# Applied Epidemiology for Evidence-Based Action

*A thesis submitted for the degree of Master of Philosophy (Applied Epidemiology) of the Australian National University*

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North East Public Health Unit 2023–2024

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*The work presented in this thesis was conducted on the unceded land of the Wurundjeri people of the Kulin nation.*

*I acknowledge the Traditional Custodians of the land, pay my respects to Elders past and present, and recognise Aboriginal and Torres Strait Islander Peoples as Australia's first researchers, healers and storytellers.*

# Originality statement

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, or substantial proportions of material which have been accepted for the award of any other degree or diploma at ANU or any other educational institution, except where due acknowledgement is made in the text. Any contribution made to the research by others, with whom I have worked is explicitly acknowledged in the thesis. I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation, or linguistic expression is acknowledged.

Aaron Osborne, October 2024

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Special shout out to all my friends and family, for their support throughout this process. I especially want to thank those who came and visited while I was in Canberra, as well as those who thought I was moving there.

*Figure 1. Masters of Applied Epidemiology 2023 cohort at the 1st SAFETY scientific conference, Canberra, Australia, 2023*

*Figure 2. From left to right: Aaron, David, Nick, Anna, Piera, Matt, Tania, Rosie, Caitlyn. Absent: Jo and Josh. Canberra, Parliament House, 2023*

# Acronyms

| | |
|---|---|
| ABS | Australian Bureau of Statistics |
| AQ | Air Quality |
| BBV | Blood borne virus |
| CAB | Clearance Antibiotics |
| CALD | Culturally and Linguistically Diverse |
| CDC | Centres for Disease Control and Prevention |
| CDNA | Communicable Diseases Network Australia |
| CHB | Chronic Hepatitis B |
| CI | Confidence Interval |
| ED | Emergency Department |
| EPA | Environment Protection Agency |
| GAS | Group A Streptococcus |
| HBV | Hepatitis B Virus |
| HBsAg | Hepatitis B Surface Antigen |
| ICD | International Classification of Disease |
| IMT | Incident Management Team |
| IRSAD | Index of Relative Socio-economic Advantage and Disadvantage |
| LGA | Local Government Area |
| MLST | Multi-locus Sequence Typing |
| NEPHU | North Eastern Public Health Unit |
| NHMRC | National Health and Medical Research Council |
| NLP | Natural Language Processing |
| PHESS | Public Health Events Surveillance System |
| PHU | Public Health Unit |
| PM | Particulate Matter |
| RSV | Respiratory Syncytial Virus |
| SA2 | Statistical Area Level 2 |
| SAEFVIC | Surveillance of Adverse Events Following Vaccination in the Community |
| VEMD | Victorian Emergency Minimum Dataset |
| WGS | Whole Genome Sequencing |
| WHO | World Health Organization |

# Abstract

This thesis details projects undertaken during my placement at the North Eastern Public Health Unit (NEPHU) from February 2023 to November 2024. The North Eastern Public Health Unit works across 11 local government areas in the north east of metropolitan Melbourne. Local public Health Units were established in Victoria in 2020 and are responsible for disease prevention and population health. I worked at the public health unit before undertaking my Master of Philosophy (Applied Epidemiology) degree. I was the first student placed at a Victorian Public Health Unit.

My projects comprised: an investigation of a genomically clustered group A Streptococcus outbreak in a primary school in Melbourne, Australia; a study analysing community-level factors associated with areas of relative underdiagnosis of Hepatitis B in the North Eastern Public Health Unit catchment; a feasibility study of how the current notification system can be adapted to track engagement in care for people living with chronic hepatitis B using routine laboratory data; an ecological study identifying ICD-10 codes associated with periods of poor air quality that can be effectively used for ongoing monitoring during bushfire events.

These projects and experiences fulfil the core requirements of the Australian National University Master of Philosophy (Applied Epidemiology) program.

# Chapter Guide

**Chapter One** provides an overview of my MAE experience, my placement and outlines the competency requirements of the program.

**Chapter Two** presents an investigation of an outbreak of genomically clustered group A Streptococcus in a primary school in Victoria in 2023.

**Chapter Three** presents a study analysing community-level factors associated with areas of relative underdiagnosis of hepatitis B in the North Eastern Public Health Unit catchment.

**Chapter Four** presents a feasibility study of how the current notification system in Victoria can be adapted to track engagement in care for people living with chronic hepatitis B using routine laboratory data.

**Chapter Five** presents an ecological study identifying ICD-10 codes associated with periods of poor air quality that can be effectively used for ongoing monitoring during bushfire events.

**Chapter Six** provides a summary of the program's teaching competencies, including the lessons from the field and teaching sessions.

# **Chapter 1:** Introduction to field placement and summary of experience

# Introduction

I conducted my placement at the North Eastern Public Health Unit (NEPHU). I had previously worked at NEPHU as the lead epidemiologist and had played a role in establishing the epidemiology branch during the COVID-19 pandemic. I chose to complete the Master of Philosophy in Applied Epidemiology (MAE) as an opportunity to consolidate my knowledge and experience in applied epidemiology and further extend myself. Conducting my placement at the newly established public health unit served as a chance to reflect on the new opportunities that exist to conduct place-based public health in Victoria.

This chapter provides an overview of my field placement and summarises the projects undertaken to meet the MAE core course competencies. It also describes additional MAE competencies I undertook during my placement from February 2023 to October 2024.

## Field placement

The North Eastern Public Health Unit works across 12 local government areas in the north east of metropolitan Melbourne. The unit serves a population of over 1.8 million people and the catchment is one of the most culturally and linguistically diverse regions in Australia.

Local public Health Units (LPHUs) were established in Victoria in 2020 during the COVID-19 pandemic to manage local cases and outbreaks of COVID-19. Since July 2022, LPHUs have begun undertaking additional public health responsibilities for other notifiable conditions. NEPHU is responsible for disease prevention and population health in the catchment. My role was in the Medical and Epidemiology branch of NEPHU, and I conducted a project with the Syndromic Surveillance team at the Victorian Department of Health.

# Summary of Degree Requirements

## Core Competencies

### Investigation of an acute public health problem

This competency is demonstrated by the drafted manuscript associated with the study investigating an outbreak of genomically clustered group A Streptococcus in a primary school in Victoria in 2023 (Chapter 2).

### Analysis of a public health dataset

This competency is demonstrated by the study analysing community-level factors associated with areas of relative underdiagnosis of Hepatitis B in the North Eastern Public Health Unit catchment (Chapter 3).

### Surveillance system evaluation

This competency is demonstrated through the feasibility study of how the current notification system can be adapted to track engagement in care for people living with chronic hepatitis B using routine laboratory data (Chapter 4).

### Epidemiological study

This competency is demonstrated through the study identifying ICD-10 codes associated with periods of poor air quality that can be effectively used for ongoing monitoring during bushfire events (Chapter 5).

## Additional requirements

### Literature review

The search strategy conducted as part of the *Hepatitis B care cascade surveillance is* detailed in Chapter 4. I reviewed the literature (unstructured) for all field projects.

### Peer-reviewed journal publication

I prepared a draft of the following scientific manuscript (included in Chapter 3) with the plan to submit it to the target journal, *Communicable Disease Intelligence*: An outbreak of genomically clustered group A Streptococcus in a primary school, Victoria, 2022

## Conference/oral presentations

I presented the following oral presentations:

- *Understanding Communities: Factors associated with high Hepatitis B incidence*. Communicable Disease and Immunization Conference 2024, Brisbane, Australia, 11-13 June 2024.
- *Schools out?! Absenteeism during a Group A Streptococcus outbreak in a school community*. Communicable Disease and Immunization Conference 2024, Brisbane, Australia, 11-13 June 2024.
- *Area variations and equity considerations for public health interventions across the NEPHU catchment*. Northern Hospital Grand Rounds, Melbourne, Australia 4 July 2024
- *Using what we already have – Analysing existing datasets to drive long term health outcomes*. Austin Hospital Grand Rounds, Melbourne, Australia 2 October 2024

## Communication to lay audience

I wrote and created a lay study summary in the form of a summary of the outbreak for the school community (Chapter 2).

## Teaching activities

I planned and conducted the following teaching activities as presented in Chapter 6:

- Lesson from the field:  Development of a case series timeline graph using R statistical software.
- Peer-to-peer teaching session: Public health in different contexts

## Coursework

I completed and passed the following coursework units of the MAE program:

- POPH8920 Outbreak Investigation

- POPH8917 Public Health Surveillance
- POPH8913 Analysis of Public Health Data
- POPH8915 Research Design and Methods
- POPH8914 Issues in Applied Epidemiology

## Additional field placement activities and experiences

In addition to activities related to the core program requirements and supporting the daily operations of the unit, I also took part in the following activities and projects:

- Member of the NEPHU Research Governance Committee: Development of authorship guidelines, work plan and supporting documents.
- Author on draft paper for submission *Epidemiology of mpox in North-East metropolitan Melbourne during 2022. Target journal: Australian and New Zealand Journal of Public Health*
- Author on draft paper for submission *Epidemiology of invasive group A streptococcus disease in the North East of Melbourne: insights from surveillance data. Target journal: Communicable Disease Intelligence*
- Investigation of suspected community associated Methicillin Resistant Staphylococcus Aureus in Northern Metro Melbourne NHMRC 2024
- Collaborations in Health Services Research Grant application: Hepatitis B framework for the co-design and implementation of interventions for the education, testing and linkage to care in target communities. Associate Investigator

# Summary of requirements

A summary of how the projects meet the core MAE degree requirements is presented in the table below.

*Table 1. Summary of MAE projects and experiences fulfilling core degree requirements*

| | Chapter | | | | |
|---|---|---|---|---|---|
| **Requirements** | **2** | **3** | **4** | **5** | **6** |
| Data analysis | | ✓ | ✓ | ✓ | |
| Evaluate a surveillance system | | | ✓ | | |
| Epidemiological study | | | | ✓ | |
| Investigation of public health problem | ✓ | | | | |
| Literature review | | | ✓ | | |
| Communication with a lay audience | ✓ | | | | |
| Conference presentation | ✓ | ✓ | | | |
| Peer-reviewed journal publication | ✓ | | | | |
| Teaching activities | | | | | ✓ |

# **Chapter 2:** An outbreak of group A Streptococcus in a primary school, Victoria, 2023

# Prologue

## Rationale

The North Eastern Public Health Unit (NEPHU) was established in 2021 to decentralise Victoria's COVID-19 response. NEPHU's scope has expanded considerably since then, with the public health management of almost all notifiable conditions sitting with public health units in 2024. While this has offered opportunities for improving public health practice in Victoria, it has also presented many challenges.

In Victoria, invasive group A Streptococcus (iGAS) became notifiable in 2022, and NEPHU was responsible for its public health management from May 2023. At the time of this outbreak, no national guidelines for the condition's management existed, and guidance on outbreak management and control was limited. In addition, the public health unit was still developing its own internal guidelines for incident management.

In 2023, Victoria experienced an increase in iGAS infections, reflecting global trends. NEPHU documented a high number of iGAS cases and identified several iGAS transmission events prior to this outbreak, including a number of household iGAS clusters. Similar occurrences were reported in other jurisdictions. At the time, there was heightened concern about the increased transmissibility of severe strains of invasive GAS in the community.

Group A Streptococcus (GAS) spreads mainly through direct person-to-person contact, most commonly via respiratory droplets.[1] Transmission can also occur after exposure to infectious secretions (such as saliva, nasal mucus, or wound discharge) or through direct skin-to-skin contact.[1] People with symptomatic GAS disease (for example, pharyngitis or impetigo) are much more infectious than asymptomatic carriers, whereas fomite-mediated transmission is rare.[1] School environments in particular have a higher baseline risk for communicable disease spread, making them a key setting for potential GAS outbreaks.[1]

NEPHU was notified of a 10-year-old male with severe invasive GAS infection. Follow-up with the principal identified additional students who were unwell in the same class, with an unusually high number of absentees. The small school, with approximately 70 students, was characterised as a close-knit community. News of the outbreak spread quickly within the school community, leading to heightened visibility and concern about the index iGAS case, who was hospitalised, and the risk of further cases.

These factors lead to the decision to conduct a formal public health investigation despite the lack of established guidance. This chapter presents the publication of the investigation of an outbreak of group A Streptococcus in a school and the public health measures implemented.

## My Role

As the epidemiological lead in the incident management team, my primary role was to provide epidemiological support in the outbreak management response. This involved participating in incident management team (IMT) meetings, presenting situational updates, and developing situation reports. I played a key role in developing case definitions for outbreak investigations, developing descriptive epidemiology summaries, and providing input into risk assessments and control measures. My responsibilities also included data management and developing case and contact line lists.

I developed the active case-finding survey sent to the class cohort, using an SMS-based tool to administer it. I drafted communications for the school community about the study's purpose, current situation, and risks. I liaised with the principal throughout the survey administration to ensure understanding and support. In collaboration with the incident controller, I developed escalation criteria for survey results and actions they would trigger, such as additional IMTs if ongoing transmission was detected.

I communicated investigation findings internally and externally through presentations and reports. A lay summary was developed and presented in this chapter, a summary of the outbreak for the school community impacted by the outbreak (Appendix A). The lay

summary was assessed as having a grade 6 level readability. I presented preliminary findings at the statewide surveillance meeting and presented this investigation at the Communicable Disease and Immunisation Conference in Brisbane in June 2024 (Appendix B). A manuscript presented in this chapter has been prepared for publication in the Communicable Disease Intelligence journal.

## Lessons learnt

The ten steps of an outbreak investigation provided a practical and important framework to structure our response to this incident. They explained our actions and ensured the outbreak investigation was conducted rigorously. I found them a valuable source of confidence in incident management meetings, reminding me of my role and enabling me to speak authoritatively when I perceived essential steps were being overlooked or insufficiently addressed.

Teamwork is crucial, particularly in time-sensitive situations. Understanding everyone's roles and responsibilities ensures that all key tasks are addressed and there is no duplication of effort. Clear and consistent communication was important, although it could have been executed more effectively at times. This includes both verbal and written communication. Communicating directly and concisely ensures that meetings are efficient and avoid circular discussions. Understanding what information is critical to making public health decisions is vital.

As a new public health unit investigating a disease outbreak, the team needed to gain experience managing the response while balancing a lack of organisational maturity and experience. This presented a significant learning curve for us, and we were required to adapt rapidly to the evolving situation. For example there were opportunities for improved data collection in retrospect. Although absenteeism in the affected class was a key indicator, monitoring absenteeism across the entire school would have provided a useful baseline for comparison and helped identify risks in other settings. These challenges also presented opportunities for us to learn and develop as a team.

I occasionally found the ambiguous nature of being a Master of Applied Epidemiology (MAE) scholar challenging. I had previously worked in the public health unit for some years prior, and my experience or expertise in epidemiology is more than just my time completing the MAE. The blurring of these lines meant that, at times, I may not have spoken up when, in retrospect, I should have based on my professional opinion.

## Public Health Impact

The response demonstrated the important role of local responses to public health incidents, particularly community engagement and place-based responses. It showed the capacity of Public Health Units (PHU) to manage something that historically may have yet to be followed up. Support of the school community was critical, ensuring that concerns were heard and that they felt their students were safe.

Following the outbreak, the learnings informed local guidelines for responding to iGAS outbreaks in school settings. This included reviewing international policies and developing specific locally tailored guidelines to ensure support for responding to such outbreaks in the future. The investigation findings highlighted the need for further study into the role of clearance antibiotics in outbreak settings to prevent additional invasive GAS cases.

The investigation highlighted the need for clear PHU incident management structures, protocols and policies. Reflections and learnings informed the development and formalisation of appropriate incident management guidelines. Outbreak situations report templates and other resources developed in this outbreak were utilised in future responses.

## References

1. Communicable Diseases Network Australia (CDNA). *Invasive Group A Streptococcal (iGAS) Disease: CDNA National Guidelines for Public Health Units* [Internet]. Version 2.0. Canberra: Australian Government Department of Health and Aged Care; 2024 Jan 1 [cited 2025 Jun 8]. Available from:

https://www.health.gov.au/sites/default/files/2024-01/invasive-group-a-streptococcal-igas-disease-cdna-national-guidelines-for-public-health-units_0.pdf

# Manuscript

## An outbreak of genomically clustered group A Streptococcus in a school community, Victoria, 2023

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## Abstract

In 2023, a global increase in invasive group A Streptococcal (GAS) disease caused serious illness and death. The North Eastern Public Health Unit (NEPHU) in Victoria Australia identified an outbreak of GAS in a school in July 2023; we investigated to describe the epidemiology, identify risk factors for severe disease, and implement control measures. We defined confirmed cases as those with laboratory, clinical and epidemiological evidence. Probable cases had clinical evidence with an epidemiological link to a confirmed case but no laboratory evidence. Absentee data were collated for students preceding the onset of the index case. We developed an online, self-administered survey for all students to identify contacts with clinically compatible illnesses. Cultures were genomically sequenced. We identified 11 cases (five confirmed, six probable) among the cohort of 38 (29% attack rate) with onset dates from 24 July to 27 August 2023. The index case had a severe invasive GAS infection requiring hospitalisation; eight (73%) of 11 cases reported sore throat and one reported scarlet fever as their primary syndrome. Fifteen (54%) of 28 students were absent from the school during the period preceding the index case's onset. We monitored for two incubation periods following the onset of the last case to 5 September 2023 (six days), with no further cases identified. Isolates all typed as *emm*1, with genomic clustering consistent with localised transmission. This outbreak demonstrated group A Streptococcus (GAS) transmissibility in a school with multiple clinical manifestations.


**Keywords:** disease outbreak; streptococcal infections; invasive group A Streptococcus; streptococcus pyogenes; scarlet fever; genomic cluster

## Introduction

Group A Streptococcus (GAS) or *Streptococcus pyogenes* is a human pathogen associated with significant mortality and morbidity globally.[1] GAS is a gram-positive bacterium that colonises both the skin and pharynx and can cause a wide range of clinical manifestations.[2] These include mild infections, such as pharyngitis and impetigo, and serious infections known as invasive group A Streptococcal (iGAS), with presentations including necrotising fasciitis and streptococcal toxic shock syndrome.[2] Following infection, complications can occur, such as acute rheumatic fever and post-streptococcal glomerulonephritis which, while rare, are important causes of mortality and morbidity globally.[1]

Invasive group A Streptococcal infection occurs when GAS infects a normally sterile site.[3] Invasive infections are often severe, with case fatality as high as 15% in high-income countries.[4,5] Several risk factors increase the likelihood of a severe invasive GAS infection. Older (>65 years) and younger age groups (<5 years) are at greater risk of developing invasive GAS infections.[6] Studies have identified an increased risk of secondary invasive GAS cases in household contacts of cases when compared to the general population.[7–9] Viral coinfection such as influenza or varicella may increase the risk of invasive GAS disease.[10–12]

In early to mid-2022 there was an increase in hospital admissions and deaths due to invasive GAS in Europe and the United States, particularly among children under ten years old.[13–16] Similar increases were noted in Australia.[17] Invasive GAS was made a notifiable condition in the Australian state of Victoria in 2022 under the Public Health and Wellbeing Regulations (2019).[18] The North Eastern Public Health Unit (NEPHU) is one of nine public health units in Victoria, serving a population of 1.8 million, accounting for 28% of the total Victorian population.[19] We describe an outbreak investigation of GAS in a school setting conducted by the North Eastern Public Health Unit (NEPHU).

On 31 July 2023, NEPHU received a laboratory notification of invasive GAS in a 10-year-old male. Through routine follow-up with the principal of the school that the case attended, it was reported that two students from the same classroom as the index case had symptoms consistent with non-invasive GAS infections. This principal also reported higher than usual levels of absenteeism in the week preceding the notification of the index case. This prompted the public

health unit to conduct an outbreak investigation in an effort to prevent secondary cases of invasive GAS in this setting.

## Aims and Objectives

This study aimed to describe the outcomes of the investigation into an outbreak of GAS in a Victorian school. The key objectives were to:

1. Describe the outbreak setting, investigation and associated public health actions.
2. Epidemiologically analyse the outbreak to describe transmission and extent of the outbreak's spread.
3. Provide evidence to inform future GAS public health response.

## Methods

### Study Design

A retrospective cohort study was conducted. All analyses were performed using R statistical software.[20]

### Outbreak setting

The setting of this outbreak was a grade five/six class of students aged 10 to 12 years old at a primary school in Melbourne, Victoria. The class under investigation comprised 28 students and one teacher in a school of 64 students and 19 staff. A social event held at a public venue on the 22 July 2023, attended by eight students from the class and four additional household members, was included in the investigation.

### Investigation team

The NEPHU Incident Management Team was established on 1 August 2023 comprising public health physicians, epidemiologists, public health officers, a communications lead, and infection prevention and control specialists. The United States Centres for Disease Control (CDC) guidelines for outbreak investigation (10 steps) and state incident management guidelines were used to investigate and manage the outbreak. [21]

### Epidemiological Investigation

School enrolment, attendance list, and details of the social event attendees were obtained on 3 August 2023. This included all staff and students in the class and data on who reported a

clinically compatible illness, attendance at the social event, and absenteeism data preceding the notification of the index case.

**Outbreak Definitions**

Confirmed outbreak case

An individual with positive detection of group A Streptococci (*Streptococcus pyogenes*) by culture or molecular methods on or after 24 June 2023 to 5 September 2023

AND

An individual with clinical evidence of GAS infection on or after 24 June 2023 to 5 September 2023

AND

Epidemiological evidence

Probable outbreak case

An individual with clinical evidence of GAS infection on or after 24 June 2023 to 5 September 2023

AND

Epidemiological evidence

*Epidemiological evidence*

An individual who attended either the grade five/six class at the school for cumulatively more than 24 hours from 24 June 2023 to 5 September 2023

OR

An individual who attended the party on the 22 July 2023

*Clinical evidence*

Clinical symptoms consistent with streptococcal sore throat (pharyngitis) OR scarlet fever OR skin sores (impetigo) OR invasive GAS. Symptoms, as documented from a medical examination or reported by the child's parents, included:

- sore throat
- skin rash – fine erythematous, punctate, blanching on pressure and with a sandpaper texture and predominantly truncal distribution
- superficial skin infection typically presenting as small blisters

- strawberry tongue
- flushing of cheeks and circumoral pallor, and
- desquamation of the skin in convalescence.
- streptococcal toxic shock syndrome that includes both hypotension and multi-organ failure
- necrotising fasciitis
- puerperal sepsis

Contact

An individual who attended either the grade five/six class at the school for cumulatively more than 24 hours since 22 June 2023

OR

An individual who attended the party on the 22 July 2023

OR

Household contact of an invasive GAS case

Case finding

Students who reported a clinically compatible illness were reported to the investigation team by the school and followed up. Active case finding was conducted using a survey sent to the school community on 22 August (Appendix A). The survey aimed to identify any additional cases in the one month prior to the index case and to assess any ongoing transmission following the administration of antibiotic prophylaxis. The survey was administered to all students and staff not already identified as cases in the investigation.

**Laboratory Investigation**

All suspected cases were requested to visit a healthcare facility for laboratory confirmation and treatment. Positive samples were sent to the Microbiological Diagnostic Unit Public Health Laboratory (MDU PHL), The University of Melbourne for whole genome sequencing (WGS) and multi-locus sequence typing (MLST) as part of the outbreak investigation. Phylogenetic trees were generated using a maximum-likelihood method based on the core genome alignment of all isolates analysed in this report and interpreted in context with available epidemiological data.

## Ethics approval

This investigation was carried out under the powers of the Victorian Public Health and Wellbeing Act 2008 and associated Public Health and Wellbeing Regulations (2019) in response to an acute threat to public health.[18,22] The Australian National University (ANU) Human Research Ethics Committee (HREC) has a standing authorisation for staff and student outbreak investigations (Protocol Number 2017/909).

## Results

Eleven cases (five confirmed, six probable) were identified amongst the cohort (n=38), which comprised staff (n=1), students (n=28) and household members (n=9), with a 29% attack rate. The index case attended school while infectious (defined as up to seven days before symptom onset[23]) on 24 July 2023 and was reported to the NEPHU on 31 July 2023; illness onset dates ranged for cases from 24 July to 27 August (Figure 1). Eight cases were students from a single class group at the school (8/29, 29% attack rate).

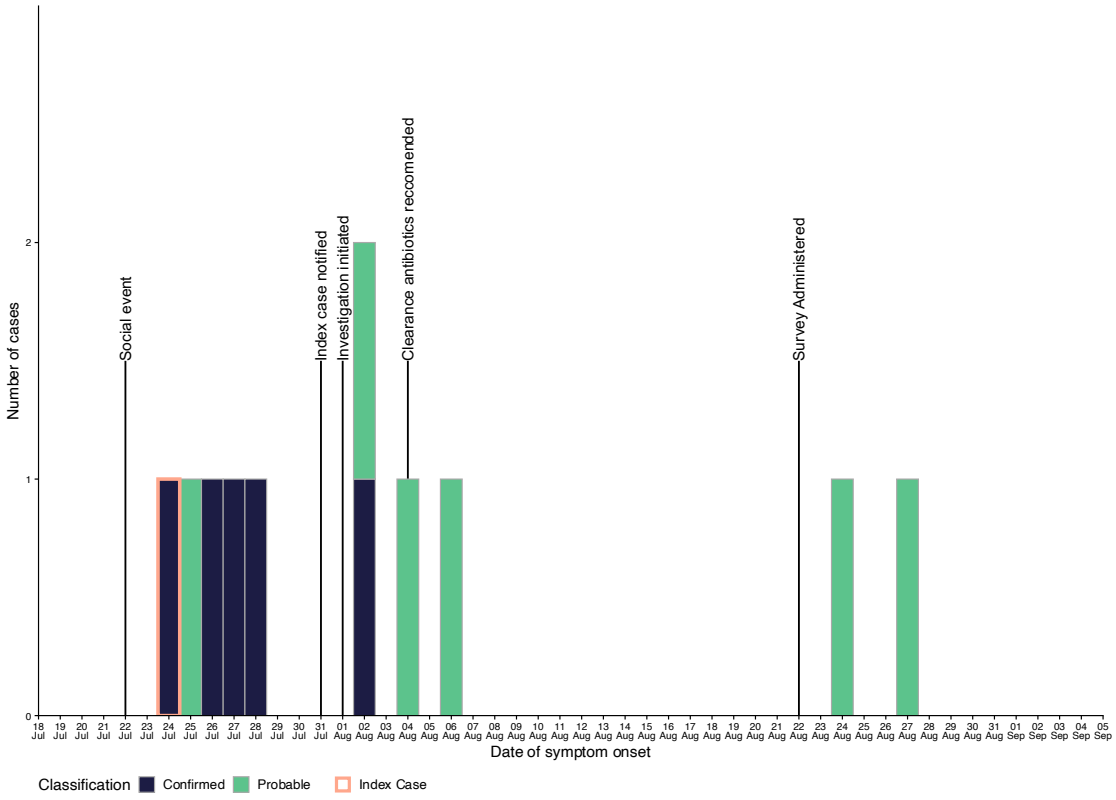


*Figure 1. The epidemiological curve of cases in a school outbreak of group A streptococcus, Victoria, July-September 2023*

The investigation included a social event held on 22 July, attended by the index case. Eight students from the same class and five household contacts participated in the event. Five of the

12 attendees were identified as cases, with an attack rate of 41%. Four cases attended the social event while potentially infectious. One additional case who was also a household contact of a case, was identified from attendees.

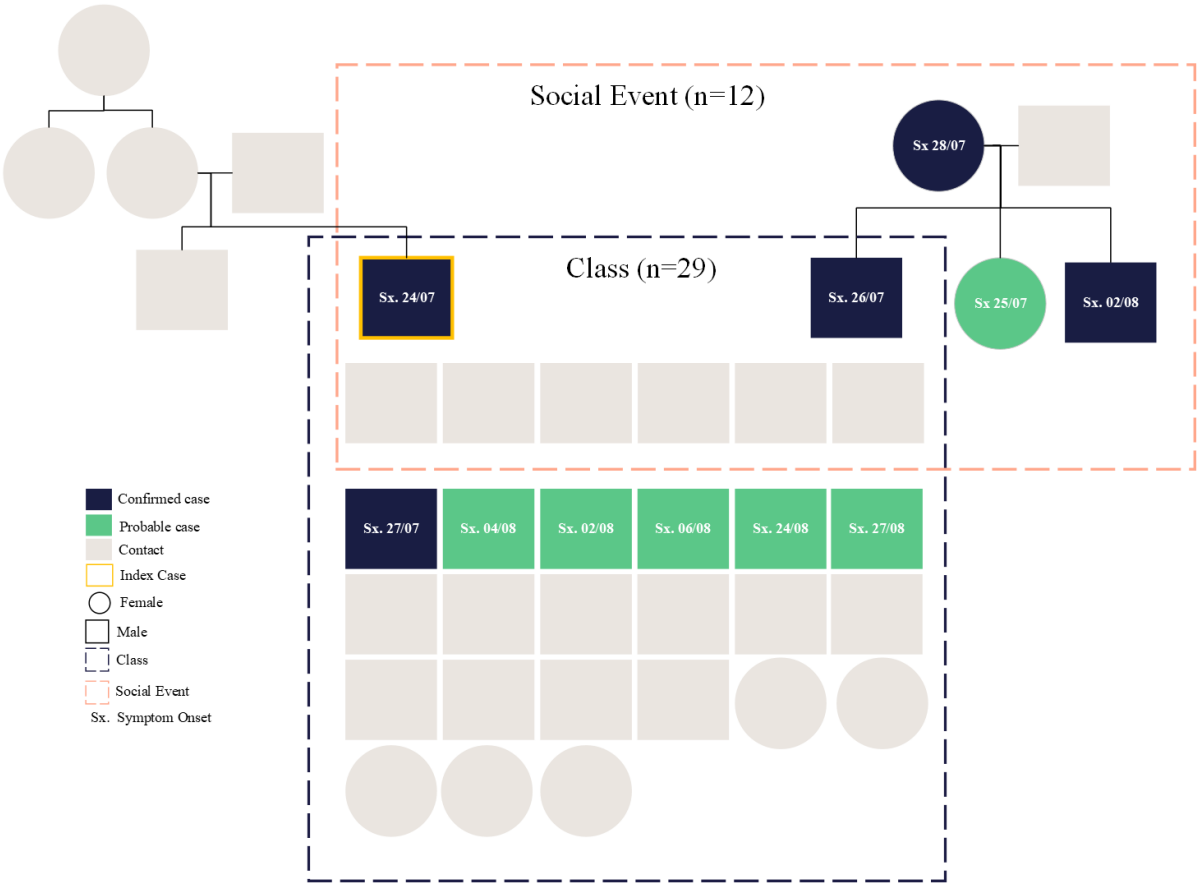


*Figure 2. Summary of exposure events in a school outbreak of group A Streptococcus, Melbourne July-September 2023*

Twenty-six investigation surveys were distributed amongst contacts in the class cohort, 12 (46%) responded, of which five (42%) reported symptoms consistent with GAS (Table 1). Reported symptom onset ranged from 2 to 27 August 2023, and two probable cases reported symptoms of sore throat after the administration of antibiotic prophylaxis on August 24 and 27 2023. The two probable cases reported seeking medical care and received alternate diagnoses, however no diagnostic tests were performed. No swabs were taken for the cases identified through the active case finding survey and all met the probable case definition. No cases were identified with a symptom onset date preceding the index case. Fifty–five investigation surveys were sent to assess the risk of further transmission outside the class cohort to the broader

school, and 17 responded (31% response rate). No additional cases were identified in other class cohorts.

The median age of cases was 11 years, with an overall age range of 10–52 years (Table 1). During the outbreak, males showed a higher attack rate (38%) compared to females (24%). The index case had a severe invasive group A Streptococcus infection that required hospitalisation for a period of ten days. Eight (73%) cases reported pharyngitis as their clinical manifestation, while one case reported scarlet fever as their primary clinical manifestation. There were no deaths during the outbreak.

*Table 1. Demographic characteristics, clinical illness, and outcomes of cases linked to the outbreak of group A Streptococcus at a school in July-September 2023*

| | Cohort | | Probable cases | | Confirmed cases | | Attack rate |
|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | % |
| Total | 38 | | 6 | | 5 | | 29% |
| Students | 28 | 74% | 5 | 83% | 3 | 60% | 29% |
| Staff | 1 | 3% | 0 | 0% | 0 | 0% | 0% |
| Household | 9 | 24% | 1 | 17% | 2 | 40% | 33% |
| Demographics | | | | | | | |
| Median age (IQR) | 11 | (10–11) | 11 | (10–12) | 11 | (11–20) | |
| Male | 13 | 34% | 3 | 50% | 2 | 40% | 38% |
| Female | 25 | 66% | 3 | 50% | 3 | 60% | 24% |
| Clinical Manifestation | | | | | | | |
| Invasive GAS | - | - | 0 | 0% | 1 | 20% | - |
| Fever | - | - | 0 | 0% | 1 | 20% | - |
| Pharyngitis | - | - | 6 | 100% | 2 | 40% | - |
| Scarlet fever | - | - | 0 | 0% | 1 | 20% | - |

Data from the school administration system identified high levels of absenteeism at the school prior to the index case from the 24 June. Across the investigation period, 15 (54%) of 28 students were reported absent during the period 24 June to 1 August (Figure 3). Five (18%) of 28 students were absent during the week preceding the index case, the school did not record a specific reason for their absences. These students were included in the subsequent active case-finding survey and among respondents, none reported symptoms consistent with GAS infection

and no additional cases were identified. Students were asked about symptoms of other respiratory illnesses, such as influenza or respiratory syncytial virus, in the month before the index case; no contacts reported other respiratory diseases.

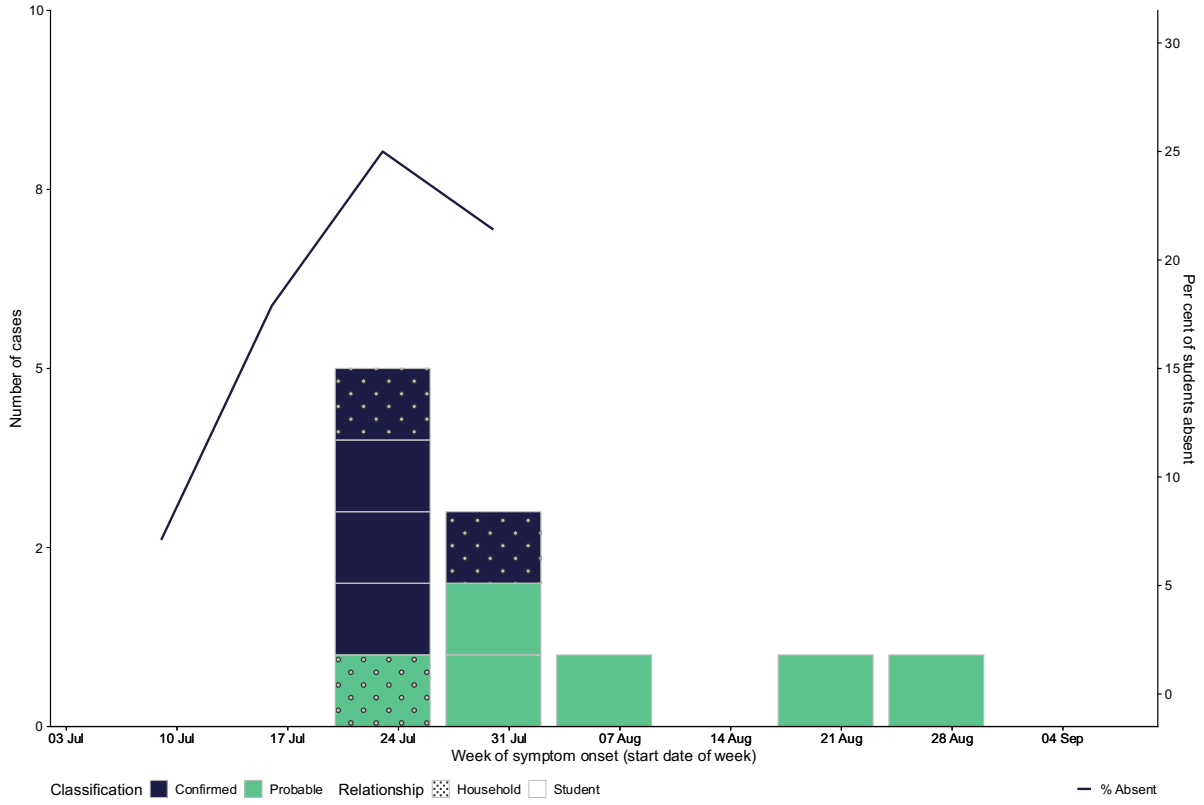


*Figure 3. Weekly percentage of students absent and cases by week of symptom onset for a school outbreak of group A Streptococcus, Melbourne, July-September 2023*

Four of the five isolates were available for typing and genomic analysis. Typing results from isolates were all found to be *emm*1, a common subtype in Victoria. The strain was genomically distinct from other *emm*1 circulating in Victoria at the time. Clustering based on single nucleotide polymorphism (SNP) thresholds found that all four cases appeared closely related (0 SNPs) and consistent with potential transmission between cases or from a common source. The isolates within the cluster were greater than 10 SNPs from all other Victorian sequenced isolates. One additional isolate from a Victorian case outside of this cluster was found to be closely related (0 SNPs) to isolates in this school outbreak. The case was a female aged in her 40s with a specimen collected on 21 June 2023. Follow-up identified no clear epidemiological link to the outbreak.

