Lead Report 2019:

Broken Hill children less than 5 years old

Broken Hill University
Department of Rural Health

NSW GOVERNMENT Health
Far West
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Executive Summary

The information contained in the 2019 Lead report provides an update on the ongoing public health issue of elevated blood lead levels in children under the age of five in Broken Hill.

All children under the age of five residing in Broken Hill have been offered blood lead testing since 1991. This testing is voluntary and offered through the Broken Hill Child and Family Health Service and Maari Ma Primary Health Care Service. In addition, screening of umbilical cord blood lead levels of newborns, born in Broken Hill to resident mothers, commenced in 1996.

In February 2016, the NSW Ministry of Health endorsed the revised National Health and Medical Research Council (NHMRC) guidelines for the notification of blood lead levels from 10 µg/dL to 5 µg/dL. This report uses the revised lead blood notification figure and therefore reports on the proportion of children with blood lead levels under 5 µg/dL.

Newborns

In 2019, a total of 159 newborn cord bloods were tested for lead content. The geometric mean was 0.7 µg/dL (the same as in 2018). All newborns, regardless of Aboriginality, had blood lead levels below the notifiable level. At this age there is very little difference in geomeans between non-Aboriginal and Aboriginal (0.7 µg/dL v 0.8 µg/dL respectively).

Children aged 6 months to <12 months

A review in 2017 of the screening data from 2016 to 2017, by age group, found that the mean blood lead level was above the notifiable 5 µg/dL for 1 year olds. This prompted a revision to the 2018 testing regime with reintroduction of testing at 6 months (aligning with the immunisation schedule).

In 2019, a total of 201 children aged 6 months to <12 months were screened during 6 month immunisation schedule. The geometric mean lead level of children aged 6 months to <12 months was 2.8 µg/dL (compared to 2.7 µg/dL from 156 children in 2018). In 2019, as in 2018, 85% of children in this age group had a blood lead level below 5 µg/dL, compared to 75% in 2012.

Children aged 1 to <5 years

The data shows that population blood lead levels have fluctuated but not changed significantly since 2012. 2012 was the first full year after the introduction of the finger-prick method (also referred to as Point of Care testing) and aligning testing with immunisation, resulting in significant increases in Aboriginal and non-Aboriginal children tested, affording a more exact indication of population blood lead levels in children in Broken Hill. Crucially, the gap between Aboriginal and non-Aboriginal children,

noticeable in the 1 year to < 5 years age group, has not changed for more than 10 years. The gap between Aboriginal and non-Aboriginal children blood lead levels remains around 4.0 µg/dL, this has been observed in previous years excluding 2016 where the gap was 2.4 µg/dL.

The geometric mean lead level (age-sex standardised) for all children (1 to <5 years) was 5.1 µg/dL in 2019, a slight rise of 0.4 µg/dL from 2018 (4.7 µg/dL). The mean result for Aboriginal and non-Aboriginal children both increased from 2018 to 2019 (Aboriginal children: 7.9 µg/dL to 8.5 µg/dL, non-Aboriginal children: 4.0 µg/dL to 4.2 µg/dL).

In 2019, a total of 681 children aged 1 to <5 years were screened for blood lead levels. The number of children aged 1 to <5 this year was higher than the last year (637 in 2018). Compared to last year, there was a 19% increase in the number of Aboriginal children screened (154 to 183) and a 2% increase in the number of non-Aboriginal children screened (480 to 489) this year. Aboriginal children represented 27% of all children tested in 2019 (24% in 2018, 30% in 2016 and 2017).

The 2019 results show 60% of non-Aboriginal children in Broken Hill had a blood lead level below 5 µg/dL, compared to only 20% of Aboriginal children. The result for Aboriginal children decreased slightly from 2016 - 2017 (both 22%) and 2018 (24%), whilst the result for non-Aboriginal children increased in the same period from 50% to 60%. When combining the results for Aboriginal and non-Aboriginal children, there was a small decrease (from 51% to 48%) of all children with blood lead levels below 5 µg/dL between 2018 and 2019.

Ongoing work is still needed to reduce blood lead levels in Broken Hill. While Aboriginal and non-Aboriginal children have comparable geomeans as newborns and when aged 6 months to < 12 months, the adjusted geomean and proportion of Aboriginal children ≥ 5 µg/dL are much higher compared with non-Aboriginal children once they are in the 1 to< 5 years age group. Although in 2019 the population mean for children aged 1 to <5 years was very close to 5 µg/dL, for a significant proportion of these children to be below 5 µg/dL the population mean will have to be considerably lower than 5.1 µg/dL.

Introduction

Unlike many other naturally found metals, lead and lead compounds are not beneficial or necessary for human health, and can be harmful to the human body. It is well established that blood lead levels greater than 10 µg/dL can have harmful effects on many organs and bodily functions. Effects on blood pressure, kidneys, blood abnormalities such as anaemia, digestive system and neurobehavioural problems (such as forgetfulness, irritability, mood changes, fatigue, weakness) are associated with high blood lead levels. Severely abnormal brain function (such as dizziness, tremors, paralysis) has occurred at levels of 70-100 µg/dL in children and 100-120 µg/dL in adults[1]. Death may also occur at these levels.

According to the World Health Organisation, blood lead levels around 10.0 µg/dL are now known to cause damage to the developing brain and nervous system of children. In addition, the immune, reproductive and cardiovascular systems are also adversely affected[1].

The possibility of health effects from lead is higher for children and babies (including unborn babies) than for adults because their bodies are smaller and their brains are rapidly developing[1]. Small children are more likely than adults to swallow small amounts of lead, because they put things in their mouths, touch dusty surfaces indoors and outdoors, and touch their mouths more. Children and babies also absorb and store a greater amount of ingested lead than adults. Blood lead levels at which people exhibit symptoms vary greatly between individuals. It is possible for people with blood lead levels of 40 µg/dL or more not to exhibit noticeable health effects.

The most common lead exposure pathways for children is via ingestion followed by inhalation of lead containing dust and less commonly absorption through skin. There is also evidence that a mother's exposure to lead during pregnancy can be transferred to the foetus. Compounding the issue in young children is that they absorb four to five times as much ingested lead compared to an adult from any given source. Undernourished children are also more susceptible to lead because their bodies absorb more lead if other nutrients, such as calcium, are lacking[1].

Once lead has entered the blood stream, it is stored in bone. For an affected pregnant woman, lead is released from the bones and into the blood and becomes a source of exposure to the developing foetus. Exposure of pregnant women to high levels of lead can cause miscarriage, stillbirth, premature birth and low birth weight, as well as minor malformations[1].

In 1996, umbilical cord blood screening commenced in Broken Hill, to determine lead levels in children at birth. This initiative tested the lead levels in newborns via collecting sample of venous blood from the umbilical cord. Venous blood lead screening of children aged 6 months to 5 years had begun in 1991.

Broken Hill Hospital only accepts expectant mothers if the pregnancy is considered low risk. If the pregnancy is rated as higher risk, expectant mothers are referred to Flinders Medical Centre or Women's and Children's Hospital (both in Adelaide).

[1] World Health Organisation, Childhood Lead Poisoning, 2010

Details of the criteria for higher risk births are contained in Appendix 1 and include, for example, a Body Mass Index of ≥ 46 at 36 weeks gestation and high risk co-morbidities. Not all births referred to South Australia will have their cord bloods tested unless the mother has requested that results be sent back to Broken Hill.

Since the commencement of the lead screening program in 1996, there has been a steady decline in umbilical cord blood lead levels, from 2.9 µg/dL in 1996 down to 1.2 µg/dL in 2008. Since 2008, cord blood lead levels have remained relatively stable.

From July 2015, following significant planning and advocacy, the NSW Government funded the Broken Hill Environmental Lead Program (BHELP) with $13 million, over 5 years. Five people have been recruited to the BHELP program under the auspices of the NSW Environment Protection Authority (EPA). The Broken Hill Environmental Lead Program Steering Committee (BHELPSC) is made up of representatives from EPA, Far West Local Health District, Aboriginal Lead Reference Group and the Broken Hill Lead Reference Group.

Reducing the amount of lead in the environment (e.g. in soil, dust, air and products) as much as possible will reduce the risk of harm from lead exposure, especially for young children and unborn babies.

Purpose of this report

This report provides the clinical outcomes of the blood lead screening program of Broken Hill in 2019 for children under the age of 5, and compares the results to previous years. Data in this report was collected from Child & Family Health Centre (C&FHC) and Maari Ma Primary Health Care Service as recorded on Community Health and Outpatient Care database (CHOC) between 1 January and 31 December 2019.

This report covers these areas:

- **Participation rate of children aged 1 to <5 years**

  The participation rate is intended as an indicator of success of recruitment to screening in this age group, which is the largest of the three age groups screened.

- **Newborns**

  Describes the trend in the number of newborns screened and provides geomean by Aboriginality from cord bloods collected from newborns born to Broken Hill mothers in Broken Hill Hospital. The trend for all cord bloods from 1996 are described.

- **All Children aged 6 months to <12 months**

  Describes the number of children screened and provides geomeans of all children by

Aboriginality who were screened at the Child & Family Health Centre or Maari Ma Primary Health Care Service. The lead testing for this age group restarted in 2018, after being discontinued from 2013 to 2017. Lead testing was discontinued for two reasons: resourcing constraints and the preliminary results showed that geometric mean blood lead levels of children in this age group were well below the notifiable level at that time (10 µg/dL).Trend data for all children from 1991 is also described.

- **All Children aged 1 to <5 years**

  Describes the trends in the number of children screened and provides age-sex standardised geomeans of all children and by Aboriginality who were screened at the Child & Family Health Centre or Maari Ma Primary Health Care Service. It also describes the blood lead results by blood lead categories by Aboriginality. Trend data for all children from 1991 is also described.

- **Seasonal changes in blood lead levels of children**

  Describes the number of children screened and their geomean by calendar month in 2019. This section, investigates seasonal changes in blood lead levels of children aged between 1 and < 5 years.

Background

History of Lead poisoning in Broken Hill

Broken Hill is a historical town founded in 1883 on mining of the 'line of lode,' the world's largest and richest silver-lead-zinc mineral deposit. Since the Broken Hill Proprietary Company Limited was established in 1885, lead poisoning had been evident among early miners and their families. Despite this evidence, lead poisoning was seen mainly as an occupational rather than population health issue.

A serological survey of school-aged children in 1982, found all had blood lead levels below 40µg/dL, the then level of concern in Australia.[2] Local dogs, apparently healthy, were found to have lead levels similar to dogs in Port Pirie, a town with a lead smelter.[3] Local concern was increased in Broken Hill by the recommissioning of open-pit mining in the centre of town, a drought in the late 1980s and the birth of three babies with delayed visual maturation (usually caused by exposure to high lead levels *in utero*) between 1988 and 1990.[4]

A 1991 survey of 1-<5 year-old Broken Hill children found that 86% had blood lead levels of 10µg/dL or above and that 38% had very high lead levels of 20µg/dL or above.[5]

History of Lead screening initiative

Since 1991, parents/carers in Broken Hill have been offered voluntary blood lead screening for children under the age of 5 years old. Lead screening is encouraged through the combination of: reminders via text message; aligning lead testing with the immunisation schedule; and promotions and advertising in the local media. From 1996, newborn umbilical cord blood has been tested to determine the impact of lead transfer from the mother to the child.

In 1994, the NSW State Government funded a lead management program to address the situation of high lead levels in Broken Hill children.[6] The capping of the Line of Lode and closure of the North Mine took place in the first years of blood lead surveillance. Over the time of the first round of government funding from 1994-2006 blood lead levels continued to significantly decrease when there was both extensive public land remediation/ abatement and housing remediation.[7]

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[2]Phillips A. Trends in and factors for elevated blood lead concentrations in Broken Hill pre-school children in the period 1991-1993 (dissertation). Newcastle: University of Newcastle; 1998.
[3]Koh TS, Babidge PJ. A comparison of blood lead levels in dogs from a lead mining, lead smelting, urban and rural island environment. *Aust Vet J* 1986; 63(9): 282–5.
[4]Gulson BL, Yui LA, Howarth D. Delayed visual maturation and lead pollution. *Sci Total Environ* 1998; 224: 215–9.
[5]Woodward-Clyde. Evaluation of environmental lead at Broken Hill. Prepared for Environmental Protection Authority, NSW. Project No. 3328. Sydney: ACG Woodward-Clyde Pty Ltd; 1993.
[6]Lyle DM, Phillips AR, Balding WA, Burke H, Stokes D, Corbett S et al. Dealing with lead in Broken Hill: trends in blood lead levels in young children 1991-2003. *Sci Total Environ* 2006; 359: 111-9. Doi:10.1016/j.scitotenv. 2005.04.002
[7]Boreland F, Lesjak MS and Lyle DM. Managing environmental lead in Broken Hill: a public health success. *NSW Public Health Bull* 2008; Vol.19 (9-10). 2008

Aligning screening with the immunisation schedule, along with point of care capillary testing resulted in great improvement in screening participation and confidence in population blood lead levels. However this also showed that blood lead levels for children in the age group 1 to <5 years have not changed significantly between 2012 -2018[8]. Aboriginal levels also have declined over time but since 2007 have remained about 3-4 ug/dl higher than non-Aboriginal children[8].

