

# Environmental attributable fractions in remote Australia: the potential of a new approach for local public health action

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In 2006, the World Health Organization (WHO) published a classification system by which to examine modifiable environmental impacts on health, defining 'environment' as all the physical, chemical and biological factors external to a person.<sup>1</sup> Air pollution, water quality, housing and land use patterns, including roads and sanitation facilities, are examples of environmental risk factors included in the WHO classification system. To then quantify the environmentally attributable burden of disease, WHO also produced environmental attributable fractions based on literature reviews and a survey of more than 100 experts worldwide.<sup>1</sup> Diseases with the largest absolute global burden attributable to the environment were diarrhoea, lower respiratory infections and malaria.<sup>1</sup> When WHO concluded that 95% of dengue in developing countries was directly due to the environmental risk factor of poor water management, this led to the powerful argument that 95% of dengue in developing countries would be prevented if governments invested in effective water quality systems.<sup>1</sup>

An identical logic has been used in Australia in tobacco control: specifically, since the tobacco attributable fraction for lung cancer is 90%, then investment in effective tobacco control programs that reduced exposure to tobacco to near zero would prevent 90% of cases of lung cancer.<sup>2</sup> Through such quantification, this approach also makes it clear that not every case of lung cancer is due entirely to tobacco.<sup>2</sup>

In 2011, the Australian Institute of Health and Welfare (AIHW) published a classification system for environmental risk factors for Australia.<sup>3</sup> However, AIHW has never specified

## Abstract

**Objectives:** To determine local values for environmental attributable fractions and explore their applicability and potential for public health advocacy.

**Methods:** Using World Health Organization (WHO) values for environmental attributable fractions, responses from a practitioner survey (73% response rate) were considered by a smaller skills-based panel to determine consensus values for Kimberley environmental attributable fractions (KEAFs). Applied to de-identified data from 17 remote primary healthcare facilities over two years, numbers and proportions of reasons for attendance directly attributable to the environment were calculated for all ages and children aged 0–4 years, including those for Aboriginal patients.

**Results:** Of 150,357 reasons for attendance for patients of all ages, 31,775 (21.1%) were directly attributable to the environment. The proportion of these directly due to the environment was significantly higher for Aboriginal patients than others (23.1% v 14.6%;  $p < 0.001$ ). Of 29,706 reasons for attendance by Aboriginal children aged 0–4 years, 7,599 (25.6%) were directly attributable to the environment, significantly higher than for non-Aboriginal children aged 0–4 years (25.6% v 18.6%;  $p < 0.001$ ).

**Conclusions:** By addressing environmental factors, 20% of total primary healthcare demand could be prevented and, importantly, some 25% of presentations by Aboriginal children.

**Implications:** KEAFs have potential to monitor impact of local environmental investments.

**Key words:** environmental health, social determinants, primary healthcare, environmental determinants

environmental attributable fractions. Because health outcomes in the Kimberley are among the worst in Australia,<sup>4</sup> our need to better understand the environment's impact on remote health required better quantification. Accordingly, we designed a project in which the WHO fractions were used as a basis to determine local Kimberley environmental attributable fractions (KEAFs). To explore the feasibility and usefulness of their application, we subsequently used an accessible healthcare database to calculate demand on primary healthcare that could be claimed as directly attributable to the environment.

This article presents our method to determine KEAFs and results from this preliminary application. We also present our recommendations for future development, especially to support evidence-based environmental advocacy in remote Australia.

## Methods

### *Determining Kimberley environmental attributable fractions (KEAFs)*

To organise environmental risk factors as a foundation for this project, we first combined both WHO and AIHW classification systems<sup>1,3</sup>

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to create 12 risk factor groups, into which we assigned individual environmental risk factors (Box 1).

Next, we developed a survey instrument of three sections. Its first section presented risk factors and their environmental attributable fractions for specific diseases reproduced from WHO.<sup>1</sup> These fractions had been published by WHO as either a precise value (e.g. '5%') or less precisely as a range (e.g. '5%–25%'). Respondents were asked to indicate whether they agreed with the published WHO value for application in the Kimberley. If they did not agree, they were asked to write their own specific estimate of the value in this context. The second section presented diseases in the Kimberley not considered by WHO. Respondents were required to provide their own specific estimate of the value of the attributable fraction without any WHO reference value. In the last section, participants were asked to rate their overall confidence in their estimates using a four-point Likert scale ('completely', 'somewhat', 'a little' and 'not at all'). Our draft questionnaire was pilot-tested with three colleagues to ascertain difficulty, readability and completion time (about 30 minutes).

