AusEnHealth

An Australian environmental health digital twin

AusEnHealth Project Output 1

Digital Framework & Material Review

30 November 2020

I. INTRODUCTION

Humans depend on the environment for energy and the materials necessary to sustain life [1]. In 2016, the **World Health Organisation (WHO)** stated that "*13.7 of deaths per year in 2016, amounting to 24% of the global deaths, are due to modifiable environmental risks*" [2]. The ongoing consideration of environmental factors is crucial for maintaining or improving the lives of humans [3]. The consideration of public health with specific respect to the environment is referred to as *environmental health*.

The United States of America's **National Environmental Health Association (NEHA)** defines environmental health as "*the science and practice of preventing human injury and illness and promoting well-being by identifying and evaluating environmental sources and hazardous agents and limiting exposures to hazardous physical, chemical, and biological agents in air, water, soil, food, and other environmental media or settings that may adversely affect human health*" [4]. Similarly, the **Australian Government Department of Health (AGDOH)** states that environmental health "*involves those aspects of public health concerned with the factors, circumstances, and conditions in the environment or surroundings of humans that can exert an influence on health and well-being*" [5].

The desire for a nationally coordinated knowledge base for environmental health has existed for almost two decades [6]. In 2010, a report on the investigation, scoping and planning of an Australian environmental health tracking system was released [7]. The conclusion of this study was that a focus on national environmental health indicators and a phased approach which allows time for establishing data agreements across jurisdictions could see success. The AusEnHealth Project aims to explore this possibility by creating a national, spatially enabled data infrastructure resource that will enable users to access, visualise and analyse environmental health data.

This document has been prepared as part of the AusEnHealth Project's material review activity, aimed at collecting information relating to national and international environmental health projects and frameworks. The material review is separated into a small number of sections. Section II includes information on the current environmental health management system in Australia. Section III provides sets of principles and frameworks established by various organisations to provide structure to future environmental health projects or digital platform development. As a way to understand the ongoing research into environmental health impacts, works of various depth relating to environmental health are summarised in Section IV. Finally, all known information relating to environmental health data custodians and indicator development will be discussed in Section V. It is understood that, as the project continues, more information relating to relevant environmental health projects and data will become available. This document serves as an overview of relevant material and is not intended to be comprehensive.

II. MANAGEMENT OF ENVIRONMENTAL HEALTH RISKS IN AUSTRALIA

The **Environmental Health Standing Committee (enHealth)** is a standing committee of the **Australian Health Protection Principal Committee (AHPPC)**. enHealth provides advice to the AHPPC, which includes Chief Health Officers (or equivalent) across all jurisdictions. This advice is based on significant collaboration with Federal and state and territory agencies, departments and organisations that deal with matters relating to environmental health [8]. enHealth is also responsible for a wide range of national duties relating to environmental health, including:

- Providing agreed environmental health policy advice,
- Implementation of the *National Environmental Health Strategy*,
- Consultation with key stakeholders, and
- The development and coordination of research, information and practical resources on environmental health matters at a national level.

One such practical resource produced by enHealth is the *enHealth Strategic Plan 2016 to 2020* [9] which, among mention of challenges, threats, opportunities and focus areas for the mentioned time period, contains a detailed description of the multi-agency system which handles environmental health systems in Australia. This section closely follows the information provided in [9] to provide insight into the

complexity of environmental health management systems in Australia. Table I, below, shows the breakdown of environmental health hazards and their relevant decision making, advisory and regulatory agencies.

Hazard	State Regulator	Standard Setting Body (Supporting Agency)
General Environmental Hygiene and Sanitation	Health	COAG (enHealth)
Water	Health	National Health and Medical Research
Pollution/Environmental Contamination	Environment	State Environment Departments
Radiation	Health, Environment	COAG Health Council (ARPANSA)
Food	Health and Agriculture	Food Standards Australia New Zealand Minsterial Forum on Food Regulators (FSANZ)
Workplace Hazards	Workplace Health and Satefy, Industrial Regulations	Safe Work
Poisons	Health and Agriculture	National Industrial Chemical Notification and Assessment Scheme (NICNAS), Australian Presticide & Veterinary Medicines Authority (APVMA)

TABLE I
ENVIRONMENTAL HEALTH SYSTEMS IN AUSTRALIA.

While health agencies were once responsible for all environmental health risks, agencies with a specific focus on certain aspects of environmental health were established as the related risks began to require a greater investment. Certain responsibilities will always remain with health agencies, who are the primary advisors to governments at state and national level on whether a particular hazard constitutes a risk to health. In Australia, non-health agencies administer regulatory schemes to maintain health standards determined by governments. As a result, health agencies can focus on

- Hazards that are emerging, or more uncommon or novel,
- Where health or environmental standards have been exceeded,
- Emergency situation, and
- On activities such as the investigation of non-communicable disease clusters.

Environmental public health, defined as "*public health work including the surveillance, investigation, control and prevention of non-communicable environmental hazards and their associated health effects (especially chemicals, radiation, and physical hazards)*" [9], is carried out by a wide range of qualified individuals. Some in this area include biology, physics, environmental science, epidemiology, risk communication and community engagement. Public health work is used to advise public health physicians, enabling medical judgement regarding public health risks to the community.

Public health work is also used by State and Local government agencies, departments and organisations in collaboration and coordination with enHealth. This coordinated effort leads to technical guidance which informs environmental health practitioners, industry and the community to practically and effectively manage environmental health risks. enHealth operates within the policy framework for health established under the **Council for Australian Governments (COAG)**. Figure 2, below, is found in [9] and details this framework.

Each of the main groups shown in Figure 2 have significant roles in the maintenance and improvement of public health in Australia.