The Broken Hill Lead Reference Group (BHLRG), founded in 2008, is a multi-agency group led by the Broken Hill City Council. It consists of community interest groups, mining companies and government agencies representing and advocating for the Broken Hill community regarding lead. The Broken Hill Lead Health Steering Committee, also founded in 2008 (and reconvened in November 2018 after a hiatus), was constituted to focus on the health issues related to elevated blood lead levels in children. Both groups have an interest in minimising the impact of lead exposure whilst maintaining a viable mining industry in Broken Hill.

From July 2015, following significant planning and advocacy, the NSW Government funded the Broken Hill Environmental Lead Program (BHELP) with $13 million, over 5 years. The EPA has committed its own funding for the program from 1 July 2020 to June 30 2021 whilst future strategies were developed for the program moving forward

Both the Child & Family Health Service (C&FHS) and Maari Ma have put significant effort into engaging with families and keeping them engaged. In 2019 C&FHS offered free lead assessments of the home to all children tested at 12 months of age regardless of result. Tangible incentives have also been offered by both C&FHS and Maari Ma such as cleaning products, towels, sandpits, sand vouchers and garden products (mulch, fertilizer, garden hoses etc).

All children over the notifiable level are offered a home assessment, which is required before a family is referred for remediation. At a home visit by C&FHS, all families received a cleaning kit and, if appropriate, a renovator kit or a garden kit. All families accepting a home assessment by Maari Ma are provided a cleaning kit and sand pit. The Broken Hill hospital maternity unit also educates pregnant mothers and provides literature on lead screening and prevention.

Though the 2015 NSW government funding has enabled home remediation and public land abatement it has been limited to date. The New England and Western Tenants Advocacy Service has also successfully used provisions of the Residential Tenancies Act 2010 to require landlords to paint premises and undertake landscaping work because of lead contamination in Broken Hill.

The numbers of homes remediated, however, are still too small to make a difference at the population level, as will be seen from the 2019 results. Additionally since 2012 several mines have reopened, and though there are increasingly more stringent environmental requirements for each new mine and the two companies are active members of the BH LRG, ongoing mining and unremediated areas of the mine leases further challenges the response to lead contamination.

[8] Lead Report 2018: Broken Hill children less than 5 years old WNSW LHD Public Health Unit, Health Protection, August 2019 available at www.leadsmart.nsw.gov.au

Broken Hill Climate

The NSW Government released its Climate Change Policy Framework in 2016 to drive consideration of climate change mitigation and adaptation across government operations [9]. Integral to the problem of lead in Broken Hill is the climate. Broken Hill LGA has a hot, dry climate and lies within the NSW arid zone. Dust storms already feature in dry spring and summers. The 2014 Far West Region snapshot modelled rainfall decreasing in winter and spring in the near future (2020-2039) with summer rainfall decreasing in more eastern parts of the region, while maximum temperatures and number of hot days would increase[10]. Seasonal effects on blood lead are reported in Broken Hill, as elsewhere. Laidlaw and colleagues suggest that seasonally higher blood lead levels may be related to a combination of hot, dry, windy weather and soil moisture, that effectively remobilizes and makes more soil lead bioavailable, especially particulate matter <10 µm[11].The climate changes predicted for Far West will enhance dust storms, soil dispersion and elevate Pb dust loading into the environment.

Broken Hill, though not new to periods of drought, has been in an intense drought for over 2 years. As in previous droughts, Broken Hill still has level 1 water restrictions in place. The total rainfall for 2019, 68mm, was the lowest since recording at the airport began in 1947 (average 247.7mm) (see Figure 1). The next 3 lowest years, 1967, 1982, 2002, had annual rainfall totals of 70 -77 mm but preceding years totals were not as low as 2017 and 2018.

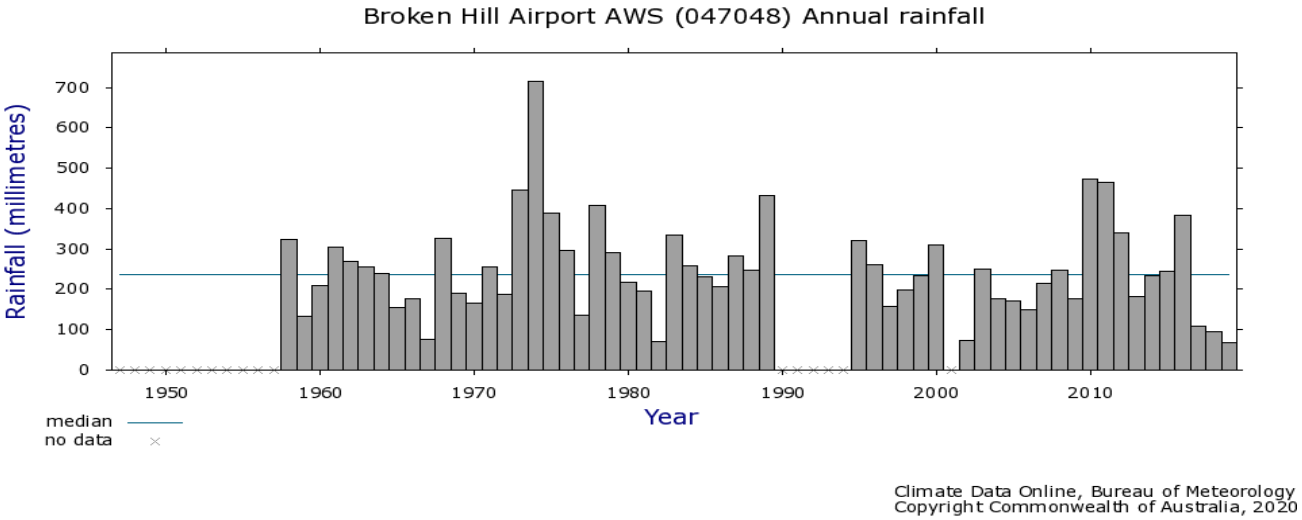

Figure 1. Broken Hill airport annual rainfall 1947-2019

[9] NSW Government Climate Change Policy Framework 2016 https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Climate-change/nsw-climate-change-policy-framework-160618.pdf

[10]Far West Region Climate change snapshot 2014 AdaptNSW Office of Environment & Heritage NSW Government available from https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/Climate-projections-for-your-region/Far-West-Climate-Change-Downloads

[11] Laidlaw MAS, Mielke HW, Filippelli GM, Johnson DL, Gonzales CR. Seasonality and Children's Blood Lead Levels: Developing a Predictive Model Using Climatic Variables and Blood Lead Data from Indianapolis, Indiana, Syracuse, New York, and New Orleans, Louisiana (USA). *Environmental Health Perspectives*. 2005; 113(6):793-800

Figure 2 below shows mean monthly rainfall for the period 1947 to 2019 as well as monthly rainfall for the individual years 2017-2019. Other rainfall minimums at Broken Hill Airport were also broken in 2017-2019. In 2017 there was the first recording of no rain for February; no rain in March and September was first recorded in 2018 and no rain in the months of April and December in 2019[12].

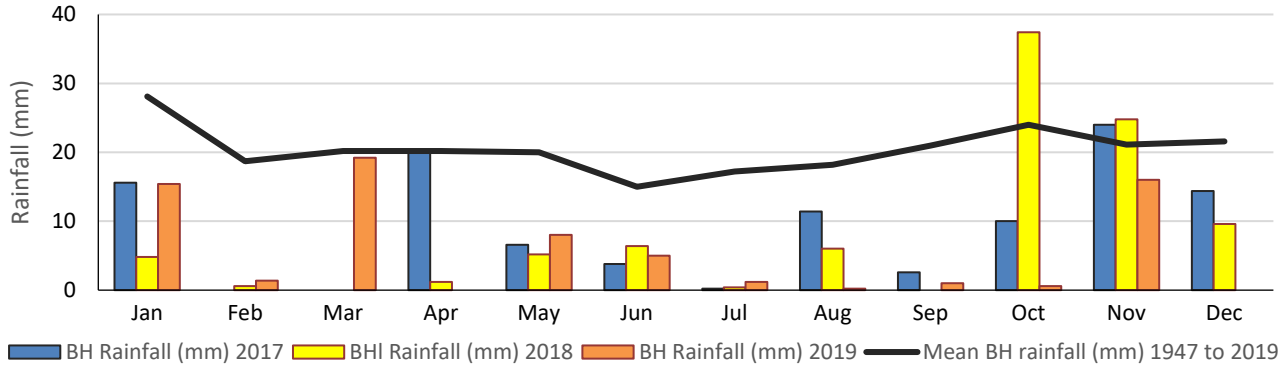

Figure 2. Broken Hill airport monthly rainfall 2017-2019 and monthly mean 1947-2019

Source Climate data online Product Code: IDCJAC0001 reference: 56095829 Bureau of Meteorology, created Thur 16 Jan 2020, Commonwealth of Australia

Figure 3 shows monthly mean maximum temperatures for the recording period 1957-2019 and individually 2017, 2018, 2019. The monthly means for January, February, March, July, October and December as well as the annual mean maximums for 2017, 2018 and 2019 were higher than the monthly maximum means for the period 1957-2019. Broken Hill temperature records[13] were also broken in 2017, 2018 and 2019. In 2017 the highest maximums for February and July and highest minimum for September were recorded and in 2018 the highest recorded maximum for April was recorded. In 2019 the months of January and December had their highest recorded maximums and January also had the highest minimum temperature since records began.

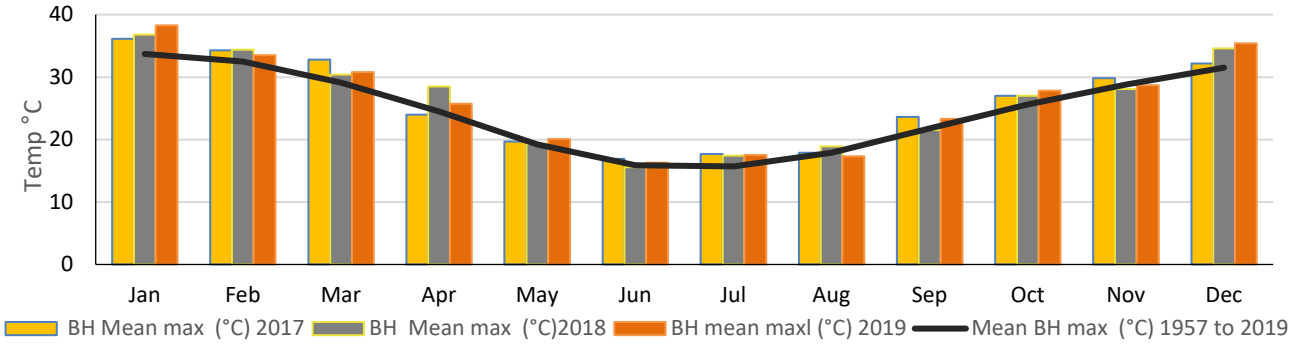

Figure 3. Broken Hill airport monthly mean temperature 2017-2019 and monthly mean 1957-2019

Source Climate data online Product Code: IDCJAC0002 reference: 56098437 Bureau of Meteorology, created Thur 16 Jan 2020, Commonwealth of Australia

[12] Bureau of Meteorology, Climate data online *Product Code: IDCJAC0001 reference: 56095829 Bureau of Meteorology, created Thur 16 Jan 2020,* www.bom.gov.au/climate/data [accessed 16 January 2020]

[13] Bureau of Meteorology, Climate data online *Product Code: IDCJAC0001 reference: 56098437 Bureau of Meteorology, created Thur 16 Jan 2020,* www.bom.gov.au/climate/data [accessed 16 January 2020]

Wind is also a feature of Broken Hill's climate. Wind roses summarise the occurrence of winds at a location, showing their strength, direction and frequency. The BoM description for moderate winds (20-29 km/hr) is 'Raises dust and loose paper; small branches are moved'. Moderate strength winds are the most common in Broken Hill, with the prevailing direction at 9am or 3pm from the south (about 25%), then north/ NE at 9am turning west/NW by 3pm (Figure 4).

