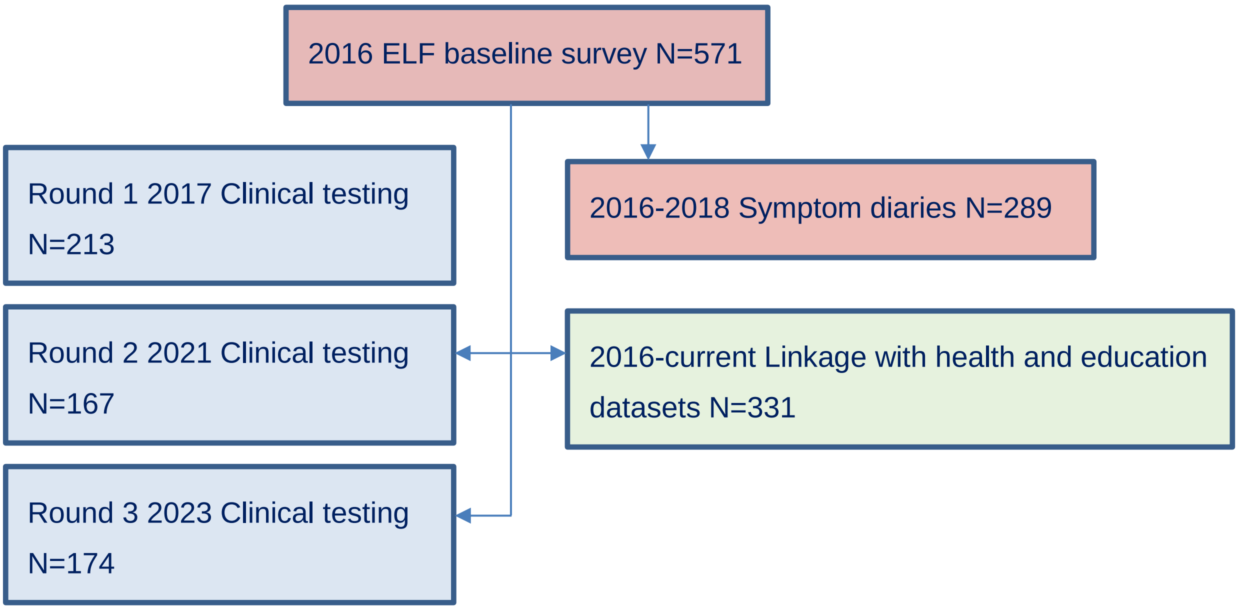


Figure 8 Participant numbers in the ELF identified cohort sub-studies

4.3.3.2 Deidentified cohort

The deidentified cohort consisted of all 3,679 children who were listed as live births on the Victorian Birth Registry between 1 March 2012 and 31 December 2015 where the maternal residence was in the Latrobe Valley.

4.3.4 Data collection

4.3.4.1 Identified cohort

Data collected from the ELF Study baseline survey and its sub-studies are demonstrated in Table 1.

4.3.4.2 Deidentified cohort

The deidentified cohort has been linked to eight different health and educational datasets by the Australian Institute for Health and Welfare and/or the Centre for Victorian Data Linkage as shown in Table 2.

Table 1 Data collected from the ELF Study identified cohort

Data source	Collected variable
Baseline comprehensive survey **(N = 571)**	• Sociodemographic details of study child and their immediate family • Child's health: including birth details, perinatal outcomes, breastfeeding history, medication use, childcare attendance, number of siblings and history of atopy in siblings • Child's residential history: details of the housing that the pregnant mother and child lived in including year of build, heating/cooling, floor coverings etc • Time-location diary – capturing maternal and/or child's residence during the smoke event and other location information on a 12-hourly basis. • Medical history of the biological parents

Clinical testing
(R1 2017; N = 213)
(R2 2021; N = 167)
(R3 2023; N = 174)
	• Demographic and anthropometric data
	• Respiratory function (Forced oscillation technique)
	  ○ Respiratory system resistance (Rrs)
	  ○ Respiratory system reactance (Xrs)
	  ○ Area under the reactance curve (AX)
	  ○ Bronchodilator response for Rrs, Xrs, AX
	• Fraction of exhaled nitric oxide (FeNO; R2 & R3 only)
	• Spirometry (R3 only)
	• Vascular indicators (carotid and abdominal aorta ultrasound)
	  ○ Pulse wave velocity (blood vessel stiffness)
	  ○ Carotid intima-media thickness (blood vessel thickness)

Symptom diary **(N = 289)**	Presence or absence of the following in each previous month: • Symptoms: runny nose, cough, wheeze, fever, rash • Healthcare provider contact: doctor/nurse telephone advice, pharmacist advice, visits from child health nurse, General Practitioner or hospital doctor • Medication use: antibiotics, asthma medications, topical steroid/ointment • Doctor-diagnosis of: upper respiratory tract infection/cold or flu, ear infection, eczema or dermatitis, chest infection, bronchiolitis, wheezing, asthma, croup, pneumonia
Administrative and health data extraction **(N = 331)**	• Perinatal data (VPDC) • Emergency Department presentations (VEMD) • Hospital admissions (VAED) • Consultations with primary healthcare practitioners (MBS) • Prescription medications dispensed under national subsidy scheme (PBS) • Educational and development outcomes (AEDC and NAPLAN data) (see Table 2 for more information about all of these data sources)

Abbreviations: AEDC: Australian Early Development Census; PBS: Pharmaceutical Benefits Scheme; MBS: Medicare Benefits Schedule; NAPLAN: National Assessment Program – Literacy and Numeracy; VAED: Victorian Admitted Episodes Data; VEMD: Victorian Emergency Minimum Dataset; VPDC: Victorian Perinatal Data Collection.

(Source Melody *et al.* 2020)[38]

Table 2 Birth, health and educational variables collected through data linkage for the ELF Study deidentified cohort

Data type	Dataset	Data source	Variables
Perinatal data	Victorian Perinatal Data Collection	Consultative Council on Obstetric and Paediatric Mortality	Maternal, pregnancy, intrapartum, neonatal and postnatal characteristics
Emergency Department presentations	Victorian Emergency Minimum Dataset	Victorian Department of Health	Episode date, child sociodemographic details, ICD-10-AM diagnosis codes
Hospital admissions	Victorian Admitted Episodes Dataset	Victorian Department of Health	Episode date, episode type, child sociodemographic details, ICD-10-AM diagnosis codes
Consultations with primary healthcare practitioner	Medicare Benefits Schedule	Commonwealth Department of Health and Aged Care	Number and date of billed General Practitioner attendances, mental health care plans, asthma cycle of care plans, respiratory function tests, pathology tests for immune function
Prescription medications dispensed under national subsidy scheme	Pharmaceutical Benefits Scheme	Commonwealth Department of Health and Aged Care	Dispensing of pharmaceuticals including antihistamines, antibiotics, antiviral medication, cough and cold preparations, corticosteroids, asthma/obstructive airway disease medications, agents used for attention deficit and hyperactivity disorder
Educational and development outcomes	Australian Early Development Census	Commonwealth Department of Education and Training	AEDC physical health and wellbeing score, social competence score, emotional maturity score, language and cognitive skills score, communication skills and general knowledge score
	National Assessment Program – Literacy and Numeracy	Australian Curriculum and Reporting Authority	Proposed future linkage only. Grades 3, 5, 7 & 9 reading score, persuasive writing score, spelling score, grammar and punctuation score
Cancer diagnoses	Victorian Cancer Registry	Cancer Council Victoria	Proposed future linkage only. Year of diagnosis and diagnosis
Mortality data	National Death Index	Australian Institute of Health and Welfare	Proposed future linkage only. Year and primary cause of death

Abbreviations: ICD-10-AM: The International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification; AEDC: Australian Early Development Census.

(Source Melody *et al.* 2020)[38]

4.4 Psychological Impacts Stream

Led by Monash Rural Health, the overall objective of the Psychological Impacts Stream is to determine whether exposure to smoke from the fire is associated with psychological trauma and distress. The Psychological Impacts Stream comprises two sub-streams: the Schools Study focusing on school-aged children and the Adult Psychological Impacts Stream based on the Adult Survey cohort. Detailed methods have been described elsewhere[13, 43-45] and only a brief overview is provided here.

4.4.1 Aims

The aims of this Stream are to:

- investigate the extent of trauma and distress symptoms in adults and school-aged children exposed to the mine fire event;
- examine the role of individual, family and social factors on recovery and wellbeing outcomes;
- explore the qualitative perceptions of adults and school-aged children regarding the fire and the ensuing circumstances;
- evaluate the impact of the mine fire event on the academic progress of exposed school children;
- examine the relationship between community wellbeing and personal wellbeing in collaboration with the Community Wellbeing Stream; and
- explore the relationship between parent and child mental health and wellbeing, and whether that influenced the impacts of the mine fire on child health in collaboration with the Early Life Follow-Up Study.

4.4.2 Schools Study

4.4.2.1 Eligible students

The Schools Study involved 20 schools from across Latrobe City (grouped by location into Morwell vs. non-Morwell schools), including government and non-government primary and secondary schools. All students at these schools in academic grades 3, 5, 7 and 9 (NAPLAN year levels) in 2015 were eligible to participate in the study. The final number of eligible students was the sum total across all participating grades and schools. This equated to 2,138 students, with the breakdown by school type shown in Table 3.

Table 3 Number of eligible students by school type

School type	Number
Government Primary	652
Government Secondary	666
Non-government Primary	262
Non-government Secondary	558
Total sample size	2,138

4.4.2.2 Recruitment

Student recruitment took place during 2015-2016. Recruitment was conducted via the schools. Each school approached parents on behalf of the Study and invited them to consent to:

- completing a survey about their child/ren;
- their child/ren completing a survey;
- their child/ren potentially participating in a qualitative interview; and
- the researchers accessing linked educational outcome data including NAPLAN results.

Recruitment was a multi-staged process taking at least six weeks in each school. The process involved advance notices being sent home, then invitations dispatched, followed by three reminders sent to parents by multiple means including written notices, emails (where possible within the school) and finally phone calls from school administrative staff. When parents returned the study consent form indicating their consent for their child/ren to participate, the names of participating students were provided to the researchers.

Table 4 outlines the number of eligible students from the 20 participating schools and participation rates broken down by academic grade and location. The response rate was 15% overall, with 25% of Morwell students agreeing to participate compared to 12% of non-Morwell students. This finding, that students from less exposed schools were less likely to participate, mirrored that in the Adult Survey where residents from the Sale comparison community were likewise less likely to participate. Additionally, it was more challenging to recruit older students, particularly those in grade 9. When secondary students were excluded, the response rate was 22% overall, 31% within Morwell and 17% outside Morwell.

Table 4 Numbers of eligible students and participation rates across grade levels

	8 Morwell schools		12 non-Morwell schools		All 20 schools	
Grade(s)	**Eligible**	**Participants n (%)**	**Eligible**	**Participants n (%)**	**Eligible**	**Participants n (%)**
3	174	58 (33.3)	300	55 (18.3)	474	113 (23.8)
5	162	47 (29.0)	278	43 (15.1)	440	90 (20.5)
7	77	16 (20.8)	550	68 (12.4)	627	84 (13.4)
9	90	5 (5.6)	507	31 (6.1)	597	36 (6.0)
Total	503	126 (25.0)	1635	197 (12.0)	2138	323 (15.1)
3+5+7	413	121 (29.3)	1128	166 (14.7)	1541	287 (18.6)
3+5	336	105 (31.3)	578	98 (17.0)	914	203 (22.2)

The recruitment rate achieved was in line with previous literature on the impact of disasters and trauma on children and youth, where the rates were between 15-35%.[46, 47] It was apparent from this review of the literature that recruiting people from impacted communities into trauma studies is considerably harder than into general community studies, perhaps due to ‘trauma fatigue’.[46, 47]

It should be noted that, upon the initial advice of the HHS Community Advisory Committee, the Schools Study did not reimburse participants with a gift card or voucher as part of its initial data collection protocol. A later decision, by both the Adult Survey and ELF Study, to provide reimbursement gift cards, was made in response to the recruitment challenges encountered in the Schools Study. We believe that had the Schools Study offered reimbursements from the outset, the participation rate would have been equivalent to the Adult Survey. The Schools Study subsequently received approval to reimburse participants in a later round of data collection.

The participation rate for parents completing surveys about their child and family was 66% and the participation rate for teachers was 87%. Additionally, the Schools Study interviewed eight staff members from a Morwell specialist school, as part of a small qualitative project.

[Figure 9](#) provides a mapping of cumulative 12-hourly $PM_{2.5}$ exposure across Morwell for the period of the mine fire, along with the location and participation rates for seven Morwell schools. There was no clear evidence for participation being higher in the more highly exposed schools, with divergent results between the two most exposed schools, and relatively consistent participation in the primary schools spanning the other exposure levels. This suggests that we achieved a sufficiently representative sample upon which to base comparisons within Morwell.

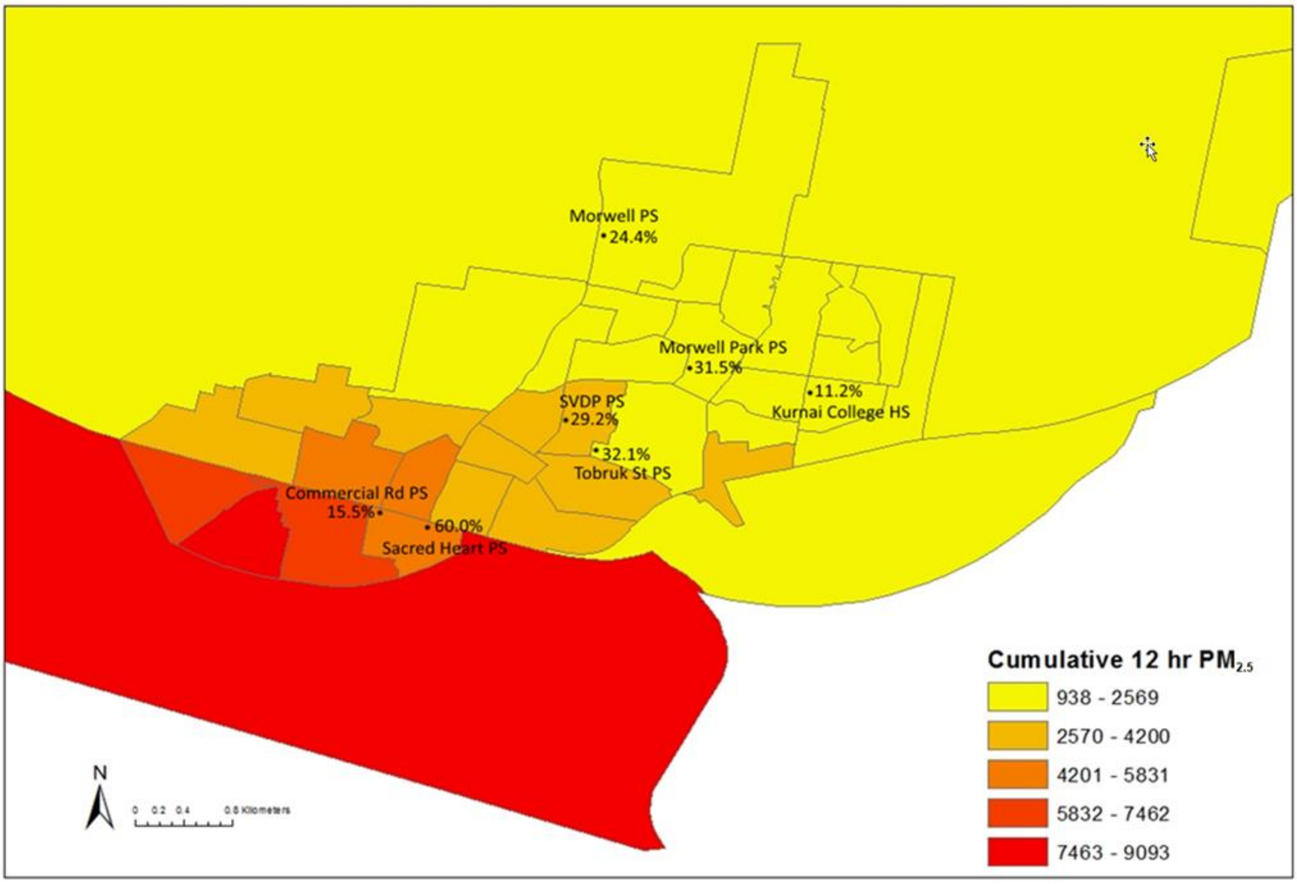


Figure 9 School participation rates in Morwell by CSIRO modelled cumulative 12 hourly $PM_{2.5}$ exposure in μg/m^3

4.4.2.3 Data collected

The 13-item Child Revised Impact of Events Scale (CRIES-13)[48, 49] was administered as the primary measure of posttraumatic stress related to the mine fire in self-report surveys completed by students over two rounds in 2015 and 2017. This was supplemented with semi-structured qualitative interviews designed to elicit further perceptions from students regarding their experiences of the mine fire and its impacts on them. The interviews specifically covered the following information:

- What, if anything, did students recall of the smoke event?
- What did students recall about the effects the event had on themselves, their family, friends or others and were these perceived as ongoing?

- What, if any, of the core characteristic symptoms of Posttraumatic Stress Disorder (PTSD; intrusive thoughts; avoidance behaviours; hyperarousal) did students experience?
- What helped students cope at the time and what did students think could be done to support them in future events?

The Schools Study also collected identified NAPLAN data for 303 consenting participants, and deidentified NAPLAN data spanning 2010 to 2018 for approximately 10,000 students in grade 3, 5, 7 or 9 from 69 schools across the Latrobe Valley and Wellington Shire.

4.4.3 Adult Psychological Impacts

4.4.3.1 Eligible subjects

The Adult Survey (see section 4.2) comprised the baseline Adult Psychological Impacts data collection. Therefore, eligibility was as per the Adult Survey; summarised as adults living in Morwell or selected areas of Sale at the time of the mine fire.

4.4.3.2 Recruitment

Initial recruitment into the Adult Psychological Impacts Stream was as per the Adult Survey (N=4,056; 3,096 Morwell, 960 Sale). Following the Adult Survey, the Psychological Impacts Stream undertook several follow-up sub-studies. The first, in 2017, involved inviting Morwell-based Adult Survey cohort members to undertake a qualitative interview about their mine fire-related experiences. In a longitudinal program of research, two further sub-studies involved inviting Morwell-based Adult Survey cohort members to complete a follow-up Mental Health and Wellbeing Survey in 2019-2020 and again in 2022. Numbers invited, and recruitment rates, are shown in Figure 10.

Figure 10 Numbers of invited Adult Survey members and recruitment rates in Psychological Impacts Stream sub-studies

4.4.3.3 Data collected

The Psychological Impacts Stream had at its disposal all of the data collected in the baseline Adult Survey (see section 4.2.4). Data collected as part of the follow-up sub-studies included the following:

Data collected in qualitative follow-up interviews

- participant descriptions of short- and long-term impacts of the mine fire on psychological health and wellbeing; and
- participant descriptions of the presence and nature of posttraumatic stress symptoms in response to the mine fire.

Data collected in follow-up surveys (2019-2020; 2022)

Demographics

- living and working circumstances; and
- general demographics including household composition, education, employment and income.

Current wellbeing in regard to the Hazelwood mine fire

- symptoms of posttraumatic stress (Impacts of Event Scale Revised; IES-R);[25] and
- posttraumatic growth (Posttraumatic Growth Inventory; PTGI-SF).[50]

Impact of recent community-wide events

- 2019-2020 Black Summer[51] concerns (a customised scale for the study included in the 2022 follow-up only); and
- COVID-19 pandemic concerns (a customised scale for the study included in the 2022 follow-up only).

Personal health and wellbeing

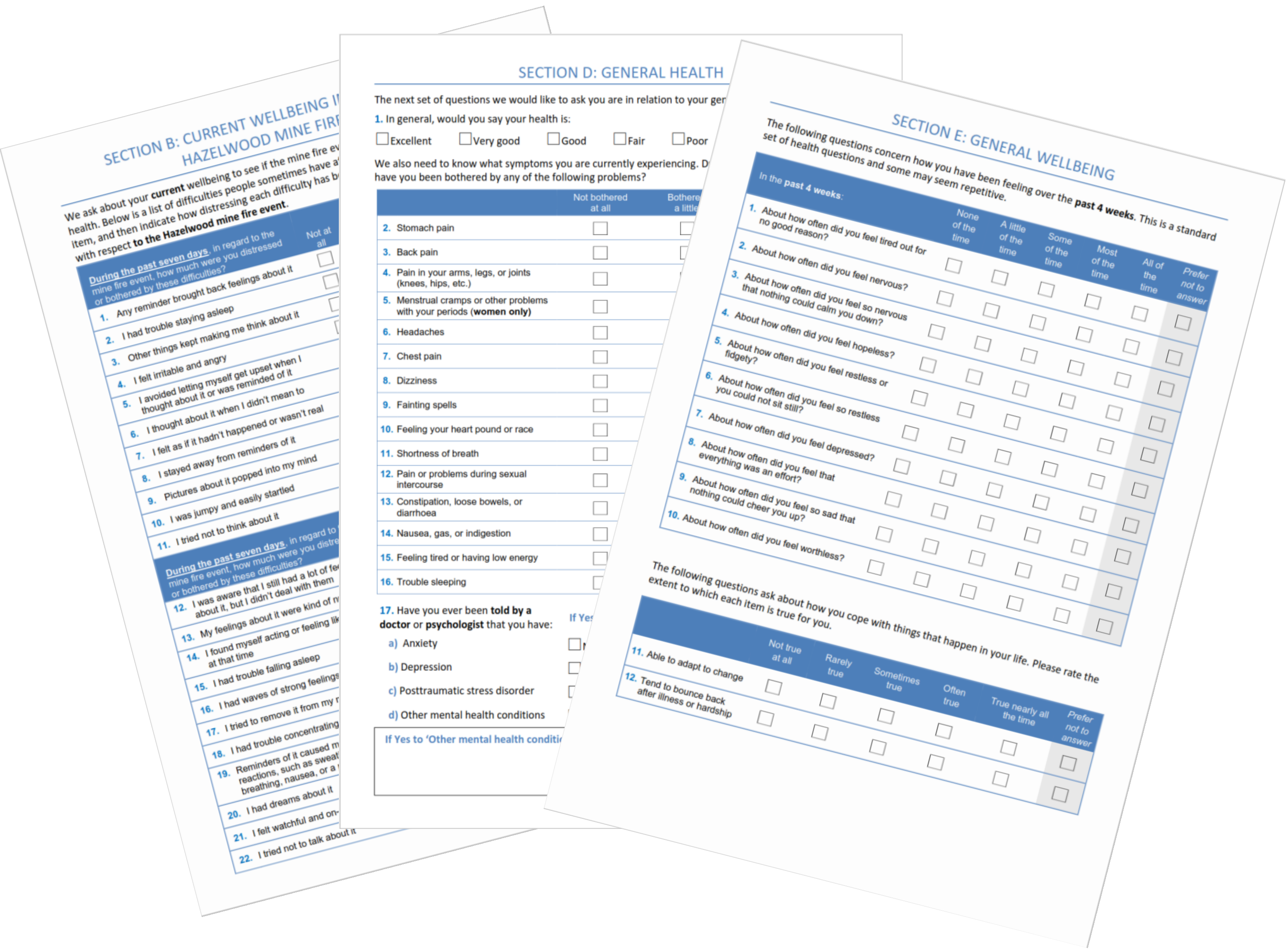
- diagnosed mental health conditions;
- general psychological distress (Kessler Psychological Distress Scale; K10);[27]
- somatic symptoms (Patient Health Questionnaire; PHQ-15);[52]
- personal resilience (Connor-Davidson Resilience Scale; CD-RISC2);[53]
- recent (past 12 months) exposure to stressful life events (List of Traumatic Experiences Questionnaire; LTE-Q);[54]
- health-related quality of life (EuroQol Group measure of health status; EQ-5D-5L);[55] and
- general health status (SF-12 general health item).[20]

Social support

- social support (Duke Social Support Index; DSSI-11);[56] and
- loneliness (Loneliness Item of the Center for Epidemiologic Studies Depression Scale).[57]

Community wellbeing

- community wellbeing (Community Wellbeing Index; CWI);[58] and
- change in community wellbeing (customised version of the CWI included in the 2022 follow-up only).



Sections of the 2019/2020 Mental Health and Wellbeing Survey

4.4.4 Family mental health and wellbeing

In collaboration with the Latrobe ELF Study, the Psychological Impacts Stream conducted the 2022 Survey of ELF Parents and Families with the objective of exploring the relationship between parent and child mental health and wellbeing among families in the ELF identified cohort, and whether it influenced associations between exposure to mine fire smoke and child health outcomes.

4.4.4.1 Eligibility and recruitment

The ELF Parents and Families Survey was a follow-up of the ELF identified cohort. Therefore, eligibility was as per the ELF baseline survey (see section 4.3.3.1). In total, 227 parents of 249 children participated in the Survey of ELF Parents and Families.

4.4.4.2 Data collected

For this analysis, the Psychological Impacts Stream had at its disposal all data collected as part of the ELF Study baseline survey (see Table 1). Further data collected as part of the Survey of ELF Parents and Families included the following:

Family circumstances

- General demographics including household composition, education and employment.

Impacts of recent community-wide events

- 2019-2020 Black Summer concerns (a customised scale for the study); and
- COVID-19 pandemic concerns (a customised scale for the study).

Family functioning and wellbeing

- History of issues in the family (School Entrant Health Questionnaire);[59] and
- Parental stress (Parental Stress Scale).[60]

Parent and caregiver mental health and wellbeing

- Diagnosed mental health conditions;
- General psychological distress (K10);[27] and
- General health status (SF-12 general health item)[19, 20]

Child mental health and wellbeing

- Diagnosed mental health conditions; and
- Emotional and behavioural development (Strengths and Difficulties Questionnaire: Parent Report; SDQ).[61]

4.5 Impact on Community Wellbeing

The Impact on Community Wellbeing Stream is led by Federation University. Detailed methods have been described in several technical reports[62, 63] and scientific manuscripts.[64, 65] A brief overview is provided here.

4.5.1 Aims

This Stream's focus in the first five years (Phase 1) was to provide narrative evidence of the perceived impact of the Hazelwood mine fire smoke event in Morwell and surrounding communities on community wellbeing. Specific objectives were to identify community perceptions of:

- the impact of the smoke event on community wellbeing and resilience;
- effective communication during and after the smoke event;
- the effectiveness of community rebuilding activities; and
- the community's vision for what recovery looks like.

In the last five years (Phase 2) the Stream has broadened its focus to look at how the community's wellbeing and recovery from the mine fire have been impacted by subsequent events. This has included the development of a Community Wellbeing Barometer that brings together community perceptions of wellbeing and existing community wellbeing indicator proxy measures. The aim of the Barometer is to provide a holistic tool to capture the changes in key dimensions that underpin community wellbeing. In collaboration with the Psychological Impacts Stream (see section 4.4), Phase 2 has also involved an examination of the relationship between community wellbeing and personal wellbeing.

4.5.2 Methods and data collection

Because the aims relate to community perceptions of wellbeing and related factors such as communication and the recovery effort, it has been relevant to focus on both subjective and objective indicators of community wellbeing. In particular, it has been important to gather: individual stories, narratives or case studies; group discussions which allowed deliberation, possible consensus or points of disagreement; and both mainstream and social media which shaped and reflected local values.[66] The Stream is using both qualitative and quantitative (mixed) research methods to address its research aims. The data collection methods are outlined below.

4.5.2.1 Coal Mine Fire Initial Impact on Community Health and Wellbeing Summary Report

While not part of the funded Hazelwood Health Study, the "Coal Mine Fire Initial Impact on Community Health and Wellbeing Summary Report"[67] drew on 21 interviews conducted with key informants in 2014. This work was completed by the Centre of Research for Resilient Communities at Federation University. With the funding of the HHS, this earlier research group became the members of the Community Wellbeing Stream. These findings provided access to the stakeholders' responses to the immediate event and helped shape the approach taken by the Community Wellbeing Stream.

4.5.2.2 Community focus group discussions (Phase 1)

The Stream hosted seven focus groups with a total of 45 participants in 2015, 2016 and 2017. Focus groups were targeted at members of the Morwell and surrounding communities. Moe and Traralgon were chosen as additional locations given their proximity to Morwell and the possible impact on communities outside Morwell. Discussion prompts for the focus groups were:

- From your perspective can you tell us the most significant aspect of the Hazelwood mine fire event?
- What impact did this have on community wellbeing?
- What has been the most significant change for community wellbeing since the fire?
- What would be the most effective way of communicating to and with the community during such an event?

4.5.2.3 Semi-structured interviews with key informants (Phase 1)

Key stakeholder interviews were drawn from health professionals, social agencies, aged care facilities, schools and community groups, and included adult organisers, supporters and participants in community emergency and recovery activities. Prompt questions were:

- From your perspective can you tell us about the community recovery activity you are, or have been, involved with?
- What prompted the activity or what need was this activity responding too?
- How was the activity implemented?
- What was your involvement in the activity?
- From your perspective how effective was the activity?
- What else needs to be done?
- What could or should be done in responding to possible future emergencies?

4.5.2.4 Semi-structured interviews with mainstream media professionals and social media practitioners (Phase 1)

Additional key informants were mainstream professionals employed by local news media and who were involved in reporting on the Hazelwood event, plus individuals who took on a significant role of disseminating information via the community-driven Facebook groups during and immediately after the mine fire event. Interviews focused on their experiences during the mine fire and on their experiences during the recovery period after the fire. Both categories of media participants were asked:

- From your perspective can you tell us about the mainstream media coverage or social media commentary on the Hazelwood mine fire smoke event you are or have been involved with?
- How do you see your organisation's/ group's role in covering the smoke event?
- What do you see as the contribution of your organisation/group to community rebuilding after the event?
- From your perspective, what is the most significant change you have noticed because of this activity?
- What is your assessment of the effectiveness of communicating key information about the smoke event to the community during and after the crisis?
- What would be the most effective way/s of communicating to and with the community during and after the crisis?

In addition, mainstream media professionals were asked:

- What do you see as the role of local mainstream media during an event like the Hazelwood mine fire? After an event like this?

Additional questions for social media administrators were:

- Can you tell us how your social media page came to be set up?
- What do you see as the role of social media during an event like the Hazelwood mine fire? After an event like this?

4.5.2.5 Participatory action research (Phase 1)

Participatory action research (PAR) involves researchers and participants working together to examine a problematic situation or action to change it for the better. Thus, a PAR approach acknowledges that the interpretation and response to complex problems such as disasters are multi-layered, multi-levelled and multi-phased. PAR is aimed at enabling those most directly affected to make positive changes. A total of 28 representatives from a range of community groups and other stakeholders involved in supporting the community in the Latrobe Valley participated. These included: Morwell Swimming Club, Rose Garden Walkers, Voices of the Valley, Latrobe Roller Derby Team, Morwell Neighbourhood House, Gippsland Centre Against Sexual Assault, Life Education, The Free Library and The Free Store, Latrobe Valley Chess Club, Asbestos Council of Victoria/GARDS, St Mary's Anglican Church, Morwell, Morwell Junior Fire Brigade, Girl Guides Morwell, Environment Protection Authority, Morwell Rose Garden Group, St Luke's Opportunity Shop, Latrobe Valley Express and the United Muslim Sisters of Latrobe Valley.

4.5.2.6 Media and archival research (Phase 1)

In addition to interviews and focus group discussions, we drew on mainstream news media, social media and reports released by government and other agencies. This material assisted us in gaining a fuller overview of community perceptions of impact of the mine fire event and effectiveness of recovery activities. News items and social media posts were collected in two distinct phases – during the event and post-event. Phase 1 of data collection was from 9 February 2014 until 25 March 2014 (during the event), and Phase 2 was from 26 March 2014 until 30 September 2017 (covering the post-fire period up until the 3rd year of the Study). The numbers of articles and posts collected are shown in Table 5.

Table 5 Combined mainstream and social media during and after the Hazelwood smoke event

Collection phase	Mainstream media	Social media	Totals
Phase 1: During the smoke event (09/02/2014 to 25/03/2014)	360	802	1,162
Phase 2: After the smoke event (26/03/2014 to 30/9/2017)	736	907	1,643
Totals	1,094	1,709	2,805

Social media

In studying social media use during the mine fire, the Stream chose to focus on Facebook rather than Twitter or other types of social media. The main reason for this was because Facebook was the most popular social media platform in Australia at the time. Three Facebook groups were chosen for the study: *The Air that We Breathe*, *Voices of the Valley* and *Occupy Latrobe*. These were the most active and popular community-initiated Facebook groups during the Hazelwood mine fire. They were selected because they were active during the mine fire event, were focused on the mine fire, and were used by members to discuss and react to the mine fire. They did not necessarily represent the views of the entire population of the Latrobe Valley, but they did provide a useful case study to show how social media could be used during a crisis.

News media

Local mainstream news media stories were collected from the Latrobe Valley Express, WIN TV (Gippsland), and ABC Gippsland. Data on news items about the mine fire were also collected from Melbourne metropolitan and state-wide news sources including *The Age*, *The Herald Sun*, 9News, ABC TV, ABC Radio Melbourne and online sources such as Factiva, Informit and YouTube.

Morwell residents waiting for health concerns to be addressed after mine fire

Community group says there has been no recognition of the adverse health effects of the 45-day blaze

Morwell locals near the fire in a disused open-cut coal mine at the Hazelwood power station. Photograph: Mike Keating/Newspix/REX Photograph: Mike Keating/Newspix/REX

The Guardian 29 August 2014

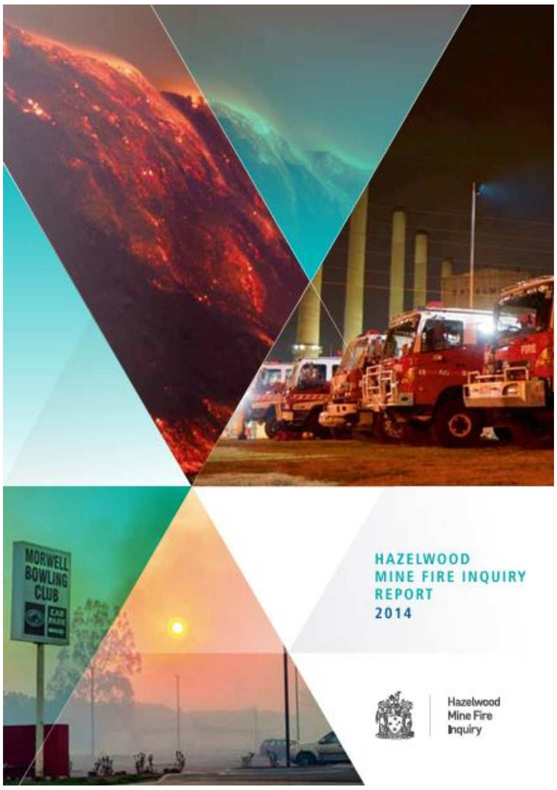
www.theguardian.com/world/2014/aug/29/morwell-residents-waiting-for-health-concerns-to-be-addressed-after-mine-fire

greg barber @GregMLC · Feb 24
Morwell, after two and half weeks of misery, you've made the front page of a metro newspaper. #quitcoal pic.twitter.com/knrKBbTQR8

Twitter post citing The Age, 25 February 2014

Archival research

To obtain data on the official communication during the HMFI,[3] we drew on archival material including previously published reports and submissions, including the Department of Health's submission to the HMFI, the HMFI Report,[3] and the Policy Review published by the HHS Older Persons Stream[68, 69] which contained substantial analyses of official communication during the HMFI.



4.5.2.7 Interviews with key stakeholders and community members (Phase 2)

Interviews with key stakeholders and members of the community were held in 2020-2021 (Round 1, 29 participants) and repeated in 2023 (Round 2, 30 participants). Participants were drawn from organisations involved in community recovery, other social service organisations, agencies set up in response to the mine fire (such as the Latrobe Valley Authority, Latrobe Health Assembly and Latrobe Health Advocate), and various organisations involved in community sports, education, multicultural groups, community advocacy and youth advocacy. Where possible, the same people were interviewed in both Round 1 and 2. If participants were unavailable or unwilling to participate in the Round 2, other people from the same organisation were invited to participate.

Discussion prompts on the topic of community wellbeing included:

- What does community wellbeing mean to you? What is important for creating a sense of wellbeing in the community?
- What are your perceptions of the current state of community wellbeing in this area?

- Do you think there have been events, initiatives or developments since the Hazelwood mine fire that have impacted on community wellbeing, either in a positive or a negative way? Can you tell me more about that?
- Are there other factors you can identify that you think are currently affecting community wellbeing?
- Do you think the wellbeing of this community will get better or worse into the future? Why do you think this?

Discussion prompts on the topic of personal wellbeing included:

- Are you experiencing any ongoing impacts, such as physical or mental health issues or any changes to your sense of personal wellbeing that you think are the result of the Hazelwood mine fire event?
- Can you tell me what issues you might have had, if any?
- Were these issues, if any, present prior to the mine fire and how did they change following the event?
- Did the recent bushfire period and smoke event bring back thoughts of the Hazelwood mine fire event? If so, can you tell me in what way.
- We're also interested in how your sense of community wellbeing affects personal wellbeing, and vice versa.
  - Do you think that the Hazelwood mine fire event has changed how you feel about living in Latrobe Valley?
  - Which characteristics of the community do you think have the biggest impact on your personal wellbeing - either in a good or bad way?
  - What helps you the most when you are dealing with events like the Hazelwood mine fire, the recent bushfires and the current impacts of the Coronavirus pandemic? For example, is it:
    - personal characteristics;
    - support from family and friends;
    - local services; and
    - other broader community factors?

In Round 1, a list of potential areas impacting community wellbeing, developed from literature in the field, was provided to interview participants prior to their interview. The following discussion prompts on the topic of factors impacting community wellbeing were included.

- Looking at the domains we have developed, can you suggest any other areas of community wellbeing that may not be captured by these categories?
- Looking at the list of themes we have identified under each domain:
  - Which ones do you see as being the most relevant for this community? Can you explain?
  - Which ones do you see as the least relevant? Can you explain?
- Can you think of other ways to measure or assess community wellbeing that have not been identified here?
- Which of these domains and themes do you think would be most sensitive to change in response to major events?

4.5.2.8 Indicators of community wellbeing sourced from existing datasets (Phase 2)

Based upon information collected from the Phase 2 interviews, the Stream has developed a Community Wellbeing Barometer focusing on five domains impacting wellbeing. Demonstrated in Figure 11, the domains are: services and infrastructure, social connection, environment, economy, and health; each of which are comprised of multiple themes.

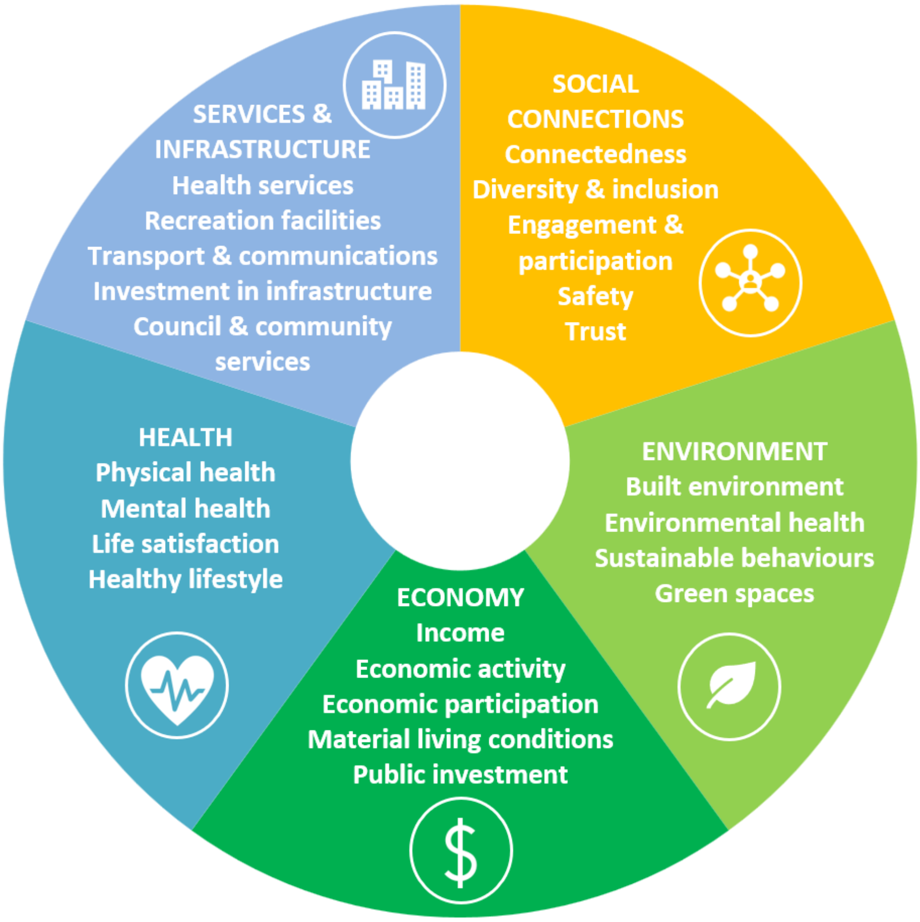


Figure 11 Model of the Community Wellbeing Barometer domains and themes

The Barometer draws upon a number of measures of community wellbeing sourced from existing publicly available datasets including:

Domain 1: Social Connections

- Australian Bureau of Statistics (ABS) Region Summary: Latrobe City – volunteering, preschool enrolments, educational attainment;
- Regional Wellbeing Survey (University of Canberra): crime and safety, feeling welcome;
- Victorian Population Health Survey: trust, tolerance of multiculturalism/diversity, feeling valued;
- Crime Statistics Victoria: rates of criminal and family violence incidents in Latrobe City;
- Victorian Health Promotion Foundation (VicHealth): sports participation; and
- Digital Inclusion Index: Latrobe City - digital inclusion score (access, affordability and ability).