- The role of **Council of Australian Governments (COAG)** is to initiate, develop and monitor the implementation of policy reforms that are of national significance. These policy reforms require cooperative action by Australian governments.
- The aim of the **COAG Health Council (CHC)** is to improve health outcomes for all Australians and ensure the sustainability of the Australian health system.
- The **Australian Health Ministers' Advisory Council (AHMAC)** is the advisory body to the CHC.
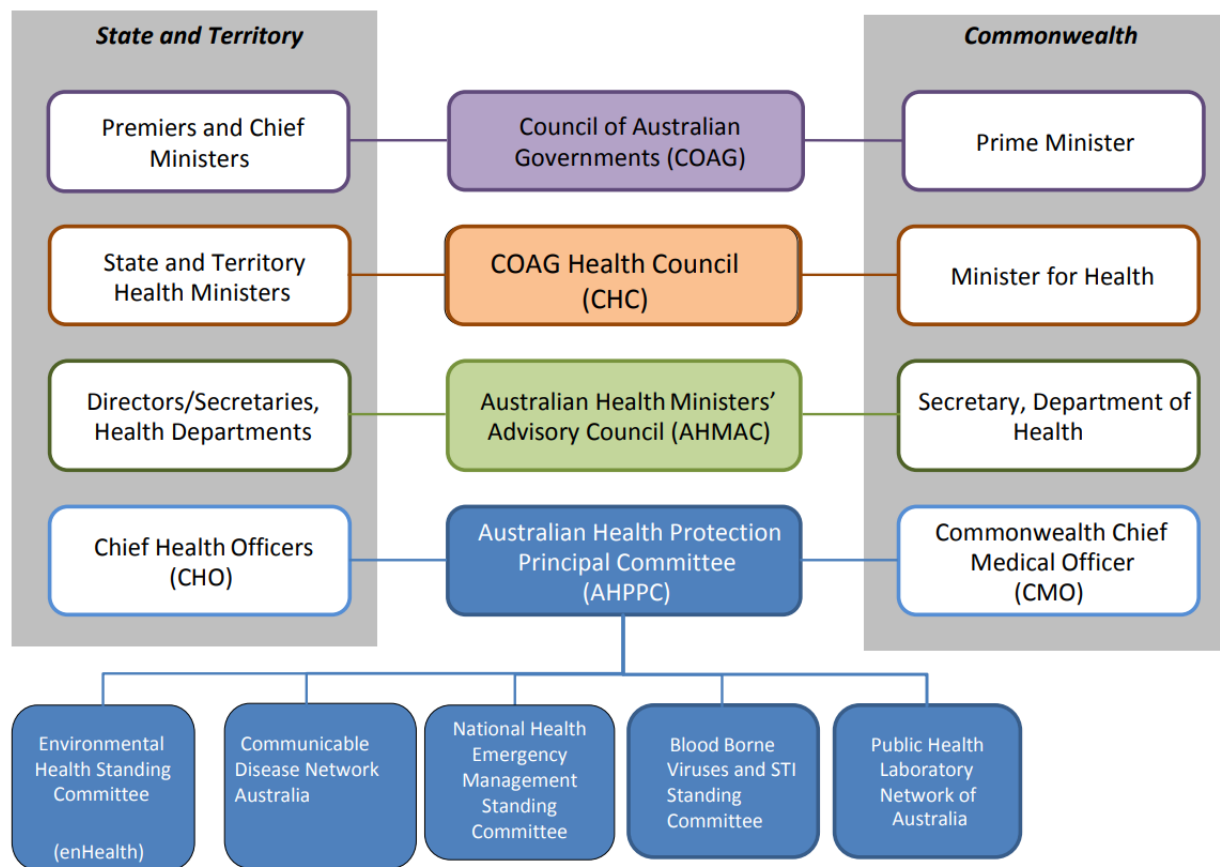
Fig. 1. Governance of health protection in Australia.

The role of AHMAC is to provide strategic advice on health issues by acting as a forum for planning, information sharing and innovation.

- The **Australian Health Protection Principal Committee (AHPPC)** is responsible for providing nationally consistent advice to the community and Government on the managemen of environmental health risks. AHPPC is also responsible for the oversight of enHealth strategic plans and annual work plans. enHealth supports and is supported by the remaining committees reporting to the AHPPC:

  – **Communicable Disease Network Australia (CDNA)**: Responsible for advising on national co-ordination of communicable disease surveillance, prevention and control, outbreak investigation, and public health response in a pandemic or national communicable disease emergency.
  – **National Health Emergency Management Standing Committee (NHEMS)**: Addresses the operational aspects of disaster medicine and health emergency management in all hazards context.
  – **Blood Borne Viruses and STI Standing Committee (BBVSS)**: Provides leadership for the coordination of the national response to blood borne viruses and sexually transmissible infections through a number of national strategies and initiatives.
  – **Public Health Laboratory Network (PHLN)**: Advises on laboratory testing associated with environmental risk factors.

The AusEnHealth Project has the potential to provide significant insight to the public health workers in Australia, which has a direct link to the AHPPC through enHealth. A platform which allows users to easily access, visualise and analyse environmental health data will allow for more efficient communication and coordination between State and Local government agencies, departments and organisations with regards to environmental health risk and management.

III. Environmental Health Digital Platform Frameworks & Principles

Existing work relating to the development of both environmental projects and digital platforms are pertinent to the AusEnHealth Project. Effecting frameworks and principles can help to guide the development and decision-making in projects which leads to improved efficiency and a higher quality end-result. The AusEnHealth Project was proposed with a set of clear motivations as a foundation, including

- Identifying vulnerable populations,
- Better targetting intervention and prevention initiatives,
- Better planning for future burden (health resources, built environment, business/economic decisions),
- Improving community awareness and education, and
- Informing policy development.

Shaping the AusEnHealth Project around established framework and proposed principles allows these motivations to drive the project while constantly considering factors such as platform quality, and value creation. The following resources have been included either for their application to digital platform development or their relevance to environmental health. Indicator development frameworks and principles have been considered, though do not fit the scope of the AusEnHealth Project. Resources relating to indicator development are briefly described in Appendix A.