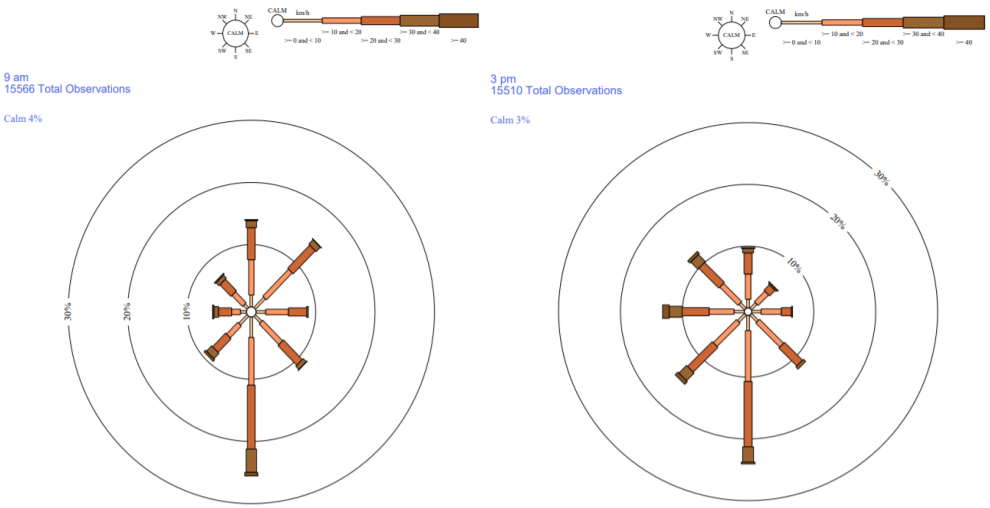

Figure 4. Rose of wind direction v wind speed at 9am and 3pm Broken Hill Airport 1947- 2019

Source Climate data online Product Code: IDCJAC0028 Bureau of Meteorology, created Thu 13 Feb 2020, Commonwealth of Australia

Southerly winds are more frequent (almost 40% at 9am, over 30% at 3pm) in January, February and March and the proportion of moderate winds also increases. In the winter months of July and August north winds prevail, turning W/NW. Windier days along with drier, hotter climate increase drying of soils and plants and the number of days with raised dust/ dust storms.

Reducing accessibility to lead in soil and dust (storms) by planting lawn, native groundcovers, plants and trees is effective. The regeneration reserves conceived and established by Albert and Margaret Morris around Broken Hill are testimony to this[14]. The reserves, Broken Hill parks and home gardens also beautify the town and moderate summer temperatures. However, as the data above show, Broken Hill is naturally dry and with climate change, likely to become drier, through decreased rain, increases in maximum and minimum temperatures and windier days. Water restrictions and cost also affect the ability of the town and residents to sustain green landscapes. This means the town needs to be better at using plants and gardening techniques which are adapted to local climate and soils. Covering soil in other ways, such as mulch, cracker dust / road base are also effective and durable, however windy days can redistribute bare contaminated soil and dust throughout town.

[14] Ardill PJ Albert Morris and the Broken Hill regeneration area: time, landscape and renewal. July, 2017. Australian Association of Bush Regenerators (AABR). Sydney. Available at http://aabr.org.au/_upload/Articles/morris-broken-hill/Ardill-3rd-ed-Broken-Hill.pdf [accessed 29 Jan 2020]

Population Profile

Each Census conducted since lead monitoring began (1991, 1996, 2001, 2006, 2011 and 2016) has seen a decreasing trend in both the number and proportion of children under the age of 5 years residing in the Broken Hill Local Government Area (Table 1). The graph in Figure 5 represents the change in estimated resident population by gender for children under 5 years of age in Broken Hill from 1972 to 2016.

Analysis conducted for the annual lead report is stratified by Aboriginality to monitor any inequitable burden of high blood lead levels which may exist. Aboriginal children population numbers are sourced from the Census and are reliant on self-identification. Unlike the total population of under 5 year olds, the number of Aboriginal children has increased from 1996 to 2016 and is projected to continue increasing (Table 1), in addition to the proportion.

Table 1. Demographic profile of children under 5 years of age in Broken Hill

Age in years	1996		2001		2006		2011		2016	
	All	Aboriginal	All	Aboriginal	All	Aboriginal	All	Aboriginal	All	Aboriginal
0-<5	1,427	112 (8%)	1,255	165 (13%)	1,191	177 (15%)	1,070	176 (16%)	970	182 (19%)

Source: Australian Bureau of Statistics (ABS) Census data.

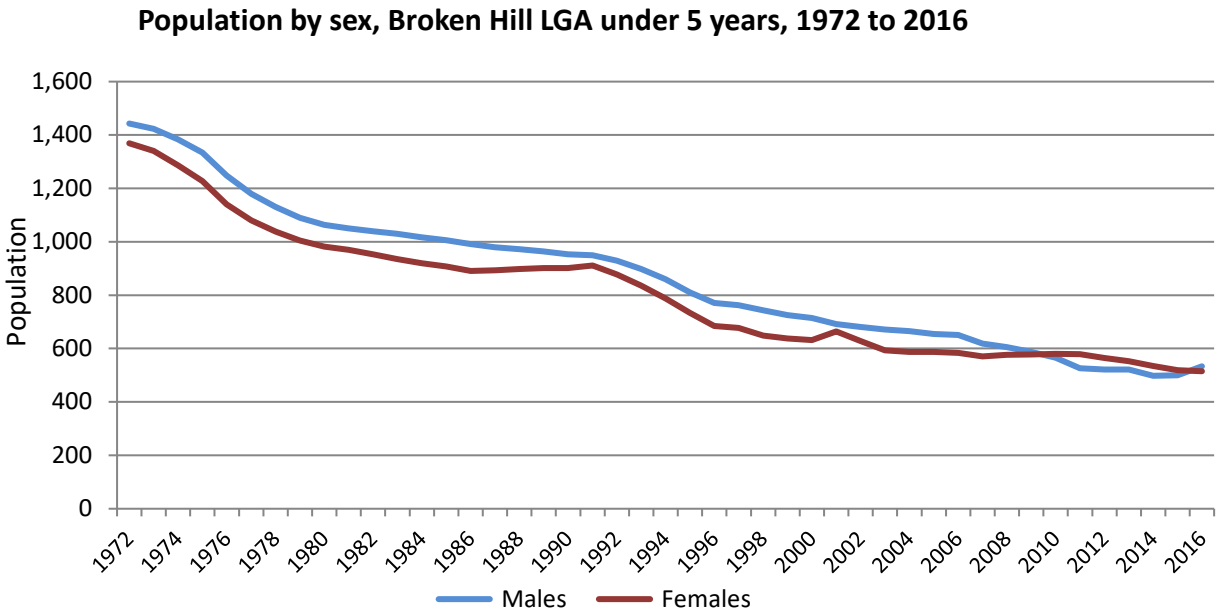

Figure 5. Estimated resident population by gender for children under 5 years of age, Broken Hill, 1972-2016

Source: Based on the Australian Bureau of Statistics estimated resident populations (SAPHaRI). Centre for Epidemiology and Evidence, NSW Ministry of Health.

Methods

Screening Program logic

The program has targeted children under 5 years old as they are more susceptible to the adverse health effects from lead than adults.

The program has evolved over time to collect blood lead samples from three distinct groups of children aged under 5 years. These groups follow the developmental progression of children from completely dependent to physically independent. Comparison of blood lead levels across the groups informs both intervention need and monitoring of the lead program.

The first two groups that started the program in 1991 were children aged between 1 year and less than 5 years and those aged 6 months to < 12 months. The first age group of children are generally able to move freely to interact with their environment. The second group are learning to explore their environment by putting objects into their mouth and have limited mobility through crawling but may be restrained outside.

The introduction of newborn screening in 1996 assists in determining the impact of lead transfusion from the mother to the unborn child and could be considered as a defacto baseline for children.

Collection of Blood Samples

For newborn babies, umbilical cord bloods are laboratory tested in the same way as a venous sample. Blood lead levels for children less than five years are taken as either a finger prick (capillary) or venous test. Since October 2008, parents have had the option of having their children aged 6 months and over screened with a less invasive capillary sampling (finger prick) method. If a child has received both a venous and a capillary test throughout the year, the measurement from the venous test is used. This is because a venous test, though a more invasive procedure than a finger prick, provides a more accurate measure of blood lead levels.

Since 2011, lead screening was aligned with immunisation for children aged from 6 months to <5 years as well as health checks in the 1 to < 5 years age group. Testing may occur over the immunisation schedule (current schedule includes vaccinations at 6 months, 12 months, 18 months and 4 years of age) and health checks at 2 and 3 years of age. Therefore, a child may present at 6 months and 12 months, 12 months and 18 months or 18 months and 2 years (in line with health checks) in the same calendar year. Only the first (younger age) test is used and this is the main reason why there are more children's first tests in the first 6 months of a year. Due to higher immunisation frequency between the ages of 1 to 3, more children within this age group are included to the study.

Children who had a 6 month and 12 month test in 2019 calendar year may be represented in two sections of the report. First in the 6 months to <12 month testing group and when they turned 12 months included in the children aged 1 to < 5 years analysis.

Reporting of Blood Lead Levels

For analysis and reporting purposes in the 1 to < 5 years group, only a child's first test in this age group in the calendar year is used for calculations, to ensure only one result per child is used per year.

The geometric mean (instead of an arithmetic mean or average) is used to report blood lead levels throughout this report. A geometric mean is calculated by taking the *n*th root of the product of *n* numbers. Where most children have lower blood lead levels and a proportion have very high levels, the arithmetic mean is strongly affected by the very high values. The geometric mean gives a value which is closer to that of most children.

Recording of blood lead levels has changed over time:

- From 1991 till 2016 all blood lead results were rounded up or down when recorded in the data base. The reason for this practice is unclear, but may have been related to the capabilities of the original Access® database.
- Capillary results were first reported from 2009 onwards. The minimum reading possible for capillary sampling is 3µg/dL compared to <1µg/dL for venous sampling. A "low result" reading is also possible and nurses were instructed to record this as 2 ug/dl. This will affect the geomeans calculated from 2009 onwards by slightly raising the average compared to previous years results.
- In 2016 all results were recorded as is with decimal places, so geomeans will not be exactly comparable to previous years but as population levels are reported here, the differences are likely to be slight and the trends in blood lead levels will still be meaningful.

Age-sex Standardisation of Results

Children's blood lead levels vary by age and gender, hence, it is difficult to compare blood lead levels from one year to another unless the same proportion of children in each age group is tested in successive years. Therefore age-sex standardisation is used to account for this change. Effectively, this determines what the blood lead level would be if all children in Broken Hill were tested by applying the proportion of children to each age-sex group from the most recent Census (i.e. 2016). This age–sex adjusted population mean is the one reported over time for children aged 1 to <5 years.

Notifiable Blood Lead Levels

NSW Health set the blood lead notification level at 10 µg/dL from 1993, however, in May 2015, the NHMRC completed an evidence review and issued a statement for a revised blood lead notification level of 5 µg/dL[15]. The evidence review found an association between levels less than 10 µg/dL and health effects. The effects include: reduced Intelligence Quotient and academic achievement in children; behavioural problems in children; a delay in sexual maturation in adolescents and increased blood pressure in adults[15].

[15]National Health & Medical Research Council (NHMRC), Evidence on the Effects of Lead on Human Health, May 2015

The 5 µg/dL notification level was implemented in February 2016 by NSW Ministry of Health. Throughout this report, less than 5 µg/dL has been used as the benchmark level to enable insight into the extent of lead as an issue for children in Broken Hill – in line with NHMRC and NSW Health guidelines.