Their responses were discarded. Our final version of the survey included pictures and multiple fonts to enhance response rates.<sup>5</sup> A copy of our survey instrument is available upon written request.

We then generated a list of potential survey respondents by referring to staff lists in local Kimberley services and consulting WA Health's Environmental Health Branch. Our agreed sample of 39 included staff from the diversity of service providers in the Kimberley: Western Australian Country Health Service (WACHS) including its Kimberley Population Health Unit (KPHU), Broome Hospital and smaller remote hospitals; Kimberley Aboriginal Medical Services Council (KAMSC); two Kimberley-based local government shires; local Aboriginal Community Controlled Health Organisations; and the Royal Flying Doctor Service (RFDS); thereby ensuring input from public health, environmental services, remote nursing, Aboriginal community-controlled services, non-government agencies, health promotion and primary healthcare.

Each potential respondent received an introductory telephone call or face-to-face invitation by CMCM to introduce the

project and ascertain their preference for an electronic or printed version of the survey. Participants were asked to complete the survey independently, based on their experience and without referring to literature. Non-respondents received a sequence of email and telephone follow-ups. Survey data collection concluded on 9 June 2014. Upon receipt, responses were de-identified. Individual responses for each risk factor were collated. On those occasions in the first section of the survey where the participant agreed with the range provided by WHO without giving a more precise value, the higher value was coded: for example, '5–25%' was coded as '25%'. On occasions where the participant gave their own imprecise value such as '>10%', this was coded as '10%'. This approach was taken to ensure consistency in presenting the range of values as well as median and mode values for environmental attributable fractions. Collated responses were never averaged. If an answer was left blank, '-or 'N/A', the response was coded as missing. Only a numerical value of '0' was entered as zero.

A report presenting the median, mode, minimum and maximum values was provided

Box 1: Environmental risk factor classification for the Kimberley region.	
Group	Examples of environmental risk factors
1 Water quality, sanitation and hygiene	Domestic food hygiene (preparation and storage) Water treatment Fluoridation Monitoring Hand hygiene Bathing Laundry facilities Soap availability Functioning toilet Functioning bathroom Rubbish removal
2 Home condition	Maintenance Home hazards (injuries and poisonings) Crowding Pests and vermin Pets (dog vectors) Temperature control
3 Indoor air pollution	Tobacco smoke Combustible fuels (wood fire)
4 Built environment and land use	Road design Road maintenance Vehicle availability and safety Lighting Transport Infrastructure Community store(s): healthy food availability, healthy food affordability Community hazards Injury potential

Box 1 continued: Environmental risk factor classification for the Kimberley region.	
Group	Examples of environmental risk factors
5 Non-occupational, non- domestic chemical exposure	Environmental chemical levels Pesticides Exposure from industry Excludes poisonings at home (under home conditions)
6 Recreational environment	Pools Gardens Playgrounds Bushland Ocean and rivers
7 Climate	Air temperature Extreme weather e.g. cyclones, floods Humidity
8 Public water resources	Drainage Irrigation Waste water removal Water storage Insect vectors
9 Outdoor air pollution	Smog Transport pollution Industry pollution Dust
10 Radiation	UV radiation Ionising radiation
11 Environmental noise	Non- occupational ambient noise
12 Occupational factors	Occupational noise Occupational chemical poisonings

to a face-to-face meeting of a smaller, five-person skills-based panel covering the disciplines of epidemiology, clinical medicine, nursing and public health to facilitate data-based discussion before producing consensus values for each. Acknowledging the utility elsewhere of distinguishing the answers of de-identified individual experts alongside collective answers to achieve credible consensus,<sup>6,7</sup> the panel was provided responses from each of two expert but de-identified respondents. When all panel members agreed, this KEAF consensus value was recorded. Our panel also reviewed any omissions or clarifications about disease or risk factor groups.