Public health measures

Probable cases were requested to not attend school from symptoms onset until 24 hours after the commencement of treatment. Following laboratory confirmation of the second GAS case within the cluster, prophylactic antibiotics were recommended for all contacts. A letter was sent to parents on 4 August 2023, advising contacts to seek medical attention to receive prophylactic antibiotics and continue monitoring for symptoms. The letter advised the treating clinician to refer to the relevant therapeutic guidelines for additional information on appropriate prophylactic regimens. 16 of 24 (67%) contacts were confirmed to have received prophylactic antibiotics .

Recommendations were provided to the school principal on reducing GAS transmission in the school. These included education resources on how GAS is spread and strategies to prevent GAS transmission.[23] It was advised that staff and students were educated in hand hygiene techniques and that hand hygiene products (soap and water in bathrooms, alcohol-based hand rubs in the classroom) were made readily available. It was recommended that a cleaning process be implemented daily for applicable classrooms, including detergent and disinfection steps for high-touch surfaces. In the situation where the classroom had access to air purifiers, it was advised that they were on during school hours. The outbreak was monitored for two incubation periods following the onset date of the last case to 5 September (six days), with no further cases identified.

## Discussion

This report describes an outbreak of group A Streptococcus (GAS) in a school with multiple clinical manifestations, including pharyngitis, scarlet fever and invasive group A Streptococcus. This occurred during a period of increased invasive group A Streptococcal notifications in Victoria and globally.[13–17] Eight of 28 students were identified as cases in this outbreak, with a 29% attack rate. This attack rate is comparable to the other published GAS attack rates in school settings which range from 23% to 72%.[24–28] However, because the survey response rate was low, the actual attack rate may differ, and these comparisons should be interpreted with caution. The investigation was supported by genomic phylogenetic analysis, which highlighted the transmission of the outbreak. The outbreak strain was identified as the

*emm*1 strain, consistent with the most prevalent strain associated with invasive GAS in Victoria.[29]

At the time of the investigation, no national or state jurisdiction guidelines existed to control invasive GAS clusters. This outbreak included both invasive and non-invasive forms of GAS, and it's possible more could be done to prevent transmission of both invasive and non-invasive GAS infections. As non-invasive forms of GAS, such as scarlet fever, are not notifiable in Victoria, the extent of transmission is not known. During the rise in GAS cases in December 2022 in the UK, more than 700 outbreaks were recorded by local health protection teams in England.[30] Reducing transmission from less severe infections, such as scarlet fever, can reduce the risk of severe invasive infection in close contacts, given the crossover of strains causing both mild and severe presentations.[31,32]

There were no additional cases of invasive GAS in this outbreak. Prophylactic antibiotics were recommended to all contacts in this outbreak to prevent secondary invasive GAS infections. The risk of secondary invasive GAS infections among close contacts is higher than the sporadic invasive GAS infection rate, ranging from 19 to 200 fold higher.[8,33] However, a recent systematic review found that the evidence for antibiotic prophylaxis was based on studies with small sample sizes and with weak study designs, so definitive conclusions cannot be drawn.[34] These findings must also be taken in the context of new and evolving practices in response to antimicrobial stewardship.

High absenteeism in the class before the onset of the index case indicated there were possibly circulating pathogens before the onset of the index case. This outbreak occurred during winter when there were higher levels of other circulating respiratory viruses, however no respiratory symptoms were reported amongst survey respondents over this time, so it is unclear what the cause was for this absenteeism. A preceding or concurrent viral respiratory tract infection can increase the risk of invasive GAS.[35–39]

The investigation survey identified two probable cases with symptom onset dates after the administration of antibiotic prophylaxis and 19 days after the most recent cases in the class cohort. While their sore throats could have been caused by an unrelated infection, both individuals had already received prophylactic antibiotics, so it remains possible they were infected with *S. pyogenes* despite prophylaxis. As probable cases were not followed up and

swabbed for confirmation at this point in the investigation, they were not laboratory tested for GAS infection, and an alternative diagnosis with symptoms consistent with GAS could not be determined.

This investigation had several limitations. Not all cases were swabbed, and given the non-specific nature of pharyngitis, we could not definitively determine GAS as the causative agent in these cases. Asymptomatic contacts were not swabbed; the role of asymptomatic carriage on transmission dynamics in this outbreak is unknown. Recent findings suggest asymptomatic shedding by children of *S. pyogenes* might perpetuate outbreaks in schools settings.[40] In addition, this investigation did not evaluate the contribution of co-infections with other circulating viruses; this may have provided additional insights, especially based on the high absenteeism prior to the index case.

There were limitations to the investigation survey in identifying additional cases. The survey had low response rates across both the class cohort (46%) and the broader school cohort (31%). We asked about GAS-related symptoms and other respiratory infections over a 2-month period and given the similarities between these in terms of clinical presentation, respondents were unable to definitively identify the cause of any illnesses. Delays in implementing the survey likely impacted response rates and respondents' recall.

**Conclusion**

This outbreak demonstrated the likely transmission of GAS in a school setting during a period of high levels of circulating GAS in the community. Multiple clinical manifestations including both invasive and non-invasive infections were identified through this investigation, and transmission was supported by genomic phylogenetic analysis. These findings highlight the need for further research into the transmission of GAS in school settings and to evaluate the effectiveness of control measures in preventing additional invasive GAS cases during outbreaks.

**Acknowledgments**

We want to acknowledge the school principal for his proactive cooperation and thank all staff, students, and families for their support during the investigation and management of the outbreak. We wish to acknowledge the medical practitioners and pathology services who diagnosed and notified the cases. We also acknowledge the public health officers, medical

officers, epidemiologists and systems specialists who have also contributed to the collection and curation of this dataset. Thank you to the Microbiological Diagnostic Unit Public Health Laboratory for performing genotyping and genomic analysis.

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## Contributors

| Author | Research Design and conceptualisation | Data collection and curation | Data Analysis | Interpretation of results | Writing – original draft | Review and editing |
|---|---|---|---|---|---|---|
| AO | X | X | X | X | X | x |
| AVD | X | | | X | X | x |
| JS | X | | | | | X |
| JM | X | | | X | | X |
| AP | X | | | X | X | x |
| HC | X | | | X | X | x |

## Appendix

Appendix A – Investigation Survey

1. First Name:
2. Surname:
3. Relationship to child:
4. Has the child received antibiotic prophylaxis for exposure to group A streptococcus (GAS)

*Section 1: GAS related Questions*

5. Select any of the following symptoms of group A streptococcal infection the child has experienced since the 24th June 2023 (24/06/2023):
    - Sore throat (may include pus or redness on throat/tonsils)
    - Pink/red skin rash on the face and body
    - Flushed face with paleness around the mouth
    - A bright red and bumpy tongue
    - Sores on the skin that tend to form blisters
    - Fever and chills
    - No symptoms

*If yes, then complete:*

2. When did the first symptom begin? Select estimated date if exact date is unknown.
3. Did you seek medical treatment/advice for any of the above symptoms?
4. Did the health professional provide a diagnosis? If yes, please best describe:
5. Describe any treatment or advice that was recommended:

*Section 2: respiratory illness related Questions*

6. Since the 24th of June, has the child had a respiratory illness such as flu or cold? E.g Cough, sore throat, runny nose, muscles aches and pain or fevers

*If yes, then complete:*

7. When did the symptoms for the respiratory illness first start? Select estimated date if exact date is unknown.
8. When did the symptoms resolve? If can not recall the exact date, please leave blank
9. Did you seek medical treatment/advice for the respiratory illness?
10. Did the health professional provide a diagnosis? If yes, please best describe:

11. Describe any treatment or advice that was recommended:

# Appendix

## Appendix A – Communication to a lay audience

### Summary: Group A Streptococcus outbreak in a Melbourne primary school

**Background**

In 2022, Group A Streptococcus (GAS) infections rose worldwide. An outbreak of GAS occurred at a primary school in Melbourne. We investigated to understand how the infection spread and to stop it.

**Investigation and Methods**

On July 31, 2023, we were told of a 10-year-old student who had a severe GAS infection. The principal noticed similar symptoms in other students. Some were also absent. We formed a team to manage the outbreak. We collected data on student absences and sent a survey to find more cases. We took samples from sick students for genetic analysis to understand how it spread.

**Findings**

We found 11 cases of GAS among 38 people, resulting in a 1 in 4 infected. The cases were aged 11 to 18. There were:

- 8 students
- 0 staff
- 3 household members

Most cases were mild, with sore throats being the most common symptom. One student needed hospitalisation. Genetic analysis showed the bacteria were all the same. The bacteria spread within the school. The outbreak lasted from July 24 to August 27, 2023.

**Control Measures**

To control the outbreak, we monitored symptoms. Sick children stayed home. We gave antibiotics to close contacts of infected students. Sixteen of twenty-four (67%) received clearance antibiotics. We advised the school on good hygiene practices.

**Conclusion**

This outbreak showed how GAS spreads in schools. We found cases with different symptoms and confirmed transmission through genetic analysis. It shows a need to study clearance antibiotics. They might prevent severe cases of GAS during outbreaks.

# Appendix B – Conference presentation slides

## Schools out?! Absenteeism during a Group A Streptococcus outbreak in a school community

Aaron Osborne[1,2], Julia Marshall[1], Janet Strachan[3], Amy Parry[2], Annaliese van Diemen[1], Hazel J Clothier[2,4,5]

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[2]National Centre for Epidemiology and Population Health, Australian National University, Acton, ACT, Australia
[3] Department of Health, Victoria, Australia
[4]SAEFVIC, Infection and Immunity, Murdoch Children's Research Institute, Parkville, Victoria, Australia
[5]Centre for Health Analytics, Melbourne Children's Centre, Parkville, Victoria, Australia

I have nothing to disclose.

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## Outbreak Identification

- On July 31st, 2023, the North Eastern Public Health Unit (NEPHU) in Melbourne, Australia, received a laboratory notification of iGAS in a 10-year-old male.
- Routine follow-up with the principal of the school the case attended identified:
  - High levels of absenteeism in the class
  - Two students with symptoms consistent with non-invasive GAS infections

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## Investigation

The Incident Management team was established on August 1st by the North Eastern Public Health Unit.

**Outbreak setting**

- Grade 5/6 class at a primary school in Melbourne(28 students and 1 Teacher).
- A social event attended by 8 students and four additional household contacts.

**Case definitions**

- Confirmed outbreak case: laboratory definitive evidence for diagnosis AND epidemiological evidence.
- Probable outbreak case: An individual who meets the clinical evidence AND epidemiological evidence.

**Case finding**

- The school reported any additional students with symptoms
- Survey sent to the school community on August 22.

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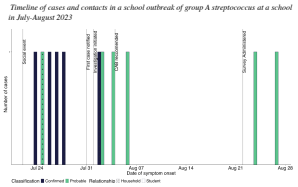
## Epidemiological summary

*Timeline of cases and contacts in a school outbreak of group A streptococcus at a school in July-August 2023*




11 cases (5 confirmed, 6 probable), 28% attack rate.
- 8 (29%) students
- 0 staff
- 3 (33%) household members

Clinical presentation: 8 (73%) pharyngitis, 1 facial rash, 1 invasive GAS

Genomic analysis suggested transmission

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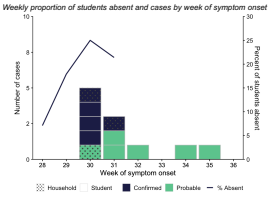
## Absenteeism preceding outbreak

15 (54%) of 28 students were absent during the investigation period

- 15% of students were absent in the week preceding the index cases.
- Cause unknown

*Weekly proportion of students absent and cases by week of symptom onset*

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## Control measures

- Following laboratory confirmation of the second GAS case post-exposure prophylaxis was recommended for all contacts.
  - 16 of 27 (67%) contacts have been confirmed as receiving CAB
- Advice was provided on infection control on hand hygiene, cleaning and exclusion criteria.

The outbreak persisted over a period of 4 weeks. The outbreak was monitored for 2 incubation periods following the last case to 5 September (six days), with no further cases identified

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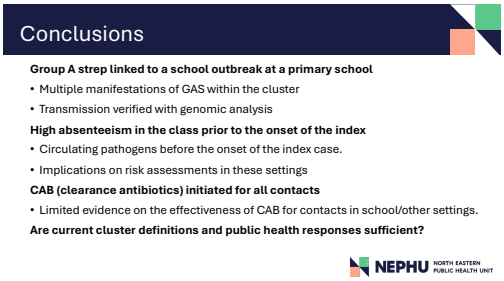
Conclusions
Group A strep linked to a school outbreak at a primary school
• Multiple manifestations of GAS within the cluster
• Transmission verified with genomic analysis
High absenteeism in the class prior to the onset of the index
• Circulating pathogens before the onset of the index case.
• Implications on risk assessments in these settings
CAB (clearance antibiotics) initiated for all contacts
• Limited evidence on the effectiveness of CAB for contacts in school/other settings.
Are current cluster definitions and public health responses sufficient?
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Thank you
Acknowledgements
NEPHU, Victorian Department of Health, Microbiological Diagnostic Unit Public Health Laboratory, School community
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# **Chapter 3:** Identifying and characterising geographic areas of hepatitis B incidence in North Eastern metropolitan Melbourne

# Table of contents

# Prologue

## Rationale

The Fourth National Hepatitis B Strategy 2023–2030 sets a national goal to eliminate hepatitis B as a public health threat in Australia by the decade's end.[1] Underpinning this is a target of diagnosing 90% of people living with hepatitis B.[1] In Victoria, where an estimated 66% of people living with hepatitis B were diagnosed in 2022,[2] increased effort will be required if Victoria is going to meet this target by 2030. For progress to happen, it is increasingly necessary to identify and understand local communities impacted by hepatitis B who may not currently be met by current strategies.

The North Eastern Public Health Unit has prioritised addressing hepatitis B in its local catchment. The aim of this analysis was to identify communities that may not currently be engaged in hepatitis B public health strategies and may not currently have their health needs addressed. This is important to ensure that public health effort is directed to where the need is greatest and to ensure an equitable public health response. This data analysis aims to increase understanding of hepatitis B in the catchment by identifying community-level factors associated with areas with relative underdiagnosis. This profile can inform targeted strategies to address the unmet needs of people living with hepatitis B in the NEPHU catchment.

## My Role

As lead investigator, I developed and designed the analysis to answer a set of analytical questions developed by my supervisor. I reviewed literature, consulted, and received supervisor feedback to develop an analytical strategy. I collated the data from the relevant datasets, cleaned all data, and assessed data quality. I conducted the data analysis using R and developed outputs.

I communicated the key findings from the work and supported the development of interventions to respond to the findings. I presented the findings at the grand rounds at the

Northern Hospital and the Austin Hospital as examples of the public health unit's use of data to inform public health action. I also presented this work at the 2024 Communicable Disease and Immunisation Conference in Brisbane (Appendix A). I supported the design of an intervention based on the findings of the analysis and was an investigator on a National Health and Medical Research Council (NHMRC) research grant application.

## Lessons learnt

This project was a good opportunity to develop my analytical skills in R, particularly geospatial analyses and visualisation. It was also a great opportunity to learn and understand a focus on a blood-borne virus, hepatitis B. My main reflection was about the importance of having a clear, answerable public health question that addresses a public health need or priority, particularly one that aligns with the organisation's strategic priorities.

This project was about identifying and profiling communities that our current public health responses may underserve. As such, the findings should be communicated to inform our response to this through clear recommendations and communication strategies appropriate to the stakeholders. It can be challenging to balance the uncertainty with the findings with the need to act on the evidence generated. Decisions often have to be made with imperfect information, and it can be a challenge when you may have a different threshold to act compared to those around you. Being involved in developing interventions to act on the findings was valuable and highlighted the important step in bridging the gaps between evidence generation and action.

## Public Health Impact

Early detection and management can prevent some of the severe outcomes of chronic hepatitis B, such as liver cancer.[3] This analysis provides insight into communities that current public health screening strategies may not address. Estimates of hepatitis B prevalence across the catchment will provide important evidence to the public health unit to inform service planning and address unmet needs.

An outcome of this work was the design of a community-based screening and linkage to care intervention to target one of the community groups identified in the results. In collaboration with Deakin, the Centre for Culture, Ethnicity, and Health, The Peter Doherty Institute for Infection and Immunity, DPV Health, Hep B Voices Australia and Cancer Council Victoria, an NHMRC grant proposal was developed and submitted. This analysis informed decision-making about which community groups to target for this work. If the project proceeds, it is anticipated that the project will evaluate the accuracy of the epidemiological estimates that have been developed.

I presented this project at the 2024 Communicable Disease and Immunisation Conference in Brisbane. There was interest in the methodological approach and analysis, so I shared the details with epidemiologists from public health units in other jurisdictions in Australia so that they could develop something similar.

# Report

## Abstract

**Background**

Chronic hepatitis B (CHB) is a major cause of morbidity and mortality worldwide, contributing to approximately 800,000 deaths annually. While Australia is considered a low-prevalence country (HBV prevalence <2%), only 66% of individuals living with HBV in Victoria have been diagnosed. HBV disproportionately affects migrant populations, particularly those from high-prevalence (>=8%) and intermediate prevalence (>=2% and <8%) countries. The North Eastern Public Health Unit (NEPHU) sought to identify areas within its catchment where HBV is likely underdiagnosed to support targeted public health responses.

**Methods**

Laboratory confirmed hepatitis B notifications in the NEPHU catchment from 2013 to 2022 from the Victorian Public Health Events Surveillance System (PHESS) were used to calculate notification rates for each statistical area level 2 (SA2). The estimated local prevalence was calculated using the 2021 Census and country-specific CHB prevalence rates. Underdiagnosis was defined as areas with a high proportion of residents from countries with high or intermediate CHB prevalence but with a lower median HBV notification rate. The geographical distribution of the underdiagnosed regions and community-level factors such as migration patterns and demographic characteristics were described.

**Results**

Over the ten-year study period, 4,783 hepatitis B cases were reported in the NEPHU catchment, with a mean annual notification rate of 138 per 100,000 population. The highest incidence SA2s of hepatitis B was in the east of Melbourne, Whitehorse, Manningham, and Boroondara Local Government Areas (LGA). In contrast, the north, Hume and Whittlesea LGAs were identified as having several SA2s with relative underdiagnosis. Areas of relative underdiagnosis had significantly larger populations of recent migrants from Central and South Asia, Sub-Saharan Africa, and the Middle East.

**Discussion**

This analysis revealed spatial disparities in CHB diagnosis across the NEPHU catchment, highlighting specific communities at risk for underdiagnosis. Factors contributing to underdiagnosis include recent migration, socio-economic disadvantage, and limited healthcare access. Public health strategies should focus on improving community engagement, enhancing culturally appropriate screening programs, and strengthening linkage to care. Identifying and addressing these areas of underdiagnosis is essential for achieving the goal of eliminating HBV as a public health threat by 2030.

# Introduction

Hepatitis B virus (HBV) is a significant global health concern, transmitted through contact with an infected person's blood or other body fluids.[4] The primary modes of transmission include perinatal transmission at birth, sexual contact, and injecting drug use.[3] HBV targets the liver, leading to both acute and chronic diseases.[3] In children, acute HBV infection is asymptomatic in over 90% of cases.[5] In people over the age of 5 years, acute hepatitis B is symptomatic in around half of infected individuals and most commonly presents with an initial phase of malaise, loss of appetite and fever after an incubation period of 90 days, followed by jaundice and abdominal pain.[5,6] Symptoms usually resolve within one to three months.[5,6]

Following acute infection, chronic hepatitis B (CHB) is defined as the persistence of hepatitis B surface antigen (HBsAg) in the blood for more than six months.[3] CHB is the most common cause of liver cancer, which is the sixth leading cause of cancer mortality in Australia.[7] More than 90% of all deaths attributable to hepatitis B globally are caused by complications of chronic infection.[8] The risk of developing chronic hepatitis B is inversely associated with age: acute infection progresses to chronic hepatitis B in 90% of infected infants, in 30% of infected children 1–4 years of age, and in approximately 5% of infected adults.[5,9]

The likelihood of progression to chronic hepatitis B infection among infants means that vaccination strategies, including universal infant immunisation, are highly effective in reducing the burden of chronic hepatitis B.[4] Although therapy for CHB is generally not curative, evolving treatments have the potential for a significant impact on progressive liver disease and survival. For these drugs to have an effect at the population level, there is a need for increased HBV screening, linkage to care, access to treatment and enhanced monitoring and evaluation of the impact of HBV programmes.[10,11]

In 2019, an estimated 296 million people were chronically infected with HBV, resulting in 820,000 deaths worldwide.[8] However, the burden of HBV infection varies geographically due to differing modes of transmission and the age at infection, which influences the

likelihood of progression to chronic disease.[8] The prevalence of hepatitis B surface antigen (HBsAg) in a population can be broadly classified into high- (>8% HBsAg prevalence), intermediate- (2%–7%), and low-prevalence (<2%) areas.[12] These categories support the understanding the patterns of transmission and population burden of the consequences of chronic hepatitis B.[13]

In Australia, a low-prevalence country for HBV, over 200,000 people are estimated to be living with the disease, representing 0.78% of the population.[2] Vaccination coverage in Australia is high; in 2020, hepatitis B vaccination coverage at 12 months was 93.2% among Aboriginal and Torres Strait Islander Australian children and 95.3% among non-Indigenous children.[1] Global migration from higher prevalence to Australia significantly influences the burden of chronic hepatitis B, with a majority of people living with chronic hepatitis B being born in high prevalence countries.[14–17] Indigenous peoples in many areas experience a higher prevalence of chronic hepatitis B and an increased burden of associated liver disease.[18]

The World Health Organization (WHO) aims to eliminate viral hepatitis as a public health threat by 2030, targeting a 90% reduction in new cases and a 65% reduction in mortality compared to the 2015 baseline.[19] The Draft Fourth National Hepatitis B Strategy 2023-2030 is a guide to eliminating hepatitis B as a public health threat in Australia by 2030.[1] The strategy aims to improve the cascade of care, which includes increasing the proportion of people diagnosed with CHB to 80%, increasing the proportion engaged in care to 50%, and increasing treatment uptake to 20%. The goal is to reduce CHB-attributable mortality by 30%.[1]

In 2022, approximately 66% of people living with HBV in Victoria were diagnosed.[2] Despite the availability of adequate vaccination, testing, and improved treatment, significant improvements are needed in access to diagnosis and care to prevent adverse outcomes in those affected by HBV. Barriers to diagnosis and treatment include lack of awareness, stigma, and access to healthcare services, particularly among high-risk groups.[20,21]

This study aims to increase understanding of Hepatitis B in the catchment by identifying community-level factors associated with areas with high Hepatitis B notifications. The project will then use this profile to identify and characterise geographical regions that may have relative underdiagnosis. Identifying local populations where hepatitis B is underdiagnosed will enable the local public health unit to develop targeted interventions to improve diagnosis and engagement in care for communities in the catchment. In turn, it is anticipated that this will improve the health outcomes of communities most impacted by hepatitis B and support progress towards the national goal of eliminating hepatitis B as a public health threat by 2030.[1]

# Methods

## Data sources

Notifications of laboratory-confirmed hepatitis B infection in the North Eastern Public Health Unit catchment by address at the time of notification from 2013 to 2022 were extracted from the Victorian Public Health Events Surveillance System (PHESS). Hepatitis B is notifiable in Victoria under the Victorian Public Health and Wellbeing Act 2008[22]. Standard national case definitions will be utilised as the National Department of Health series of national guidelines (SoNG) outlines.[23] The case definition for confirmed hepatitis B required the detection of hepatitis B surface antigen (HBsAg), or hepatitis B virus, by nucleic acid testing in a patient with no prior evidence of hepatitis B virus infection. Latitude and longitude of the address at the time of notification were used to assign hepatitis B cases to their corresponding geographical area. Cases with missing or incorrect latitudes and longitudes were excluded from the analyses.

We obtained population denominators and sociodemographic data for statistical area level 2 (SA2) from the Australian Bureau of Statistics (ABS) 2021.[24] SA2s have a population between 3,000 and 25,000, with an average of about 10,000 people. Their purpose is to represent a community that interacts socially and economically. Demographic data on age, sex, country of birth, year of arrival and Aboriginal and Torres Strait Islander populations was collated at the SA2 level. Country of birth data was

categorised into World Health Organization levels of hepatitis B prevalence levels, using estimates from the Polaris observatory[25] to calculate the proportion of geographically born overseas and from low, intermediate and high prevalence countries.

## Analysis

Demographic information, including sex, age, local government area, country of birth, and date of notification, was analysed for all cases. Age-standardised 10-year notification rates were calculated per SA2 in the northeastern public health unit catchment. SA2 were aggregated into quartiles of hepatitis B notification rates of low, low-medium, medium-high, and high. Population-level demographics were described. Population-level demographics included proportion born overseas, 20-year age groups, sex, proportion of the population identifying as Aboriginal or Torres Strait Islander and year of arrival. The proportion of a statistical area born in low, intermediate, and high prevalence of hepatitis B countries was also calculated. Descriptive statistics (Chi-squared tests and two sample t-tests) were calculated to assess demographic differences between the four quartiles of hepatitis B 10-year case incidence.

Based on the 2021 Australian census, the prevalence of hepatitis B in the NEPHU catchment area was estimated using country-specific prevalence rates for chronic hepatitis B among migrants. Estimates for hepatitis B prevalence were obtained from the Polaris Observatory.[25] We used the Australian national prevalence rate of 0.7% for all other residents.[26] The overall prevalence of chronic hepatitis B was calculated for each SA2 in the NEPHU catchment area.

Areas with relative underdiagnosis were classified and described. Using 2018 – 2022 surveillance data linked to 2021 Census denominators, each Statistical Area 2 (SA2) was placed in one of two categories:

**Relative under-diagnosis.** SA2s in which:

1. the proportion of residents born in countries with high chronic-HBV prevalence was above the state-wide median, and

2. the age-standardised HBV notification rate fell below the state-wide median.

These are areas of high-risk population but yield comparatively few notifications, suggesting missed diagnoses or access barriers.

**High diagnosis.** SA2s whose age-standardised HBV notification rate is in the upper quartile (≥ 75th percentile) of the state distribution, representing a benchmark for case detection.

Demographic and geographical characteristics of under-diagnosis SA2s were compared with those of high-diagnosis SA2s. Categorical variables were tested with the $\chi^2$ test, and continuous variables with two-sample t-tests (two-sided, $\alpha = 0.05$).

All analyses were performed using R statistical software.[27]

### Ethical considerations

Ethics approval for this project was granted through the Australian National University Human Ethics Research Committee (Protocol 2019/249).

## Results

### Summary of notified hepatitis B cases

Between 1 January 2013 and 30 December 2023, 4,783 cases of hHepatitis B were notified in the North Eastern Public Health Unit Catchment. Across the study period, the annual notification rate was 26.4 notifications per 100,000 population; there was a reduction in incidence during the COVID-19 pandemic, with a yearly notification rate of 19.7 per 100,000 population from 2020 to 2023, compared to an annual notification rate of 29.3 per 100,000 population in the period prior, 2013-2019 (Figure 1).

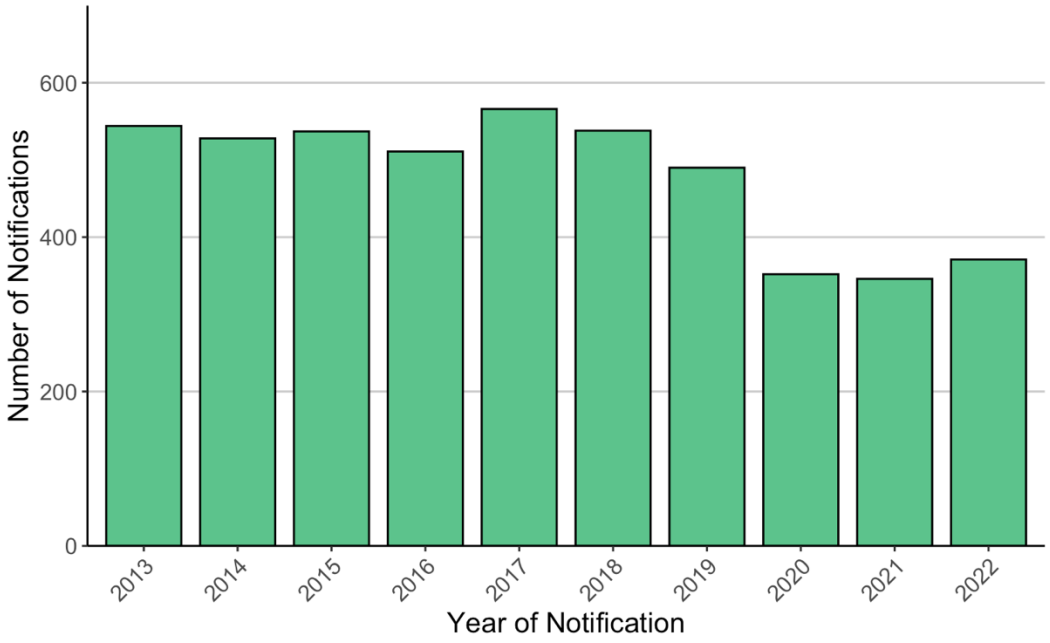



*Figure 1111. HBV diagnosis by year of notification in the NEPHU catchment, 2013-2022*

During the study period, 79 of 4,783 (1.7%) notified cases were newly acquired (infection determined to be acquired within the prior 24 months). The population included 2,179 female participants (46.0%). The median age was 40 years (IQR 31–53). By age group, 99 participants (2.1 %) were 0–19 years, 2,214 (46 %) were 20–39 years, 1,685 (35 %) were 40–59 years, 720 (15 %) were 60–79 years, and 62 (1 %) were 80–99 years; age was unknown for three individuals (Table 1).

Ten notifications were among people who identified as Aboriginal or Torres Strait Islander (0.2%). Indigenous status was missing or not stated for 2,389 participants (50%). Under half of notifications (44%) were recorded as being born overseas. The most common country of birth outside of Australia was China, with 19% of notifications (n=898), followed by Vietnam (4.6%, n=219) and Malaysia (1.6%, n=11). Country of birth data was missing or not stated for 2,541 participants (53%). Missing data was high for both Indigenous status and country of birth. High levels of missing data limit the utility of these fields and notification data to assess populations most impacted by hepatitis B.

*Table 1111. Demographic summary of hepatitis B cases in the NEPHU catchment, 2013-2022*

| Characteristic | N = 4,783[1] |
|---|---|

| | |
|---|---|
| Condition | |
| Hepatitis B - Newly acquired | 79 (2%) |
| Hepatitis B - Unspecified | 4,704 (98%) |
| Sex | |
| Female | 2,179 (46%) |
| Male | 2,558 (53%) |
| Not stated | 46 (1%) |
| Median age (years) | 40 (31, 53) |
| Age group | |
| 0-19 | 99 (2.1%) |
| 20-39 | 2,214 (46%) |
| 40-59 | 1,685 (35%) |
| 60-79 | 720 (15%) |
| 80-99 | 62 (1%) |
| Unknown | 3 |
| Indigenous Status | |
| Aboriginal and Torres Strait Islander origin | 10 (0.2%) |
| Missing/Not Stated | 2,389 (50%) |
| Not Aboriginal or Torres Strait Islander | 2,384 (50%) |
| Born overseas | |
| Born overseas | 2102 (44%) |
| Australia | 140 (3%) |
| Missing/Not Stated | 2541 (53%) |

[1] n (%); Median (IQR)

## Geographical distribution of hepatitis B notifications

The NEPHU catchment has 12 local government areas (LGA). The highest age-standardised notification rate was in the LGA of Whitehorse, with 491 notifications per 100,000 population, followed by Manningham, 405 notifications per 100,000 population and Boroondara, 324 notifications per 100,00 population. All LGAs are found in the eastern region of the catchment and border each other (Figure 2 and Table 2).

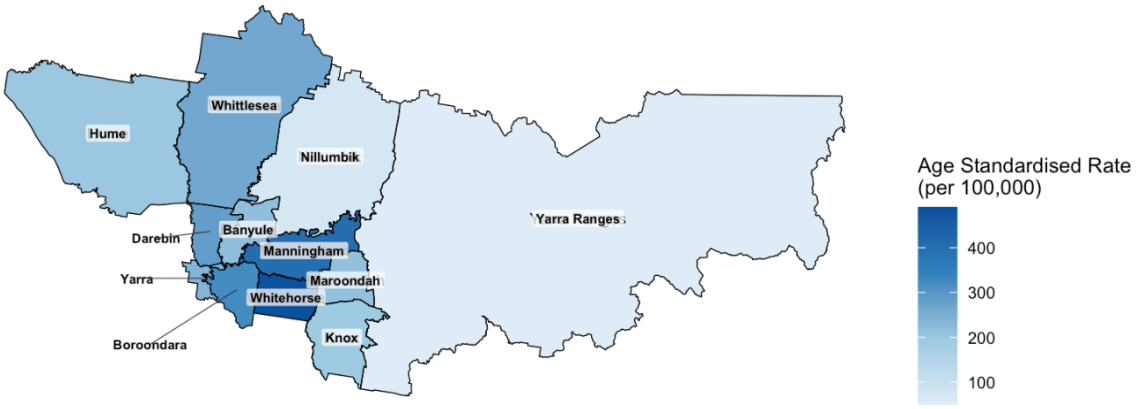
*Table 22222. Summary statistics of SA2 Age standardised hepatitis B notification by local government area*

| Local Government Area | Number of SA2 | Mean notification rate per 100,000 | Standard deviation | Minimum SA2 notification rate | Maximum SA2 notification rate |
|---|---|---|---|---|---|
| Banyule | 9 | 218 | 154 | 89 | 577 |
| Boroondara | 12 | 324 | 191 | 109 | 789 |
| Darebin | 11 | 286 | 137 | 98 | 453 |
| Hume | 18 | 201 | 165 | 0 | 552 |
| Knox | 12 | 193 | 105 | 23 | 354 |

| | | | | | |
|---|---|---|---|---|---|
| Manningham | 8 | 405 | 248 | 60 | 717 |
| Maroondah | 8 | 216 | 98 | 125 | 414 |
| Nillumbik | 6 | 68 | 46 | 0 | 137 |
| Whitehorse | 12 | 491 | 116 | 291 | 768 |
| Whittlesea | 18 | 264 | 175 | 0 | 702 |
| Yarra | 8 | 238 | 166 | 78 | 523 |
| Yarra Ranges | 14 | 49 | 48 | 0 | 163 |
| NEPHU total | 136 | 247 | 184 | 0 | 789 |

Across the NEPHU catchment, hepatitis B cases were reported in 133 out of 136 Statistical Area 2 regions from 2013 to 2022. The mean age-standardised notification rate was 246 per 100,000 population, ranging from 0 to 789 per 100,000 population between 2013 and 2022. Incidence was highest in the Balwyn SA2 (789 per 100,000 population) – located in the Boroondara local government area, followed by Box Hill (768 per 100,000 population) in the Whitehorse LGA and Doncaster (717 per 100,000 population) in the Manningham LGA (Figure 3).