Participation Rates

The participation rate is intended as an indicator of success of recruitment to screening, through programs such as the 1994 door knock or aligning lead testing with immunisation. Only in census years are LGA populations by single year age group (and gender) available for both Aboriginal and non-Aboriginal people. For intercensal years the most recent census data is used to calculate participation. This is not ideal as census requires a minimum residency period to be counted as a resident, however, Aboriginal families may be more transient in their movements between extended family and, in Broken Hill, the mining related workforce (and family) can ebb and flow depending on ore prices.

Data source

From 1991 through to the end of 2017, children's demographics, blood lead levels as well as environmental data, were stored on a standalone Access® database. This included data from children tested at Maari Ma Primary Health Care Service. With the ending of Access® software use by NSW Health, data from late 2017 was also loaded onto the Powerchart/CHOC application of the Electronic Medical Records from Cerner systems solutions. Maari Ma have continued to provide their blood lead screening data for loading on the CHOC application. From 2018 lead data was stored only on CHOC.

If results from a private practice return as 5 µg/dL or higher, this result is notified to NSW Health (Public Health). From these notifications additional children have been tested through alternative health care providers (e.g. private General Practitioners) but these children have been outside the age range for this report or were followed up by a paediatrician. There is no obligation to forward these results to the Child and Family Health Centre to be recorded onto CHOC, therefore any results for children screened privately under 5 years are excluded from this analysis.

Results

Estimate of Participation Rate

The estimated participation rate for lead screening in all children at Broken Hill (aged 1 to <5 years) was 87% in 2019. In 2019 the 183 Aboriginal children screened (aged 1 to <5 years) is noticeably more than the 2016 census count of 162 for this age group. Both Maari Ma and Child & Family Health Services have made concerted efforts at maintaining engagement with families, including tangible incentives in 2016, 2017 and 2018, which have been major factors in reversing participation in screening.

There has been a significant increase since the period 2008-2010 (rates around forty percent) to close to 80% and above from 2012 (Figure 6). There is significant under reporting of Aboriginality in the Census, and for both 2011 and 2016 the count of Aboriginal children between 1 to <5 years old is actually less than the total tested in Broken Hill between 2012-2017. Therefore, participation rate calculation for Aboriginal children is not shown from 2012 as the result exceeds 100% from 2012 -2019.

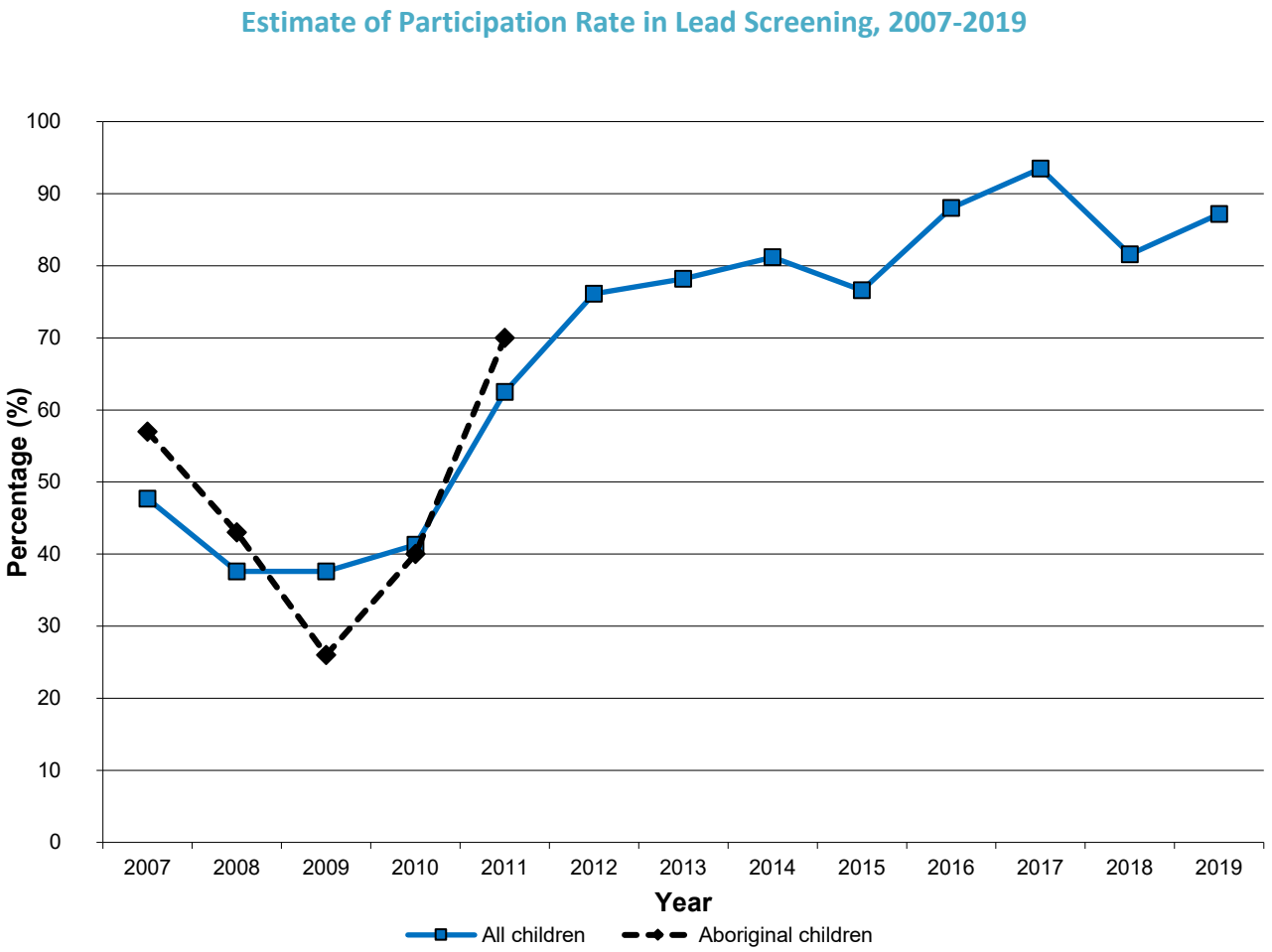

Figure 6. Estimate of blood lead level screening participation rates for Broken Hill children aged between 1 and < 5 years old.

Screening of Newborns

In 2019, there were 218 births at Broken Hill Hospital (including by women who live elsewhere). The number of births varies from year to year (220 in 2015; 231 in 2016; 205 in 2017, 192 in 2018). Approximately 30% of all births are Caesareans and these cord bloods are not usually tested. Of these remaining babies, 159 were born to families residing in Broken Hill hence their cord blood was taken for lead testing, 3 babies with clotted cord bloods were excluded and 156 successful tests reported.

The geometric mean of umbilical cord lead level was 0.7 µg/dL, in 2019 (Figure 7). The 2019 geomean was the same as observed in 2018. While the overall trend from 1996 shows the reduction in blood lead levels over time, the actual geomeans cannot be compared against years prior to 2016. This is because there was an improvement in recording cord blood levels, through the inclusion of decimal points, resulting in greater accuracy since 26 April 2016.

Of newborns with a valid test 86% (n=132) were non-Aboriginals. All newborns, regardless of Aboriginality, had blood lead levels below the notifiable level. At this age there is very little difference in geomeans between non-Aboriginal and Aboriginal (0.7 µg/dL v 0.8 µg/dL respectively).

Umbilical Cord Blood Lead Screening in Broken Hill newborns 1996-2019

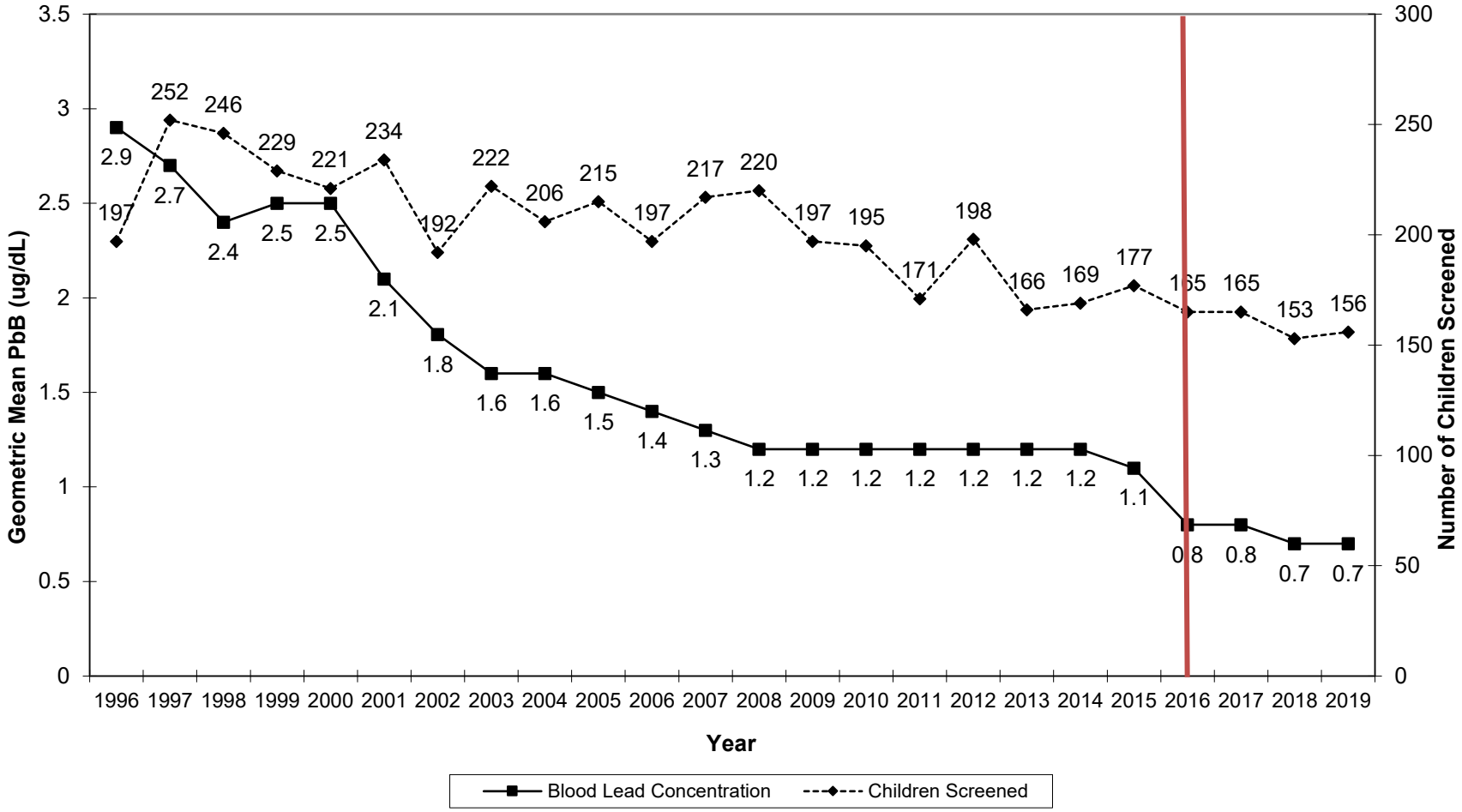

Figure 7. Geometric mean for cord blood lead (PbB) concentration and number of resident newborns screened at Broken Hill Health Service, 1996-2019. The vertical red line is indicative of the improvements made in the recording of results since 26th of April 2016. The geometric means collected since 2016 should not be compared to the previous years. See Methods- Reporting of Blood Lead Levels.

Screening of All Children Aged 6 months to < 12 months

From 1991 to 2012, testing was conducted on children aged between 6 months to < 12 months. Once the screening was aligned to the immunisation schedule in the latter half of 2011, children aged between 6 months and under 12 months of age were tested. In 2012, the geometric mean of children under 1 year was 3.9 µg/dL; 25% of children tested would have had notifiable levels using current guidelines (5 µg/dL).

The lead testing for this age group was discontinued from 2013 to 2017 because of two reasons: resourcing constraints and the preliminary results showed that geometric mean blood lead levels of children in this age group were well below the notifiable level at that time (10 µg/dL).