### Applying KEAFs to health service data

Health care in the Kimberley is provided through multiple services, including: six hospitals managed by WACHS; 17 community health clinics and remote area nurse clinics with capacity to provide outreach to schools, outstations and family centres managed by KPHU as a subsidiary of WACHS; nine independent Aboriginal Community Controlled Health Services; a regional Kimberley Aboriginal Medical Service (KAMS); and the Royal Flying Doctor Service (RFDS), which maintains 'fly in/fly out' primary healthcare services along the Gibb River Road and elsewhere. In the Kimberley, there is no functioning digital bridge such as *My eHealth Record* in the Northern Territory, which enables centralised data extraction to capture all rendered health care services irrespective of provider or setting whether emergency department, hospital in-patient ward or primary health care clinic. Furthermore, primary healthcare clinical record systems in the Kimberley include Communicare, Medical Director and MMEEx. To explore the feasibility of applying KEAFs in the Kimberley, we therefore elected to access the only universal database mandatory in all WACHS-based primary healthcare settings in the Kimberley irrespective of clinical medical record system. This is a DOS-based database known as HCARE. Presentations to hospital emergency departments and inpatient admissions are not included in this HCARE database.

HCARE codes an 'occasion of service' that is defined as any time an individual presents to one of the WACHS primary healthcare services for clinical attention. HCARE requires every 'occasion of service' to be allocated one code from a reference list of codes

that corresponds to the main health issue of the consultation ('primary issue'). This reference list is standardised across WACHS. As every 'occasion of service' has only one 'primary issue', this was used to calculate the number of attendances and also to describe the 'primary reason for attendance'. Up to two additional codes ('other issues') can be entered for any 'occasion of service' if appropriate. Hence, every 'occasion of service' has a 'primary reason for attendance' and up to two 'other' reason(s) for attendance.

Using HCARE, we obtained de-identified data for 'occasions of service' for a two-year period (1 July 2012 to 30 June 2014 inclusive) for 17 KPHU-managed primary healthcare sites across the Kimberley. Coding errors were checked manually where possible. We summed all 'primary' reasons to arrive at the total number of attendances in primary health care. All 'other' reasons also were summed. Having obtained a dataset of all 'primary' reasons for an occasion of service as well as all reasons, we multiplied the totals of each disease or health condition by its respective KEAF first for all ages and then for children aged 0–4 years. As 43.5% of our resident population is Aboriginal,<sup>8</sup> we also analysed sets of consultations coded as having been provided to Aboriginal patients.

To compare proportions, we used Epi Info 7 to perform two-tailed chi square analyses.<sup>9</sup>

### Ethics

This project was approved by WA Country Health Service Human Research Ethics Committee (Reference 2014-18).

## Results

### Consensus values for KEAFs

Of 39 original respondents in our sampling frame, two were on leave from the Kimberley for an extended period while four gave convincing responses that they were not sufficiently experienced in the subject matter. From 33 eligible respondents, we received 24 surveys (73% response rate). No respondent was 'completely' confident in their answers although nine were 'somewhat' and another nine 'a little' confident. All responses were collated, presented to and discussed at length by the skills-based panel in June 2014. Table 1 presents a complete list of KEAFs determined through consensus by this panel. KEAFs for unintentional injuries, scabies and urinary tract infection, for example, are 95%, 95%

and 10%, respectively (Table 1). Of those 125 original WHO environmental fractions,<sup>1</sup> the panel concurred with values for 48 (38%).

### Estimates of demand on primary healthcare attributable to the environment

#### All ages

From 1 July 2012 to 30 June 2014, HCARE showed 104,596 'occasions of service'. Table 2 shows reasons for attendance by patients of all ages by HCARE classification. Data for individual diseases where otherwise combined are available from the authors. Table 2 also shows 45,761 'other' reasons entered and coded in HCARE in addition to 'primary' reasons, giving a total of 150,357 reasons in HCARE for patients of all ages attending WACHS primary health care facilities across the Kimberley. Applying KEAFs, we found that 21,706 primary reasons were environmentally attributable (20.7% of primary reasons for attendance). Of 150,357 total reasons for attendance, we found that 31,775 were environmentally attributable, representing 21.1% of total reasons for attendance (Table 2).