A. *The Gemini Principles*

In 2018, the **Centre for Digital Built Britain** released a framework titled the "Gemini Principles" aimed at promoting the sensible development of digital twins, with emphasis on the national level [10]. A digital twin is a dynamic virtual representation of a physical object or system which uses data to enable understanding, learning and reasoning [11]. In the context of environmental health, a digital twin represents a digital system at a state level which utilises technology to potentially enable

- Potential futures: Strategy and planning support, running "What if?" scenarios, predictive and preventative maintenance regimes.
- Current state: Intervention management (operation and maintenance interventions or capital investment projects), real-time status monitoring and control, diagnostics and prognostics to optimise performance and safety of assets.
- History: Record keeping and learning from the past.

A national digital twin combines information from the state level to create a more comprehensive understanding of the underlying system. There are effectively nine (9) principles which guide the development of a national digital twin, separated into three overarching headings:

1) *Purpose:* Must have clear purpose. Ideally ongoing and supported by future data.
   - *Public good:* The purpose of the digital twin should start with end-user needs. The purpose should be to deliver benefits to the public.
   - *Value creation:* Must be structured to promote innovation and competition, and to ensure wide access to the benefits.
   - *Insight:* Must enable the generation of meaningful metrics to provide insight on performance and improvement in the built environment.
2) *Trust:* Must be trustworthy with an ethical and transparent design.
   - *Security:* Must be secure by design. Ensure that data sharing is managed effectively. Data security is essential to ensuring the integrity of the digital twin.
   - *Openness:* The digital twin must be as open as possible so that it creates the most value for everyone.
   - *Quality:* Must be built on data of an appropriate quality for the purpose to which it is built. The success of the digital twin will be judged on the quality of decisions it enables.
3) *Function:* Must function effectively and be available to users when required.

- *Federation:* Must be based on a standard, collective and connect environment. Must be able to work with different classes of data, different spatial and temporal scales and different approaches to modelling.
- *Curation:* All parts of the digital twin should be clearly and transparently owned, governed and regulated.
- *Evolution:* The digital twin and framework must be able to adapt and develop as everything evolves (technology, society, requirements, information management, cyber-security, data science and the built environment itself).

The AusEnHealth project aims to circumnavigate the modelling aspect of the Federation principle by creating a single digital twin on a national level. Different spatial / temporal scales should still be functionally implemented into any modelling approach.

B. Conceptual Framework for Environmental Health Tracking

To better understand how environmental pollution from natural and man-made sources can affect public health, an environmental health tracking system has been considered for the **Environment Protection Authority (EPA), Victoria**. The idea of public health environmental surveillance is to collect, integrate, analyse and disseminate data over time. As the AusEnHealth project aims for a similar outcome on a national scale, the objectives of the tracking system when considered for Victoria are repeated below.

- To proactively investigate the short- and long-term temporal and spatial trends of environmental conditions and adverse health effects to help guide interventions and prevent harm to human health resulting from environmental pollution or waste.
- To have access to short- and long-term trends to respond to community concerns related to environmental public health issues.
- To make relevant environmental public health tracking data available to stakeholders (e.g., public, government departments, and researchers) on a spatial and temporal scale in an easy to understand format.
- To respond to emerging environmental health threats, clusters, and outbreaks by identifying populations at risk for adverse health effects.
- To investigate relationships between environmental contamination and health effects for specific cases.
- To develop routine tracking of adverse health effects on a small scale and identify areas warranting further investigation.
- To increase partnerships and collaborations between traditional environmental and health entities at federal, state, and local government levels by developing networks.

In 2019, a paper was released detailing the development of conceptual framework in preparation for implementation of an environmental health tracking system [12]. The conceptual framework development process included a literature review and focused workshops which led to the modification of an existing conceptual framework. The following frameworks considered in [12] were those used in the reporting of environmental and health issues.

- Environmental public health conceptual framework (EPHCF) [13],
- Driving force-pressure-state exposure-effect-action (DPSEEA) [14],
- Driving force-pressure-state-impact-response (DPSIR) [15], and
- Pressure-state-response (PSR) [16].

The result of the report is the modification of the DPSEEA conceptual framework to suit the needs of EPA's environmental health tracking objectives. The result is the "*driver-pressure-environmental condition-health impact-action*" (DPEHA) framework, which does not include exposure and effect due to unavailability of exposure data from personal monitoring or biomonitoring.