The lead testing recommenced in 2018 for children aged between 6 months to < 12 months of age. In 2019 a total of 201 children were tested with a geometric mean of 2.8 µg/dL (Fig 8), which was a decrease of 1.1 µg/dL from the last testing that was done in 2012. Additionally, the proportion of children who had blood lead levels above the current notifiable level (5 µg/dL) fell to 15% from 25% in the same period (Fig 9).

Of all children tested 79% (n=159) were non-Aboriginal. Non-Aboriginal newborns had a geomean of 2.6 µg/dL and Aboriginal newborns had a slightly higher geomean of 3.8 µg/dL.

While the overall trend from 1991 shows the reduction in blood lead levels over time, the actual geomeans cannot be compared against years prior to 2016. There was an improvement in cord blood levels, through the inclusion of decimal points, resulting in greater accuracy from 2016. As well the earlier change to capillary blood testing in 2009, where the minimum is 3 with a "low result" recorded as 2 will have affected the geomean. However the overall trend in decreasing blood lead levels remains valid.

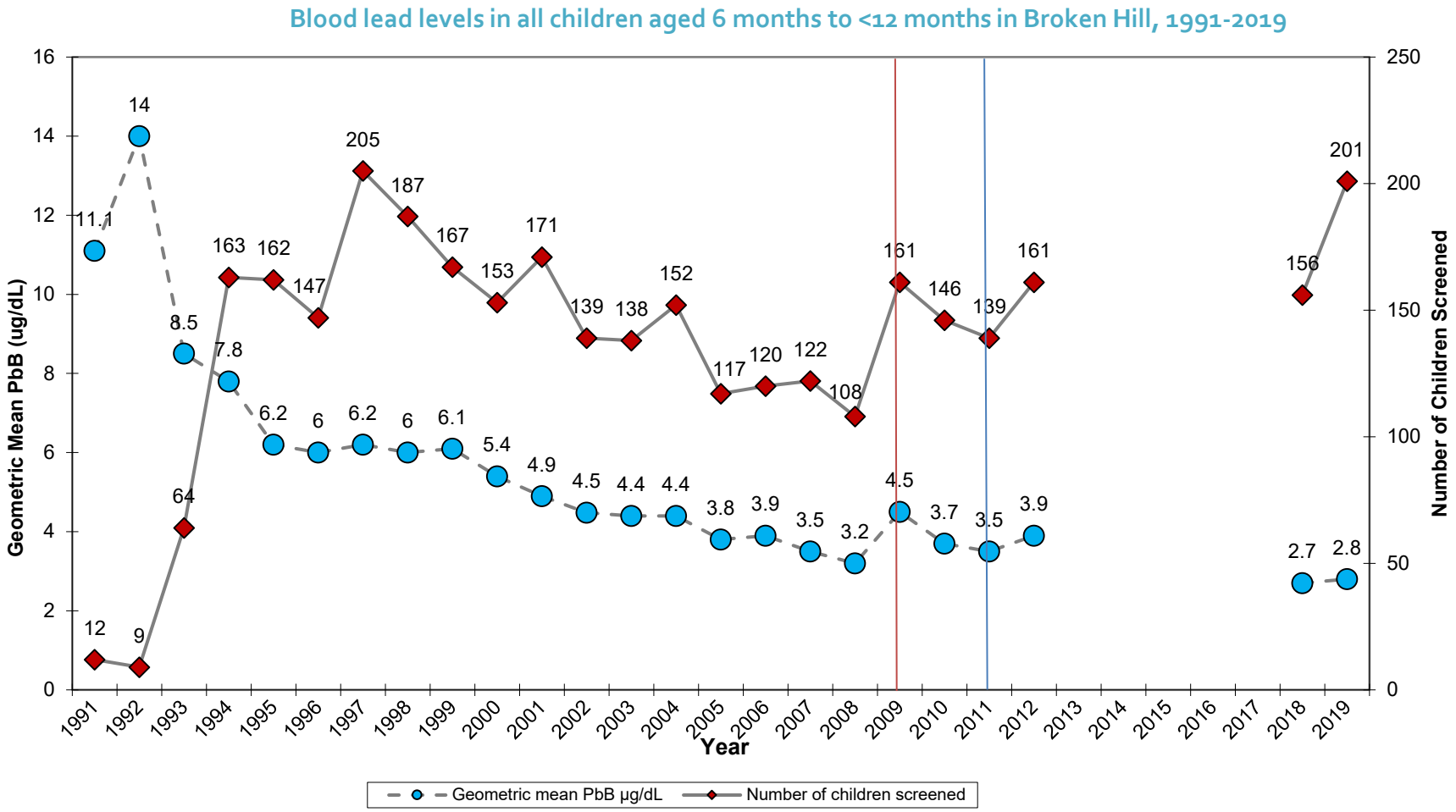

Figure 8. Geometric mean blood lead concentration and number of children screened aged 6 months to <12 months in Broken Hill, 1991-2019. The red vertical line indicates the point in which both venous and capillary samples are reported together and the blue vertical line indicates the point in which the lead testing was aligned with childhood immunisation. The geomean collected in 2018 cannot be compared to previous geomeans as recording of results and use of the capillary method affects geomeans. See Methods – Reporting of Blood Lead Levels.

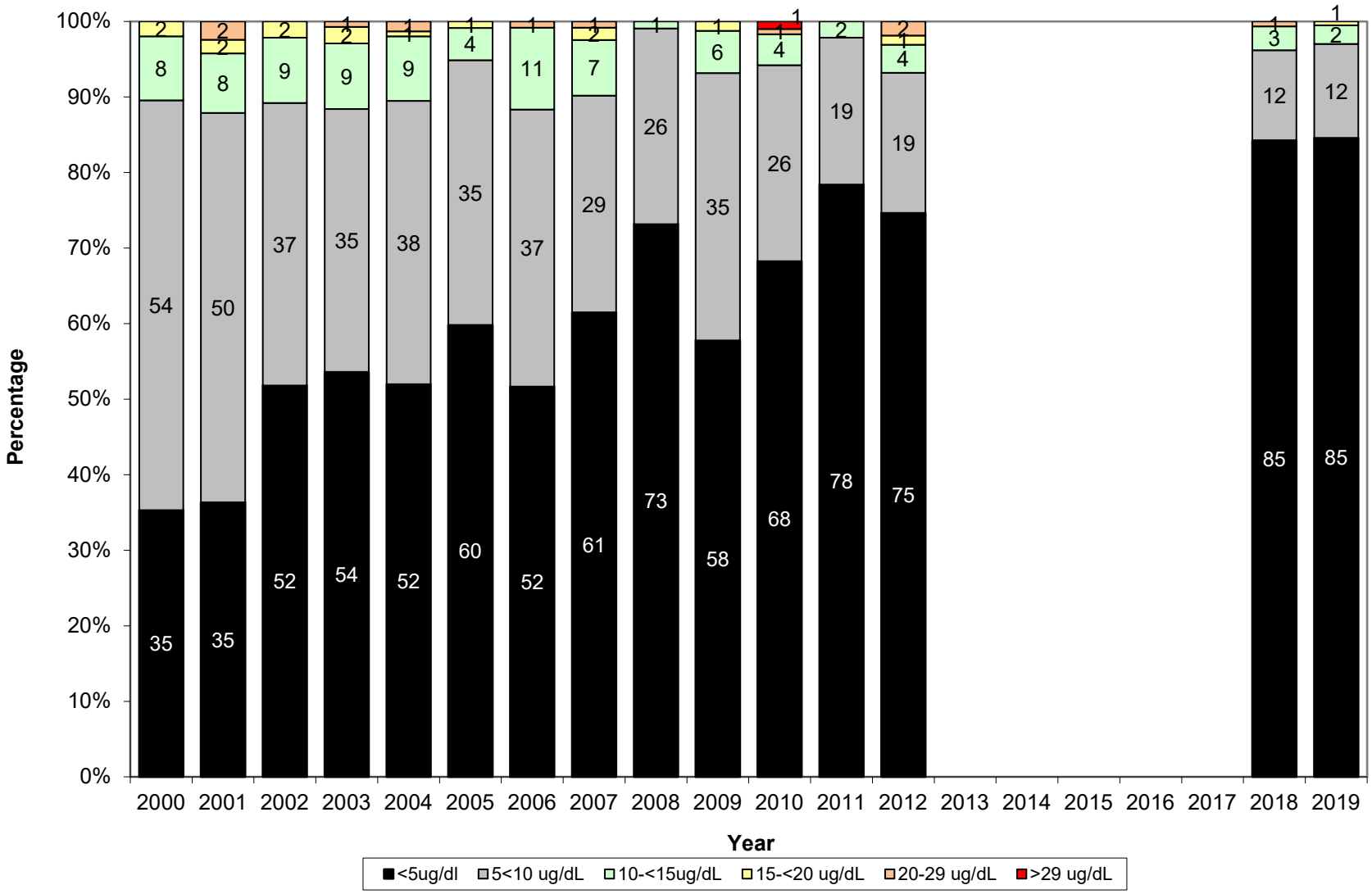

Figure 9. P ercentage of Broken Hill children aged 6 months to <12 months in each blood lead category (2000-2019).

Screening of Children Aged 1 to < 5 years

Screening of all children

In 2019, a total of 681 children had at least one test, an increase of 7% from children tested in 2018. The number of Aboriginal children screened increased 19% (154 to 183) and there was a 2% increase in the number of non-Aboriginal children screened (480 to 489). There were also a few children whose Aboriginal status was unknown, these children were only counted in overall screening results. This explains why Aboriginal and non-Aboriginal totals do not add up to the overall total children tested.

Over the duration of the voluntary blood lead screening program there has been a decreasing trend in the geometric mean blood lead levels in all children tested (1 to <5years), from a high of 16.7 µg/dL in 1991 to an adjusted geometric mean of 5.1 µg/dL in 2019 (Figure 10). Since the beginning of the program in 1991, there have been three previous years (2008, 2010 and 2011) when mean blood lead levels of children in this age group mean were under 5 µg/dL. However 2008 and 2010 were two of the three years with the least children screened. There was a slight increase in blood lead levels of the non-Aboriginal children from 2018 to 2019 (4.0 µg/dL to 4.2 µg/dL). Results for Aboriginal children are further explored later in the report.

The proportion of all children with blood lead levels under the benchmark (<5 µg/dL) has risen from 13% in 2000 to 48% in 2019 (Figure 11). The slight increase in mean blood level (from 4.7 µg/dL in 2018 to 5.1 µg/dL in 2019) inversely correlates with the slight decrease in the proportion of children with blood lead levels <5 µg/dL. The highest proportion (59%) of all children with a blood lead level under the benchmark was observed in 2010.

The proportion of children with blood lead level between 5 to <10 µg/dL range decreased from 47% in 2000 to 31% in 2019 (Figure 10). However from 2018 to 2019 there was a 5% rise in the proportion of all children with 10 to <15 µg/dL range blood lead levels (11% to 16% respectively). The proportions of children in all the higher blood lead categories remains around 5% in 2019 as in 2018. This is a decrease from the 8-9% seen in years 2012-2017 (Figure 11).

The total number of children tested in 2019 was similar to totals for 2015 and 2016, however, the number of children in the <5 µg/dL category is greater than seen in these years (Figure 12). Except for the 10 to <15 µg/dL category the numbers of children in categories above 5 have decreased compared to 2015 and 2016. Compared to 2018 the distribution of children by blood lead category is similar, the exception being again the 10 to <15µg/dL category where numbers increased 62%.