*Figure 22222. Ten-year Age standardised HBV incidence rate by local government area in NEPHU catchment, 2013-2022*



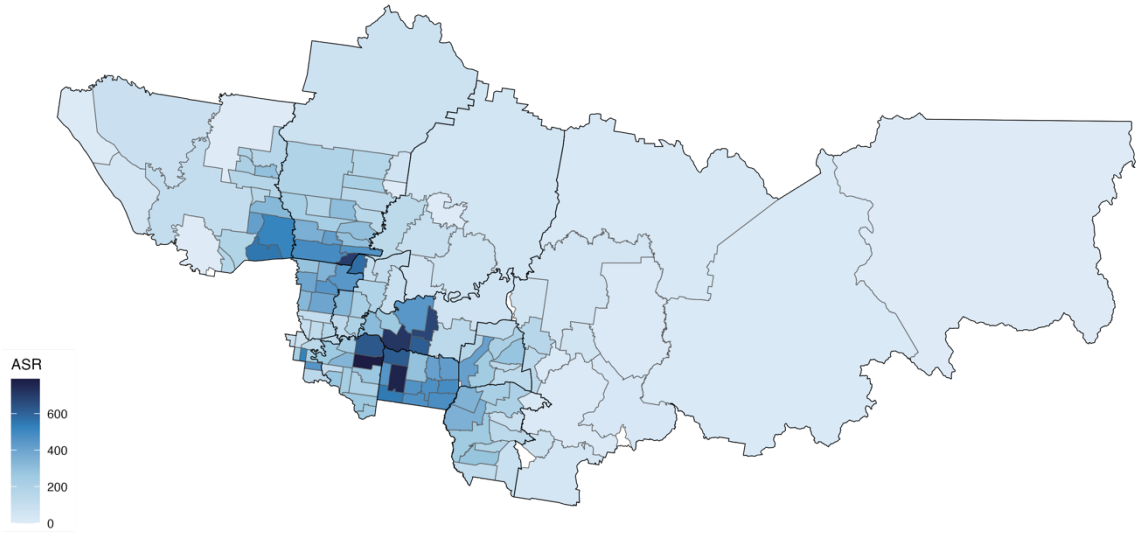



*Figure 33333. Ten-year age standardised HBV notification rate by SA2 in NEPHU catchment, 2013-2022*

## Community-level factors associated with hepatitis B notifications

The distribution of hepatitis B incidence and its association with demographic factors and country of birth was analysed across four quartiles of notification rates: low, low-medium, medium-high, and high. Descriptive statistics were calculated for the characteristics of statistical area 2 by quartile of age-standardised notification rates.

The proportion of the population born overseas varied significantly across incidence levels, from 23.1% in the SA2's with the lowest quartiles of incidence compared to 47.3% in the SA2's of the highest quartiles of incidence ($p < 0.001$). The proportion of individuals from high prevalence countries increased from 0.2% in the low quartile to 0.7% in the high quartile ($p < 0.001$), and from intermediate prevalence countries from 9.7% in the low quartile to 32.7% in the high quartile ($p < 0.001$). There was no significant difference in the proportion of individuals born in low prevalence countries across the quartiles of notification ($p = 0.6$).

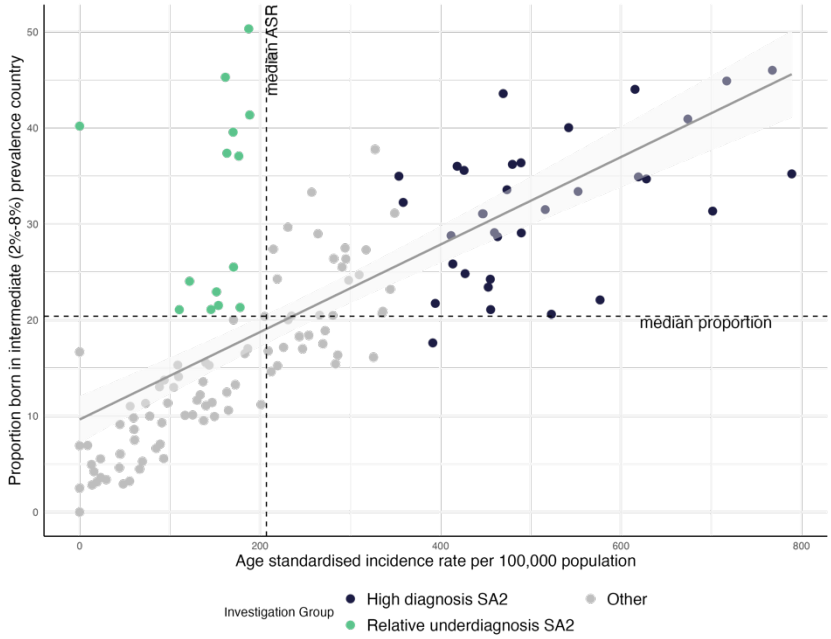
*Table 33333. Population level descriptive statistics of statistical area 2 by quartile of incidence*

| Characteristic | Low | Low Med | Med High | High | Significance |
|---|---|---|---|---|---|
| **1. Hepatitis B incidence** | | | | | |
| Total Cases | 242 | 737 | 1,265 | 2,536 | |
| Notification rate per 100000 | 65.7 | 154.9 | 274.6 | 520.9 | |
| **2. Demographics** | | | | | |
| Total population | 368,229 | 475,636 | 460,566 | 486,821 | |
| Proportion male | 49.2 | 49.1 | 48.8 | 49.1 | p= 0.39 |
| Proportion aboriginal or Torres strait islander | 1.0 | 0.6 | 0.6 | 0.6 | p=0 |
| Proportion born overseas | 23.1 | 33.9 | 37.2 | 47.3 | p < 0.001 |
| **3. Country of birth by Hep B prevalence (%) *** | | | | | |
| High prevalence country | 0.2 | 0.4 | 0.4 | 0.7 | p < 0.001 |
| Intermediate prevalence country | 9.7 | 20.8 | 22.9 | 32.7 | p < 0.001 |
| Low prevalence country | 9.3 | 9.1 | 9.5 | 9.0 | p = 0.6 |
| **4. Population by year of arrival** | | | | | |
| Arrived 2012 to 2021 | 4.5 | 8.8 | 9.7 | 14.0 | p < 0.001 |
| Arrived 2002 to 2011 | 4.6 | 8.0 | 7.9 | 9.5 | p < 0.001 |
| Arrived 1992 to 2001 | 1.9 | 3.5 | 3.8 | 4.9 | p < 0.001 |
| Arrived prior to 1992 | 8.1 | 10.0 | 11.5 | 13.9 | p < 0.001 |

* Proportion of people born overseas by hepatitis B prevalence WHO groupings. Groupings: <2% is low, >=2% and <8% intermediate and >=8% is high prevalence

## Characterising areas with lower-than-expected diagnosis rates

Areas of relative underdiagnosis, defined as an SA2 with a higher proportion of the population from a country with high HBV prevalence (>=8%) or intermediate HBV prevalence (2%-<8%) compared to the median proportion and lower than the median HBV notification rate were identified (Figure 4). A total of 18 SA2 were identified as having relative underdiagnosis compared to the highest quartile of SA2s diagnosis rate (n=34).



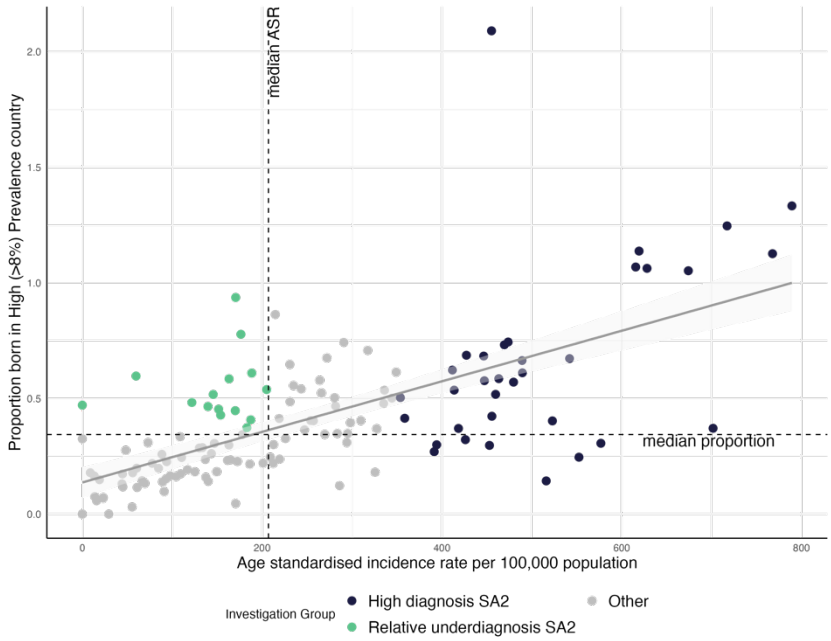



*Figure 44444. Proportion of an SA2 from intermediate and high prevalence country vs age standardised diagnosis rate of hepatitis B*

## Demographic factors

There were no significant differences between the areas of relative underdiagnosis and areas of high diagnosis proportion of the population who are male (49.4% vs. 49.1% male; p = 0.44) or proportion of population who identify as Aboriginal or Torres Strait Islander (0.6% vs. 0.5%; p = 0.14). The proportion of individuals born overseas was significantly lower in areas of relative underdiagnosis (40.9% vs. 47.3%; p < 0.001). Areas of high diagnosis had a greater proportion of individuals born in high prevalence countries (0.7% vs. 0.5%; p < 0.001), and low prevalence countries (9% vs. 7.7%; p = 0.0014), no significant difference was observed in the proportion from intermediate prevalence countries.

Areas of relative underdiagnosis had a significantly lower proportion of population who arrived between 2012 and 2021 compared to high diagnosis areas (12.5% vs. 14%; p < 0.001). Areas of relative underdiagnosis had a higher proportion of population who arrived between 2002 and 2011 (11.4% vs. 9.4%; p < 0.001). The proportion of population who arrived prior to 1992 were significantly lower in areas of relative underdiagnosis when compared to areas of high diagnosis (8.8% vs. 13.9%; p < 0.001).

*Table 44444. Population level descriptive statistics of statistical area 2 by areas of relative underdiagnosis compared to areas of high diagnosis*

| Characteristic | Relative underdiagnosis* SA2 | High diagnosis‡ SA2 | Significance |
|---|---|---|---|
| **1. Hepatitis B incidence** | | | |
| Number of SA2s | 18 | 34 | |
| Total Cases | 433 | 2,536 | |
| Case rate per 100000 | 154.8 | 520.9 | |
| **2. Demographics** | | | |
| Total population | 279,804 | 486,821 | |
| Proportion Male | 49.4 | 49.1 | p = 0.44 |
| Proportion Aboriginal or Torres strait islander | 0.6 | 0.5 | p = 0.14 |
| Proportion born overseas | 40.9 | 47.3 | p < 0.001 |
| **4. Country of birth by Hep B prevalence⁺** | | | |
| Proportion born in high prevalence country | 0.5 | 0.7 | p < 0.001 |
| Proportion born in intermediate prevalence country | 28.7 | 32.7 | p < 0.001 |
| Proportion born in low prevalence country | 7.7 | 9 | p = 0.0014 |
| **5. Population by Year of arrival** | | | |
| Proportion of population who arrived 2012 to 2021 | 12.5 | 14 | p < 0.001 |
| Proportion of population who arrived 2002 to 2011 | 11.4 | 9.4 | p < 0.001 |
| Proportion of population who arrived 1992 to 2001 | 4.4 | 4.9 | p < 0.001 |
| Proportion of population who prior to 1992 | 8.8 | 13.9 | p < 0.001 |

* Relative under-diagnosis are SA2s in which:

1. the proportion of residents born in countries with high chronic-HBV prevalence was above the state-wide median, and
2. the age-standardised HBV notification rate fell below the state-wide median.

‡ High diagnosis. SA2s whose age-standardised HBV notification rate is in the upper quartile (≥ 75th percentile) of the state distribution

⁺ Proportion of people born overseas by hepatitis B prevalence WHO groupings. Groupings: <2% is low, >=2% and <8% intermediate and >=8% is high prevalence

## Geographic Distribution

The geographical distribution of Hepatitis B burden and potential underdiagnosis was assessed across 12 Local Government Areas (LGAs) in the North Eastern Public Health Unit (NEPHU) catchment. (Figure 5). SA2s identified as areas of relative underdiagnosis were concentrated in the outer metropolitan LGAs of Hume and Whittlesea, where 33% (n=6) of SA2s in each LGA were classified as relative underdiagnosis. Whitehorse had 92% (n=11) of its SA2s classified within the high diagnosis group and no SA2s with relative underdiagnosis.

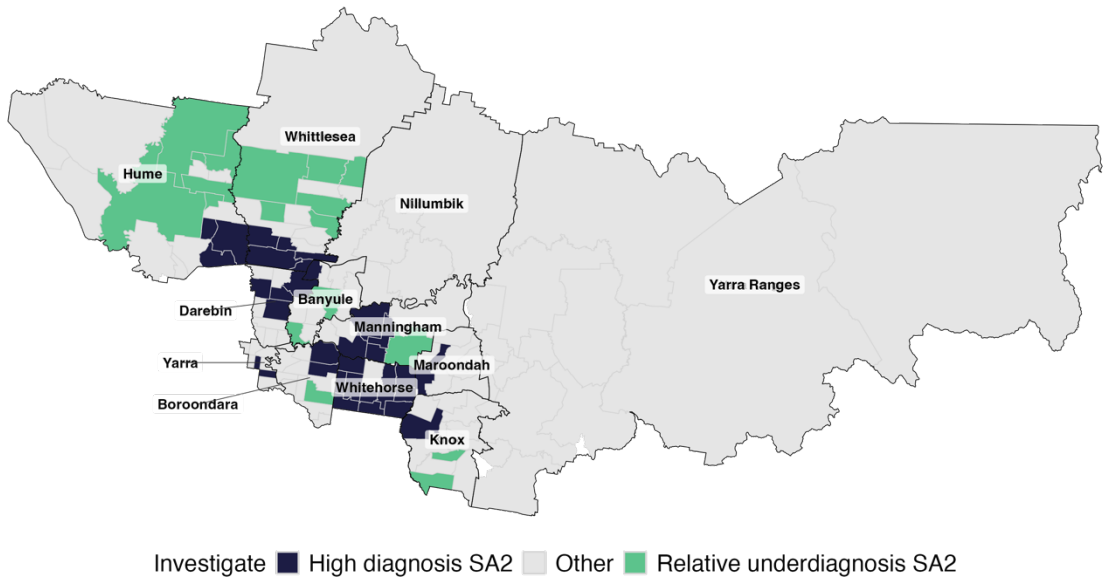



*Figure 55555. Geographical distribution of SA2's with potential underdiagnosis (green) compared to the top quartile age standardised HBV notification rate (blue)*

## Area estimates of hHepatitis B prevalence

SA2-level prevalence estimates were calculated using country of birth census data, as depicted in Figure 7.

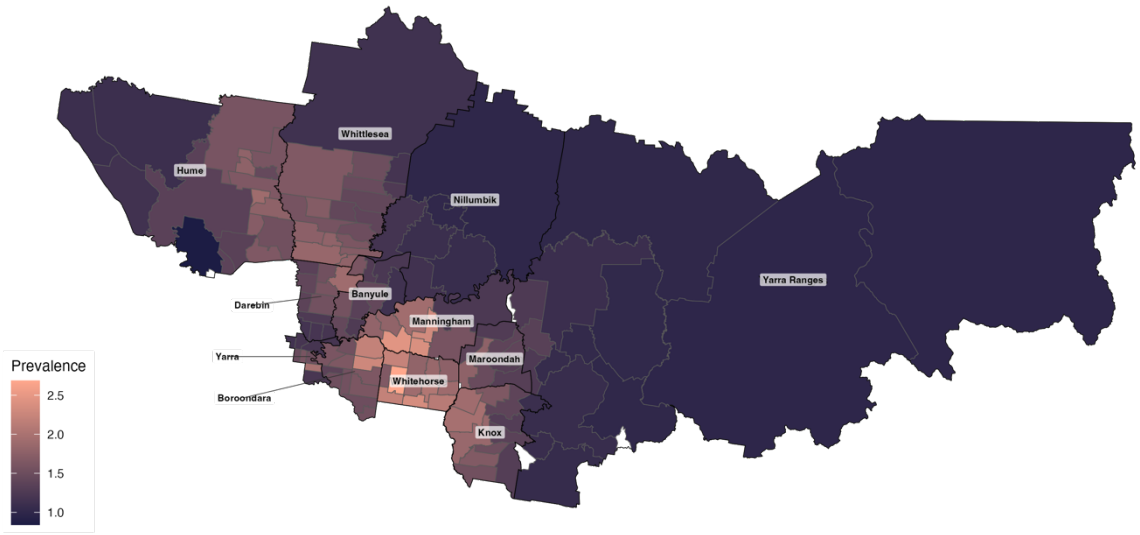



*Figure 66666. Geographical Distribution of Estimated hHepatitis B Prevalence (%)*

### Population by region of birth distribution

The distribution of estimated individuals living with hepatitis B differed significantly between areas of relative underdiagnosis and high diagnosis across major world regions in the North Eastern Public Health Unit (NEPHU) catchment (Table 5 and Figure 7). An estimated 657 individuals, or 15.2% of all estimated people living with hepatitis B in areas of relative underdiagnosis, were from Southern and Central Asia, compared to 585 individuals (6.1%) in high diagnosis areas (p <0.001). The population proportion, the proportion of the total population, was higher in relative underdiagnosis areas 0.23% compared to 0.12% in high diagnosis areas. An estimated 577 individuals, 13.3% of all estimated people living with hepatitis B in areas of relative underdiagnosis, were from North Africa and the Middle East, compared to 517 individuals (5.4%) in high diagnosis areas (p <0.001). The estimated population proportion was 0.21% in areas of relative underdiagnosis and 0.11% in high diagnosis areas.

*Table 55555. Population distribution by significant region of birth for SA2 areas by areas of relative underdiagnosis to areas of high diagnosis*

| Major Group | Relative underdiagnosis SA2s | | High diagnosis SA2s | | |
|---|---|---|---|---|---|
| | Estimated number (% of total SA2) | Proportion of population (%) | Estimated number (% of total SA2s) | Proportion of population (%) | Significance |
| Americas | 16 (0.4%) | 0.01 | 39 (0.4%) | 0.01 | 0.9 |
| North Africa and the Middle East | 577 (13.3%) | 0.21 | 517 (5.4%) | 0.11 | <0.001 |
| North-East Asia | 432 (10.0%) | 0.15 | 3,336 (34.9%) | 0.69 | <0.001 |
| Oceania and Antarctica | 59 (1.4%) | 0.02 | 120 (1.3%) | 0.02 | 0.7 |
| South-East Asia | 1,802 (41.6%) | 0.64 | 2,733 (28.6%) | 0.56 | <0.001 |
| Southern and Central Asia | 444 (10.3%) | 0.16 | 1,554 (16.3%) | 0.32 | <0.001 |
| Southern and Eastern Europe | 657 (15.2%) | 0.23 | 585 (6.1%) | 0.12 | <0.001 |
| Sub-Saharan Africa | 165 (3.8%) | 0.06 | 412 (4.3%) | 0.08 | 0.2 |

People living with hepatitis B from North-East Asia were significantly overrepresented in high diagnosis areas, with an estimated 3,336 individuals (34.9%), compared to an estimated 432 individuals (10.0%) in underdiagnosed areas (p <0.001). The local estimated population proportion was 0.69% in high diagnosis areas compared to 0.15% in areas of relative underdiagnosis. Significant differences were identified in people living with hepatitis B from Southern and Central Asia, with an estimated 1,554 individuals (16.3%) were in high diagnosis areas compared to 444 individuals (10.3%) in underdiagnosed areas (p <0.001). The estimated population proportion was 0.32% in high diagnosis areas and 0.16% in underdiagnosed regions.

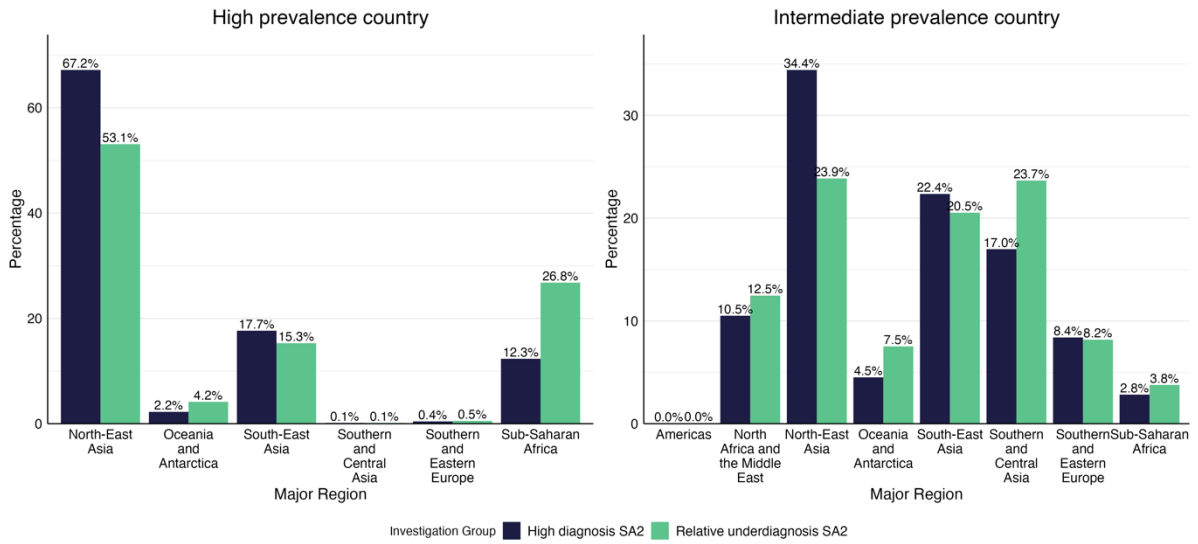



*Figure 77777. Population distribution by significant region of birth for SA2 areas with relative underdiagnosis (green) compared to the high diagnosis SA2 areas (blue)*

There was no significant difference between the estimated populations of people living with hepatitis B from Sub-Saharan Africa, with a calculated estimate of 165 individuals (3.8 %) in areas of relative underdiagnosis and 412 individuals (4.3 %) in high diagnosis areas (p = 0.2). The estimated population proportion was similar, at 0.06 % in areas of relative underdiagnosis and 0.08 % in high diagnosis areas. There was no significant difference in the estimated populations of people living with hepatitis B from Oceania and Antarctica regions, with an estimated 59 individuals (1.4 %) in relative underdiagnosis areas, compared to 120 individuals (1.3 %) in high diagnosis areas (p = 0.7). The estimated population proportion was 0.02 % in both underdiagnosed and high diagnosis areas.

Figure 8 summarises these differences in population proportion, with green markers indicating relative underdiagnosis areas and blue markers representing high diagnosis areas.

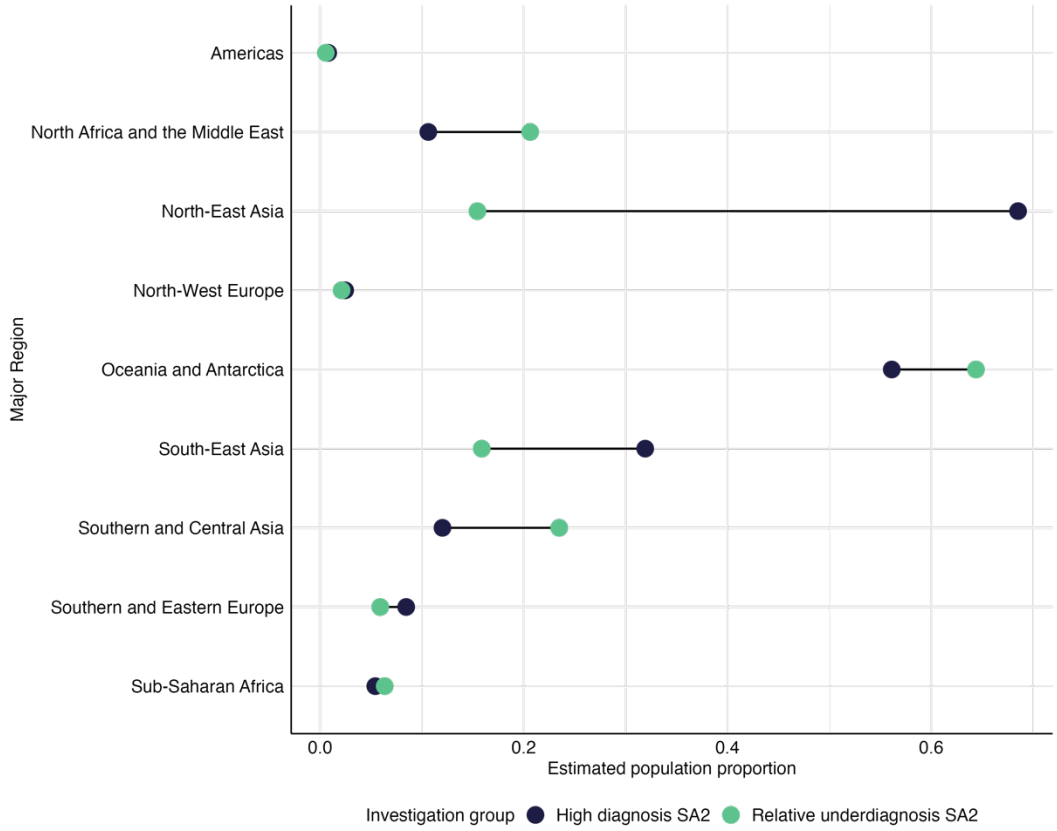



*Figure 88888. Estimated local population prevalence by major region of birth for SA2 areas with relative underdiagnosis (green) compared to the high diagnosis SA2 areas (blue)*

## Discussion

This study demonstrated the significant spatial and demographic disparities in the distribution and diagnosis of hepatitis B across various communities within the North Eastern Public Health Unit (NEPHU) catchment. It was estimated that areas with underdiagnosis had substantial populations from Southern and Central Asia, North Africa and the Middle East when compared to areas of high hepatitis B notification. These results suggest that focusing only on the highest-burden groups may mask at-risk populations and hinder progress towards public health elimination goals.[1] The high level of variability in the granular estimates of hepatitis B prevalence emphasises the need for targeted local screening and engagement strategies that address community-level factors that play an important role in hepatitis B, such as migration and demographics. By identifying areas of relative underdiagnosis, this study can provide important insights to ensure equitable health outcome across diverse communities across the NEPHU catchment and ensure progress towards national targets.

Estimates of prevalence were calculated using census data, a methodology applied in other jurisdictions, such as by Turnour et al. in western Sydney.[28] This method was validated using HBsAg seroprevalence data from public maternity hospitals. They found that the Census method overestimates the prevalence of hepatitis B infection by 30% but produces similar patterns of hepatitis B burden across the area. This method can be utilised to understand the spatial patterns of hepatitis B across the community, as it is estimated that 95% of new chronic hepatitis B infections are in people born outside of Australia.[29] The estimates derived in this study are likely overestimates of true population prevalence. The estimates, however, have important utility in understanding relative differences and spatial variability of hepatitis B among communities impacted by hepatitis B.

Analyses indicated that the local government areas of Hume and Whittlesea may have areas with higher levels of relative underdiagnosis. These are the fastest-growing LGAs in the catchment, with an estimated 40% of that growth being driven by overseas migration.[30] Migrants from CALD backgrounds living with hepatitis B have often experienced social marginalisation, hepatitis-related stigma upon arrival to Australia, and challenges in adapting to a new healthcare system that has resulted in barriers to hepatitis testing, diagnosis, and care.[20,31] Additionally, rapid urban growth in these areas may have increased issues related to access to healthcare services[32] and could have contributed to the underdiagnosis of hepatitis B.

Migrants' attitudes and knowledge of hepatitis B can reduce their likelihood of accessing healthcare and contribute to underdiagnosis in some migrant communities.[31] Migrants from countries where hepatitis B is endemic may consider the condition as expected and normal and display complacency around testing and management.[33] There are often low levels of hepatitis knowledge and awareness among migrants from CALD backgrounds.[34] This is further exacerbated by the asymptomatic nature of the disease, which can result in lower health-seeking behaviour.[34]

Migrants from China represent the most significant proportion of estimated cases of hepatitis B cases in the catchment. China has the largest population affected by hepatitis B, with 33% of all people with hepatitis B globally being born in China.[19] It is also the third-largest migrant group in Australia.[24] HBV prevalence in infants and children younger than five years declined by 77% between 1990 and 2019 to 1.0% globally.[35] These declines in HBV prevalence notably correspond with the scale-up of vaccination programs in newborns and infants.[28] The Chinese government began providing free vaccination to newborns and children in 2005, resulting in a significant increase in vaccine coverage rates, with birth-dose vaccination coverage reaching 95%.[36] In 2022, the estimated HBV prevalence of people aged ≥18 years old, 6% (95% CI: 4-8%), was higher than that of people aged <18 years old, 0% (95% CI: 0-1%).[28]

Areas of underdiagnosis had more populations from Africa and the Middle East. The Middle East varies from 0.6% in Iraq to 5.1% in Yemen, 3.6% in Algeria, and 3.5% in Kuwait.[37] Generally, countries in the Middle East region can be categorised as either high or intermediate prevalence. Of the 47 countries in the WHO African Region, 18 had hepatitis B prevalence rates above the high endemic threshold of 8%.[38] In Africa, where chronic HBV prevalence is high, less than 10% of newborn babies receive timely hepatitis B vaccination.[38]

Migrants from South and Central Asia are represented in many areas identified as having underdiagnosis. Indian-born migrants (754,000) are the second-largest group of migrants to Australia.[24] India accounted for a significant 11.6% of the world's hepatitis cases in 2022 and has the second-largest hepatitis B population behind China.[19] Wide variations in social, economic, and health factors in different regions may explain variations in carrier rates from one part of the country to another.[39] In 2015, global coverage of the three doses of the hepatitis B vaccine in infancy was 84%; however, coverage of the initial birth dose was still low at 39%.[39]

Currently, the diagnosis of most people affected by hepatitis B in Australia is dependent on risk group-based screening.[40] The National Hepatitis B Testing Policy lists 16 indications and 13 risk groups that should be considered for testing.[1] For clinicians,

conducting a guideline-based ascertainment of risk is complex, requiring knowledge of country of birth, Indigenous status, history of travel, vaccination, incarceration, medical procedures, occupation, sexual activity, family history, and previous or current injecting drug use. A study of GPs identified that 33% could not identify the central communities that are the at-risk population for hepatitis B, and 67% agreed that assistance with identifying patients who should be tested was needed.[41]

Community-based screening may be a more appropriate strategy to address gaps in diagnosis, particularly in communities with barriers to accessing healthcare. Culturally relevant interventions, incorporating appropriate language and sensitivity, are essential for engaging migrants from culturally and linguistically diverse (CALD) backgrounds.[31] Culturally tailored education and awareness programs involving facilitators from similar backgrounds and resources in native languages are crucial. Screening strategies can fall short due to a lack of linguistic-specific methods or culturally competent health workers.[42] Language barriers remain critical, impacting migrants' ability to describe health concerns or understand advice despite basic English proficiency.[43]

Effective programs should correct myths about HBV transmission, educate on long-term health risks, and involve community leaders to promote dialogue and reduce stigma.[20] Health education must include healthcare system navigation, connecting patients with primary care, and encouraging patient-physician dialogue. However, challenges like high screening costs and limited affordable long-term care persist, necessitating new approaches and financing arrangements to ensure sustainable care access.[42]

## Limitations

This study has several limitations. Areas with high notification levels may still have a sizeable undiagnosed population, and efforts to increase diagnosis are likely still needed. Ten years of hepatitis B notification data were used in this analysis, and they did not fully capture historical diagnosis patterns. This may skew the conclusions about underdiagnosis regions, as areas with high historical diagnosis could be incorrectly classified as areas of relative underdiagnosis.

Analysing at the SA2 level may impact the quality and reliability of the data, as small numbers may obscure findings. Additionally, the analysis was conducted using the place of residence at the time of diagnosis, which may not reflect changes in residence over time. This limitation could affect the spatial patterns observed, particularly for highly mobile populations or communities.

The prevalence estimates for hepatitis B in different countries were drawn from studies that utilised various methods of variable quality over different periods, potentially affecting the reliability of the estimates. We assumed that the hepatitis B prevalence among migrants is like that of the general population in their country of birth. However, this assumption may be incorrect for several reasons: migrants may come from socioeconomic backgrounds different from the average or distinctive regions or ethnic groups. Demographic characteristics such as year of birth can also influence hepatitis B prevalence within migrant populations, as changes to vaccination policies and health infrastructure can vary a person's level of risk over time. Estimates could be improved through the use of stratified prevalence estimates where available.

Additionally, using the prevalence estimate of 0.7% for Australian-born individuals may inflate the results for the country of birth, as this figure is derived from national serosurveys that included migrants from high and intermediate-prevalence countries.

## Conclusion

This study provides insights into the spatial variability of hepatitis B across the NEPHU catchment and highlights the community-level factors that play an essential role in this variability. The analysis identified several communities that need to be the focus of public health interventions to improve diagnosis if progress towards national targets is to occur by 2030. This analysis demonstrates how, by using data, we can ensure targeted and equitable public health strategies to prevent adverse outcomes of hepatitis B.

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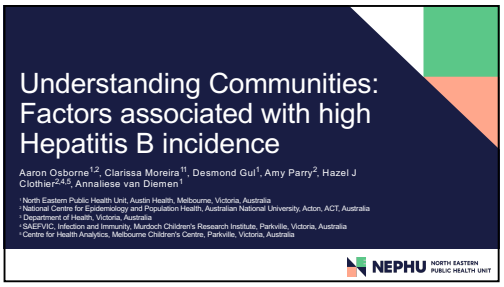
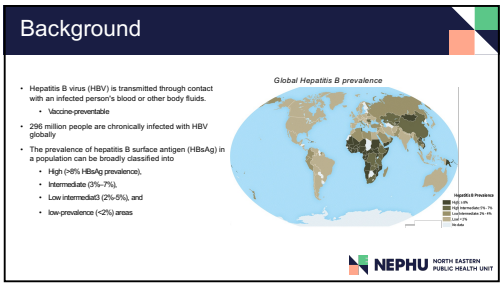
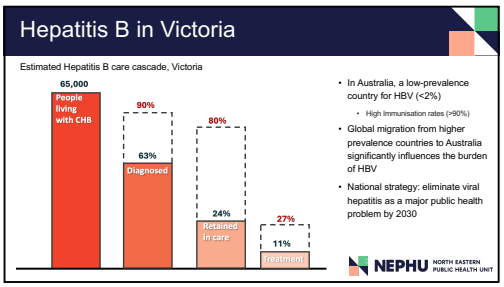
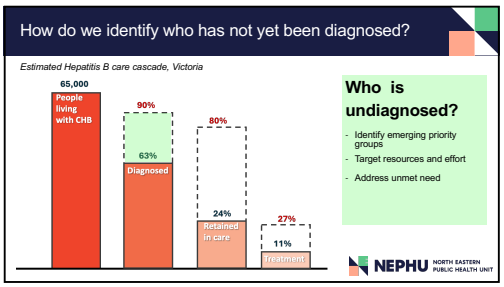
# Appendices

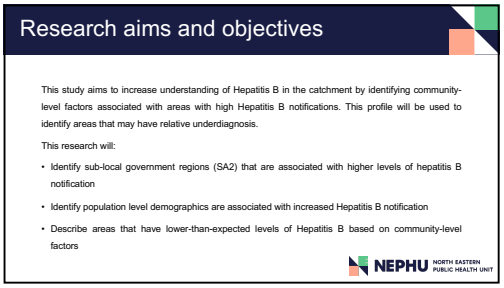
## Appendix A: Conference presentation slides

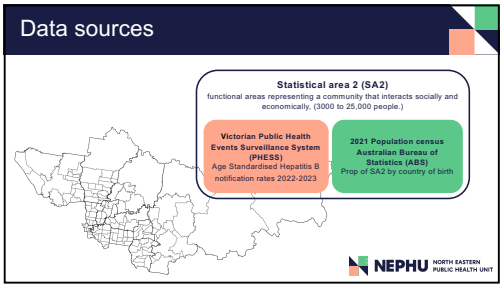


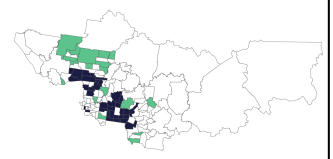



## Geographic distribution

*Distribution of SA2's with the top quartile Age standardised HBV notification rate and high proportion from prevalence country and low notification rate by local government area*

| | Number of SA2 | Highest quartile ASR notification rate SA2 | | High proportion from high/intermediate country and low ASR notification rate | |
|---|---|---|---|---|---|
| | | N | % | N | % |
| Banyule | 9 | 1 | 11% | 2 | 22% |
| Boroondara | 12 | 2 | 17% | 1 | 8% |
| Darebin | 11 | 4 | 36% | 0 | 0% |
| Hume | 18 | 3 | 17% | 6 | 33% |
| Knox | 12 | 1 | 8% | 2 | 17% |
| Manningham | 8 | 4 | 50% | 1 | 13% |
| Maroondah | 8 | 1 | 13% | 0 | 0% |
| Nillumbik | 6 | 0 | 0% | 0 | 0% |
| Whitehorse | 12 | 11 | 92% | 0 | 0% |
| Whittlesea | 18 | 5 | 28% | 6 | 33% |
| Yarra | 8 | 2 | 25% | 0 | 0% |
| Yarra Ranges | 14 | 0 | 0% | 1 | 7% |

*Map of SA2's with high proportion from prevalence country and low notification rate (green) compared the top quartile Age standardised HBV notification rate (blue)*



Investigate: High notification rate SA2 | High proportion from high/intermediate country and low notification rate | Oth

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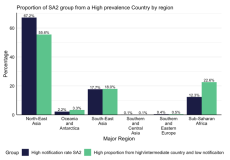
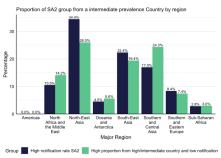
## Country of birth by regions

*Distribution of countries of birth for high HBV prevalence countries by major region comparing the two groups*




*Distribution of countries of birth for intermediate HBV prevalence countries by major region comparing the two groups*

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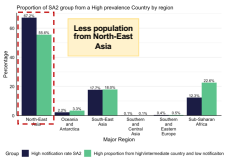
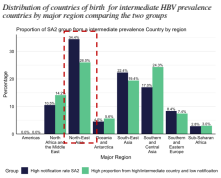
## Country of birth by regions

*Distribution of countries of birth for high HBV prevalence countries by major region comparing the two groups*




*Distribution of countries of birth for intermediate HBV prevalence countries by major region comparing the two groups*

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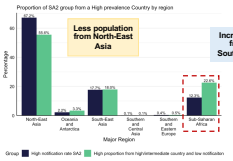
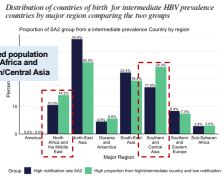
## Country of birth by regions

*Distribution of countries of birth for high HBV prevalence countries by major region comparing the two groups*




*Distribution of countries of birth for intermediate HBV prevalence countries by major region comparing the two groups*

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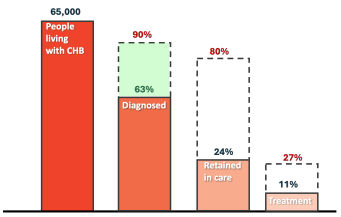
## How do we identify who has not yet been diagnosed?