Domain 2: Environment

- ABS Regional Summary: Latrobe City - protected land area, small scale solar panel installations;
- Regional Wellbeing Survey (University of Canberra): perception of environment;
- Australia's Environment Report (The Australian National University): tree cover, rainfall, days > 35ºC, emission of carbon from wildfire;
- Latrobe City Council performance data (annual reports): waste diverted from landfill;
- Victorian Local Government Grants Commission: council expenditure on environment; and
- EPA Air Monitoring: exceedances of $PM_{2.5}$ and $PM_{10.}$

Domain 3: Economics

- ABS Labour Statistics and Region Summary: Latrobe City - income, number of jobs and businesses, labour force statistics;
- Valuer-General Victoria (Land Use Victoria): house sales prices;
- Social Health Atlas (Public Health Information Development Unit; PHIDU, Torrens University Australia): low-income households under financial stress from mortgage or rent;
- Australian Institute of Health and Welfare (AIHW) specialist homelessness services annual reports: use of homelessness services;
- REMPLAN (Remplan.com.au): Latrobe City - real Gross Regional Product;
- Victorian Women's Health Atlas: female and male individual weekly income;
- Victorian Local Government Grants Commission: council expenditure (council functions); and
- Regional Wellbeing Survey (University of Canberra): cost of living affordability.

Domain 4: Health

- Victorian Population Health Survey: percentage of residents who are obese, sedentary, comply with fruit/vegetable consumption guidelines, have fair/poor health, have high psychological distress and/or are current smokers;
- Victorian Gambling and Casino Control Commission (VGCCC): gaming expenditure;
- Turning Point, Eastern Health: hospital admissions for drugs and alcohol;
- Australian Immunisation Register (Department of Health and Aged Care): infant immunisations;
- AIHW: use of Medicare-subsidised mental health-specific services;
- Regional Wellbeing Survey (University of Canberra): life satisfaction/feeling that life is worthwhile;
- ABS Region Summary: Latrobe City – need for assistance (chronic disease and disability); and
- School Entrant Health Questionnaire: prevalence of very good/excellent child health;

Domain 5: Services and Infrastructure

- AIHW: housing assistance;
- Social Health Atlas (PHIDU, Torrens University Australia): hospital admissions for potentially preventable conditions, residential care places;
- Latrobe City Council performance data (annual reports): satisfaction with council decisions and sealed roads, infrastructure per head of population, use of libraries and aquatic facilities;
- Regional Wellbeing Survey (University of Canberra): access to roads, public transport and telecommunications;
- Health Workforce Data (Department of Health and Aged Care): number of dental practitioners, medical practitioners and pharmacists; and
- AIHW hospital performance data: Latrobe Regional Hospital - emergency department waiting times.

Preliminary analysis of data using an initial selection of relevant indicators for each of the domains was undertaken. Those preliminary results were presented in two stakeholder consultations in late 2022, which included representatives from the Latrobe Health Assembly, Latrobe Health Advocate, Latrobe Valley Authority, Latrobe City Council and GPHN. Feedback was sought on the appropriateness of the initial set of indicators for each domain, whether the changes in each indicator over time were as expected (i.e., had face validity) and whether there were any areas missing and, if so, potential data sources to address those gaps. This feedback was used to revise the Barometer, to maximise its capacity to track community wellbeing in this region. The Barometer results have also been externally validated through comparison with other composite measures. Benchmarking has also been carried out against the State as a whole.

4.5.3 Data analysis

Both qualitative and quantitative forms of analysis were used in this Study. Quantitative analysis has the benefit of being able to provide an overview of broad trends, whereas qualitative research can address important questions in greater detail. The main qualitative approach used was thematic analysis, which identified prominent themes in texts (such as media texts, interview transcripts). Quantitative analysis of mainstream media and social media data was used to identify peaks of activity and to track the level of attention to specific events (especially the mine fire). Quantitative analysis of interview themes was used to establish which topics and themes were most frequently expressed. Quantitative analysis of data relating to measures in the Barometer was used to measure factors contributing to community wellbeing in order to compare changes over time.

4.6 Policy Review of the Impact on Older People

Led by Monash Rural Health, the Impact on Older People Stream completed its Report and Policy Brief in November 2017.[68, 69] A brief overview of this Stream's methods is provided here. The Older People Stream has since merged into the Community Wellbeing Stream, bringing together the findings from both programs of work, with the objective of ensuring that there continues to be a focus on the impacts of the event on older people across the broader Hazelwood Health Study research program.

4.6.1 Aims

The aim of this Stream was to assess the impact of the smoke event on older people, focusing particularly on a review of the policy decisions made with respect to older people during the event. The objective of this work was to inform best practice for future emergency events.

4.6.2 Data collection

Data collection included focus group discussions with over 90 local older people from key groups in the local community, as well as targeted interviews with 17 local decision-makers involved in overseeing the response and representatives of services who were engaged in supporting older people during and following the mine fire event. Additional information was collected via a literature review on older people and disasters. Further data collection included a review of key emergency management policies in Victoria at the time of the Hazelwood mine fire and how they intersected. This brought together a considerable body of knowledge from data gathered over 13 months with the conclusions drawn subsequently verified in a workshop with key respondents.

4.7 Cardiovascular Stream

Led by Monash University SPHPM, the Cardiovascular Stream has two parts. The first part was a clinical sub-study of the Adult Survey which concluded in 2018. The second part is a collaboration with Hazelinks (see sections 4.7.2 and 4.10) which is ongoing.

4.7.1 Cardiovascular Stream clinical sub-study

Detailed methods have been described elsewhere[14, 70-72] and only a brief overview is provided here.

4.7.1.1 Aims

The aims of the completed Cardiovascular Stream clinical sub-study were to determine whether exposure to smoke from the Hazelwood mine fire was associated with blood pressure; abnormal electrocardiographs (ECG); endothelial function (as a marker of early vascular disease); and inflammatory markers such as C-Reactive Protein (CRP).

The research questions were:

Is there evidence that people in general, and susceptible sub-populations in particular, who were heavily exposed to emissions from the Hazelwood fire, compared with otherwise similar people who were minimally exposed to emissions from the fire:

a) currently have clinical or sub-clinical cardiovascular conditions that could be associated with clinically important adverse health consequences in the future?
b) over time develop clinical or sub-clinical cardiovascular conditions that could be associated with clinically important adverse health consequences in the future?

4.7.1.2 Eligible subjects

Eligible subjects for the Cardiovascular Stream's clinical data collection were Adult Survey cohort members who were males aged 55-89 years or females 60-89 years. Cohort members who identified any underlying cardiovascular condition on the Adult Survey were oversampled to increase power, such that 50% of those invited had reported a diagnosis of angina, heart attack, heart failure, irregular heart rhythm/arrhythmia, stroke and/or other cardiovascular disease (CVD).

4.7.1.3 Recruitment

Approximately half (n=2,198) of the 4,056 Adult Survey cohort members met eligibility criteria for participation in the Cardiovascular Stream. Statistical power calculations indicated that a sample size of 330 Morwell and 165 Sale participants was required to observe a 33% difference in mean high sensitivity C-reactive protein (hsCRP) level, assuming two-sample t-test of logarithm transformed hsCRP values, a two-sided alpha value of 0.05 and 80% power. Invitations were sent to weighted random sub-samples of eligible participants between October 2017 and May 2018 until the desired sample size was achieved. In total, 1,333 Adult Survey cohort members received invitations into the Cardiovascular Stream clinical testing and 498 participated (336 from Morwell and 162 from Sale; see Figure 12).

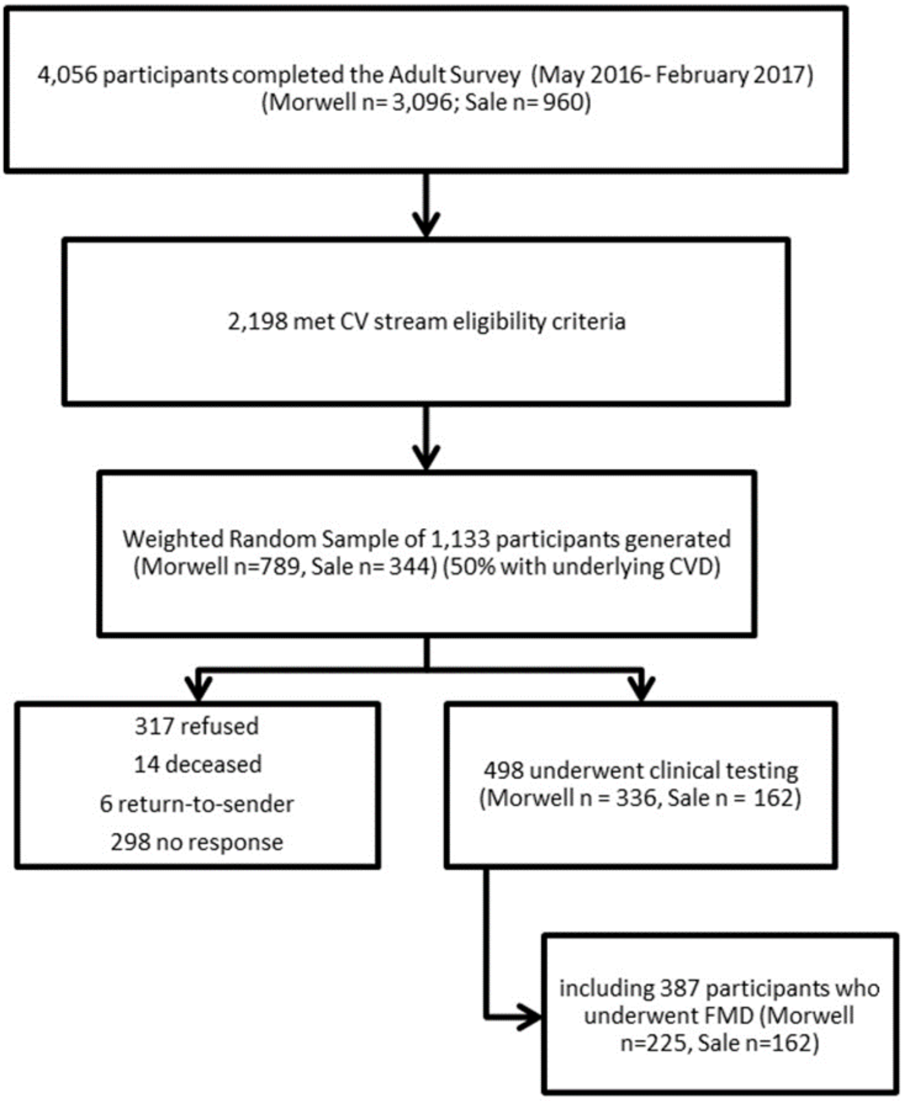


Figure 12 Participant recruitment into the Cardiovascular Stream clinical sub-study

4.7.1.4 Data collected

Data collected by interview:

- previously diagnosed cardiovascular conditions;
- family medical history;
- cigarette smoke exposure;
- alcohol use;
- physical activity;
- dietary habits/food frequency collected using the Australian Eating Survey®;[73] and
- medications.

Data collected by sonographer with vascular ultrasound:

- endothelial function by flow mediated dilatation (FMD).

Data collected by research nurse:

- 12-lead electrocardiograph (ECG);
- Biometrics;
- blood pressure; and
- blood sample.

Blood sample analysis

- hsCRP;
- fibrinogen;
- hs-troponin;
- N-terminal pro B-type natriuretic peptide (NT-pro-BNP);
- Lipids (cholesterol, triglycerides);
- glycosylated haemoglobin (HbA_{1c});
- creatinine; and
- estimated glomerular filtration rate (eGFR).

Endothelial function test being undertaken with ultrasound in the Cardiovascular Stream clinic

4.7.2 Cardiovascular Stream collaboration with Hazelinks

The Cardiovascular Stream's clinical sub-study concluded in 2018 and the Stream has since collaborated with Hazelinks in order to continue to monitor cardiovascular outcomes in the region. This collaboration identifies major adverse cardiovascular events (MACE) using VACIS (ambulance attendances), VACAR (cardiac arrests), VAED (hospital admissions) and VEMD (hospital emergency department presentations). See section 4.10 for greater detail.

The Hazelwood mine fire, February 2014

Photo courtesy of Keith Pakenham, CFA Victoria, Australia

4.8 Respiratory Stream

Led jointly by the Monash University SPHPM and Alfred Health Respiratory Medicine, the Respiratory Stream is a longitudinal sub-study of the Adult Survey.[14] Detailed methods have been described elsewhere[14, 74-77] and only a brief overview is provided here.

2017 Respiratory Stream clinic

4.8.1 Aims

The aims of the Respiratory Stream have been to determine whether exposure to smoke from the Hazelwood mine fire was associated with respiratory symptoms, asthma control and lung inflammation, rate of decline in lung function, gas transfer, small airway function and lung mechanics.

Specific research questions are:

Is there evidence that people in general, and susceptible sub-populations in particular, who were heavily exposed to emissions from the Hazelwood fire, compared with otherwise similar people who were minimally exposed to emissions from the fire:

a) currently have clinical or sub-clinical respiratory conditions that could be associated with clinically important adverse health consequences in the future?

b) over time develop clinical or sub-clinical respiratory conditions that could be associated with clinically important adverse health consequences in the future?

4.8.2 Eligible subjects

Eligible subjects were Adult Survey cohort members excluding those who had specified no further contact, were of unknown age or sex, or were aged over 90 years or were deceased. Adult Survey cohort members were further excluded where a contraindication to spirometry was identified – including recent surgery, myocardial infarction, pneumothorax, pulmonary embolism, open pulmonary tuberculosis or known aneurysms. A weighted random sample (to correct for lower response rate in some subgroups of participants, such as young people) of the eligible Adult Survey cohort was invited for assessment of respiratory function. Cohort members who had reported an asthma attack or current asthma medication use in the Adult Survey were oversampled (40%) to enable further evaluation of possible effects on asthma.

4.8.3 Recruitment

The Respiratory Stream has involved recruitment into three rounds of clinical testing, each intended to be approximately 3 years apart. Statistical power calculations indicated that an initial sample size of 339 Morwell and 170 Sale participants was required to observe a mean decline in forced expiratory volume in 1 second (FEV_1) in the Sale group of 23.1 (±17.1) ml/year, assuming a two-sample t-test, a two-sided alpha value of 0.05 and 90% power. Figure 13 outlines the Respiratory Stream's recruitment results.

Round 1 clinical testing was conducted between August 2017 and March 2018. As shown in Figure 13, a weighted random sample of 1,346 eligible Adult Survey participants was invited into Round 1 of the Respiratory Stream. Of those, 519 participated, forming the Respiratory Stream cohort. They comprised 346 adults from Morwell and 173 from Sale, slightly exceeding the required sample size.

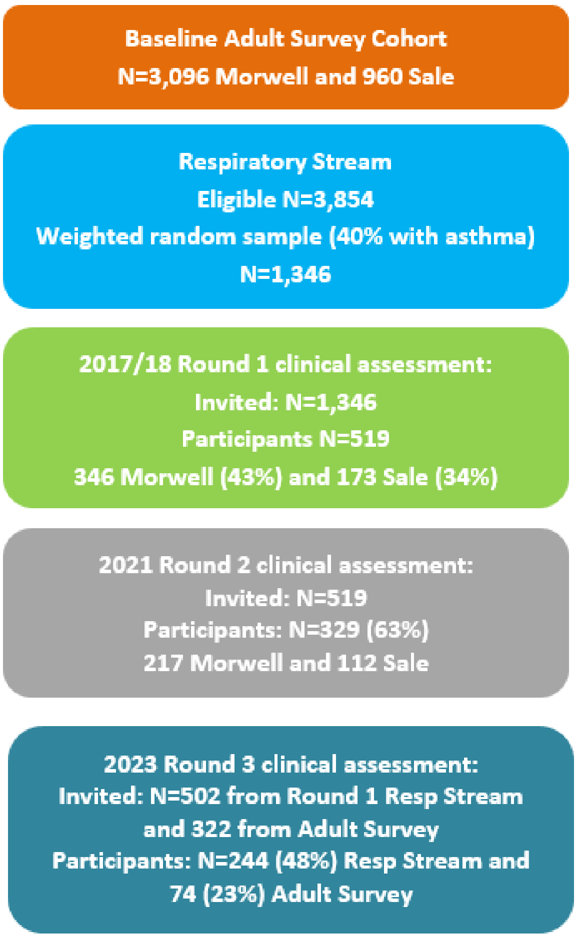


Figure 13 Participant recruitment from the Adult Survey into the Respiratory Stream clinical assessment rounds

Round 2 clinical testing was intended to take place in 2020, however, this was delayed due to the COVID-19 pandemic and associated restrictions. Testing for Round 2 was eventually undertaken between May and November 2021. From the Round 1 Respiratory Stream cohort of 519 adults, 329 (63%) participated in Round 2 (see Figure 13). This recruitment rate was lower than expected and it was believed that ongoing disruption associated with the pandemic was a likely contributor.

Round 3 clinical testing took place from June to October 2023. Invitations were sent to all Round 1 Respiratory Stream cohort members regardless of participation in Round 2, excluding those who had specified no further contact or had been identified as deceased (eligible N=502). Early recruitment rates were lower than hoped for. In response, and to maximise the value of the investment of resources into the clinic, the researchers decided to expand recruitment to include a limited sample of 322 Adult Survey cohort members who had not previously been recruited into the 2017 Respiratory Stream cohort. As shown in Figure 13, the final number recruited into the Round 3 Respiratory Stream clinical testing was 316, comprising 244 (48% of 502) Respiratory Stream cohort members and 74 (23% of 322) additional Adult Survey cohort members.

4.8.4 Data collected

Data collection has included:

- respiratory symptoms and medications;
- asthma history and control;
- allergen exposure;
- smoking history;
- fraction of exhaled nitric oxide (FeNO);
- spirometry before and after bronchodilator, including forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC) and FEV_1/FVC;
- respiratory system resistance and reactance by forced oscillation technique (FOT);
- small airways function via multiple breath washout (MBW) test;
- gas exchange by transfer factor for carbon monoxide (T_Lco);
- blood haemoglobin concentration; and
- Severe-acute-respiratory-syndrome-related coronavirus SARS-CoV-2 antibody test (in Round 3 only).

4.9 Long-term Respiratory Health Follow-up

Led jointly by the Monash University SPHPM and Alfred Health Respiratory Medicine, the Long-term Respiratory Health Follow-up was launched in 2022 and is a longitudinal sub-study of the Adult Survey.[14] Detailed methods have been described elsewhere[78, 79] and only a brief overview is provided here.

4.9.1 Aims

The Long-term Respiratory Health Follow-up aims to address the following research questions.

1. Does mine-fire smoke exposure predict poorer respiratory health eight years later?
    a. Are effects moderated by previous COVID-19 infection, the 2019-2020 Black Summer bushfires, or dietary quality?
2. Does smoke exposure from the mine fire or the 2019-2020 Black Summer increase the risk of COVID-19 infections and severity?
3. Is diet quality associated with slower deterioration in lung function in people with high mine-fire smoke exposure?

4.9.2 Eligible subjects

Eligible subjects were 2,385 living members of the Adult Survey cohort who had not declined further contact nor participated in the concurrent 2022 Mental Health and Wellbeing Follow-up Survey (see section 4.4.3), and for whom the researchers had current email or phone contact details.

4.9.3 Recruitment

Recruitment and data collection took place between August and December 2022. From 2,385 invited Adult Survey cohort members, 612 (26%) participated.

4.9.4 Data collected

Long-term respiratory symptoms

Respiratory symptom questions were derived from a modified version of the European Community Respiratory Health Survey (ECRHS) Short Screening Questionnaire and included current wheeze, chest tightness, nocturnal shortness of breath, resting shortness of breath, current nasal symptoms, chronic cough and chronic phlegm.[22, 80] These same questions had been asked in the baseline Adult Survey[14] and in each of the Respiratory Stream clinical assessments.

COVID-19 infection

COVID-19 infections were identified using a standardised questionnaire[81] with items about infections in 2020, 2021, 2022 (non-concurrent) or current. To identify likely but undiagnosed cases, participants were asked about a series of COVID-related symptoms[82] in the years 2020 and 2021 and each month in 2022. Probabilities were determined using a standardised formula based on symptoms and demographics.[82] Severe COVID-19 infections were indicated by self-reported hospitalisation.

Dietary quality

Diet quality was based on Australian Recommended Food Scores (ARFS) measured using the Australian Eating Survey® Food Frequency Questionnaire.[73]

Exposure to smoke from the 2019-2020 Black Summer

We asked participants about their locations during the 2019-2020 Black Summer bushfire period with the intention of examining how smoke exposure from that period could have compounded the effects of previous smoke exposure from the 2014 Hazelwood coal mine fire. However, as shown in Figure 14 there was little difference between Study sites (Morwell vs the rest of Latrobe Valley vs Sale) in ambient smoke distribution during the 2019-2020 Black Summer bushfire period.[78] As a result of this lack of variability, it was not practical to examine whether the 2019-2020 Black Summer exacerbated the Hazelwood coal mine fire's effects.

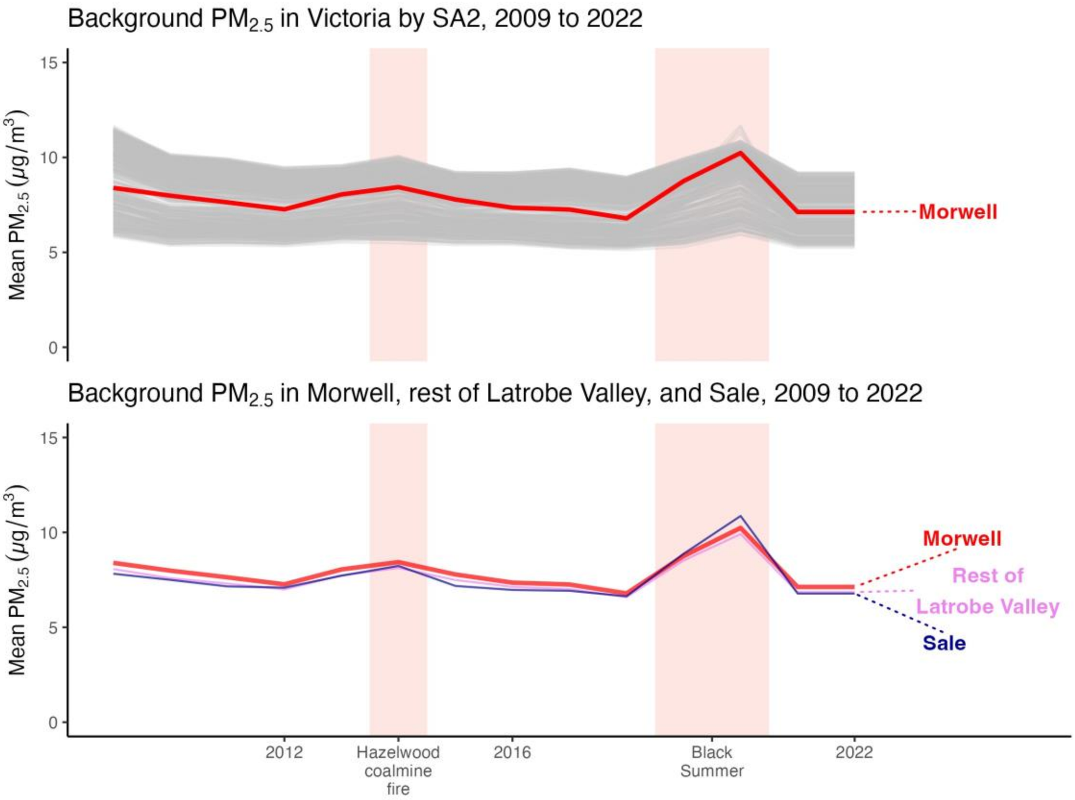


Figure 14 Background ambient $PM_{2.5}$ for 2009-2022, not including mine fire-related $PM_{2.5}$

4.10 Hazelinks, including Cancer Stream

Led by the Monash University SPHPM, Hazelinks is a study of adult health outcomes in the Gippsland region as indicated by routinely collected administrative data on health service use, medication dispensing, cancer and deaths. The Stream has two main components: an identified data linkage study and an anonymised data extraction study. Detailed methods have been described elsewhere[7, 83-87] and only a brief overview is provided here.


4.10.1 Identified linkage study

4.10.1.1 Aims

The Hazelinks identified linkage study primarily aims to identify members of the Adult Survey cohort who develop respiratory, cardiovascular, psychological or cancer conditions, or who die, by linking to routinely collected ambulance, hospital, cancer and death registry data health databases.

4.10.1.2 Eligible subjects and data sources

The Hazelinks identified linkage study comprises all Adult Survey cohort members (see section 4.2) who provided informed consent to the researchers accessing their information from relevant health databases. They included 2,223 (72%) Adult Survey cohort members from Morwell and 649 (68%) from Sale who consented to the researchers accessing their "*information from health databases such as ambulance, hospital, cancer and death records in future years for as long as it remains scientifically valid to do so*". Of those, a slightly smaller group, 2,115 from Morwell and 610 from Sale, also consented to the Victorian Department of Health extracting their "*hospital and emergency information in future years for as long as it remains scientifically valid to do so*."

The Hazelinks identified linkage study has since negotiated to receive a number of linked datasets as shown in Table 6.

Table 6 Datasets received by the Hazelinks identified linkage study

Data Custodian	Datasets	Time period included	Date received
Ambulance Victoria	VACIS and VACAR: ambulance attendances and cardiac arrests	01/01/2013 - 31/12/2017 01/01/2018 - 31/12/2022	November 2019 May 2023
Department of Health Centre for Victorian Data Linkage	VAED and VEMD: hospital admissions and hospital emergency department presentations	01/01/2009 - 01/03/2019 01/01/2009 - 31/05/2023	July 2019 Dec 2023
Cancer Council Victoria	VCR: cancers	01/01/1983 - 31/12/2019 01/01/1983 - 31/12/2021	October 2020 June 2023
Australian Institute of Health and Welfare	NDI: deaths	02/05/2016 - 27/06/2023 for date of death data and 02/05/2016 - 1/06/2021 for cause of death data	August 2023

Abbreviations: VACIS: Victorian Ambulance Clinical Information System; VACAR: Victorian Ambulance Cardiac Arrest Registry; VAED: Victorian Admitted Episodes Data; VEMD: Victorian Emergency Minimum Dataset; VCR: Victorian Cancer Registry; NDI: National Death Index.

4.10.2 Anonymous data extraction study

4.10.2.1 Aims

The Hazelinks anonymised data extraction study aims to investigate the short, medium and longer-term impacts of mine fire smoke upon the health of Morwell residents and those of the wider Latrobe Valley compared with Gippsland and south-eastern Victoria by accessing routinely collected Medicare, pharmaceutical, ambulance, hospital, cancer and death registry databases.

4.10.2.2 Data sources

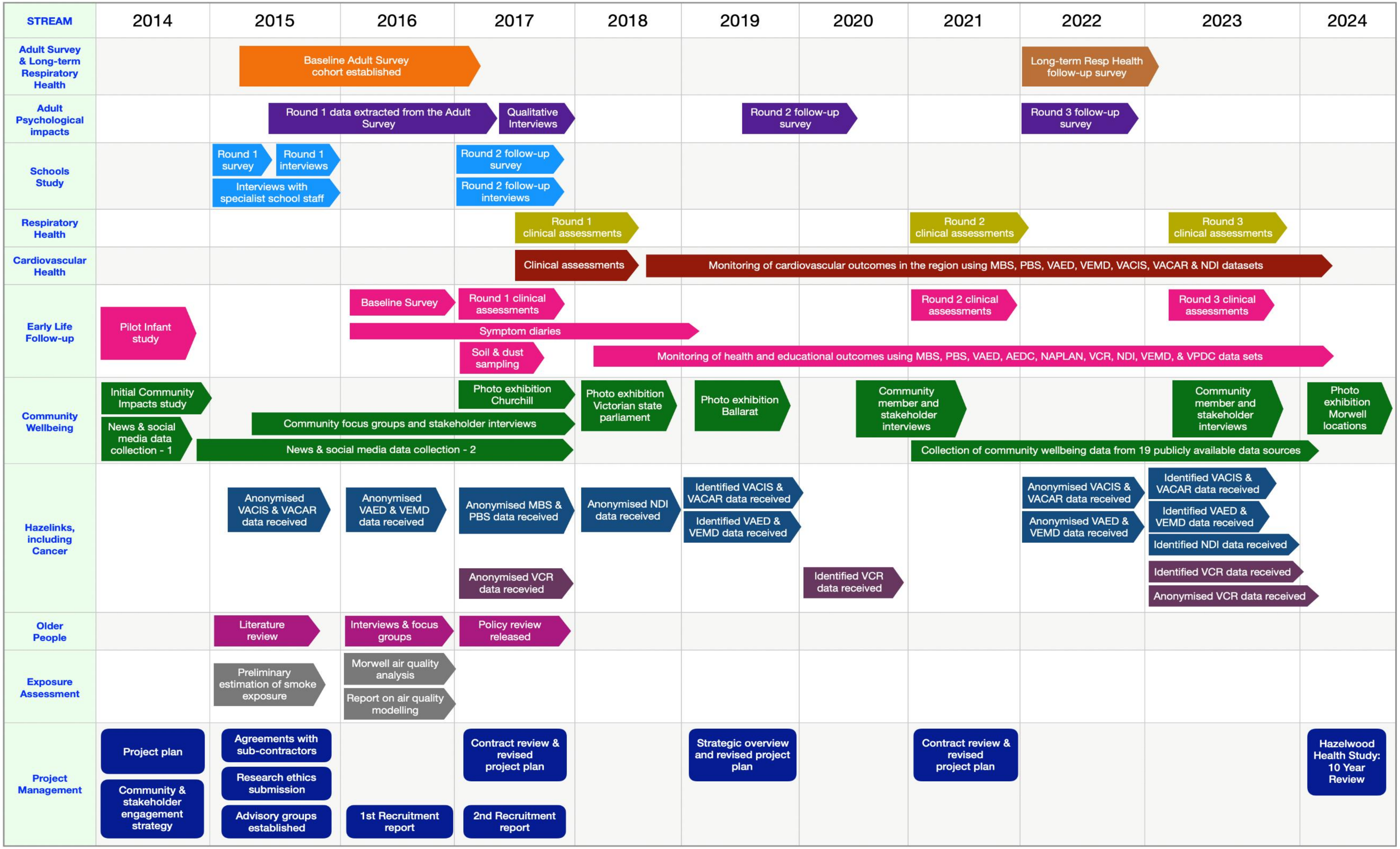
The data sources, time periods and geographical regions included in the Hazelinks anonymised data extraction study are shown in Table 7.

Table 7 Data sources, time periods and geographical regions included in the Hazelinks anonymised data extraction study

Data Custodian	Datasets	Time period and region included	Date received
Australian Institute of Health and Welfare	Medicare Benefits Schedule	01/07/2012 - 30/06/2016 Latrobe Valley SA3	May 2017
Australian Institute of Health and Welfare	Pharmaceutical Benefits Scheme	01/01/2013 - 31/12/2016 Latrobe Valley SA3	May 2017
Ambulance Victoria	VACIS and VACAR: ambulance attendances and cardiac arrests	01/01/2013 - 31/03/2015 Hume, Gippsland, Eastern Metropolitan	Sept 2015
		01/01/2013 - 31/12/2021 All of Victoria	January 2022
Department of Health Centre for Victorian Data Linkage	VAED and VEMD: hospital admissions and hospital emergency department presentations	01/01/2009 - 30/06/2015 Hume, Gippsland, Eastern Metropolitan, Cardinia	November 2016
		01/01/2009 - 30/06/2022 All of Victoria	November 2022
Cancer Council Victoria	VCR: cancers	01/01/2009 - 31/12/2015 SA3s Latrobe City, Baw Baw, South Gippsland, Wellington	March 2017
		01/01/2009 - 31/12/2021 All of Victoria	January 2023
Australian Institute of Health and Welfare	NDI: deaths	01/01/2009 - 31/12/2015	August 2023

Abbreviations: VACIS: Victorian Ambulance Clinical Information System; VACAR: Victorian Ambulance Cardiac Arrest Registry; VAED: Victorian Admitted Episodes Data; VEMD: Victorian Emergency Minimum Dataset; VCR: Victorian Cancer Registry; NDI: National Death Index.

4.11 Timeline indicating the Study's key data collection activities and contract deliverables



Abbreviations used in the table above: **MBS** (Medicare Benefits Schedule), **PBS** (Pharmaceutical Benefits Scheme), **VAED** (Victorian Admitted Episodes Data), **VEMD** (Victorian Emergency Minimum Dataset), **VACIS** (Victorian Ambulance Clinical Information System), **VACAR** (Victorian Ambulance Cardiac Arrest Register), **NDI** (National Death Index), **AEDC** (Australian Early Development Census), **NAPLAN** (National Assessment Program - Literacy and Numeracy), **VCR** (Victorian Cancer Registry), **VPDC** (Victorian Admitted Episodes Data).

Figure 15 Timeline indicating the Study's key data collection activities and contract deliverables

5 Overview of Hazelwood Health Study findings

In response to the research questions and further requested information, the HHS has made numerous findings which have been made available to a wide range of audiences. The Study Findings page on the HHS website (https://hazelwoodhealthstudy.org.au/study-findings) and the HHS Outputs Directory (Volume 3 Appendix 3) lists technical reports, scientific manuscripts, conference proceedings, videos, exhibits, lay language Research Summaries (Volume 3 Appendix 4) and Annual Reports. Also available on the HHS website are recordings of our annual community briefings (https://hazelwoodhealthstudy.org.au/news-and-events/community-briefings), and links to our e-newsletters (https://hazelwoodhealthstudy.org.au/news-and-events/e-newsletters) and news stories (https://hazelwoodhealthstudy.org.au/news-and-events/media).

This report presents only a broad overview of the Study's key findings. For in-depth descriptions and discussions of the findings, their strengths, weaknesses and implications, please refer to the numerous sources described above and the scientific manuscripts or technical reports referenced against each finding.

5.1 Requested Information 1 and 2 about key pollutants

RI 1 and 2 in regard to relevant key air pollutants and how they would be assessed, were informed by the Exposure Assessment Stream which involved collaboration with CSIRO to produce several reports on air quality related to the mine fire.[1, 4, 9]

5.1.1 Air quality monitoring

CSIRO's work initially included an evaluation of direct air quality monitoring which had been conducted by themselves and also EPA Victoria and CFA Victoria, for a range of criteria pollutants including $PM_{2.5}$, PM_{10}, CO, O_3, NO_2 and SO_2. Continuous monitoring of these pollutants was conducted at three sites; in the south of Morwell, in the east of Morwell and at Traralgon. However, monitoring in the Morwell locations did not commence until three to ten days after the fire started. Additional monitoring of air toxics (e.g., volatile organic compounds, carbonyls, polycyclic aromatic hydrocarbons, dioxins, furans and metals) started on 26 February 2014, when particle and CO concentrations had already subsided considerably. Since the fire was most intense during the initial two days before direct air monitoring program had commenced, it is likely that the highest smoke concentrations were not directly measured.[9]

Based on the delayed direct measurements, the highest $PM_{2.5}$ concentrations were observed in the southern part of Morwell with a maximum hourly $PM_{2.5}$ concentration of 1349 micrograms (millionths of a gram) per cubic metre of air (µg/m^3) and a maximum daily (24-hour) concentration of 731 µg/m^3. At that time in Australia, the National Environment Protection Measure outdoor air quality standard (Air NEPM) for $PM_{2.5}$ particles was, and remains, 25 µg/m^3 as a 24-hour average with a maximum allowable exceedance of no (zero) days.[88] Contemporaneously, the World Health Organization (WHO) Air Quality Guidelines recommended a 24-hour mean $PM_{2.5}$ limit of 25 µg/m^3; however, that has since been revised down to a 15 µg/m^3 limit (www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines). The measured 24-hour concentration of 731 µg/m^3 in southern Morwell was approximately 30 times higher than the Air NEPM standard and three to four times greater than the community Smoke, Air Quality and Health standard for $PM_{2.5}$ category of 'extremely poor' (www.emv.vic.gov.au/responsibilities/standards/the-community-smoke-air-quality-health-standard).

CSIRO reported that, during the Hazelwood mine fire, EPA Victoria recorded its highest 8-hour average CO concentration ever measured up to that time.[89] Direct measurements of CO peaked at 33 parts per million (ppm) in southern Morwell averaged across 8 hours. The corresponding NEPM outdoor air quality standard for CO was 9 ppm as an 8-hour average with a maximum allowable exceedance of one day per year. Also based on direct measurement, concentrations of O_3, NO_2, SO_2 remained within air quality guidelines and no significant impact from the Hazelwood mine fire was observed.

Based on CSIRO's research, and consistent with a growing international literature on the health effects of fine particles,[90, 91] the HHS researchers decided to focus on $PM_{2.5}$ as the key pollutant of concern. Whilst CO was also a pollutant of concern, its concentrations were both lower than, and co-linear with, $PM_{2.5}$. Therefore, differentiating the health effects of CO from $PM_{2.5}$ was not feasible.