Blood lead levels in all children and children identifying as Aboriginal aged 1 to <5years in Broken Hill, 1991-2019

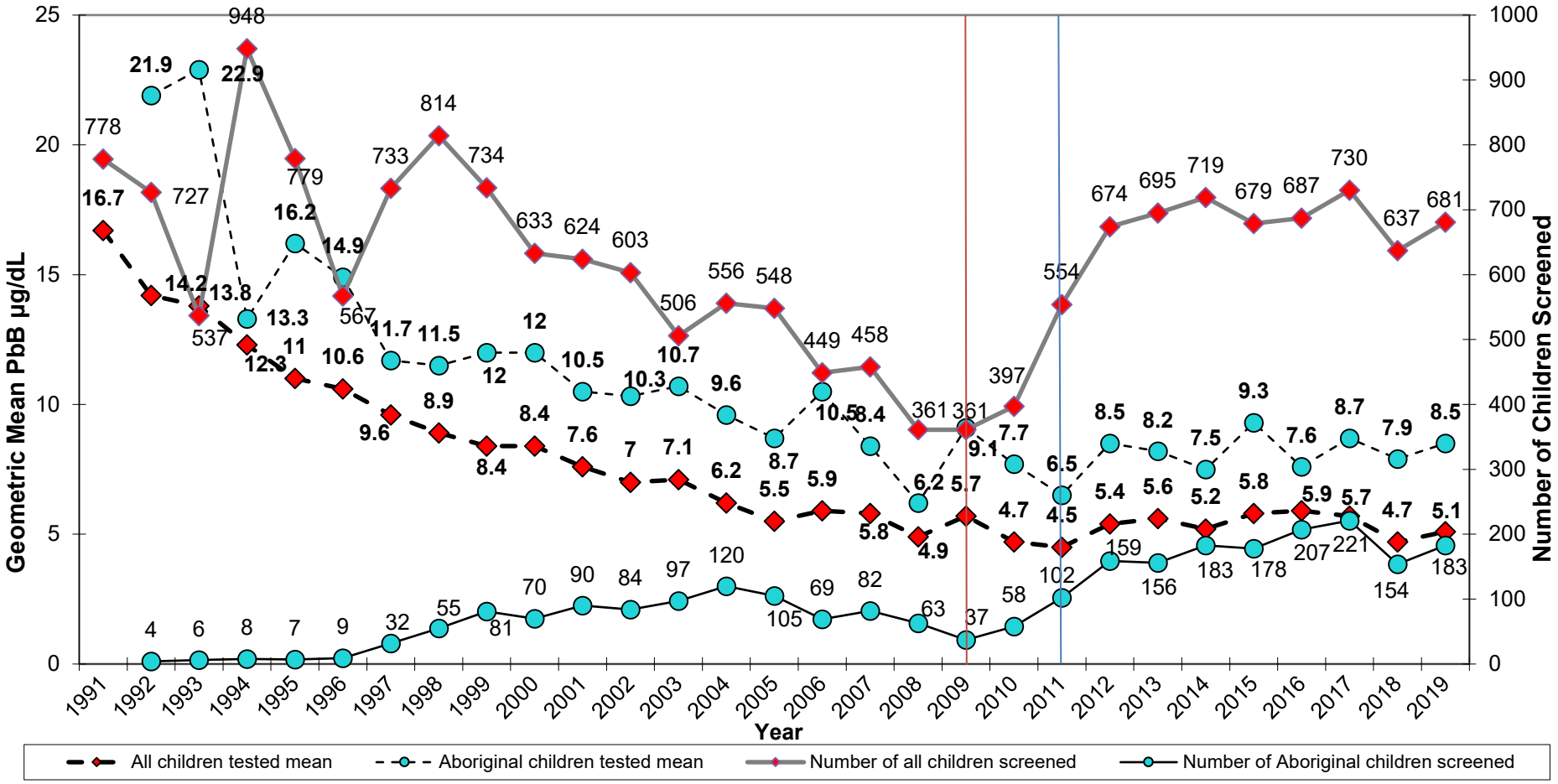

Figure 10. Population age-sex standardised geometric mean blood lead concentration and number of all children and Aboriginal* children screened aged between 1 to <5 years in Broken Hill, 1991-2019. The red vertical line indicates the point in which both venous and capillary samples are reported together and the blue the inclusion of screening with childhood immunisation. *There were no recorded tests for Aboriginal children in 1991. Standardisation applied only from 1997 onwards, due to small sample size. Additionally, Aboriginal status was only consistently collected from 1997. The geomeans reported since 2016 cannot be compared to previous geomeans as recording of results and use of the capillary method affects geomeans. See Methods – Reporting of Blood Lead Levels.

Percentage of children aged 1 – <5 years in Broken Hill by category of blood lead level and age-sex-standardised geometric mean by year

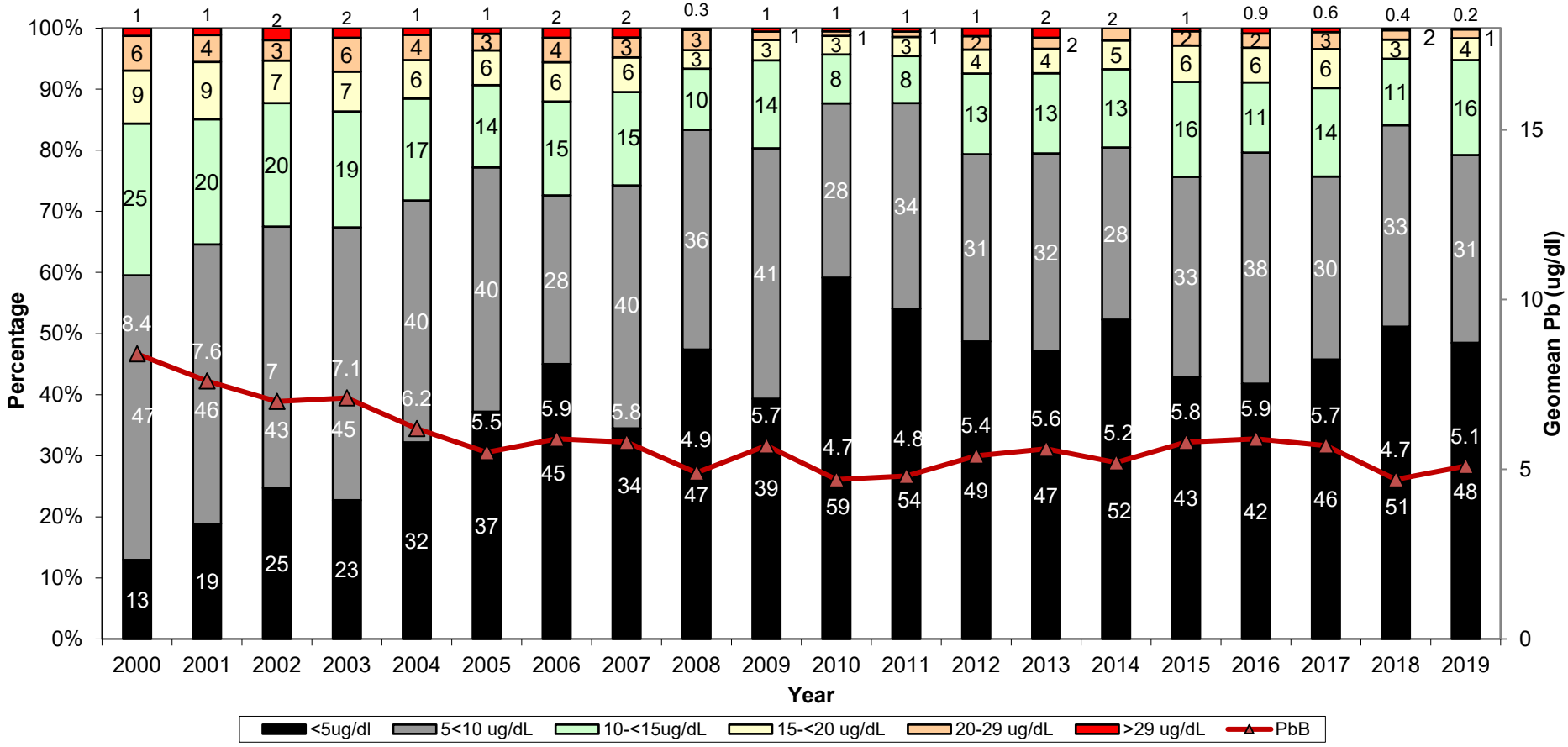

Figure 11. Age-sex standardised percentage of Broken Hill children aged 1 to <5 years in each blood lead category and population age sex standardised geometric mean (2000-2019).

Number of children aged 1 to <5 years in Broken Hill by category of blood lead level by year

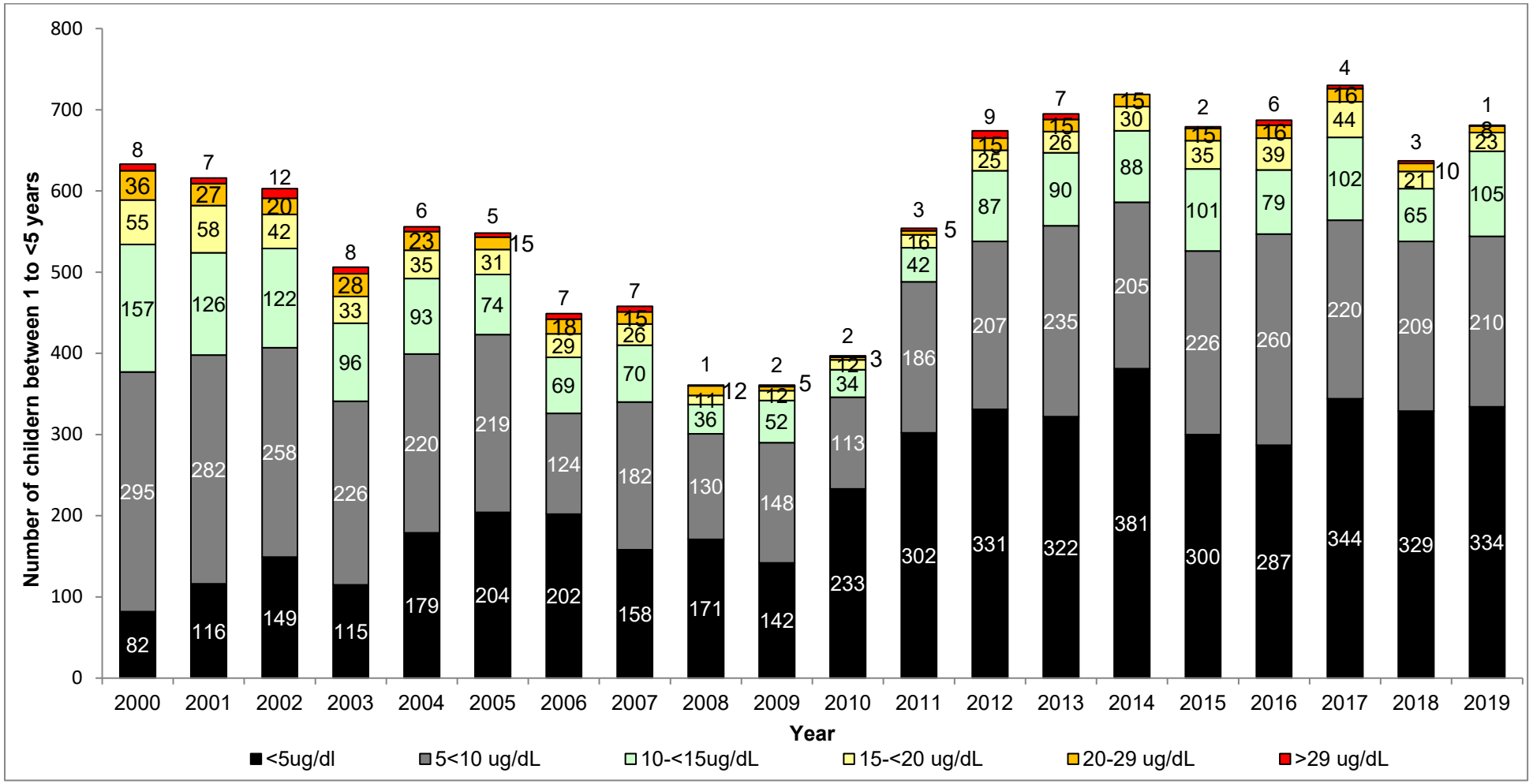

Figure 12. Count of all tested Broken Hill children in each blood lead category, aged between 1 to <5 years, 2000-2019.

Screening of Aboriginal Children

Blood lead screening for Aboriginal children aged 1 to <5 years has its own section as the historical burden of high blood lead levels in Aboriginal children in Broken Hill has been most evident in children aged 1 to <5 years. Unlike the results for cord blood and children aged 6 months, this age group reveals substantial differences between Aboriginal and non-Aboriginal children.

The mean blood lead level for Aboriginal children is higher than the overall geometric mean for all Broken Hill children, however the gap has been decreasing. In 2011 Maari Ma began doing their own blood lead testing and, along with the alignment of immunisation and lead schedules, the number and proportion of children tested markedly increased.