#### Children 0–4 years

As shown in Table 3, there were 25,870 occasions of service for children aged 0–4 years. Attendances for children aged 0–4 years represented nearly one-quarter (24.7%) of all primary healthcare attendances during the two-year period. As shown in Table 3, there were 18,727 other reasons entered and coded in HCARE in addition to primary reasons, giving a total of 44,597 reasons in HCARE for children aged 0–4 years attending WACHS primary health care facilities across the Kimberley. Applying KEAFs, we found that 6,544 were environmentally attributable (representing 25.3% of primary reasons for attendance by very young children). Of 44,597 total reasons for attendance, we found that 10,375 were environmentally attributable (23.2%), see Table 3. Further, the proportion of all reasons for attendance directly attributable to the environment for children aged 0–4 years was significantly higher than that for all other ages (23.2% v 20.2%; chi square 169.9; df=1;  $p<0.001$ ). In decreasing order, the top five reasons given for attendance by children aged 0–4 years that were directly attributable to environmental factors comprised: 1) malnutrition and nutritional concerns; 2) otitis media; 3) skin infections;

**Table 1: Consensus values for Kimberley environmental attributable fractions (KEAFs) by disease.**

Disease/ Condition	Group	KEAF (%)	
		Group(s)	Total
Skin infection incl. pustules, abscess, cellulitis, impetigo	Water quality, sanitation and hygiene	60	100
	Home condition	25	
	Climate	15	
Scabies	Water quality, sanitation and hygiene	25	95
	Home condition	70	
Unintentional injuries incl. dog bite	Home condition	25	95
	Built environment and land use	50	
	Recreational environment	10	
	Climate	5	
	Occupational factors	5	
Skin cancer	Radiation	95	95
Otitis Media	Home condition	45	90
	Indoor air pollution	40	
	Outdoor air pollution	5	
Trachoma	Water quality, sanitation and hygiene	80	90
	Outdoor air pollution	10	
Intestinal nematodes (hookworm)	Water quality, sanitation and hygiene	90	90
Diarrhoeal diseases	Water quality, sanitation and hygiene	70	80
	Recreational environment	5	
	Climate	5	
Acute Rheumatic fever (ARF)	Water quality, sanitation and hygiene	50	80
	Home condition	30	
Throat infection	Home condition	45	80
	Indoor air pollution	30	
	Outdoor air pollution	5	
Ross River Virus	Climate	50	80
	Public water resources	30	
Other arboviruses (Barmah Forest)	Climate	50	80
	Public water resources	30	
Murray Valley Encephalitis	Climate	50	80
Pterygium	Radiation	80	80
	Radiation	80	
Malnutrition and nutritional concerns	Water quality, sanitation and hygiene	10	78
	Climate	8	
	Built environment and land use	60	
	Occupational factors	22	
Post-streptococcal glomerulonephritis	Water quality, sanitation and hygiene	50	75
	Home condition	25	
Cataracts	Radiation	60	70
	Occupational factors	10	
	Occupational factors	10	
Drowning	Built environment and land use	30	66
	Recreational environment	30	
	Climate	5	
	Occupational factors	1	
Rheumatic heart disease (RHD)	Water quality, sanitation and hygiene	40	65
	Home condition	25	
Falls	Home condition	25	60
	Built environment and land use	10	
	Recreational environment	20	
	Occupational factors	5	
Conjunctivitis (Infective)	Water quality, sanitation and hygiene	30	60
	Home condition	30	
Road traffic accident	Built environment and land use	50	60
	Occupational factors	10	
Dental caries, abscess, extractions	Water quality, sanitation and hygiene	60	60
Failure to thrive	Water quality, sanitation and hygiene	20	60
	Built environment and land use	40	