The benefits of developing DPEHA are listed in [12]: "*to organise indicators in a causal chain, support the development of environmental health indicators, and help develop the technical architectural framework*
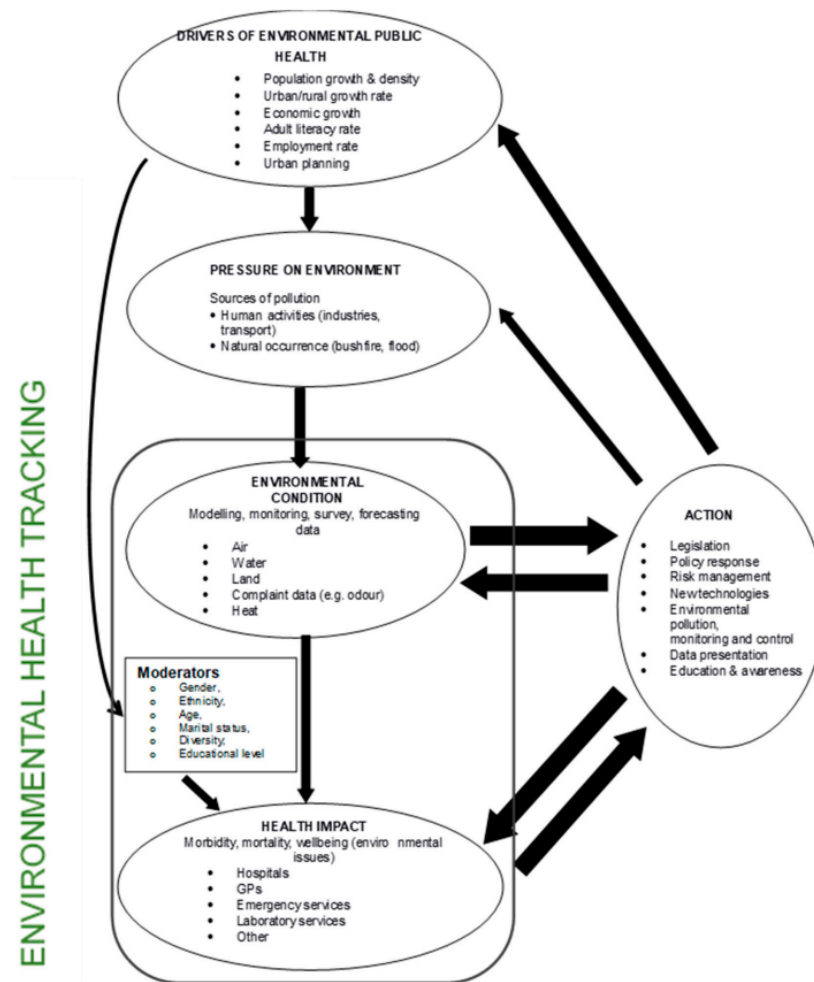
Fig. 2. Governance of health protection in Australia.

for the environmental health tracking system". The AusEnHealth Project will utilise frameworks with such detailed focus on indicators as criteria for the selection of existing environmental health indicators.

An application of DPEHA to anthropogenic $PM_{2.5}$ emissions in [12] is particularly useful for use in the decision of focus areas in the AusEnHealth Project and is shown below, in Table II.

The links between environmental health problems and their causes are effectively shown in Table II. In addition, the action component of the framework forces consideration potential end use.

C. Investigation, Scoping and Planning of a National Environmental Health Tracking System

In 2010, a pilot study was conducted with the aim of investigating, scoping and planning a national environmental health tracking system [7]. The aims of the pilot study were to address the accessibility of data sets (disease, hazards etc.), to assess the benefits and limitations of accessing and displaying these in a single location, and to demonstrate the operational usefulness of this information for different levels of government and researchers for decision making and hypothesis generation.

Ultimately, the scope of this project was changed based on advice from **Jurisdictional Environmental Health Group (JEHG)** to focus on Environmental health indicators. The justification for this work to be revisited with a change of scope in the AusEnHealth Project is the significant work completed in the past decade on the development of environmental health indicators. The work from [7] is included in the framework and principles section of this Material Review due to the use case selection criteria stated in the report:

- Data available from more than one jurisdiction and/or level of government.

DPEHA Conceptual Aspect	Data Inputs
Driving Force	Population increase in Victoria
	Increased demand for road networks
	Increased total number of private and commercial vehicles (cars, vans, trucks, and buses)
	Increase in ownership of petrol and diesel vehicles
Pressure	Average age of vehicles (older vehicles may release more PM2.5 and PM10 than newer vehicles)
	Busy roads
	Emissions from petrol and diesel vehicles
	Cars not maintained well could produce more emissions
Environmental Conditions	Monitoring and modeled concentrations of ambient PM2.5 and PM10 from car emissions collected over time
Health Impact	Premature deaths and hospital admissions for respiratory and respiratory conditions
	Estimated disability-adjusted life years lost attributable to PM2.5 exposure
Action	Policies to improve air quality
	Use of available technologies and controls to reduce emissions from road vehicles
	Public awareness campaign
	Community engagement through educational programs

TABLE II
APPLICATION OF THE DPEHA CONCEPTUAL FRAMEWORK TO ANTHROPOGENIC PM$_{2.5}$ EMISSIONS.

- Addresses an ongoing environmental health issue, not a unique one-off incident.
- Poses a significant or emerging health hazard.
- One of the priority environmental health issues nominated during the workshop.
- Ability to discover knowledge that would go unchecked using other processes.
- Results expected to be hypothesis generating.
- Would illustrate both a technical and a scientific process, from accessing relevant data to presentation and interpretation of the data.

This criteria is effective and will be used in the consideration of use cases in the AusEnHealth Project. This report discusses the selection of various use cases. The details of the use cases considered are covered in Section V.

IV. RELATED PROJECTS IN ENVIRONMENTAL HEALTH

There has been a large number of documents released summarising the effects of environmental health in an effort to minimise the impact of environmental factors on human health. This section aims to include relevant works in this area to motivate the need for the platform the AusEnHealth Project aims to provide, and to better understand the justification for how urgent intervention is for certain environmental health exposure domains.

A. Climate Change and Human Health Literature Portal

In 2019, The National Institute of Environmental Health Sciences in America released a bibliographic database of research on climate impacts on human health [17]. This database contains international journals and reports from a variety of sciences and is a valuable resource itself for identifying key environmental health work on indicators, modelling, etc.

B. Atlas of Environmental Health

The Atlas of Environmental Health was launched in 2016 by the **Environmental Health Hazards (EHH) Unit**, **Department of Health Western Australia**, with support from the **Cooperative Research Centre for Spatial Information (CRCSI)** [18]. There are three modules in this atlas; Medical Entomology,

Aboriginal Environmental Health and Water Quality Testing. The atlas can be accessed via website as well as through Android and iOS mobile apps, though a login is required with no current registration method. The atlas has not been updated since 2018.

The **Medical Entomology** module has three components;

- A website containing data entry forms, reports and a field guide,
- A mobile tool for offline data entry, and
- Web-based help manuals.