In 2019, the number of Aboriginal children tested rose, from 154 in 2018 to 183. There was also an increase in the proportion of all children tested who were Aboriginal, in 2019 27% compared to 24% in 2018. There was an increase in the Aboriginal age-sex standardised mean, from 7.9 µg/dL (2018) to 8.5 µg/dL in 2019 (Figure 10). The gap between Aboriginal and non-Aboriginal children blood lead levels remains 4.0 µg/dL which was similar in 2015, 2017 and 2018, and almost twice as much as the gap observed in 2016 (2.4 µg/dL).

In 2019, 20% of tested Aboriginal children had a blood lead level less than 5 µg/dL, a decrease from the proportions in 2016, 2017 and 2018 (Figure 13). While previous years (2008, 2010) have seen a higher proportion of Aboriginal blood lead results under 5 µg/dL these years were among the lowest numbers of Aboriginal children tested since recording of Aboriginality began (see Figure 10).

The discrepancies in blood lead levels between Aboriginal and non-Aboriginal children are greatest in the <5 µg/dL category (Figure 14) – 20% compared to 60% (Aboriginal and non-Aboriginal respectively). As the blood lead level increases (i.e. all above 5 µg/dL), the proportion of Aboriginal children is higher than the non-Aboriginal children. In 2019, the 5 to < 10 µg/dL category has the highest proportion of the Aboriginal children results (43%) – similar to the highest proportions for this category in 2011, 2016 and 2018.

Clustering of high results in two age-sex cohorts, also observed in 2015, 2017 and 2018, was further investigated. Of all Aboriginal children with results under the notifiable level only 14% were found in these two cohorts. Unlike cohort clusters from previous years the majority of these children had been tested before. Those few not tested were in the oldest age cohort. Strategically, any prompting of earlier intervention such as referrals for follow up home assessments and remediation is crucial to reduce blood lead levels. As Aboriginal children have a higher blood lead geometric mean early detection and regular testing is crucial.

The expansion of the blood lead screening program has resulted in a more accurate depiction of the burden of blood lead levels among Aboriginal children. This more accurate picture can better inform public health action to reduce the blood lead level discrepancy seen between Aboriginal and non-Aboriginal children in Broken Hill. It suggests that discrepancies between Aboriginal and non-Aboriginal children emerge once children become toddlers and have greater freedom to roam and explore.

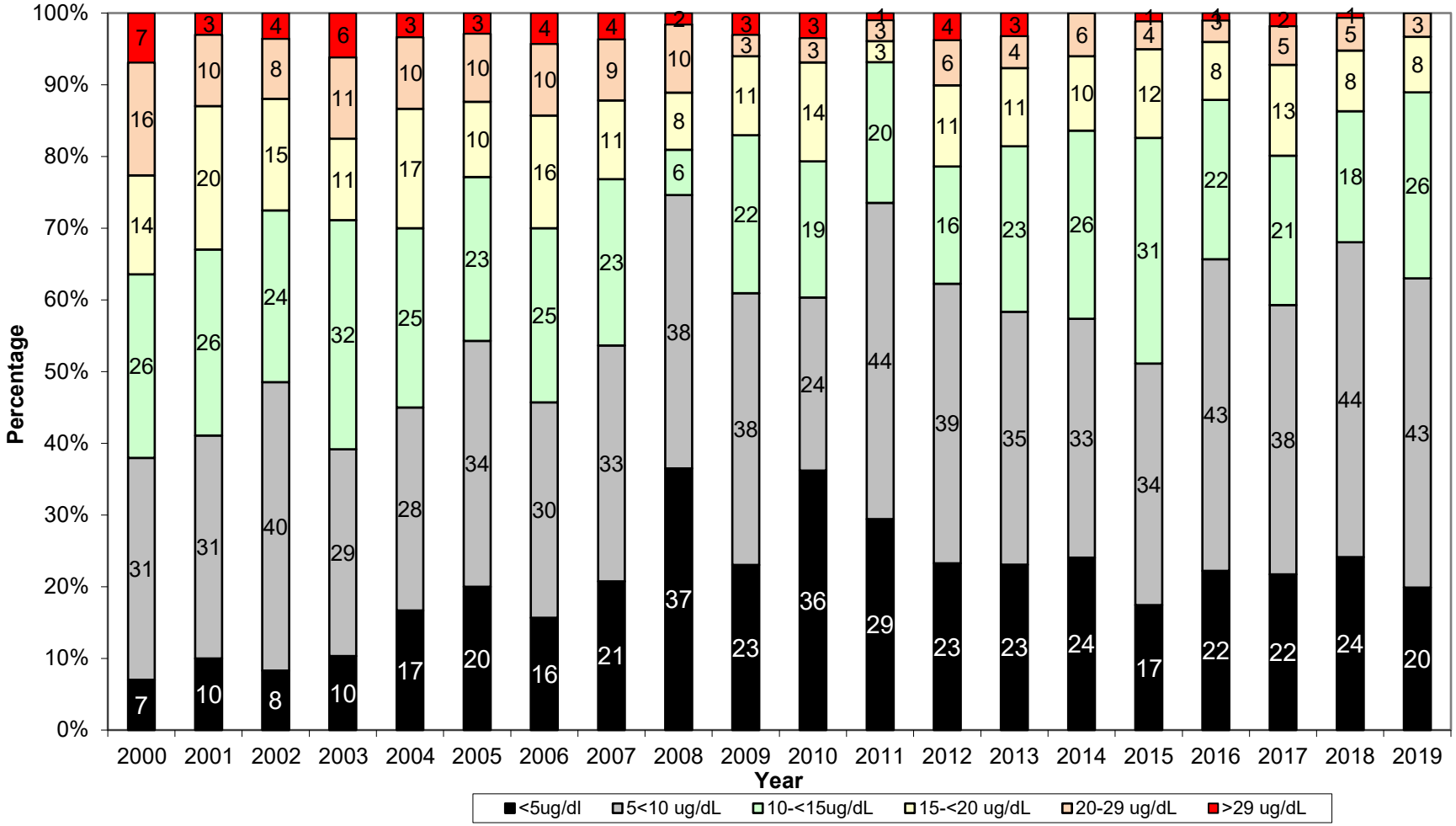

Figure 13. Percentage of Broken Hill Aboriginal children in each blood lead category, aged between 1 to < 5 years, 2000-2019. Data is presented from 2000 as before that the proportion and number of Aboriginal children tested was small, additionally caution should be used with the 2006 – 2010 results as this was also a period of low attendance by Aboriginal children.

Blood lead level categories by Aboriginal status for children aged 1 to <5 years, Broken Hill, 2019

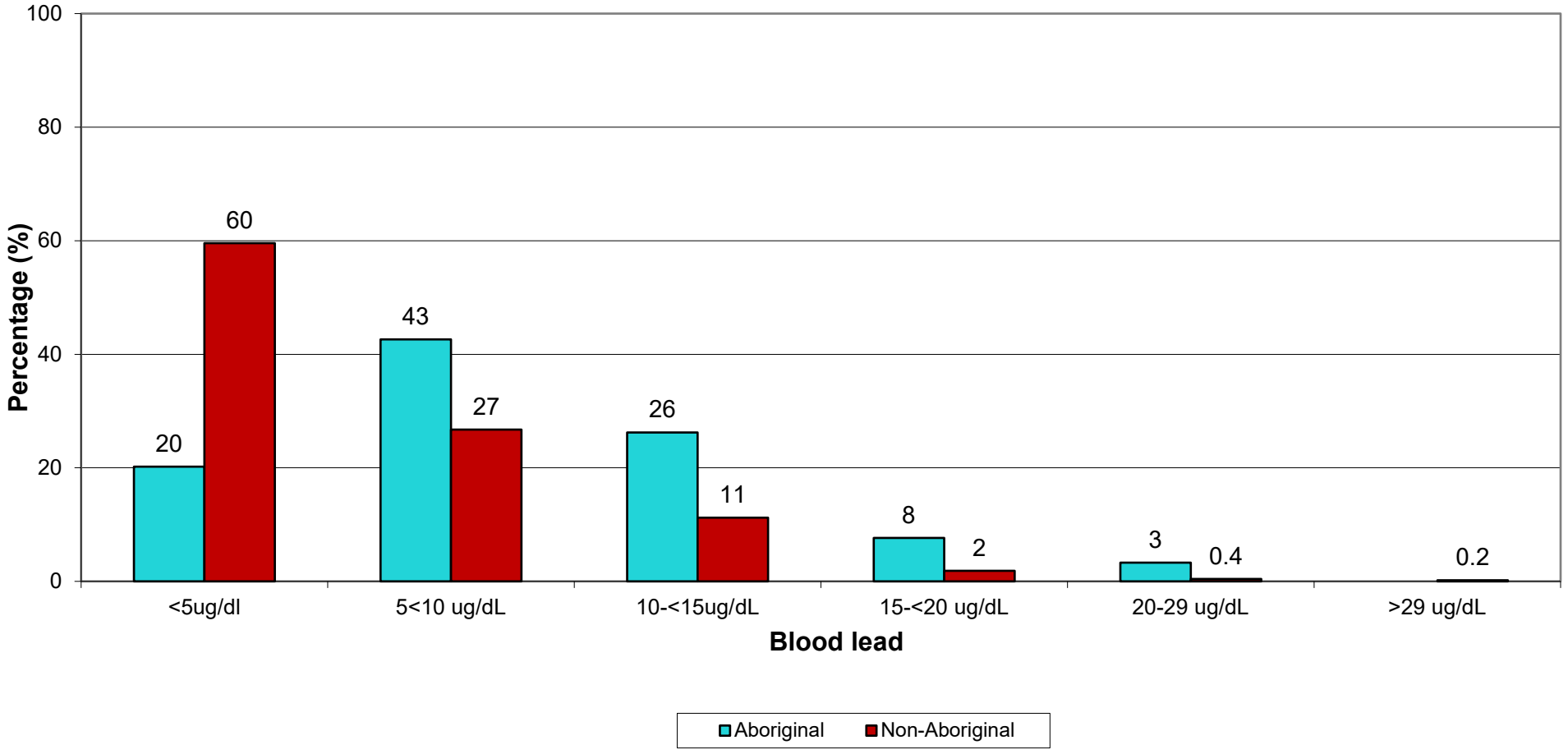

Figure 14. Comparison of Aboriginal versus non-Aboriginal aged 1 to <5 years by blood lead categories (2019).

Seasonal changes in blood lead levels of all children aged 1 to < 5 years

Climate change is predicted to bring more extremes, such as longer dry, hot periods with longer intervals between heavier rainfall events so monitoring is justified. Seasonal analysis showed that the highest blood lead levels were generally between January-March/ April which also corresponds with many children having their first test (Figure 15). Blood lead levels have been shown to be seasonal[16], increasing in warm/ hot dry weather. As stated in the Introduction the minimum total rainfall, 68mm, and maximum and highest minimum temperature records were set in 2019.

Small monthly decreases in geomeans in the latter half of the year are seen in 2019 as also were seen in 2018 and 2017 (see previous annual reports), however the first three months in a year remain essentially the same. Special attention to decreasing blood lead levels in these months will affect a large number of children and therefore the overall population blood lead levels. The number of children is always greater in the first half of the year because reporting uses the first test in the calendar year.