Estimated Hepatitis B care cascade, Victoria




**Who is undiagnosed?**

- LGAs of Hume and Whittlesea
  - growth corridors
  - High recent migration
- Migrant groups from
  - Sub-Saharan Africa
  - North Africa and the middle east
  - Southern and central Asia

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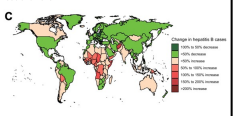
## Discussion

- Areas of high incidence may be masked when conducting analyses at higher geographic areas
  - Implications for service delivery, resourcing and needs
- Hepatitis B in Australia influenced by global hepatitis B epidemiology
  - Changes in migration trends
  - Changes in global epidemiology
- Notification data is only effective at identifying those historically at risk
- Need for strategies to to identify and support evolving CHB risk groups
  - Improved screening (is risked based screening sufficient?)
  - Resourcing in emerging geographical areas

*The relative change in incident cases of hepatitis B between 1990 and 2019*

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## Analysis

- Age-standardized notification rates by SA2 of hepatitis B were calculated for each SA2 from 2013 to 2022.
- Country of birth data was aggregated for each SA2
  - Categorised into World Health Organisation levels of hepatitis B prevalence levels,
  - The proportion of an SA2 born overseas and from low, intermediate, and high prevalence countries.
- Areas with a high proportion of the population from a country with high HBV prevalence and lower HBV notification rate were identified and characterised.

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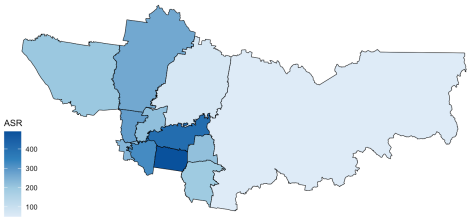
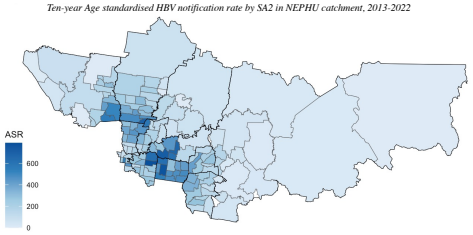
## Age-standardised rate by LGA

*Ten-year Age standardised HBV notification rate by Local Government Area in NEPHU catchment, 2013-2022*




## Age-standardised rate by SA2

*Ten-year Age standardised HBV notification rate by SA2 in NEPHU catchment, 2013-2022*




## Country of birth by HBV prevalence

*Proportion of SA2 population born in countries outside of Australia by HBV prevalence category by quartile of HBV age standardised notification rate*

| | Low | Low Med | Med High | High | Significance |
|---|---|---|---|---|---|
| Proportion born in high prevalence country (>=8%) | 0.19% | 0.36% | 0.44% | 0.71% | X= 36367.14 p= 0 |
| Proportion born in intermediate prevalence country (>=2% and <8%) | 9.66% | 20.83% | 22.92% | 32.67% | |
| Proportion born in low prevalence country (<2%) | 9.28% | 9.06% | 9.51% | 9.03% | |

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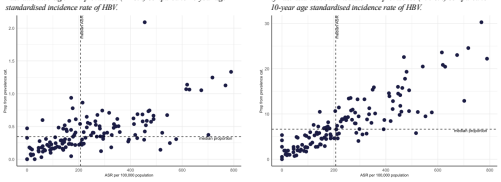
## Comparing country of birth to HBV notifications

*Scatter plot of. Proportion of SA2 population born in countries outside of Australia with high HBV prevalence (>=8%) compared to 10-year age standardised incidence rate of HBV.*

*Scatter plot of. Proportion of SA2 population born in countries outside of Australia with intermediate HBV prevalence (2%-8%) compared to 10-year age standardised incidence rate of HBV.*



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## Comparing country of birth to HBV notifications

*Scatter plot of. Proportion of SA2 population born in countries outside of Australia with high HBV prevalence (>=8%) compared to 10-year age standardised incidence rate of HBV.*

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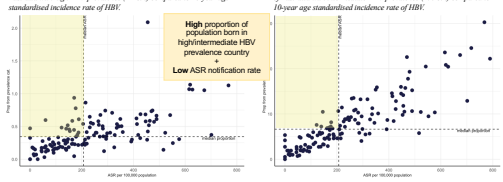


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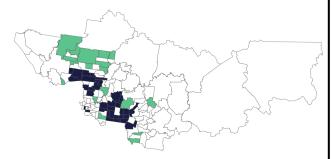
## Geographic distribution

*Distribution of SA2's with the top quartile Age standardised HBV notification rate and high proportion from prevalence country and low notification rate by local government area*

| | Number of SA2 | Highest quartile ASR notification rate SA2 | | High proportion from high/intermediate country and low ASR notification rate | |
|---|---|---|---|---|---|
| | | N | % | N | % |
| Banyule | 9 | 1 | 11% | 2 | 22% |
| Boroondara | 12 | 2 | 17% | 1 | 8% |
| Darebin | 11 | 4 | 36% | 0 | 0% |
| Hume | 18 | 3 | 17% | 6 | 33% |
| Knox | 12 | 1 | 8% | 2 | 17% |
| Manningham | 8 | 4 | 50% | 1 | 13% |
| Maroondah | 8 | 1 | 13% | 0 | 0% |
| Nillumbik | 6 | 0 | 0% | 0 | 0% |
| Whitehorse | 12 | 11 | 92% | 0 | 0% |
| Whittlesea | 18 | 5 | 28% | 6 | 33% |
| Yarra | 8 | 2 | 25% | 0 | 0% |
| Yarra Ranges | 14 | 0 | 0% | 1 | 7% |

*Map of SA2's with high proportion from prevalence country and low notification rate (green) compared the top quartile Age standardised HBV notification rate (blue)*



Investigate: High notification rate SA2 | High proportion from high/intermediate country and low notification rate | Oth

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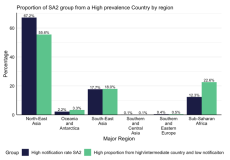
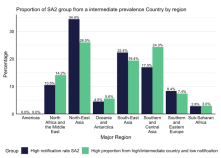
## Country of birth by regions

*Distribution of countries of birth for high HBV prevalence countries by major region comparing the two groups*




*Distribution of countries of birth for intermediate HBV prevalence countries by major region comparing the two groups*

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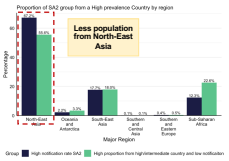
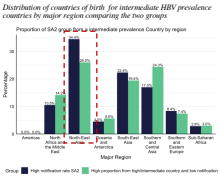



*Distribution of countries of birth for intermediate HBV prevalence countries by major region comparing the two groups*

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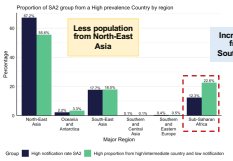
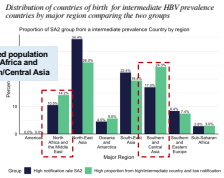



*Distribution of countries of birth for intermediate HBV prevalence countries by major region comparing the two groups*

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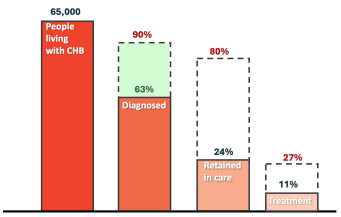
## How do we identify who has not yet been diagnosed?

Estimated Hepatitis B care cascade, Victoria




**Who is undiagnosed?**

- LGAs of Hume and Whittlesea
  - growth corridors
  - High recent migration
- Migrant groups from
  - Sub-Saharan Africa
  - North Africa and the middle east
  - Southern and central Asia

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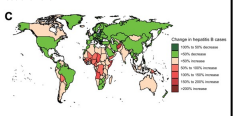
## Discussion

- Areas of high incidence may be masked when conducting analyses at higher geographic areas
  - Implications for service delivery, resourcing and needs
- Hepatitis B in Australia influenced by global hepatitis B epidemiology
  - Changes in migration trends
  - Changes in global epidemiology
- Notification data is only effective at identifying those historically at risk
- Need for strategies to to identify and support evolving CHB risk groups
  - Improved screening (is risked based screening sufficient?)
  - Resourcing in emerging geographical areas

*The relative change in incident cases of hepatitis B between 1990 and 2019*

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# **Chapter 4:** Adapting notifiable data for hepatitis B cascade of care surveillance:  A feasibility study

# Table of contents

# Prologue

## Rationale

The Fourth National Hepatitis B Strategy 2023–2030 sets out to eliminate hepatitis B as a public health threat in Australia by the decade's end.[1] Key to this strategy is improving the cascade of care for people living with hepatitis B. A care cascade model tracks the proportion of people progressing through the care continuum: diagnosis, engagement in care, treatment and viral suppression. Where my previous chapter focused on improving the diagnosis of people living with hepatitis B, this chapter explores how we can better monitor who is engaged in care.

There are opportunities to further integrate national strategy targets into Victorian surveillance strategies and North Eastern Public Health Unit responses. This project explores developing an indicator to monitor people living with hepatitis B who are engaged in care by adapting the current surveillance system and utilising routinely notified laboratory data. This can provide an opportunity to improve local-level progress towards the national target of 80% engagement in care.[1] Embedding these targets at the local level can strengthen place-based responses to hepatitis B and improve health outcomes for people impacted.

## My Role

I designed a methodology and developed a plan for this project. I began by reviewing the current hepatitis B surveillance system and creating a framework for an enhanced system incorporating care cascade monitoring. For the pilot study, I led the design and development of the outcome measure. I completed data cleaning and conducted the data analysis. I developed a methodology to assess the proposed system's feasibility and provided recommendations for implementation.

## Lessons Learnt

This project challenged me to think differently about how surveillance should be conducted. Hepatitis B is a chronic condition, and it requires a different surveillance approach than other compared to other conditions. There should not be a one-size-fits-all surveillance system. The project also highlighted the value of aligning surveillance objectives with national strategies to ensure priorities are focused where they can have the most impact.

I found conducting a feasibility assessment challenging at times. Developing a framework for the feasibility of adapting existing systems is potentially more complicated than simply evaluating a current system. Using the CDC guidelines didn't always fit nicely with the project style as it was theoretical and prospective. The project scope and development required careful consideration and discussion. However, the proposed system will be valuable to the public health unit. For this project to be successful, actionable recommendations and varying communication strategies were essential to ensure the findings existed beyond this report.

## Public Health Impact

This work was presented internally to stakeholders at the North Eastern Public Health Unit, including an audience of Epidemiologists, Public Health Physicians, and Public Health Officers. It was also presented to members of the World Health Organisation Collaborating Centre for Viral Hepatitis, The Peter Doherty Institute for Infection and Immunity. The findings and recommendations for implementation were shared, and considerations for implementation are currently being explored.

This project identified significant data quality issues that would need to be addressed if the proposed system were implemented. If these issues are addressed, the proposed system could help identify individuals not engaged in care, enabling more targeted interventions. The monitoring indicators developed by the proposed system could

identify gaps in access to care, which could inform strategies to address inequities in engagement in care in the catchment.

# Report

## Abstract

**Background**

The Fourth National Hepatitis B Strategy 2023–2030 aims to eliminate hepatitis B as a public health threat in Australia by 2030, setting ambitious targets for diagnosis, care engagement, and treatment uptake. However, current surveillance systems in Victoria do not systematically track patients' progression through the care continuum. This study assessed the feasibility of adapting Victoria's hepatitis B surveillance system to monitor engagement in care, addressing a critical gap in public health response. The proposed system involved using Electronic Laboratory Reporting (ELR) in the Victoria state surveillance system to monitor hepatitis B virus (HBV) DNA viral-load results. As HBV DNA testing is recommended at diagnosis and at least annually thereafter, each result acts as a proxy that the patient is linked to clinical follow-up.

**Methods**

This project consisted of three key activities: describing the proposed surveillance system and proposed adaptations, conducting a pilot study to estimate engagement in care, and assessing surveillance system attributes. The proposed surveillance system adaptations were assessed in terms of usefulness, data quality, simplicity, and flexibility.

**Results**

From 2019 to 2023, 21,563 tests were linked to 6,872 individuals with confirmed hepatitis B. The estimated proportion of individuals engaged in care at 12 months was 17.5%, and 21.2% within 24 months. These estimates are well below the national target of 80% engagement in care and estimates from New South Wales, who estimated that 50% of cases had timely DNA testing within four weeks of positive notification. Data quality issues were identified, with only 13% of HBV DNA viral load tests recorded in the Public

Health Event Surveillance System (PHESS) compared to Medicare Benefits Schedule (MBS) data from January 2022 to October 2023.

**Conclusion**

This surveillance system has the potential to significantly contribute to achieving national Hepatitis B elimination targets by providing more accurate and actionable data on the care cascade, ultimately improving public health outcomes for people living with Hepatitis B in Victoria. Data quality issues need to be addressed before the system can be implemented.

## Introduction

Chronic Hepatitis B (CHB) is a blood-borne viral infection that poses a significant public health burden in Australia.[2] For those already living with CHB, the disease is lifelong and incurable.[2] Without treatment, hepatitis B can cause liver inflammation, which can lead to liver disease, cancer, and death.[2] It is the most common cause of liver cancer, which is the sixth leading cause of cancer mortality in the country.[3]

Although therapy for CHB is generally not curative, treatments have the potential to impact progressive liver disease and survival significantly.[2] For these treatments to have an effect at the population level, there is a need for increased Hepatitis B virus (HBV) screening, linkage to care, access to treatment, and enhanced monitoring and evaluation of the impact of programmes.[4,5] Underpinning this is a series of laboratory tests to ascertain an individual's disease status and progression, informing clinical decision-making.

The hepatitis B diagnostic panel is a blood test that assesses three markers to determine an individual’s hepatitis B status.[6,7] Combining the three tests can determine a person's susceptibility and immunity through vaccination and past or current infection.[6,7] This panel is a serological test that examines blood serum for specific antibodies and antigens to diagnose diseases. The blood test measures HBsAg (Hepatitis B surface antigen), which shows if the virus is present; anti-HBs (Hepatitis B surface antibody), which indicates immunity; and anti-HBc (Hepatitis B core antibody), which suggests past or current infection (Figure 1 and Table 1).[6,7] A positive HBsAg means active infection,

while positive anti-HBs show protection against the virus. Anti-HBc results need to be interpreted along with the other two tests.[6,7]

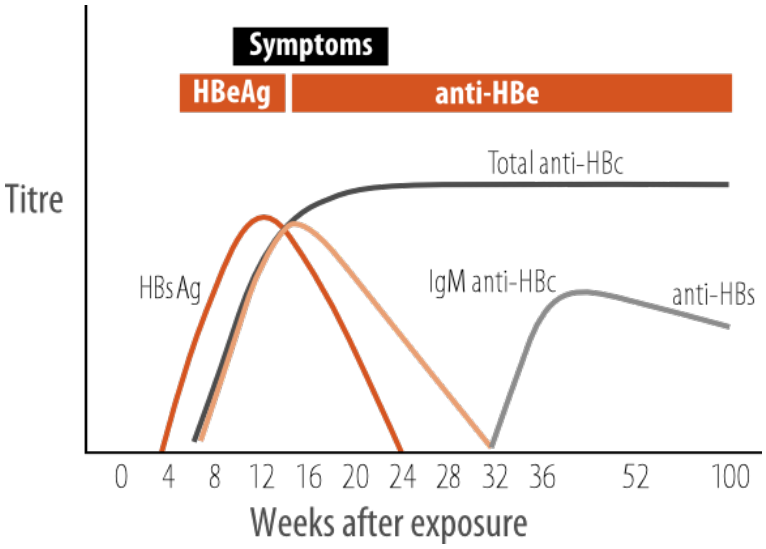


*Figure 1. Progression to chronic hepatitis B virus infection*

Source: ASHM Testing Portal[6]

Adapted from: Centres for Disease Control and Prevention (CDC). Recommendations for Identification and Public Health Management of Persons with Chronic Hepatitis B Virus Infection. MMWR Recomm Rep 2008;57(RR-8):1-10.

*Table 1 Hepatitis B test results and their interpretation*

| Test | Result | Interpretation |
|---|---|---|
| **HBsAg**<br>**anti-HBc**<br>**anti-HBs** | Negative<br>Negative<br>Negative | Susceptible to infection (if at risk, vaccination should be recommended) |
| **HBsAg**<br>**anti-HBc**<br>**anti-HBs** | Negative<br>Positive<br>Positive | Immune due to resolved infection |
| **HBsAg**<br>**anti-HBc**<br>**anti-HBs** | Negative<br>Negative<br>Positive | Immune due to hepatitis B vaccination |
| **HBsAg**<br>**anti-HBc**<br>**IgM anti-HBc***<br>**anti-HBs** | Positive<br>Positive<br>Positive<br>Negative | Acute HBV infection<br>*(high titre) |

| | | |
|---|---|---|
| **HBsAg**<br>**anti-HBc**<br>**anti-HBs** | Positive<br>Positive<br>Negative | Chronic HBV infection |

Source: ASHM Testing Portal[6]

Hepatitis B Virus (HBV) DNA Quantification, or viral load testing, is important in managing chronic hepatitis B infections. The results of these tests are used to assess disease progression, guide treatment decisions, evaluate treatment efficacy, and predict long-term outcomes (Figure 2).[6] This blood test uses Polymerase Chain Reaction (PCR) technology to measure HBV genetic material in a patient's blood.[6,7] Viral load correlates with the risk of people living with chronic hepatitis B (CHB) developing severe complications; patients with higher viral loads have an increased risk of both cirrhosis and hepatocellular carcinoma.[8,9]

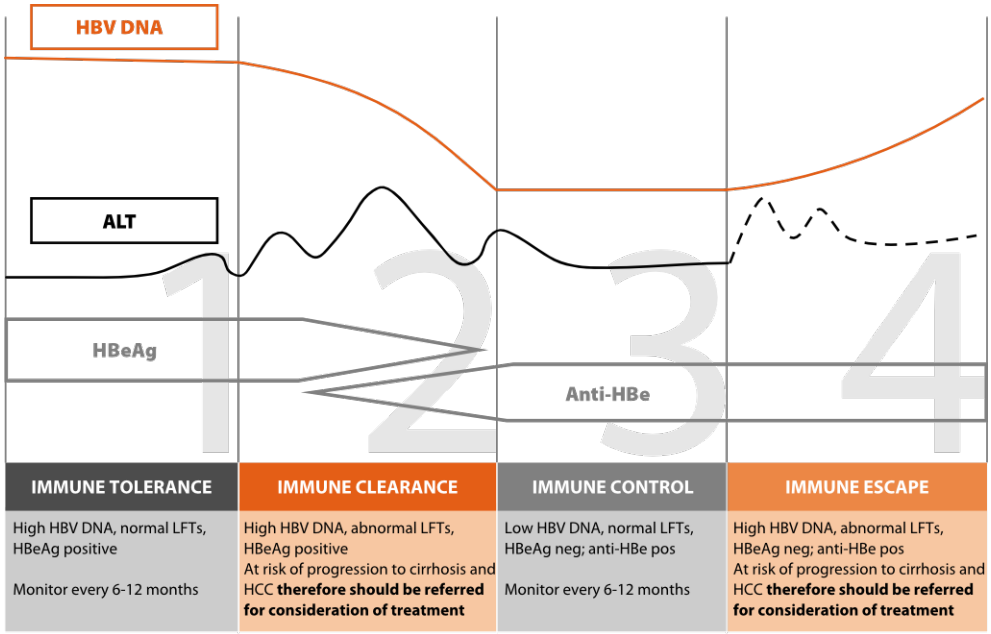


*Figure 2 . The four phases of chronic hepatitis B*

Source: ASHM Testing Portal[6]

Liver health is monitored through specific blood tests, as HBV primarily targets this organ.[6,7] These tests measure liver enzymes in the bloodstream caused by cell damage due to viral infection. Alanine aminotransferase (ALT) is significant in chronic HBV infections.[6,7] ALT levels guide treatment decisions; normal upper limits for ALT are 35 U/L for men and 25 U/L for women, with higher values suggesting greater liver damage.[6,7]

The care cascade is a framework that models the proportion of individuals who achieve each successive step in the continuum of diagnosis, linkage to care, retention, treatment initiation, and viral suppression. It was first introduced for HIV and has become a critical tool in national program assessments.[10,11] Monitoring and identifying the care cascade is needed to evaluate the effectiveness of existing public health programmes and provide a future framework to guide services and efforts to address HBV as a health priority.[12] Laboratory tests are essential in defining and monitoring each stage of the care cascade, from initial diagnosis to assessing treatment effectiveness and viral suppression. By integrating these laboratory indicators into surveillance systems, public health teams can monitor patients' progression through the care continuum, identify gaps in care, and implement targeted interventions to improve outcomes.

The Fourth National Hepatitis B Strategy 2023–2030 is a guide to eliminating hepatitis B as a public health threat in Australia by 2030.[1] The strategy aims to improve the cascade of care, which includes increasing the proportion of people diagnosed with CHB to 90%, increasing the proportion engaged in care to 80%, and increasing treatment uptake to 27%. The goal is to reduce CHB-attributable mortality by 30%.[1]

| | |
|---|---|
| People living with CHB | ≤0.1% hepatitis B surface antigen prevalence in ≤5yr olds. |
| Diagnosed | ≥90% people living with chronic hepatitis B are diagnosed |
| Engaged in Care | ≥80% of all people living with chronic hepatitis B are in care |
| Maintained in HBV treatment | 27% of all people living with chronic hepatitis B are receiving treatment |
| Virally Supressed | Reduce hepatitis B attributable mortality by 30% |

*Figure 3. HBV Care cascade step and corresponding national targets*

Source: The Fourth National Hepatitis B Strategy 2023–2030[1]

In 2022, an estimated 25.5% of people diagnosed with chronic hepatitis B received regular clinical care in Australia, and 13% received antiviral treatment.[13] There is a significant gap between the target of 80% of all people living with chronic hepatitis B being in care and the actual number. Opportunities exist to understand this gap better and improve health outcomes for people with chronic hepatitis B.

Despite the importance of monitoring the hepatitis B care cascade to achieve national elimination targets, there are gaps in the current surveillance system in Victoria. The current system relies on case notification, and there is no capacity to monitor individuals through the care cascade. This leaves a gap in understanding how diagnosed individuals are linked to care, retained in care, initiated on treatment, and have achieved viral suppression. In addition to this, there is limited capacity to identify disparities in engagement in care across different populations or geographic areas.

Local public health units were established in Victoria in 2020.[14] The decentralisation of the public health response in Victoria leads to an increase in public health capacity and a shift towards place-based prevention. This represents a shift towards localised and place-based responses to public health challenges and an opportunity to meet the needs of Victorians living with hepatitis B at the community level. Through increased local efforts, there is the potential to bridge gaps in the hepatitis B care cascade, ensuring better linkage to and engagement in care across communities.

This report explores the feasibility of implementing a hepatitis B surveillance system that incorporates care cascade monitoring. It assesses whether the current surveillance system can be adapted to track engagement in care using routine laboratory data. It is anticipated that this would inform targeted public health interventions and support progress towards the national goal of eliminating hepatitis B as a public health threat by 2030.

# Methods

## Aims and Objectives

This project explored how the current system can be adapted to track engagement in care for people living with chronic hepatitis B using routine laboratory data. It will also assess the feasibility of implementing the proposed system.

The project objectives were to:

- Describe the current hepatitis B surveillance system in Victoria as it relates to care cascade monitoring
- Describe adaptations required for enhancing engagement in care monitoring
- Conduct a pilot study to establish indicators for engagement in care in Victoria among people newly diagnosed with hepatitis B using HBV DNA tests between 2019 and 2023.

- Assess the usefulness of the engagement in care indicator compared to current surveillance systems used to measure engagement in care and describe its application in hepatitis B surveillance.
- Provide recommendations for establishing and embedding a surveillance process to produce indicators of engagement in care trends among people living with hepatitis B.

This work's purpose is exploratory. The implementation of the surveillance system is out of scope.

## Description of surveillance system

Hepatitis B case definitions were sourced from Communicable Diseases Network Australia (CDNA) National Guidelines for Public Health Units.[15] The current objectives of the Victorian surveillance system and details of its structure and operation were obtained through a review of relevant internal documents and discussions with the staff who operate it. Proposed adaptations to the surveillance system were designed to capture and monitor care cascade surveillance, focusing on engagement in care.

## Pilot study

A retrospective cohort study was conducted using state-wide de-identified notification data reported to the Public Health Events Surveillance System (PHESS) from 1 January 2019 to 31 December 2023. Laboratory tests linked to notified cases were described.

The estimated proportion of people newly diagnosed with hepatitis B engaged in care at any time within two time points following diagnosis (12 months, 24 months) was calculated (Table 3). The primary outcome of engagement in care was defined as reporting an HBV DNA laboratory test in the PHESS surveillance system at any time within 12 and 24 months after diagnosis with hepatitis B infection.

*Table 2. Summary of outcome measure for people newly diagnosed with Hepatitis B*

| Outcome measure | Definition |
|---|---|

| | |
|---|---|
| **The estimated proportion of people newly diagnosed with hepatitis B who are engaged in care.** | Proportion reporting an HBV DNA laboratory test in the PHESS surveillance system at:<br>• 12 months following diagnosis<br>• 24 months following diagnosis |

De-identified data was extracted and stored on secured network drives. Analysis was conducted in R.[16]

## Assessment of the proposed system

Several sources of information were used to inform the feasibility of the proposed surveillance system. Sources used to inform this work included data analysis and a literature search (Appendix A). Assessment of the indicator and its application were guided by Principles and Practice of Public Health Surveillance[17] and Centre for Disease Control's (CDC) Updated Guidelines for Evaluating Public Health Surveillance Systems.[18] Key attributes for assessment were determined to be data quality, usefulness, simplicity and flexibility. Appropriate methods for their evaluation were developed (Table 3).

*Table 3. Methods used to evaluate proposed monitoring system and against selected attributes*

| Attribute | Evaluation Definition | Evaluation Method |
|---|---|---|
| Usefulness | Contribution to the prevention and control of health-related events. | Pilot study to demonstrate the proposed indicator could be provided by the surveillance system.<br><br>Literature on surveillance of hepatitis B cascade monitoring was used to compare the outputs and inform usefulness |
| Simplicity | The structure and ease of operation of the surveillance system. | Pilot study to demonstrate the outputs of the proposed monitoring indicator and assessment of whether proposed changes to system are simple. |
| Flexibility | How well the system can adapt | Proposed surveillance system outputs were compared to surveillance systems identified in |

| | | |
|---|---|---|
| | to changes in needs or surveillance system operation. | literature and assessed on their ability to adapt to emerging priorities in care cascade surveillance. |
| Data Quality | Completeness and validity of data collection as part of the surveillance system. | Pilot study to assess the number of notified individuals with data available and identified any limitations in data validity.<br><br>A comparison of data reported in HBV DNA viral load tests reported in PHESS for the period of 01 January 2022 to 30 October 2023 for all Victorian residents was compared to HBV viral load tests for Victorian residents extracted the Medicare Benefits Schedule (MBS).<br><br>Literature on surveillance of hepatitis B cascade monitoring was used to identify barriers to data completeness and validity for cascade monitoring |

### Ethical considerations

Ethics approval for this project was granted through the Australian National University Human Ethics Research Committee (Protocol 2019/249).

# Results

### Description of surveillance system

#### Part 1. Overview of the current system

#### 1.1 The Purpose and Objectives of the Surveillance System

In Victora, under the Public Health and Wellbeing Act 2008 *and Public Health Regulations 2019,* hepatitis B infection is notifiable on pathological diagnosis by laboratories to the Victorian Department of Health.[19,20] The purpose of the public health response and responsibilities are defined in Box 1. The purpose of the response is to minimise the public health risk of hepatitis B for all Victorians and to inform actions to achieve national and Victorian goals for the elimination of viral hepatitis as a public health concern by 2030.[1]

### Box 1. Purpose of the public health response

To minimise the public health risk of Hepatitis B for all Victorians and to inform actions to achieve National and Victorian goals for elimination of Viral Hepatitis as a public health concern by 2030.

State-wide surveillance (Communicable Disease Epidemiology and Surveillance)

- Monitor the epidemiology of Hepatitis B with respect to time, population groups, geography and risk factors to inform and guide public health strategies
- Monitor cases of newly acquired Hepatitis B, outbreaks, or clusters, monitor cases with rarer mode of transmission, so that appropriate public health action can be taken at state-wide level to prevent further cases and the associated complications.

Local Surveillance (LPHU)

- Monitor local Hepatitis B epidemiology within LPHU catchment.
- Rapidly detect local clusters and outbreaks of Hepatitis B to inform timely local public health interventions.
- Collaborate with DH regarding statewide Hepatitis B surveillance and trends.

Local level response (Local Public Health Units)

- Investigate all notifications of Hepatitis B that meet the follow-up criteria as defined in this protocol to identify risk factors and guide public health actions and strategies
- Investigate clusters, lookback, or cases with public health concerns occurring within a single Local Public Health Units (LPHU) to identify emerging areas of local transmission.
- Collect enhanced surveillance data including cascade of care data, to promote linkage to care through notifying clinicians.

State-wide response (Communicable Disease Prevention and Control)

- Coordinate investigations that cross LPHU boundaries
- Coordinate multidisciplinary investigations, outbreaks, clusters and lookbacks

Source: Hepatitis B Protocol: Public Health Response[21]

The surveillance system for hepatitis B in Victoria is designed to meet multiple objectives outlined in Box 2. Specifically, objectives five and six relate to the implementation of care cascade surveillance and monitoring. The fifth objective focuses on improving linkage to care for all Victorians with chronic hepatitis B. The sixth objective relates to the guide planning and implementation of policy, service provision, prevention strategies, and other public health interventions. These objectives emphasise the need for surveillance systems in broader public health strategies.

The current national strategy aims to minimise the public health risk of hepatitis B and contribute to the national and state goals of eliminating viral hepatitis as a public health concern by 2030.[1] This strategy is underpinned by critical targets to improve the cascade of care, which includes increasing the proportion of people diagnosed with CHB to 90%, increasing the proportion engaged in care to 80%, and increasing treatment uptake to 27%.[13]

Currently, there is no monitoring against national targets for hepatitis B elimination occurs at the local public health level. While the surveillance strategy acknowledges the importance of care cascade monitoring, a gap exists between strategic objectives and practical implementation. Embedding these targets at all levels offers an opportunity to strengthen place-based responses to hepatitis B. Doing so will help to identify where to focus efforts if hepatitis B is to be eliminated as a public health threat by 2030.

Box 2. Surveillance system objectives

1. Monitor the epidemiology and trends for Hepatitis B with respect to time, population groups, geography and other risk factors.
2. Guide immediate action for cases of public health importance to prevent further transmission.
3. Identify and investigate cases in HCWs, cases potentially associated with nosocomial (health care acquired) transmission (medical/dental procedure), or transmission through other skin penetration practices.
4. Identify and manage clusters of cases or outbreaks.
5. Improve linkage to care for all Victorians living with chronic Hepatitis B.
6. Guide planning and implementation of policy, service provision, prevention strategies and other public health interventions.
7. Provide a basis for epidemiological research.
8. Monitor and evaluate the impact of interventions.
9. Contribute to the core and enhanced surveillance data for Hepatitis B to the National Notifiable Disease Surveillance System (NNDSS)

Source: Hepatitis B Protocol: Public Health Response[21]

## 1.2 Structure of the current surveillance system

Hepatitis B surveillance in Victoria is a population-based passive surveillance system.[17] Table 4 describes the case definition for hepatitis B. Only confirmed cases of hepatitis B are notified, and definitive laboratory evidence is required. As such, pathology laboratories must notify the Department of Health when the examination of a specimen indicates that the individual has a pathological diagnosis. Hepatitis B infection is a 'routine' notifiable condition and must be notified by both pathology services and the diagnosing clinician in writing within five days of diagnosis.

*Table 4. Communicable Disease Network Australia national case definition for Hepatitis B*

| Case definition – Hepatitis B (newly acquired)<br>A confirmed case requires **laboratory definitive evidence** only. | |
|---|---|
| **Laboratory definitive evidence** | |
| 1 | Detection of Hepatitis B surface antigen (HBsAg) in a patient shown to be negative within the last 24 months |
| OR | |
| 2 | Detection of HBsAg and IgM to hepatitis B core antigen, except where there is prior evidence of hepatitis B infection |
| OR | |
| 3 | Detection of hepatitis B virus by nucleic acid testing, and IgM to hepatitis B core antigen, except where there is prior evidence of hepatitis B infection |
| **Case definition – Hepatitis B (unspecified)**<br>A confirmed case requires **laboratory definitive evidence** AND that the case does not meet any of the criteria for a newly acquired case. | |
| **Laboratory definitive evidence** | |
| 1 | Detection of hepatitis B surface antigen (HBsAg), or hepatitis B virus by nucleic acid testing, except where there is prior evidence of hepatitis B infection. |

Source: Hepatitis B CDNA National Guidelines for Public Health Units[15]

Figure 4. highlights the patient flow, surveillance, and data flow. At-risk populations are screened using a combination of serology tests, including Hepatitis B surface antigen (HBsAg), Hepatitis B core antibody (anti-HBc), and Hepatitis B surface antibody (anti-HBs). Positive HBsAg serology indicates a person is infected with hepatitis and meets the

case definition for Hepatitis. The laboratory result will be automatically reported to the Public Health Events Surveillance System (PHESS) via electronic laboratory reporting (ELR). Appendix B describes the main types of hepatitis B virus diagnostic tests used to inform the clinical management of hepatitis B in Australia.