This module is designed for mosquito monitoring for Environmental Health Officers (EHO) and the public. The main aspects of the module:

- Monitor mosquito counts by species across different sites,
- View notifications of diseases borne by mosquitoes, and
- Allow collected data to be accessed by Local Governments straight away.

Increased functionality was added in 2017 which improved the monitoring component of the module and allowed for additional monitoring methods.

The **Aboriginal Environmental Health** module is a data entry module created to help the various groups that undertake environmental health activities in remote Aboriginal communities. Allows community to note time spent on environmental health related activities. Produces the following outputs:

- Number of environmental health activities completed per region,
- Number of hours taken to address certain activities per region (with breakdown by region), and
- Total number of activity items and time spent on those activities per month.

Entries in the report include activities related to drinking water, solid waste, community housing, pest control, animal management, water tanks and treatment plants.

In the **Water Quality** module, departmental staff would load data into the system to allow for querying of the data. New data is compared to thresholds (E. coli levels, etc) and alerts sent if action is required. Currently available resources suggest this module never left testing phases.

A **Food Quality** module was planned in 2017. No other information is publicly available regarding the functionality of progress made on the development of this module. The Medical Entomology module is the main product of the atlas, which received additional funding from **Department of Health and Human Services (VIC)** to continue development. The atlas has allowed for

- The identification of trends in mosquito activity,
- The involvement of the community in environmental health, and
- Communication to and between Local Governments for the benefit of the public.

There are a number of differences between the GAIA Resources Environmental Health Atlas and the AusEnHealth Project vision. Some items of note:

- Collects data using forms, rather than sourcing data from established organisations.
- There is no statistical modelling in this atlas. Collected data is only reproduced visually. Query-based outputs are limited as a result.
- Modules are not designed for national use. Targetted for use only in Western Australia.

Currently, the Medical Entomology module cannot be accessed using the website. This leaves only the Aboriginal Environmental Health module which may be accessible (cannot verify as a login is required). This warrants increased caution when planning the future of the AusEnHealth Project.

C. State of Global Air, 2020

A report and interactive website were released in mid-2020 to give citizens, journalists, policy makers and scientists access to meaningful information about air pollution exposure and its health effects [19]. The interactive website shows trends in air quality and health for over 200 countries, produced annually by the **Health Effects Institute** and the **Institute for Health Metrics and Evaluation's (IHME's) Global Burden of Disease (GBD)** project.

Trends can be seen as early as in 1990 up to 2019. In the last year, the document boasts improved estimates of particulate matter and household pollution as well as the inclusion of air pollution's effects on adverse birth outcomes. The report compares data to the **WHO Air Quality Guidelines** for various parameters, such as PM2.5 concentrations and tropospheric ozone exposure. For areas without specific ozone exposure monitoring, national monitoring stations were used to generate estimates. Methods applied to give these estimates are listed in [19]. Household pollution is also considered, based on the burning of solid fuels for cooking in the household.

Population-weighted values in the report show little or no progress in particulate matter reduction in the most polluted regions, as well as a gradual increase in ozone exposure over the past decade. One positive trend is seen; that household air pollution is decreasing in developed countries over the past decade.

The health consequences of exposure to air pollution are also discussed in [19]. It is estimated that at least 19% of global deaths from COPD, diabetes, ischemic heart disease, lower-respiratory infections, lung cancer, stroke and neonatal deaths are attributable to total air pollution. Burden of disease estimation methods are discussed in the report, as well as the impact of air pollution on COVID-19. The main conclusion note of the report is that, despite a large increase in data availability, there has been no progress made towards reducing air pollution and its associated health burden in many regions on Earth.

D. Health Impacts of Climate Change: Adaptation Strategies for Western Australia

A report was released in 2008 by the Department of Health in Western Australia to provide an understanding of the potential health impacts and associate social implications of climate change [20]. This document reports on projections for 2030 produced by IPCC, CSIRO and IOCI reports and focused on the Western Australia region. These projections are summarised as:

- WA will be generally hotter, particularly in inland regions.
- WA will be dryer, particular in the South West.
- there will be more frequent, intense droughts, heatwaves and fires.
- there will be more intense storms, flood, rainfall events and tropical cyclones.
- Coastal regions will experience an increase in sea level.

Resulting health impacts listed in [20] are:

- Increase in heat stress, dehydration.
- Change in the incidence of mosquito-borne diseases. item Impacts on a range of health issues related to diet.
- Increase mental health issues for farmers.

The document identifies vulnerable communities and provides risk assessment to categorise health impacts. The following impacts are rated from low through to extreme. In the original document, justification for the classification of each health impact is also provided.

- Low:
  - Health impacts from exposure to pesticide.
  - Health impacts from increased chemical exposure.
- Low/Medium:
  - Sleep deprivation.
- Medium:
  - VOC exposure.
  - Legionnaire's disease.
  - Mycotoxins.
  - Seafood poisoning.
  - Bites, stings.
  - Changes to availability/cost of food - reduction in quality of diet.
  - Health impacts from higher levels of imported foods.

- – Increase in crime.
- – Increase in accidents.
- – Health impacts from effects on recreation.
- – Health impacts from increased alcohol consumption.
- – Neglect of physical health during times of crisis, such as drought.
- – Health impacts from loss of green space and gardens.
- Medium/High:
  - – Health impacts from exposure to pathogens from grey-water and non-potable water.
- High:
  - – Flooding.
  - – Water-borne diseases from contamination of drinking water in extreme events.
  - – Health impacts from exposure to pathogens in recreational water.
  - – Ross River virus, Barmah Forest virus, Dengue, Murray Valley encephalitis, malaria, JE, WNV, Tick-borne, Rodent-borne.
  - – Asthma/allergies.
  - – Food poisoning
  - – Dislocation.
  - – Mental health impacts.
  - – Health impacts from population reduction and loss of goods and services.
  - – Health impacts resulting from reductions in biodiversity.
- High/Extreme:
  - – Fires.
  - – Respiratory disease.
- Extreme:
  - – Tropical cyclones.
  - – Heat events.
  - – Health impacts from UV exposure.
  - – Reduced access to health care, food and water.
  - – Inability to meet demand for energy.