**Table 1 continued: Consensus values for Kimberley environmental attributable fractions (KEAFs) by disease.**

Disease/ Condition	Group	KEAF (%)		
		Group(s)	Total	
Cardiovascular disease (Not RHD)	Indoor air pollution	3	56	
	Built environment and land use	30		
	Recreational environment	5		
	Climate	3		
	Occupational factors	10		
Asthma	Home condition	5	55	
	Indoor air pollution	40		
Lower respiratory infections	Outdoor air pollution	5		47
	Occupational factors	5		
Deafness	Home environment	10		
	Indoor air pollution	30		
	Outdoor air pollution	5		
	Built environment and land use	2		
Tuberculosis	Occupational factors	5	33	
	Home condition (Otitis media)	25		
	Indoor air pollution (otitis media)	10		
Fires/ burns	Home condition	30	30	
	Occupational factors	3		
Low birth weight	Home condition	25	27	
	Occupational factors	5		
	Built environment and land use	20		
	Occupational factors	2		
Violence	Water quality, sanitation and hygiene	3	25	
	Indoor air pollution	2		
Musculoskeletal diseases	Occupational factors	2	25	
	Built environment and land use	20		
Poisonings	Home condition	20	20	
	Chemicals	5		
	Occupational factors	5		
Mental health / psychosocial	Home condition	5	20	
	Climate	5		
	Occupational factors	5		
	Environmental noise	5		
Cancer	Home condition	5	16	
	Indoor air pollution	4		
	Built environment and land use	5		
	Chemical exposure	2		
Chronic lung disease incl. COPD	Occupational factors	5	12	
	Indoor air pollution	10		
	Outdoor air pollution	1		
Urinary tract infection	Indoor air pollution	1	10	
Suicide	Water quality, sanitation and hygiene	10	9	
	Built environment and land use	5		
	Occupational factors	2		
Perinatal infections	Home condition	2	8	
	Built environment and land use	5		
	Occupational factors	1		
Miscarriage	Water quality, sanitation and hygiene	5	7	
	Indoor air pollution	1		
	Occupational factors	2		
	Built environment and land use	1		
Premature birth	Water quality, sanitation and hygiene	3	7	
	Indoor air pollution	2		
	Occupational factors	1		
	Built environment and land use	1		
Perinatal deaths	Water quality, sanitation and hygiene	2	5	
	Occupational factors	1		
	Built environment and land use	2		
STD	Occupational factors	5	5	
Shingles	Water quality, sanitation and hygiene	5	5	

4) throat infections; and 5) diarrhoea (Table 3). These five accounted for 83.4% of reasons for attendance by young children attributed to the environment. Each of these had KEAFs equal to or greater than 75%.

#### Attendances by Aboriginal patients directly attributable to the environment

As HCARE codes ethnicity of the patient attending, we were able to ascertain that 82,206 of 104,596 (86.6%) occasions of service for patients of all ages were for Aboriginal patients. Of 115,504 total reasons for attendance by Aboriginal patients of all ages, 26,685 (23.1%) were directly attributable to the environment. The proportion of all reasons for attendance directly due to the environmental was significantly higher for Aboriginal patients than for all others (23.1% v 14.6%; chi square 1160; df=1;  $p < 0.001$ ).

We were also able to ascertain that 17,611 occasions of service out of all 25,870 for children aged 0–4 years were for Aboriginal children (68.1%). Of 29,706 total reasons for attendance recorded for Aboriginal children aged 0–4 years, 7,599 (25.6%) were directly attributable to the environment. This proportion was significantly higher than the proportion of total reasons for attendance directly attributable to the environment for non-Aboriginal children aged 0–4 years (25.6% v 18.6%; chi square 271.7; df=1;  $p < 0.001$ ).

## Discussion

This is the first time that WHO's environmental attributable fractions have been adapted locally to quantify the impact of the environment on health in remote Australia. As published, global WHO fractions could not be applied without such adaptation. Certain diseases such as Rheumatic Heart Disease (RHD) had not been afforded a fraction by WHO. For other diseases, the WHO fraction had little credibility for the Kimberley. For example, WHO had determined that >25% of Human Immunodeficiency Virus (HIV) infection was environmentally attributable.<sup>1</sup> WHO also acknowledged that environmental risk factors change as countries transition from 'developing' to 'developed' status, inviting regular review and policy response.<sup>1</sup> Rather than maintaining a broad view on environmental risk factors, WHO has most recently focussed on single determinants or disease consequences.<sup>10-12</sup> Our approach needed to be comprehensive from the outset (Box 1).

Our pragmatic method to determine KEAFs first obtained values from a large and diverse sample of respondents. Although self-ratings of their confidence in doing so were disappointing, presentation of their collated mode, median, minimum and maximum values assisted the deliberations of a smaller, skills-based panel to arrive at consensus values (Table 1). Three examples are highlighted. This panel agreed that 65% of RHD in the Kimberley was directly attributable to the environment, redressing WHO's omission. Only one KEAF – that for skin infection – was determined through this process to have a value of 100%. In this case, the skills-based panel considered factors in the Kimberley other than the environment to be so small as to be negligible. As a third

example, by deciding a value for KEAF of 90% for otitis media, the panel recognised that anatomical variation also contributes to the development of otitis media (Table 1). We acknowledge, however, that a different panel may have arrived at different KEAF values. It would be useful for this to be explored in future.