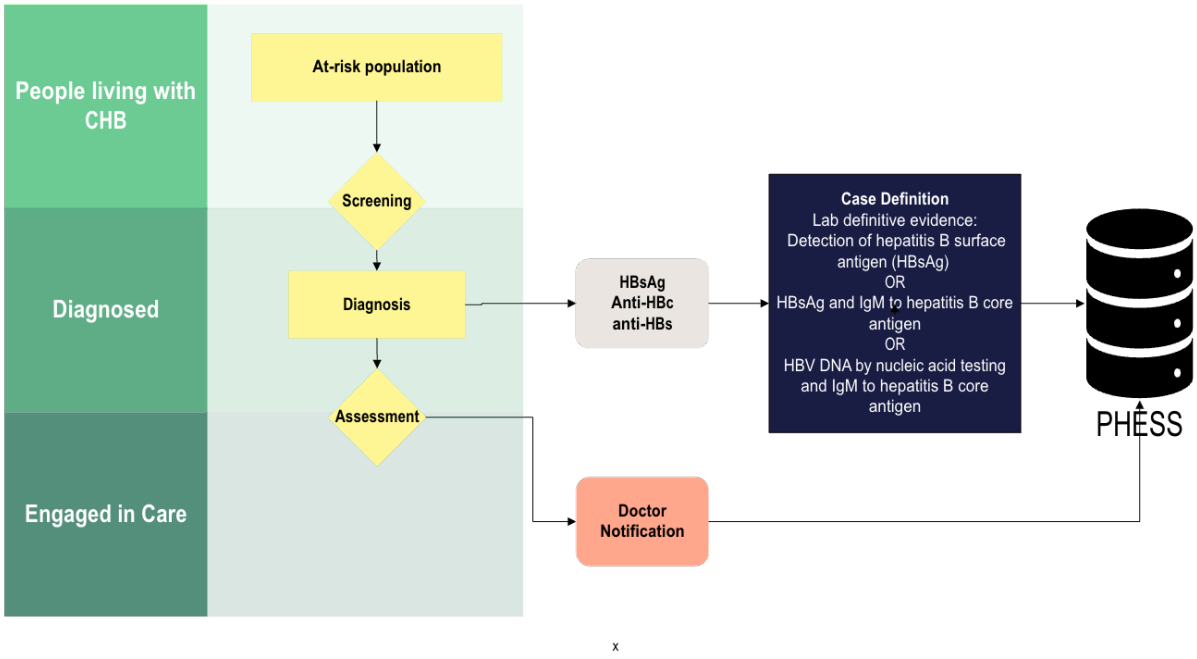


*Figure 4. The current surveillance system structure*

A feature of the current system is the Electronic Laboratory Reporting mechanism. The majority of laboratories report positive hepatitis B results to the Department of Health through this electronic system. Over 80% of hepatitis B cases in 2023 were reported through electronic laboratory reporting. This automated process ensures that positive results are promptly sent to the Victorian Department of Health and entered the PHESS. A small number of laboratories still report results via mail or facsimile.

In addition to laboratory notification, clinicians are required to notify Hepatitis B cases. Notification of Hepatitis B must be made in writing within five days of diagnosis under the *Public Health and Wellbeing Regulations 2019*.[20] The doctor should complete this process using the secure online form on the Department of Health notification page. They may also return the form via mail or facsimile.

This form collects additional information about the individual case. The data includes demographic information, risk history and questions on the care cascade. Care cascade questions included whether hepatitis B viral load testing was completed, the result and whether the treatment had been offered.

Cases are allocated to the relevant LPHU for appropriate public health and surveillance actions. In cases where a notification form has been received, the public health officer (PHO) reviews it. If it contains sufficient information to close the case investigation, no further follow-up with the doctor is required. If no notification form has been received, the PHO requests information from the notifying doctor.

This data source has several limitations. It represents a single point in time and cannot capture information on ongoing engagement in care or treatment. Response rates for notification forms are low. In 2023, internal reports indicated that of the 377 cases notified in NEPHU, notification forms were requested for 302 cases, with 168 ESFs returned, a 56% completion rate.

## Part 2. Proposed adaptations to the system

### 2.1 Adapted Purpose and Objectives of the Surveillance System

It is within the scope of the current surveillance system objectives to monitor cascade surveillance. While this is happening to some extent in the current surveillance system, it is focused on data collection, and there are opportunities to embed national cascade targets further into local public health unit responses.

This would represent a move away from more conventional surveillance approaches to a more active intervention-focused surveillance system. By monitoring engagement in care, the system could enable the effective monitoring and improvement of care cascade outcomes at the individual and population levels. This is crucial if the targets for hepatitis B elimination are to be met by 2030, including increasing the proportion of people engaged in care.

Adapting the system to track engagement in care using HBV DNA tests aligns with its established national and international goals. The surveillance system should also be adapted to monitor care cascades, as this is within the scope of the defined objectives.

## 2.2 Proposed system structure

Figure 5 highlights the proposed additional patient flow, surveillance, and data flow that could allow the capture cascade monitoring and engagement in care. At diagnosis, the treating clinician will perform further tests to assess whether the individual requires treatment, and these test results may be uploaded to PHESS. A notifying form is sent to the notifying clinician to collect information on the individual, such as demographics, risk history, and whether they have been linked to care.

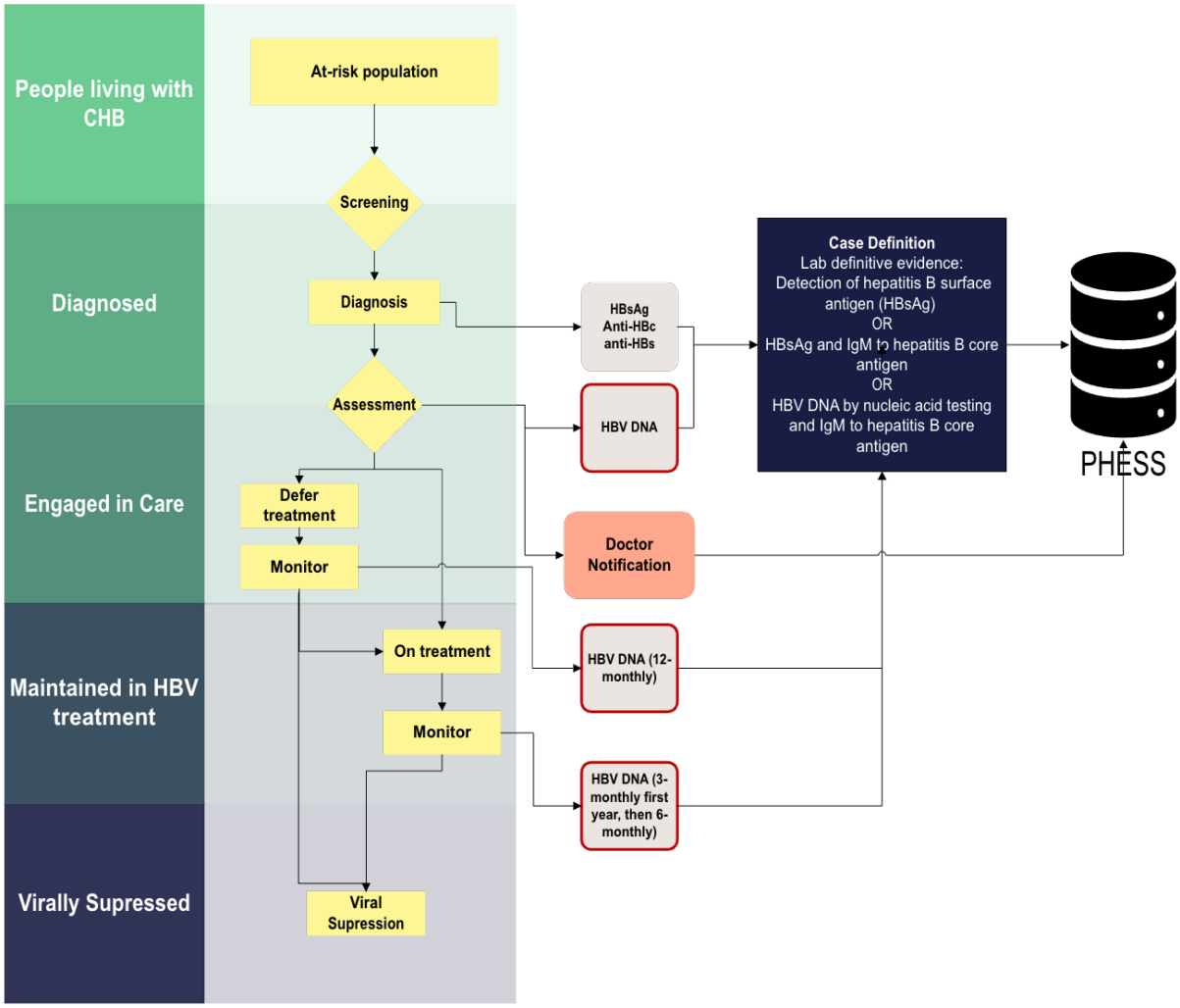


*Figure 5. Proposed surveillance system structure. Proposed additional data flows are highlighted in red*

Once confirmed and when individuals are linked to care, regular testing is required to monitor their virological response and treatment needs. HBV DNA is recommended annually for those in the monitoring phase and every six months for individuals on treatment. HBV forms part of the hepatitis B case definition (Box 3) and should be reported through electronic laboratory reporting.

Notifying HBV DNA through electronic laboratory records would provide a source to monitor individuals who have received their routine laboratory tests and are currently engaged in care. The data pathway is red in the system diagram in Figure 5. The proportion of individuals who have a recorded HBV DNA test 12 to 24 months after a positive diagnosis can be calculated. This will act as an estimate of the proportion of people newly diagnosed with hepatitis B who are engaged in care.

## Pilot Study

### Part 1. Description of laboratory tests in the surveillance system

A total of 21,563 hepatitis B tests were extracted that were linked to 6,872 confirmed hepatitis B cases. Table 5 describes the tests linked to records of notified cases of hepatitis B. Over half, 11,737/21,563 (54%) of tests are hepatitis B surface Antigen (HBsAg), followed by IgM to hepatitis B core antibody, 6,916/21,563 (29%) and HBV DNA viral load tests: 2808/21,563 (13%). These three tests are notifiable as part of the case definition for hepatitis B. HBV DNA tests are recommended annually for those in the monitoring phase and every six months for individuals on treatment.

*Table 5. Test types reported through electronic laboratory reporting in the surveillance system*

| Laboratory test type | Number of tests | % |
|---|---|---|
| Hep B Surface Antigen (HBsAg) | 11,737 | 54.4% |
| Hep B Core Antibody (Anti-HBcIgM) | 6,916 | 29.1% |
| HBV DNA viral load | 2,808 | 13.0% |
| **Other tests** | | |
| Not stated | 269 | 1% |
| Hep B Core Total Antibody (Anti-HBc) | 50 | 0.2% |
| Not stated | 31 | 0.1% |
| Hep B e antigen (Anti-HBeAg) | 12 | 0.1% |
| Hep B e antibody (Anti-Hbe) | 8 | 0.1% |
| Culture | 1 | 0% |

The test of notification was Hep B Surface Antigen (HBsAg) for 97% of cases (n = 6,938), and 3% (n=239) of cases were notified of hepatitis B with an HBV DNA viral load test. People diagnosed with an HBV DNA viral load test included situations where an individual had previously been diagnosed overseas but engaged in care for the first time in Australia. Of the 6,872 confirmed cases, 5,443 (79%) had more than one hepatitis B test reported. Most individuals, 73%, had more than one laboratory result reported on

the same day as their initial notification (Figure 6); in subsequent time intervals, there was a decreasing percentage of additional tests.

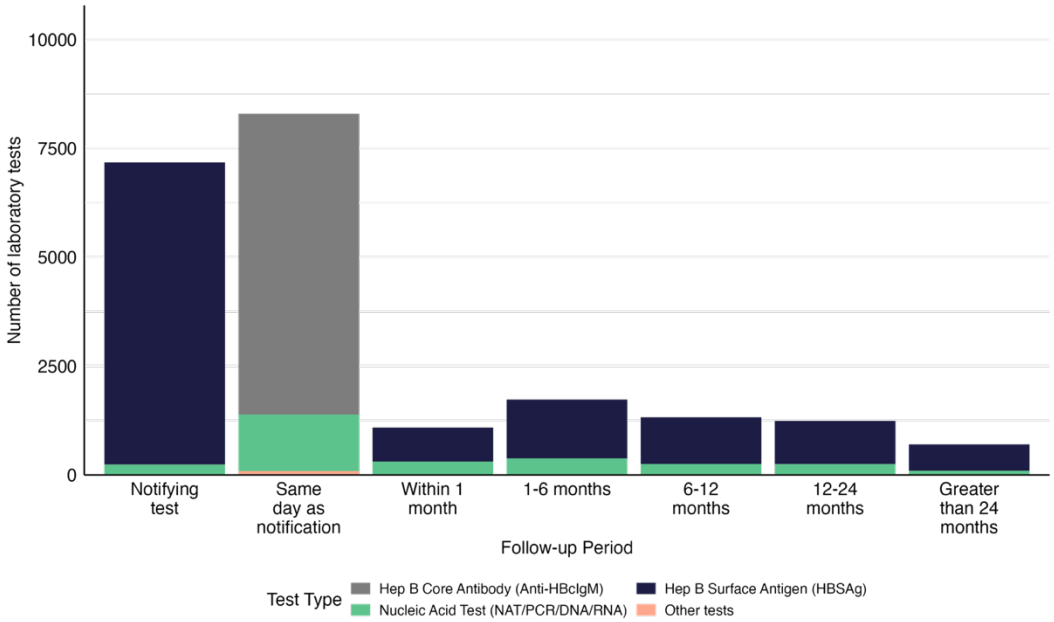


*Figure 6. Distribution of hepatitis B laboratory tests from the time since the first notification*

Figure 7 describes the number and percentage of confirmed hepatitis B notifications with HBV DNA tests in each period following initial notification. Of the 21,563 tests, 2808 HBV DNA tests were recorded during the study period (13%). Over the study period, 15% of all confirmed cases had a positive HBV DNA test collected on the same day as a positive diagnosis by hepatitis B Surface Antigen (HBsAg). Benefits for HBV DNA tests under Medicare are only payable when the patient is suspected of having acute or chronic Hepatitis, using the provisional diagnosis or relevant clinical or laboratory information.[6] This suggests the diagnosing clinician requested the pathology service to perform reflexive PCR testing for HBV DNA of the same sample if the HBV serology sample was positive.[22] This practice reduces the number of visits required for patients, voiding the need for a second visit and further blood samples.

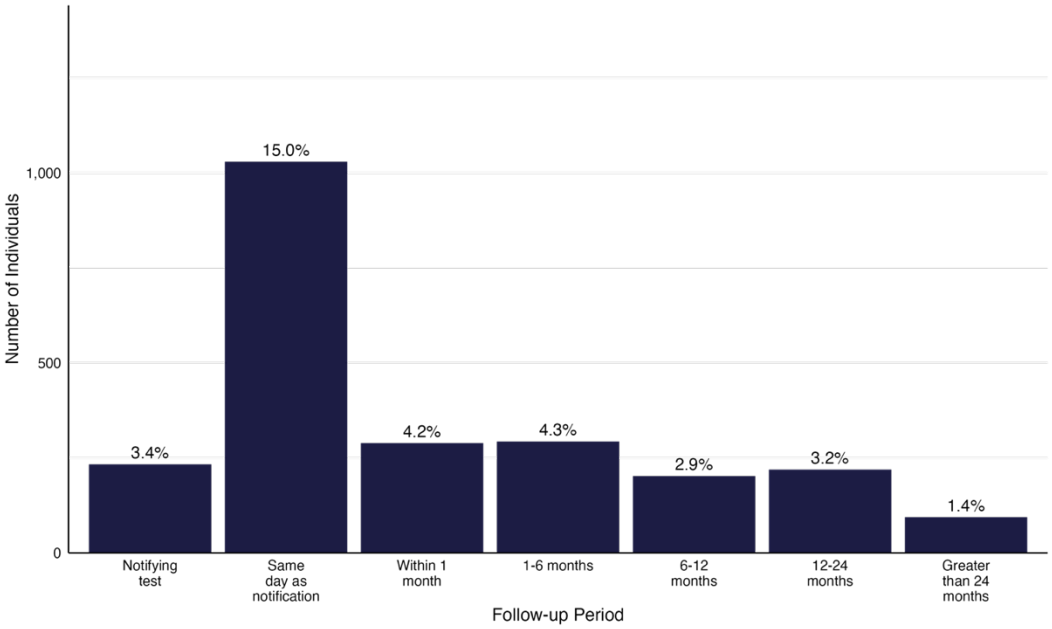


*Figure 7. Number and percentage of individuals with confirmed hepatitis B who have an HBV DNA test in the study period following initial notification*

## Part 2. Outcome Measure

Figure 8 illustrates the cumulative percentage of individuals with confirmed hepatitis B who have undergone HBV DNA testing since their initial notification, that was recorded in the surveillance system.

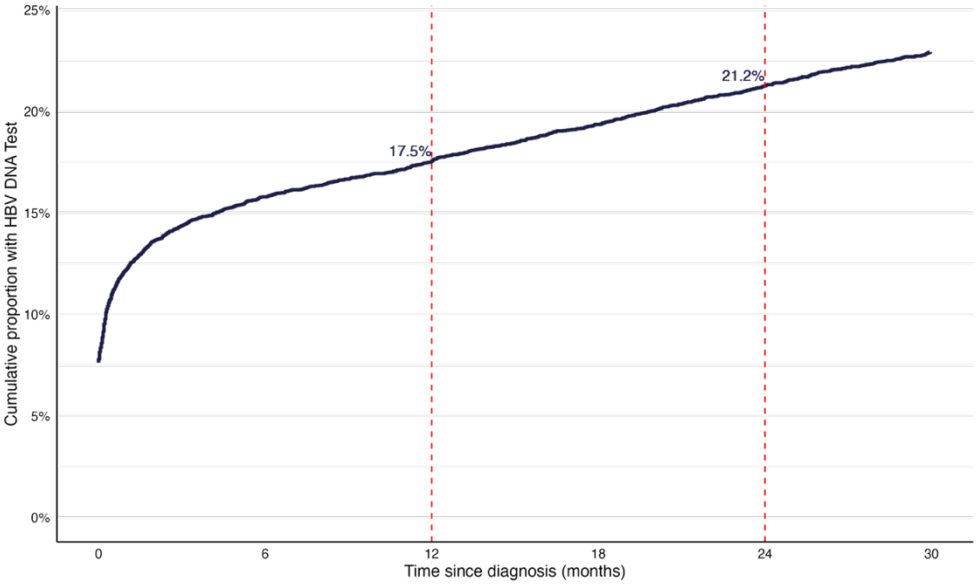


*Figure 8. Cumulative percentage of individuals with confirmed hepatitis B who have had an HBV DNA test since initial notification*

Over the study period, an estimated 1205 (17.5%) newly diagnosed people were engaged in care within 12 months of diagnosis. This increases to 1460 (21.2%) newly diagnosed people engaged in care within 24 months (Table 6). Engaged in care was defined as the proportion reporting an HBV DNA laboratory test in the PHESS surveillance system following diagnosis.

*Table 6. Summary of outcome measure for people newly diagnosed with Hepatitis B*

| Outcome measure | Definition | Estimate |
|---|---|---|
| **The estimated proportion of people newly diagnosed with hepatitis B who are engaged in care.** | Proportion reporting an HBV DNA laboratory test in the PHESS surveillance system after diagnosis | **17.5%** of cases were engaged in care within 12 months of diagnosis<br>**21.2%** of cases were engaged in care within 24 months of diagnosis |

This estimate indicates that the proportion of people who are engaged in care is well below the national target of 80%, and there are significant opportunities to improve engagement in care for people living with hepatitis B (Figure 9).

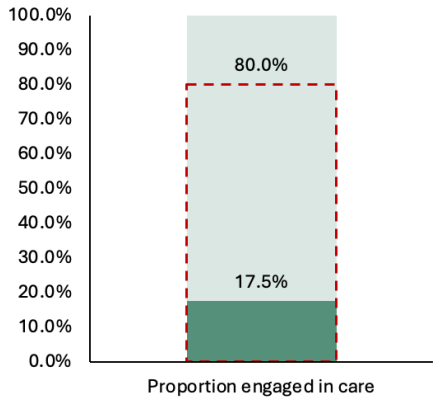


*Figure 9. Estimated proportion of individuals who had a recorded HBV DNA tests 12 months after positive diagnosis compared to national targets*

## Feasibility assessment of adapting to the proposed system

In the previous sections, a proposed system to monitor the people newly diagnosed with hepatitis B who are engaged in care was described. A pilot study developed a draft metric to measure the public health measure of the proportion of people newly diagnosed engaged in care. The feasibility of implementing the proposed system was assessed by comparing the system to key surveillance systems identified in the literature (Table 7). The feasibility of implementing the system was assessed using attributes of usefulness, data quality, simplicity, and flexibility.

*Table 7. Summary of surveillance systems for generating engagement in care estimates used for comparison*

| Summary of system | How estimates are derived |
|---|---|
| **The National Viral Hepatitis Project**[3]<br>Provides a comprehensive understanding of chronic hepatitis B in Australia, assessing geographic variation in prevalence, management, and treatment. | **Estimate**<br>Proportion engaged in care was defined as percentage of diagnosed individuals who received care each year.<br><br>**Data source**<br>Aggregate data from the Medicare Benefits Schedule (MBS) for those who had a HBV DNA test in a given year.<br>Total number of people living with CHB who have been diagnosed modelled output and calibrated using National Notifiable Disease Surveillance System notifications data. |
| **Cascade of care among people with hepatitis B in New South Wales, Australia**[23]<br>Research study to evaluate care cascade with HBV DNA testing and treatment in New South Wales. | **Estimate**<br>Timely HBV DNA testing was defined by an HBV DNA test within 4 weeks of HBV notification. HBV DNA testing was defined as HBV DNA testing recorded in the MBS dataset and evaluated among all people with HBV notification.<br><br>**Data source**<br>Data linkage of hepatitis B notifications in New South Wales to HBV DNA test from Medicare Benefits Schedule (MBS) and Pharmaceutical Benefits Scheme (PBS). |

| | |
|---|---|
| **Australian Collaboration for Coordinated Enhanced Sentinel Surveillance (ACCESS)** [24]<br>A sentinel surveillance system comprising health services (sexual health clinics, general practice clinics, drug and alcohol services, community-led testing services, and hospital outpatient clinics) and pathology laboratories in Australia's eight states and territories. | **Estimate**<br>No estimate of engagement in care generated.<br><br>**Data source**<br>Line-listed diagnostic and monitoring hepatitis B testing data among Victorian individuals was collated from six laboratories participating in ACCESS. |

## Usefulness

The estimated proportions of newly diagnosed people engaged in care by 12 and 24 months were calculated.

- 17.5% of cases were engaged in care within 12 months of diagnosis
- 21.2% of cases were engaged in care within 24 months of diagnosis

The cascade of care analysis detected engagement in care and provided outputs allowing assessment of prevention and control programs. As a passive population-based system to capture data on all hepatitis B cases across Victoria, the proposed system has the potential to give a more complete understanding of hepatitis B engagement for people living with hepatitis B in Victoria.

These estimates, however, are much lower than estimates calculated in New South Wales.[23] The NSW Cascade of Care study estimated that from 1993 to 2017, in newly notified cases, 50% had timely DNA testing within four weeks of positive notification.[23] The cumulative probability of HBV DNA testing over three years rose to 66.6%.[23] This suggests that there are data quality issues significantly impacting the utility of the indicators developed in this pilot to monitor people newly notified with hepatitis B engaged in care.

The National Viral Hepatitis Project estimates the proportion engaged in care to be 28.7% in 2022.[13] Due to differences in calculation methods, it is not possible to directly

compare our preliminary estimates with those from the National Viral Hepatitis Project. The National estimates calculate the percentage of diagnosed individuals who received care each year, arriving at 28.7% care uptake. Our approach, in contrast, focuses on the proportion of newly notified cases that receive testing within specific timeframes following diagnosis.

## Data Quality

Several data quality issues were identified during the pilot study that would need to be addressed prior to the proposed system being implemented. First, not all laboratories in Victoria are consistently reporting HBV DNA tests; second, currently only positive results are reported; and lastly, improvements to the completion of doctor notification forms would improve opportunities for reporting. These issues are explored below.

A comparison of HBV DNA viral load tests reported in PHESS, and the Medicare Benefits Schedule (MBS) was conducted for Victorian residents from 01 January 2022 to 30 October 2023. During this period, 2,421 HBV DNA tests were reported in PHESS, while 18,743 were recorded in the MBS. This indicates that only 13% of HBV viral load tests are captured in PHESS. The discrepancy can be partially explained by differences in the reporting systems: PHESS includes both Medicare-relatable and privately received tests but only records positive HBV DNA results, while the MBS dataset includes both positive and negative Medicare-rebatable tests.

These findings indicate incomplete reporting of HBV DNA tests by laboratories to PHESS. This is further evidenced by the disaggregation of HBV DNA testing by laboratory in Figure 10 and Appendix C. Only two laboratories consistently report HBV DNA tests beyond the initial date of notification, while others report these tests only when linked to an HBsAg test as part of reflexive testing. Reflexive testing occurs when PCR testing for HBV DNA is automatically performed on the same sample if the HBV serology sample is positive.[22] Further follow-up with pathology services that are not currently reporting HBV DNA consistently would be required to understand barriers, if any, for this system to be implemented.

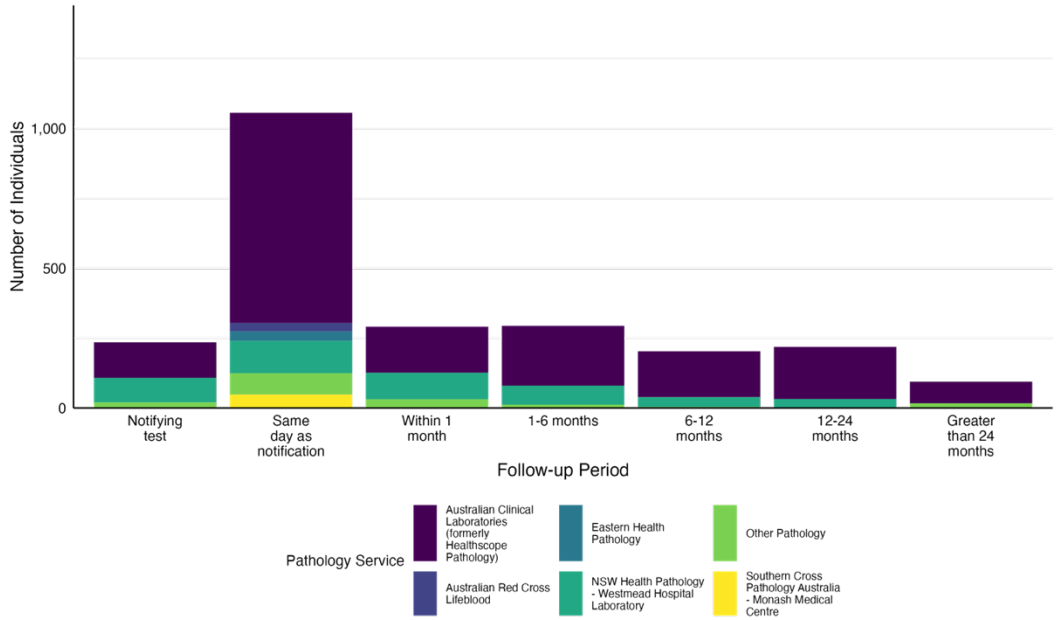


*Figure 10. Number of individuals with confirmed Hepatitis B who have an HBV DNA test in the study period following initial notification by pathology service*

Not all laboratories were onboarded to Electronic Laboratory Reporting during the pilot study. This process has been ongoing, and it likely impacted the estimates calculated in the pilot project due to early years, including periods where not all laboratories were onboarded to ELR. This likely caused an underestimate in the number of people engaged in care. This issue was identified in 2022, when the Coordinated Hepatitis responses to Enhance the Cascade of Care by optimising existing Surveillance systems (CHECCS) investigated the use of notified hepatitis C RNA tests in PHESS to monitor engagement in care.[25] At the time, it was not possible to use this method, as only a few laboratories were onboarded to ELR.[25] This has improved considerably since then and most laboratories are onboarded to ELR, especially after the COVID-19 pandemic.

Currently, under the proposed system, only positive hepatitis B viral load DNA tests are reported, which is a limitation of this system. There are situations where a person still infected with chronic hepatitis B may return an undetectable HBV DNA test. The United States Centre for Disease Control (CDC) has identified a limitation of utilising routine surveillance data as a longitudinal surveillance monitoring tool for engagement to care for people living with chronic hepatitis B. The United States CDC recommends reporting negative/undetectable HBV DNA results as these results can be a proxy indicator that

people living with hepatitis B have been linked to care.[26] This information can support accurate surveillance and measurement of the hepatitis B care cascade.[26]

Legislation surrounding the provision of negative testing data to the Department of Health has been developed. The regulations allow negative results to be reported for some communicable diseases. The Public Health and Wellbeing Regulations 2019 require that pathology services notify the department of notification details for all tests performed in relation to chlamydia trachomatis infection, influenza, Respiratory Syncytial Virus (RSV), and COVID-19.[20] The inclusion of hepatitis B negative results could significantly improve this approach for assessing which people with hepatitis B are engaged in care.

An advantage of this system is the data disaggregation by the fields of country of birth or Indigenous status. For this to be of value, improvements would be required in completing doctor notification forms, where there are known challenges with completion. In 2023, internal reports indicated that of the 377 cases notified in NEPHU, doctor notification forms were requested for 302 cases, with 168 returned, a 56% completion rate.

## Simplicity

The surveillance system's simplicity refers to both its structure and ease of operation.[18] Simplicity was assessed regarding the data collection requirements and the ease of collection, compilation, analysis, and reporting. The proposed adaptations to the hepatitis B surveillance system in Victoria demonstrate simplicity.

A key strength of this approach is that it does not require significant infrastructure changes to the existing Public Health Events Surveillance System (PHESS). Instead, the system relies on already collected information. Specifically, the established Electronic Laboratory Reporting (ELR) routinely reports the HBV DNA test results. This removes the need for system overhauls or new data collection processes, reducing barriers to implementation.

The NSW Cascade of Care study generated estimates using data linkage between NSW notifiable disease data. The study team probabilistically linked notifications with HBV testing and treatment records using the Medicare number. Something similar could be possible in Victoria through the Centre of Victorian Data Linkage.[27] This process has several limitations; it would not allow real-time monitoring of engagement in the care, as the data linkage is conducted with a 6-12 month delay, and data would be deidentified.[28] Adding additional systems and processes could contribute to a more complex system than the proposed system that does not require additional data linkage or infrastructure.

The focus on a single measure of engagement in care provides a straightforward and easily implementable metric for monitoring progress. No additional data collection is required. The clear link between this measure and the national target of 80% engagement in care further simplifies the process of evaluating progress and identifying areas for improvement in the hepatitis B care continuum.

## Flexibility

In the context of implementing this surveillance system, flexibility refers to the ability of the system to adapt to monitor engagement in care with as little cost in time or cost as possible.[18] In addition, we explore the future flexibility of the proposed system in terms of future changes, emerging priorities and reporting.

The system's implementation is dependent on laboratories reporting HBV DNA tests. Due to the number of private laboratories operating in Victoria, implementing this may be complex and take time. A key objective of this system was to monitor progress towards national elimination targets in 2030[1], and it may not be feasible for the system to implement these changes in an appropriate timeframe. Other already established systems, such as ACCESS sentinel surveillance, may be better utilised if these issues cannot be addressed.

Sentinel surveillance systems, such as the Australian Collaboration for Coordinated Enhanced Sentinel Surveillance (ACCESS), have been utilised to monitor cascades of

care for hepatitis B and C in Australia.[29] As a sentinel surveillance system, ACCESS offers more focused monitoring of a subset of cases. Sentinel systems are typically less resource-intensive to implement and maintain, making them practical for monitoring trends and evaluating interventions in key populations or healthcare settings.[17] Their results may not always be generalisable to the entire population.

The estimates enable real-time monitoring of differences across geographic areas and demographic groups. Recent improvements in data collection fields through enhanced surveillance may allow data disaggregation by country of birth or Indigenous status. The estimates provide opportunities to develop targeted interventions to improve linkage to care and monitor engagement in care for key populations. The system's longitudinal nature enables the development of measures to track individuals over time. This could lead to establishing metrics to monitor the time to first test, providing insights into the efficiency of early care engagement. By expanding these capabilities, this surveillance system contributes to a more comprehensive understanding of hepatitis B management, informing population-specific strategies for care.

Adapting a passive population-based system to capture data on all hepatitis B cases across Victoria offers flexible coverage that can be scaled or modified as needed to respond to changes in the response, capture emerging trends, and improve estimates of total cases, diagnosis rates, and progression through the care cascade. This approach allows for better estimating total cases, diagnosis rates, and progression through the care cascade.

By tracking post-notification testing at the individual level, the proposed surveillance system provides a flexible approach to gaining insight into early engagement with care after diagnosis. This is a limitation of estimates derived from the National Viral Hepatitis Mapping Project; they offer population-level data that cannot be as readily disaggregated.

## Summary of findings and recommendations

The adaptations to the surveillance system fit within the purpose of the public health response to eliminate viral hepatitis as a public health concern by 2030 and the objective to improve linkage to care. The proportion of people living with hepatitis B in care, as measured by the percentage of individuals who have recorded HBV DNA tests 12 months after a positive diagnosis, was estimated to be 17.5%; this estimate, however, is an underestimate. Significant data quality issues limit the system's feasibility and need to be addressed before the system can be implemented.

**Engage all with pathology services to ensure consistent reporting of HBV DNA results.** Only two laboratories were found to consistently report HBV DNA tests beyond the date of initial notification. In contrast, others only reported these tests when linked to an HBsAg test as part of reflexive testing. This inconsistency limits the effectiveness of the surveillance system.

**Explore reporting negative HBV DNA test results into PHESS.** Including negative results would provide a more comprehensive view of the care cascade, allowing for better monitoring of treatment efficacy and patient engagement. This aligns with recommendations from the US CDC for improving hepatitis B surveillance. However, implementing this change may require legislative and operational changes.

**Consider the implications of implementing this system, including the impact on staff who use it.** The proposed system would likely increase the volume of data being processed, particularly if negative test results are included. This could lead to an increased workload for staff responsible for data entry, cleaning, analysis, and interpretation.

**Develop enhanced reporting and analyses disaggregated by populations and geographies**. This proposed surveillance system's advantage is its ability to identify disparities between geographic regions and demographic groups distinguishable by other systems. This information provides valuable opportunities to develop targeted

interventions to improve linkage to care and retention for key populations, leading to better health outcomes.

**Explore opportunities to improve the number of people living with chronic hepatitis B who are engaged in care.** The surveillance system's advantage is its ability to follow up with individuals or more targeted population sub-groups and understand whether they have engaged in care following a positive hepatitis B diagnosis. The development of programs to improve linkage to and participation in care could significantly improve progress towards the target of 80% of all people living with chronic hepatitis B being in care.

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# Appendix

## Appendix A Literature Search Strategy

A literature search was conducted using the PubMed database to find relevant studies on Hepatitis B surveillance, focusing on care cascade surveillance. The search was restricted to articles published in English, and the data was filtered to find published articles between 2013 and 2024.

The following search strategy was employed:

**Hepatitis B/ or Hepatitis B, Chronic/**

1. **exp Population Surveillance/**
   This step involves exploring literature indexed under population surveillance.
2. **1 and 2**
   Combining the results from steps 1 and 2 to identify articles that address both chronic Hepatitis B and population surveillance.
3. **Cascade.mp.**
   This step searches for the term "Cascade" in multiple fields of the articles.
4. **"Continuity of Patient Care"/sn, td [Statistics & Numerical Data, Trends]**
   Searching for terms related to the continuity of patient care, specifically focusing on statistics, numerical data, and trends.
5. **4 or 5**
   Combining the results of steps 4 and 5 to capture studies discussing either cascades or continuity of patient care.
6. **2 and 6**
   Combining population surveillance (step 2) with the results from step 6 to find relevant articles.
7. **3 or 7**
   Combining the results of step 3 and step 7 to ensure a comprehensive search.
8. **Limit 8 to yr="2013 - 2024"**
   Limiting the search results to articles published from 2013 to 2024.