5.1.2 Air quality modelling

Because of the sparseness of the monitors, and the fact that the fire was most intense prior to the start of the air monitoring, the pollutant concentration measurements were insufficient in time and space for a comprehensive study of exposure and health impacts due to the smoke. Therefore, CSIRO reconstructed the hourly spatial distributions of smoke (as represented by $PM_{2.5}$ and CO distributions) in and around Morwell by developing a methodology for estimating the fire emissions, and then building a high-resolution prognostic meteorological and dispersion model with local wind data assimilation and an appropriate plume rise mechanism.[7, 9]

The modelled air pollution data estimated that the hourly averaged concentration of $PM_{2.5}$ in southern Morwell reached as high as 3,730 µg/m^3 during the early days of the fire. This was in contrast to modelled background levels of about 6 µg/m^3; 'background' being defined as the level of $PM_{2.5}$ that would have been present if the mine fire had not taken place. In the same locality, modelled hourly concentrations of CO reached 58.6 ppm compared to modelled background levels of 0.07 ppm.[9]

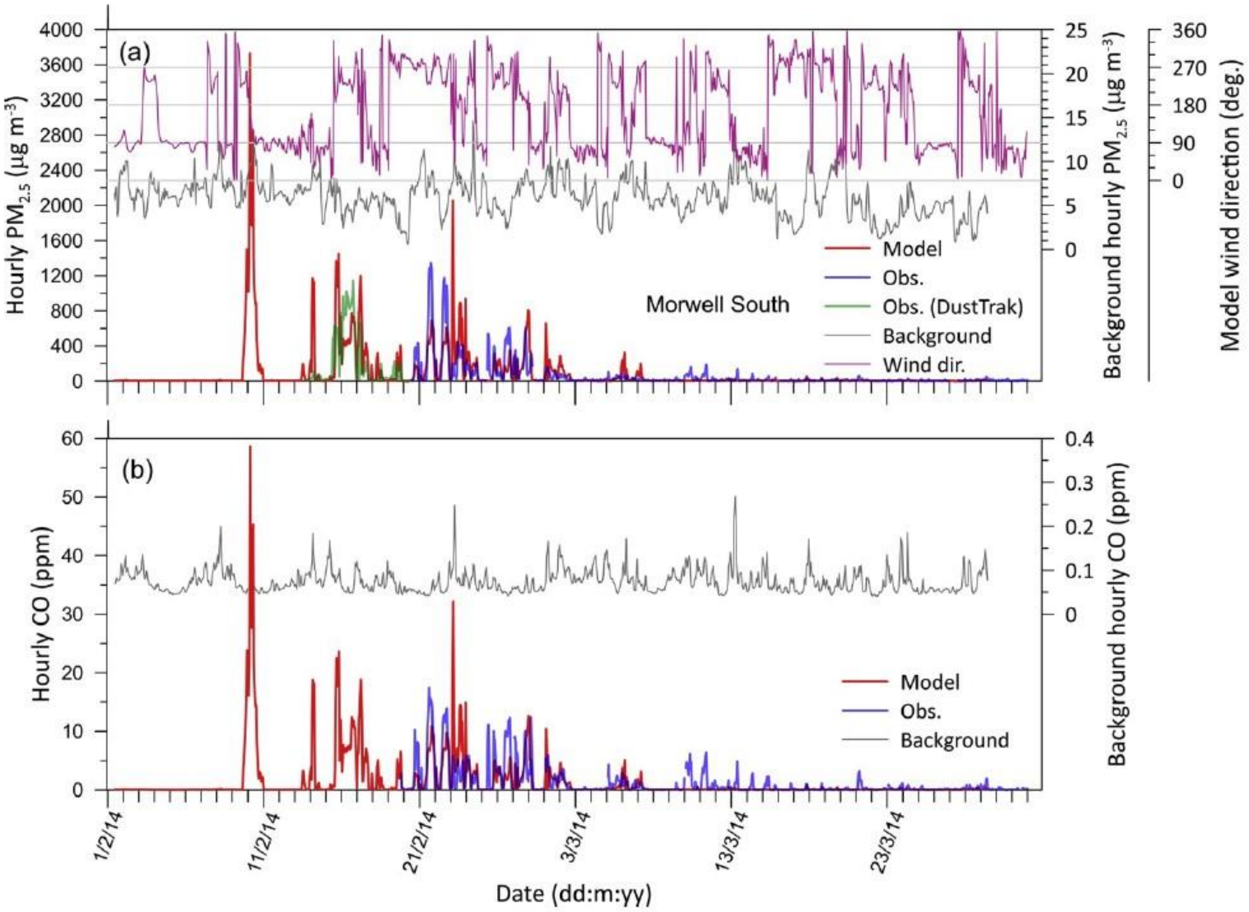
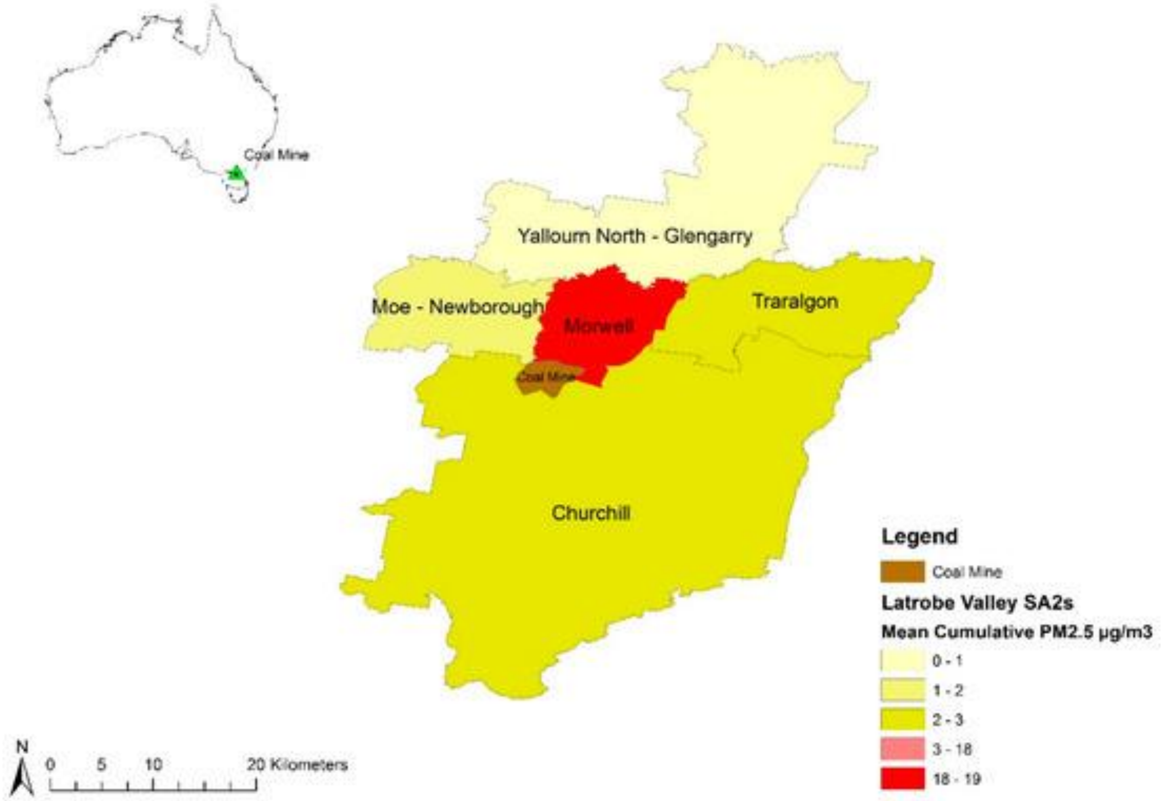


Figure 16 Time series of the hourly-averaged observed and modelled concentrations of (a) $PM_{2.5}$ and (b) CO in the southern part of Morwell with modelled background concentration and wind direction time series
(Source: Luhar *et al.* 2020)[9]

Figure 16 presents time series of the hourly-averaged observed (monitored) and modelled concentrations of $PM_{2.5}$ and CO in the southern part of Morwell, as well as the corresponding modelled background concentration and wind direction. Smoke concentration levels were often highest in the afternoons. The modelling showed that Morwell areas were exposed to the greatest number of exceedances of the daily averaged $PM_{2.5}$ Air NEPM standard of 25 µg/m³, with 23 days in southern Morwell and 12 days in eastern Morwell when the 24-hour average $PM_{2.5}$ was above the standard.[9] There were five days above the $PM_{2.5}$ Air NEPM standard at Traralgon, three days at Churchill and two days at Moe. The concentrations of $PM_{2.5}$ returned to usual background levels of about 6 µg/m³ in the Latrobe Valley by about 12 March 2014. The number of modelled exceedance days for CO was eight in southern Morwell, one in eastern Morwell and zero in other towns.[9] Figure 17 demonstrates the cumulative mean 24-hour modelled mine fire-related $PM_{2.5}$ concentrations across the Latrobe Valley for the period 9 February - 31 March 2014.



Insert top left indicates the location of the mine within Australia

Figure 17 Cumulative mean modelled 24-hour mine fire-related $PM_{2.5}$ concentrations across the Latrobe Valley SA2s for the period 9 February-31 March 2014 (Source: Johnson *et al.* 2019)[15]

5.1.3 Individual participant's exposure assessment

It was apparent from CSIRO modelling that $PM_{2.5}$ exposure concentrations varied greatly from morning to evening during the mine fire, from one day to the next, from one part of Morwell to another, and from Morwell to other towns in the Latrobe Valley and wider Gippsland region. This meant that individual people who were located in Morwell or the Latrobe Valley during the event could have experienced vastly variable concentrations of smoke exposure, depending on where they were on each day and night.

For this reason, Adult Survey participants and the parents of ELF Study children were invited to complete a time-location diary with their residential, work and any relocation addresses for each 12-hour day (6am to 6pm) or 12-hour night (6pm to 6am) of the mine fire period. The self-reported time-location diaries were used to create a metric which included every address reported, the SA1 in which those addresses were located and an estimate of the fraction of each 12-hour day, or 12-hour night, that the participant spent at that address. CSIRO's gridded high resolution 12-hourly $PM_{2.5}$ estimates were then linked to the participant's SA1s and associated fractions to give each participant a mine fire-related $PM_{2.5}$ exposure level for every 12-hour day and night of the mine fire period. These were then aggregated and averaged to estimate each individual's mean cumulative 24-hour fire-related $PM_{2.5}$ level.

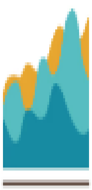
The frequency of Adult Survey participants across modelled mean cumulative 24-hour fire-related $PM_{2.5}$ levels is shown in Figure 19, section 5.2.1. The pattern of $PM_{2.5}$ exposure in the ELF Study identified cohort is shown in Figure 29, section 5.4.1.2.

Summary of key findings: Air pollutants

Since the fire was most intense during the initial two days before direct air monitoring had commenced, it is likely that the highest smoke concentrations were not directly measured.

Direct measurements in southern Morwell showed the maximum hourly $PM_{2.5}$ concentration to be 1349 µg/m³ and the maximum daily (24-hour) concentration to be 731 µg/m³; almost 30 times the 25 µg/m³ Air NEPM standard and three to four times greater than the community Smoke, Air Quality and Health standard for $PM_{2.5}$ category of extremely poor'.

During the mine fire, EPA Victoria recorded its highest 8-hour average CO concentration ever measured, peaking at 33 ppm in southern Morwell; almost four times the corresponding Air NEPM standard for CO.



Modelled air pollution data estimated that in southern Morwell the hourly averaged concentration of $PM_{2.5}$ reached as high as 3,730 µg/m³, and CO reached 58.6 ppm, during the early days of the fire. The daily averaged $PM_{2.5}$ Air NEPM standard of 25 µg/m³ was exceeded on 23 days in southern Morwell, 12 days in eastern Morwell, five days in Traralgon, three days in Churchill and two days in Moe. The CO Air NEPM standard was exceeded on 8 days in southern Morwell, one day in eastern Morwell and no days in other towns.

During the mine fire, modelled $PM_{2.5}$ exposure concentrations varied greatly across days and locations. Adult Survey participants and parents of ELF Study children completed a diary with their residential, work and any relocation addresses for each day and night of the mine fire period. Modelled high resolution $PM_{2.5}$ estimates were then blended with the diary data to give each participant a mine fire-related $PM_{2.5}$ exposure level for every 12-hour day and night of the mine fire period.

5.2 Research Questions 1 and 2: respiratory health

The respiratory health components of RQs 1 and 2 are informed by findings from the Adult Survey, the Respiratory Stream, Hazelinks and Long-term Respiratory Health Follow-up. Please note that those Streams deal with adult respiratory health. The respiratory health of children is addressed under RI 4 (see section 5.4).

5.2.1 Respiratory health findings from the Adult Survey 2.5 - 3 years after the mine fire

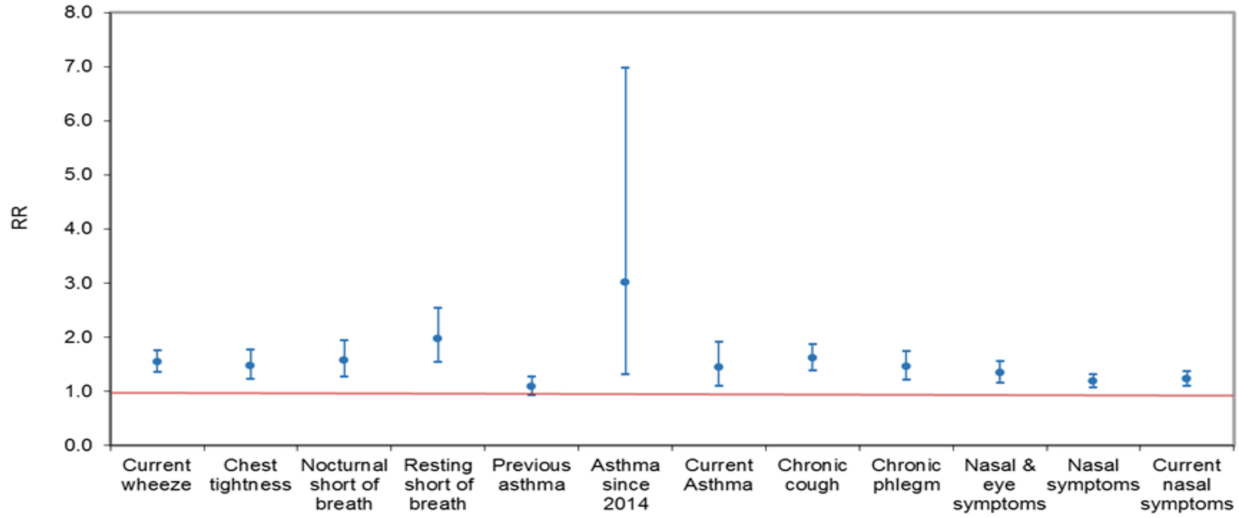
Morwell versus Sale

Approximately 2.5 to 3 years post-mine fire, self-reported respiratory symptoms in the previous 12 months, including current wheeze, nocturnal and resting shortness of breath, and irritant symptoms from the chest and nose consistent with chronic bronchitis and rhinitis, were more common in adult residents of Morwell than of Sale, after adjusting for age, sex, employment, education and smoking (Table 8 and Figure 18)[11, 14] Risk of self-reported doctor-diagnosed asthma was also increased. Furthermore, the Adult Survey responses indicated that self-reported symptoms of asthma were more severe (based on the Pekkanen asthma severity score)[23] among people with asthma from Morwell compared with people with asthma from Sale.[11]

Table 8 Self-reported respiratory symptoms and conditions in Morwell and Sale participants

Respiratory symptom or condition	Morwell participants	Sale participants			
	Weighted %	Weighted %	RR	Adj RR (95% CI)	p-value
Current wheeze	42.4%	25.8%	1.64	1.52 (1.33, 1.73)	<0.001
Chest tightness	26.8%	16.4%	1.63	1.48 (1.23, 1.79)	<0.001
Nocturnal shortness of breath	20.0%	11.4%	1.75	1.55 (1.26, 1.92)	<0.001
Resting shortness of breath	20.3%	8.9%	2.27	1.94 (1.50, 2.50)	<0.001
Asthma diagnosed 2013 or prior	25.7%	23.2%	1.11*	1.13* (0.96, 1.34)	0.140
Asthma diagnosed 2014 or later	1.9%	0.6%	3.49	3.71 (1.53, 8.98)	0.004
Current Asthma	11.5%	7.4%	1.56	1.46 (1.10, 1.94)	0.009
Chronic cough	30.9%	17.4%	1.78	1.60 (1.37, 1.86)	<0.001
Chronic phlegm	25.3%	15.1%	1.67	1.41 (1.18, 1.69)	<0.001
Nasal & eye symptoms	31.5%	22.7%	1.39	1.35 (1.16, 1.57)	<0.001
Nasal symptoms - ever	49.6%	41.5%	1.19	1.18 (1.07, 1.30)	<0.001
Current nasal symptoms	44.3%	35.4%	1.25	1.23 (1.10, 1.37)	<0.001
	Weighted mean (SD)	Weighted mean (SD)	Mean difference	Adj mean diff (95% CI)	p-value
Amongst asthmatics symptom severity score	3.64 (2.06)	2.85 (1.84)	0.79	0.58 (0.25,0.90)	<0.001

Abbreviations. Adj = adjusted; CI = confidence interval; diff = difference; RR = risk ratio; SD = standard deviation.

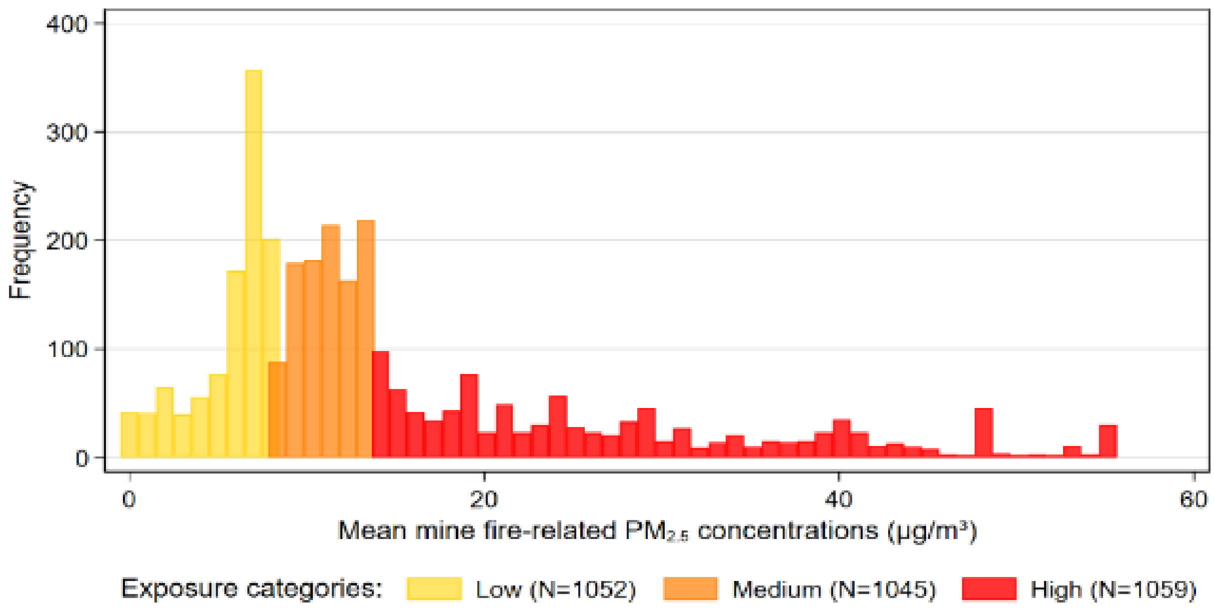


The red line indicates no difference in risk between Morwell and Sale.

Figure 18 Adjusted Rate Ratios and 95% Confidence Intervals for self-reported asthma and current respiratory symptoms in Morwell compared with Sale
(Source: Abramson et al. 2017, Figure 1)[11]

Mine fire-related $PM_{2.5}$ exposure and respiratory health

In order to present the associations between mine fire-related $PM_{2.5}$ exposure and respiratory outcomes collected in the Adult Survey, we first assessed $PM_{2.5}$ exposure in the Cohort.



The 2005 WHO Air Quality Guidelines recommended a 24-hour mean $PM_{2.5}$ limit of 25 µg/m^3

Figure 19 Frequency of Adult Survey participants across modelled mean cumulative 24-hour mine fire-related $PM_{2.5}$ levels
(Source: Blackman *et al.* 2017, Figure 2)[12]

As detailed in sections 4.1, 4.2.4 and 5.1, in order to estimate each participant's mine-fire related $PM_{2.5}$ exposure level, their Adult Survey time-location diaries were linked with CSIRO's modelled data.[4, 9, 14, 15] There were 899 Sale participants and one Morwell participant (who left the Latrobe Valley for the duration of the mine fire) with zero cumulative exposure to mine fire related $PM_{2.5}$. They comprised the 'no exposure' reference group. The remaining participants were divided into *low*, *medium* and *high* $PM_{2.5}$ exposure, groups based on tertiles of their average cumulative 24-hour exposure to $PM_{2.5}$. The distributions are shown in Figure 19 and Table 9 along with an indicator for the 2005 WHO Air Quality Guideline for 24-hour mean $PM_{2.5}$ which was the latest global version at the time of the mine fire (https://www.who.int/publications/i/item/WHO-SDE-PHE-OEH-06.02).

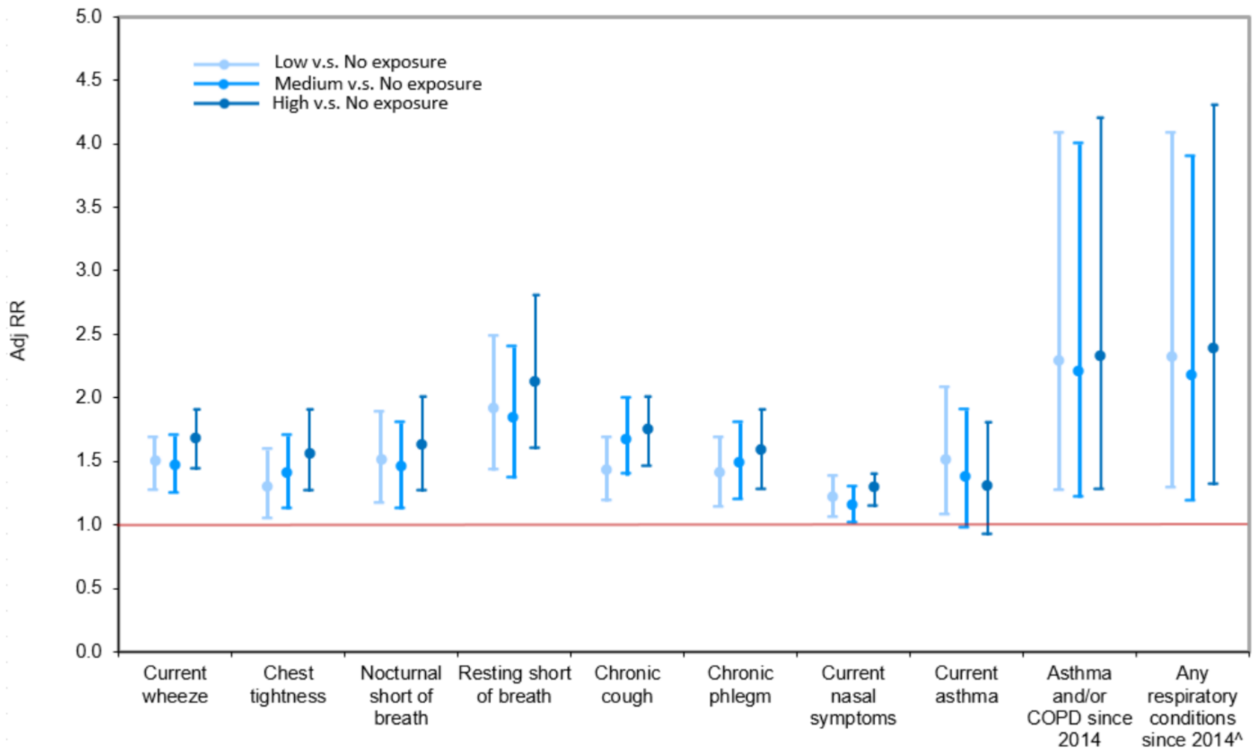
Table 9 Mean cumulative 24-hour fire-related $PM_{2.5}$ concentrations for Adult Survey participants by exposure tertile

No exposure N=900	Low N=1052	Medium N=1045	High N=1059
Weighted mean µg/m³ (Range)	**Weighted mean µg/m³ (Range)**	**Weighted mean µg/m³ (Range)**	**Weighted mean µg/m³ (Range)**
0 (0-0)	5.8 (>0.0-8.3)	11.2 (>8.3-14.1)	27.8 (>14.1-56.0)

(Source: Blackman *et al.* 2017, Table 3)[12]

The *low* exposure group included 992 participants from Morwell and 60 from Sale and the *medium* exposure group included 1,045 participants from Morwell and none from Sale. The *high* exposure group, comprising 1,058 participants from Morwell and one from Sale, represented the participants with the heaviest mine fire smoke exposure. Sale participants with mine fire-related $PM_{2.5}$ exposure were found to have been exposed because they worked, or travelled for other reasons, in the areas effected by mine fire smoke. In the *high* exposure group the mean cumulative 24-hour fire-related $PM_{2.5}$ level of almost 28 µg/m³ exceeded the 2005 WHO Air Quality Guideline of a 25 µg/m³ limit. It should be noted that the WHO have since revised the $PM_{2.5}$ Air Quality Guideline to a 15 µg/m³ limit (https://www.who.int/publications/i/item/9789240034228).

Approximately 2.5 to 3 years post-mine fire, participants in *low*, *medium* and *high* $PM_{2.5}$ exposure tertiles were at greater risk of all self-reported respiratory outcomes, than those not exposed (Figure 20).[12] The magnitude of the increases in respiratory symptom risk ranged from 15% to 110%. The Pekkanen asthma severity scores[23] were slightly higher in those with *low* (Mean 3.75, Standard Error; SE 0.15) or *high* (Mean 3.79; SE 0.15) versus no exposure (Mean 2.89; SE 0.14).[12]



The red line indicates no difference in risk between the exposed group and the not exposed group.
^ Comprises asthma, chronic obstructive pulmonary disease (COPD) and nasal allergy.

Figure 20 Adjusted Risk Ratios for self-reported respiratory symptoms or self-reported doctor-diagnosed respiratory conditions in Adult Survey participants with low, medium or high $PM_{2.5}$ exposure, each compared to those with no exposure
(Source: Blackman *et al.* 2019, Figure 3)[12]

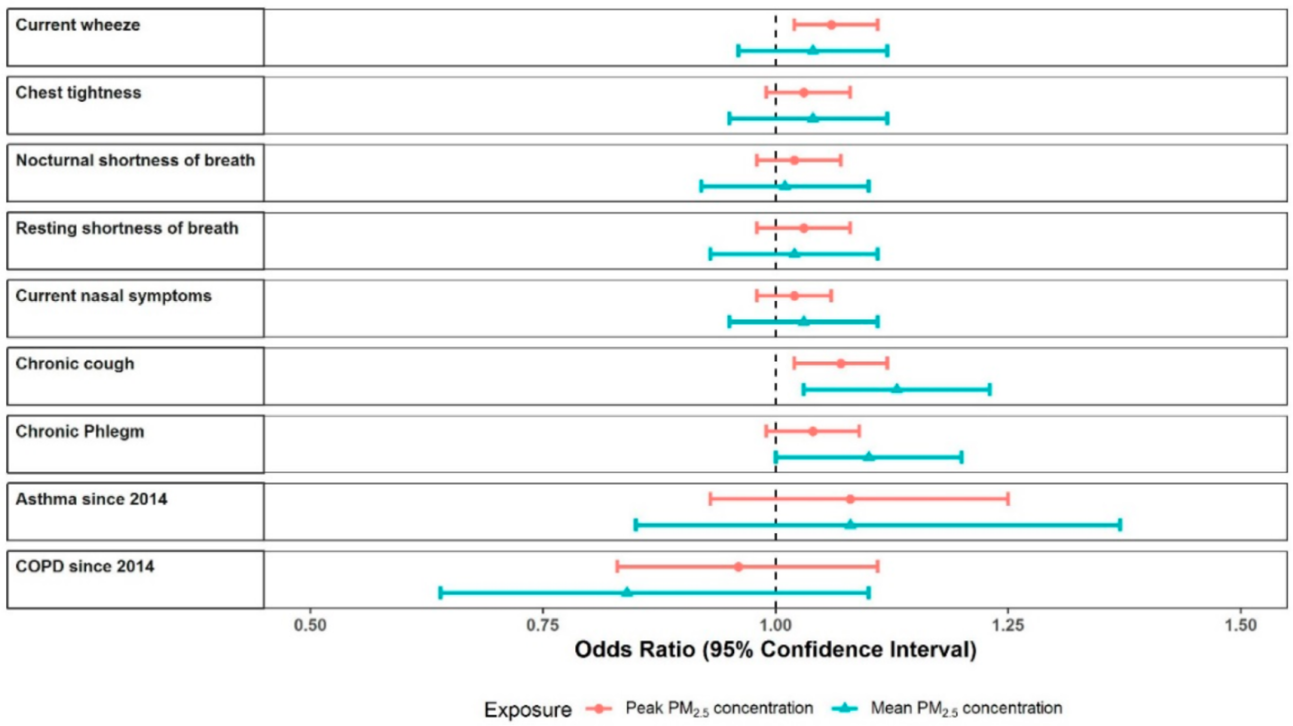


Figure 21 Multivariate model results for associations between Adult Survey respiratory outcomes and each 10 μg/m³ increment in mean $PM_{2.5}$ or each 100 μg/m³ increment in peak $PM_{2.5}$
(Source: Johnson *et al.* 2019, Figure 4)[15]

Further analysis utilised daily mean and peak mine fire-related $PM_{2.5}$ exposure as continuous data rather than tertiles of exposure category. Mine fire-related $PM_{2.5}$ exposure was associated in a dose-response relationship with increased odds of self-reporting cough, phlegm and wheeze (Figure 21).[15] There was a 13% increase in the odds of chronic cough per 10 µg/m^3 increment in mean $PM_{2.5}$, and a 7% increase per 100 µg/m^3 increment in peak $PM_{2.5}$.[15] Current wheeze was associated with peak $PM_{2.5}$; odds ratio, OR=1.06 (95% Confidence Interval; 95% CI 1.02-1.11) and chronic phlegm was associated with mean $PM_{2.5}$, OR=1.10 (95% CI 1.00-1.20).

Sex stratified analyses suggested that estimated dose-response ORs were generally higher for men compared with women (Figure 22).[15] The highest ORs were observed in men for self-reported doctor-diagnosed asthma since 2014: there was a 58% increase in odds per 10 µg/m^3 increment in mean $PM_{2.5}$ (OR 1.58, 95% CI 1.10 - 2.29) and a 43% increase in odds per 100 µg/m^3 increment in peak $PM_{2.5}$ (OR 1.43, 95% CI 1.14 - 1.78), with little evidence in women. Among men, the odds for chronic cough were increased by 20% per increment in mean $PM_{2.5}$ (OR 1.20, 95% CI 1.05 - 1.37) and 7% per increment in peak $PM_{2.5}$ (OR 1.07, 95% CI 1.00 - 1.14), and the odds for current wheeze were increased by 10% per increment in peak $PM_{2.5}$ (OR 1.10, 95% CI 1.03 - 1.17). Amongst women, the highest OR was for chronic cough; 1.06 (95% CI 1.00 - 1.12) per increment in peak $PM_{2.5}$, representing a 6% increase.

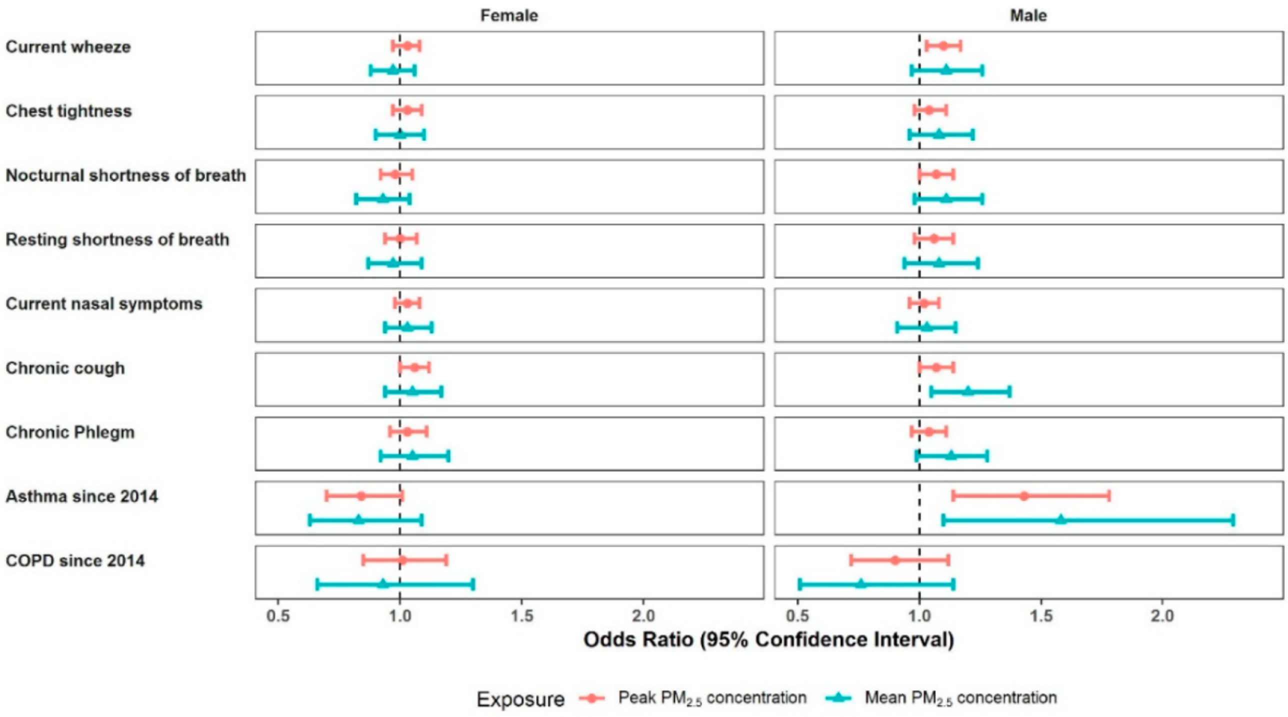


Figure 22 Sex stratified forest plots of multivariate model results for associations between respiratory outcomes and each 10 µg/m^3 increment in mean $PM_{2.5}$ or each 100 µg/m^3 increment in peak $PM_{2.5}$ (Source: Johnson *et al.* 2019, Figure 5)[15]

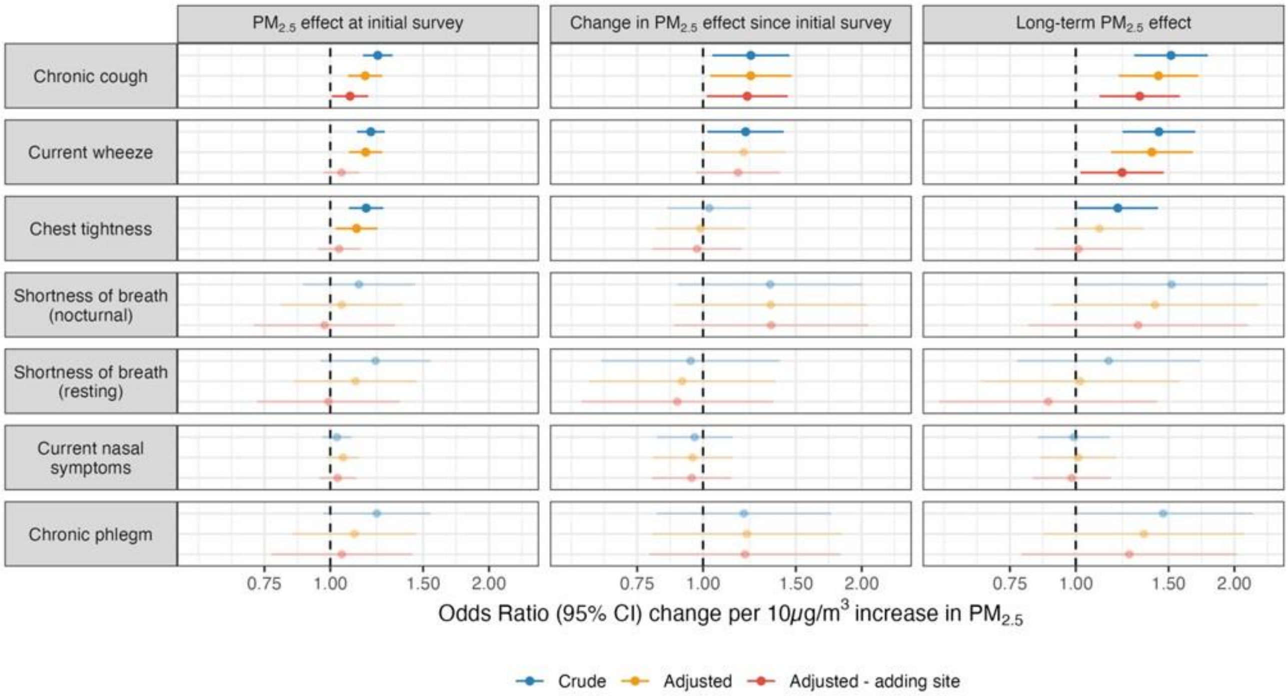
Age stratification (not shown) revealed associations between increments in mean $PM_{2.5}$ and increased odds of chronic cough OR 1.17 (1.04-1.30), and chronic phlegm OR 1.14 (1.02-1.28), amongst participants aged 64 or less. Those associations were not observed in participants aged 65 and over.[15]

Building materials of participants' residences were associated with respiratory outcomes (not shown). Residences constructed from brick/concrete were protective. This was possibly because, relative to weatherboard houses, there was reduced penetration of $PM_{2.5}$. Residences with roofs constructed from tin/metal were associated with increased symptom prevalence. This was possibly because, in the study area, houses with tin roofs were often constructed from weatherboard whilst houses with tile roofs were often constructed from brick.[15]

5.2.2 Respiratory health findings from the Long-term Respiratory Health Follow-up survey 8.5 - 9 years after the mine fire

Mine fire-related $PM_{2.5}$ exposure and longitudinal respiratory symptoms

From the 2016/17 Adult Survey cohort, 612 members participated in the 2022 Long-term Respiratory Health Follow-up survey (8.5-9 years post-fire).[92] Between the two surveys, the prevalence of self-reported chronic cough increased in association with mine fire-related $PM_{2.5}$ (Figure 23). There was also evidence, although weaker, of an association between mine fire-related $PM_{2.5}$ and increasing self-reported current wheeze over this time period. That is, the effect of mine fire smoke exposure on cough and, possibly wheeze, seemed to have increased over time.



Faded points and intervals indicate non-significant effects.

Figure 23 Associations between $PM_{2.5}$ and respiratory symptoms in the Adult Survey, change between the two survey rounds and the cumulative long-term effect at the 2022 Long-term Respiratory Health Follow-up
(Source: Lane *et al.* 2024, Figure 2)[92]

Furthermore, mine fire smoke-exposed people who had contracted COVID-19, compared to mine fire smoke-exposed people who had not contracted COVID-19, were more likely to report shortness of breath at night, chronic phlegm and possibly chest tightness. That is, mine fire smoke exposure and COVID-19 combined, resulted in more respiratory symptoms than mine fire smoke exposure alone.[92]

Mine fire-related $PM_{2.5}$ exposure and COVID-19

Previous research has linked $PM_{2.5}$ exposure to higher rates of COVID-19 infection, severity of COVID-19 illness and death.[93] One proposed causal mechanism is $PM_{2.5}$ leading to increased expression of the Angiotensin-Converting Enzyme 2 (ACE2) receptor, which the COVID-19 virus uses to bind to and infect cells throughout the body.[94] However, it is unclear whether the effect persists for years after exposure. Nor is it clear whether discrete but extreme exposures have this effect as most existing evidence is from background urban sources of $PM_{2.5}$, as opposed to landscape fire events like the Hazelwood coal mine fire.

The 2022 Long-term Respiratory Health Follow-up survey included standardised items to capture COVID-19 infections, hospitalisations, and vaccinations. 271 (44%) participants self-reported or met symptom criteria for at least one COVID-19 infection.[78] All models found a positive association, with odds of infection increasing by between 4-30% for every 10µg/m^3 increase in mean mine fire-related $PM_{2.5}$ exposure. However, across 24 modelling approaches this only achieved statistical significance in two models, and this was only when using a symptom-based rubric to identify likely COVID-19 cases. Unfortunately, one of the symptoms in this rubric was chronic cough, a known consequence of mine fire-related $PM_{2.5}$ exposure, increasing the likelihood that this finding was a false-positive.[78] There were insufficient hospitalisations to examine severity (n=7; 1%). The overall findings were inconclusive in being unable to rule out an effect of $PM_{2.5}$ exposure from coalmine fire on long-term vulnerability to COVID-19 infection. Given the positive association that was robust to modelling variations as well as evidence for a causal mechanism, the researchers consider it prudent to treat $PM_{2.5}$ from fire events as a risk factor for long-term COVID-19 vulnerability until more evidence accumulates.[78] An Editor of *Respirology*, the journal that this study was published in, wrote an editorial noting that the results were compelling enough to serve as a warning of the potential consequences of disasters like the Hazelwood coal mine fire.[95]

Mine fire-related $PM_{2.5}$ exposure, diet and respiratory symptoms

The 2022 Long-term Respiratory Health Follow-up survey included the Australian Eating Survey®, which was completed by 448 participants.[79] The purpose of including this validated food frequency questionnaire was to investigate whether the long-term adverse effects of $PM_{2.5}$ on respiratory health were moderated by diet quality. The results indicated that diet quality was generally poor in this sample, with 60% in the lowest category of overall diet quality.[79] However, higher diet quality and specifically fruit and vegetables, significantly diminished the association between $PM_{2.5}$ and prevalence of chronic cough and phlegm. That is, higher diet quality had a protective effect on respiratory health.[79] It was possible that antioxidants found in fruits and vegetables, especially vitamin C, carotenoids and flavonoids, may reduce respiratory damage caused by $PM_{2.5}$. In contrast, sauce/condiment intake was associated with a greater adverse effect of $PM_{2.5}$ on prevalence of chronic obstructive pulmonary disease (COPD).[79] No other moderating effects were significant. The moderating effects of overall diet quality and vegetable and fruit intake aligned with an *a priori* hypothesis, suggesting potential protective benefits. Considering the poor-quality diet in this community, we would encourage better eating habits including improving fruit and vegetable intake.