We also report what we propose is the first known systematic application of any set of explicit environmental attributable fractions to regional health services data. As shown in Table 2, one in five of the reasons that were given for attending primary healthcare in the Kimberley is attributable to the environment. By contrast, other methods have been less rigorous. For example, the latest *Overcoming Indigenous Disadvantage: Key Indicators*

**Table 2: 'Primary' and all reasons for primary healthcare attendances in the Kimberley for all ages and those due to environmental factors. (1 July 2012-30 June 2014).**

Disease/Condition	All ages (Aboriginal and non-Aboriginal)			
	Primary reason for attendance (n)	Any reason for attendance (n)	Primary reason due to environment (n)	Any reason due to environment (n)
Skin infection	3,867	5,571	3,867	5,571
Otitis Media	3,983	5,648	3,585	5,083
Scabies	425	689	404	655
Unintentional injuries incl. dog bite	1,335	1,841	1,268	1,749
Skin cancer	4	4	4	4
Trachoma	395	463	356	417
Intestinal nematodes (hookworm)	1,016	1,264	914	1,138
Diarrhoeal diseases	597	867	478	694
Upper respiratory: Throat	2,446	3,357	1,957	2,686
Ross River Virus	3	3	2	2
Malnutrition	4,093	7,287	3,193	5,684
Rheumatic heart disease (RHD)	1,322	1,567	1,058	1,254
Falls	2	4	1	2
Conjunctivitis (Infective)	564	923	338	554
Road traffic accident	253	330	152	198
Dental caries, abscess, extractions	984	1,550	590	930
Failure to thrive	186	240	112	144
Cardiovascular disease (Not RHD)	258	326	144	183
Asthma	211	294	116	162
Lower respiratory infections	752	1,099	353	517
Deafness	1,306	2,622	522	1,049
Tuberculosis	41	44	14	15
Fires/ burns	214	325	54	81
Violence	54	75	14	19
Musculoskeletal diseases	1,675	2,304	419	576
Poisonings	14	18	3	4
Mental health/ psychosocial	6,117	8,386	1,223	1,677
Cancer	444	476	71	76
Chronic lung disease	161	187	19	22
Urinary tract infection	718	1,056	72	106
Complaints about the environment <sup>#</sup>	136	167	136	167
Suicide	27	33	2	3
STD	5,302	7,058	265	353
<b>Totals</b>	<b>104,596</b>	<b>150,357</b>	<b>21,706</b>	<b>31,775</b>

<sup>#</sup> For internal coherence, these few attendances coded for concerns about the environment were analysed as having KEAF of 100%.

2014 report released by the Productivity Commission shows all hospitalisations for a suite of diagnoses including influenza and pneumonia, diphtheria, intestinal infectious diseases and meningococcal infection as entirely environmentally based.<sup>13</sup> In other words, the Productivity Commission assumed the environmental attributable fractions for each of these diseases is 100%, perpetuating what we perceive is a poorer method.<sup>14,15</sup>

By developing and applying more credible fractions, we also were able to examine attendances at primary health care by Aboriginal children aged 0–4 years (Table 3). Children are powerless to control their environment.<sup>16</sup> It is cause for concern that one in four of the reasons that were given for attendance at primary healthcare for Aboriginal children aged 0–4 years in the Kimberley is directly attributable to their environment.

Methodologically, our efforts to apply KEAFs to health utilisation data were constrained

by factors unique to the Kimberley. As described, there are multiple service providers in our region. Incompatibility of their clinical record software precluded any further regional application of KEAFs to measure environmental determinants of health. Our reliance on HCARE as a primary healthcare database also likely introduced several biases. Certain diseases appear under-represented in HCARE, despite their known high incidence. For example, both acute rheumatic fever (ARF) and acute post-streptococcal glomerulonephritis (APSGN) are only diagnosed definitively during in-patient assessment by a paediatrician, so any preceding HCARE code reflecting this 'occasion of service' in primary healthcare will be non-specific, such as 'pyrexia of unknown origin' for ARF or 'haematuria' for APSGN. Yet their KEAFs are relatively high (Table 1). Furthermore, follow-up attendances in primary healthcare by patients with complications of ARF are typically coded

in HCARE simply as 'medication' because of the need to document adherence to intramuscular injections every 28 days. Other examples of poor data capture in HCARE include drowning, premature birth and miscarriage, as these are typically emergency department attendances. While anecdotal feedback also suggested HCARE does not capture all primary healthcare attendances due to the burden of double data entry for clinical staff, those six WACHS primary care clinics with Section 19(2) Medicare exemptions would have all 'occasions of service' accurately coded because of billing requirements.<sup>17</sup>