## Appendix B Types of hepatitis B virus diagnostic tests

| Marker | Abbreviation | Purpose | Technology |
|---|---|---|---|
| Hepatitis B surface antigen | HBsAg | Donor screening – screening of blood and tissue donations<br>Diagnostic testing<br>Monitoring of therapy | Immunoassay |
| Hepatitis B surface antigen neutralisation | | Confirming the presence of HBsAg | Immunoassay |
| Hepatitis B surface antibody | anti-HBs or HBsAb | Determining protective immunity | Immunoassay |
| Hepatitis B core total antibody | anti-HBc total or HBcAb total | Part of strategy to determine exposure to HBV | Immunoassay |
| IgM to Hepatitis B core antigen | anti-HBc IgM or HBc IgM | Part of strategy to diagnose acute Hepatitis B infection | Immunoassay |
| Hepatitis B e antigen | HBeAg | Determining infectivity of a person with HBV infection and phase of the infection for clinical management | Immunoassay |
| Hepatitis B e antibody | Anti-HBe or HBeAb | Determining seroconversion from Hepatitis B e antigen and phase of the infection for clinical management | Immunoassay |
| Hepatitis B DNA | HBV DNA | Monitoring and management- quantifies virus for clinical management<br>Confirm the presence of circulating HBV<br>Determining HBV reactivation<br>Donor screening – screening of blood and tissue donations | Nucleic acid testing |
| Hepatitis B genotype / mutation | | Characterising virus for clinical management | Sequencing or Line probe assay |

| | | | |
|---|---|---|---|
| conferring resistance | | | |

Source: ASHM Testing Portal[6]

## Appendix C HBV DNA Viral load tests by pathology service

| Pathology Service | Number of laboratory results |
|---|---|
| 4Cyte Pathology | 6 |
| Alfred Pathology Service | 8 |
| Austin Health | 1 |
| Australian Clinical Laboratories (formerly Healthscope Pathology) | 2284 |
| Australian Red Cross Blood Service NSW | 6 |
| Australian Red Cross Lifeblood | 27 |
| Dorevitch Pathology | 10 |
| Douglass Hanly Moir Pathology | 4 |
| Eastern Health Pathology | 18 |
| Melbourne Health Shared Pathology Service | 3 |
| Melbourne Pathology Pty Ltd | 13 |
| National Serology Reference Laboratory, Australia | 1 |
| NSW Health Pathology - Gosford Hospital Laboratory (Central Coast) | 2 |
| NSW Health Pathology - North Sydney | 1 |
| QML Pathology | 1 |
| SA Pathology trading as IMVS | 2 |
| Southern Cross Pathology Australia - Monash Medical Centre | 28 |
| St Vincent's Hospital Pathology | 5 |
| Sullivan Nicolaides Pathology | |

# **Chapter 5:** ‘Bellwether' conditions for surveillance: ICD-10 codes associated with periods of poor air quality, Victoria, 2014–2023

# Table of Contents

# Prologue

## Rationale

The Syndromic Surveillance team in the Victorian Department of Health develop innovative syndromic surveillance tools to monitor when hazards impact human health. Their objective is to detect as fast as possible when the hazard is causing human illness, so that prompt public health action can be enacted. The team has developed many innovative surveillance tools to monitor environmental hazards, including thunderstorms and heatwaves and their impact on emergency department presentations.

Bushfires are common in Australia, and exposure to fine particulate matter ($PM_{2.5}$) from bushfire smoke can cause serious health consequences.[1] Monitoring of events related to air pollution aids in surge capacity planning and risk communication, allowing officials to provide timely and accurate health impact information to the public.

This study seeks to identify syndromes associated with bushfire smoke that would be appropriate candidates for syndromic surveillance, particularly conditions that demonstrate a rise or start of a hazard that could act as a 'bellwether'. The ICD-10 codes will then be associated with triage text using natural language processing (NLP) to develop a 'Poor Air Quality Syndrome' that can be used for rapid monitoring during the bushfire season. The work presented in this chapter is exploratory and represents the first steps towards developing this air quality monitoring syndrome.

## My Role

My role was to conduct an ecological study on periods of poor air quality and all ICD-10 codes used in emergency departments to develop a set of ICD-10 codes that show an association with poor air quality hazard periods. I created a data analysis plan and obtained ethics approval from the Department of Health and the Department of Families, Fairness, and Housing Human Research Ethics Committee. I then cleaned the data and ensured that it was structured appropriately for analysis.

I was responsible for developing an analysis approach and adapting the strategy in response to data quality issues and limitations with the data. An example of this included adapting the regression in part one of the analysis from a continuous to a categorical regression to address extreme values in the $PM_{2.5}$ data. Other issues arose with the data quality of the Environmental Protection Agency (EPA) air quality data. I had to adapt the analytical strategy from the initial plan to conduct a state-wide analysis.

## Lessons learnt

The methodological approach used in this study was novel and different from one I was familiar with. It was a different approach to a public health problem than what I had taken before, and this provided many opportunities to explore a public health problem from a new perspective. This involved lots of conversations with my supervisor and deep thinking and consideration. The analysis was conducted using R in Databricks. Using this platform had a significant learning curve, and while I am a competent coder, I had to adjust the way I code and work for the platform.

Data quality issues meant that we had to adapt the analysis multiple times, which, while time-consuming, allowed us to explore and conduct many different regression approaches. This included exploring Poisson and negative binomial regression and understanding the situations in which you would apply them.

It was my first experience with environmental data, and it was an exciting opportunity to work on a project so different from my other projects. It took time to adapt to the differences in the framework of environmental health data when compared to infectious diseases. The concentration-response relationship of $PM_{2.5}$ is complicated and has implications for handling the analysis. Understanding the hazard-event framework was critical to ensure the project was clearly articulated.

## Public Health Impact

This analysis identified several ICD-10 codes associated with periods of poor air quality. Further investigation of the subset of ICD-10 codes will be required to ensure their suitability for monitoring during poor air quality events. The ICD-10 codes will then be associated with triage text using natural language processing (NLP) to develop 'Poor Air Quality Syndrome'. This will aid in creating a robust 'Poor Air Quality Syndrome' monitoring system during such events and insights for rapid and effective public health responses.

My work identified a number of ICD-10 codes associated with periods of poor air quality. These findings were consistent with the literature on poor air quality emergency department presentations. I was also able to identify a collection of symptom-based ICD-10 codes used in emergency departments that may have been missed had we used other methods.

Further investigation of the subset of ICD-10 codes will be required to ensure their suitability for monitoring during poor air quality events. The ICD-10 codes will then be associated with triage text using natural language processing (NLP) to develop 'Poor Air Quality Syndrome'. This will aid in developing a 'Poor Air Quality Syndrome' for use during the bushfire season in Victoria to support public health and emergency management decision-making.

## Acknowledgements

I wish to thank the support of project supervisor, Professor Jim Black, for his guidance throughout this project. I also wish to thank the wider syndromic surveillance team at the Victorian Department of Health for their wisdom and tips throughout this project.

# Report

## Abstract

**Introduction**

Bushfire smoke poses significant health risks due to its complex composition of gases and particulate matter, including $PM_{2.5}$, which can cause serious health consequences. This analysis aims to identify the acute clinical conditions in emergency departments associated with poor air quality, which can be effectively used for ongoing monitoring during bushfire events.

**Methods**

A retrospective ecological study examining the association between $PM_{2.5}$ levels and emergency department (ED) visits was conducted in Victoria, Australia, from 2014 to 2023. A Poisson regression assessed associations between daily maximum categorical $PM_{2.5}$ and ICD-10 count. Second, poor air quality hazard days were defined by peak $PM_{2.5}$ exceeding 100 $\mu g/m^3$ for one hour, with two baselines calculated for comparison. Rate ratios, 95% confidence intervals, and p-values were used to quantify associations between $PM_{2.5}$ levels and ICD-10 codes.

**Results**

During poor air quality events ($PM_{2.5}$ > 100 $\mu g/m^3$), emergency department (ED) presentations significantly increased for multiple ICD-10 codes. Asthma (J45) showed associations across all analyses with rate ratios from 1.28 to 3.27 ($p < 0.001$), followed by other respiratory conditions. Clinical symptoms also increased, such as cough (R05, rate ratio 1.43, $p < 0.001$), abnormalities of breathing (R06, rate ratio 1.38–1.74, $p < 0.001$ to 0.01), pain in throat and chest (R07, rate ratio 1.13, $p < 0.001$), malaise and fatigue (R53, rate ratio 1.74, $p = 0.01$), and syncope and collapse (R55, rate ratio 1.44, $p < 0.001$).

**Discussion**

This study identified a set of ICD-10 codes that could be candidates for use in syndromic surveillance. Consistent with the literature, emergency department presentations for asthma increased during periods of poor air quality. It was also identified that ED presentations for general symptoms increase during periods of poor air quality. These findings will aid in developing a 'Poor Air Quality Syndrome' to monitor the impact of smoke during bushfire seasons and inform public health responses.

# Introduction

Bushfires are a natural part of the Australian landscape but pose significant risks to both people and the environment.[2] This is exemplified by the extreme fire events of the Black Saturday fires of 2009 [3] and the Black Summer season of 2019/2020.[4] Bushfires have become more frequent, with the mean number of years between fires being shorter over the past four decades, while the frequency of forest mega fire years (>1 million hectares burned) has increased since 2000.[5] Prescribed burning for fuel reduction has also increased.[6] Climate change will continue to increase the risk of fire in Australia by increasing extremely hot days, decreasing rainfall, increasing drought, increasing the number of high fire danger days and longer fire seasons for Australia.[7–9]

Bushfire smoke contains a mixture of gases and particulate matter, with particles varying in size and potential health impacts based on their ability to penetrate the respiratory system.[1,10] Particulate matter is a mixture of solid and liquid particles that are classified by size ($PM_{2.5}$ and $PM_{10}$ ).[10] $PM_{2.5}$ classifies fine particle measurements with a diameter of 2.5µm or less, while a measurement of $PM_{10}$ identifies larger, more coarse particles measuring a diameter of 10µm or less. $PM_{2.5}$ is small enough to penetrate the lungs and enter the bloodstream, and $PM_{10}$ can enter the lungs through the nose and throat.[11,12]

Exposure to fine particulate matter ($PM_{2.5}$) from bushfire smoke can cause serious health consequences.[1] Exposure to $PM_{2.5}$ can trigger severe immune and stress responses, leading to serious health impacts.[11,13] These responses can result in chronic and acute respiratory and cardiovascular impacts, such as heart attack or stroke.[12,14] In 2019–20, Australia recorded one of the most severe bushfire seasons, with an estimated additional 417 excess deaths attributable to air pollution from the fires.[12] In addition, an estimated 1124 hospital admissions for cardiovascular problems, 2027 hospital admissions for respiratory problems and 1305 emergency department attendances for asthma.[15]

Victoria's Environmental Protection Agency (EPA) monitors air quality across the state, but its coverage is limited in certain areas. The EPA plan sets out to monitor ambient air

quality at all urban centres with a population of at least 25,000.[15] However, prior to 2020, EPA did not collect information on ambient air quality for most parts of the state, including many parts of metropolitan Melbourne.[16] Its network of ambient air quality monitors is limited to parts of the Port Phillip and Latrobe Valley regions (figure 1).[16] EPA can also deploy incident air monitoring equipment when emergency services request this. EPA uses five categories to describe the overall air quality at each of the monitoring sites, with a poor, very poor or extremely poor category indicating when the level of a pollutant is higher than its air quality guideline or standard (figure 2).[17]

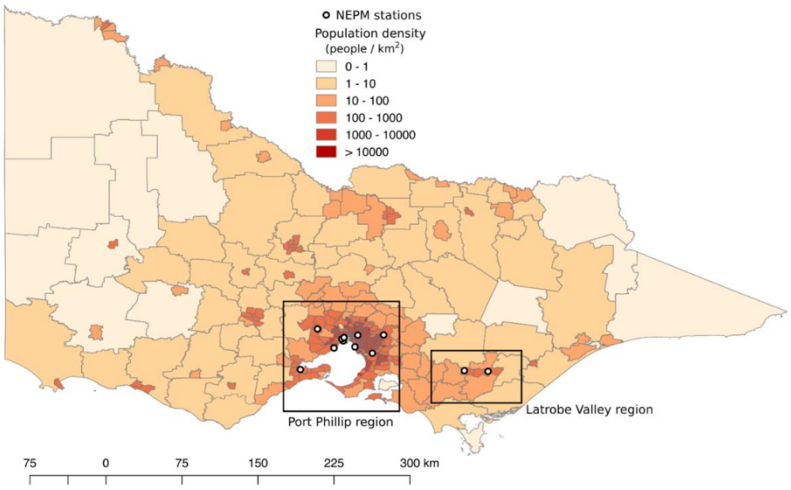


*Figure 1. EPA defined regions, population density and monitoring sites in Victoria, 2020*

Source: Environment Protection Authority Victoria[16]

| Air quality category | $PM_{2.5}$ µg/m³ averaged over 1 hour | $PM_{2.5}$ µg/m³ averaged over 24 hours |
|---|---|---|
| Good | Less than 25 | Less than 12.5 |
| Fair | 25–50 | 12.5–25 |
| Poor | 50–100 | 25–50 |
| Very poor | 100–300 | 50–150 |
| Extremely poor | More than 300 | More than 150 |

*Figure 2. EPA air quality categories and corresponding levels of PM2.5*

Source: Environment Protection Authority Victoria[17]

The 2019-2020 bushfires highlighted the need for improved monitoring of the health events associated with bushfire smoke. Following the 2019-2020 Bushfires, the Royal

Commission proposed several recommendations, including establishing a near real-time, nationally uniform system that provides consistent and clear public health advice.[18] Health monitoring of events related to air pollution from bushfires aids in surge capacity planning and ensures effective risk communication, allowing officials to provide timely and accurate health impact information to the public.[18]

## Syndromic surveillance for bushfire events

Syndromic surveillance is a public health tool that can be used to identify when smoke from bushfires is impacting human health. Syndromic surveillance generates evidence for public health action by collecting, analysing and interpreting routinely collected health-related data.[19] Often, the data are symptoms and clinical signs reported by patients and clinicians rather than being based on confirmed cases.[20] The main objective of syndromic surveillance is to identify as fast as possible when an environmental hazard is having an impact on human health, allowing a timelier public health response.[19]

Data collected in emergency departments (ED) is a useful source of information for syndromic surveillance and monitoring the impacts of poor air quality.[21] Emergency departments code clinical diagnoses of people presenting using standardised coding methods.[22] The International Classification of Diseases, tenth revision Australian modification (ICD10-AM) contains several diagnosis codes that, when used alone or in combination, should accurately indicate the impacts of air pollution on human health.[22]

A challenge with ICD-10 for monitoring is delays in coding may limit their utility for rapid monitoring. Triage data, however, is routinely collected structured data and an unstructured free-text history of presenting complaints, capturing the rapid assessment of the presentation.[23] Natural language processing (NLP) uses various methods to analyse and understand human language and has been applied to data acquired at Emergency Department (ED) triage to predict various outcomes.[23] By identifying ICD-10 associated with triage text using natural language processing (NLP), syndromic surveillance practitioners can develop a 'Poor Air Quality Syndrome' that can be used for rapid monitoring.

### Identifying 'Bellwether' conditions for monitoring

The objective of syndromic surveillance is to detect as soon as possible when an environmental hazard is impacting human health.[21,24] Previous studies have explored the relationship between bushfire smoke and emergency department presentations.[25,26] This research will focus on identifying health events that demonstrate a rapid and consistent rise at the start of exposure to a health hazard. These conditions will act as a 'bellwether' or something that leads or indicates a trend.[27] This will enable syndromic surveillance to identify when poor air quality impacts human health as fast as possible to allow for prompt public health action.

This analysis aims to identify the acute clinical conditions associated with the start of poor air quality hazards that can be effectively used for ongoing monitoring during bushfire events. First, we investigate which ICD-10 codes used in emergency departments correlate with daily maximum 24-hour $PM_{2.5}$ level changes. Second, we seek to determine which ICD-10 codes exhibit a rapid and consistent increase during periods of elevated $PM_{2.5}$, making them suitable candidates for syndromic surveillance. This will aid in developing a robust 'Poor Air Quality Syndrome' surveillance system to inform rapid and effective public health responses.

## Methods

### Study Design and Setting

This study employed a retrospective, ecological design to investigate the relationship between air quality, specifically $PM_{2.5}$ levels, and health outcomes measured by emergency department (ED) visits in Victoria, Australia. The study period was ten years, from 2014 to 2023.

### Data sources

#### Victorian Emergency Minimum Dataset (VEMD)

The Victorian Emergency Minimum Dataset (VEMD), a database containing information on all ED presentations across Victoria, was used for ED visit data for the study period.

For this study, variables included in the analysis were the postcode of the patient's home address, arrival date at the emergency department, and clinical diagnosis (ICD-10).

ED visits are coded by clinicians, using the International Classification of Diseases, 10th Revision (ICD-10) coding system, which has been in use in Australia since 1997.[22] All ICD-10 codes were included in the analysis. ICD-10 codes were aggregated to core category codes, consisting of one letter and two numbers, which represent broad diagnostic categories. Daily ICD-10 counts were calculated for each postcode from 12:00 am to 11:59 pm.

### Environmental Protection Authority (EPA) Data

Air quality data were obtained from the Victorian Environmental Protection Authority (EPA). The EPA maintains 39 monitoring sites in population centres throughout Victoria (Appendix A and B). Daily maximum $PM_{2.5}$ values were calculated for each monitoring site from 12:00 a.m. to 11:59 p.m.

Postcodes were assigned to an EPA monitor if they were within a 10km radius of each monitor (Appendix C). Hourly mean concentrations for sites within 20 km of each other are highly correlated.[28] Postcodes with at least 50% of their area within the radius were included, while those with less than 50% were excluded. The nearest station's value was used for postcodes in the buffer zone of multiple monitoring stations.

## Analysis

### Analysis Part 1: Association between ICD-10 Codes and $PM_{2.5}$ Levels

A time series analysis was conducted to identify ICD-10 codes used in emergency departments that correlate with changes in $PM_{2.5}$. Quasi-Poisson regression models were performed to assess the association between daily maximum $PM_{2.5}$ levels and each daily counts of ICD-10 code under investigation. This was used to adjust for overdispersion in any of the regressions.

$PM_{2.5}$ was categorised as poor air quality for a 24-hour period when the $PM_{2.5}$ level peaked at over 100 µg/$m^3$ for an average of one hour or more. These periods were compared to days with good air quality, defined as those with a peak $PM_{2.5}$ level never above 25 µg/$m^3$ for an average of one hour. These thresholds were chosen to align with the Environmental Protection Agency of Victoria's standard categorisation for good (<25$PM_{2.5}$ µg/$m^3$ averaged over 1 hour) and very poor air quality (100-300 $PM_{2.5}$ µg/$m^3$ averaged over 1 hour).[17] Consistent with other analyses, the model controlled for several potential confounding factors, including the day of the week, season, and average maximum daily temperature.[29–31] Annual population estimates for each postcode were calculated using data from the 2011, 2016, and 2021 censuses and incorporated into the model.[32]

Separate models were run for each ICD-10 code of interest. A ranked table of ICD-10 codes based on the strength of their correlation with $PM_{2.5}$ levels was then made based on the results of the models. Rate ratios, 95% confidence intervals, and p-values were calculated. P-values were adjusted using the Bonferroni correction method to adjust for multiple comparisons and type I errors.[33]

## Analysis Part 2: Identification of Rapidly Rising ICD-10 Codes During Poor Air Quality Events

A time series analysis was conducted to identify ICD-10 codes that demonstrate a rapid and consistent rise during periods of poor air quality hazard. A poor air quality hazard period was defined as a 24-hour period when the $PM_{2.5}$ level peaked at over 100 µg/$m^3$ for an average of at least one hour. This threshold was chosen to align with the Environmental Protection Agency of Victoria's standard categorisation for very poor air quality (100-300 $PM_{2.5}$ µg/$m^3$ averaged over 1 hour).[17] The start of a hazard period was defined when $PM_{2.5}$ levels first exceeded the threshold, and the end was marked when levels dropped below the threshold. Days with high $PM_{2.5}$ levels were grouped into continuous hazard periods.

Two baselines were calculated and compared. Baseline 1 was the average daily count of ICD-10 codes for the 60-day period prior to the start of the poor air quality event, where

air quality was below levels considered good. Analyses conducted using 15 and 30 produced wider confidence intervals, and none of the outcomes remained statistically significant. A 60-day window reduced variance and yielded significant results, so the 60-day baseline was adopted.

Good air quality days were defined as days with a peak $PM_{2.5}$ level never above 25 $\mu g/m^3$ for an average of one hour. This threshold was chosen to align with the Environmental Protection Agency of Victoria's standard categorisation for good air quality (less than 25 $PM_{2.5}$ $\mu g/m^3$ averaged over one hour).[17] Baseline 2 is the average of the seven daily counts immediately before the event in each of the previous five years.

The statistical analysis was conducted at two levels: for hazard periods at each monitoring station and the associated ICD-10 counts for assigned postcodes within a 10-kilometre radius, and for ICD-10 counts across Victoria during the January 2020 bushfire period, where air quality was poor across the whole State.[15] This stratified approach accounted for limitations associated with the air monitoring coverage.[16] Rate ratios, 95% confidence intervals, and p-values were calculated. P-values were adjusted using the Bonferroni correction method to adjust for multiple comparisons and type I errors.[33]

## Analysis Part 3: Summary of findings

ICD-10 events that approached statistical significance were included in the analysis ($p < 0.2$). ICD-10 codes were categorised into the chapter level of the ICD-10, the highest level of the ICD-10, and grouped diagnoses into broad categories based on body systems, conditions, or specific health-related themes.[22] Daily counts of emergency department presentations for each identified ICD-10 code were plotted against poor air quality periods during the 2019–2020 Victorian bushfire season and described.

## Ethical considerations

Ethics approval for this project was granted through the Department of Health and Department of Families, Fairness, and Housing Human Research Ethics Committee

(Protocol 104557). The main concern related to maintaining the privacy of people whose data were used, which was achieved by working only with de-identified data.

# Results

## Air quality

During the study period from 2014 to 2023, the daily mean $PM_{2.5}$ air quality reading was 13.5 *μm/m³*, while the maximum recorded $PM_{2.5}$ hourly average value was 1,349 *μm/m³* (Table 1 and Figure 3). This was recorded in Morwell South during the Hazelwood mine fire event in 2014.[34] Sites such as Morwell East (mean = 16.5 μg/m$^3$, max = 346.8 μg/m$^3$), Melbourne CBD (mean = 16.6 μg/m$^3$, max = 411.5 μg/m$^3$), and Churchill (mean = 15.9 μg/m$^3$, max = 362.5 μg/m$^3$) reported the highest mean daily maximum $PM_{2.5}$ concentrations (Appendix A).

*Table 1. Distribution characteristics of daily maximum PM2.5 for Victoria from January 2014 to December 2023*

| | Daily Maximum (μg/m$^3$) | | | | |
|---|---|---|---|---|---|
| | Minimum | Median | Mean | Maximum | SD |
| Victoria | 0 | 10.9 | 13.5 | 1,349 | 18.7 |

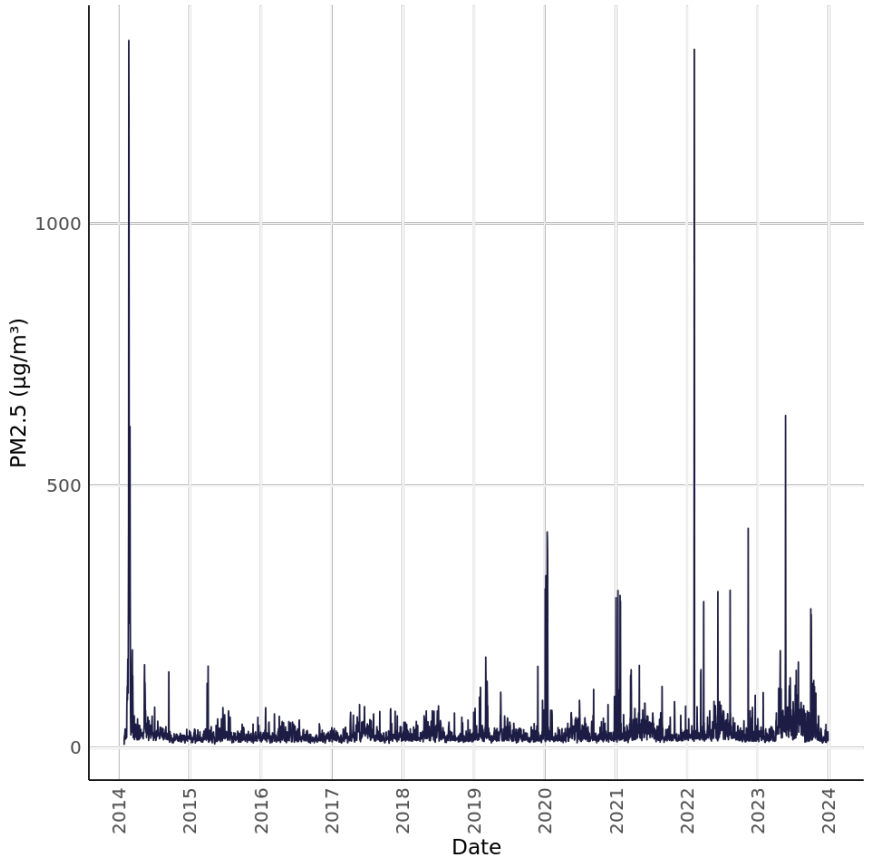


*Figure 3. Daily maximum $PM_{2.5}$ across the whole of Victoria from January 2014 to December 2023*

## Emergency Department presentations

From 2014 to 2023 there were a total of 11,654,903 emergency department presentations. Across the study period, the annual number of patient presentations increased from 1,569,189 in 2014 (27,593 per 100,000 population) to 1,953,911 in 2023 (30,077 per 100,000 population) (Figure 4). The daily number of emergency department patient presentations was 11,654,903 across the investigation period. This increased from an average daily number of patient presentations of 4296 (76 per 100,000 population) in 2014 to 5350 in 2023 (82 per 100,000 population). The types of presentations by the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) groups are outlined in Appendix D.

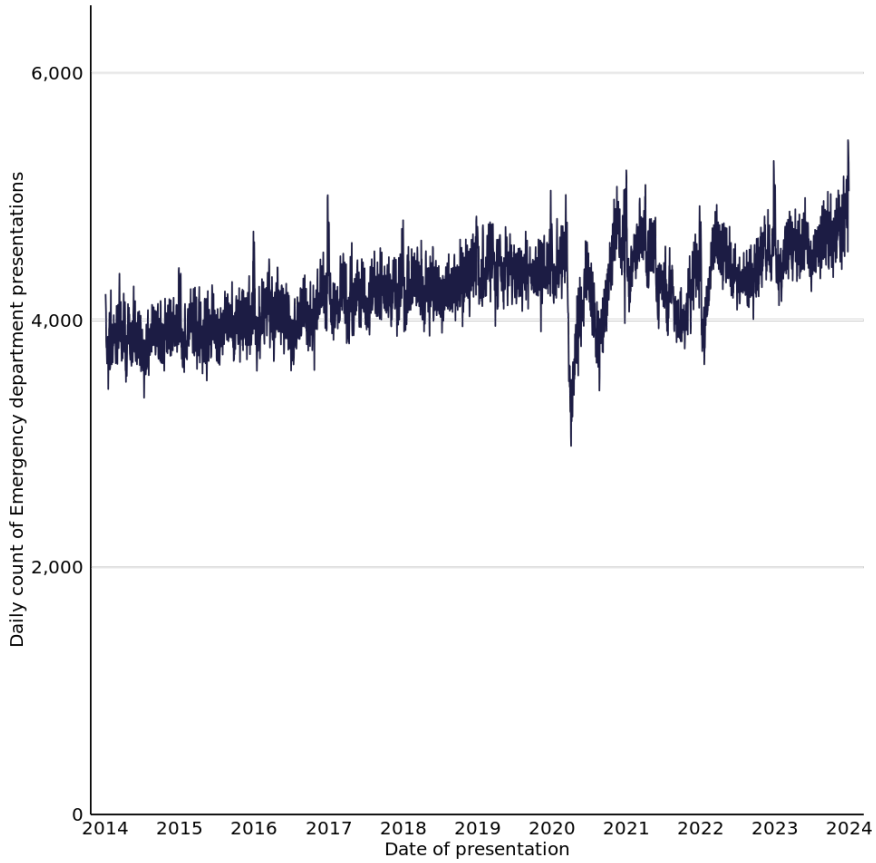


*Figure 4. Daily counts of Emergency Department presentations in Victoria from January 2014 to December 2023*

## Analysis Part 1: Association between ICD-10 Codes and $PM_{2.5}$ Levels

Time series analysis was conducted using Poisson regression models comparing hazard periods of poor air quality (days with hourly peak of greater than 100 µg/$m^3$) with days of good air quality (days with hourly peak of less than 25 µg/$m^3$). Identified ICD-10 codes that were approaching statistical significance (p-value < 0.2) with changes in $PM_{2.5}$ levels are presented in Table 2 and Figure 5.

Emergency department presentations for angina pectoris (I20) were significantly higher, with a rate ratio of 1.82 (95% CI 1.49–2.23, p < 0.001). Other cardiovascular conditions, such as heart failure (I50), showed a significant increase, with a rate ratio of 1.52 (95% CI 1.31–1.76, p < 0.001). The rate of asthma presentations (J45) increased significantly during high $PM_{2.5}$ days, with a rate ratio of 1.28 (95% CI 1.14–1.44, p < 0.001). The general

symptom presentation of cough (R05) also showed a significant increase, with a rate ratio of 1.43 (95% CI 1.24–1.66, p < 0.001).

*Table 2. Poisson regression results calculated between ICD-10 coded cases and daily maximum $PM_{2.5}$: all Victorian data, 2014-20223*

| ICD-10 Code | Description | Rate, n/day | Rate ratio | 95% confidence interval | p value |
|---|---|---|---|---|---|
| I20 | Angina pectoris | 23 | 1.82 | 1.49–2.23 | < 0.001 |
| I50 | Heart failure | 31 | 1.52 | 1.31–1.76 | < 0.001 |
| M25 | Other joint disorders, not elsewhere classified | 24 | 1.49 | 1.30–1.71 | < 0.001 |
| R05 | Cough | 25 | 1.43 | 1.24–1.66 | < 0.001 |
| I21 | Acute myocardial infarction | 30 | 1.37 | 1.13–1.66 | 0.16 |
| K35 | Acute appendicitis | 30 | 1.31 | 1.12–1.54 | 0.10 |
| I49 | Other cardiac arrhythmias | 28 | 1.29 | 1.12–1.49 | 0.07 |
| J45 | Asthma | 67 | 1.28 | 1.14–1.44 | < 0.001 |

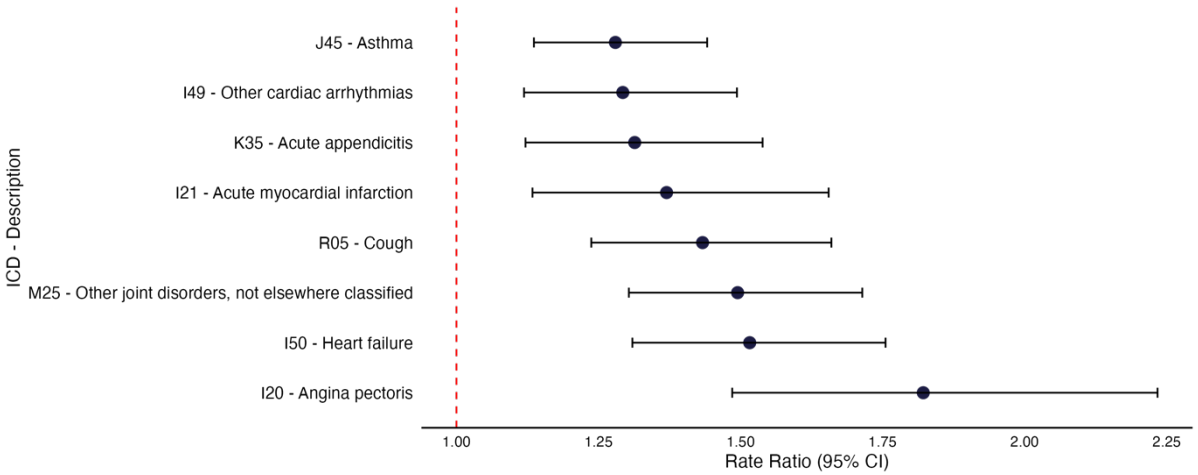


*Figure 5. Forest plot of rate ratio and 95% confidence interval for the relationship between ICD-10 coded cases and daily maximum $PM_{2.5}$: Quasi-Poisson regression results, 2014-2023*

## Analysis Part 2: Identification of Rapidly Rising ICD-10 Codes During Poor Air Quality Events

### Monitoring station level

A time series analysis was conducted to identify ICD-10 codes that exhibited a rapid and consistent increase at the start of each hazard period. Hazard periods were defined at each monitoring station, and the associated ICD-10 counts for assigned postcodes within a 10-kilometre radius of each monitoring station.

### Hazard periods compared to leading 60-day baseline

For each monitoring station, the start of a poor air quality hazard period (days with an hourly peak of greater than 100 µg/m$^3$) was compared to days of good air quality (days with an hourly peak of less than 25 µg/m$^3$) in the 60 days leading up to the start of each hazard period. Identified ICD-10 codes approaching statistical significance (p-value < 0.2) with changes in $PM_{2.5}$ levels are presented in Table 3. Only one presentation, asthma (J45), increased significantly during high $PM_{2.5}$ days, with a rate ratio of 1.53 (95% CI 1.24–1.89, p < 0.001) compared to the 60-day baseline.

*Table 3. Rate ratios calculated between ICD-10 coded cases and daily maximum $PM_{2.5}$ for hazard periods compared to the 60 days prior: 10 km radius of monitoring stations, 2014-2023*

| ICD-10 Code | Description | Rate, n/day | Rate ratio | 95% confidence interval | p value |
|---|---|---|---|---|---|
| J45 | Asthma | 67 | 1.53 | 1.24–1.89 | < 0.001 |

### Hazard periods compared to 5-year seven-day baseline

For each monitoring station, the start of a poor air quality hazard period (days with an hourly peak of greater than 100 µg/m$^3$) was compared to the average of the seven daily counts immediately before the event in each of the previous five years. Identified ICD-10 codes that were approaching statistical significance (p-value < 0.2) with changes in $PM_{2.5}$ levels are presented in Table 4. Only one presentation, asthma (J45), increased

significantly during high $PM_{2.5}$ days, with a rate ratio of 1.83 (95% CI 1.48–2.27, p < 0.001) compared to the 5-year baseline.

*Table 4. Rate ratios calculated between ICD-10 coded cases and daily maximum $PM_{2.5}$ for hazard periods compared to the 5-year baseline: 10 km radius of monitoring stations, 2014-2023*

| ICD-10 Code | Description | Rate, n/day | Rate ratio | 95% confidence interval | p value |
|---|---|---|---|---|---|
| J45 | Asthma | 67 | 1.83 | 1.48–2.27 | < 0.001 |

## The whole of Victoria during the 2020 bushfire period

A time series analysis was conducted to identify ICD-10 codes that exhibited a rapid and consistent increase at the start of each hazard period. The hazard period was defined as a severe poor air quality period during the bushfire season of December 2019 to January 2020, specifically from January 13 to January 15, 2020, for the whole of Victoria.

### Hazard periods compared to leading 60-day baseline

The poor air quality hazard period for the whole of Victoria was compared to days of good air quality (days with an hourly peak of less than 25 µg/$m^3$) in the 60 days leading up to the start of the hazard period. Identified ICD-10 codes approaching statistical significance (p-value < 0.2) with changes in $PM_{2.5}$ levels are presented in Table 5 and Figure 6.

Asthma (J45) presentations increased, with a rate ratio of 1.59 (95% CI 1.45–1.73, p < 0.001). Presentations for toxic effects of gases, fumes, and vapours (T59) increased, with a rate ratio of 2.53 (95% CI 1.57–4.08, p = 0.07). Significant increases were observed for abnormalities of breathing (R06), which had a rate ratio of 1.38 (95% CI 1.25–1.51, p <

0.001), and pain in the throat and chest (R07), which increased with a rate ratio of 1.13 (95% CI 1.07–1.19, p < 0.001).