The final portion of the report lists potential adaptations to reduce the impact of climate change and possible interventions as part of environmental health management. These are not included in detail as response/action is not in the scope of the AusEnHealth Project. The report includes a call for improved environmental health surveillance and identifies that conditions in Western Australia will continue to worsen without intervention.

E. Doctors for the Environment Australia

The section represents two documents, the **Doctors for the Environment Australia (DEA)**'s climate change action plan [21], and the 2017-18 annual report [22]. These documents promote the use of renewable energy and discuss actions relating to energy use, waste management, transport and land use to reduce the impacts of climate change. Data is used in both sources to improve community awareness. Publications submitted by the DEA on environmental health have led to increased public awareness and policy consideration [22].

F. Human Health and Wellbeing Climate Change Adaptation Plan for Queensland

This report, released in 2018, aims to support human health and well-being services to be innovative and resilient in managing the risks associated with climate change [23]. The document provides framework and detailed case studies of climate change impact management. This document is included in this section

of the material review because it contains a ranked list of climate change impacts of health and well-being. When proposed to stakeholders, the percentage of physical and mental impacts which are a concern were recorded as follows.

- Heat stress (80%)
- Changes in patterns of infectious and vector-borne diseases (72%)
- Death and injuries from extreme events (70%)
- Mental health issues, and emotional and social distress (67%)
- Social vulnerability and increasing inequalities from climate change impact on social (energy, housing transport, livelihood . employment) and ecological (quality o water, air, soil) determinants of health; and cross-sectorial impacts (63%).
- Food and water safety and security (52%)
- Cardiovascular and respiratory illness related to climate change effects on aeroallergens and air pollution (rating omitted).
- Impacts on children's health and development (rating omitted).

This list promotes the importance of certain environmental health factors, useful for prioritisation in the AusEnHealth Project.

G. Other Relevant Environmental Health Reporting

- Spatio-temporal Analysis Using Earth Observation Data to Identify Adverse Health Effect and Location Correlations of Landscape Fire in the Perth Metropolitan Areas of Western Australia [24].
- Climate change and Health: Local Solutions to Local Challenges [25].
- Health Environment: Managing the Linkages for Sustainable Development [26].
- From Townsville to Tuvalu [27].
- Interim Observations (Royal Commission into National Natural Disaster Arrangements) [28].

H. Unreleased Documents

Also included in the material review are a number of projects or documents shared by members of the AusEnHealth Project Advisory Group. A brief summary of each of these documents is given, though details are omitted.

- *Environmental health indicators for selected environmental risk/health outcome pairs in New South Wales* [29]: A New South Wales report describing methods for the development of environmental health indicators, utilising the DPSEEA framework [14], [30]. The baseline assessment of environmental risk presented in this report is supported by the **University of Sydney**, **NSW Health** and the **Human Health and Social Impacts (HHSI)** node of the **NSW Adaptation Research Hub**. Not all components of the DPSEEA framework were used to develop the indicators due to resource limitations.
- *Reducing lives lost from heatwave events* [31]: A national project on heatwaves which utilises a wide range of data from sources including
  - Multi-Agency Data Integration Project (MADIP),
  - National Non-admitted Patient Emergency Department Care Database (NNAPEDCD),
  - Australian Bureau of Statistics (ABS),
  - Public Health Information Development Unit (PHIDU),
  - National Health Services Directory (NHSD), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), and Digital Earth Australia (DEA).

This project noted difficulty using existing geographical methods due to discrepancies in data collected, solving this issue by using the discrete global grid system (DGGS).

V. Environmental Health Data, Use Cases & Indicators

Terms such as *indicator* and *exposure domain* are repeated often below. As such it is important to formally define both terms. "Environmental health indicators describe the link between the environment and health" [1]. Exposure domains represent groups or categories of environmental health indicators. Examples of exposure domains include *air quality*, *vector borne disease*, *built environment*, etc. Environmental health indicators usually describe one aspect of the environment-health relationship and are classified as one of

- **Exposure indicators:** Possible environmental determinants of health, or
- **Health indicators:** Health effects from environmental hazards and risks.

The development of indicators requires time and funding, as the relationship between the environment and health should not be assumed. The following works each add to the understanding of either indicators and their development or potential sources of data relevant to environmental health.

A. Conceptual Framework for Environmental Health Tracking

Included in the paper on conceptual framework development [12] covered in Section III-B is a small discussion on data availability. Potential collaborative stakeholders explored in this paper were:

- Department of Health and Human Servises (DHHS) Victoria,
- Department of Environment, Land, Water and Planning (DELWP) Victoria,
- Bureau of Meteorology (BOM),
- Australian Bureau of Statistics (ABS),
- Commonwealth Scientific and Industrial Research Organisation (CSIRO), and
- Other state government agencies and universities that might provide relevant data.

Data considered to the environmental health tracking system included environmental monitoring and modelling of air and water quality, land use data, and health data from hospital emergency departments and ambulance services.

B. Investigation, Scoping and Planning of a National Environmental Health Tracking System

As well as a valued set of use case selection criteria presented in III-C is significant discussion on the selection process of use cases. The use cases considered in this report are

- Trachoma and housing functionality and personal hygiene,
- Alternative water supplies and gastroenteritis,
- Air quality and asthma,
- Cancer Rates and Surrounding Land Uses,
- Cardiovascular disease and surrounding land uses, and
- Level of aboriginal and Torres Strait Islander community environmental health infrastructure and gastroenteritis and skin health.