Direct access to electronic clinical medical records and additional clinical detail would readily rectify these methodological aspects. Direct access to clinical record systems would also permit an adjustment for preventative care visits, which are not readily distinguished in HCARE. Scheduled health checks for both adults and children inflate the denominator, thereby reducing the proportions of environmentally attributable attendances that were calculated. A truer picture of demand due to the environment would emerge if health checks were excluded from the denominator in primary healthcare. Application of KEAFs to service data from emergency departments and hospital admissions would also be a future priority. Although not designed primarily as an Aboriginal health project, our findings reaffirm the inequitable health sequelae for Aboriginal people due to the poor environmental conditions in which they have been compelled to live, without true control, for decades.<sup>13,18-23</sup> We argue that environmental attributable fractions will lead to more convincing evidence-based advocacy. Environmental conditions have been upheld as especially critical in remote Western Australia.<sup>24,25</sup> Observational studies remain the 'workhorse' of environmental health research designs.<sup>26</sup> We detect a readiness in the Kimberley for further application of relevant, credible fractions such as KEAFs. We especially support their application by individual clinics, communities and non-government organisations including each Aboriginal community-controlled health service to highlight the demand on their services from unmitigated environmental factors. Furthermore, costs for health services, individuals and governments that could otherwise be prevented by investing in environmental health initiatives also could

**Table 3: 'Primary' and all reasons for primary healthcare attendances in the Kimberley for children 0-4 years and those due to environmental factors (1 July 2012-30 June 2014).**

Disease/ Condition	Children 0-4 (Aboriginal and non-Aboriginal)			
	Primary reason for attendance (n)	Any reason for attendance (n)	Primary reason due to environment (n)	Any reason due to environment (n)
Skin infection	769	1,175	769	1,175
Otitis Media	957	1,497	861	1,347
Scabies	142	229	135	218
Unintentional injuries incl. dog bite	115	155	109	147
Trachoma	44	55	40	50
Intestinal nematodes (hookworm)	160	230	144	207
Diarrhoeal diseases	272	402	218	322
Throat infections	821	1,128	657	902
Malnutrition and nutritional concerns	3,750	6,293	2,925	4,909
Rheumatic heart disease (RHD)	6	7	5	6
Conjunctivitis (Infective)	139	260	83	156
Road traffic accident	15	20	9	12
Dental caries, abscess, extractions	86	194	52	116
Failure to thrive	155	197	93	118
Cardiovascular disease (Not RHD)	5	5	3	3
Asthma	51	71	28	39
Lower respiratory infections	245	358	115	168
Deafness	129	239	52	96
Fires/ burns	70	109	18	27
Violence	3	5	1	1
Musculoskeletal diseases	86	136	22	34
Poisonings	6	7	1	1
Mental health/ psychosocial	912	1,443	182	289
Carer complaints about the environment <sup>#</sup>	13	20	13	20
Cancer	2	4	0	1
Chronic lung disease	18	19	2	2
Urinary tract infection	38	61	4	6
STD	56	65	3	3
<b>Totals</b>	<b>25,870</b>	<b>44,596</b>	<b>6,544</b>	<b>10,375</b>

<sup>#</sup> For internal coherence, these few attendances coded for concerns about the environment were analysed as having a KEAF of 100%.

be calculated. Use of KEAFs to monitor the impact of these initiatives, remote housing policies or community development that successful advocacy might elicit,<sup>27-29</sup> by communities themselves with their own health data, could be particularly empowering.

To conclude, public health advocacy for environmental health could be strengthened by the development and application of defensible environmental attributable fractions. We used the international WHO reference to determine values for such fractions for a remote setting by way of survey and expert consensus using a method that others could replicate elsewhere in Australia. Having developed KEAFs, their preliminary application was enlightening when used with an accessible primary healthcare database. There is already interest among service providers to apply KEAFs to their own clinical data. Our project also provides quantitative evidence that ill health from environmental causes in the remote Kimberley imposes a large yet preventable burden on the WA health system.

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