Monthly mean blood lead levels and screening count of children aged 1 to <5 years in 2019

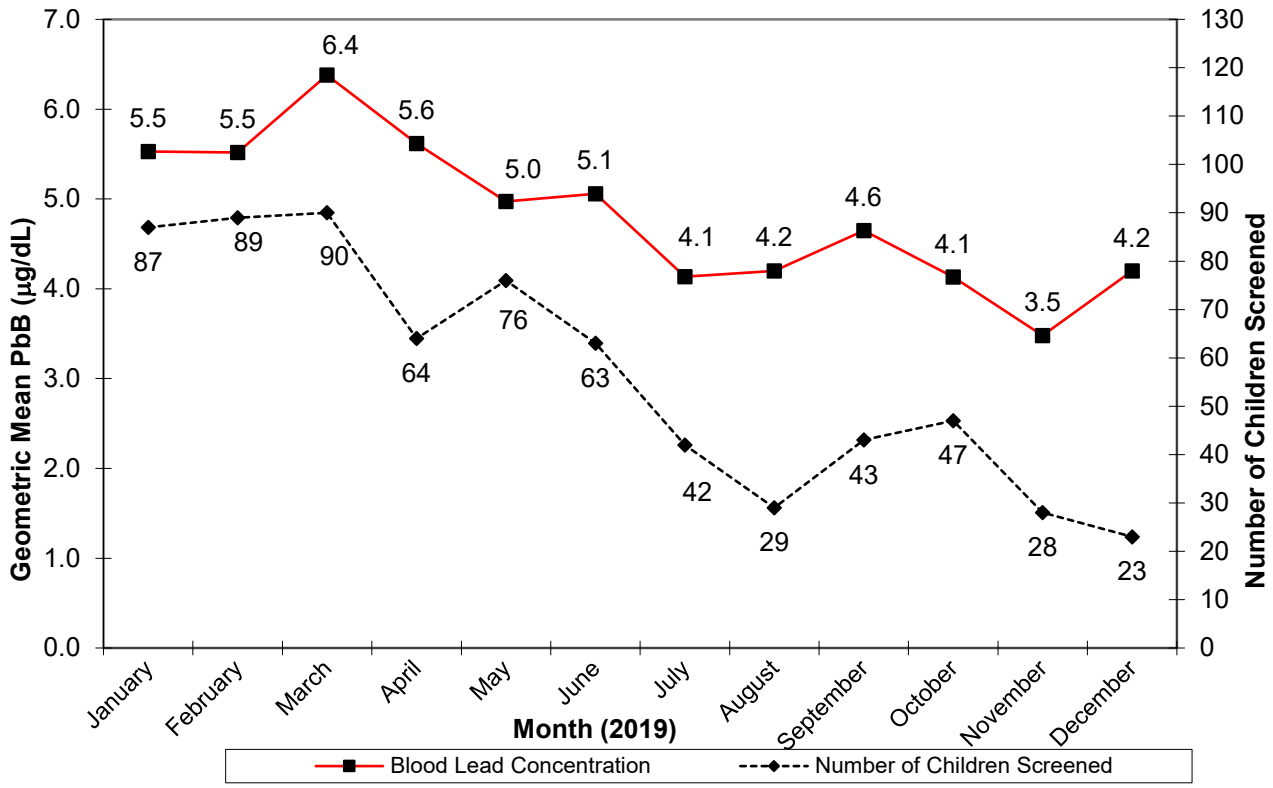

Figure 15. Monthly geometric mean blood lead level comparison of first visit blood lead levels for Broken Hill children aged between 1 to <5 years of age for 2019.

[16] Laidlaw MAS, Mielke HW, Filippelli GM, Johnson DL, Gonzales CR. Seasonality and Children's Blood Lead Levels: Developing a Predictive Model Using Climatic Variables and Blood Lead Data from Indianapolis, Indiana, Syracuse, New York, and New Orleans, Louisiana (USA). *Environmental Health Perspectives*. 2005; 113(6):793-800

Conclusion

Newborns had a geomean of 0.7 µg/dL. Children aged between 6 months to <12 months had a geomean of 2.8 µg/dL. While this age group was not part of the 2013-2017 screening schedule they may, nevertheless, have benefited from the lead program.

Geometric means (age-sex standardised) for all children aged 1 to <5 years increased by 0.4 µg/dL from 2018 to 2019 (4.7 to 5.1 µg/dL respectively).

The total number of children screened aged 1 to <5 years increased by 7% from 637 in 2018 to 681 in 2019. Both Aboriginal and non-Aboriginal children participation numbers increased from 2018 to 2019 (154 to 183 and 480 to 489 respectively). Including children aged 6 months and older there were 582 non-Aboriginal children and 201 Aboriginal children and 9 Aboriginal status unknown tested at least once by C&FHC and Maari Ma.

Once children become toddlers (ie are 1 year and older) and have greater freedom to roam and explore both Aboriginal and non-Aboriginal blood lead levels increase and divergences between Aboriginal and non-Aboriginal children emerge. For children aged 1 to <5 years the non-Aboriginal blood lead level increased slightly from 4.0 to 4.2 µg/dL while the Aboriginal children lead level increased somewhat more from 7.9 to 8.5 µg/dL. The 2019 results showed 60% of non-Aboriginal children aged 1 to <5 years in Broken Hill had a blood lead level below 5 µg/dL, compared to 20% of Aboriginal children. The large gap between Aboriginal and non-Aboriginal children in the proportion under the notifiable blood lead level of 5 µg/dL is reinforced by the difference in geometric mean levels remaining at 4.0, similar to 2015, 2017 and 2018.

Over half (52%) of the children aged 1 to <5 years are above the notifiable level of 5 µg/dL. The non-Aboriginal population, with a mean of 4.2 µg/dL, had 40% of children with blood lead levels ≥ 5 µg/dL. Even with a geomean of 2.8 µg/dL, children aged 6 months to < 12 months still had 15% with a notifiable blood lead level.

The BHELP reports that there has been over 11 hectares of public land abated since 2015 in 12 different locations across the city including parks ovals and children's playgrounds along with over 60 homes remediated under the home remediation program since 2015. Undoubtedly those children with high lead levels who have had homes remediated will have benefited, as will those living nearby or use the public land that has been abated. However, as the data shows, population blood lead levels have fluctuated but not changed significantly since 2012. This was the first full year after the introduction of point of care testing and aligning testing with immunisation, resulting in significant increases in Aboriginal and non-Aboriginal children tested, affording a more exact indication of population blood lead levels in children in Broken Hill. Crucially the gap between Aboriginal and non-Aboriginal children, so noticeable in the 1 year to < 5 years age group, has not changed for more than 10 years.

Next Steps

Lead monitoring in Broken Hill has been business as usual since 1991. Although the population mean lead levels for children under the age of 5 are below 5 µg/ dL, there is still opportunity to implement community initiatives to increase the number and proportion of children with blood lead levels below 5 µg/dL as opposed to the population mean. There is a need for ongoing work to reduce blood lead levels for all children in this age group in Broken Hill, particularly those with an Aboriginal background. Hence, maintaining the child blood lead monitoring program and having to meet agreed outcomes will be an important public health initiative in Broken Hill.

The Public Health lead monitoring and evaluation team would recommend the establishment of targets to assess the improvements made in reducing lead blood levels. This will involve establishment of targets based on the program's vision. From a human health perspective a measure recommended based on literature:

Measure 1: greater or equal to 80% of children aged 1 to < 5 years with a blood lead level <5 µg/dL [17]. This proportion should be maintained over a period of time, for example 5 years, and if the NSW Health notifiable blood lead level changes then this should be reflected in the local goal. Ensuring that all children continue to be screened and that screening data is collected and reported is basic as blood lead levels are key indicators that the Program is succeeding.

A program model with a prevention focus, in contrast to reactive response once a child is found with a raised blood lead level, is essential. Critical to this is that new mining emissions need to be effectively controlled. Mark Taylor and his students have shown significant relationships between lead dust and blood lead levels [18,19,20]. While there has been a huge improvement in lead in air since the line of Lode was capped, there is now strong evidence that lead emissions from the leases are still impacting children's blood lead levels [20,21,22]. The literature also shows that remediating individual homes is less effective than remediating whole areas (eg zonal remediation) [23]. This is because some children move house and so can move into homes that have a higher lead risk, unremediated areas can recontaminate remediated areas, and a recent study by Lyle et al (manuscript submitted) showed that children spend lots of time outside their home, mostly in other private homes.

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[17]Yang K, Cattle SR Bioaccessibility of lead in urban soil of Broken Hill, Australia: A study based on in vitro digestion and the IEUBK model *Sci Total Environ* 2015; 923-933

[18]Dong C, Taylor MP, Zahran S The effect of contemporary mine emissions on children's blood lead levels Environment International 122 (2019) 91–103

[19]Taylor,M.P.,Mould SA, Kristensen LJ, Rouillon M., Environmental arsenic, cadmium and lead dust emissions from metal mine operations: Implications for environmental management, monitoring and human health. *Environ.Res*. (2014),135: 296-303

[20] Dong C, Taylor MP, Gulson B A 25-year record of childhood blood lead exposure and its relationship to environmental sources *Environ Res*186 (2020) 109357

[21]Kristensen LJ, Taylor MP. Unravelling a 'miner's myth' that environmental contamination in mining towns is naturally occurring. *Environ Geochem Health* 2016; 38(4):1015-1027

[22]Dong, C., & Taylor, M. P. Applying geochemical signatures of atmospheric dust to distinguish current mine emissions from legacy sources. *Atmospheric Environment*, 2017,*161*, 82-89

[23] Nussbaumer-Streit, B., Yeoh, B., Griebler, U., et al., 2016. Household interventions for preventing domestic lead exposure in children. Cochrane Database Syst. Rev. 10 Article ID: CD006047

Taylor and his group have also shown higher lead levels were statistically associated with lower socio-economic status as well as children living in homes built before 1940 and conclude Aboriginal childrens' high blood levels and the difference in blood lead level of Aboriginal and non-Aboriginal children are linked, in part, to their lower socio-economic status[24]. As Dong et al conclude[24] "Overall, the key goal should be to eliminate risk by removing contamination in the wider environment as well as in individual homes."

Recent results from Trail, Canada (Trail Area Health & Environment Committee meeting 16/9/2020) show reducing lead levels in air can dramatically reduce children's blood lead levels, and sustained efforts to identify and control sources of lead emissions on their industrial site have reaped big rewards – their average children's blood lead level is now below 3 ug/dl, and industry is still operating.

The combination of (a) January-March for the last few years having been considerably hotter and drier than the average, (b) 2019 having had the lowest rainfall on record and (c) a hotter, drier climate change outlook for the Far West, the development of a long term climate strategy should be incorporated into future strategies and actions. Climate affects multiple systems and so risks from climate require a systemic, coordinated response which can only enhance a prevention focus. The NSW Government hopes to embed consideration of climate change mitigation and adaptation across government operations including service delivery, infrastructure, purchasing decisions and regulatory frameworks [25,26].

There are foreseeable financial pressures in maintaining and improving the Lead program in Broken Hill. The NSW Government funded Broken Hill Environmental Lead Program funding concludes in 2020 and while the EPA has committed its own funding for the program from 1 July 2020 to June 30 2021, further substantial funding is crucial to achieve this level of lead abatement.

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[24] Dong C, Taylor MP, Gulson B A 25-year record of childhood blood lead exposure and its relationship to environmental sources *Environ Res*186 (2020) 109357

[25]Office of Environment and Heritage 2017 Western Enabling Regional Adaptation- Far West Region ISBN 978-1-76039-872-9

[26] NSW Government Climate Change Policy Framework 2016 https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Climate-change/nsw-climate-change-policy-framework-160618.pdf

Appendix 1

The criteria for birthing in Broken Hill is that they have to be "low risk". The most recent revision of the capability of the Obstetric Birth Unit at Broken Hill allows for:

- Normal labour and birth care for women ≥37 weeks gestation.
- Induction of labour for women ≥38 weeks gestation.
- Vaginal birth after caesarean section for women ≥37 weeks gestation without medical induction or augmentation with oxytocin (Syntocinon®.)
- Antenatal and intrapartum continuous electronic fetal heart rate monitoring as a means of fetal welfare assessment when clinically indicated.
- Instrumental births when clinically indicated.
- Elective caesarean section ≥39 weeks gestation.
- Elective caesarean for DC/DA twins ≥37 weeks gestation.
- Emergency caesarean section when clinically indicated.
- BMI recommendation: Women with a BMI of ≥35 at the booking visit are referred to dietetic services and/or Get Health in Pregnancy services. If BMI is ≥ 46 at 36 weeks gestation, the woman is referred to Flinders Medical Centre for labour and birth management. All women with a BMI ≥35 at booking are informed of this possibility and documentation is made in the woman's antenatal risk assessment to reflect this.

The following women are not eligible to give birth in Broken Hill:

- Less than 37 weeks gestation
- If BMI is ≥ 46 at 36 weeks gestation, the woman is referred to Flinders Medical Centre for labour and birth management
- High risk comorbidities requiring specialist treatment
- Uncontrolled gestational diabetes
- Severe intrauterine growth restrictions/foetal abnormalities
- High risk pre-eclampsia
- High risk twins or triplets
- Women with type 1 diabetes
- Induction of labour or caesarean prior to 38 weeks gestation

All of the above women are referred to Flinders Medical Centre or Women's & Children Hospital, Adelaide.

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