5.2.3 Respiratory health findings from Hazelinks

5.2.3.1 Population wide respiratory health findings using Hazelinks data

Extraction of anonymous emergency department presentations and hospital admissions data, January 2009 to June 2015

Analysis of this first extraction of anonymous emergency department presentations, and hospital admissions data, investigated whether there were increased risks of respiratory-related health service use during the coal mine fire period (defined as 9 February to 10 March 2014 for the purpose of these analyses), compared with non-fire periods.[96] The risks of emergency department presentations for ‘all respiratory diseases’ and COPD combined with asthma, and risk of hospital admissions for asthma, were increased during the fire period compared with non-fire periods.[96] Associations between daily concentrations of $PM_{2.5}$ and emergency department presentations for respiratory diseases appeared after two days’ exposure. In contrast, associations with hospital admissions for respiratory diseases appeared on the same day of exposure. A 10 µg/m^3 increase in 0-7 days moving average $PM_{2.5}$, was associated with a 22% increase in risk of emergency department presentations for COPD combined with asthma (95% CI 2% - 45%), a 28% increase in hospital admissions for COPD combined with asthma (95% CI 1% - 63%) and a 14% increase in emergency department presentations for ‘all‘ respiratory conditions (95% CI 2% - 29%).[96]

Extraction of anonymous hospital admissions and emergency presentations data, January 2009 to June 2022

Using this second extraction of anonymous emergency department presentations and hospital admissions data, we investigated whether smoke from the mine fire resulted in increased respiratory-related emergency department presentations or hospital admissions in Morwell or the Latrobe Valley, during the 8 years after the mine fire compared with before the fire and compared with service use trends in the rest of regional Victoria.[97] Findings were inconsistent. We found that, overall, respiratory-related emergency department presentations and hospital admissions remained unchanged in Morwell, however, increased slightly in the wider Latrobe Valley (Figure 24).[97] In the Latrobe Valley, people under age 65, and women, demonstrated an increase in respiratory-related emergency department presentations and hospital admissions. Amongst those subgroups there was also a pattern of increasing respiratory-related emergency department presentations in a dose-response relationship with $PM_{2.5}$ exposure (Figure 24). However, these findings in the Latrobe Valley were unlikely to represent mine fire effects, as they were not observed in Morwell.[97]

Extraction of anonymous ambulance attendance data, July 2010 to March 2015

Ambulance attendances for respiratory conditions increased by 41% during the mine fire period (defined as 9 February to 10 March 2014 for the purpose of these analyses), compared with the remainder of the period analysed (95% CI 11% - 78%).[98] This corresponded to approximately 37 additional ambulance attendances for respiratory conditions. Increases in $PM_{2.5}$ levels were followed by increases in ambulance attendances for respiratory conditions for about 5 days, during which each 10 µg/m^3 increase in $PM_{2.5}$ was associated with a 22% (95% CI 2% - 46%) increase in respiratory-related ambulance attendances.[98]

Extraction of anonymous ambulance attendance data, January 2013 to December 2021

These data showed no detectable change in respiratory-related ambulance attendances in Morwell or the Latrobe Valley during the 8 years after the mine fire, compared with before the fire and compared with service use trends in the rest of regional Victoria (Figure 24).[97]

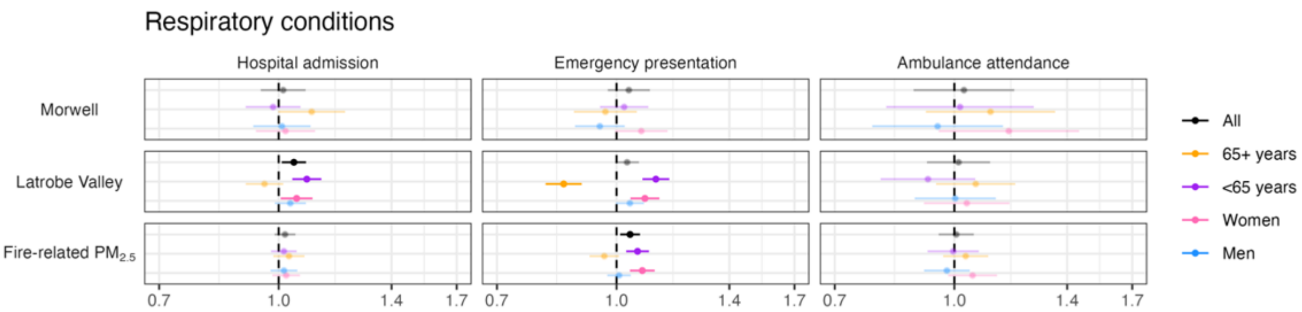


Figure 24 Relative risks for changes in respiratory-related hospital admissions, emergency presentations and ambulance attendances in the eight years following the mine fire (Source: Lane *et al.* 2024, Figure 3)[97]

$PM_{2.5}$ was associated with increased respiratory-related emergency presentations (RR 1.04, 95% CI 1.01 - 1.07 per 10 µg/m^3 increase in $PM_{2.5}$). Interestingly, where there were increases, they were predominantly observed among adults <65 years and women.[97]

Extraction of anonymous Medicare Benefits Schedule (MBS; July 2012 to June 2016) and Pharmaceutical Benefits Scheme data (PBS; January 2013 to December 2016)

Among men, but not women, each 10 µg/m^3 increase in $PM_{2.5}$ was associated with a 37% (95% CI 11% - 69%) increase in respiratory-related health service use during the mine fire period, as recorded in the MBS.[84] Increases in respiratory service use were predominantly observed in those aged 20-49 years, and not observed in older or younger subgroups. The MBS also showed an overall 11% increase in short and long General Practitioner (GP) consultations; however, the proportion of those that might be respiratory-related was unknown.[84] PBS data showed that, over a lag range of 3-7 days, each 10 µg/m^3 increase in $PM_{2.5}$ was associated with a 25% increase in the dispensing of prescribed respiratory medications (95% CI 19% - 32%).[7]

Extraction of anonymous mortality data for the period 1 July 2009 to 30 June 2015

During the first 30 days of the mine fire when $PM_{2.5}$ concentrations were at their highest (9 February to 10 March 2014), and during the following 6 months, compared with before and after these time periods, there was no increase in risk of respiratory-related deaths in Morwell, nor in the Latrobe Valley or surrounding areas.[99] This is unlikely to mean that the smoke posed no threat to people with respiratory illnesses. Instead, it was more likely that vulnerable people with respiratory illnesses took preventive action including leaving the smoke impacted areas, wearing protective masks, increasing their use of preventive medications (demonstrated above) and presenting to health services for assistance (also demonstrated above). It is also possible that the numbers of respiratory-related deaths were too small to detect an association with the mine fire period.

5.2.3.2 Respiratory health findings in the identified Adult Survey cohort using Hazelinks data

Linkage with Adult Survey participants' identified ambulance attendances (January 2009 to December 2017), hospital emergency department presentations (January 2009 to March 2019) and hospital admissions data (January 2009 to February 2019)

These data were used to evaluate the association between mine-fire-related $PM_{2.5}$ exposure and respiratory-related ambulance attendances,[100] hospital emergency department presentations[87] and hospital admissions[101] in the years following the mine fire. Data were available for up to 2,725 Adult Survey participants who consented to linkage.

Each 10 µg/m^3 increase in mine fire-related $PM_{2.5}$ was associated with a 21% increased hazard ratio (HR 1.21, 95% CI 1.02 - 1.44) for respiratory-related ambulance attendance over the following 3.5 years.[100] Each 10 µg/m^3 increase in $PM_{2.5}$ was associated with a 10% increase in respiratory-related emergency department presentations (HR 1.10, 95% CI 1.00 - 1.22) over the next five years.[87] Similarly, increments in $PM_{2.5}$ were also associated with a 9% increased hazard ratio (HR 1.09, 95% CI 1.01 - 1.17) for respiratory-related hospitalisations over the next five years, but these were only observed among females (HR 1.16, 95% CI 1.06 - 1.27). In particular, increased hazard ratios over five years were observed for hospitalisations for asthma (HR 1.43, 95% CI 1.19 - 1.73) and COPD (HR 1.14, 95% CI 1.02 - 1.28).[101]

5.2.4 Respiratory health findings from Respiratory Stream clinical assessments

Round 1 clinical assessments 3.5 to 4 years after the mine fire

Round 1 Respiratory Stream clinical assessments were conducted on 519 Adult Survey participants (346 from Morwell and 173 from Sale).[74, 75, 77] In a dose-response relationship, a 10 $\mu g/m^3$ increase in mean $PM_{2.5}$ exposure was associated with a 69% (95% CI 11% - 158%) increase in odds of spirometry consistent with COPD amongst non-smokers.[75] COPD is characterised by persistent obstruction of lung airflow. There was also a 30% increase in odds of chest tightness (95% CI 3% - 4%) and a 24% increase in odds of chronic cough (95% CI 2% - 51%) in the previous 12 months in all participants. Amongst current smokers, increments in mean $PM_{2.5}$ exposure were associated with a 113% (95% CI 24% - 265%) increase in odds of chronic cough.[75]

In addition to spirometry, Round 1 participants underwent a test of lung health using FOT. This test involved normal breathing on a machine while sound waves were used to measure the 'stretchiness' of the lungs and how easily air could move through them. It is normal for the lungs to become less stretchy (stiffer) as people age. However, we found that a 10 $\mu g/m^3$ increase in mine fire related $PM_{2.5}$ was associated with reduced stretchiness that you would normally observe after approximately four years of ageing.[74]

Round 1 participants also undertook a more complex test of ventilation heterogeneity, called multiple-breath washout. This measures how evenly and efficiently gases we breathe, such as oxygen and nitrogen, are mixed and distributed throughout different parts of the lungs as people breathe in and out. Uneven mixing of gases in the lung (termed *ventilation heterogeneity*) occurs in people with asthma, COPD or other small airway diseases, and is an indication of impaired lung function. Exposure to mine fire-related $PM_{2.5}$ was associated in a dose-response relationship with increasing conductive ventilation heterogeneity (indicating poorer mixing of gases), in the conductive region of the lung (Scond; β=1.57/kL, 95% CI 0.20 - 2.95, p=0.025).[102] It is normal for lung ventilation to become more uneven as we age. However, our findings indicated that each 10 $\mu g/m^3$ increase in smoke exposure was associated with a change in ventilation that you would normally observe after approximately 4.7 years of ageing.[102] This finding was independent of participants' actual age. No other MBW outcomes were statistically significant.

In adults from Morwell with asthma who were exposed to the smoke (n=165), compared to adults with asthma from Sale who were unexposed (n=64), there were no differences in asthma-related symptoms or severity, lung function or airway inflammation, but some evidence of poorer asthma control.[77] These findings were adjusted for age, employment, smoking and use of asthma medications, particularly inhaled corticosteroids.

Round 2 clinical assessments 7.5 years after the mine fire

Round 2 Respiratory Stream clinical assessments were conducted on 217 Adult Survey participants from Morwell and 112 from Sale.[103, 104] Round 2 participants undertook spirometry, FOT and also a breath test of airway inflammation called FeNO. Unlike Round 1, the previously observed airflow obstruction and reduced stretchiness in the lungs showed signs of recovery at Round 2.[104] Also, there was no evidence of airway inflammation.[103] That is, 7.5 years after the mine fire, higher levels of smoke exposure appeared to be no longer associated with poorer lung function in adults.

Round 3 clinical assessments 9 years after the mine fire

Round 3 Respiratory Stream clinical assessments were conducted on 164 Adult Survey participants from Morwell and 80 from Sale. Similar to the Round 2 results, higher levels of smoke exposure were not associated with poorer lung function in adults, indicating potential recovery evident 9 years after the mine fire.[105]

Considerations

We could not be absolutely certain that the mine fire smoke caused the features of COPD, reduction in lung stretchiness, or ventilation heterogeneity observed at Round 1. Other factors could have affected lung health, such as genes, previous exposure to other sources of smoke, respiratory infections or access to health services or treatment.

The improvements that we observed at Round 2, which were maintained at Round 3, may have reflected a true recovery in lung health after 7.5 and 9 years. However, many participants from Round 1 did not take part at Round 2 or Round 3, which meant that we couldn’t know whether their lung health also improved or not.

2021 Respiratory Stream clinic

Summary of key findings: Respiratory health in adults

During the mine fire period, small increases in smoke exposure levels were associated with 25% increases in dispensing of respiratory medications and, among men, 37% increases in respiratory health-related consultations.

Using population-wide ambulance data: During the mine fire period, there were approximately 37 additional ambulance attendances for respiratory conditions. Increases in smoke levels were followed by increases in ambulance attendances for respiratory conditions for about 5 days. In the following 8 years, there were no changes in respiratory-related ambulance attendance rates in Morwell or the Latrobe Valley compared with before the fire and compared with trends in the rest of regional Victoria.

Using ambulance data linked to study participants: Small increases in smoke exposure levels were associated with 21% increases in respiratory-related ambulance attendances over a 3.5-year period.

Using population-wide hospital data: During the mine fire period, increasing smoke levels were associated with increases in emergency presentations and hospital admissions for COPD combined with asthma, and with increases in emergency presentations for ‘all respiratory diseases’. In the following 8 years, there were no changes in respiratory-related emergency presentations or hospital admissions in Morwell compared with before the fire and with trends in the rest of regional Victoria.

Using hospital data linked to study participants: Small increases in smoke exposure levels were associated with 10% increases in respiratory-related emergency department visits and, among women, 9% increases in hospitalisations over a 5-year period.

During the 6 months after the fire in Morwell, there was no observed increase in risk of death from respiratory conditions.

Approximately 2.5-3 years after the fire, smoke exposure was associated with increased respiratory symptom reporting, particularly cough, phlegm and wheeze.

At 8.5-9 years after the fire, the effect of mine fire-smoke exposure on self-reported cough and, possibly wheeze, had increased. Mine fire smoke exposure also possibly increased risk of COVID-19 infection. Better quality diet had a protective effect on respiratory health.

In clinical assessments 3.5 to 4 years after the fire, mine fire-smoke exposure was associated with increased chest tightness and chronic cough, reduced lung stretchiness and poorer mixing of gases in the lungs. Amongst non-smokers, exposure was also associated with increased COPD. Amongst smokers, exposure was associated with chronic cough. In exposed asthmatics compared to unexposed, there was some evidence of poorer asthma control. At clinical assessments 7.5 and 9 years after the mine fire, previously observed associations between mine fire smoke exposure and poorer lung health were no longer evident, suggesting recovery.

5.3 Research Questions 1 and 2: cardiovascular health

The cardiovascular health components of RQs 1 and 2 are informed by findings from the Adult Survey, the Cardiovascular Stream and Hazelinks. Please note that those Streams deal with adult cardiovascular health. The cardiovascular health of children is addressed as part of RI 4 (see section 5.4).

5.3.1 Cardiovascular health findings from the Adult Survey

Morwell versus Sale

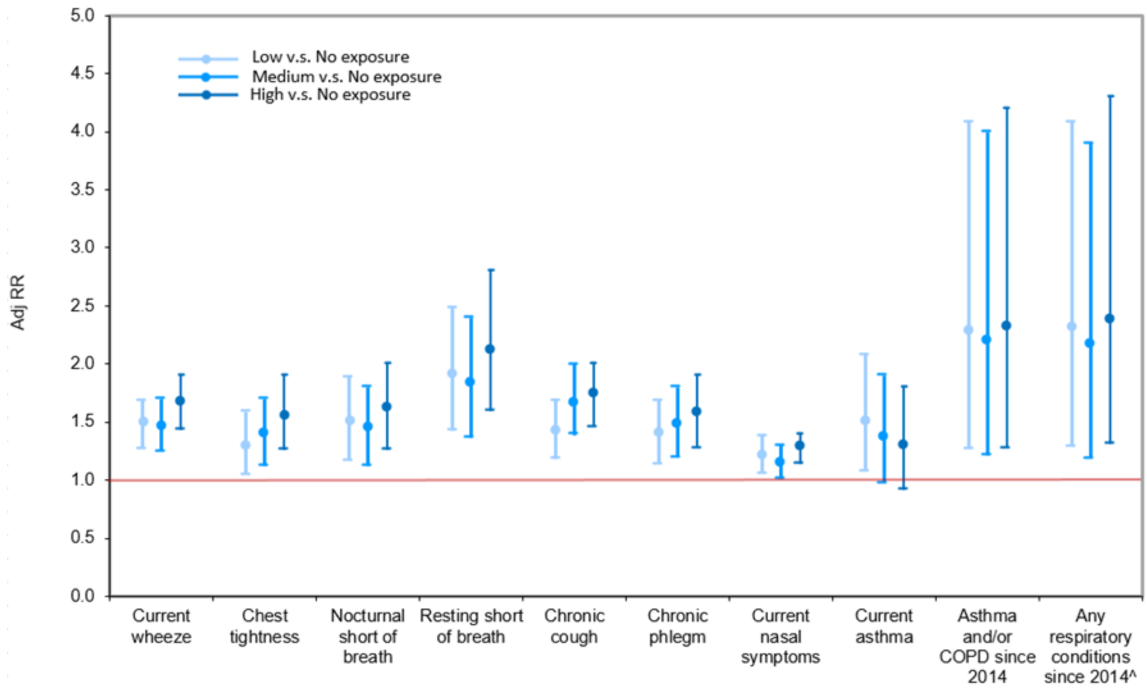
Self-reported, doctor-diagnosed medical conditions data indicated that, prior to the mine fire, there was a higher prevalence of high cholesterol (adjusted prevalence ratio; adj PR 1.24, 95% CI 1.08 - 1.42) and angina (adj PR 1.48, 95% CI 1.02 - 2.14) among Morwell participants compared to Sale participants, but a lower prevalence of arrhythmias/abnormal heart rhythms (adj PR 0.78, 95% CI 0.63 - 0.97). The prevalences of other pre-existing cardiovascular conditions were similar between the two towns.[11]

In the 2.5 to 3 years since the mine fire, Morwell participants were more likely to report doctor-diagnosed high blood pressure (adjusted relative risk; adj RR 1.41, 95% CI 1.01-1.96) and 'heart attacks' (adj RR 6.98, 95% CI 1.64 - 29.7). However, the numbers reporting 'heart attacks' were very small: 1.0% and 0.1% in Morwell and Sale respectively.[11] Further analyses of ambulance, hospital and anxiety symptom data for these participants were considered important to provide some insight into the accuracy of these self-reported findings.


Stock image

Mine fire-related $PM_{2.5}$ exposure and cardiovascular health

There were no detectable associations between $PM_{2.5}$ exposure categories and self-reported doctor-diagnosed high blood pressure, high cholesterol or 'any' cardiovascular disease (comprising angina, heart attack, heart failure, arrhythmia, stroke or other heart diseases) first presenting in 2014 or during the 2.5 to 3 years after the mine fire.[12] This included the finding of no detectable difference in self-reported doctor-diagnosed cardiovascular outcomes between people exposed and not exposed, between *medium* and *low* exposure, or between *high* and *low* exposure categories, during the period 2.5 to 3 years since the mine fire (Figure 25).[12]



The red line indicates no difference in risk between the exposed group and the not exposed group. ^ Comprised self-reported doctor diagnosed angina, heart attack, heart failure, arrhythmia, stroke or other heart disease in 2014 or during the 2.5 to 3 years after the fire.

Figure 25 Adjusted Risk Ratios for self-reported doctor-diagnosed medical conditions in participants with low, medium or high exposure, each compared to those with no exposure

5.3.2 Cardiovascular health findings from the adult Cardiovascular Stream clinical assessments

Approximately 3.5 to 4 years after the mine fire, cardiovascular testing was undertaken on 498 participants drawn from the Adult Survey; 336 from Morwell and 162 from Sale.[14, 70, 72] When comparing exposed Morwell with unexposed Sale adults, there were no differences in blood levels of high sensitivity C-reactive protein (hsCRP), a well-established inflammatory marker associated with cardiovascular disease.[72] Also, there were no differences in blood levels of NT-proBNP, which indicated reduced heart function, or troponin, which indicated heart muscle damage.[72] Furthermore, there were no differences in terms of the presence of atrial fibrillation (a common irregular heart rhythm) or underlying heart disease detected via ECG. Finally, there were no differences in measured blood pressure, nor FMD detected via ultrasound, which were markers of blood vessel health.[72] However, cholesterol levels were slightly higher in Sale participants.[72]

Cardiovascular Stream clinic, 2017

When FMD was investigated more closely, there was no evidence of a difference between participants with *high*, *medium*, *low* and *no* mine-fire related $PM_{2.5}$ exposure (4.09% vs 4.06% vs 4.02% vs 3.98%, respectively, p=0.99).[70] Overall, the cardiovascular testing suggested no association between Hazelwood mine fire smoke exposure and subclinical cardiovascular disease 3.5 to 4 years after the fire.

Supplementary analysis of dietary data, which had been collected because of its potential confounding effects on cardiovascular health, showed that more than half of the Cardiovascular Stream participants did not meet recommended intakes of fibre, while 60% of men and 42% of women exceeded recommended dietary sodium intakes.[106] Higher diet quality in terms of intake of vegetables, grains and non-processed meat, as well as intake of non-fried fish, was associated with more favourable cardiometabolic risk profiles, while sugar-sweetened soft drink intake was strongly associated with adverse cardiometabolic risk factor levels.[106] These findings have since formed the basis of a study called My FoodSwaps, funded by the Latrobe Health Assembly (www.healthassembly.org.au/all-projects/my-foodswaps/).

5.3.3 Cardiovascular health findings from Hazelinks

5.3.3.1 Population wide cardiovascular health findings using Hazelinks data

Extraction of anonymous mortality data (July 2009 to June 2015)

Health effects during, and up to 6 months after, the mine fire period: During the first 30 days of the mine fire there was no increase in risk of cardiovascular-related deaths in Morwell, the Latrobe Valley or surrounding areas. However, in the six months immediately after the mine fire, a 62% increase (95% CI 25% - 110%) in risk of death from cardiovascular conditions was observed in Morwell including an 88% increase (95% CI 32% - 167%) in deaths from ischaemic heart disease (IHD).[83, 99] In total, there were 26 cardiovascular-related deaths in Morwell attributed to this six month post-mine fire period, including 17 with IHD. These 26 cardiovascular deaths represented 38% of all cardiovascular deaths in Morwell during this six-month period. Males and residents aged 80 and above in the Latrobe Valley were at an increased risk of death from IHD in the six months after the fire.[83, 99]

Extraction of anonymous Medicare Benefits Scheme (MBS) and Pharmaceutical Benefits Schedule (PBS) data (July 2012 to June 2016)

Health effects during the mine fire period: There was no observed association between $PM_{2.5}$ and use of cardiovascular health services recorded in the MBS, such as specialist consultations and diagnostic tests.[84] There was an 11% increase in short and long GP consultations, but the proportion that were cardiovascular-related was unknown.[84] However, there was a 10% increase in the dispensing of prescribed cardiovascular medications over a lag range of 3-7 days, associated with each 10 $\mu g/m^3$ increase in $PM_{2.5}$.[7]

Extraction of anonymous ambulance attendance data (July 2010 to March 2015) and emergency department presentations and hospital admissions data (January 2009 to June 2015)

Health effects during the mine fire period: Analysis of this first extraction of anonymous ambulance attendance, emergency department presentations and hospital admissions data, investigated whether there were increased risks of cardiovascular-related health service use during the coal mine fire period (defined as 9 February to 10 March 2014 for the purpose of these analyses), compared with non-fire periods.[96, 98] There was no association with the mine fire period, or daily concentrations of $PM_{2.5}$, and ambulance attendances,[98] emergency department presentations nor hospital admissions for cardiovascular conditions, including IHD.[96] However, there was a non-significant trend for cardiovascular-related ambulance attendances to increase between lag 2–5 days (Figure 26).[98]

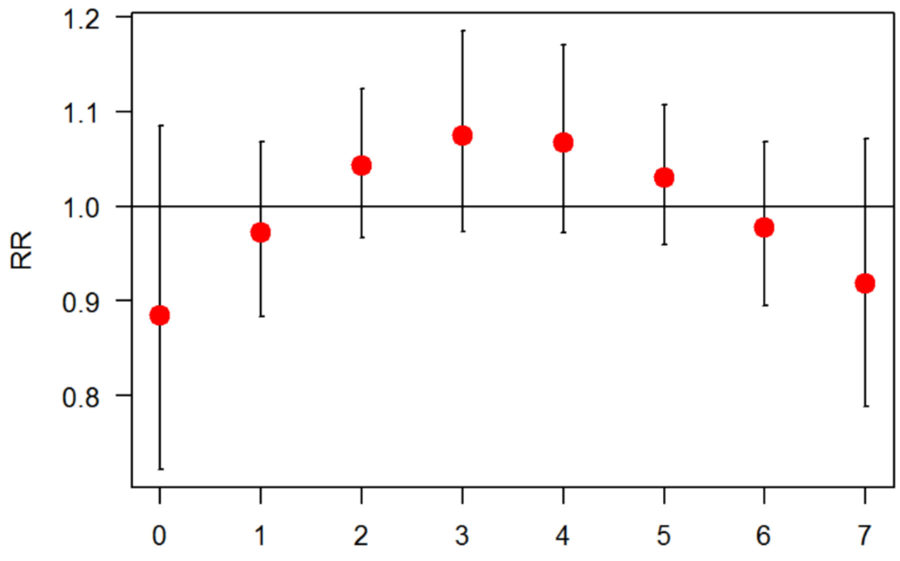


Figure 26 Relative risk for a cardiovascular-related ambulance attendance on the specified lag day, associated with a $PM_{2.5}$ exposure level of 10 µg/m^3 on day zero relative to no exposure on day zero

Extraction of anonymous ambulance attendance data (January 2013 to December 2021) and hospital admissions and emergency presentations data (January 2009 to June 2022)

Health effects during the 8 years post mine fire: Using this second extraction of anonymous ambulance, emergency department and hospital admissions data, we investigated whether smoke from the mine fire resulted in increased cardiovascular-related ambulance attendances, emergency department presentations or hospital admissions in Morwell or the Latrobe Valley, during the 8 years after the mine fire compared with before the fire and compared with service use trends in the rest of regional Victoria.[97]

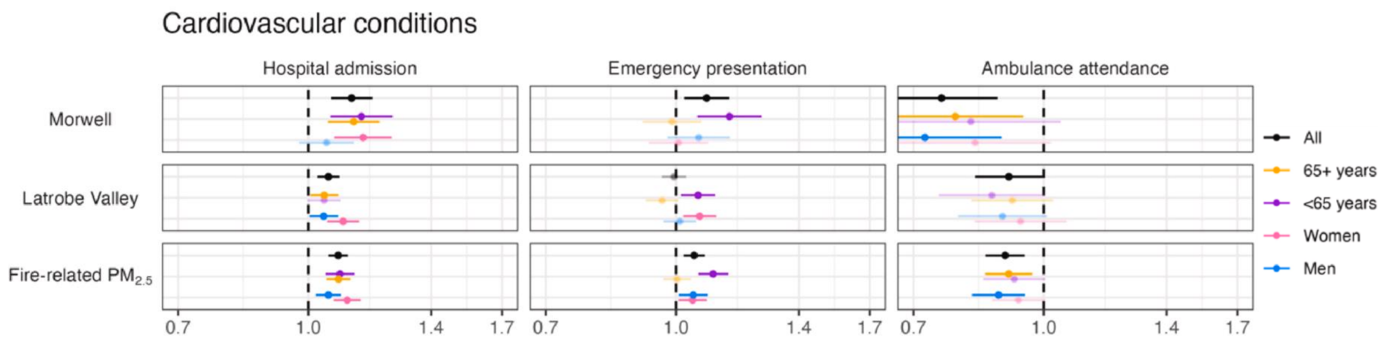


Figure 27 Relative risks for changes in cardiovascular-related hospital admissions, emergency presentations and ambulance attendances in the eight years following the mine fire (Source: Lane *et al.* 2024, Figure 3)[97]

As shown in Figure 27, cardiovascular-related ambulance attendances notably declined over the 8-year period, particularly in Morwell, with the biggest effect observed in men, and consistent with a $PM_{2.5}$ dose response relationship. In contrast, cardiovascular emergency department presentations increased in Morwell over the 8-year period, primarily amongst younger adults, and cardiovascular-related hospital admissions increased, particularly in Morwell and in women, consistent with a $PM_{2.5}$ dose-response relationship. Additional analysis (not shown) indicated that hospital admissions peaked in early 2018, particularly among younger adults and men.[97]

5.3.3.2 Cardiovascular health findings in the identified Adult Survey cohort using Hazelinks data

Linkage with Adult Survey participants' identified ambulance attendances (January 2009 to December 2017), hospital emergency department presentations (January 2009 to March 2019) and hospital admissions data (January 2009 to February 2019)

Health effects up to 5 years post mine fire: These data were used to evaluate the association between mine-fire-related $PM_{2.5}$ exposure and cardiovascular health-related ambulance attendances,[100] emergency department presentations[87] and hospital admissions[101] up to five years following the mine fire. Data were available for up to 2,725 Adult Survey participants who consented to linkage.

For each 10μg/m^3 increase in mean mine fire-related $PM_{2.5}$ exposure, there was a 13% increase in cardiovascular related ambulance attendances (HR 1.13, 95% CI 1.01 - 1.28) within 3.5 years of the mine fire[100] and a 10% increase in cardiovascular-related emergency department presentations (HR 1.10, 95% CI 0.99 - 1.22) within 2.5 years.[87] The increase in emergency department presentations was no longer evident between 2.5 and 5 years after the mine fire.[87] No association was observed between increments in $PM_{2.5}$ exposure and changes in cardiovascular-related hospital admissions in the 5 years following the mine fire.[101]

Summary of key findings: Cardiovascular health in adults

During the mine fire period, there were no increases in cardiovascular-related visits to health specialists or services.

During the mine fire period, small increases in smoke exposure levels were associated with 10% increases in dispensing of cardiovascular medications.

During the 6 months after the fire in Morwell, there was a 62% increase in risk of death from cardiovascular conditions, particularly deaths from Ischaemic Heart Disease.

Using population-wide ambulance data: During the mine fire period, there was no association between mine fire smoke exposure and ambulance attendances for cardiovascular conditions. In the following 8 years, there was an overall decrease in cardiovascular-related ambulance attendances in Morwell, compared with before the fire and with trends in the rest of regional Victoria.

Using ambulance data linked to study participants: Small increases in smoke exposure levels were associated with 13% increases in cardiovascular-related ambulance attendances over a 3.5-year period.

Using population-wide hospital data: During the mine fire period, there was no increase in emergency department presentations or hospital admissions for cardiovascular conditions. In the following 8 years; however, there was an overall increase in both emergency department presentations and hospital admissions for cardiovascular conditions.

Using hospital data linked to study participants: Small increases in smoke exposure levels were associated with 10% increases in cardiovascular-related emergency department visits during the first 2.5 years but not later. There were no observed changes in cardiovascular-related hospital admissions in the 5 years following the mine fire.

Approximately 2.5-3 years since the fire, mine fire-smoke exposure was associated with increased self-reporting of high blood pressure and 'heart attack', however, case numbers were very small.

Approximately 3.5 to 4 years after the fire, there were no measured differences between exposed and unexposed adults in markers of underlying cardiovascular disease, reduced heart function, heart muscle damage, abnormal heart rhythm or blood vessel health.

Dietary vegetables, grains, fresh meat and non-fried fish were associated with better cardiovascular health, while soft drinks were associated with poorer cardiovascular health.

5.4 Research Question 3 about birth weight and further requested information on child development

RQ 3 pertaining to the birth weight of babies, and RI 4 pertaining to child development, are informed by findings from the Latrobe Early Life Follow-Up (ELF) Study.[38]

This child health and development stream of the Hazelwood Health Study is made up of two parallel lines of inquiry.

(1) *The Latrobe Early Life Follow-up (ELF) Cohort Study* follows the health and development of an identified cohort of 571 children from the wider Latrobe Valley who were: (1) exposed to mine fire emissions while *in utero*, (2) exposed to mine fire emissions during their first two years after birth, or (3) were conceived and born after the fire and were thus an unexposed comparison sample of children.[38]

(2) *The Latrobe ELFLinks Studies* examine anonymous health and education records for a deidentified cohort of 3700 children from the Latrobe Valley born from 1st March 2012 to 31st December 2015, the same period as participants in the Latrobe ELF identified cohort. This Study stream also includes evaluation of a state-wide cohort of 293,316 children born during the same period to enable impacts of the coal mine fire pollution to be compared with other serious pollution events from bushfires, and with background ambient air pollution.

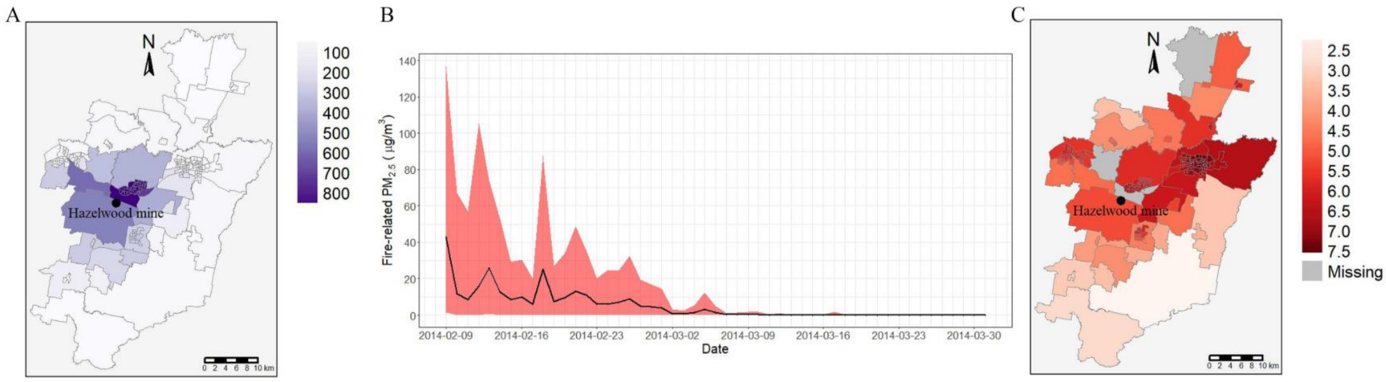
Ash

5.4.1 Mine fire-related $PM_{2.5}$ exposure amongst pregnant women and young children

In order to present the associations between health outcomes and exposure to mine fire-related smoke emissions, as estimated using $PM_{2.5}$ modelling, it is first useful to describe the assessment of $PM_{2.5}$ exposure in the ELF Studies.

5.4.1.1 $PM_{2.5}$ exposure in the deidentified cohort

In order to estimate mine-fire related $PM_{2.5}$ exposure levels for each mother and child in the ELF deidentified cohort, CSIRO's modelled $PM_{2.5}$ for the mine fire period was mapped against the residential address of the parent at the time of the child's birth. The patterns of both mine fire $PM_{2.5}$, and background ambient $PM_{2.5}$ exposure levels are indicated in Figure 28.



(A) Mine fire-related cumulative $PM_{2.5}$ concentration over the fire period by SA1. (B) Mine fire-related daily $PM_{2.5}$ concentrations by day of the fire (black line, average; red shade, range minimum to maximum across SA1s). (C) Background ambient $PM_{2.5}$ average for years 2011–2015 (excluding 2014) by SA1

Figure 28 Modelled concentrations of $PM_{2.5}$ in the Latrobe Valley (Source: Ziou *et al.* 2023)[107]

5.4.1.2 $PM_{2.5}$ exposure in the identified cohort

As detailed in sections 4.1 and 5.1, in order to estimate mine-fire related $PM_{2.5}$ exposure levels for each mother and child in the ELF identified cohort, parent-reported time-location diaries for the 6-week mine fire period were blended with CSIRO's modelled data. Because the spatial variability of the smoke was extreme during the mine fire period, daily travel for education, work or to escape extreme air pollution likely influenced individual exposure. Therefore, the time-location diaries invited parents to log their location for every 12-hour day and 12-hour night of the mine fire period. This location data was then mapped to CSIRO's detailed spatio-temporal pollution data to calculate the daily mean and maximum exposures for each child during the fire period. Mine fire-related $PM_{2.5}$ levels were estimated for the 401 cohort members who were either young children or *in utero* at the time of the mine fire, not the 170 who were conceived after the fire period and therefore had no exposure to the mine fire smoke. Averaged daily mine fire smoke exposure over the fire period was estimated to be 8.4 μg/m^3 (range 0.0 to 52.9 μg/m^3), and averaged maximum (peak) exposure was estimated to be 147.7 μg/m^3 (range 0.0 to 991.3 μg/m^3). As shown in Figure 29, children living in

Morwell had higher mean and maximum exposures than those living further from the mine fire; mean 16.1 μg/m^3 in Morwell and 2.8 μg/m^3 elsewhere ($p<0.001$), maximum 238.0 in Morwell and 81.6 μg/m^3 elsewhere, $p<0.001$.[34]

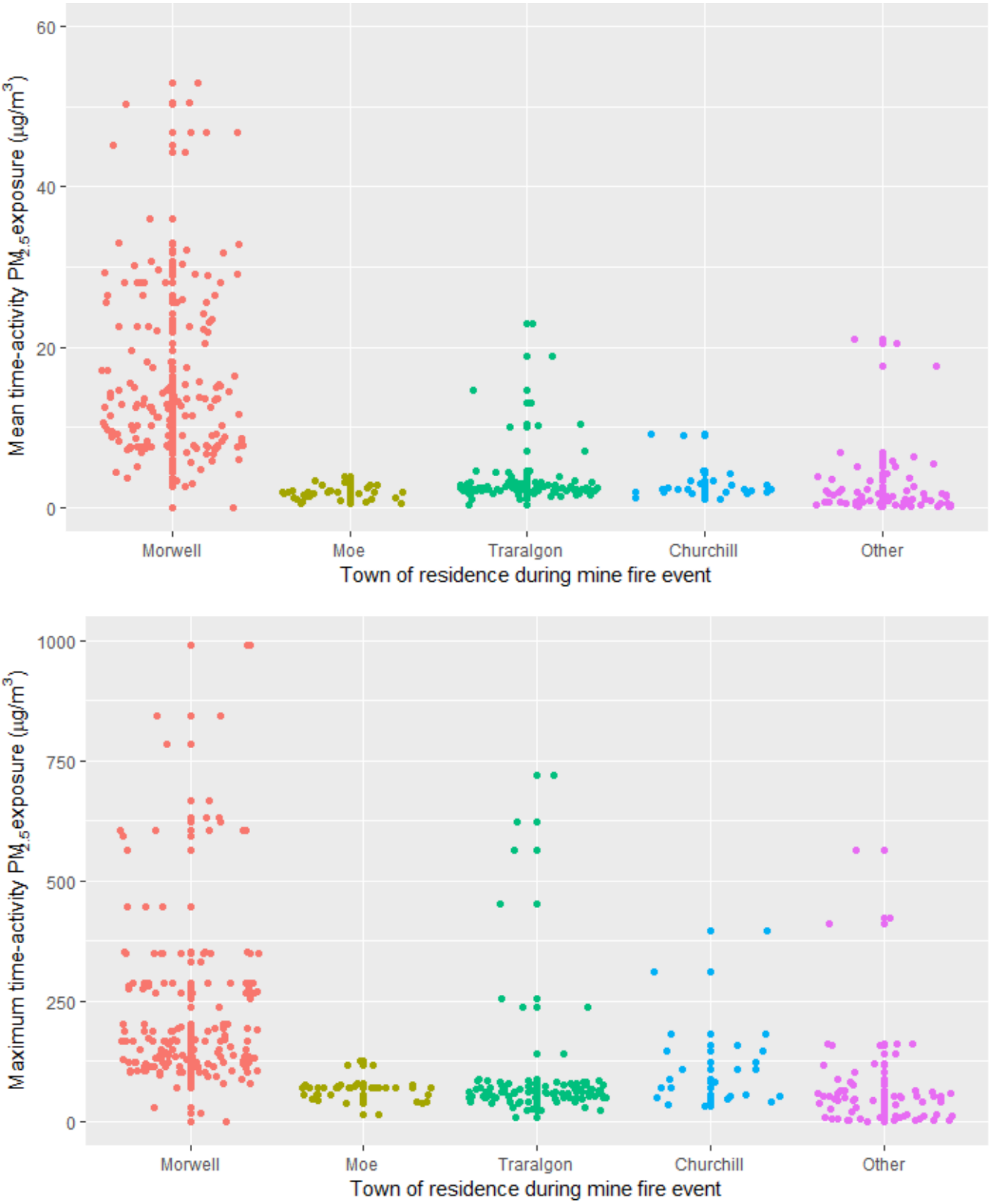


Figure 29 ELF identified cohort: (a) daily mean and (b) maximum exposure to mine fire-related $PM_{2.5}$ by town, estimated using the time-location diaries and CSIRO modelled $PM_{2.5}$ data (Source: Chappell *et al.* 2020)[34]

5.4.2 Foetal growth and maturity-related health outcomes including birth weight

The ELF Study evaluated 571 surveys containing parent-reported birth outcomes for the identified cohort[30, 33] and 3,591 anonymous birth records from the Victorian Perinatal Data Collection (VPDC) for the deidentified cohort.[108] The outcomes investigated were indicators of foetal growth and maturity including birthweight at term, being small or large for gestational age, pre-term delivery and gestational age at delivery.