*Table 5. Rate ratios calculated between ICD-10 coded cases and daily maximum $PM_{2.5}$ for hazard periods compared to the 60 days prior: Whole of Victoria December January 2019–2020*

| ICD-10 Code | Description | Rate, n/day | Rate ratio | 95% confidence interval | p value |
|---|---|---|---|---|---|
| T59 | Toxic effect of other gases, fumes and vapours | 1 | 2.53 | 1.57–4.08 | 0.07 |
| H60 | Otitis externa | 18 | 1.75 | 1.44–2.12 | < 0.001 |
| K61 | Abscess of anal and rectal regions | 10 | 1.6 | 1.27–2.03 | 0.05 |
| J45 | Asthma | 67 | 1.59 | 1.45–1.73 | < 0.001 |
| O21 | Excessive vomiting in pregnancy | 10 | 1.59 | 1.25–2.02 | 0.09 |
| E87 | Other disorders of fluid, electrolyte and acid-base balance | 17 | 1.47 | 1.22–1.77 | 0.03 |
| O36 | Maternal care for other known or suspected fetal problems | 15 | 1.43 | 1.19–1.73 | 0.09 |
| R06 | Abnormalities of breathing | 57 | 1.38 | 1.25–1.51 | < 0.001 |
| R07 | Pain in throat and chest | 202 | 1.13 | 1.07–1.19 | < 0.001 |

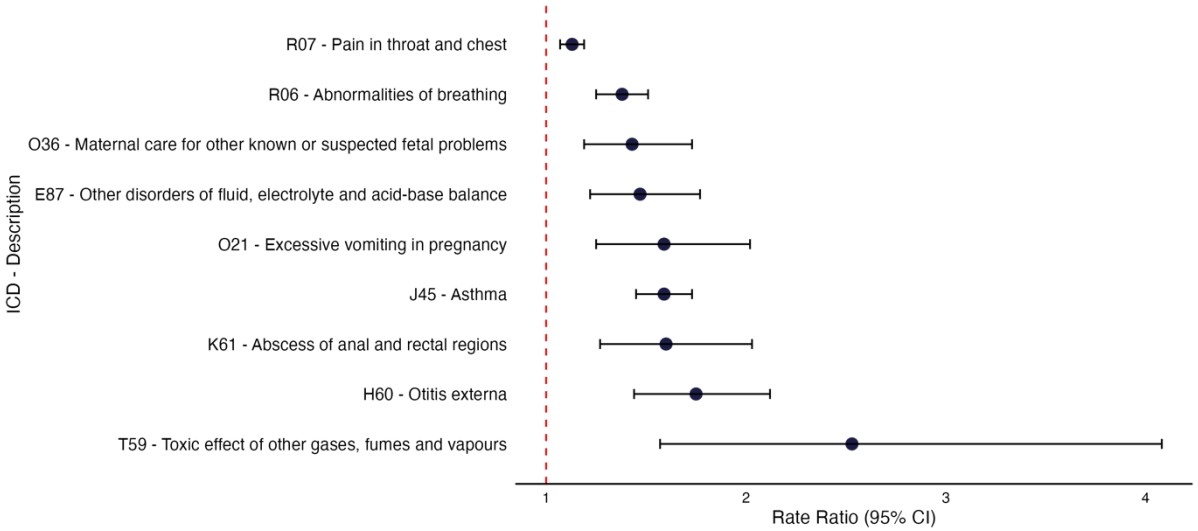


*Figure 6. Forest plot of rate ratios calculated between ICD-10 coded cases and daily maximum $PM_{2.5}$ for hazard periods compared to the 60 days prior: Whole of Victoria December January 2019–2020*

## Hazard periods compared to 5-year annual baseline

The poor air quality hazard period was compared to the average of the seven daily counts immediately before the event in each of the previous five years. Identified ICD-10 codes approaching statistical significance (p-value < 0.2) with changes in $PM_{2.5}$ levels are presented in Table 6 and Figure 7.

The toxic effects of other gases, fumes, and vapours (T59) significantly increased, with a rate ratio of 3.75 (95% CI 1.92–7.32, p = 0.05), Emphysema (J43) and asthma (J45) also increased, with rate ratios of 3.66 (95% CI 1.98–6.77, p = 0.02) and 3.27 (95% CI 2.88–3.72, p < 0.001), respectively.

Other respiratory-related diagnoses, including the symptom-based abnormalities of breathing (R06) and other respiratory disorders (J98), demonstrated increases in presentations, with rate ratios of 2.36 (95% CI 2.07–2.70, p < 0.001) and 2.22 (95% CI 1.50–3.27, p = 0.03), respectively. During hazard periods, there were increased presentations for maternal care for conditions related to pregnancy (O26), with a rate ratio of 2.29 (95% CI 1.84–2.85, p < 0.001).

Presentations for symptom-based presentations including malaise and fatigue (R53), symptoms involving emotional state (R45), and syncope and collapse (R55) all increased significantly during the hazard periods, with rate ratios of 1.74 (95% CI 1.36–2.23, p = 0.01), 1.7 (95% CI 1.46–1.98, p < 0.001), and 1.44 (95% CI 1.26–1.65, p < 0.001), respectively.

*Table 6. Rate ratios calculated between ICD-10 coded cases and daily maximum $PM_{2.5}$ for hazard periods compared to a 5-year baseline: Whole of Victoria December January 2019–2020*

| ICD-10 Code | Description | Rate, n/day | Rate ratio | 95% confidence interval | p value |
|---|---|---|---|---|---|
| T59 | Toxic effect of other gases, fumes and vapours | 1 | 3.75 | 1.92–7.32 | 0.05 |
| J43 | Emphysema | 2 | 3.66 | 1.98–6.77 | 0.02 |
| J45 | Asthma | 67 | 3.27 | 2.88–3.72 | < 0.001 |
| R06 | Abnormalities of breathing | 57 | 2.36 | 2.07–2.70 | < 0.001 |
| O26 | Maternal care for other conditions predominantly related to pregnancy | 23 | 2.29 | 1.84–2.85 | < 0.001 |
| J98 | Other respiratory disorders | 8 | 2.22 | 1.50–3.27 | 0.03 |
| R29 | Other symptoms and signs involving the nervous and musculoskeletal systems | 27 | 2.1 | 1.74–2.52 | < 0.001 |
| R53 | Malaise and fatigue | 20 | 1.74 | 1.36–2.23 | 0.01 |
| R45 | Symptoms and signs involving emotional state | 45 | 1.7 | 1.46–1.98 | < 0.001 |
| E87 | Other disorders of fluid, electrolyte and acid-base balance | 17 | 1.65 | 1.27–2.14 | 0.09 |
| R69 | Illness, unspecified | 78 | 1.61 | 1.43–1.82 | < 0.001 |
| T07 | Unspecified multiple injuries | 28 | 1.55 | 1.26–1.92 | 0.02 |
| R55 | Syncope and collapse | 72 | 1.44 | 1.26–1.65 | < 0.001 |
| R07 | Pain in throat and chest | 202 | 1.27 | 1.18–1.37 | < 0.001 |
| M79 | Other soft tissue disorders, not elsewhere classified | 91 | 1.26 | 1.11–1.42 | 0.13 |

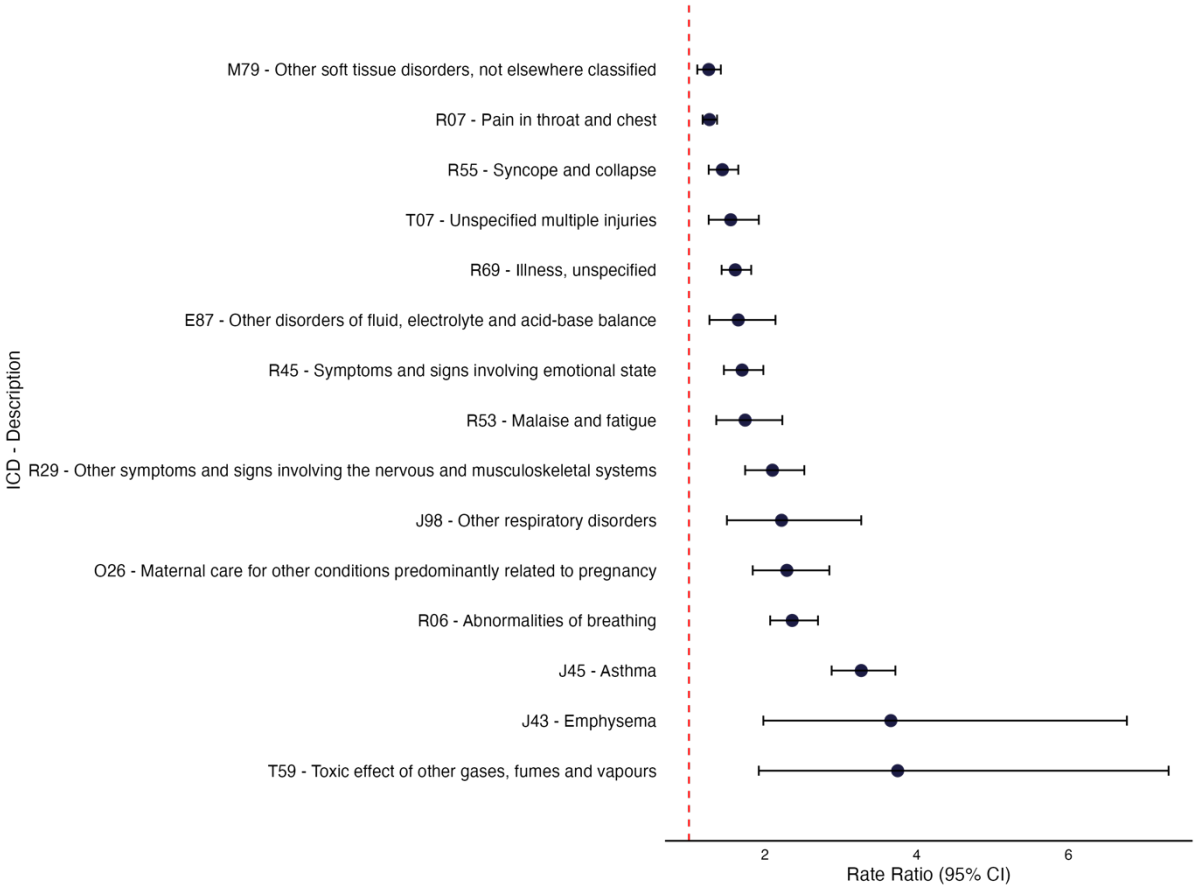


*Figure 7. Forest plot rate ratios calculated between ICD-10 coded cases and daily maximum $PM_{2.5}$ for hazard periods compared to the 5-year baseline: Whole of Victoria December January 2019–2020*

## Summary of findings

This summary presents the short-term health impacts of elevated PM2.5 levels from periods of poor air quality, based on findings from Parts 1 and 2 of the analysis (Figure 8). Toxic effects of gases, fumes, and vapours (T59) increased presentations during poor air quality hazards, with rate ratios ranging from 2.53 (p = 0.05) to 3.75 (p = 0.07).

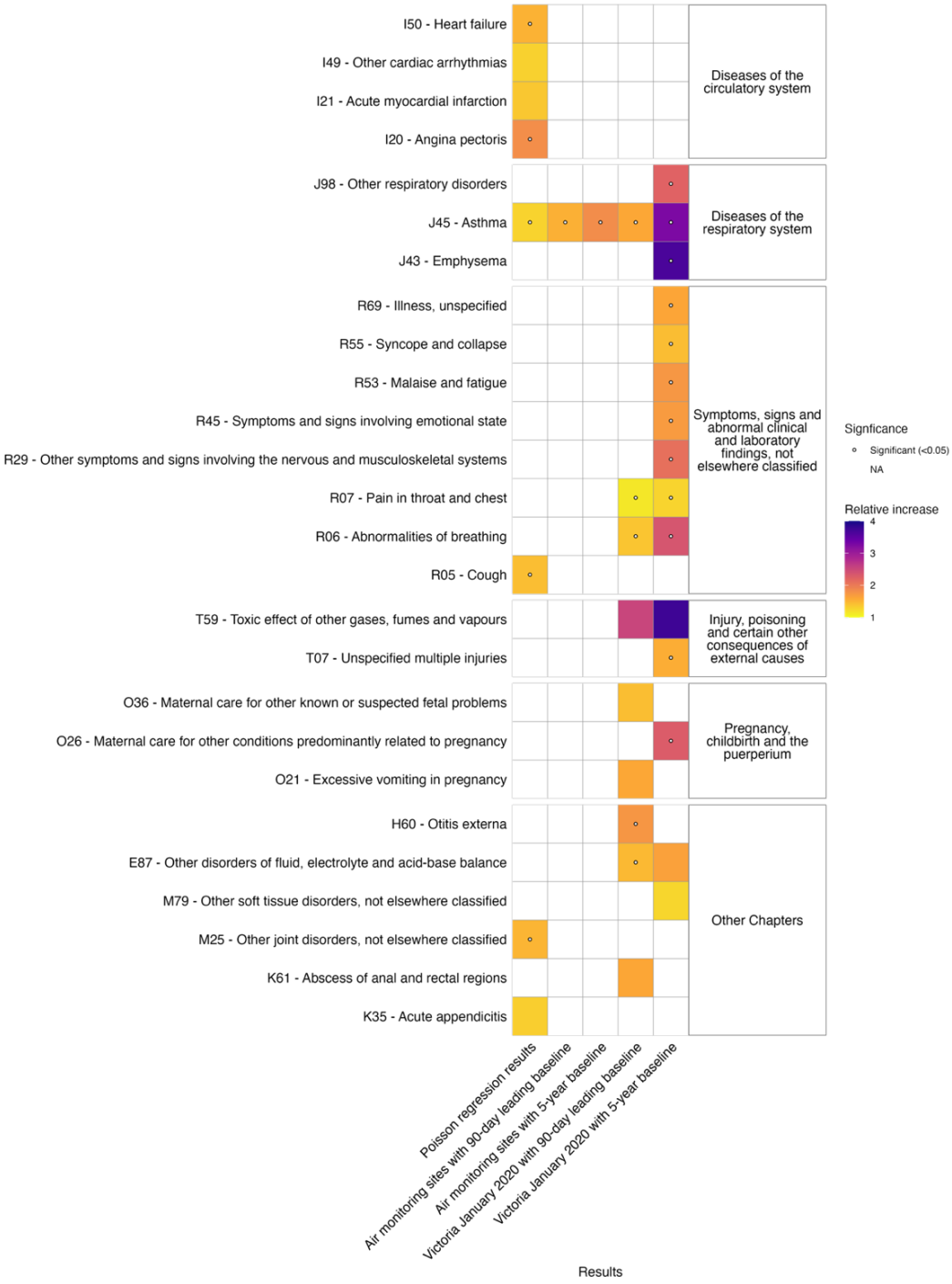


*Figure 8. Heatmap for selected (p<0.2) results of analysis of $PM_{2.5}$ for hazard periods and ICD-10 codes. The colour gradient indicates the strength of the association*

Increases in presentations were identified for multiple respiratory conditions during periods of poor air quality. Asthma (J45) was identified in all analyses, with rate ratios ranging from 1.28 to 3.27 ($p < 0.001$). Other respiratory conditions, emphysema (J43, rate ratio 3.66, $p = 0.02$), and respiratory disorders not classified elsewhere (J98, rate ratio 2.22, $p = 0.03$), showed increases in one analysis. Statewide trends in emergency department presentations for asthma are presented during the 2019–2020 December January bushfire season (Figure 9).

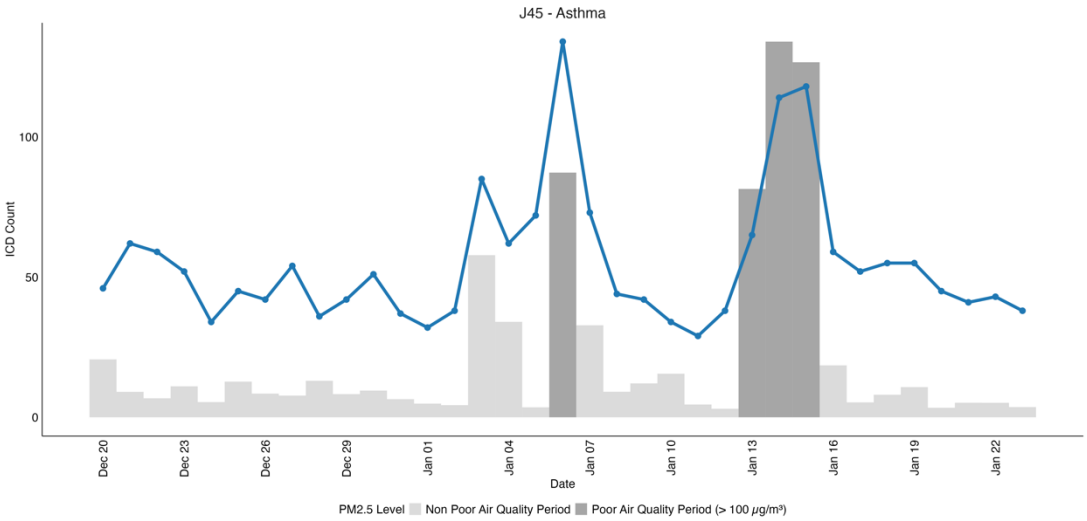


*Figure 9. Trends in emergency department presentations for Asthma (J45) during poor air quality periods ($PM_{2.5}$ > 100 µg/m$^3$)*

Cardiovascular impacts were identified in one analysis, although rate ratios were smaller when compared to respiratory conditions. Associations were found for conditions including angina pectoris (I20, rate ratio 1.82, $p < 0.001$), heart failure (I50, rate ratio 1.52, $p < 0.001$), and other cardiac arrhythmias (I49, rate ratio 1.29, $p = 0.07$).

Across the analyses, increases in presentations were identified ICD-10 codes from the chapter: 'Symptoms, signs, and abnormal clinical and laboratory findings not classified elsewhere'. Conditions including cough (R05, rate ratio 1.43, $p < 0.001$), abnormalities of breathing (R06, rate ratio 1.38–1.74, $p < 0.001$), pain in throat and chest (R07, rate ratio 1.13, $p < 0.001$), malaise and fatigue (R53, rate ratio 1.74, $p = 0.01$), and syncope and collapse (R55, rate ratio 1.44, $p < 0.001$) had significant associations.

Several pregnancy-related conditions were associated with high $PM_{2.5}$ levels. Presentations for excessive vomiting in pregnancy (O21, rate ratio 1.59, $p = 0.09$) and maternal care for other conditions related to pregnancy (O26, rate ratio 2.29, $p < 0.001$) increased during periods of poor air quality.

## Discussion

This study identified a set of ICD-10 codes used in emergency departments that demonstrate a rapid rise during poor air quality hazard periods that could be candidate 'bellwether conditions' for use in syndromic surveillance. Consistent with other literature, we find strong evidence of emergency department presentations for asthma increasing during periods of poor air quality.[35–37] It was also identified that emergency department presentations for general symptoms, rather than specific diagnoses, increase during periods of poor air quality.

The finding that asthma consistently increases during poor air quality events indicates it is likely an appropriate candidate for syndromic monitoring. Consistent with the literature, it is well established higher rates of hospital admissions for respiratory diseases and emergency department visits are associated with exposure to particulate matter.[35–37] Bushfire smoke has been found to be associated with less severe symptoms in those with asthma, including breathlessness, wheezing, and cough.[38] A systematic review identified significant associations between bushfires and asthma, with the most significant effects on the day of exposure.[39] The clear relationship between asthma and poor air quality and its rise at the start of the hazard period supports its use in monitoring for syndromic surveillance.

A collection of general symptoms classified in Symptoms, Signs, and Abnormal Findings Not Elsewhere Classified were associated with periods of poor air quality. This chapter includes symptoms, signs, abnormal results of clinical or other investigative procedures, and ill-defined conditions regarding which no diagnosis classifiable elsewhere is recorded.[22] These findings suggest a broad collection of symptoms, such as cough and difficulty breathing, rather than specific diagnoses during poor air quality periods. These findings are supported by research that found ED visits for general symptoms increase

during periods of increased bushfire smoke.[37] the non-specific nature of these symptom categories, the strength of associations may be greater when they are grouped together. Further investigation of these symptom-based ICD-10 should be conducted to inform their use for poor air quality syndromic surveillance in emergency departments.

Cardiovascular conditions, such as cardiac arrhythmia and heart failure, demonstrated some associations but were not as strong when compared to respiratory. Exposure to bushfire smoke has demonstrated increases in presentations of cardiovascular-related health issues such as acute myocardial infarction, cardiovascular mortality, cardiovascular emergency department visits and hospitalisation, cardiac arrest, as well as heart failure.[14,40,41] Evidence for cardiovascular impacts indicates they demonstrate a lagged effect of 48 hours of exposure for cardiac arrest and 2 to 3 days for ischaemic heart disease.[39] This likely is why an effect was only found in the Poisson regression and not in analyses looking at the first day of hazard periods. The weaker association and lagged effect of cardiovascular conditions limit their suitability for monitoring, where the objective is to identify as fast as possible where a hazard is impacting human health.

Several associations were identified with pregnancy-related ICD-10 codes and monitoring high-risk groups could improve the ability of the syndromic surveillance system to detect health events associated with poor air quality. Pregnant individuals are at risk of the adverse health effects of air pollutant exposure due to increased respiration and cardiovascular output during pregnancy.[42] There is limited evidence on the short-term effects, with research focusing on birthweight reduction, low birthweight and preterm birth.[42] Other at-risk groups identified as being more sensitive to changes in air quality include people over 65 years old, people with heart or lung conditions, and children under 14 years old.[17] Stratified analysis by age, and further analysis of pregnancy related symptoms during poor air quality period could provide a further understanding of groups at highest risk during these periods.

Further analysis of the identified ICD-10 codes would be helpful to improve research findings. Prior to the implementation of ICD-10 codes in syndromic surveillance, the findings could be improved by validating the findings against other known poor air quality

events. Additionally, assessing how identified ICD-10 codes change across a poor air quality period at a more granular level, such as hourly, may improve understanding of the most appropriate codes to use for monitoring. Additional investigations may also provide insight into potential false positives generated from this study.

This analysis has several limitations. The methodological approach is prone to Type I error.[33] Testing for multiple associations between the exposure and multiple ICD-10 codes increases the risk of false positive research findings, which can falsely inflate research findings. This is the plausible explanation of the unlikely significant associations identified. The unit of analysis was postcode and could be subject to mismeasurement, particularly for residents who spend time outside of their home postcode.

There was poor coverage of the Victorian monitoring stations prior to 2020.[16] The EPA network of ambient air quality monitors is limited to parts of the Port Phillip and Latrobe Valley regions,[16] and the analysed data may not be representative of the general Victorian population. This analysis used a $PM_{2.5}$ threshold of greater than 100 µg/$m^3$ based on EPA guidelines. However, there is no evidence of a threshold below which exposure to $PM_{2.5}$ does not cause any health effects.[43] There may be health effects at lower levels not measured by our analysis. $PM_{2.5}$ measurements reflect ambient conditions and do not reflect variations in how much ambient pollution filters indoors, which may better reflect a person's true exposure during poor air quality periods.

**Conclusions**

This analysis identified several acute clinical conditions associated with poor air quality that can be effectively used for ongoing monitoring during bushfire events including for respiratory conditions and general symptoms. Further investigation of the subset of ICD-10 codes will be required to ensure their suitability for monitoring during poor air quality events. The identified ICD-10 codes can then be associated with triage text using natural language processing (NLP) to develop a 'Poor Air Quality Syndrome'. This will aid in developing a robust 'Poor Air Quality Syndrome' surveillance system to monitor the impacts of smoke during bushfire seasons.

As global warming continues to increase the frequency of bushfires in Australia, smoke pollution will increasingly become an important environmental hazard. This work contributes to the growing literature on the impact of smoke pollution on human health. The development of surveillance systems to monitor the health impacts rapidly is crucial to responding to this impact and preventing the negative consequences of bushfire smoke on human health.

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# Appendix

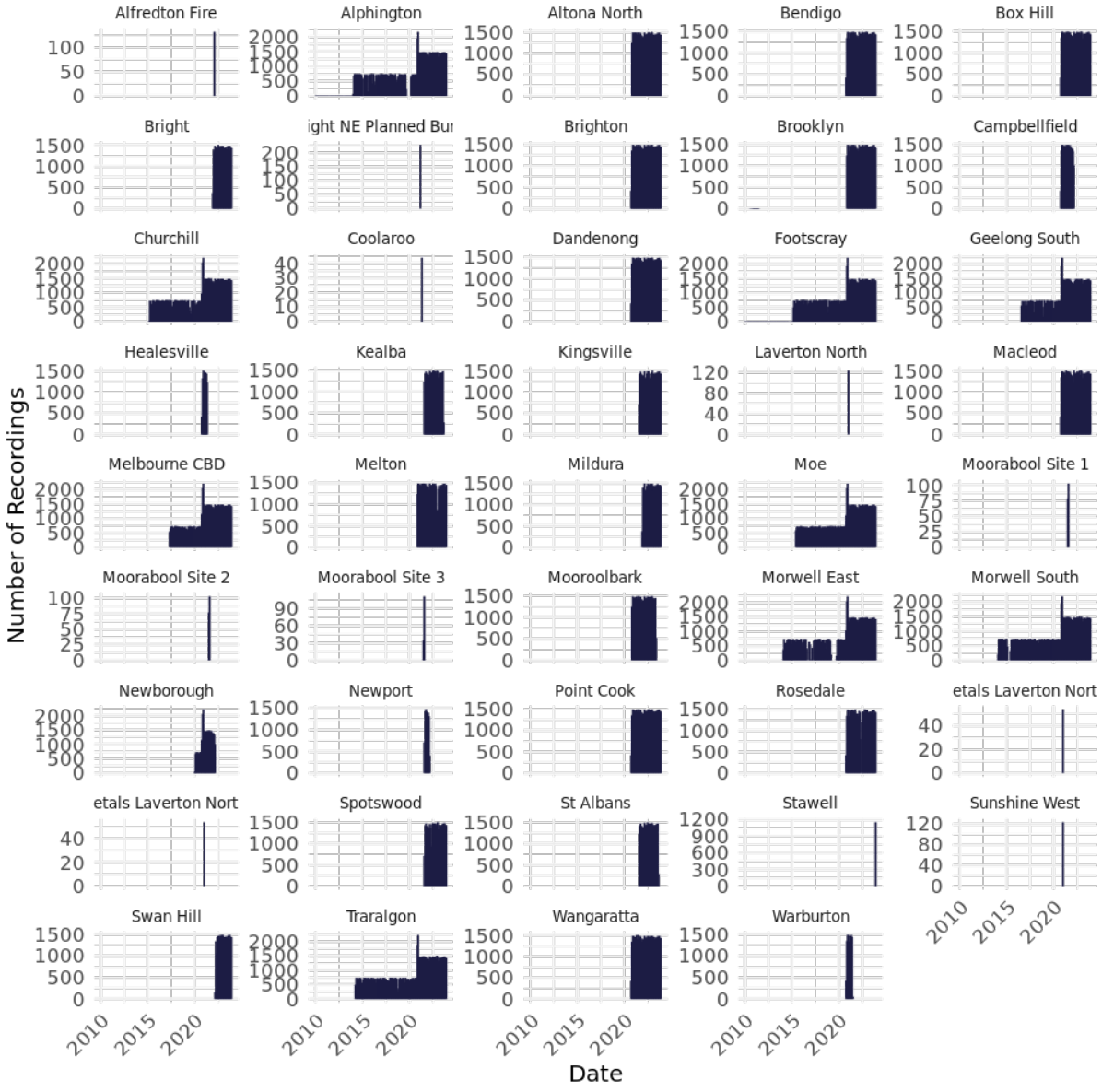
## Appendix A – Summary of Air Quality Monitoring Sites: distribution characteristics, days of operation, year first and last record

| | Daily Maximum ($\mu g/m^3$) |
|---|---|

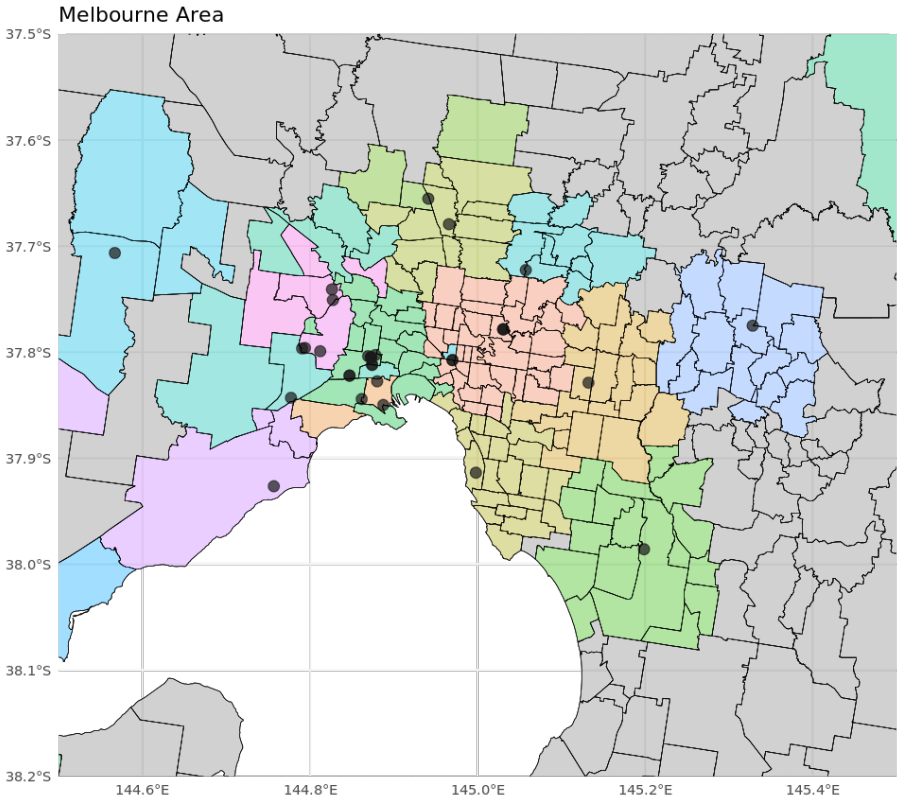
| Monitoring Site | Minimum | Mean | Maximum | Days with recordings | Year of first record | Year of last record |
|---|---|---|---|---|---|---|
| Wangaratta | 0 | 16.3 | 133.3 | 1071 | 2020 | 2023 |
| Brighton | 0.8 | 13.1 | 157 | 1152 | 2020 | 2023 |
| Bendigo | 1 | 10.4 | 86.2 | 1145 | 2020 | 2023 |
| Coolaroo | 3.8 | 6.4 | 8.9 | 2 | 2021 | 2021 |
| Laverton North | 3.5 | 4.6 | 6.8 | 4 | 2021 | 2021 |
| Macleod | 0.6 | 9.2 | 1332 | 1101 | 2020 | 2023 |
| Moorabool Site 3 | 0.9 | 3.5 | 6.4 | 4 | 2021 | 2021 |
| Swan Hill | 0.1 | 8.4 | 147.5 | 527 | 2022 | 2023 |
| Warburton | 1.1 | 12.6 | 299.9 | 258 | 2020 | 2021 |
| Moorabool Site 2 | 0.9 | 1.5 | 2.1 | 5 | 2021 | 2021 |
| Mildura | 0.4 | 8.7 | 163.4 | 661 | 2021 | 2023 |
| Moe | 0 | 15.6 | 327.1 | 3064 | 2015 | 2023 |
| Geelong South | 2.7 | 13.1 | 366.3 | 2498 | 2016 | 2023 |
| Morwell East | 0.9 | 16.5 | 346.8 | 3036 | 2014 | 2023 |
| Point Cook | 3.6 | 8.9 | 100 | 1143 | 2020 | 2023 |
| Newborough | 4.2 | 15.6 | 71.4 | 771 | 2020 | 2022 |
| Bright | 0.2 | 12.7 | 633.7 | 720 | 2021 | 2023 |
| Altona North | 0.7 | 6.4 | 45.8 | 1109 | 2020 | 2023 |
| Newport | 0 | 1.7 | 15.1 | 174 | 2021 | 2022 |
| Campbellfield | 2.2 | 15.9 | 286.1 | 517 | 2020 | 2022 |
| Melton | 4 | 14.4 | 300.2 | 1078 | 2020 | 2023 |
| Brooklyn | 2 | 10.3 | 47.3 | 1112 | 2020 | 2023 |
| Healesville | 0 | 7 | 48.9 | 207 | 2020 | 2021 |
| Alphington | 1.2 | 16.6 | 129.3 | 3269 | 2014 | 2023 |
| Stawell | 1 | 3.5 | 11.5 | 24 | 2023 | 2023 |
| Melbourne CBD | 3.6 | 16.6 | 411.5 | 2363 | 2017 | 2023 |
| Dandenong | 4.1 | 11.3 | 199.6 | 1165 | 2020 | 2023 |
| Churchill | 1.1 | 15.9 | 362.5 | 3062 | 2015 | 2023 |
| Kealba | 0 | 6 | 43 | 691 | 2021 | 2023 |
| Traralgon | 2.8 | 16.7 | 338.4 | 3422 | 2014 | 2023 |
| Rosedale | 0 | 10.4 | 159.7 | 967 | 2020 | 2023 |
| Box Hill | 0.9 | 12 | 105.1 | 1158 | 2020 | 2023 |
| Mooroolbark | 3.4 | 13.7 | 290.5 | 940 | 2020 | 2023 |
| Kingsville | 1 | 6.5 | 51.8 | 669 | 2021 | 2023 |
| Alfredton Fire | 5.3 | 11.4 | 28.6 | 4 | 2022 | 2022 |

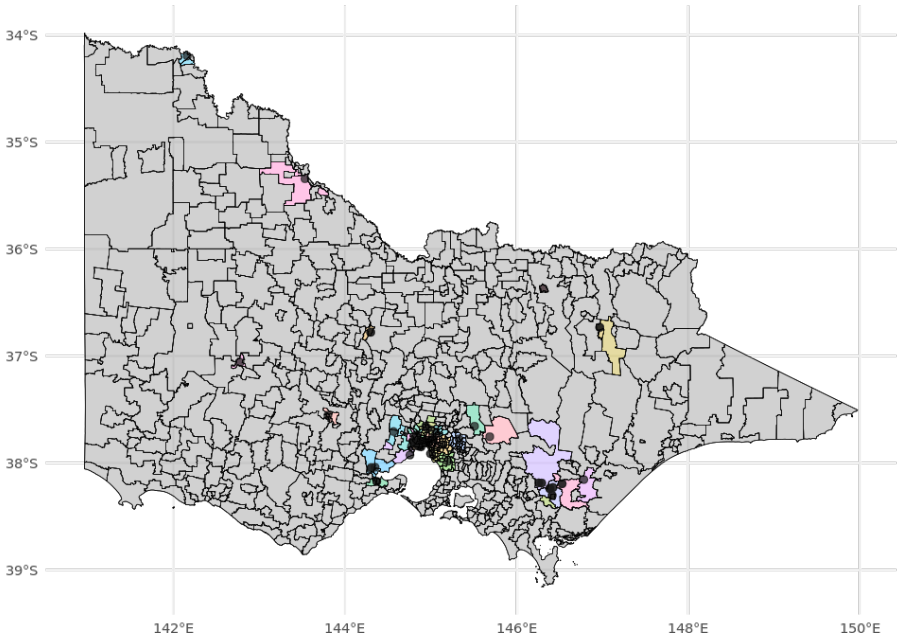
| | | | | | | |
|---|---|---|---|---|---|---|
| Footscray | 1.3 | 13.6 | 389.6 | 3088 | 2015 | 2023 |
| Moorabool Site 1 | 1 | 6.7 | 12.9 | 5 | 2021 | 2021 |
| Bright NE Planned Burns | 4.7 | 100.1 | 148.1 | 6 | 2021 | 2021 |
| St Albans | 0.3 | 5.6 | 40.8 | 680 | 2021 | 2023 |
| Morwell South | 2.3 | 15.2 | 1349 | 3320 | 2014 | 2023 |
| Spotswood | 0.1 | 7.1 | 418.4 | 724 | 2021 | 2023 |
| Sunshine West | 3.5 | 4.7 | 7 | 3 | 2021 | 2021 |
| SIMS Metals Laverton North Site 2 | 2.6 | 2.6 | 2.6 | 1 | 2021 | 2021 |
| SIMS Metals Laverton North Site 1 | 2.2 | 2.2 | 2.2 | 1 | 2021 | 2021 |

## Appendix B – Count of $PM_{2.5}$ recordings by Air Quality Monitoring Sites, 2014–2023



# Appendix C – Air Quality Monitoring Sites and postcode allocations



## Appendix D. Emergency Department presentations ICD-10 categorised into chapter groups for Victoria from January 2014 to December 2023

| Chapter | Number of records | Percent of total records |
|---|---|---|
| Congenital malformations, deformations and chromosomal abnormalities | 3,556 | 0.02% |
| Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified | 3,202,903 | 20.77% |
| Codes for special purposes | 246,241 | 1.60% |
| Diseases of the eye and adnexa | 310,907 | 2.02% |
| Injury, poisoning and certain other consequences of external causes | 3,885,448 | 25.20% |
| Neoplasms | 57,813 | 0.37% |
| Pregnancy, childbirth and the puerperium | 391,470 | 2.54% |
| Endocrine, nutritional and metabolic diseases | 165,855 | 1.08% |
| Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism | 114,206 | 0.74% |
| Diseases of the circulatory system | 765,639 | 4.97% |
| Diseases of the genitourinary system | 696,286 | 4.52% |
| Diseases of the musculoskeletal system and connective tissue | 687,597 | 4.46% |
| Diseases of the ear and mastoid process | 235,589 | 1.53% |
| Certain conditions originating in the perinatal period | 43,045 | 0.28% |
| Diseases of the skin and subcutaneous tissue | 479,718 | 3.11% |
| Certain infectious and parasitic diseases | 713,363 | 4.63% |
| Diseases of the respiratory system | 1,123,104 | 7.28% |
| Factors influencing health status and contact with health services | 517,448 | 3.36% |
| Diseases of the digestive system | 909,962 | 5.90% |
| Mental and behavioural disorders | 569,031 | 3.69% |
| Diseases of the nervous system | 299,329 | 1.94% |

# **Chapter 6:** Lessons from the field and additional teaching activities

# Preface

The Master of Applied Epidemiology (MAE) program has two core teaching requirements: peer learning through developing and participating in 'Lessons from the Field' and preparing and delivering a teaching session to first-year MAE students. This chapter describes the development of these teaching activities and critical lessons learned.