These use cases are accompanied by discussion on the why they were or were not selected as a focus use case in the report. Also included are data sets relevant to specific environmental health issues:

- Gastroenteritis,
- Asthma,
- Cancer,
- Arboviruses, and
- Cardiovascular disease.

These can be found in Appendix 1 of [7] and are not listed as comprehensive.

C. The Imperative for Climate Action to Protect Health

In early 2019, an article on climate change noted several associated health risks as part of a call to lower global net human-related emissions of carbon dioxide [34]. These health outcomes are direct environmental health indicators for various exposure domains and are as follows.

- Air quality:
  - Exacerbations of asthma and other respiratory diseases
  - Respiratory allergies
  - Cardiovascular disease
- Climate change:
  - Injuries
  - Fatalities
  - Mental health effects
- Water quality:
  - Campylobacter infection
  - Cholera
  - Cryptosporidiosis
  - Harmful algal blooms
  - Leptospirosis
- Food safety:
  - Undernutrition
  - Salmonella food poisoning and other foodborne diseases
  - Mycotoxin effects
- Vector borne disease
  - Chikungunya
  - Dengue
  - Encephalitis (various forms)
  - Hantavirus infection
  - Lyme disease
  - Malaria
  - Rift Valley fever
  - West Nile virus infection
  - Zika virus infection

D. Notification of infectious diseases and related conditions

The **Western Australian Department of Health** contains a public list of notifiable infectious diseases online [35]. These diseases are indicators of health that have not been linked to an exposure domain and have been recorded as potential health outcomes worth exploring in the future of the AusEnHealth Project. As there are 83 total diseases listed, the specific list is omitted here.

E. Indicators and Data (Centers for Disease Control and Prevention)

Over the past two decades, the **Centers for Disease Control and Prevention** in America have established an environmental public health tracking system [33]. Federal partners of the tracking network project include:

- Census Bureau
- Department of Education
- Environmental Protection Agency
- Federal Emergency Management Agency

- National Aeronautics and Space Administration
- National Cancer Institute
- National Center for Education Statistics
- National Oceanic and Atmospheric Administration

This tracking system has led to improvements in public health decision making and action at state and local levels. There are a large number of indicators recorded in this source, spanning multiple exposure domains.

- Air quality:
  - Air Toxics
  - Pollutants
  - Asthma prevalence among adults
  - Asthma prevalence among children
  - Emergency department visits for asthma
  - Hospitalisations for asthma
  - COPD emergency department visits
  - COPD hospitalisations
  - COPD mortality
- Climate change:
  - Flood vulnerability
  - Future projections of extreme heat
  - Future projections of extreme precipitation
  - Heat stress emergency department visits
  - Heat stress hospitalisations
  - Heat vulnerability - adaptive capacity
  - Heat vulnerability exposure
  - Heat vulnerability - sensitivity
  - Heat-related mortality
  - Historic extreme heat days and events
  - Historic extreme precipitation
  - Temperature distribution
  - Drought duration and severity
  - Sunlight
  - Sunlight/UV vulnerability and preparedness
  - Ultraviolet
- Water quality:
  - Arsenic in community water systems
  - Atrazine in community water systems
  - DEHP in community water systems
  - Disinfection byproducts in community water systems
  - Nitrates in community water systems
  - PCE in community water systems
  - Perchlorate in drinking water
  - PFAS in community water systems
  - Public water use
  - Radium in community water systems
  - TCE in community water systems
  - Uranium in community water systems
- Built environment:
  - Unintentional carbon monoxide poisoning mortality

- – Unintentional CO poisoning emergency department visits
- – Unintentional CO poisoning hospitalisations
- – Flood vulnerability
- – Households
- – Internet access
- – Land cover
- – Land use
- – Medical infrastructure
- – Access to parks and public elementary schools
- – Commute time
- – Motor vehicle-related fatalities
- – Proximity of population and schools to highways
- – Types of transportation to work
- Land contamination:
  - – Age of housing
  - – Annual blood lead levels
  - – Pesticide related illness
  - – Reported pesticide exposure
  - – Radon tests from labs
  - – Radon tests from states

Environmental health systems function differently in Australia to those in America. As a result, the parameters recorded within the above indicators may not be available in multiple states and territories in Australia. The indicators remain a valuable source of information which link health and environmental factors together within certain exposure domains.

F. Tools for the Monitoring of Parma Conference Commitments

The **World Health Organisation (WHO) European Centre for Environment and Health (ECEH)** released a report on environmental health indicators in 2010 [36]. This report defined the minimum set of indicators for monitoring the commitments to reduce health effects of environmental hazards in children, made at the Fifth Ministerial Conference on Environment and Health in Parma, Italy. This set of indicators are shown below.

- Air quality:
  - – Exceedance of the national environmental standards for air quality
  - – Exposure to second hand tobacco smoke in the home
  - – Respiratory Disease
- Water quality:
  - – Exceedance of guidelines at recreational marine and freshwater beaches
  - – Estimated number of people with access to safe drinking water supplies
  - – Notifications of water-borne disease
- Vector borne disease:
  - – Distribution of potential disease-vectors species in New Zealand
  - – Overseas outbreaks of notifiable diseases
  - – Vector borne disease notifications
- Land contamination:
  - – Incidence of childhood leukemia
  - – Incidence of melanoma under 55 years of age
  - – Persistent organic pollutants in human milk
  - – Exposure of children to chemical hazards in food

- Levels of lead in children's blood
- Radon levels in dwellings
- Work injuries in children and young people

The focus on child health does not impact the relevance of this set of indicators. A number of additional indicators are mentioned in [36] which were not defined as part of the minimum set of indicators and could be considered if indicators are explored in more depth in the future of the AusEnHealth Project.