When all babies were included in the evaluation, we did not find evidence for overall associations between the exposure of pregnant women to emissions from the fire during pregnancy and indicators of foetal growth and maturity in Latrobe Valley babies.[108]

However, in the analysis of the anonymous VPDC records, we found that higher exposure to mine fire emissions was associated with increased birthweight in the subgroup of babies born to mothers who had a diagnosis of gestational diabetes mellitus (GDM).[108] It is usual for the babies of mothers with GDM to be heavier than the babies of mothers without GDM. However, our findings indicated that the babies of mine-fire exposed mothers with GDM were heavier than the babies of unexposed mothers with GDM. Every 10 $\mu g/m^3$ increase in the average $PM_{2.5}$ exposure was associated with an additional 97 gram increase in birth weight (95% CI 74 - 120) in babies born to mothers with GDM; this association was not present in babies of mine fire smoke-exposed mothers without GDM.[108]

5.4.3 Other health findings in regard to pregnancy outcomes and child development

5.4.3.1 Pregnant women

Among women who were pregnant during the mine fire, evidence was found for an association between maternal exposure to emissions from the fire and an increase in incidence of GDM, especially for exposure during the second trimester of pregnancy.[42] An interquartile range increase in average $PM_{2.5}$ was associated with a 6% increased likelihood of GDM (RR 1.06, 95% CI 1.03 -1.10, $p<0.001$). Similarly, an interquartile range increase in peak $PM_{2.5}$ was associated with a 15% increased likelihood of GDM (RR 1.15, 95% CI 1.08 - 1.22, $p<0.0001$).[42] There were 16 additional cases of gestational diabetes mellitus directly attributable to fire smoke exposure. Examining the relationship by timing of exposure in pregnancy (see Figure 30) demonstrated that exposure in the 2nd trimester appeared to be of most importance, whereas exposure in the 1st or 3rd trimesters was less important.[42] However, no evidence was found for any association between maternal exposure to emissions from the fire and hypertensive disorders or abnormal placentation.[42]

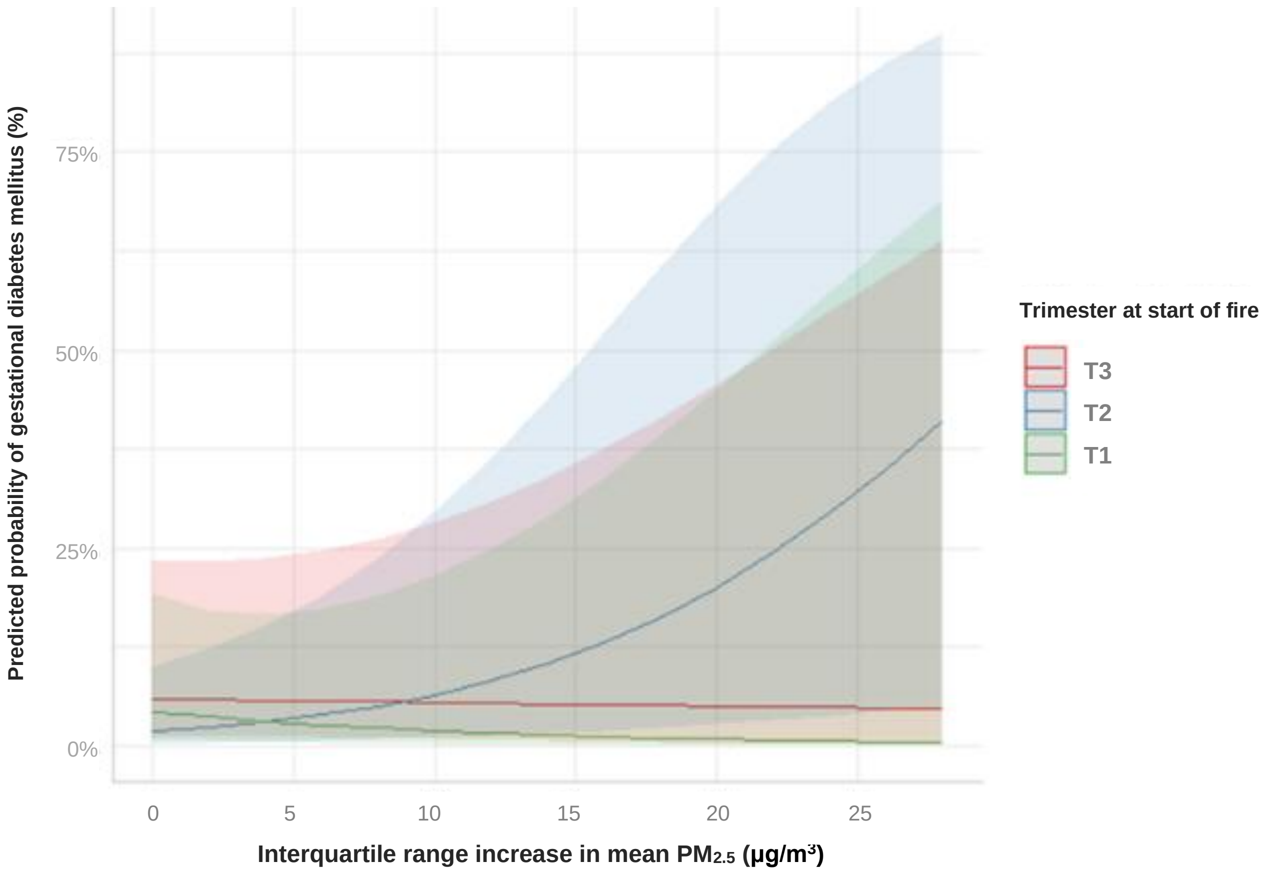


Figure 30 Relationship between mean $PM_{2.5}$ exposure and likelihood of gestational diabetes mellitus by trimester at the start of the coal mine fire
(Source: Melody *et al.* 2020)[42]

5.4.3.2 Infants *in utero* during the mine fire

Parent-reported health outcomes in their children, 2-4 years after the fire

Evidence was found for an association between 10µg/m^3 increments in mean daily $PM_{2.5}$ exposure *during pregnancy* and parent-reported symptoms of cough or runny nose (RR 1.09, 95% CI 1.02 - 1.17), wheeze (RR 1.56, 95% CI 1.18 - 2.07), seeking health professional advice (RR 1.17, 95% CI 1.06 - 1.29) and doctor-diagnoses of upper respiratory tract infections, cold or flu (RR 1.35, 95% CI 1.14 - 1.60).[35, 40] Associations with peak 24-hour $PM_{2.5}$ exposure were similar.

Identified MBS and PBS data linked to the ELF Cohort from birth to December 2016

Based on the ELF identified cohort of 88 Latrobe Valley babies exposed to the mine fire *during pregnancy*, there was no evidence for any association between 10µg/m^3 or 100 µg/m^3 increments in mean and peak $PM_{2.5}$ exposure and general practitioner attendances or dispensing of prescribed medications used to treat asthma (asthma inhalers), atopic dermatitis (steroid skin creams), and bacterial infections (antibiotics) during the first 1 year of life.[109]

Anonymous MBS and PBS data linked to the ELF deidentified cohort from birth to June 2018

Based on a deidentified cohort of 589 Latrobe Valley babies exposed to the mine fire *during pregnancy,* cumulative and daily peak exposure $PM_{2.5}$ were associated with modest increases in dispensing of systemic steroids (Cumulative: Incidence rate ratio; IRR 1.11, 95% CI 1.00 - 1.24 per 240 µg/m^3; Peak: IRR 1.15, 95% CI 1.00 - 1.32 per 45 µg/m^3) over the duration of their first 2 years of life.[110] These medications are mainly used to treat croup and asthma symptoms.

Anonymous emergency department presentations and hospital admissions data linked to the ELF deidentified cohort; first year of life

Based on a deidentified cohort of 518 Latrobe Valley babies exposed to the mine fire *during pregnancy*, higher cumulative $PM_{2.5}$ exposure was associated with higher odds of presentation to the emergency department (ED) for allergies or skin rash in the first year of life; (OR 1.34, 95% CI 1.01 - 1.76 per 240 µg/m^3).[107] There were no increases in ED presentations for other respiratory-related or infectious causes and no increases in hospital admissions for any cause.

Round 1 clinical assessments 3 years after the mine fire

Cardiovascular health

In Round 1, approximately 3 years after the mine fire, we did not find any associations between exposure to $PM_{2.5}$ and any markers of vascular stiffness (using pulse wave velocity; PWV; n=56) or thickness (using carotid intima-media thickness; CIMT; n=75) in the *in utero* exposure group. However, when combined with the children who were exposed postnatally between birth and two years of age (see section 5.4.3.3 for further detail), there was evidence of an association between mine fire $PM_{2.5}$ and increased risk of markers of stiffer blood vessels in some children.[32, 41].

ELF Study Round 1 clinical assessment

Respiratory health

At the time of the Round 1 clinical assessments, the children who had been *in utero* at the time of the mine fire were generally considered too young to undertake reliable lung function tests. There were 21 *in utero*-exposed children who attempted FOT; however, only 15 had recordable measurements; too few for informative analysis.

Round 2 clinical assessments 7 years after the mine fire

Cardiovascular health

Initially planned for 2020, six years after the mine fire, COVID-19-related restrictions resulted in the Round 2 clinical assessments being delayed until 2021. At that time point, approximately seven years post-fire, each 10 μg/m^3 increase in daily $PM_{2.5}$ exposure *in utero* (n=61) was found to be associated with a mild increase in vascular stiffness (β = 0.13 m/s, 95% CI 0.02 - 0.24; P = 0.02).[111] The association was not altered by adjustment for covariates, body mass index, and maternal fire stress. There was no association between $PM_{2.5}$ exposure *in utero* and vascular thickness using CIMT.[111] There was a trend toward increased vascular stiffness over time in this *in utero* exposed group suggesting that there may be a longer latency period for these children, compared with children exposed during infancy, before subclinical changes appear.[111]

Respiratory health

In the Round 2 clinic, acceptable lung function measurements were obtained from 79 children; 25 unexposed and 54 exposed *in utero*. There was no detectable effect of *in utero* exposure to mine fire-related $PM_{2.5}$ on lung function approximately 7-years later. However, statistical power was limited.[36]

ELF Study Round 2 clinical assessment

Allergic sensitisation

In the Round 2 clinic, 29 children who were exposed *in utero* provided a blood sample from which specific immunoglobulin E (IgE) levels for seven common aeroallergens (dust, cat, fungi and grasses) as well as total IgE levels were measured. No associations were found between the levels of smoke exposure and allergic sensitisation seven years after the event. However, statistical power was limited.[112]

5.4.3.3 Children aged up to 2 years at the time of the mine fire.

Parent-reported health outcomes in their children, 2-4 years after the fire

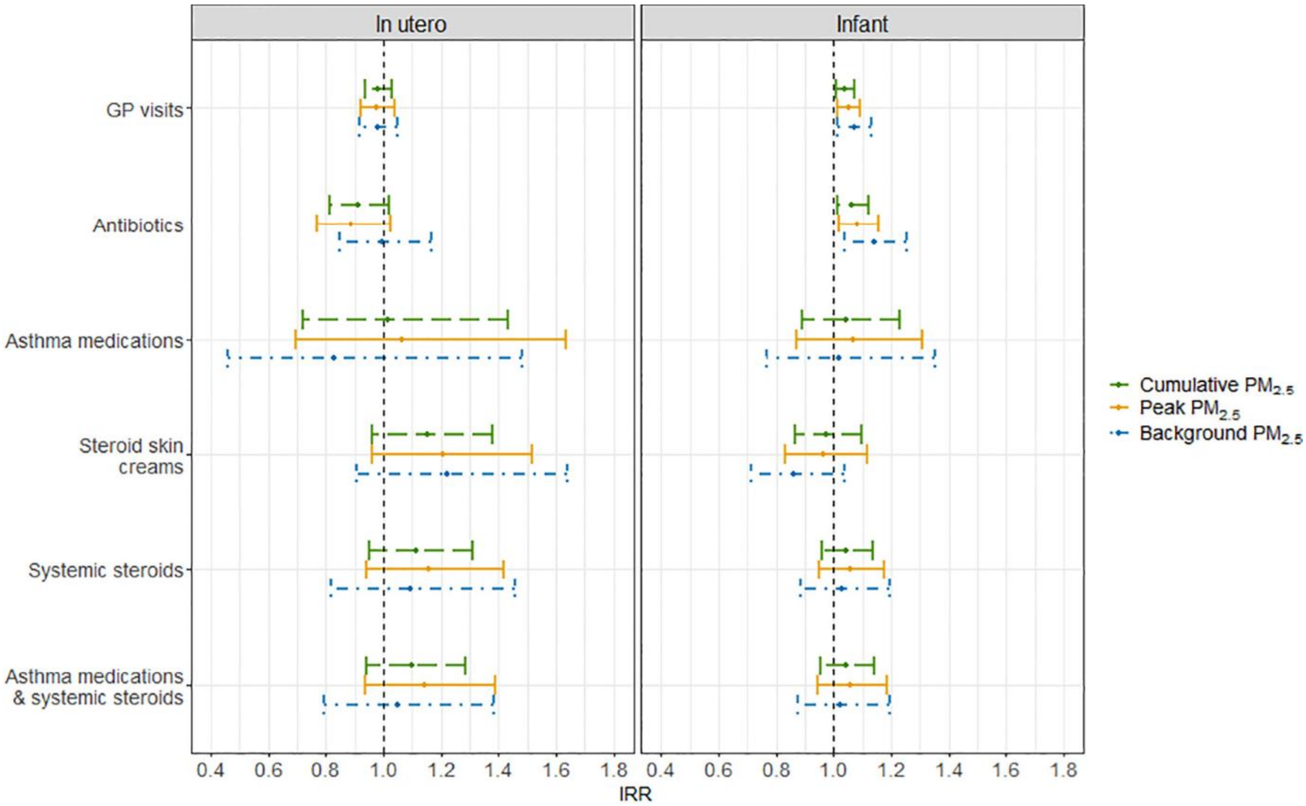
Weak evidence was found for an association between 100 μg/m^3 increments in peak daily $PM_{2.5}$ between birth and the age of two years and parent-reported symptoms of cough and runny nose (RR 1.04, 95% CI 1.00–1.09), and use of inhaled medication for asthma or wheeze (RR 1.26, 95% CI 1.01–1.58).[35, 40]

Identified MBS and PBS data linked to the ELF Cohort from birth to December 2016

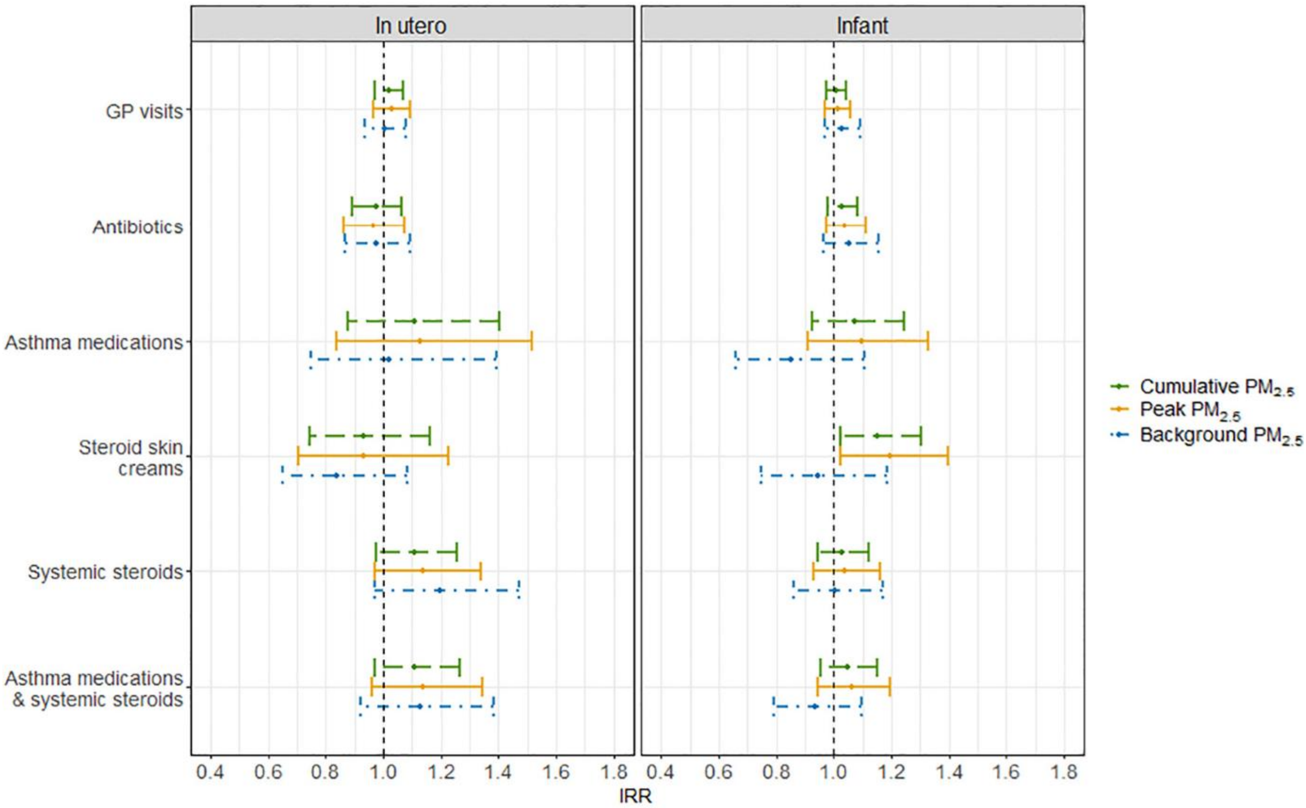
Based on the ELF identified cohort of 121 Latrobe Valley infants exposed to the mine fire between birth and the age of two years, evidence was found for an association between increments in $PM_{2.5}$ exposure and dispensing of prescribed antibiotics during the first year following the fire; RR 1.24, 95% CI 1.02 - 1.50 per 10μg/m^3 increment in mean $PM_{2.5}$ and RR 1.14, 95% CI 1.00 - 1.31 per 100 μg/m^3 increment in peak $PM_{2.5}$.[109] No association was found between $PM_{2.5}$ exposure and general practitioner attendances or dispensing of prescribed asthma inhalers or steroid containing skin creams during the first year following the fire.[109]

Anonymous MBS and PBS data linked to the ELF deidentified cohort from birth to June 2018

Shown in Figure 31, and based on the deidentified cohort of 1,832 Latrobe Valley infants exposed to the mine fire between birth and the age of two years, cumulative and daily peak $PM_{2.5}$ exposure were associated with increases in antibiotic dispensing (Cumulative: IRR 1.06, 95% CI 1.01 - 1.12 per 240 μg/m^3; Peak: IRR 1.08, 95% CI 1.01 - 1.16 per 45 μg/m^3), and GP visits (Cumulative: IRR 1.04, 95% CI 1.01 - 1.07; Peak: IRR 1.05, 95% CI 1.0 - 1.09) during the 1st (but not 2nd) year following the fire.[110] In the 2nd (but not the 1st) year following the fire, cumulative and daily peak $PM_{2.5}$ exposure were associated with increases in dispensing of steroid creams commonly used for eczema (Cumulative: IRR 1.15, 95% CI 1.02–1.30; Peak: IRR 1.19, 95% CI 1.02-1.39).[110]



(A) First year of life or after birth



(B) Second year of life or after birth

Figure 31 Adjusted IRR for exposure-response relationship per interquartile range increase in mine fire-related and background $PM_{2.5}$ by year
(Source: Ziou *et al.* 2023)[110]

Anonymous emergency department presentations and hospital admissions data for the first year after the fire, linked to the ELF deidentified cohort

Based on a deidentified cohort of 861 Latrobe Valley babies exposed to the mine fire between birth and the age of one year (note: revised eligibility for these analyses), compared with 1,915 unexposed babies, exposure was associated with increased ED presentations for any respiratory cause (OR 1.37, 95% CI 1.05 - 1.80) and for respiratory-related infectious conditions (OR 1.39, 95% CI 1.05 - 1.83), but not with hospital admissions, during the first year after the fire.[107] There was no dose-response relationships observed between mine fire $PM_{2.5}$ exposure during early childhood and ED presentations or hospital admissions during the first year after the fire.

Anonymous emergency department presentations and hospital admissions data for the first 5 years after the fire, linked to the ELF deidentified cohort

These analyses were based on a deidentified cohort of 1,788 Latrobe Valley babies exposed to the mine fire between birth and the age of two years, divided into terciles of cumulative fire-related $PM_{2.5}$ exposure: (*low* 0-57.6 µg/m^3; *medium* 57.6-195.1 µg/m^3; *high* 195.1-889 µg/m^3).[113] Over the five years following the fire, children with *medium* (HR 1.16, 95% CI 1.06 - 1.28) or *high* exposure (HR 1.11, 95% CI 1.01 - 1.21) had higher rates of all-cause presentations to the ED than those with *low* exposure. Children with *medium* exposure still had marginally higher rates of presentation to the ED (HR 1.13, 95% CI 1.00 - 1.27), after exclusion of cases where the diagnosis was missing, the diagnosis was unlikely to have a clinical connection to smoke pollution exposure (such as poisonings and burns) or where the appointment was scheduled or a follow-up.[113] When reasons for ED presentations were divided into 'infectious causes'; 'respiratory causes'; and 'allergies/skin rashes' there were no associations between exposure tercile and outcomes. This was in contrast to our previously reported findings, showing increased respiratory-related ED presentations in the first year after the fire,[107] suggesting resolution over time. In the current analyses, there were also no associations between smoke exposure and hospital admissions over this 5-year period; nor when the follow-up was divided into 0 to 2.5, and 2.5 to 5-year periods.[113]

Round 1 clinical assessments 3 years after the mine fire

Cardiovascular health

Evidence was found for an association between 10µg/m^3 increments in mean daily $PM_{2.5}$ exposure between birth and the age of two years, and very small increases in vascular stiffness measured using PWV (n=91) but no increases in thickness measured using carotid IMT (n= 95).[32, 41] As already indicated above, when the children exposed during pregnancy and between birth and age of two years were combined, there was evidence of an association between mine fire smoke and increased risk of markers of stiffer blood vessels amongst those whose mothers smoked during pregnancy.[32, 41] Specifically, in this postnatal-exposure group, each 10 µg/m^3 increase in mean $PM_{2.5}$ level was independently positively associated with increased vascular stiffness (β=0.116, p=0.028). When these *in utero* and postnatally exposed groups were combined, there was an association between mean $PM_{2.5}$ and increased PWV in those children who had environmental tobacco smoke (ETS) exposure (β=0.148, p=0.033) or whose mothers smoked (β=0.151, p=0.011), but not in those without ETS or maternal smoke exposure.

Respiratory health

From 203 children exposed to mine fire $PM_{2.5}$ between birth and the age of two years, 101 attended the Round 1 clinic and 84 had acceptable lung function measurements. Each 10 μg/m^3 increase in average $PM_{2.5}$ was associated with slightly increased lung stiffness, indicating modest evidence of poorer lung health. Independent of mine fire smoke exposure, we also found that lung function was reduced (poorer) in children whose mothers smoked during pregnancy.[31, 39]

Round 2 clinical assessments 7 years after the mine fire

Cardiovascular health

The previously observed association between $PM_{2.5}$ exposure during infancy and increased vascular stiffness at Round 1 was attenuated at the 7-year follow-up (β −0.06 m/s, 95% CI −0.22 - 0.09, P = 0.43).[111] There was a trend toward less vascular stiffness over time in this group suggesting that the mild effects demonstrated earlier on did not persist over time.[111]

ELF Study Round 2 clinical assessment

Respiratory health

There were no associations between mine fire-related $PM_{2.5}$ exposure during infancy and any of the lung function measures, 7 years later.[114] There was a moderate improvement in lung stiffness, consistent with an early deficit in lung function at 3 years after the fire that had resolved by 7 years, suggesting that postnatal mine fire smoke exposure was not sufficient to cause permanent lung function changes in children.[114]

Allergic sensitisation

In the Round 2 clinic, 50 children who were exposed during infancy provided a blood sample from which specific immunoglobulin E (IgE) levels for dust, cat, fungi and grasses as well as total IgE levels were measured. No associations were found between the levels of smoke exposure and allergic sensitisation seven years after the event. However, statistical power was limited.[112] Levels of background exposure were positively associated with sensitisation to dust (OR 1.90, 95% CI 1.12 - 3.21 per 1 μg/m^3) but not with cat, grass, fungi, or overall sensitisation.[112]

5.4.4 Important results from the ELF Cohort and ELFLinks studies not directly related to mine fire emissions

- Independently from exposure to the fire, exposure to ambient (background) sources of $PM_{2.5}$ (not mine fire-related) during the 1st two years of life was associated with an increase in dispensing of antibiotics (IRR 1.14, 95% CI 1.04 - 1.25 per 1.4 μg/m^3) and an increase in GP presentations (IRR 1.07, 95% CI 1.01 - 1.13) in the 1st (but not the 2nd) year following the fire in the deidentified cohort[110] (see Figure 31). This was despite relatively low levels ambient background $PM_{2.5}$ from a global perspective (ELF participant median = 6.1 μg/m^3).
- Early life exposure to ambient (background) $PM_{2.5}$ in the 1st year of life was associated with overall ED presentations for any cause (OR 1.17, 95% CI 1.05 - 1.30 per 1.4 μg/m^3) in the deidentified cohort during the 1st year after the fire.[107]
- Exposure *in utero* to background ambient (not mine fire-related) $PM_{2.5}$ was associated with increased overall ED presentations (OR 1.18, 95% CI 1.05 - 1.33 per 1.4 μg/m^3) and infection-related hospital admissions (OR 1.23, 95% CI 1.00 - 1.52 per 1.4 μg/m^3) in the 1st year of life in the deidentified cohort.[107]
- Among Round 2 clinic participants, early life exposure to ambient (background) $PM_{2.5}$ was positively associated with sensitisation to dust (OR = 1.90, 95%CI = 1.12,3.21 per 1 μg/m^3) but not with cat, grass, fungi, or overall sensitisation.[112]
- Over a third (35%) of children lived in a house with an unflued gas heater.[34]
- Maternal stress in pregnancy was associated with a higher risk of pre-term birth and lower birthweight.[30]
- Almost a third (30%) of children had a mother who smoked in pregnancy and/or lived in a house with a smoking adult in early childhood.[34]
- Maternal smoking during pregnancy was associated with lower birth weight and babies being small for gestational age.[30]
- Maternal smoking during pregnancy/second hand smoke exposure in the home was independently associated with markers of stiffer lungs in Round 1 clinic participants three years after the fire.[31, 39]
- Maternal smoking in pregnancy/second hand smoke exposure in the home was independently associated with thicker carotid arteries (an early sign of the development of atherosclerosis) in Round 1 clinic participants three years after the fire.[32, 41]

Summary of key findings: Health in mine fire smoke-exposed pregnant women, babies in utero and young children

Among women who were exposed to mine fire smoke during pregnancy

There was an association between increasing smoke exposure, increased incidence of GDM particularly when exposure was during the 2nd trimester, and increased birth weight in babies born to smoke exposed mothers with GDM.

Among the babies exposed to mine fire smoke while *in utero*

***At birth**:* No association between mine fire smoke exposure and overall indicators of foetal growth and maturity including birthweight at term, being small or large for gestational age, pre-term delivery and gestational age at delivery.

First year of life: No association between smoke level and GP visits or dispensing of prescribed medications used to treat asthma, atopic dermatitis or bacterial infections. However, there was an association between increasing smoke exposure and increased ED presentations for allergies or skin rash, but not for other respiratory or infectious causes and no increases in hospital admissions.

***First 2 years of life**:* There was an association between increasing smoke exposure and increased dispensing of medications commonly used to treat croup and asthma.

2 - 4 years after the fire: There was an association between increasing smoke exposure and increased parent-reported cough, wheeze, health service use and doctor-diagnosed respiratory infections, cold or flu.

3 years after the fire: No association between smoke level and any markers of vascular stiffness or thickness.

7 years after the fire: There was a modest association between increasing smoke exposure and small increases in vascular stiffness. There were no associations with lung function or allergic sensitisation, although statistical power was limited.

Among the infants exposed to mine fire smoke between birth and the age of two years

First year post fire: In the identified cohort (n=121) there was a dose-response association between increasing smoke exposure and increased dispensing of prescribed antibiotics, but no association with GP visits or dispensing of prescribed asthma inhalers or steroid containing skin creams. In the deidentified cohort (n=1,832) there was a dose-response association between increasing smoke exposure, GP visits and increased dispensing of prescribed antibiotics. In a deidentified cohort restricted to those exposed to the mine fire smoke between birth and one year of age (n=861) exposure was associated with increased ED presentations for any respiratory cause, and for respiratory-related infectious conditions, but not with hospital admissions.

Second year post fire: In the deidentified cohort (n=1,832) there was a dose-response association between increasing smoke exposure and increased dispensing of steroid containing creams commonly used for eczema

2 - 4 years post fire: There was a modest dose-response association between increasing smoke exposure and increased parent-reporting of cough, runny nose and use of inhaled medication for asthma or wheeze.

3 years post fire: There were modest dose-response associations between increasing mine fire smoke exposure and small increases in both lung stiffness and vascular stiffness. When the *in utero* and infant-exposed children were combined, there was an association between mine fire exposure and increased vascular stiffness amongst those whose mothers smoked during pregnancy.

Up to 5 years post fire: Higher category of smoke exposure was associated with increased all-cause ED presentations over the 5 years, but not when ED presentations were divided into 'infectious'; 'respiratory'; and 'allergies/skin rashes', and there was no association with hospital admissions.

7 years after the fire: The previously observed associations between smoke exposure, lung stiffness and vascular stiffness after 3 years, were no longer evident after 7 years, suggesting recovery. No associations were found between smoke exposure and allergic sensitisation; however, statistical power was limited.

Summary of key findings: Early childhood findings not directly related to mine fire emissions

Independently from exposure to the mine fire smoke, early life exposure to background sources of $PM_{2.5}$ was associated with increased dispensing of antibiotics, GP presentations, ED presentations, infection-related hospital admissions and sensitisation to dust.

Approximately a third of children had a mother who smoked in pregnancy and/or lived in a house with a smoking adult and/or unflued gas heater.

Maternal smoking during pregnancy was associated with lower birth weight and babies being small for gestational age.

Maternal smoking during pregnancy/second-hand smoke exposure in the home was independently associated with markers of stiffer lungs and thicker carotid arteries (an early sign of the development of atherosclerosis) in Round 1 clinic participants.

Maternal stress in pregnancy was associated with a higher risk of pre-term birth and lower birthweight.

Xavier

5.5 Research Questions 4 and 5 about psychological health

RQ 4 and RQ 5 in regard to prevalence and persistence of psychological distress, and factors associated with distress, are informed by findings from the Schools Study, the Adult Psychological Impacts Stream (including the Adult Survey) and Hazelinks. The Schools Study also informed findings about educational attainment. Those have been included in this section.

5.5.1 Psychological health and academic progress findings from the Schools Study

Survey findings

In late 2015 (16 to 21 months after the fire), the CRIES-13[49] was completed by 323 students in grades 3, 5, 7 or 9, from 20 schools across the Latrobe Valley region, comprising government (public-funded) and non-government (public and privately funded; religious-affiliated) primary and secondary schools.[43] Across the sample, the weighted mean CRIES-13 total score was 17.22 (95% CI 13.19 - 21.25) suggesting a moderate overall level of posttraumatic stress associated with the mine fire.[43] In total, 22% of all students (n = 23) recorded a score exceeding the ≥30 threshold suggestive of a diagnosis of PTSD.[43] This prevalence was more than double that observed among adults who completed the similar Impact of Events Scale Revised (IES-R)[24] in the Adult Survey; see section 5.5.2.[11] Closer proximity to the mine fire was associated with greater posttraumatic stress, with students from schools located in Morwell reporting more mine fire event-related stress, on average, than students from schools outside of Morwell.[43, 115] This difference was primarily driven by higher scoring among Morwell students on the *Arousal* symptom domain of the CRIES-13.[43] Regardless of location, primary school students (grades 3 and 5), reported more symptoms of posttraumatic stress related to the mine fire event than secondary school students (grades 7 and 9).[115] In fact the average CRIES-13 score for primary school participants was more than double that of secondary school participants and their *Avoidance* symptom-domain scores were, on average, three times greater. However, those differences did not reach statistical significance.[43] In general, posttraumatic stress levels were found to have reduced by the time of the second survey round in 2017.

Face-to-face interviews

In interviews conducted in 2015 with personnel at a small specialist secondary school which had relocated during the fire, multiple adverse impacts on staff and students at the time of the mine fire were identified. These included increased anxiety and frustration amongst students, difficulty adjusting to the relocation environment, reduced sense of safety and reductions in both attendance and schoolwork completion.[44] Increased stress at home was also reported. Staff reported that they themselves experienced frustration and anxiety around the event, including carrying concerns for themselves, their families and their students.[44]

In interviews conducted in 2015 and 2017 with students from mainstream schools across the Latrobe Valley, the majority of students reported little or no ongoing concerns in relation to the mine fire event.[116] However, some students continued to experience thoughts and physiological responses related to the event that were consistent with symptoms of posttraumatic stress. A core theme from the analysis of the second round of interviews was that many students had 'moved on' from the event.[116]

Linked NAPLAN findings

Longitudinal analysis of all available NAPLAN data from before the mine fire (2013 and earlier) and after (2015 and 2017), linked to 303 Schools Study participants, was undertaken to assess changes in the trajectories of their academic progress.[117] The analysis accounted for mine fire event-related posttraumatic stress CRIES-13 score during the baseline survey, and controlled for age, sex and school-sector (government versus non-government).[117] Before the mine fire there was some evidence, although inconsistent, that Morwell students likely had poorer NAPLAN scores than students from schools elsewhere in the Latrobe Valley, equivalent to a 6 to 11-month delay in academic progress. After the mine fire, however, a substantial 18.5 month further delay in academic progress was observed in secondary (grade 7 and 9) students from Morwell schools (95% CI 13.6 - 23.5), which was not observed in non-Morwell secondary students. Increased posttraumatic stress, as measured using the CRIES-13 during the baseline survey, was not associated with delays in academic progress.[117]

Stock image

Deidentified NAPLAN findings

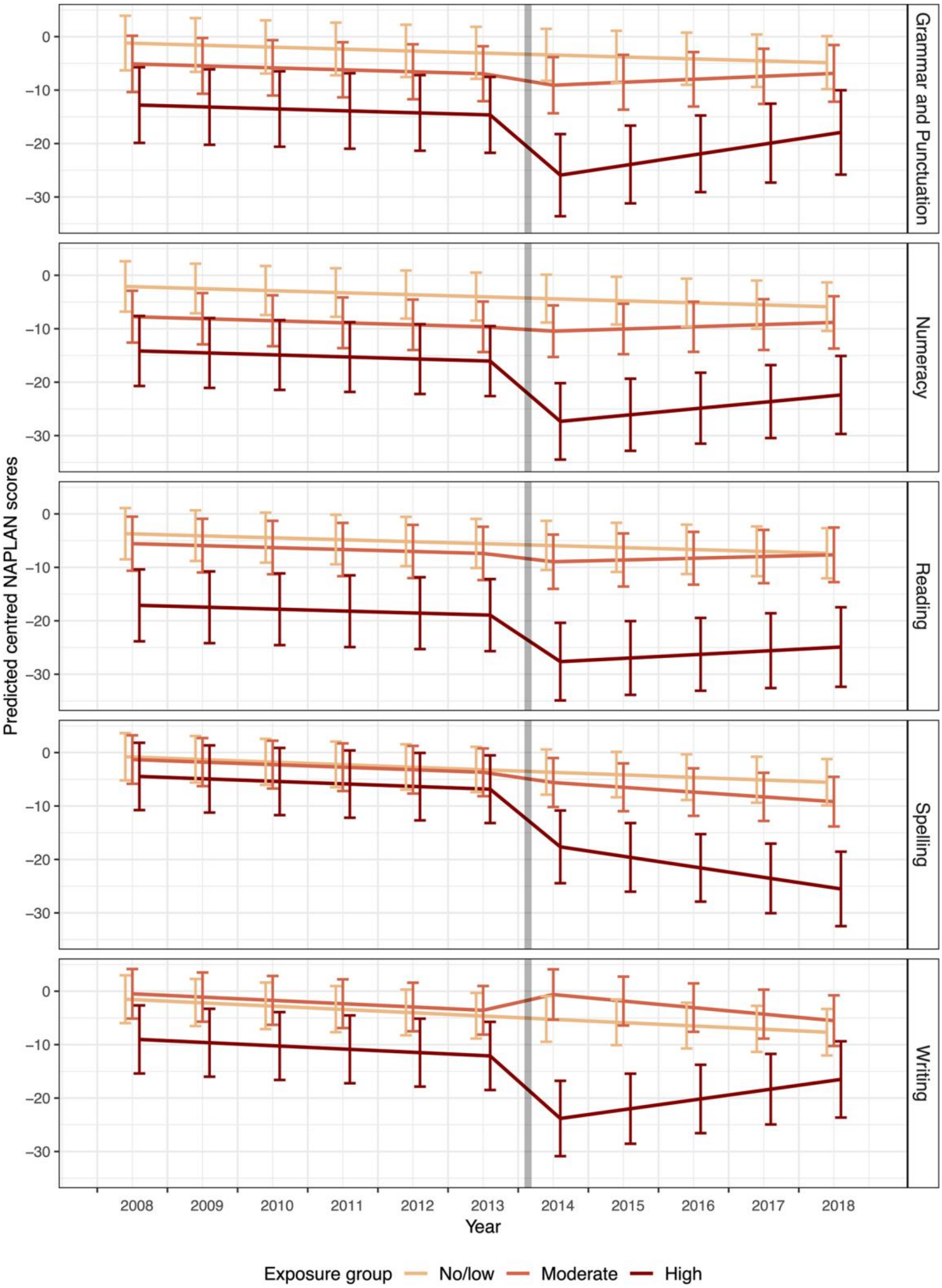
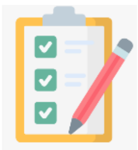


Figure 32 NAPLAN domain scores before and after the mine fire by smoke exposure group (Source: Gao *et al.* 2023)[45]

A new statistical approach was used to analyse deidentified NAPLAN and school administrative data from 2008 to 2018 to estimate changes in trajectories of academic progress as a result of exposure to the mine fire.[45] In this analysis, school-level data from 69 primary and secondary schools, including average scores in each NAPLAN learning domain for grades 3, 5, 7 and 9, were used rather than linked individual student-level data. The analysis compared academic progress in all students from highly exposed schools in Morwell to those from moderately exposed schools in the rest of the Latrobe Valley, and students from schools in Wellington Shire which had little or no exposure to the smoke event.[45] The analysis took into consideration differences in school profile, including socioeconomic status, school size, sex ratio and school sector as well as grade level and longer-term trends in NAPLAN.