# Teaching activity: Lesson from the field

## Background

The Lessons from the Field (LFF) component of the MAE teaching requirement allows MAE students to share key lessons we have learned through our placements and projects within a sub-group of the cohort. The session focused on developing a case series timeline graph using R statistical software. Increasingly, R has become a widely used tool in Epidemiology, and the cohort reported interest in learning R for their projects.

At the time, training in R was limited in the formal MAE teaching program; some sessions were run on R in the second-course block for the entire cohort but were limited in scope and applicability. The cohort reflected that the R training needed to be delivered earlier in the program as many of the cohort had already initiated projects in STATA. In response, I facilitated several introductory sessions for the cohort to build their skills and gain confidence in the software. The sessions were intended to help demystify R for many, giving them the confidence to conduct their analyses in R and create a culture of peer learning, troubleshooting, and code sharing. To follow this, I ran the LFF session on how to generate a specific type of graph using R.

## Lesson Overview

For those involved in my LFF group, before the virtual workshop, I provided participants with a sample code and a mock dataset to generate a simple case series in R. The objectives of the sessions were to:

1. Describe the utility of case timeline graphs for investigations.
2. Generate and customise a case timeline using R.

Two weeks before the LFF teleconference, participants were asked to complete a short worksheet. The worksheet reviewed examples of case series graphs in the literature and discussed their strengths and weaknesses (Appendix A). It also included instructions on running the code and generating the desired outputs, adapting formatting such as colours and symbols, and assessing the output for colour blindness appropriateness.

A one-hour teleconference was held, during which responses were discussed and issues resolved. Areas of focus included the utility and limitations of visuals of this nature, principles of coding in R, and the development of high-quality data visualisations. I developed and distributed a short evaluation of the LFF to the group at the end of the session.

## Lessons learnt

The field lesson highlighted the importance of clear focus and learning objectives. It was also important to revisit these throughout the process to minimise change in the scope or purpose of the session. Providing students with an example code and asking them to adapt elements of the code was a helpful strategy, as it catered to the varying levels of R coding experience with the group. It also provided a valuable resource for the participants to share with others in their field placement settings, as one student mentioned they had in their evaluation. Using the teleconference to discuss this visual was productive, and the group was engaged and offered suggestions for changes and improvements.

Finding the balance between keeping the session structure while allowing the flow of discussion to explore unexpected avenues of inquiry was sometimes challenging. It was important to be adaptable to respond to the interests and experiences of those in the session. In retrospect, actively trying to adapt code during a session can create undue pressure and cause confusion – having an updated version of the code with additional extensions would be sufficient. Feedback from the session was positive, with all

participants reporting that the session was valuable and relevant to their work (Appendix B).

# Teaching Activity: Peer-to-peer teaching session

## Background

During course block three in 2024, The MAE cohort provided a teaching session to the MAE first-year students on a topic of our choice. As a cohort, we allocated ourselves into four groups. Each group prepared a teaching session on a topic relevant to the first-year students that fell outside the formal MAE teaching sessions. Using discussion-based activities, we applied adult learning principles learned during course block two, such as participatory learning.

## Lesson Overview

For our session, we explored the contextual factors that impact public health responses, using our experiences in our placements as examples. This topic was chosen as an opportunity for the participants to apply the theoretical knowledge they learned earlier in the course regarding outbreak investigation to different settings.

It was expected by the end of the session, students should be able to:

1. Describe public health in different geographical settings (including urban, regional, remote and international settings).
2. Explain challenges and opportunities associated with public health responses in these geographical settings.
3. Discuss the political, cultural, economic and social considerations in conducting public health responses in these geographical settings.

The class began by introducing a framework to consider the macro-level factors influencing public health, including political, economic, social, and cultural factors. This was followed by a presentation of four different settings (urban, rural, remote, and

international) based on the teacher's experiences in this placement, discussing the context and some considerations (Appendix C).

Students were then divided into groups and assigned to different settings: urban, regional, remote, and international. They were then asked to consider how the macro-level factors (political, economic, social, cultural) may impact some of the steps of an outbreak investigation in each setting. Students were provided butcher paper and markers to write out their answers. After presenting back to the group, their peers provided any additional comments or considerations based on what they offered. At the end of the session, participants were asked to give feedback on the session through a web-based survey (Appendix D).

## Lessons learnt

The session went well, and the students provided positive feedback during the evaluation. The cohort was engaged and participated actively; it was good to have a session allowing participants to bring their own experience and expertise. A shorter presentation time at the start could have been beneficial, especially when describing different contexts. This could have allowed more time for discussion and some deeper dives into topics of interest. Timing can be challenging, especially with the number of facilitators. It is critical to anticipate time delays at the start of the session and the time it takes to set up and organise activities. Activities take longer than expected, especially when they involve discussion and presentation to the group. I particularly enjoyed working with my peers to develop the session; while creating a session collaboratively with five people can be challenging, we were considerate and respectful and always found time to laugh.

# Appendix

## Appendix A: Lesson from the field

### Lessons from the field: generating case timeline visuals in R

Case timelines are valuable tools in epidemiology to present information in a way that can allow you to understand an outbreak and transmission dynamics more easily. Presenting information this way can be a powerful tool to support you in conveying public health messages through storytelling.

As part of this lesson from the field, you have been provided with an R code and dummy linelist to generate and customise your case timeline graph. The code has been written in a generalisable way, and you should be able to apply this code to your investigation.

At the end of this LFF, you should be able to:

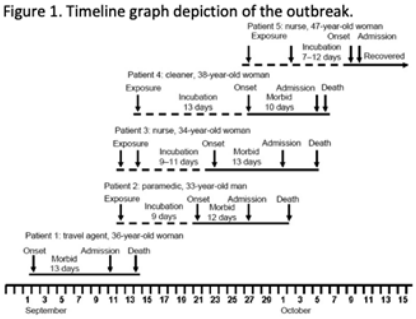
1. Describe the utility of case timeline graphs for investigations.
2. Generate and customise a case timeline using R.

## Section 1

Review the following examples of case timeline graphs utilised in outbreak investigations.

**Clinical Features and Patient Management of Lujo Hemorrhagic Fever**

Figure 1. Timeline graph depiction of the outbreak.




**Monkeypox outbreak in a piercing and tattoo establishment in Spain**

**Figure 2.** Timeline of the incubation period of monkeypox virus and dates of symptom onset from July 6 to July 27, 2022

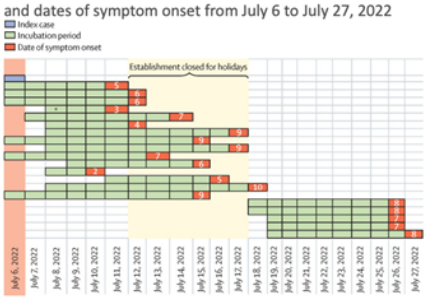



Figure 1. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4230886/
Figure 2. https://www.thelancet.com/journals/laninf/article/PIIS1473-3099%2822%2900652-1/fulltext?s=09

**Question 1.** How might they aid the understanding of an outbreak? What kinds of insights can be taken from these types of graphs?

| |
|---|
| *Visually represent data more clearly.* |

*It is easier to visualise and draw conclusions from the timeline.*
*Case timelines provide a visual representation of when cases report exposures, helping to determine when an exposure event may have occurred.*

*More easily interpret dates and date ranges.*
*Demonstrate incubation periods, transmissions and known **cross-over** periods. Specifically, the goal is to determine the crossover periods between cases, identify when transmission occurred, and determine which cases were likely linked.*

*Understand the impact of controls.*
*They can also provide insight into where control measures should be targeted to reduce further cases of illness.*
*Impact of other events on transmission (School closures)*

## Section 2

Before running the code
- You have been provided with a code and dummy linelist for this analysis
- Before running the code, you must create a folder and store the script and code.
- In this code, the working directory will be automatically set based on the folder in which the code is stored.

Run the code
- Run the code. If there are no issues, an output should be generated. If you receive an error message, reach out, and we will review it.
- The data is reformatted into a new file structure to create the graph. A new data frame called "Timeline" is generated in the section *Create case timeline*.
- This data frame is then used to generate the graph using ggplot.

Review the outputs
- The code will develop an output folder and save the files: *outputs/Todaysdate*
- Open the image file created and review the output.
- Compare the output to the line list. Are all the dates correct? Are there any issues?

**Question 2:** Review the data frame "Timeline" created from the linelist. How has the data been transformed? Describe the data structure and how it differs from a conventional linelist structure.

*The data has been transformed from a conventional linelist format, where each row represents an individual record, to a long format based on dates. Each row represents a unique combination of the date during the investigation period, each case record, and the case status (incubation or infectious). There are many more rows in the dataset than previously, and now we can readily evaluate a case's status on a given day.*

The code you have been provided has been set up to be customisable to fit the needs of your investigation. You can change colour symbols, infectious periods, and incubation periods by changing the values in the *Define Parameters* section.

Choose a condition (e.g. measles, crypto) of interest and collect information on the incubation period, infectious period and effect of treatment on the *contagious period*. You may find this information on the CDC website or elsewhere.

Change condition-specific values

Change the parameters in the code based on what you have found and rerun the entire code

- Condition <- "Condition of your choice"
- incubation_start <- 5 *# days before symptom onset,*
- infectious_start <- 1 *# days before symptom onset*
- infectious_end <- 8 *# days post to symptom onset*
- infectious_end_treatment <- 1 *# days post to symptom onset if on treatment*

Change features such as colours.

Change the colours and shapes in the graph by changing:

- cols_status
- shapes

Select colours by looking up hex codes (https://htmlcolorcodes.com/color-picker/ ) or the shapes (https://ggplot2.tidyverse.org/articles/ggplot2-specs.html ).

Rerun entire code

Review the output. Did it work?

**Question 3:** How did you go? Does your chosen condition make sense for the data and symptom onsets provided? What can you interpret from this graph?

*Participants should assess if the visual generated makes sense based on the parameters they have chosen. Issues may arise if the condition chosen has long incubation or infectious periods or if the values chosen show no overlap between cases, suggesting there was no transmission between the groups.*

***Useful***

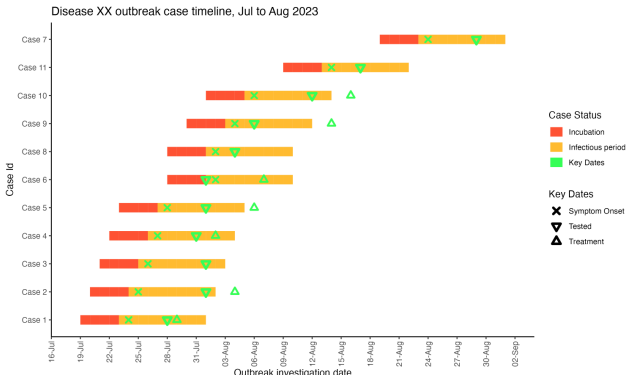
*Defined cohort or exposure*
*Transmission within a group*
*Person-to-person transmission*

***Less useful***

*Point source outbreak*
*A large number of cases*
*Zoonotic/Environmental exposures*

*Discussion will be prompted around the situations where it would be helpful to utilise the visual to utilise this form of visual.*

**Question 4:** Upload a copy of your graph.



Assess whether the colours you chose were appropriate for people with colour blindness by running the following code:

*palette_check(cols_status, plot = TRUE)*

This will generate a table and visual. The column min_dist shows the minimal distance between colours, where a smaller number means there is less difference between these colours and they are harder to differentiate.

**Question 4:** When looking at the min_dist and the plot output, do you see any issues with the colours you chose for your plot? Would these colours be legible for people with colour blindness?'

*When **tolerance < min_dist,** the colour palette is colour blind friendly*

```
          name n tolerance ncp ndcp  min_dist mean_dist max_dist
1       normal 3  49.77993   3    3 49.779926  61.08653 67.80402
2 deuteranopia 3  49.77993   3    2  9.916106  48.21998 74.57834
3   protanopia 3  49.77993   3    2  1.783460  44.05505 66.38301
4   tritanopia 3  49.77993   3    3 55.274388  59.19591 66.32724
> |
```

•tolerance: minimal value of the acceptable difference between the colours to distinguish between them

•min_dist: minimal distance between colours

*Participants should assess whether the colours chosen would be legible by a person with colour blindness.*

# Appendix B: Lessons from the field – R code

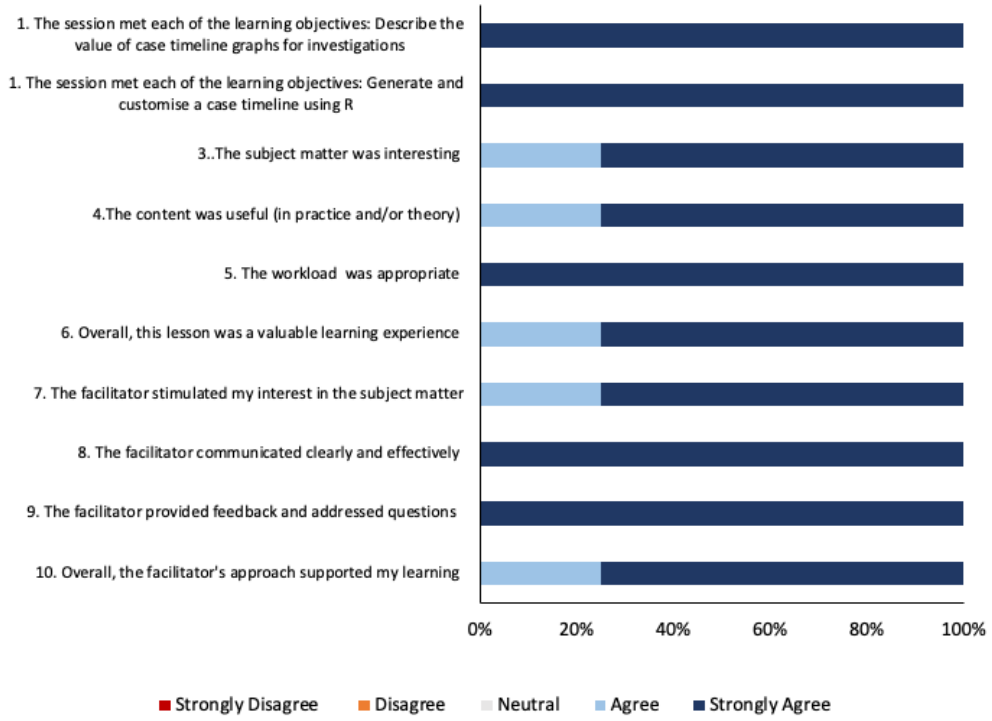
```
########################################
#
# Case Timeline Graph
# Created by: Aaron Osborne
# Date created: 2023/06/01
# Date Updated: 2024/01/01
#
####################################

############################## Setup and Install Packages
##############################
# Clear the memory
rm(list = ls())

# Set the working directory
script_dir <- dirname(rstudioapi::getSourceEditorContext()$path)
setwd(script_dir)

# Load necessary libraries
if (!require("pacman")) install.packages("pacman")
pacman::p_load(
  rio,        # import/export of many types of data
  tidyverse,  # includes many packages for tidy data wrangling and presentation
```

```
  here,
  janitor,
  colorblindcheck
)

############## Define Parameters ######################
# Specify parameters used to generate the output
condition <- "Condition X"
incubation_start <- 6 # days prior to symptom onset, will be overridden by infectious start
infectious_start <- 1 # days prior to symptom onset
infectious_end <- 12  # days post to symptom onset
infectious_end_treatment <- NA # days post to symptom onset if on treatment if no effect
leave as NA

# Specify colors of the graph
cols_status <- c("Incubation" = '#ffa78c', # navy
                 "Infectious period" = '#5cc38c',
                 "Key Dates" = '#1c1c44')

# Specify shapes of the graph
shapes <- c("Tested" = 4,
            "Symptom Onset" = 0,
            "Treatment" = 21)

# Key investigation dates
Key_investigation_dates <- data.frame(Event  = c( "Investigation initiated", "School
closed"),
                                      Date = c( dmy("01/08/2023"), dmy("10/08/2023")))

############## Load and Clean Data ######################
# Load and tidy up the linelist data
linelist_raw <- import('Linelist_LFF.xlsx')

linelist <- linelist_raw %>%
  janitor::clean_names("upper_camel") %>%
  mutate(SymptomOnsetDate = as.Date(SymptomOnset, "%d/%m/%Y",  tz = "UTC"),
         TestDate = as.Date(TestDate, "%d/%m/%Y",  tz = "UTC"),
         Dob = as.Date(Dob, "%d/%m/%Y",  tz = "UTC"),
         TreatmentDate = as.Date(TreatmentDate, "%d/%m/%Y",  tz = "UTC")) %>%
  mutate(InfectiousStartDate = SymptomOnsetDate - infectious_start,
         InfectiousEndDate = case_when(!is.na(TreatmentDate) &
!is.na(infectious_end_treatment) & (TreatmentDate + infectious_end_treatment) <
(SymptomOnsetDate + infectious_end)~  TreatmentDate + infectious_end_treatment,
                                       TRUE ~ SymptomOnsetDate + infectious_end,),
         IncubationStartDate = SymptomOnsetDate - incubation_start,
         IncubationEndDate = InfectiousStartDate - 1)

############## Create case timeline ######################
# Reformat data from linelist to create a dataframe for the case timeline
gathercols <- c("InfectiousStartDate", "InfectiousEndDate", "IncubationStartDate",
"IncubationEndDate")

linelist_long <- gather(linelist, Status, Date, gathercols) %>%
  mutate(Date = as.Date(Date, "%d/%m/%Y",  tz = "UTC"))
```

```
Timeline <- linelist_long %>%
  select(Caseid, Status, SymptomOnsetDate, Date) %>%
  group_by(Caseid) %>%
  complete(Date = seq.Date(min(Date, na.rm = TRUE), max(Date, na.rm = TRUE), by =
"day")) %>%
  fill(c(Caseid, Status, SymptomOnsetDate), .direction = "down") %>%
  ungroup() %>%
  mutate(Status = case_when(
    Status == "IncubationStartDate" | Status == "IncubationEndDate" ~ "Incubation",
    Status == "InfectiousStartDate" | Status == "InfectiousEndDate"  ~ "Infectious period"
  ))

earliest_date <- min(linelist$SymptomOnsetDate)
latest_date <- max(linelist$SymptomOnsetDate)



############## Create timeline plot ######################
# Generate and format the ggplot
plot_case_timeline <- Timeline %>%
  ggplot() +
  geom_line(aes(x = Date, y = forcats::fct_reorder(Caseid, SymptomOnsetDate), col =
Status, group = Caseid),
            size = 5) +
  scale_color_manual(values = cols_status, name = "Case Status") +
  geom_point(data = linelist, aes(x = TestDate, y = Caseid, col = "Key Dates", shape =
"Tested"), size = 2, stroke = 2) +
  geom_point(data = linelist, aes(x = SymptomOnsetDate, y = Caseid, col = "Key Dates",
shape = "Symptom Onset"), size = 2, stroke = 1.5) +
  geom_point(data = linelist, aes(x = TreatmentDate, y = Caseid, col = "Key Dates",
shape = "Treatment"), size = 2, stroke = 1.5) +
  geom_vline(data = Key_investigation_dates, aes(xintercept = Date), linetype =
"dashed", color = "black") +
  geom_text(data = Key_investigation_dates, aes(x = Date, y = Inf, label = Event), angle
= 90, vjust = -0.5, hjust = 1, size = 3, color = "black") +
  theme_bw() +
  scale_shape_manual(values = shapes, name = "Key Dates") +
  scale_x_date(expand = expansion(add = c(3, 3)),
               date_breaks = "3 day",
               date_labels = "%d-%b") +
  labs(x = "Outbreak investigation date", y = "Case Id",
       title = paste(condition, "outbreak case timeline,", format(earliest_date, "%b"), "to",
format(latest_date, "%b %Y"))) +
  theme_classic() +
  theme(axis.text   = element_text(size = 9),
        axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1),
        panel.grid.minor = element_blank(),
        legend.position = "right")

plot_case_timeline
```

```
############## Save Output ######################
# Create an output folder and save the output
today <- format(Sys.Date(), "%Y-%m-%d")
timestamp <- format(Sys.time(), "%Y-%m-%d_%H%M")
folder_path <- file.path("outputs", today)

if (!dir.exists("outputs")) {
  dir.create("outputs")
}
if (!dir.exists(folder_path)) {
  dir.create(folder_path)
}

output_file <- file.path(folder_path, paste0(condition, "_CaseTimeline_", timestamp,
".png"))
ggsave(output_file, plot = plot_case_timeline, width = 10, height = 6)
```

# Appendix C: Lesson from the field - summary of feedback



# Appendix B: Teaching first-year MAE students - Presentation

## Public Health in Different Geographical Contexts

Aaron Osborne
Annie Gerrell
Daniel Faktaufon
Megan Ellis
Sarah Alland
Scott Umali

Australian National University

## Learning objectives

At the end of this session, students should be able to:

1. Describe public health in different geographical settings (including metro, regional, remote and global settings).
2. Explain challenges and opportunities associated with public health responses in these geographical settings.
3. Discuss the political, cultural, economic and social considerations in conducting public health responses in these geographical settings.

## Factors that influence an outbreak response

| Political | Economic | Cultural and Social |
|---|---|---|
| • Stakeholders and Organisations<br>• Planning and preparedness<br>• Policies<br>• Public Relations<br>• Leadership | • Scale of response<br>• Resourcing (HR)<br>• Infrastructure<br>• Availability of Health Services | • Demographics<br>• Health Seeking Behaviour<br>• Cultural Beliefs/Attitudes<br>• Employment/Work |

## Examples of public health in different geographical settings

## MAE Experiences

Australian National University

## North Eastern PHU

Aaron Osborne

NEPHU NORTH EASTERN PUBLIC HEALTH UNIT

## North Eastern Public Health Unit

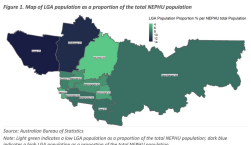
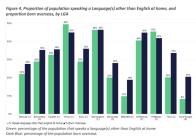


*Figure 1. Map of LGA population as a proportion of the total NEPHU population*

NEPHU NORTH EASTERN PUBLIC HEALTH UNIT

## Key Populations

- Culturally and linguistically diverse
  - 40% of catchment born overseas
  - Cultural groups vary by region
- Aboriginal and Torres Strait Islander
  - 6%
- LBGTQIA+ Populations
  - Darebin (10.6%)
  - Yarra (10.0%)



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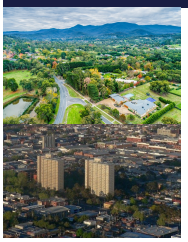
## Environment



- Mild, temperate climate
- Mostly urban
  - Large urban sprawl
  - Some areas that are still "green"
- Population high density
- Industries
  - Mixed
  - Industrial in the north
  - Large movement in and out of the catchment for work

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## Resources

- High levels of primary, secondary and tertiary health services
  - Specialist services
  - Challenges esp in growth corridors (Hume Whittlesea)
- Testing not generally in issue and rapid access to the reference lab (VIDRL)
- Varying health seeking behaviors due to populations

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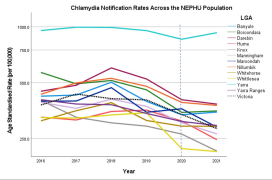
## Health Conditions of interest

- Large number of STI notifications
  - High incidence?
  - health seeking behavior?
- COVID
- Imported conditions: Measles, MPOX




NEPHU NORTH EASTERN PUBLIC HEALTH UNIT

# Regional NSW

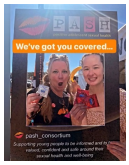
**Meg Ellis and Sarah Alland**
Epidemiology Scholars

1 March 2024

NSW Health

## Who and where we are

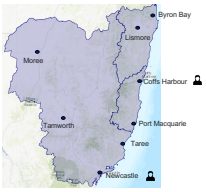
**Sarah Alland**
Hunter New England Health Protection




**Megan Ellis**
North Coast Population and Public Health Directorate

## Geography


## Geography




NSW Health 14

## Region Snapshot

| Hunter New England | |
|---|---|
| **Major Centre** | Newcastle |
| **Geographical Area** | 131,785 km2 |
| **Population** | 962,309 - ~8% Aboriginal |
| **Climate** | temperate with warmer, sub-humid climate in the north |
| **Industries** | coal mining, wineries, tourism, country music, farming (cattle, cotton) |

NSW Health 15

## Region Snapshot

| Mid North Coast and Northern NSW | |
|---|---|
| **Major Centres** | Coffs Harbour, Port Macquarie, Lismore |
| **Geographical Area** | 32,067 km2 |
| **Population** | 531,279 - ~6% Aboriginal |
| **Climate** | subtropical and temperate |
| **Industries** | cattle, macadamias, fruit and veg |

NSW Health 16

## Priority Population Groups

- Aboriginal People
- Migrants
- Seasonal Workers
- Substance Users
- Agricultural Communities

NSW Health 17

## Resources

**Lab Capacity**

- Main labs in Newcastle and Brisbane
- Limited testing services and no microbiologist available elsewhere

**Healthcare Access**

- John Hunter (Newcastle) major hospital for the region
- Network of smaller hospitals
- Limited specialist services in regional areas
- Northern NSW often travel to Gold Coast for medical services

**Healthcare Beliefs**

- Antivax population: North Coast NSW one of the lowest vaccination rates nationally

NSW Health 18

## Health Concerns

| Zoonoses | Lead Poisoning | Arboviruses | Overseas-Related |
|---|---|---|---|
| • Q fever<br>• Leptospirosis<br>• Brucellosis<br>• STEC<br>• Hendra<br>• Australian bat lyssavirus exposure | • Mining<br>• Railway industry | • Ross River Virus<br>• Barmah Forest Virus<br>• Japanese Encephalitis | • Tuberculosis<br>• Leprosy<br>• Measles |




## Alice Springs CDC




## Central Australia

Alice Springs rural and urban districts:
Population: 40,100,
43% First Nations

Barkly districts:
Population: 6,200
71% First Nations

Young population

NPY Lands




## Environment

Alice Springs districts: 544,000 km2
- Desert
- Contributes an estimated 18% (2.9 billion) to the NT gross product
  - Mining
  - Tourism
  - Cattle
  - Government funding

Barkly districts: 323,000 km2
- Semi-arid monsoonal
  - Very variable
- Mining
- Cattle
- Government funding

## Resources

Alice Springs
- 1 hospital: 207 beds, 10 in intensive care
- 1 CDC unit

Tennant Creek
- 1 hospital: 20 beds
- 1 CDC nurse

Pathology laboratory capacity
- Limited

Primary healthcare clinics
- NT Health & ACCHOs

Health behaviours
- Varying

| Papua New Guinea | |
|---|---|
| **Capital city** | Port Moresby |
| **Geographical Area** | ~462,840 km² |
| **Population** | 11.7 Million, 85% living in **rural areas** |
| **Economy** | Papua New Guinea is ranked 29th out of 39 countries in the Asia–Pacific region, and its overall score is below the world and regional averages. |
| **Climate** | Tropical |
| **Industries** | Agriculture, fisheries, mineral and energy extraction |
| **Health Challenges** | ... |


| Papua New Guinea | |
|---|---|
| **Health challenges** | **Deaths**<br>• 50% attributed to NCDs<br>• 35% infectious and parasitic disease<br>**Infectious Disease**<br>• HIV (highest incidence in the pacific region)<br>**Respiratory Illness**<br>• Tuberculosis<br>**Water-based and Arboviral Disease**<br>• Malaria<br>• Dengue<br>• Cholera<br>• Diarrhoea<br>**Immunisation**<br>• Low rates of vaccination |


| Daru Island | |
|---|---|
| **Geographical Area** | 14.7 km² (5.7 sq mi) |
| **Population** | ~19,000 |
| **Health Partners** | Western Provincial Health Authority (WPHA)<br>World Vision (WV)<br>National Department of Health (NDoH) |
| **Resources** | **Lab Capacity**<br>• Rapid NAAT testing, PCR<br>**Healthcare Access**<br>• One main hospital (Daru General)<br>**Health-seeking Behaviour**<br>• Sensitivities around conditions, stigma |
| **Cultural considerations** | • Large household numbers<br>• Multiple residencies<br>• Multiple names<br>• Circulating misinformation |

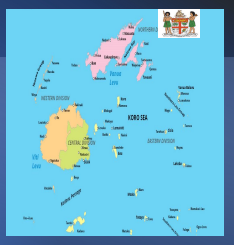

## Enhanced Public Health Responses – Tuberculosis

- Community Engagement
- In-country staff/capacity building
- Health system strengthening
- SWEEP-TB – systematic screening for TB on Daru Island

## Public Health Settings Non-Australian Context Fiji MoHMS

Daniel Faktaufon

| Fiji | |
|---|---|
| **Capital city** | Suva |
| **Geographical Area** | More than 300 islands, Rural and Urban settings with islands that isolated |
| **Population** | 884,887 (2017 census)<br>Priority population: Children, Pregnant women, elderly |
| **Ethnic Group** | I-Taukei, Fijians of Indian Descent, Others |
| **Climate** | Tropical, Western Division-Dry, Central Division Wet and rainy Weather |
| **Industries** | Tourism, Sugar and Agricultural Industry |
| **Health concerns** | NCD's Diabetes, Hypertension, Obesity, CDs Zoonoses such as LTDs, TB HIV AIDS Meningococcal 2017-2018, Measles Outbreak in 2019, COVID 2020 |
| **Health Divisions** | Divisions, Central, Eastern, Western, Northern and 3 Tertiary Hospitals, PPP |
| **Public Health Service** | Main health service provider with 200 HCFs covered by 7000+ HCWs<br>Free health services for citizens |



## Key conditions

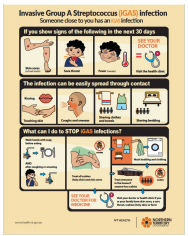
Sexually transmitted infections

Group A streptococcal infection
- Impetigo/skin sores & sore throats
- Invasive group A strep
- Acute post-streptococcal glomerulonephritis (APSGN)
- Acute rhematic fever

Scabies

Enteric diseases

Non-communicable diseases






Australian National University

NORTHERN TERRITORY UNIVERSITY

# Public Health in Papua New Guinea

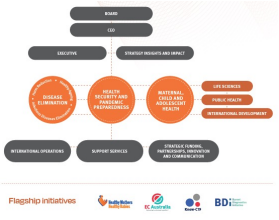
SCOTT UMALI

Burnet

## The Burnet Institute

- The Burnet Institute is a not-for-profit ***medical research institute*** that specialises in Global Health.
- The institute was launched in 1986, and has offices in Australia, Papua New Guinea (PNG) and Myanmar

## The Burnet Institute

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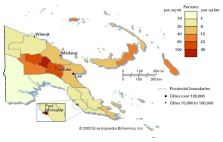
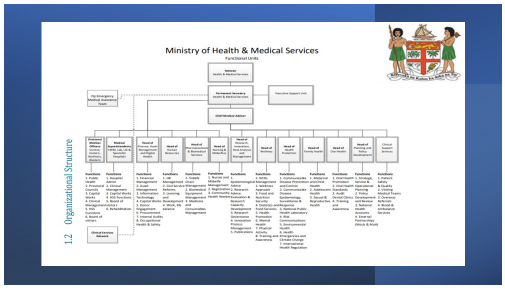
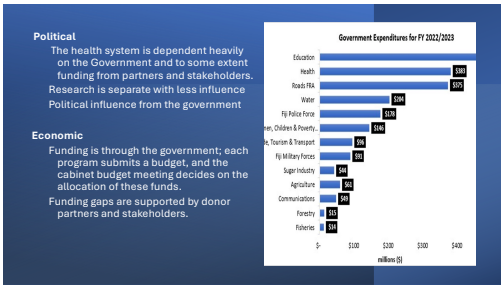
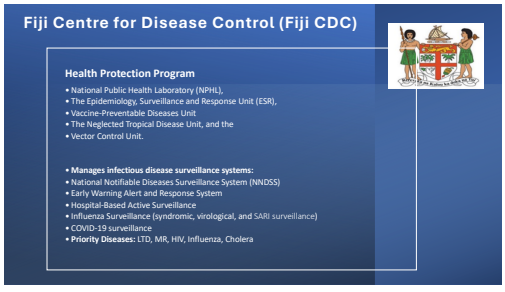


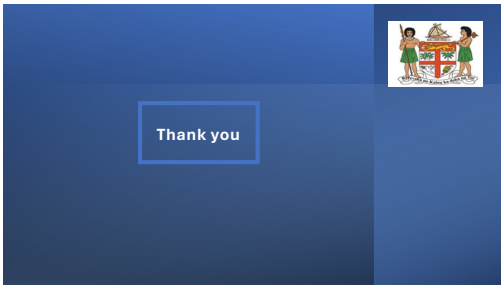

Ministry of Health & Medical Services
1.2 Organizational Structure


Political
The health system is dependent heavily on the Government and to some extent funding from partners and stakeholders.
Research is separate with less influence
Political influence from the government
Economic
Funding is through the government; each program submits a budget, and the cabinet budget meeting decides on the allocation of these funds.
Funding gaps are supported by donor partners and stakeholders.
Government Expenditures for FY 2022/2023
Education
Health
Roads FBA
Water
Fiji Police Force
Fiji Military Forces
Sugar Industry
Agriculture
Communications
Forestry
Fisheries
millions ($)


Cultural and Social
Most urban areas have access to health facilities, however, issues related to remote and isolated areas are not able to access these facilities.
There are outreach programs conducted, screening, and immunization programs.
Health Seeking behavior among indigenous populations is less compared to FID and others.
Living in extended families and communities in rural and urban areas


MATANIKA HOUSE
FIJI CENTRE FOR DISEASE CONTROL (Fiji CDC)


Fiji Centre for Disease Control (Fiji CDC)
Health Protection Program
National Public Health Laboratory (NPHL),
The Epidemiology, Surveillance and Response Unit (ESR),
Vaccine-Preventable Diseases Unit
The Neglected Tropical Disease Unit, and the
Vector Control Unit.
Manages infectious disease surveillance systems:
National Notifiable Diseases Surveillance System (NNDSS)
Early Warning Alert and Response System
Hospital-Based Active Surveillance
Influenza Surveillance (syndromic, virological, and SARI surveillance)
COVID-19 surveillance
Priority Diseases: LTD, MR, HIV, Influenza, Cholera


Thank you

## Factors that influence an outbreak response

| Political | Economic | Cultural and Social |
|---|---|---|
| • Stakeholders and Organisations<br>• Planning and prepardness<br>• Policies<br>• Public Relations<br>• Leadership | • Scale of response<br>• Resourcing (HR)<br>• Infrastructure<br>• Availability of Health Services | • Demographics<br>• Health Seeking Behaviour<br>• Cultural Beliefs/Attitudes<br>• Employment/Work |

## Group work

Australian National University

## Scenario

**There is a measles outbreak in your setting and you've been asked to help coordinate and lead the team's response.**

Discuss the opportunities and challenges in responding to this outbreak while considering the political, economic, cultural and social factors in your context.

- Forming an Outbreak Management Team
- Diagnostic Capacity
- Surveillance
- Contact Tracing
- Intervention/Control Measures
- Communication

## Evaluation

## Thank You

Enjoy the MAE Experience!

Australian National University

## Appendix D: Teaching first-year MAE students - summary of feedback