G. Environmental Health Indicators for New Zealand 2008

The **Ministry of Health** in New Zealand released a information of environmental health indicators relating to air quality, water quality and biosecurity [37]. This document uses the DPSEEA framework [14], [30] to present the following environmental health indicators.

- Air quality:
  - Prevalence of asthma and allergies in children
  - Infant mortality due to respiratory diseases
  - Population exposure to outdoor air particulate matter
  - Population exposure to outdoor air ozone
  - Children's exposure to second hand tabacco smoke
  - Population living in homes with problems of damp
  - Proportion of children living in homes using solid fuels
  - Policies to reduce children's exposure to second-hand tabacco smoke
- Water quality:
  - Outbreaks of water-borne diseases
  - Access to improved water sources and public water supply
  - Access to waste water treatment and improved sanitation
  - Bathing water quality
- Biosecurity:
  - Persistent organic pollutants in human milk
  - Exposure of children to chemical hazards in food
  - Levels of lead in children's blood
  - Radon levels in dwellings

This report justifies the choice of indicators suggests actions to reduce the impact of the exposure domains. This information is not included, as it is not in the scope of the AusEnHealth Project.

H. Indicator List (Environmental Health Indicators New Zealand)

The environmental health indicator program run by the Ministry of Health in New Zealand has produced a large list of indicators that are publicly available online [1]. The indicators have been used in New Zealand to monitor trends of both environment and health parameters, compare environmental health across the country, raise awareness about environmental health issues and to initiate further investigations into links between the environment and health.

- Air quality
- Climate change
- UV exposure
- Drinking-water quality
- Air quality and transport
- Indoor environment
- Transport
- Hazardous substances

This work is an expansion of the work in [37], resulting in indicators presented for over a dozen exposure domains. A detailed breakdown of the above indicators are given in [1], coupled with averages of collected data over time for a simple comparison.

I. The Victorian Environmental Health Indicator Project

The only Australia-specific indicator project is a report in 2006 describing the structure of a future environmental health surveillance system for Victoria, Australia [38]. This paper answers calls by **enHealth** and the **Australian Institute of Health and Welfare (AIHW)** for the suggestion of priority environmental health issues to be covered by a core and extended set of environmental health indicators. The report discusses previous Victorian indicator work, as well as conceptual framework used in the selection of the following indicators.

- Air quality:
  - Ambient
  - Indoor
- Climate:
  - Solar radiation
  - Temperature
  - Rainfall
  - Bushfire
  - Severe weather events
  - Salinity
  - Sea level rise
- Water quality:
  - Drinking
  - Recreational
  - Recycled
  - Harmful algal blooms
- Food safety:
  - Contamination
  - Disease
  - Nutrition
- Vector borne disease
  - Arbovirus
- Built environment:
  - Transport
  - Public open space
  - Noise
  - Legionella
  - Asbestos
  - Shelter
  - Chemical hazards
  - Urban fires
- Land contamination:
  - Pesticides
  - Contaminated Land

While the above indicators are considered for use in Australia, systems relating to environmental health vary across the continent. As a result, indicators that are suitable for use in Victoria may not be suitable

in other Australian states or territories. These indicators will be used alongside the others collected in the material review to determine priority use cases in the data audit portion of the AusEnHealth Project.

J. Other Environmental Health Data and Indicator Work

The **UK MEDMI** data mashup project does not appear to be maintained, however, some of the data stored elsewhere is still maintained or updated regularly [39].

The **World Health Organisation** released a report in 1999 which included environmental health indicators [30]. This document is referred to by many other sources for their work in indicator development.

APPENDIX A

INDICATOR DEVELOPMENT DOCUMENTS

The following sources have been included for their work on indicator development, despite the AusEn-Health Project's reliance on completed indicator development projects. The inclusion of the following documents serves to justify the use of existing indicator project results, as it is clear from selection criteria why certain indicators have been selected.

A. *Good Practice Guidelines for the Development and Reporting of Indicators*

The following indicator selection criteria comes from a 2009 paper focused on the development of indicators for the purpose of environmental, economic and social progress [40]. The criteria listed are as follows.

- *Available data:* Indicator must have data that can be easily and reliably extracted.
- *Scientifically valid:* Indicator must have an established, scientifically sound link to the environmental health issue.
- *Sensitive:* Indicator should respond relatively quickly and noticeably to changes, but not show false movements.
- *Consistent:* Indicator should be consistent with those used in other indicator programmes (including internationally), so comparisons can be made.
- *Comparable:* Indicator should be consistent to allow comparisons over time.
- *Methodologically sound measurement:* Indicator measurement needs to be methodologically sound.
- *Intelligible and easily interpreted:* Indicator should be sufficiently simple to be interpreted in practice, and be intuitive in the sense that it is obvious what the indicator is measuring.
- *Able to be disaggregated:* Indicator needs to be able to be broken down into population subgroups or areas of particular interest, such as ethnic groups or regional areas.
- *Timely:* Data needs to be collected and reported regularly and frequently, to ensure it is reflecting current and not historical trends.
- *Public health impact:* Indicator needs to relate to an environmental health issue of significant public health impact to Australia. This health impact may include affecting a large number of people, a vulnerable population, or indigenous health; or having substantial policy relevance.

B. *Performance and Accountability Framework Indicator Selection Criteria*

A number of criteria were used in the selection of authority performance indicators for the National Health Reform Performance and Accountability Framework in 2011 [41]. These criteria are briefly noted as follows.

- Policy:
  - Relevance and appropriateness for policy makers.
  - Avoidance of perverse incentives.
  - Relevance to NHHN agreement and the NHRA.
- Scientific soundness:
  - Valid.
  - Reliable.
  - Attributable.
  - Comparable.
  - Ability to measure progress over time.
- Efficiency:
  - Administratively simple and cost effective

While these criteria are applicable to indicators in the original source, aspects of the criteria can be directly applied to use case selection in the AusEnHealth Project.

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