In the year following the mine fire, major interruptions to academic progress across all NAPLAN learning domains were evident in the highly exposed Morwell schools (Figure 32). Compared to the Victorian regional average, this equated to a four to five-month delay in academic progress, which had not fully recovered several years later.[45]

Summary of key findings: Schools Study



Approximately 1.5 years after the mine fire, 22% of surveyed students reported mine fire-related posttraumatic stress symptoms suggestive of PTSD. On average, Morwell students reported more mine fire-related posttraumatic stress symptoms than non-Morwell students. Primary school aged students, regardless of their distance from the smoke event, reported more posttraumatic stress symptoms than secondary students. By the time of the follow-up survey two years later, posttraumatic stress levels had generally reduced.

Specialist school personnel and students reported experiencing particular difficulties at the time of the mine fire, including anxiety, frustration, difficulty adjusting to the relocation environment, reduced sense of safety and declines in attendance and schoolwork.

In interviews conducted in 2015 and 2017, the majority of mainstream school students reported few or no ongoing mine fire-related concerns and had 'moved on' from the event. However, some continued to report symptoms consistent with PTSD.

NAPLAN data linked to 303 Schools Study participants showed that Morwell students had poorer academic performance than non-Morwell students before the mine fire, approximating a 7-month delay in academic progress. After the fire, however, the observed delay in academic progress had blown out to almost 15 months in Morwell grade 7 participants, and more than 21 months in Morwell grade 9 participants.

Victoria-wide deidentified NAPLAN data showed major academic interruptions occurred at Morwell schools across all NAPLAN learning domains in the aftermath of the mine fire. Compared to the Victorian regional average, this interruption equated to a four to five-month delay in academic progress recorded by Morwell school students, which had still not fully recovered several years later.

5.5.2 Psychological health findings from the Adult Psychological Impacts Stream

Adult Survey baseline findings (Round 1 data collection)

The Adult Survey baseline data (collected May 2016 to February 2017) showed there were no differences between Morwell and Sale participants in self-reported mental health conditions or number of stressful life events prior to the mine fire, indicating that Sale was a suitable comparison community for the purposes of investigating mine fire-related psychological impacts.[118] Based on the IES-R[24] completed approximately two and a half years after the mine fire, adult participants from Morwell reported more symptoms of mine fire-related posttraumatic stress than Sale participants.[11, 118] Using an IES-R cut-off score of 33 or above,[119] 10% of Morwell participants were considered to have levels of posttraumatic stress that indicated the likely presence of PTSD (this was approximately half of the percentage observed amongst school students; see section 5.5.1).[43] Morwell participants scored higher than Sale participants on all three IES-R symptom domains: *Intrusion*, *Avoidance* and *Arousal*. Morwell participants also recorded greater levels of general psychological distress in the previous four weeks using the 10-item Kessler Psychological Distress Scale (K10).[26, 118] Increasing mine fire-related $PM_{2.5}$ exposure (categorised as *low*; *medium*; *high*) was associated with greater levels of both mine fire-related posttraumatic stress and generalised psychological distress.[12]

A dose-response relationship was observed between small increments in both mean and peak mine fire-related $PM_{2.5}$ exposures and IES-R score, with an interaction between age and mean $PM_{2.5}$ exposure; indicating that the effect of $PM_{2.5}$ exposure on posttraumatic stress levels was most pronounced in younger adults.[120] A number of factors, independent of $PM_{2.5}$ exposure, were also predictors of higher IES-R score. Being younger, having lower educational levels, being unemployed or unable to work due to illness, and having experienced multiple historical traumatic exposures, were all found to be independently associated with higher IES-R scores.[120] Chronic health conditions, including having any mental health condition, or either a pre- or post-fire diagnosis of asthma or COPD, were also independently associated with higher IES-R scores.[120] After controlling for these factors, older participants reported less mine fire event-related stress than those who were younger, indicating that advanced age was protective against posttraumatic stress after the mine fire.

Interview findings

Interviews with 27 Morwell-based Adult Survey participants in 2016 found that the majority of participants reported experiencing little or no distress at the time of the mine fire event.[118] However, some reported continuing symptoms that were consistent with posttraumatic stress, such as heightened alertness, poor sleep, feeling 'on edge' and experiencing intrusive thoughts.[118] As in the Schools Study, the interview findings were concordant with the Adult Survey results, further validating the findings. Furthermore, the interviews highlighted the acute vulnerability of people with pre-existing mental health concerns to experiencing psychological distress as an outcome of the mine fire event, which again aligned with the Adult Survey findings.[120]

2019-2020 Mental Health and Wellbeing Follow-up Survey (Round 2 data collection)

Between December 2019 and March 2020, 713 Adult Survey participants from Morwell completed a Mental Health and Wellbeing Follow-up Survey.[121-123] As described in section 4.4.3.3, this comprised a repeat of the IES-R and K-10 measures of posttraumatic stress and general psychological distress, respectively, as well as the introduction of new instruments measuring somatic symptoms, social support, loneliness, sense of community wellbeing and resilience. Analysis of Round 1 (Adult Survey) and Round 2 (2019-2020 Mental Health and Wellbeing Follow-up Survey) IES-R results indicated that mean scores increased by 2.6 points (95% CI 1.2 - 3.9) between survey rounds, with increases evident across all three IES-R posttraumatic stress symptom domains, particularly intrusive symptoms.[121, 122] Increases in posttraumatic stress were evident across all levels of mine fire-related $PM_{2.5}$ exposure, suggesting there had been a population-wide increase in posttraumatic stress between survey rounds.[121]

In both survey Rounds 1 and 2, age was an effect modifier between mine fire $PM_{2.5}$ exposure and posttraumatic stress, with younger adults more severely impacted by their exposure to the mine fire smoke.[121, 122] Importantly, the Round 2 survey coincided with Australia's catastrophic 2019-2020 Black Summer bushfires,[51] meaning that some participants would have been experiencing smoky conditions and the media would have been dominated by reports about the bushfires. Those events may have activated or exacerbated unwanted thoughts about the earlier mine fire event. This suggests that subsequent events have the potential to stimulate posttraumatic stress symptoms related to previous trauma, which is pertinent given the growing likelihood of catastrophic environmental events including fires as a result of climate change.

Further analysis explored whether individual participants' mine fire-related posttraumatic stress, as measured in both rounds using the IES-R, had remained the same, become worse or improved over time.[124] Participants were grouped into one of four posttraumatic stress trajectory categories based on the combination of their IES-R scores, relative to clinical concern, at each survey Round (see Figure 33).

- Resilience – a low level of posttraumatic stress at the time of both surveys;
- In-recovery – posttraumatic stress that progressed from a high to low level across surveys;
- Delayed-onset – posttraumatic stress that progressed from a low to high level across surveys; and
- Chronic – a high level of posttraumatic stress at the time of both surveys.

While our previous analyses of posttraumatic stress utilised a cut-off of 33, which was indicative of probable PTSD,[119] for this and subsequent analyses we utilised a lower cut-off of 24, considered to be indicative of clinically concerning stress levels.[125] This allowed a more nuanced understanding of the stress levels in the community, rather than focusing on the small proportion at the upper extreme.

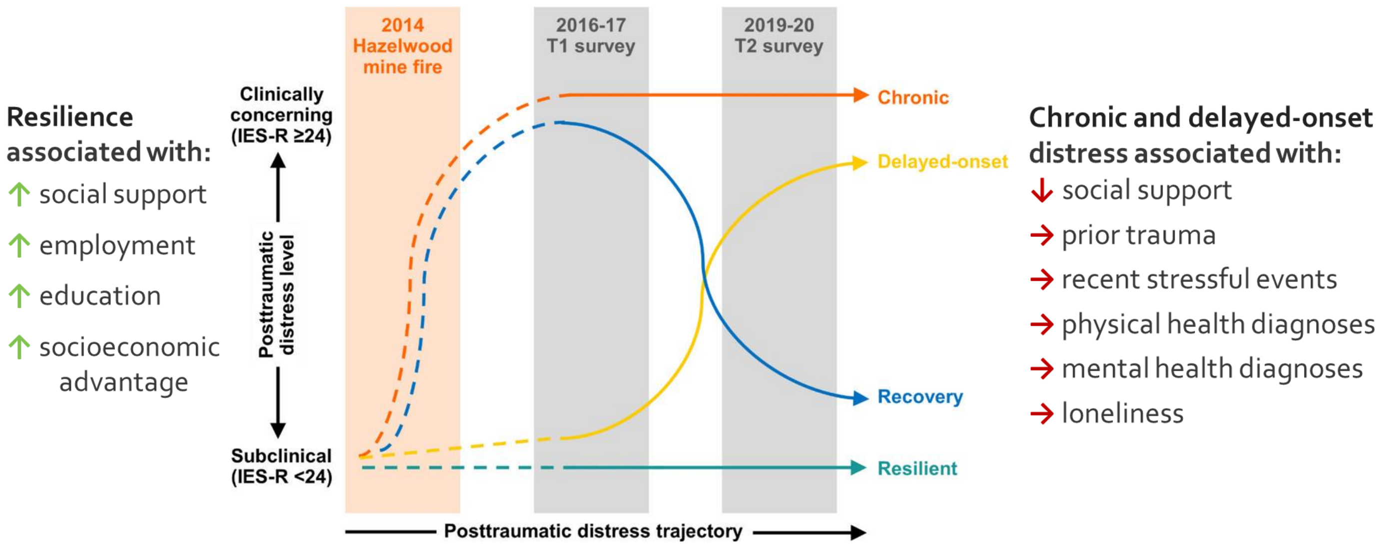


Figure 33 Posttraumatic stress trajectories after the 2014 Hazelwood mine fire

We explored how each of these posttraumatic stress trajectories were related to participants' levels of smoke exposure during the mine fire, and to a variety of important personal and social circumstances such as medical history, social support, education, employment and experiences of other stressful life events.

The most common posttraumatic stress trajectory was resilience (77% of participants), which was associated with higher levels of social support, paid employment and education. Loneliness and low levels of social support were associated with chronic and delayed-onset posttraumatic stress trajectories. Adversities such as prior trauma, recent stressful life-events, and diagnosed physical or mental health conditions were also associated with chronic and delayed-onset posttraumatic stress trajectories. The amount of smoke that participants were exposed to during the mine fire was not a strong determinant of which posttraumatic stress trajectory they were on. These findings indicate that socioeconomic circumstances, connections with others, health and life experiences were the most important factors shaping peoples' posttraumatic stress trajectories during the six years after the mine fire.

Further analyses explored the role of mine fire-related posttraumatic stress, and general psychological distress, in the presentation of physical (somatic) symptoms such as pain, fatigue, shortness of breath and gastrointestinal problems.[123] Just over one third (36%) of survey respondents reported a medium or high level of somatic symptoms. The most frequently reported symptoms included fatigue, limb pain, trouble sleeping, back pain, headaches and shortness of breath. We found that higher levels of posttraumatic stress and general psychological distress were each associated with the presence of most somatic symptoms. These associations were independent of other risk factors that could also have influenced somatic symptoms, such as age, smoking history and diagnosed medical conditions.[123]

In collaboration with the Community Wellbeing Stream (see sections 4.5 and 5.8.2) the researchers also investigated: (1) levels of community wellbeing using the CWI[58] six years after the mine fire; (2) relationships between levels of community wellbeing and mine fire smoke exposure, demographic, social, and health factors; and (3) perceived changes in community wellbeing since the mine fire.[126] For context, the CWI score range was 10-50. A score of 30 indicated a neutral perspective on community wellbeing, scores <30 indicated lower satisfaction with community and scores >30 indicated higher satisfaction with community.[58] The 2019-2020 Mental Health and Wellbeing Follow-up Survey CWI responses indicated that participants were somewhat dissatisfied with community (weighted mean total score 28.47, 95% CI 27.69 - 29.25) and that their satisfaction with community had deteriorated since the mine fire.[126]

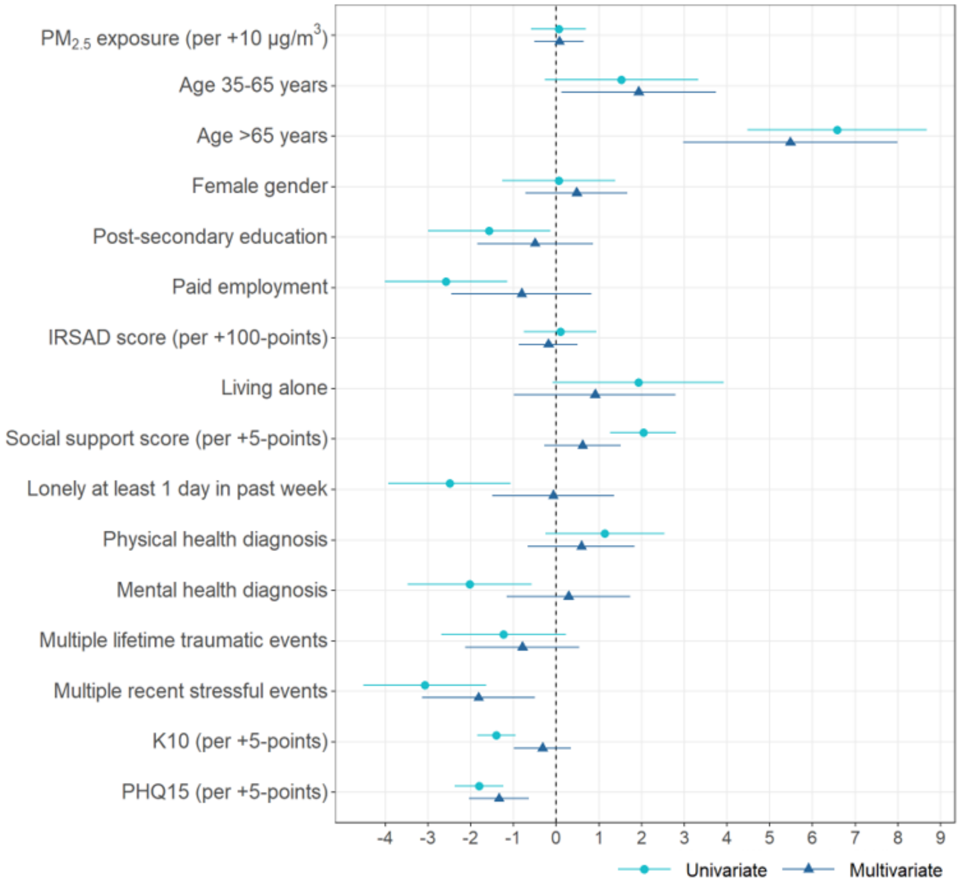


Figure 34 Mean difference in CWI score per unit increase in predictor variables (Source: Carroll *et al.* 2024)[126]

As shown in Figure 34, multiple recent adverse life-events, somatic symptoms (based on the PHQ-15), and being younger were strong, independent predictors of negative perceptions of community wellbeing. For example, compared with the <35 years age-group, the >65 years age-group scored 5.48 points higher on the CWI (95% CI 2.97 - 7.99). This investigation also found that 42% of participants reported experiencing loneliness ≥1 day during the preceding week, 54% a physical health diagnosis, 41% a mental health diagnosis, 49% multiple traumatic events, and 42% multiple recent stressful events (not shown).[126]

2022 Second Mental Health and Wellbeing Follow-up Survey (Round 3 data collection)

The 2022 Mental Health and Wellbeing Follow-up survey (Round 3) was conducted between October and December 2022. With 524 participants, this follow-up survey enabled the Stream to investigate longitudinal psychological health and wellbeing in the local community across three time-points after the mine fire, as well as within the context of more recent events such as the 2019-2020 Black Summer bushfires and the COVID-19 pandemic.[127]

On average, mine fire-related posttraumatic stress levels at Round 3 had dropped significantly from the heightened levels observed in Round 2 (see Figure 35). This suggested that mine fire-related posttraumatic stress had largely dissipated by Round 3, approximately 8.5 years after the event. The increase observed in posttraumatic stress levels in Round 2 was likely attributable to the Black Summer bushfire and smoke event which coincided with that survey and potentially triggered reminders of the earlier mine fire. This is supported by the finding that posttraumatic stress across all three survey rounds was primarily driven by impacts within the *Intrusion* symptom domain, characterised by uninvited thoughts about the mine fire and feeling disturbed when reminders of the event were encountered.[127]

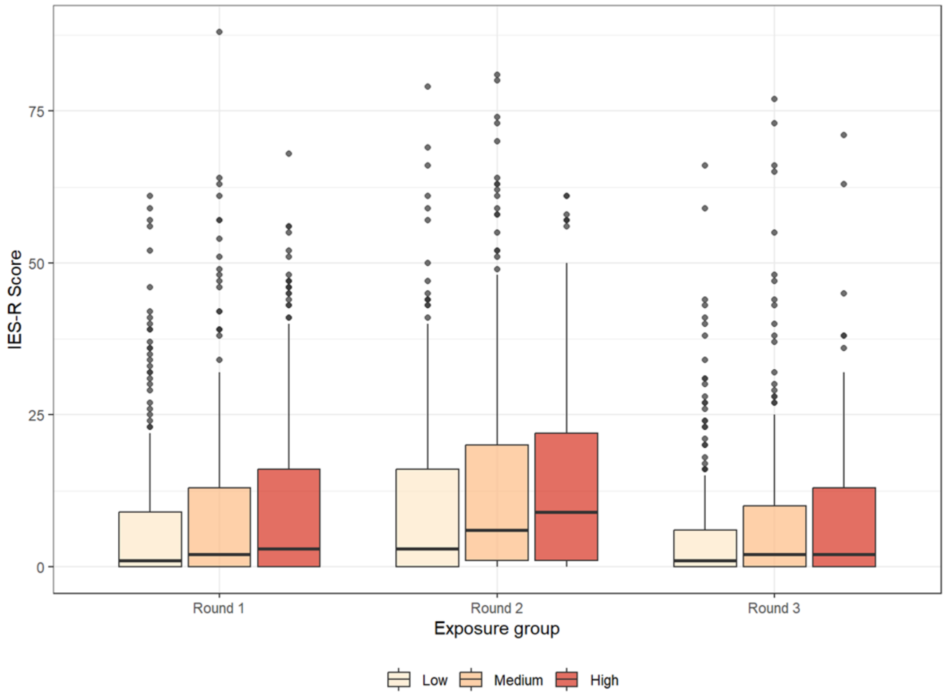


Figure 35 Posttraumatic Stress: IES-R score distributions at each Round categorised by exposure

The modifying effect of age previously observed in analyses of Rounds 1[120] and 2[121] data was no longer evident at Round 3.[127] This indicated that the greater susceptibility of younger adults to posttraumatic stress as a function of smoke exposure had also dissipated over time, likely because of the general dissipation in posttraumatic stress. Overall, the study revealed that, by 8.5 years post-mine fire, participants' sociodemographic circumstances, such as employment status, education level, household income, physical health conditions and prior exposures to other potentially traumatic events, were more integral to shaping longer-term posttraumatic stress outcomes than their level of exposure to mine fire smoke.[127]

The Study found that 23% of 484 participants who provided complete IES-R data for all three survey rounds recorded an IES-R score ≥24 indicating a clinically concerning posttraumatic stress level[125] in at least one of those surveys. In total, 77% recorded subclinical IES-R scores at all three time-points (resilient trajectory) and 5% recorded clinically concerning scores at all three time-points (chronic trajectory). In multivariate analysis, three dominant risk factors for clinically concerning IES-R scores at Round 3 were identified; they were annual incomes below $50,000, greater level of concern about the 2019/2020 Black Summer, and higher somatic symptoms (PHQ-15) score.[127]

Whilst mine fire-related posttraumatic stress had greatly reduced at Round 3, the average level of general psychological distress (K10 score) across the cohort had continued to increase over time. At Round 3, the average K10 score was at a level indicative of moderate general psychological distress. Numerous adverse sociodemographic circumstances were associated with greater general psychological distress, including being unemployed or unable to work, having a physical health diagnosis (cardiac, asthma or COPD), having a prior mental health diagnosis, or having a lifetime exposure to multiple other traumatic events. While mine fire smoke exposure was a significant predictor of general psychological distress in the wider cohort at Round 1,[12] this was no longer the case at Rounds 2 and 3. This suggested that the trajectories of general psychological distress and mine fire-related posttraumatic stress over time had diverged and that the longitudinal increase in general psychological distress in Morwell was not a direct result of the mine fire.[127]

5.5.3 Psychological health findings from Hazelinks

5.5.3.1 Population wide psychological health findings using Hazelinks data

Extraction of anonymous data from the MBS (July 2012 to June 2016) and PBS (January 2013 to December 2016)

Analysis of MBS/PBS data for mental health outcomes indicated that $PM_{2.5}$ was associated with moderate increases in mental health-related consultations and also dispensing of psychiatric medications during the first 30 days of the mine fire. In men, but not women, a 10 µg/m^3 increase in $PM_{2.5}$ was associated with a 32% (95% CI 2% - 72%) increase in mental health consultations.[84] A 10 µg/m^3 increase in $PM_{2.5}$ was also associated with a 12% (95% CI 8% - 16%) increase in dispensing of psychotropic medications.[7]

Extraction of anonymous ambulance attendances, emergency department presentations and hospital admissions data (July 2010 to March 2015)

Analyses of these data showed that levels of mine fire-related $PM_{2.5}$ during the first 30 days of the fire were associated with short-term increases in ambulance attendances and emergency department presentations, but not hospital patient admissions, for mental health conditions in the Latrobe Valley area.[128] The most prominent effects were observed after about five days of smoke exposure (see

Figure 36) when, for each 10 µg/m^3 increase in mine fire-related $PM_{2.5}$, the estimated risk of an ambulance attendance for anxiety increased by 38% (95% CI 13% - 69%) and the risk of an emergency department presentation for depression increased by 36% (95% CI 3% - 79%).[128]

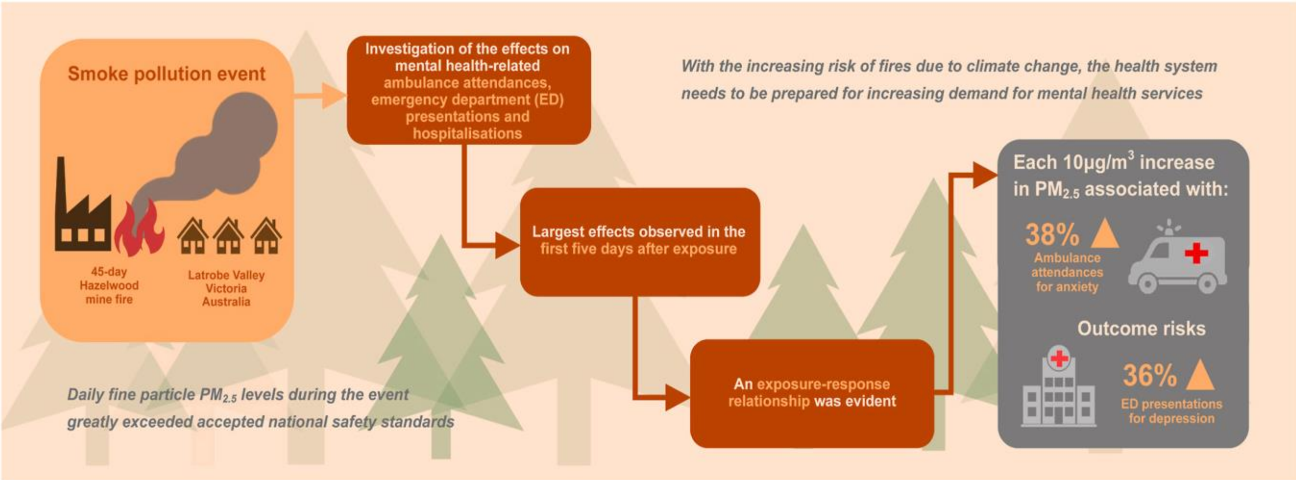


Figure 36 Graphical abstract describing anonymous ambulance attendances, emergency department presentations and hospital admissions findings (July 2010 to March 2015) (Source: Carroll *et al.* 2022)[128]

Extraction of anonymous ambulance attendances data (January 2013 to December 2021), and emergency department presentations and hospital admissions data (January 2009 to June 2022)

Analyses of these data explored whether smoke from the mine fire resulted in increased ambulance attendances, hospital emergency department presentations or hospital admissions for mental health-related conditions during the eight years after the event.[97] Compared with before the fire, and compared also with service use trends in the rest of regional Victoria, overall mental health-related hospital admissions increased by 46% in Morwell and by 42% in the wider Latrobe Valley during the eight years after the event (Figure 37). Furthermore, mental health-related emergency department presentations increased by 10% in Morwell, but remained unchanged in the wider Latrobe Valley. There were no detectable increases in mental health-related ambulance attendances. Time series analysis (not shown) indicated that in Morwell, the increase was most prominent in the three years following the mine fire. There was also an overall peak in late 2018 observed among younger persons and men, whereas among older persons mental health-related hospital admissions peaked in late 2019.[97]

Increments of 10µg/m^3 in mine-fire-related $PM_{2.5}$ exposure, were associated with a 29% increased risk of hospital admission, and a 4% increased risk of emergency department presentation, for mental health-related conditions during this eight-year follow-up period (Figure 37).[97]

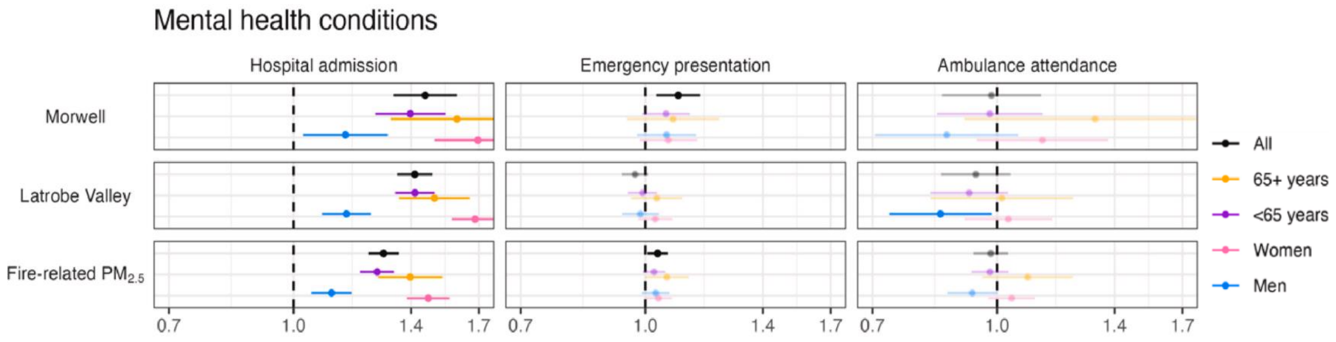


Figure 37 Change in relative risk of mental health service use during the 8 years after the mine fire (Source: Lane *et al.* 2024, Figure 3)[97]

5.5.3.2 Psychological health findings in the identified Adult Survey cohort using Hazelinks data

Linkage with Adult Survey participant's identified ambulance attendances (January 2009 to December 2017), hospital emergency department presentations (January 2009 to March 2019) and hospital admissions data (January 2009 to February 2019).

These data were used to evaluate the association between mine-fire-related $PM_{2.5}$ exposure and mental health-related ambulance attendances,[100] hospital emergency department presentations[87] and hospital admissions (hospitalisations)[101] in the years following the mine fire. Data were available for up to 2,725 Adult Survey participants who consented to linkage.

Amongst the consenting Adult Survey cohort participants, there were no associations observed between each 10 µg/m^3 increase in mine fire-related $PM_{2.5}$ and mental health-related ambulance attendances over 3.5 years (HR 0.93, 95% CI 0.64 - 1.34),[100] emergency department presentations over 5 years (HR 1.01, 95% CI 0.83 - 1.23)[87] nor hospitalisations over 5 years (HR 1.04, 95% CI 0.94 - 1.14).[101]

Summary of key findings: Adult Psychological Impacts

During the mine fire period, small increases in smoke exposure levels were associated with 32% increases in mental health-related consultations among men, and 12% increases in dispensing of psychiatric medications.

Using population-wide ambulance data: During the mine fire period, small increases in smoke exposure levels were associated with 38% increases in ambulance attendances for anxiety. In the following 8 years, there were no changes in mental health-related ambulance attendance rates in Morwell or the Latrobe Valley compared with before the fire and compared with trends in the rest of regional Victoria.

Using ambulance data linked to study participants: Higher smoke exposure was not associated with higher rates of mental health-related ambulance attendances over a 3.5-year period.

Using population-wide hospital data: During the mine fire period, small increases in smoke exposure levels were associated with 36% increases in emergency department presentations for depression. In the following 8 years in Morwell, compared with before the fire and with trends in the rest of regional Victoria, there was a 10% increase in mental health-related emergency department presentations and a 46% increase in mental health-related hospital admissions. Increases were most prominent during the first 3 years.

Using hospital data linked to study participants: Higher smoke exposure was not associated with higher rates of mental health-related emergency department visits or hospitalisations over a 5-year period.

Approximately 2.5 years after the mine fire, moderate levels of both mine fire-related posttraumatic stress and general psychological distress were reported by adults in Morwell. The levels of each increased in line with levels of smoke exposure. Vulnerable groups included younger adults and those with pre-existing respiratory or mental health conditions. Approximately 10% of Morwell participants recorded levels of posttraumatic stress indicating possible PTSD.

Some adults interviewed in 2016 reported symptoms consistent with PTSD such as heightened alertness, poor sleep, feeling *on edge* and intrusive thoughts. Adults with pre-existing mental health conditions were particularly vulnerable.

Approximately 5.5 years after the mine fire, the first follow-up survey of Morwell participants showed a small but significant increase in mine-fire related posttraumatic stress across all smoke exposure levels, particularly in relation to *intrusive* symptoms and among younger adults. Intrusive thoughts may have been activated or exacerbated by co-occurring smoke from the 2019-2020 Black Summer bushfires and associated media coverage. Morwell participants reported being somewhat dissatisfied with their community, and their satisfaction had deteriorated since the mine fire. Multiple recent adverse life-events, somatic symptoms and being younger predicted negative perceptions of community wellbeing. Between 40% and 54% of Morwell participants reported experiencing recent loneliness, a physical health diagnosis, a mental health diagnosis, multiple traumatic events and/or multiple recent stressful events.

Resilient participants, with low levels of distress 2.5 and 5.5 years after the fire, on average had higher levels of social support and socioeconomic advantage. Participants with delayed-onset (low at 2.5 years but high at 5.5 years) or chronic posttraumatic stress (high at both times) were more likely to have prior trauma, recent stressful life-events, or diagnosed physical or mental health conditions.

Higher levels of both mine fire-related posttraumatic stress and general psychological distress were associated with physical (somatic) symptoms. Common symptoms were fatigue, limb pain, trouble sleeping, back pain, headaches and shortness of breath.

Approximately 8.5 years after the mine fire, Morwell participants reported that mine fire-related posttraumatic stress had largely dissipated, however, general psychological distress was rising across the cohort. Being unemployed or unable to work, having a physical diagnosis (cardiac, asthma or COPD), having a prior mental health diagnosis or having exposure to other traumatic events were all associated with greater levels of general psychological distress.

5.6 Research Question 6 about cancer

RQ 6 relating to the incidence of malignant disease (cancer) is informed by findings from the cancer component of Hazelinks.

5.6.1 Population-wide cancer outcomes

Extraction of anonymous Victorian Cancer Registry data (January 2009 – December 2013)

To understand the cancer patterns in the Latrobe City and its surrounding areas **prior** to the Hazelwood mine fire, Hazelinks analysed an anonymous extract of Victorian Cancer Registry (VCR) data for the period 1 January 2009 to 31 December 2013 for Latrobe City, as well as the surrounding areas of Baw Baw, Gippsland-South West and Wellington.[86] Understanding the baseline, or pre-mine fire, rates of cancers in these areas were considered important when interpreting the rates of cancer that occurred after the mine fire.

Results showed the overall numbers of baseline, pre-mine fire, cancers in Latrobe City and combined surrounding areas (Baw Baw, Gippsland-South West, and Wellington) to be similar to the expected number of overall cancers in the rural and regional Victorian population.[86] However, when cancers were sub-divided by type, a higher rate of mesothelioma was observed in males in Latrobe City when compared to the expected rate in the rural and regional Victorian population (Standard Incidence Ratio; SIR 2.67, 95% CI 1.73 - 3.95).[86] The excess of mesothelioma was most likely due to past asbestos exposure, as this is the only known cause of mesothelioma found in Australia. This may relate to past asbestos exposure in the power industry or other worksites in the region, or domestic exposure due to asbestos-containing building materials. For males, the observed number of bladder cancers was also higher than expected in Latrobe City (SIR 1.37, 95% CI 1.01 - 1.82); however, colon cancers were lower than expected (SIR 0.79, 95% CI 0.62 - 0.98). For females in Latrobe City, excesses of liver (SIR 2.28, 95% CI 1.21 - 3.89), lung (SIR 1.26, 95% CI 1.03 - 1.53) and all-type blood cancers (SIR 1.22, 95% CI 1.01 - 1.46) were observed, while melanoma was observed to be lower than expected (SIR 0.69, 95% CI 0.52 - 0.88). Cigarette smoking is a well-known cause of both lung and bladder cancers; however, we do not have individual smoking data for these VCR anonymous cancer cases. These patterns of cancer incidence by type, observed in Latrobe City, were not evident in the surrounding areas (Baw Baw, Gippsland-South West, and Wellington).[86]

Extraction of anonymous Victorian Cancer Registry data (January 2009 – December 2021)

We obtained an anonymous extract of VCR data for the period 1 January 2009 to 31 December 2021 for all of Victoria. The data were categorised into three groups: Morwell, with the most exposure; the rest of the Latrobe Valley, with less exposure compared with Morwell; and the rest of regional Victoria (excluding Melbourne) as a control group. These data were then used in two separate analyses; the first investigating the association between mine fire smoke exposure and incidence of new cancers in the region; the second investigating the association between mine fire smoke exposure and survival in people who already had cancer.

Incidence of new cancers

This sub-study aimed to investigate whether mine fire smoke exposure increased yearly rates of cancer in Morwell or the rest of Latrobe Valley during the 7.5 years after the fire, taking into consideration trends in cancer rates before the fire and trends in the rest of regional Victoria.[129] The theory was that, if there was a change in the yearly trend of new cancers diagnosed in smoke effected areas after the fire compared with before that was not seen in other parts of regional Victoria, then a likely cause was the mine fire.

These analyses were limited to people aged 40 years and older due to low numbers of cancers in younger persons. We identified 851 new cancers in Morwell after 2014, and 2,460 in the rest of the Latrobe Valley. When we combined all cancer types together and compared the years before the mine fire with the years after in both areas, we found no difference in the yearly trend of new cancer cases. That is, after the mine fire we could see no annual increase in the overall rates of cancer.[129] When we looked at people of different ages, cancer incidence was 2% higher than expected each year after the mine fire among people aged 60-69 years in 'the rest of the Latrobe Valley' compared with the 'rest of regional Victoria' (95% CI 0% - 4%). However, the evidence was weak and this was not likely to be an effect of mine fire smoke because the trend was not observed in Morwell where smoke exposure levels were higher. When we divided cancers into subtypes, incidence of newly diagnosed blood-related cancers (leukaemia, lymphoma, myeloma) in Morwell was 8.2% lower than expected each year after the fire (95% CI -14.3% to -2.1%). There are a number of chemicals including solvents, pesticides and herbicides, and jobs such as farming, painting and construction, that have been linked to blood cancer. Closure of industries in or around Morwell that might have increased blood cancers in workers, or relocation of previously exposed workers out of Morwell, could be explanations for the decreased rates of new blood cancers in the area. Alternatively, this may have been a chance finding. We do not believe that the mine fire had a preventive effect on blood cancers. While not statistically significant, there were sizeable annual increases in small cell lung carcinoma in both Morwell (IRR 1.15, 95% CI 0.89 - 1.46) and the rest of the Latrobe Valley (IRR 1.10, 95% CI 1.00 - 1.21).[129]

We concluded that, after 7.5 years, there was no definitive evidence that air pollution from the mine fire increased cancer incidence in the Latrobe Valley.

Survival in people who already had cancer

There are studies which show that air pollution can shorten the lives of people living with cancer. Therefore, this HHS sub-study aimed to investigate whether exposure to smoke from the mine fire shortened survival among people living with cancer in the Latrobe Valley.[130]

We searched the VCR for all new cancers diagnosed during the 5 years before the mine fire (January 2009 to February 2014). There were 488 cases of cancer in residents of Morwell, 1,738 in the rest of the Latrobe Valley and 42,738 in the rest of regional Victoria excluding Melbourne. We looked at the monthly pattern of survival from these cancers in the years before and then after the mine fire up to August 2019, 5.5 years post-mine fire. We used the August 2019 cut-off because, after that time, large parts of eastern Victoria experienced high levels of smoke exposure from the 2019-2020 Black Summer bushfires and it was considered that this could confound the results. The theory underlying the analysis was that, if there was a change in the monthly pattern of cancer survival in mine fire smoke-effected areas after the Hazelwood event compared with before, that was not seen in other parts of regional Victoria, then a likely cause was the mine fire.

When we combined all cancer subtypes together, we found no change from before to after the fire, in the monthly pattern of cancer survival in Morwell and the rest of the Latrobe Valley. When we divided cancers into subtypes, we found that survival was shortened after the fire for females residing in Morwell who had reproductive organ cancers (examples include cervical, ovarian and uterine cancers).[130] However, there were only 27 cases of female reproductive cancers in Morwell and, with such small numbers, it was likely that this was a chance finding that was not due to the mine fire. There was also a small reduction in survival from breast cancers observed in the 'rest of the Latrobe Valley' after the fire. This was unlikely to be caused by the mine fire because the same pattern was not observed in the more highly exposed area of Morwell. There were no other changes in cancer survival observed for lung, blood, brain, melanoma, digestive, urinary and male reproductive cancers.[130]

5.6.2 Cancer outcomes in the identified Adult Survey cohort

Identified VCR data linked to the Adult Survey cohort, August 2014 – December 2019

VCR data for the period 9 August 2014 (6 months after the start of the mine fire) to 31 December 2019, linked to 2,854 consenting Adult Survey cohort members, were analysed to evaluate the relationships between mine fire-related smoke $PM_{2.5}$ concentrations and cancer incidence during the 5.5 years post-mine fire.[131] Because the data were linked to the Adult Survey cohort, we were able to control statistically for known confounders including age, sex, marital status, education, employment, occupational exposures, smoking and alcohol consumption. In total, 14,849 person-years follow-up were accumulated. During the 5.5 year period after the mine fire, a higher risk of cancer incidence was observed for participants in Morwell compared with Sale (Hazard Ratio; HR 1.67, 95% CI 1.05 - 2.67), but no evidence to suggest dose-response associations between 10 µg/m^3 increments in $PM_{2.5}$ exposure and overall cancer incidence (HR 1.02, 95% CI 0.91 - 1.13), or any site-specific cancers in the Adult Survey cohort.[131] It was possible that the difference in cancer incidence between Morwell and Sale reflected residual confounding such as an unmeasured risk factor for cancer that differed between the two towns; e.g., diet or employment industry. Five years is quite short for long latency cancers and therefore, longer follow-up was considered needed.

Identified VCR data linked to the Adult Survey cohort, August 2014 – December 2022

Building on our earlier work,[131] VCR and NDI data for the period 9 August 2014 (6 months after the start of the mine fire) to 31 December 2022, were linked to 2,874 consenting Adult Survey cohort members and analysed to evaluate the relationships between mine fire-related smoke $PM_{2.5}$ concentrations and cancer incidence during the 8 years post-mine fire. In total, 23,273 person-years follow-up were accumulated.[132]

After 8 years, there was no detectable dose-response association between 10 µg/m^3 increments in fire-related $PM_{2.5}$ exposure and overall cancer incidence (Hazard Ratio 1.00, 95% CI 0.90 - 1.11) in the Adult Survey cohort, nor were there any dose-response associations for any of the cancer subtypes.[132] The cancer subtypes with the highest HRs were urinary tract (n=18) and respiratory/intrathoracic (n=33), but due to small numbers these risk estimates were very imprecise. Limitations to the interpretation of these results include the relatively short follow-up period for long latency cancers, which was potentially exacerbated by an additional lag between carcinogenic exposure and cancer diagnoses in regional and socioeconomically deprived areas. Furthermore, COVID-19-related restrictions led to a small reduction in cancer diagnoses during 2020-2022; effectively reducing case numbers and statistical power.[132]

Summary of key findings: Cancer in adults

Population-wide cancer rates before the mine fire

Before the mine fire, the overall rate of cancer in Latrobe City and surrounding areas was similar to the overall rate of cancer in the rural and regional Victorian population. However, when cancers were divided by type, males in Latrobe City were more likely to have mesothelioma (a cancer caused by asbestos exposure) and bladder cancer, but less likely to have colon cancer, than males in other rural and regional Victorian areas. Also, females in Latrobe City were more likely to have liver, lung or blood cancer, but less likely to have melanoma, than females in other rural and regional Victorian areas.

Population-wide cancer incidence up to 7.5 years after the mine fire

We found no change from before to after the fire, in the overall yearly trend of new cancer cases in Morwell or the rest of the Latrobe Valley. When cancers were divided by type, we found that annual incidence of blood cancers decreased (improved), however, we do not believe that the mine fire smoke had a preventive effect leading to this improvement. Annual incidence of lung cancer increased, however, evidence for this was weak. There were no changes in cancer incidence believed to be mine fire-related.

Population-wide cancer survival up to 5.5 years after the mine fire

We found no change from before to after the fire, in the overall monthly pattern of cancer survival in Morwell and the rest of the Latrobe Valley. When cancers were divided by type, we found that survival was shortened after the fire for females in Morwell who had reproductive organ cancers. However, there were only 27 cases in Morwell and, with such small numbers, it was likely that this was a chance finding that was not due to the mine fire. There were no other changes in cancer survival believed to be mine fire-related.

Adult Survey cohort: cancer incidence up to 5.5 years after the mine fire

Amongst Adult Survey cohort members, a 67% higher risk of overall cancer was observed in Morwell compared with Sale 5.5 years post mine fire, but there was no evidence to suggest that this was related to mine fire smoke. When new cancers were divided by type there were no differences between Morwell and Sale, and no evidence of mine fire-related effects.

Adult Survey cohort: cancer incidence up to 8 years after the mine fire

Amongst Adult Survey cohort members, when new cancers were divided by type, there was no definitive evidence of mine fire-related effects.

Limitations to cancer findings

It is generally considered that our longest available follow-up period of 8 years, is likely too short to confidently assess long latency cancer outcomes following mine fire smoke exposure. Further, cancer diagnoses in socioeconomically deprived areas tend to lag behind wealthier areas, plus COVID-19-related restrictions likely delayed cancer diagnoses further. Follow-up over a longer time period is necessary to confidently assess the impact of mine fire smoke exposure on cancer.

5.7 Requested Information 3 about comparator populations

RI 3 regarding what comparator populations might be suitable, was informed by the Exposure Assessment, Adult Survey, Schools Study, Adult Psychological Impacts Stream, ELF Study, Hazelinks and Cancer streams. The Hazelwood Health Study has utilised a number of different comparator populations depending on which stream or analyses were being undertaken.

5.7.1 Comparing outcomes between Morwell and selected areas in Sale

In the Adult Survey and Adult Psychological Impacts Stream, some analyses have compared health outcomes between residents of Morwell and residents of selected areas in Sale. As indicated in Figure 38, CSIRO's Victoria-wide model indicated that Morwell experienced the very highest $PM_{2.5}$ concentrations whilst, outside of Morwell, concentrations decreased substantially. The model predicted low to no mine fire-related concentrations of $PM_{2.5}$ and CO for the population at Sale, supporting the selection of Sale as a minimally exposed comparator population.

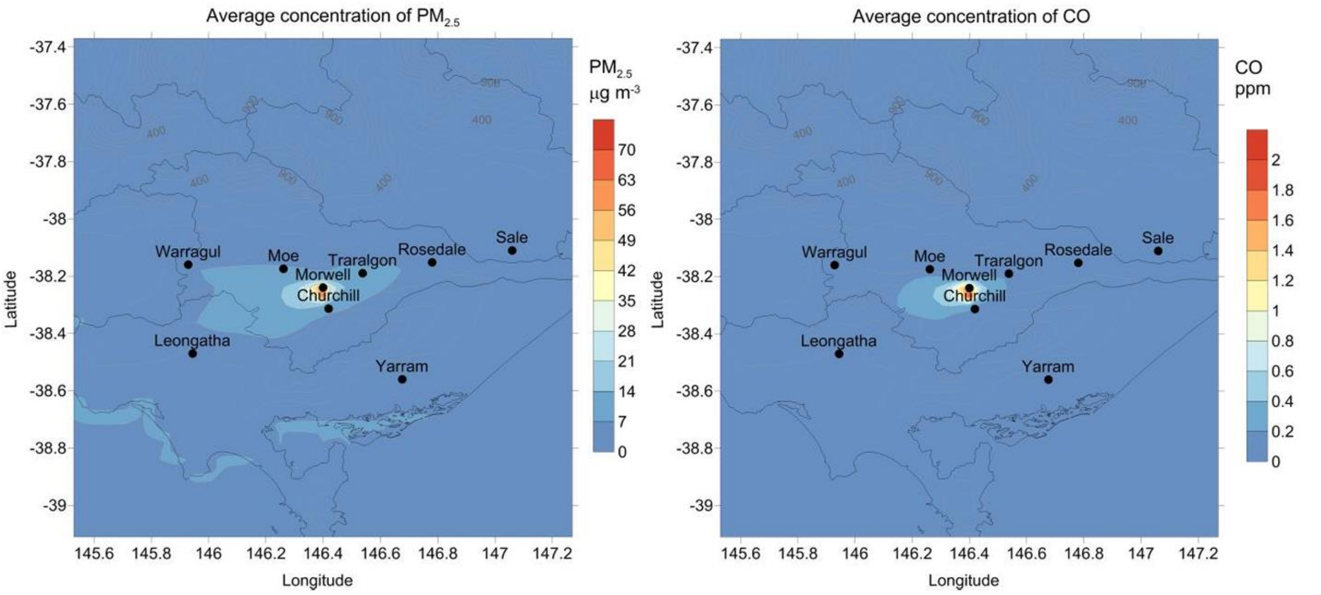


Figure 38 Predicted average concentrations of $PM_{2.5}$ and CO as a result of the mine fire across the Latrobe Valley and parts of Gippsland, including Sale, during the Hazelwood mine fire period (Source: Emmerson *et al.* 2016, Figure 23)[4]

The peak hourly averaged $PM_{2.5}$ concentration predicted at Sale was 17 µg/m³ on 10th February, whereas Morwell peaked at 3700 µg/m³. The peak CO at Sale was 0.46 ppm on 22nd February, whereas Morwell peaked at 60 ppm. No exceedances of either Air NEPM standard were predicted by the model for Sale during the mine fire.[4]

Within Sale, 16 SA1s were selected which had comparable median age, household size, Socio-Economic Indexes For Areas (SEIFA)[16] and population stability as Morwell. By limiting recruitment in Sale to these SA1s, the comparison population was as similar to Morwell as practically possible with the exception of Hazelwood mine fire exposure.

5.7.2 Comparing outcomes across a gradient of $PM_{2.5}$ exposure levels

The addresses at which people resided, worked and/or relocated to, in combination with the dates and times spent at those addresses, determined their individual cumulative $PM_{2.5}$ exposure concentrations for the duration of the event. In general, people who resided and also worked in the southern-most parts of Morwell for the duration of the mine fire comprised the most highly exposed population. Some who resided and also worked in the southern-most parts of Morwell, but who relocated to less exposed locations on very smoky days or nights, will have had less cumulative exposure. Those Morwell residents who worked in the southern parts of Morwell but who resided further away from the mine fire, may have had higher cumulative $PM_{2.5}$ exposure concentrations than their neighbours who worked elsewhere. Some Morwell residents who were able to relocate for any or all of the mine fire period may have had minimal exposure regardless of their residential address. Although lower in concentration on average, similar variations in exposure levels would have been experienced by residents in other towns across the Latrobe Valley.

For these reasons, many Adult Survey, Adult Psychological Impacts Stream, ELF Study and Hazelinks analyses have been able to compare lesser exposed participants with higher exposed participants along a gradient of exposure. Some analyses have compared participants with zero cumulative $PM_{2.5}$ exposure (a 'no exposure' reference group) with 'exposed' participants divided into *low*, *medium* and *high* exposure groups based on tertiles of their average cumulative 24-hour $PM_{2.5}$ exposure. Further analyses have investigated the health outcomes associated with each 10 µg/m^3 increment in mean daily $PM_{2.5}$, and each 100 µg/m^3 increment in peak daily $PM_{2.5}$. For the Adult Survey and Adult Psychological Impacts Stream, these analyses have been limited to residents from Morwell or Sale. However, for the ELF Study, these analyses have included children born across the wider Latrobe Valley region (see Figure 29). The ELF Study has also included a group of children who were born in the Latrobe Valley but conceived after the mine fire period and therefore, not exposed to mine fire smoke whilst *in utero* or during infancy. They have served as a not-exposed comparator group in some ELF Study analyses.

5.7.3 Comparing outcomes across school locations, school types and grade levels

As described in section 4.4.2, the Schools Study comprised 20 schools across Morwell and the wider Latrobe Valley region, including government and non-government, primary and secondary, and students in academic grades 3, 5, 7 and 9. Each subgroup effectively became a comparator group for the others, with analyses comparing Morwell versus non-Morwell schools to create a gradient in smoke exposure, government versus non-government and older grades versus younger grades.

5.7.4 Comparing health outcomes over time and across Victoria

Hazelinks and its cancer sub-stream often employed a statistical method called time series analysis to investigate trends in health outcomes observed before the mine fire, compared with trends in the same health outcomes observed after the mine fire. Many of these analyses have included Morwell, the wider Latrobe Valley, select areas of Gippsland and even all of regional Victoria. For example, the Cancer Stream's 2024 cancer incidence analysis compared the yearly trends in cancer incidence in Morwell, the wider Latrobe Valley and the rest of regional Victoria before the mine fire, with the yearly trends in the same areas after the fire.[129] The theory was that, if there was a change in the yearly trend of new cancers diagnosed in smoke effected areas after the fire compared with before, that was not seen in other parts of regional Victoria, then a likely cause was the mine fire. In these analyses, post-fire Morwell was effectively compared with itself pre-mine fire, and the pattern of change in Morwell was compared with the pattern of change in the other areas. Hazelinks used a similar method to investigate changes over time, and across Victoria, in ambulance attendances, emergency department presentations and hospital admissions. A visual representation is provided in Figure 39, where the trends in pre- and post-mine services use are shown for Morwell, the wider Latrobe Valley and the rest of regional Victoria.[97]

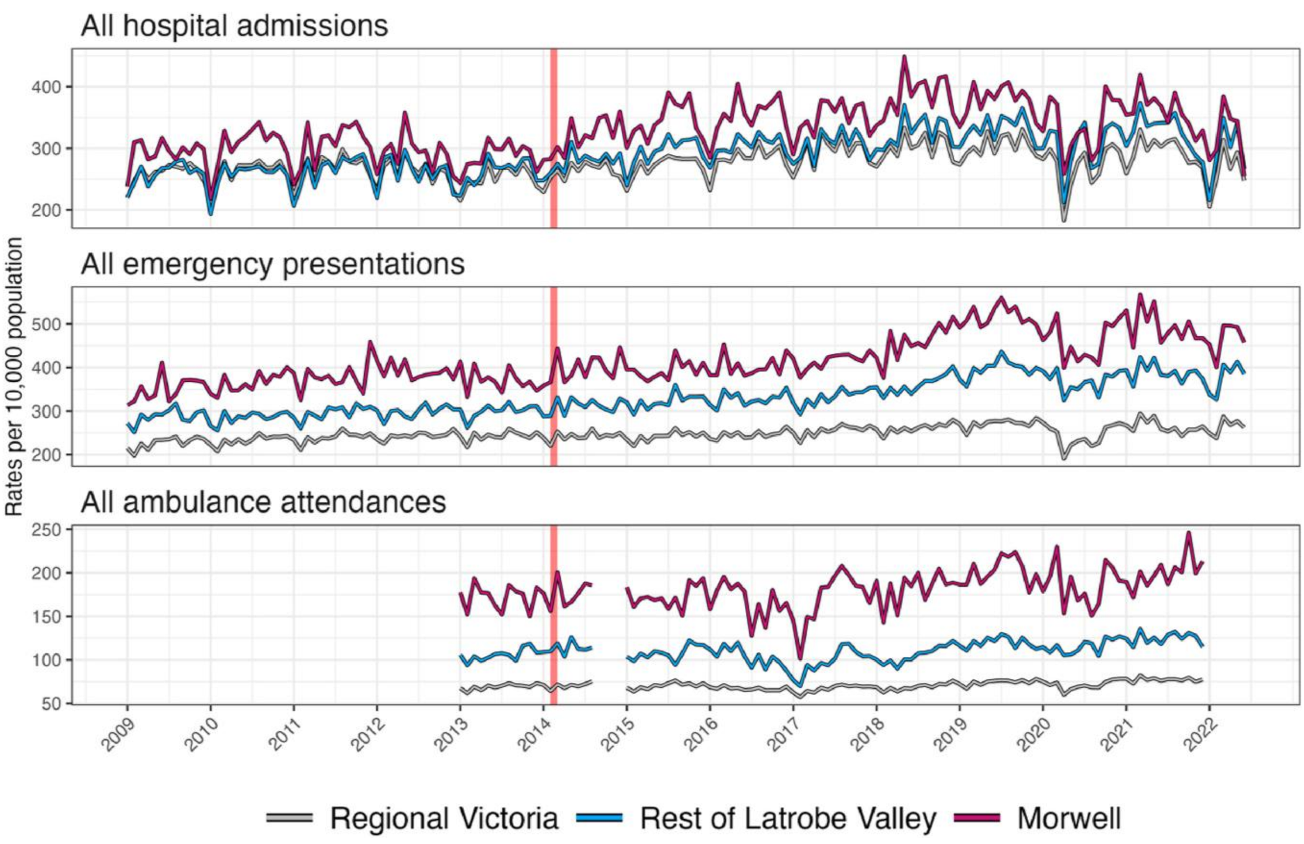


Figure 39 Trends over time in ambulance attendances, emergency department presentations and hospital admissions. The red vertical line represents the mine fire period (Source: Lane *et al.* 2024)[97]

Summary of key findings: Suitable comparator populations

Comparing outcomes between Morwell and Sale

CSIRO's Victoria-wide $PM_{2.5}$ model indicated that Morwell experienced the highest air pollution concentrations whilst Sale experienced little to none. Furthermore, the researchers were able to identify 16 SA1s in Sale with comparable median age, household size, socioeconomic index and population stability to Morwell. By limiting recruitment in Sale to these SA1s, this comparator population was as similar to Morwell as practically possible with the exception of Hazelwood mine fire exposure.

Comparing outcomes across a gradient of $PM_{2.5}$ exposure levels

Sizeable variability in $PM_{2.5}$ exposure levels experienced by residents within Morwell and across the Latrobe Valley meant that many HHS streams have been able to compare lesser exposed participants with higher exposed participants along a gradient of exposure. This has included no exposure versus low, medium or high exposure categories, or change in health outcomes per increment in mean or peak $PM_{2.5}$ exposure for people residing across the Latrobe Valley. The ELF Study also included a not-exposed comparator group by including children who were conceived after the mine fire smoke had dissipated.

Comparing outcomes across school locations, school types and grade levels

In the Schools Study, government and non-government schools across the Latrobe Valley, primary and secondary schools, and students in academic grades 3, 5, 7 and 9 each effectively became comparator groups for each other.

Comparing health outcomes over time and across Victoria

Time series analyses have been used by several HHS streams to investigate trends in health outcomes observed before the mine fire, compared with trends in the same health outcomes observed after the mine fire. In effect, the pre-mine fire population became the comparator group for itself post-mine fire. Many of these analyses have compared trends in Morwell with trends in the wider Latrobe Valley, select areas of Gippsland or even all of regional Victoria.

5.8 Requested Information 4 about older people, community wellbeing and community rebuilding

RI 4 in regard to the impact on older people and impact on community wellbeing and community rebuilding efforts, is informed by the Impact on Older People Stream and the Impact on Community Wellbeing Stream.

5.8.1 Impact on older people

5.8.1.1 Policy Review of the Impact of the Hazelwood Mine Fire on Older People

The Policy Review of the Impact of the Hazelwood Mine Fire on Older People[68] explored the impact of the Hazelwood mine fire on older people living in the Morwell community in the context of policy-driven decisions made at the time. We were able to gain an understanding of older people's experiences of the smoke event and the efforts put in place to support them using a mix of qualitative research methodologies. We combined the findings from focus groups held with local older people and community members and interviews with local decision-makers and representatives of services which supported older people during the smoke event, with reviews of relevant literature and various government policies. We are confident that our review has important implications for policy development and program planning in relation to older people and disasters. We hope that this results in best practice to improve preparations for, and responding to, future disaster events. The key, verified conclusions about the impact of the Hazelwood mine fire on older people, in the context of future policy and planning, are summarised under the following four headings.[68]

The impact of the Hazelwood mine fire event on older people

Our discussions with older residents showed that there was considerable diversity in terms of the impacts of the smoke event, with many older residents reporting a wide array of physical and psychological symptoms at the time of the event, and some reporting ongoing symptoms as well as concerns about long-term health impacts.[68] Conversely, other older residents reported being minimally impacted by the smoke event and that it was no worse than previous smoke exposures. The diverse range of responses may be because we talked with an array of groups and included independent older people who were not receiving health and community services and who received little or no support during the event. Discussions with service providers tended to reinforce the stoic and robust nature of older residents. It may be that these service providers were largely consulting with only those who were receiving their services, who would have felt confident that help was available should the need arise.[68]

The impact of policy-driven decisions made at the time on older people

There was almost universal agreement that the Hazelwood smoke event was a unique occurrence which was beyond the scope of existing policies that had been developed for bushfires and other emergencies. One of the challenges faced by the Department of Health and other agencies during the smoke event was the lack of a strong evidence base regarding the impacts of coalmine fire smoke events, including impacts on sub-groups such as older people. A review of the literature[2] noted that the lack of evidence on the short and long-term impacts of exposure to coal mine fire smoke hampered the public health response to the mine fire event.

A number of respondents from the general community and from service provider representatives felt that the community should have been evacuated early into the event, However, our review of the literature made it clear that the decision to evacuate or temporarily relocate a community or sub-sets of that community is incredibly challenging, especially for frail older people with chronic health conditions. So, the Department of Health faced a very challenging situation, having to weigh the concerns of the community against the risks of a major community relocation effort in the absence of clear evidence.[68]

There was a clear thread through the older community, service provider and decision maker discussions regarding the mismatch between existing emergency policies and the extended, dynamic and uncertain nature of the Hazelwood mine fire event. The development of policy on the run and the resultant change in health advice to older people and other at-risk groups to temporarily relocate, coming as late as it did in the event period, was a source of annoyance for some older residents.[68]

In addition to developing new policies and protocols, there were issues in the way in which existing policies interacted, such as the Municipal Emergency Management Plans. In the case of a major event such as the Hazelwood mine fire, these Plans were overridden by the state level plan, relegating local council to a minimal but supportive role. This approach may be suitable when responding to short sharp disaster events such as bushfire, allowing councils to take a more active role once the emergency has passed. However, in the current example of an extended duration event which was impacting a community, this approach resulted in clear issues.[68]

The impact of the mixed roles of emergency personnel and agencies on older people

One of the 'unique' challenges of the Hazelwood event was the extended duration. The emergency response continued over a 6-week period, with the public focus shifting from the response to multiple bushfires which initially directly threatened Morwell property, to an ongoing fire largely restricted to the mine site and threatening state electricity supplies, and to a long-term emerging smoke-related public health threat. These shifts, coupled with the fact that multiple agencies were involved (including emergency, environmental, health, local and state government) and that their roles changed in line with the changes in the response focus, clearly created issues with the response, the engagement of the local community and the subsequent impact on older people.[68]

The increasing focus on the impacts of the smoke event on the health of the community saw the event change from being a fire event under the control of the CFA to a public health event under the control of the Department of Health. The command structures of these two bodies varied considerably. These differences, combined with the fact that the fire event continued at the same time as the smoke event, led to some role confusion and mixed messaging. Roles were blurred rather than distinct. One of the most obvious manifestations of this role confusion was the breakdown in communication which occurred during the smoke event, and led to older residents reporting having less trust in the emergency response and in the people and organisations at the centre of that response.[68]

The impact of communication during the event on older people

It was clear from the findings of the HMFI (convened in 2014 and again in 2015/16) and from the feedback of older residents that there were challenges engaging with older people and the broader community.[68] Communication was not well coordinated and at points appeared contradictory. Older community members in particular found it hard to comprehend, and many older people not in residential care or not receiving services, felt disengaged and ignored. Macnamara[133] described the Hazelwood event as a “crisis of communication” and argued that there was confusion between provision of information and real communication and that there was a lack of empathy with the community.

One issue with policy that became apparent in the response to the Hazelwood mine fire was when and how to target older people in the response, including which groups to target. The focus during the event on older people appeared to be targeted on people in residential care settings or receiving services – those perceived to be most vulnerable. Our review of the literature made it clear that it was also important to consider the needs of other older people who were living in the community and not receiving care and monitoring as part of a residential care or support service. This was backed up in a number of our discussions where older people living independently reported suffering from physical health symptoms or being unable to access supports to get respite from the smoke or to clean their properties. How to access the broader group of older people living in the community was highlighted in the literature as being very challenging. Instead of trying to identify lists of people to be individually targeted, a more successful approach could be to increase engagement activities with the different sectors of the community, including older residents.[68]

In addition to engaging the community in a two-way conversation the messages being shared with older people and the broader community should be appropriate and do-able. While the Victorian Department of Health was advising residents to seek respite away from the smoke, including the later message for ‘at risk’ groups to temporarily relocate, it was apparent from our discussions that the capacity to relocate was closely associated with a number of other factors including access to alternative accommodation, social networks, transport, and sufficient funds.

5.8.1.2 Policy Brief

The Policy Brief,[68, 69] which accompanied the Policy Review of the Impact of the Hazelwood Mine Fire on Older People, presented four key considerations for policy development and program planning. The recurring issue arising throughout the research process, culminating in the verification workshop with key community and organisational participants, was the requirement to listen to and include the voices of older people.

The criticality of who is delivering the message

- Guarantee consistency among spokespersons – respondents felt that there were too many voices, and that the various spokespersons were rostered on a rotating basis and so had no chance to build local knowledge and engagement.
- Appoint spokespersons who are seen to be part of the event – so either use a local person (much preferred) or, if an external person, then they need to be seen as staying in/with the community.
- Respond to the clear preference for local government to take the communications lead – the older community looks to their local council.
- Provide age-relevant spokespersons – include older people or known senior health professionals as support speakers. A 20-year-old carries little weight with the older cohort.
- Make use of existing community groups involving older people to disseminate information to and to seek advice from.

The criticality of how the message is delivered

- Ensure that roles and responsibilities amongst and between agencies are known and understood in order to reduce anxiety and confusion among the elderly.
- Avoid presenting the elderly in an unfairly negative light.
- Engage with the older community in two-way conversations showing empathy and understanding rather than talking via a leaflet and citing previous reports.
- Provide information that is comprehensible and do-able.
- Avoid conflicting communications and mis-information.
- Provide simple and helpful emergency information via social media from a clearly-identified trusted source.
- Avoid leaving an emergency information vacuum which may be filled by less-informed people.

The criticality of who is being targeted

- Demonstrate awareness of the diverse vulnerabilities of older people - e.g., focus on people with chronic conditions, mobility limitations and limited social networks rather than targeting all older people as a single 'vulnerable' group. Nb. the Psychological Impacts Stream showed that when they controlled statistically for chronic health conditions, older adults were less likely than younger adults to report posttraumatic stress,[120] reinforcing the argument that older people should not be treated as all equally vulnerable.
- Demonstrate awareness of the needs of the 'robust elderly' who do not receive health and community services and so may be overlooked but in need during an emergency event where normal routines and services are disrupted.

The criticality of communication with older people to build and maintain confidence and trust

- Actively communicate what has changed, the protocols in place, changes in agency structure, relevant new policies and procedures, mitigation and prevention strategies.
- Make use of existing community groups involving older people to disseminate information.
- Make use of disaster management exercises to involve agency personnel and community volunteers and engage with local media.

Summary of key findings: Impacts on older people

Voices of older people, especially those usually robust older people living independently in the community, were paid little attention during the event.

There was little support for older people who were not receiving health and community services.

Engagement focused on information provided via fact sheets and alerts rather than two-way engagement, leading to confusion, mixed messaging and mistrust.

There was a mismatch between existing policies, and the extended and dynamic nature of the Hazelwood smoke event prompted policy on the run which further eroded trust.

Lack of a strong evidence base for short- and long-term health impacts from coal mine fires hampered the public health response.

It is critical that future policy development and program planning requires careful consideration around: who is delivering information; how information is delivered; who is being targeted; and how to communicate to build and maintain confidence and trust.

5.8.2 Community perceptions of the impact of the smoke event on community wellbeing and of the effectiveness of communication during and after the event

The Older People Research Stream pre-empted some of the findings of the Community Wellbeing Stream. To enhance cross stream collaboration and maximise resources and findings it was merged with the Community Wellbeing Stream to ensure that a focus on older people continued.

5.8.2.1 Key findings from the Community Wellbeing Stream's phase 1 research

What the community experienced

The Hazelwood mine fire had significant impacts on the Morwell and wider Latrobe Valley communities.[62] People suffered physically, and this was compounded by the emotional toll due to the length of the event, the lack of clear information about the disaster and its impacts, as well as the daily inconvenience of attempting to remove ash and dust. There was a considerable impact on community wellbeing, most notably a loss of trust in authorities when dealing with a crisis.[62, 65] This led some community members and groups to find ways to support one another, meet the needs of those impacted, and lobby for government to address their concerns. Problems with official communication during the event played a prominent part in the community's distress, and local mainstream media and social media were important in filling communication gaps. From these challenges emerged the possibility for growth following the event, with these groups advocating for a positive future for Morwell and the wider community.[62]

Communication

Communication issues impacted on the way the community experienced the crisis. We found that communication from authorities responding to the emergency was perceived by the community to be flawed, at times contradictory, not reflecting their experiences and not meeting all of their needs for timely, accurate and empathetic communication.[62] A relatively narrow range of channels was used in the initial communication to the public by authorities. The lack of an appropriate communication plan, tailored to the needs of the community and implemented at the beginning of the crisis, eroded the community's trust in authorities.[62, 65]

The community perceived an information vacuum in relation to some aspects of the smoke event, particularly in relation to its health impacts. Because of this, local mainstream media and social media took on a particularly important role, providing more plentiful sources of information than official sources and better able to meet the community's information and communication needs.[134] However, the use of social media, in particular, was not without its problems relating to issues around who can speak on behalf of the community and which information sources can be trusted.[62, 64, 134]

According to our interviewees, and supported by a review of previous research, the elements important for effective communication were:

- use local mainstream media and social media as a sounding board and a strategic resource;
- communication should be fast, accurate and honest;
- use a broad range of channels;
- face-to-face communication with the community is important;
- use a trusted spokesperson, preferably someone local;
- communicate with empathy;
- ensure continuity of spokespeople; and
- form a local communications team.[62, 64]

Factors leading to a loss of trust

There were three main factors leading to the community's loss of trust in authorities.[62] The first related to the problems with communication and information noted above. People's loss of trust was a result of inadequate, and at times non-existent, communication between authorities and the community. There was at times a mismatch between the information people received and their experience on the ground, which led to a sense that their experience was not validated. In addition to the anger and frustration felt by the community in relation to poor communication from authorities, this flawed communication also led to the perception that authorities were attempting to conceal the nature of the event and its impact on the community.[62]

Second, the lack of an emergency plan was raised by participants as a serious concern. The community looks to government and authorities for leadership in disaster situations and failure to provide effective leadership reinforces mistrust. Local government and agencies expressed frustration with the handling of the state-level emergency management response and lack of coordination between different authorities associated with the initial fire event.[62]

Third, at the time of being interviewed two years after the event, some in the community felt that the government, authorities and mine owners GDF Suez (later Engie) had not accepted responsibility for what happened and were not held accountable. This caused anger.[62]

Community empowerment and activism

An important perception, held by those interviewed, was that agencies and all levels of government had abandoned them and failed to provide adequate information about the potential health effects of the smoke event.[62, 64, 65] In response, community members organised public rallies, created a social media presence and network, and began to demand answers to their questions and concerns. These initiatives were important to addressing the concerns of the community and determining ways forward. However, many also questioned the motives of those who took on this work, while others were concerned about the repercussions on the community's reputation by taking part in activism.

Social media took on an important function in empowering the community to self-organise in response to the crisis. However, some questioned the authority of a few community members to speak on behalf of the range and diversity of people impacted.[64] Thus, social media inadvertently contributed to divisions already present within the community. Social media was an important avenue for members of the community to question and challenge the poor response from government and other authorities. For some, social media also assisted in creating a stronger sense of community. This intimate and rapid form of communication helped reactivate social relationships and constitute a base to support a range of community projects.

The recovery process and the effectiveness of rebuilding

Changing mainstream media and social media ecology

Phase 1 analysis of the media ecology in the period after the mine fire found that:

- In 2014-2015, social media posts to the Voices of the Valley Facebook site exceeded the number of mainstream media news items, but from 2016 onward mainstream media items began to outnumber social media posts, suggesting diminishing need for sharing and drawing attention to mine fire-related experiences and issues.
- Health concerns continued to be covered throughout the period of analysis, but did not dominate social media posts as they had during and immediately after the fire. However, release of HMFI findings and HHS results continued to prompt social media discussion of health-related topics.
- The expression of negative emotions (fear, mistrust of authorities, anger) diminished over time.
- There was a shift in the social media towards a more future-facing agenda (transition to the future, sustainable energy, etc.) from 2015 onward.
- Social media increasingly followed the news agenda (unlike during the fire, when social media were setting the news agenda), suggesting that community concerns were finally being sufficiently dealt with through mainstream public institutions such as news media, the courts, government processes.[63]

Pre-existing vulnerabilities

Phase 1 interviews with community stakeholders indicated that:

- There were deep divisions in the intersecting communities that made up Morwell, linked to those which had a prior relationship to the mines and the former State Electricity Commission (SEC), and those which did not.
- Intergenerational disadvantage exacerbated the vulnerabilities within some community sectors.
- Negative external perceptions of the Latrobe Valley also impacted on the community’s self-perception, which in turn led to a mistrust of government.

- These perceptions need to be taken into account in efforts to rebuild trust.[63]

Concerns regarding a lack of future emergency planning

Phase 1 findings from key stakeholder interviews highlighted the need for an emergency plan for the community to respond to future similar events.

- In 2017 there was the perception that there was still no emergency plan, despite Emergency Management Victoria (EMV) having been tasked with the job and having started the process.
- What needs to be determined is who is responsible for developing the plan, and more specifically who should develop the plan at the community level.
- EMV has argued that it has the capacity and approach to adequately develop a plan for this region. The process adopted by EMV is a community-based emergency management approach, which is focused on ensuring communities and organisations work collaboratively in planning for emergencies.
- Latrobe City Council is considering what opportunities there may be for rethinking the context for emergency planning, such as the approach used to develop the Local Emergency Action Plans that was under discussion with EMV and the CFA prior to the mine fire event.
- Both Latrobe City Council and EMV participants explained, given the size of the population in Morwell, this is a significant undertaking requiring strong financial support.
- This is a complex space for development of emergency management planning. Developing a future emergency plan, which is appropriate for this community, and communicating this plan to the community, will be important for community recovery.[63]

Perceptions of community recovery and effectiveness of rebuilding efforts

Phase 1 interviews conducted with stakeholders indicated that:

- From the perspective of agencies who had played a role in the immediate recovery period, two years on from the fire people were not likely to frame issues as being about recovery nor attribute new initiatives as being part of the recovery process.
- Many did not recognise the work that was being done as part of the official community rebuilding effort, and some felt that activities were of little benefit. In addition, some activities were one-off events.
- Since 2015 there had been many initiatives by local and state government, as well as other agencies.
- The question of “recovery to what” (i.e., not returning to a previous state) was very important to this community.

- A key issue that emerged during community consultations for the first HMFI was the desire for the development of a long-term vision for Morwell and the Latrobe Valley, which was then reinforced at the second HMFI.
- Over time the focus had shifted from concerns about physical health to that of community wellbeing more broadly, and thus recovery became conceptualised in terms of job creation and sustainability, particularly as the Latrobe Valley faced the implications of a transition from coal, and the closure of its mines, the first of which was the closure of Hazelwood Power Station in March 2017.
- The more effective recovery initiatives involved those where an agency and a community group formed a partnership to address a common goal, and in which communication was open and dialogic.
- The range of community-generated projects that arose after the mine fire suggested some of the directions that community members wished to take in creating a future for the Latrobe Valley.[63]

Social capital and hopes for the future

The Phase 1 PAR enabled a cross-section of community members and organisations to express their thoughts, hopes and dreams for the future of the Latrobe Valley through participation in creating a photographic exhibition. Development of this project, titled 'Our hopes for the future of Morwell, indicated that there was a strong desire from members of the community to be part of the conversation about the future, and the exhibition was a contribution to this conversation.[63]

Del and Bev displaying the Morwell Centenary Rose Garden Group's contribution to the 'Our hopes for the future of Morwell' exhibition, 2018

Key findings from the PAR were:

- The objects chosen symbolised a number of strengths and assets within the community, including: pride; social connectedness; diversity; dignity and respect for others; resilience; having a voice; and supporting others.

- Some images emphasised the need to increase economic capital in the form of employment and a stronger economy. Linked to this was a desire to see a transition towards alternative energy industries, and energy security for the Valley.
- Improving and supporting physical and emotional health was another strong theme.
- Morwell possesses diverse forms of institutional capital which should be built upon as part of the recovery process moving forward.[63]

"Greater economic diversity and job opportunities"
Morwell Neighbourhood House

"A brighter future for the children"
Vicky, Morwell Neighbourhood House

"Energy security in the Latrobe Valley: We have the skills"
Voices of the Valley

"That all families in the region have access to safe and stable housing"
Christina Melrose: Gippsland Centre Against Sexual Assault

Some examples of the 'Our hopes for the future of Morwell' exhibition items
All images can be found at www.hazelwoodhealthstudy.org.au/media/our-hopes

Implications for future planning

The findings presented can be used to inform the community, local government, and various community and health agencies about the factors shaping community recovery following a disaster. This research identifies the importance of community perceptions of how authorities and agencies respond and address concerns in community recovery, and the need for clear, coherent and effective communication during the disaster and recovery phases. Of particular importance is acknowledgement that the phases associated with disaster and recovery are not linear, and that recovery often lacks a clear endpoint. This is especially significant in disaster recovery for events such as the Hazelwood mine fire; recovery is associated with rebuilding efforts, but it is not always clear what is being rebuilt. In addition, the impact of the mine fire on the Latrobe Valley was complicated by pre-existing social inequities and vulnerabilities. Our narrative analysis suggested that although the narrative of recovery was complicated, some progress had been made towards recovery, and that this recovery was more than a return to something that may or may not have served the community well in the past.[63]

What needs to be considered are the factors which are most critical for communication during a crisis and recovery and, in complex emergencies like this, how to ensure communication includes the community, speaks to them through the appropriate channels, and listens and responds to their concerns.

We recommend that:

- Government, agencies and other authorities should consider how best to use mainstream and social media given the differing roles they play in disaster and recovery. This communication space is dynamic in its responsiveness to the concerns of the community and authorities. Knowledge of how it is used to communicate different messages at different times within the disaster and recovery periods should be more effectively incorporated into emergency plans.
- Effective communication with the community should be through a trusted spokesperson, and accessible to the community through clear channels. This also means considering the differing ways that members of the community access information during the emergency and recovery periods, including the role played by community groups.[63]

Interviews with participants whose roles involved emergency and recovery responses following the mine fire revealed that the following considerations need to be addressed in devising plans and strategies for future events:

- There needs to be a clear overall management structure and lines of responsibility for the periods of disaster and recovery.
- There needs to be an appropriate process that provides clear and effective communication to agencies and the community about the emergency and any changes in that situation.

- Shifts from emergency to recovery management structures need to be clearly demarcated and managed in terms of roles and responsibilities.
- There needs to be a clear and appropriately managed determination of priorities for emergency and recovery responses, especially when transitioning between these two response phases.
- Those placed in positions of leadership and responsibility need to have appropriate levels of skill and experience.
- As much as possible, there should be continuity of personnel and response structure to ensure that appropriate knowledge about the emergency response is maintained, along with community trust in the response of government and agencies.[63]

A number of factors were identified by our interviewees as crucial to effective rebuilding and recovery.

- inclusive and participatory processes;
- an acknowledgement, where necessary, that "we were wrong", in order to build trust between an agency or government department and the community;
- establishing partnerships, preferably community-led;
- collaborative approaches (e.g., the EPA's citizen science initiative for air monitoring); and
- asking the community what they want in terms of assisting the recovery process.[63]

In addition, the distinctive characteristics of this community (and any community) require place-based approaches:

- A focus on a location's challenges and opportunities is integral to recovery, an approach advocated in the Victorian Government's community resilience strategy following the 2009 Victorian bushfires. This strategy was based on evidence that any recovery strategy should integrate a place-based approach and part of that approach involves developing a vision for the future of the community.
- Social disadvantage creates health inequities and the impact of the mine fire was likely to have been exacerbated by existing social disadvantage. Any recovery then needs to include measures that tackle the causes of such social disadvantage.
- Recovery and rebuilding efforts need to address job creation and sustainability, as well as health and wellbeing after a complex disaster with health impacts in an already disadvantaged community. This has increasingly been recognised and acted on by the State Government in relation to the Latrobe Valley, through initiatives such as the Latrobe Health Innovation Zone (with its focus on the social determinants of health), the Latrobe Health Assembly, the Latrobe Health Advocate, and the Latrobe Valley Authority.[63]

5.8.2.2 Key findings from the Community Wellbeing Stream's Phase 2 research

In Phase 2 which took place in years 6-10, the Community Wellbeing Stream's focus broadened to consider other events and initiatives that had occurred since the mine fire. We investigated how community wellbeing had been affected by events since the mine fire, as well as considering the impact of other social and economic factors. Our aim was to determine the strengths and capacities of this community as well as its areas of vulnerability which may need further investment and support.

The research questions were:

- How does the Latrobe Valley community perceive wellbeing at the community level?
- How has the community's wellbeing and recovery from the Hazelwood mine fire been impacted by subsequent events and initiatives?
- What factors are indicative of current and future changes in community wellbeing?
- What is the relationship between community wellbeing and personal wellbeing? (investigated in collaboration with the HHS Psychological Impacts Stream).

Findings from Phase 2 interviews with key stakeholders and community members

How does the Latrobe Valley community perceive wellbeing at the community level?

This question addressed the place-based elements that make up community wellbeing in the Latrobe Valley and formed the basis for addressing all three of the above research questions.

Our interviewees defined community wellbeing in terms of:

- social connection;
- social, physical and mental health;
- engagement and participation; and
- economic and social inclusion.[135]

They told us that a strong community is one where people:

- have opportunities to connect with the community and feel connected;
- are happy, healthy and satisfied with their lives;
- are engaged with and participating in the community; and
- are included (not just socially but economically).[135]

In addition, strong community wellbeing is achieved when community members:

- feel safe;

- feel seen and heard;
- feel resilient and empowered;
- have pride of place; and
- show respect and care for others.[135]

How has the community's wellbeing and recovery from the Hazelwood mine fire been impacted by subsequent events and initiatives?

Major events since the mine fire, as identified in our interviews, have had both positive and negative effects on the community's wellbeing and recovery. The closures of Hazelwood Power Station and other large employers in Latrobe during this period have had negative impacts on the economy, due to job losses. In addition to the direct economic impacts, the Hazelwood Power Station closure increased fears around the economic future of the region, especially for young people. It was also linked to loss of identity and pride of place for those who identify with the region's proud history of power generation for the state. More positively, others noted the health benefits of getting rid of polluting power stations and argued that going through the experience with some success has built resilience for handling future closures.[135]

The Latrobe Valley also experienced natural disasters during this period, including the Yinnar bushfires (2019), smoke from the Black Summer bushfires (2019-2020) and widespread flooding (2021). While noted as adverse events, these received less commentary on their negative impacts than industry closures and concerns about proposed new "dirty" industries, such as the lead acid battery recycling plant.

There were divided views regarding the approval of the lead acid battery recycling plant at Hazelwood (2021). Most viewed it as having potentially negative impacts on health and the environment, while some viewed it as good for the local economy. The State government's handling of the proposal reinforced existing mistrust in government (the proposal was rejected by Latrobe City after community lobbying against it, but the State Planning Minister overruled the Council decision and approved the plant). Community members felt this reinforced an existing negative external view of the Latrobe Valley as a "dumping ground for dirty industries" and argued it was at odds with the creation of the Latrobe Health Innovation Zone. However, the community advocacy against this proposal was seen as indicating that this community is not afraid of speaking out about decisions affecting their wellbeing.[135]

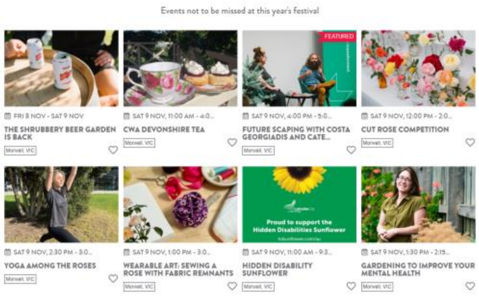
Other events and initiatives were seen as having more positive impacts, although some also attracted criticism or doubt as to their benefits. The investment and government attention since the mine fire was mentioned as beneficial for the community in broad terms. This included initiatives such as the designation of the Latrobe Health Innovation Zone and the establishment of the LHA (2016), and the appointment of the Latrobe Health Advocate (2018). Some questioned the effectiveness of these initiatives, while others noted the favourable impact on wellbeing of specific projects (e.g., Hello Campaign, Street Games, We are Latrobe, Nurses in Schools, Reach for the Stars).

Investment to assist the community with the impacts of the Hazelwood Power Station closure was also seen as having positive impacts on community wellbeing. The State Government provided a $266 million rescue package for the Latrobe Valley and established the Latrobe Valley Authority (2016) to assist with the transition away from carbon. These initiatives resulted in infrastructure projects which many felt contributed to pride of place, and local projects which were viewed as innovative and community-led.[135]

Local grassroots initiatives were also mentioned as contributing positively to the community's wellbeing, in particular:

- Latrobe Youth Space established (2018);
- Gippsland Pride Initiative formed (2019); and
- International Rose Garden Festival (online in 2020 due to the COVID-19 pandemic, then resumed as a face-to-face event from 2021 onward).

Their benefits were linked to social connection, inclusion, feeling safe and pride of place.[135]



Latrobe Youth Space, International Rose Garden Festival and Gippsland Pride Initiative promotional material

What factors are indicative of current and future changes in community wellbeing?

We asked our interviewees about the current state of community wellbeing in the Latrobe Valley. Their assessments varied, reflecting the variability within this diverse community. About a third of our interviewees said community wellbeing was not good or was worsening, and this proportion remained consistent across the two interview rounds three years apart. A smaller proportion said community wellbeing was "OK" or "improving". However, this proportion reduced in 2023, with the majority of interviewees talking about how community wellbeing varied across different groups. The variability in wellbeing within the community was attributed by several of our interviewees to what they described as "pockets of socioeconomic disadvantage".[135]

The two most prominent factors relating to changes in community wellbeing were the COVID-19 pandemic and the transition away from coal. Both were seen primarily in negative terms, although some positives were noted. The pandemic had predominantly negative impacts on health (especially mental health), the economy, services, and social connection. Moreover, its negative impacts were more severely experienced by disadvantaged groups within the community, while those who are relatively advantaged experienced some positive consequences.

Given how closely the community's economy and identity has been tied to coal-fired power generation, and the historical and ongoing impacts of the privatisation of the SEC, transition away from carbon is of great concern for this community. Interviewees discussed fears for the economic future of the Latrobe Valley, especially in terms of the future for young people, and concerns regarding general impacts on mental health. Yet for some community members, it is viewed as an opportunity to build a different basis for economic prosperity without sacrificing the health of the community and the local environment. Some are seeing positive signs of engagement and participation on this issue.[135]

Other facets of community wellbeing that were of concern among those we interviewed were health, services and infrastructure, and social connections.

Topics relating to health and health services included adverse health statistics, post-pandemic rates of mental ill health, and the need to improve the connectedness and inclusivity of services. Social issues were of great concern, particularly those issues impacting the ability to connect, participate and flourish in the community (e.g., family violence, drug use, poverty, intergenerational disadvantage).

The community also has a range of strengths and assets, according to our interviewees. These include:

- increasing collaboration and innovation among organisations;
- a strong community spirit;
- a "revival in caring";
- many vibrant local community groups;
- a strong volunteer workforce; and
- exceptional leaders in service organisations.[135]

In terms of future changes in community wellbeing, many of our interviewees said that community wellbeing in the Latrobe Valley varied. When we asked our interviewees whether they expected it to improve, the majority felt that it would, about a third were uncertain and a minority expected it to worsen. Although their predictions for the future varied, there was considerable commonality in their discussion of the conditions necessary for improving future wellbeing.

Interviewees identified a number of specific factors they saw as critical to the Latrobe Valley's future wellbeing. Barriers and challenges included:

- short-term funding cycles;
- overcoming intergenerational trauma and disadvantage;
- recovering from the impacts of repeated adverse events;
- bringing together the disparate, disconnected and sometimes polarised groups within the community, including within and between the towns in the Latrobe Valley;
- inequality and unequal access to the resources that promote community wellbeing (health, economy, environment, services and infrastructure, social connections);
- ongoing economic, social and health impacts of the COVID-19 pandemic;
- the "skills gap" and "brain drain";
- negative external perceptions of this community; and
- levels of current mistrust in government and authorities.[135]

The following factors were seen as strengths and opportunities which, if acted upon, would improve community wellbeing:

- empowering the community to work together;
- encouraging citizen participation in decision-making;
- forging a new identity for the Latrobe Valley in order to "change the narrative" and "reinvent ourselves as a community";
- listening to local voices in order to generate local solutions for local problems;
- building on community strengths, such as friendliness, community spirit, the "revival of caring", and pride of place;
- improving service provision through collaboration and through investment in human capital;
- planning and investment in primary health intervention;
- attracting new industries/employers while balancing the competing demands of the economy and health;
- promoting social inclusion and inclusivity, in services and in the wider community; and
- ensuring ongoing viability of organisations and projects with proven local impact.[135]

What is the relationship between community wellbeing and personal wellbeing?

We found this relationship to be complex. Events in the life of a community can affect individual wellbeing, but a single event like the mine fire can impact individuals differently. Some people told us their personal wellbeing was negatively impacted by the mine fire, while other people experienced positive impacts or were unaffected. Individuals draw some of their resilience in coping from their community, but also from within themselves and from their family and friends. Experiencing a traumatic community-wide event can also strengthen community bonds and which can in turn enhance personal wellbeing.

The quality of conditions within the five domains of community wellbeing can also impact individual wellbeing. In the Latrobe Valley, the main impacts of these community-level conditions came from social connections. This entailed both negative impacts due to social problems and positive impacts, in terms of friendliness, inclusion and pride of place. Other community-level factors were economic (e.g., the lack of a vibrant local economy), environmental (e.g., access to beautiful natural places) and relating to services and infrastructure (e.g., difficulty accessing health services).

Findings from the Community Wellbeing Barometer

As described in section 4.5.2.8, we created a tool called a Community Wellbeing Barometer to monitor changes in community wellbeing in the Latrobe City Council area. We aimed for the Barometer to be a practical, updatable and replicable monitoring tool that could be easily used by other agencies and groups in the Latrobe Valley and other areas, to support regional planning and policy initiatives. Quantitative data on community wellbeing in Latrobe City was collected using 68 measures relating to these domains and themes, from nineteen publicly available data sources, covering the years 2008-2023. We analysed this data to show trends in community wellbeing in the Latrobe City Council area and Victoria over this time-period. We assessed the Barometer through consultation with community stakeholders, against other measures of wellbeing, and through comparison with Victoria-wide data.[136]

As previously demonstrated in Figure 11, the Barometer comprises five domains – health, economy, environment, services and infrastructure, and social connections – and associated themes.

Figure 40 demonstrates composite scores for the five domains across time, and for the overall community wellbeing score, along with two trend lines. The dashed linear trend line shows an overall upward trend in community wellbeing. The dotted polynomial trend line is more responsive to changes over time and, arguably, provides a better representation of change in community wellbeing. That line follows a U-shaped pattern which falls from 2008 to a low point in 2015/2016 and then continues to rise until the end of the data collection period in 2023.[136]

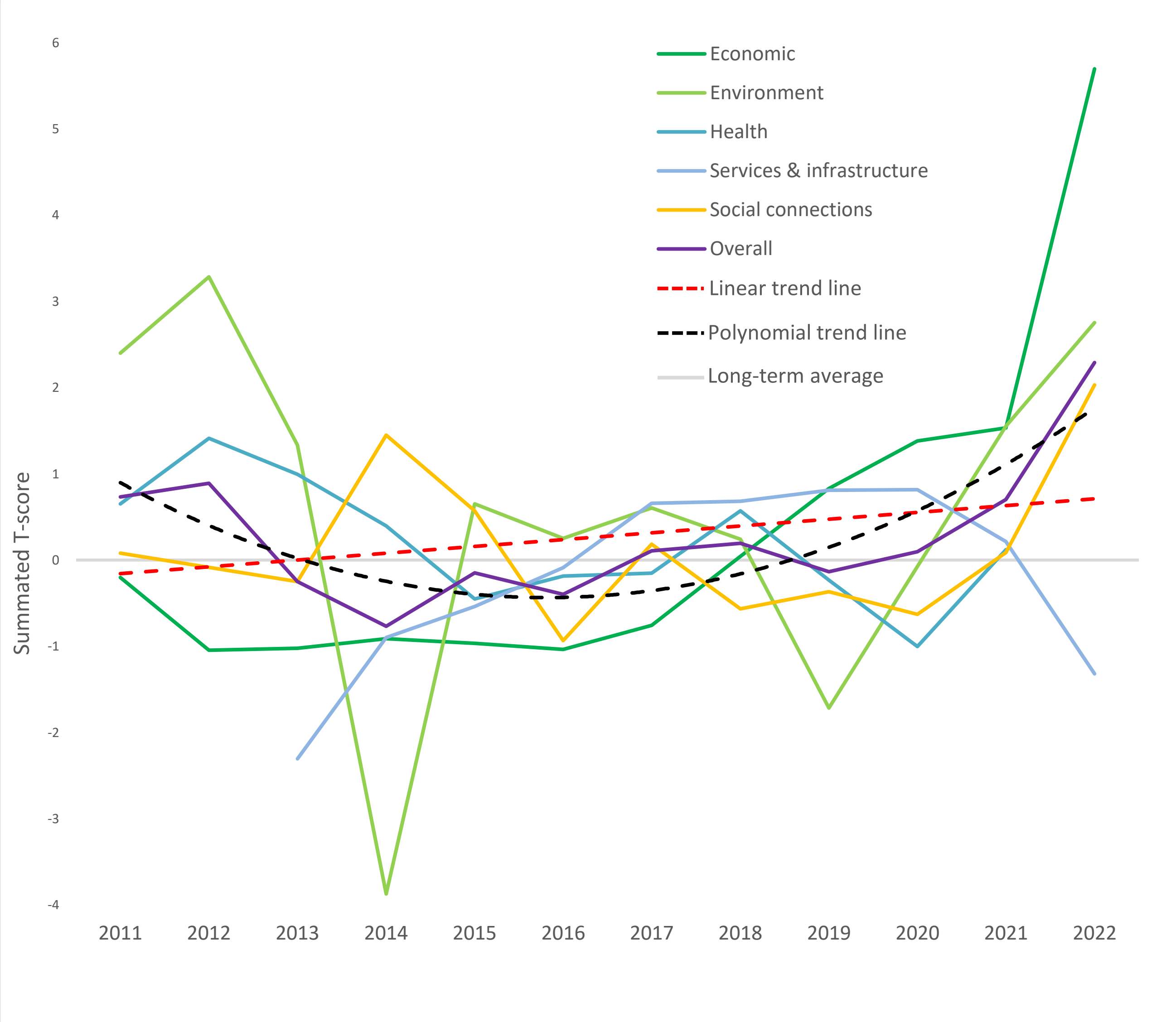


Figure 40 Composite scores for the Community Wellbeing Barometer's five domains and the overall community wellbeing score across time
(Source: Morgan et al. 2024)[136]

More detailed results are as follows.

- Most *economic* domain measures in the Latrobe Valley were trending upward (increasing community wellbeing).
- While there is an upward trend in the *environment* domain, there was considerable annual variation from the average score in each of the measures and, subsequently, in the domain score.
- The *health* domain shows a general downward trend, although the most recent data (2021) indicates a return to average.
- The *services and infrastructure* domain shows a general upward trend, with the most recent data consistent with the long-term average.

- There was a slight upward trend in the *social connections* domain.
- Changes in the *environment*, *services and infrastructure*, and *social connections* domains may be explained by events such as fires, the COVID-19 pandemic or government interventions.
- The *economic*, *environment*, *services and infrastructure*, and *social connections* domains have all been trending upwards over time, indicating that overall community wellbeing is improving. The *health* domain is the exception.
- The overall community wellbeing trend shows wellbeing falling from 2012, and then on a largely consistent upward trajectory after that point.
- When comparing the Latrobe City region with wider Victoria, similar trajectories were apparent, indicating the influence of state-level policy settings on local outcomes. However, there were a number of noticeable divergences in the plots which were suggestive of locally specific differences outlined below (not shown).
    - In 2016-2017 the *economic* domain saw a sharper improvement for Victoria overall, whereas Latrobe City remained almost flat for this period. More recently (i.e., from 2021) Latrobe City has trended upward.
    - In 2018, Latrobe City showed a marked increase in *health*-related community wellbeing while there was a decline in Victoria, with both then returning to points just below the long-term average.

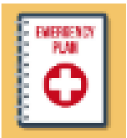
Overall, and subject to some limitations, the results provide evidence supporting proof-of-concept for the Community Wellbeing Barometer as a tool for monitoring community wellbeing in Latrobe City and other regions and providing insights into the different factors underlying community wellbeing. With ongoing and consistent reporting of data, the Barometer may be useful in identifying the influence of specific events on changes in community wellbeing, which has potential to inform policy and planning, as well as assess the impact of intervention strategies.

Summary of key findings: community wellbeing and rebuilding (Phase 1)

There was a notable loss of trust in the authorities which were dealing with the crisis. Factors leading to the loss of trust included that:

- official communication was perceived to be flawed, at times non-existent, not reflecting the community's experiences nor meeting their needs;
- an emergency management plan seemed to be lacking and coordination between authorities was perceived as poor;
- government, authorities and mine owners GDF Suez were perceived as not accepting responsibility nor being held accountable for what happened.

Local social media were important in filling communication gaps and empowering the community to self-organise and demand answers to their questions and concerns. However, some questioned the authority of social media groups to speak on the behalf of other community members.



The development of a new emergency management plan will be complex but essential to recovery. The plan should include: clear lines of responsibility; trusted, accessible and effective communication channels; and appropriately qualified and experienced leaders.

The concept of 'recovery' needs to involve the development of a long-term vision for Morwell and the Latrobe Valley, including community wellbeing and job creation and sustainability in the context of the transition from coal and the closure of its mines.

Hopes for the future include social connectedness and supports, diversity, dignity and respect for others, resilience, having a voice, appropriate resources for physical and mental health, a stronger economy and greater employment, a smooth transition towards alternative energy industries, and energy security for the Valley.

Summary of key findings: community wellbeing and rebuilding (Phase 2)

Quantitative Community Wellbeing Barometer data for the period 2008-2023, show:

- most *economic* measures in the Latrobe Valley were trending upward;
- an upward trend in the *environment* domain, although considerable annual variation across measures;
- a general downward trend in the *health* domain, although the most recent data (2021) indicates a return (rise) to the previous average;
- a general upward trend in the *services and infrastructure* domain;
- a slight upward trend in the *social connections* domain;
- changes in the *environment*, *services and infrastructure*, and *social connections* domains may be explained by events such as fires, the pandemic, or government interventions;
- The overall community wellbeing trend shows wellbeing falling to 2016, then rising. Relative to long-term averages, community wellbeing has risen to a recent high point.

Qualitative data from our interviews show:

- there have been events since the Hazelwood mine fire that have impacted community wellbeing, both positively and negatively;
- there is fatigue in the community from repeated adverse events, but also some increasing resilience;
- community wellbeing in the Latrobe Valley is variable: some groups are doing well, but there are also pockets of severe disadvantage;
- the COVID-19 pandemic and the transition away from carbon along with social issues arising from socioeconomic disadvantage and intergenerational trauma are major factors currently impacting community wellbeing;
- there are mixed views on whether community wellbeing in Latrobe Valley will improve in the future; however, most of our interviewees were cautiously optimistic.

Improvements in wellbeing will depend on a number of factors, including:

- bringing together disparate groups within the community;
- overcoming intergenerational trauma and disadvantage, the impacts of the COVID-19 pandemic and the fatigue associated with repeated adverse events;
- forging a new identity for the Latrobe Valley as it transitions away from coal;
- listening to local voices to generate local solutions to local problems;
- creating a vibrant economic future by attracting new employment opportunities, but not at the expense of the environment or the health of the community;
- improving service provision through collaboration and investment in human capital;
- addressing inequality and unequal access to the resources that promote community wellbeing (health, the economy, the environment, services and infrastructure, social connections).

6 Community engagement and dissemination of findings

Throughout the Study's tenure, it has employed a number of strategies to engage with the local community and to disseminate findings across a wide range of audiences. Many of these strategies have already been referred to in this report, but a consolidated summary is provided here for the reader's convenience.

6.1 Community and stakeholder engagement strategy

From the very beginning it was considered that engagement with the community and key stakeholders was critical to the successful running of this large, complex and long-term project. The Study had been established in response to the concerns of the local community and, therefore, a key measure of the Study's success would be that community voices had been heard.

Prior to the Study's commencement, early engagement with key stakeholders took place during the development of the research plan and was outlined in the tender response. Initial media following the announcement of the Study on 4 November 2014 highlighted the need to work closely with the community, with local groups making it clear that the community had expectations of ongoing input into the Study's directions and being kept aware of outcomes.

The strong local connection within the research program, including key roles for Gippsland-based Monash Rural Health and Federation University, the establishment of a local Study site at Monash Rural Health offices in the Latrobe Regional Hospital and subsequently in Churchill, and employment of local personnel, were strategies to ensure that the community has a sense of ownership of the Study.

Under the terms of the Contract with the Victorian Department of Health, a Community Advisory Committee (CAC; see section 3.2.3) was formed. Its purpose was to ensure that the Study heard directly from, and worked in partnership with, Latrobe Valley community members, health and community service providers and local government in undertaking the research program and ultimately to improve health services and health outcomes for the local community.

The Clinical Reference Group (CRG; see section 3.2.2) comprised of key local clinicians was formed to provide input and advice on the clinical operations of the project, oversight of individual abnormal results, and act as a key dissemination outlet to professional health-related organisations.

Broad local representation through the CAC and the CRG, identification of key stakeholders and a two-way communication process aimed to ensure that community input was incorporated into the Study's operations at all levels. It also aimed to ensure that information arising from the Study was disseminated broadly and taken up in the operations of local health and community service agencies.

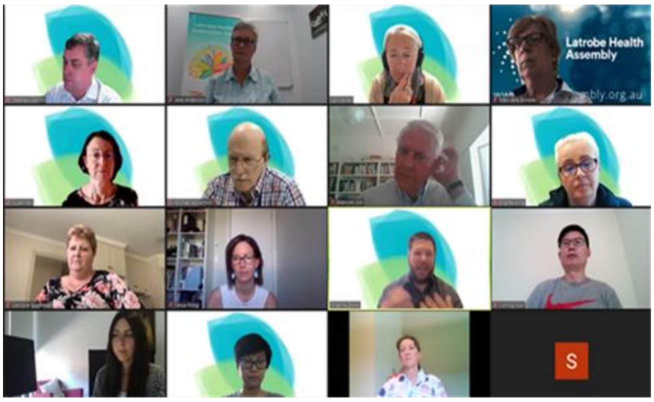
The Study's Community and Stakeholder Engagement Strategy included undertaking an audit of key community and stakeholder groups, including local government, hospital and health services, aged care, community groups and community service organisations, schools and pre-schools, emergency services, politicians, local media, businesses and residents.

Possible means of communication were brainstormed, including a website, social media, quarterly community briefings, open office sessions, door knocking, presence at community events and presentations at community meetings. The strategies that were utilised evolved over time.

6.2 Annual community briefings

It was a contractual requirement that the Study run a community briefing in each year of the Study. The delivered milestone dates are listed in Volume 3 Appendix 1. Up until 2019, annual community briefings took place in-person in Morwell, with an additional briefing held in Sale in 2017 to coincide with the recruiting of Sale residents into the Adult Survey (see section 4.2.3). From 2020 to 2023, initiated by COVID-19-related restrictions, a hybrid model was employed, comprising online presentations by Zoom webinar plus in-person hubs in Melbourne, Latrobe Valley and Hobart. Community members, supporters and stakeholders were all invited to the annual community briefings with the events typically advertised via the Latrobe Valley Express Newspaper, the HHS website and e-newsletters.

Annual community briefing, Morwell, 2017



Hybrid annual community briefing, 2020

The purpose of the briefings has been to foster a two-way communication channel between researchers and community members. Customarily, presenters have included representatives from the PMG and each Study stream, reporting on Study activities and findings from the previous year and responding to questions and suggestions from community members. Additional panellists have been invited, such as the Latrobe Health Advocate and representatives from the Latrobe Health Assembly, Emergency Management Victoria, EPA Victoria, and the Community Advisory Committee, to address any questions from the audience relevant to their roles. Slides from, and/or recordings of, the annual community briefings can be found on the HHS website at www.hazelwoodhealthstudy.org.au/news-and-events/community-briefings.

In 2024, in place of the typical annual community briefing, the Study hosted a stand and presented an overview of findings at a community-led event commemorating 10 years since the mine fire (www.lifeaftercoal.com/event/). Held at Kernot Hall, Morwell, on 17 February 2024, more than 1,000 community members attended this successful event, which included information stands and/or presentations from numerous stakeholder and community groups. These included the Latrobe Health Advocate, Latrobe Health Assembly, Environment Victoria, Latrobe Valley Authority, Voices of the Valley, Mine Land Rehabilitation Authority, Gunaikurnai Land and Waters Aboriginal Corporation, SEC Victoria, Friends of the Earth, Yes2renewables and the Gippsland Trade and Labour Council. The Hazelwood Health Study researchers, in partnership with the Latrobe Health Advocate and the Latrobe Health Assembly, convened a 60-minute Health and Wellbeing panel to speak about the long-term health impacts of the mine fire.

Our stand and our panellists (L-R HHS representatives Lieke Scheepers, Tim Campbell, Sue Yell and Matthew Carroll; Latrobe Health Advocate Jane Anderson and LHA Executive Officer Ellen-Jane Browne) at the 10th anniversary community event, February 2024

6.3 Marketing

Considerable effort went into developing effective marketing campaigns with the dual aims of informing the relevant Gippsland communities of the presence of the HHS and maximising participation in the various Streams.

A meeting of key communications personnel from local health and service agencies was held, to develop a partnership approach to promote the HHS throughout its recruitment periods.

The initial marketing plans were refined with input from *Wordwise Communications*, a Latrobe Valley company, which facilitated promotion of the HHS via local print, radio and television media outlets. A key messages document was developed and used as the basis for local media releases, radio advertisements etc. Media releases, prepared during recruitment periods, were often picked up and run by local media outlets.


GIPPSLAND Times & MAFFRA SPECTATOR

Hazelwood Health Study uses Sale as control comparison

9 Jun 2016, noon


LATROBE VALLEY Express

Health study survey deadline approaching

10 Nov 2016, midnight

Examples of local media headlines, 2016

Ms Susan Denny, the HHS Recruitment and Community Engagement Coordinator, worked closely with Latrobe City and Wellington Shire Councils and the Reactivate Latrobe initiative to identify and attend community events, meetings of existing groups and other populous locations where the HHS could be represented and recruitment promoted. Examples include the monthly Morwell 50 Mile Farmers Market, 2015 Latrobe Valley Health & Wellbeing Expo, the Morwell Pop-Up Park, Probus Club, Voices of the Valley, Bunnings, libraries, Mid Valley Shopping Centre, Morwell Neighbourhood House, Morwell District Community Recovery Committee, Rotary Club, Morwell Country Women's Association, Latrobe Valley Support Network, Gippsland Migrant Resource Centre, Morwell Football Netball Club, Morwell Historical Society, Latrobe Valley Sustainability Group, Sale Men's Shed, Wellington Community Connect, Sale and District Garden Club and the Sale Producers Market.

Susan Denny at the Morwell 50 mile Farmers Market

Roadside banner

Numerous promotional materials were utilised to ensure that the Study had high visibility within the community. These included a flyer/fridge magnet which was delivered to eligible households (see Figure 3). An application to VicRoads was granted to install large banners at five major entrances to Sale and Morwell. Posters were printed and delivered to local shops, businesses, sporting venues, medical facilities and educational organisations. Additional marketing materials included Study balloons, fleet vehicle signage, print media advertisements and flyers notifying the community of upcoming events.

Example of an Adult Survey promotional poster

Latrobe ELF Study postcards promoting the Study and describing eligibility, were distributed to child care centres and relevant businesses across the Latrobe Valley.

Latrobe ELF Study postcard

Promotional events were held in Mid Valley Shopping Centre where local residents were invited to meet the researchers. Val Morgan advertising was used to promote these events on all screens in the Centre, maximising visual exposure. A local franchise was used to offer free tea/coffee and muffins to participants completing the survey. An additional catered promotional event was held at Tribes indoor play centre in Morwell, where parents/grandparents/carers were invited to meet the researchers while their children played for free.

An additional promotional initiative was the preparation of community information packs' which were placed in public venues such as libraries, council offices, medical clinics, sports clubs and community centres.

6.4 Dissemination of findings

As demonstrated in section 4, the HHS has made numerous findings in regard to the health and wellbeing of the community throughout its tenure. The researchers have endeavoured to translate, package and disseminate the findings in a variety of ways as appropriate for diverse audiences.

As of 1 September 2024, the Study Findings pages on the HHS website (https://hazelwoodhealthstudy.org.au/study-findings) listed 21 technical reports, 70 scientific manuscripts, 27 scientific conference proceedings, 58 lay language Research Summaries (Volume 3 Appendix 4) and 9 annual progress reports. There is also a video summary and a photographic exhibition. These all describe HHS findings and are either directly available to the public or available upon request. A directory of Study outputs (Volume 3 Appendix 3) is regularly updated and posted to the HHS website at www.hazelwoodhealthstudy.org.au/study-findings/outputs-directory. As mentioned in section 6.2, slides and/or recordings of our annual community briefings are also available on the HHS website (https://hazelwoodhealthstudy.org.au/news-and-events/community-briefings). The Research Streams section of the HHS website is also routinely revised to reflect the current status for each Stream's activities (www.hazelwoodhealthstudy.org.au/research-areas).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ELSEVIER

Maternal exposure to fine particulate matter from a coal mine fire and birth outcomes in Victoria, Australia

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ELSEVIER

Chemosphere

Volume 285, December 2021, 131351

Exposure to mine fire related particulate matter and mortality: A time series analysis from the Hazelwood Health Study

Christina Dimitriadis[a], Caroline X. Gao[a,b], Jillian F. Ikin[a], Rory Wolfe[a], Belinda J. Gabbe[a], Malcolm R. Sim[a], Michael J. Abramson[a], Yuming Guo[a]

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Examples of publicly available scientific manuscripts

When appropriate, new findings have been accompanied by lay language Research Summaries which were written specifically with the local community as their intended audience. These are available on the Fact Sheets and Summaries page of the HHS website (www.hazelwoodhealthstudy.org.au/study-findings/fact-sheets-and-summaries) and have been included in e-newsletters. Many have been printed and utilised to facilitate discussion at community engagement activities. They have also been distributed for display in public locations including the Latrobe City Council Headquarters, Traralgon Library, Morwell Library, Moe Library, Churchill Hub Library, Morwell Leisure Centre, Moe/Newborough Leisure Centre and the Churchill Leisure Centre. In addition, with the support of the Gippsland Primary Health Network, copies of HHS Research Summaries have been put on display at over 30 GP clinics in the region.

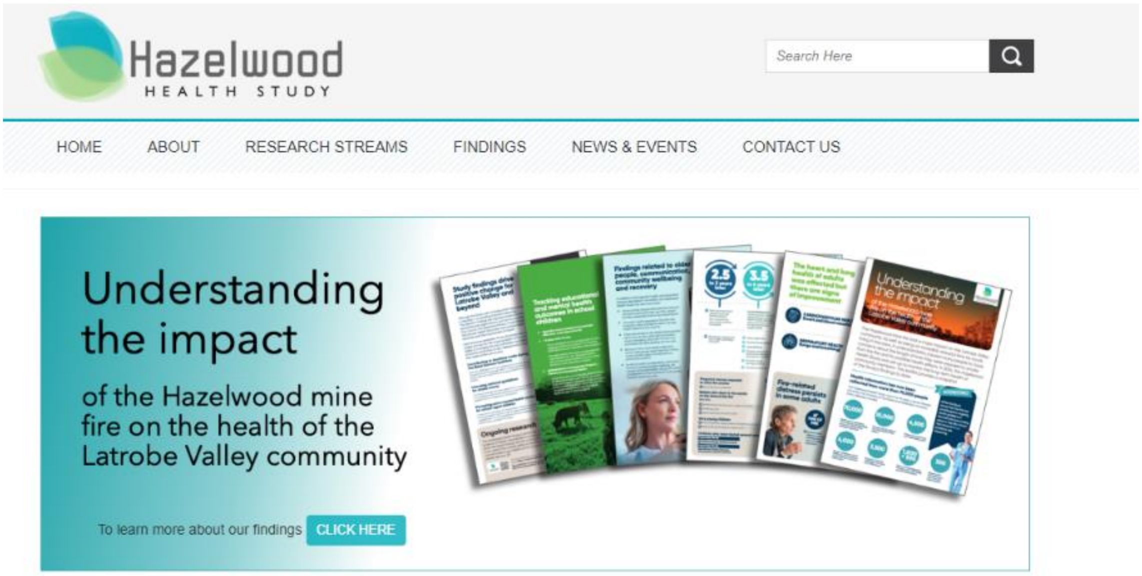
Hazelwood Health Study Research Summaries on display at the Traralgon Public Library

Similarly describing findings and Study progress, nine e-newsletters have been disseminated, each time to more than 2,100 subscribers. This has been a further activity aimed at maintaining the Study's public profile, keeping the community updated and maintaining contact with the participating cohorts. All e-newsletters are available on the HHS website at https://hazelwoodhealthstudy.org.au/news-and-events/e-newsletters.

To further improve local community engagement, but also broaden the audiences who access our findings, the Study has regularly produced media releases summarising key findings. These have resulted in numerous local, national and international news stories which can be viewed at https://hazelwoodhealthstudy.org.au/news-and-events/media.

The Community Wellbeing Stream’s ‘Our hopes for the future of Morwell’ photographic exhibition has been shown across the state of Victoria, including in Queen’s Hall at the Victorian State Parliament, the Ballarat International Foto Biennale, Federation University’s Switchback Gallery, Mid-Valley Shopping Centre and, now, the walls of the Latrobe Health Assembly (https://www.healthassembly.org.au/hope-on-display-at-latrobe-health-assembly/), along with subset of images on display at Morwell Neighbourhood House (https://morwellnh.org.au/).

The PMG have also worked with Wellmark (www.wellmark.com.au), an advertising agency specialising in healthcare marketing, on a campaign designed to enhance the profile of the Study findings in the local community. The campaign comprised a 6-page lay language flyer (Volume 3 Appendix 5), which was disseminated across the Latrobe Valley community as an insert in the Latrobe Valley Express newspaper in June 2023. The flyer summarised findings from the first several years of the Study. A second flyer, currently being prepared in-house, is proposed for late 2024.



Screenshot of the Hazelwood Health Study website promoting the community flyer

A focus for the PMG has been to ensure that Hazelwood Health Study findings influence meaningful change in health service provision for the mine fire-effected community and emergency response planning for communities impacted by similar events in the future. In this regard, the PMG and relevant Stream Leads have met with the Manager, Latrobe Municipal Emergency Management, and have made presentations to EMV, the Latrobe Municipal Emergency Management Planning Committee (MEMPC) and the Gippsland Regional Emergency Management Planning Committee (GREMPC).

7 The influence of the Hazelwood Health Study on policy and practice

As mentioned above, a focus for the Hazelwood Health Study throughout its tenure has been to ensure that the findings meaningfully influence public health-related policy and practice. This has been achieved through extensive dissemination of findings to diverse audiences (see section 6.4) and ongoing collaboration and codesign with end-users; including the community, local and State government organisations, medical and allied health services and emergency management agencies.

As a result of these efforts, the findings of the Hazelwood Health Study have informed health authorities' guidelines, decision making and policy around interventions for protecting human health. We are aware of the following impacts of the Study on policy and practice, however, no doubt there are others.

- Latrobe ELF Study Lead, Professor Fay Johnston, holds dual roles at the University of Tasmania (Head, Environmental Health group) and the Tasmanian Department of Health (Specialist Medical Advisor for Population Health Services). During the extreme bushfire and smoke event in Tasmania in early 2019, Professor Johnston's advice to relocate smoke-effected communities to safer fire evacuation shelters, and to supply air purifiers so that all shelters had clean air spaces for vulnerable people, was directly informed by HHS findings.
- EMV included HHS findings in its assessment of the appropriate response to the 2018 peat fire in Cobrico, south-west Victoria, which burned for 50 days; including the temporary relocation of nearby residents. Following the event, HHS team members met with EMV leadership for a post-event debrief and further sharing of relevant findings. Subsequent to this, HHS findings informed the response to the 2019-2020 Port Macquarie peat fire in New South Wales which burned for 201 days.
- Professor Johnston appeared as an expert witness at the Royal Commission into National Natural Disaster Arrangements (https://www.royalcommission.gov.au/natural-disasters) which examined the extreme 2019-2020 Black Summer bushfire season. Her testimony included evidence drawn from the HHS.
- The Royal Australian and New Zealand College of Obstetricians and Gynaecologists (RANZCOG) Air Pollution and Pregnancy guidelines (https://ranzcog.edu.au/wp-content/uploads/2022/05/Air-Pollution-and-Pregnancy.pdf) cite HHS research and advise pregnant women to minimise exposure to air pollution.
- The Environmental Health Standing Committee of the Australian Health Protection Principal Committee report "Guidance for public health agencies: Managing prolonged smoke events from landscape fires" (https://files-em.em.vic.gov.au/public/Smoke/EMK-01.19-Community-SAQH-

Protocol.pdf) describes vulnerable groups as those with chronic diseases including heart and lung conditions and diabetes, people over 65, pregnant women, young children and infants and cites the HHS among its evidence base.

- The Thoracic Society of Australia and New Zealand 2023 position statement on asthma and landscape fire smoke[137] cites seven HHS scientific manuscripts in relation to its review of the impacts of landscape fire smoke on health, advice for asthma management, smoke mitigation strategies, clinical awareness and public health messaging and preparation. The Hazelwood principal investigator Professor Michael Abramson was Deputy Chair and senior author of this position statement.
- The Centre for Safe Air, which supports translation of evidence into policy, cites five HHS scientific publications in its Factsheet "Bushfire Smoke: What are the health impacts and what can we do to minimise exposure?" (https://safeair.org.au/bushfire-smoke-factsheet/?#gf_1)
- Professor Johnston drew on HHS findings in a Medical Journal of Australia article calling for a national health protection strategy.[138] The article advocates that managing the health impacts of fire smoke should be integral to landscape fire planning and emergency responses; that public access to local, user-friendly air quality information and reliable smoke forecasts are essential for managing personal exposure and health; and that consistency of air quality information and accurate, practical and consistent public health advice across jurisdictions is essential.
- In addition to informing responses to major events and position statements from key organisations, HHS findings have informed the way that the Victorian Government communicates regarding smoke events. This includes the development of a smoke alert rating scale to help community members gauge potential health risks, and the inclusion of smoke alerts on the VicEmergency app which is the official Victorian State Government app for emergency warnings and information (https://emergency.vic.gov.au/respond/)
- The Schools Study finding that 22% of students surveyed in 2015 reported mine fire-related posttraumatic stress symptoms suggestive of PTSD (see section 5.5.1) prompted considerable discussion with local and state health and education policy makers. On the advice of the Chief Health Officer, special meetings of the Community Advisory Committee and the Clinical Reference group were convened to develop a clinical pathway, which included increasing access to mental health services for young people and producing a fact sheet which was sent to all families participating in the Schools Study.
- The suite of findings from the HHS has been cited, among others, as globally significant and an example of the research urgently needed for tackling the ongoing challenges of climate change and increasingly severe fire smoke episodes.[139]

Going beyond the health impacts of the mine fire:

- HHS Respiratory Stream findings regarding poorer asthma control (see section 5.2.1) informed a public health awareness campaign by the Latrobe Health Assembly highlighting the need for asthma management plans. The campaign was run in 2018 and 2019 and just over half of participants reported not having a current management plan, with most of the participants committing to engaging with their GP to create or update their plans. Other HHS Respiratory Stream findings regarding e-cigarette use[76] have informed the Latrobe Health Assembly smoking cessation campaigns.
- HHS findings showed that more than half of men and women in the Latrobe Valley did not meet recommended intakes of fibre, while 60% of men and 42% of women exceeded recommended dietary sodium intakes. As a result, the Latrobe Health Assembly partnered with Monash University to create the My FoodSwaps project (https://www.healthassembly.org.au/all-projects/my-foodswaps/), which aimed to monitor and change the dietary patterns within the Latrobe Valley by introducing a co-designed, community based, innovative, personalised dietary feedback system. The My FoodSwaps project was led by HHS investigator Associate Professor Tracy McCaffrey, and also involved Professor Michael Abramson.
- The Impact on Community Wellbeing Stream's 'Our hopes for the future of Morwell' photographic exhibition (see section 5.8.2.1 and https://hazelwoodhealthstudy.org.au/media/our-hopes) stemming from participatory action research, provided a vehicle for the local community members and groups to present their visions for the future of Morwell and the region, and for this compelling and enduring vision to be disseminated locally and state-wide.
- HHS findings were included in the 2019 Supreme Court trial finding the coal mine operators guilty of 10 WorkSafe breaches, and an earlier trial which found them guilty of three Environment Protection Act breaches. Specifically, the mine operators were found guilty of polluting the atmosphere so as to make it harmful to health.
- Professor Michael Abramson was one of few non-fellows invited to a roundtable convened by the Australian Academy of Health and Medical Sciences following the 'Black Summer'. This resulted in a document providing evidence on the health impacts of Australian bushfires (https://aahms.org/wp-content/uploads/2022/02/The-Australian-Bushfires-and-the-impact-on-health_evidence-doc.pdf) which was disseminated by the Academy, submitted to a Senate Inquiry and used to brief politicians and other decision makers.
- As mentioned previously, the researchers have shared their findings with key state-wide and local organisations including the Department of Health, the LHA, the Latrobe Health Advocate, the GPHN and the Latrobe City Council. With a view to informing local and regional emergency management plans the researchers have also made presentations to EMV, the Latrobe MEMPC and the GREMPC

8 Acknowledgements

This Study would not be possible without the good will of our many research participants. Across the Latrobe Valley, and Gippsland more widely, our participants have generously volunteered their time. Often travelling to one of our research sites, they have participated in focus groups, completed interviews, filled in surveys or undergone clinical testing. Of particular note, the parents of our Early Life Follow-up and Schools Study participants are gratefully acknowledged for allowing their children to take part. To each and every Hazelwood Health Study participant, you are sincerely thanked.

Listed in this Volume already, there are many organisations, data custodians and individual contributors to this Study who we gratefully acknowledge for their respective contributions. There are numerous others who have all played an important part. They includes groups who have actively supported the study, such as local media who have reliably informed the public about our activities and findings, and other organisations and businesses who voluntarily displayed our posters or Research Summaries, acted as pick-up points for participants to collect vouchers, or hosted our annual community briefings, focus groups and recruitment activities. Numerous businesses, many Gippsland-based, have also provided important services such as assisting with the design of our data collection or promotional materials, delivering flyers, transporting our medical equipment and providing accommodation. For all of your contributions, we are grateful.

The Hazelwood mine fire, February 2014
Photo courtesy of Keith Pakenham, CFA Victoria, Australia

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