

Lead Program Annual Report 2023: Broken Hill children less than 5 years old



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We acknowledge the traditional owners of country throughout the region. We pay respects to the people and their culture and to Elders past and present.

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Executive Summary

Background

Broken Hill is a town established around the mining of the world's largest deposit of lead, silver, and zinc, known as the 'Line of Lode'. The Line of Lode has been mined continuously for almost 140 years, resulting in ubiquitous lead in soil and dust throughout the town and surrounding areas. Lead is a naturally occurring element that can be harmful to the human body. Children aged under 5 years of age are more likely to breathe in or ingest small amounts of lead-contaminated dirt or dust as they interact with their physical environment. They can absorb a higher proportion of lead than adults, as their smaller bodies are rapidly growing and developing and are therefore more at risk to the harmful effects of long-term lead exposure. It is well established that blood lead levels (BLLs) greater than 10 micrograms per decilitre ($\mu\text{g}/\text{dL}$) can have harmful effects on many organs and bodily functions. However, while it is widely accepted that there is no 'safe' level of lead in a developing child, there is less conclusive evidence for the association of BLLs ranging from 5 $\mu\text{g}/\text{dL}$ to less than 10 $\mu\text{g}/\text{dL}$ with adverse cognition and behaviour, as well as other poor health outcomes. In New South Wales (NSW), BLLs of 5 $\mu\text{g}/\text{dL}$ and over are required to be notified to public health units and are managed in accordance with the [Lead in Blood Control Guidelines](#). For the purposes of this document 'guideline' refers to BLLs less than 5 $\mu\text{g}/\text{dL}$.

Broken Hill Lead Program

The Broken Hill Lead Program (the Program) aims to undertake BLL screening of all resident children aged under 5 years, aligning this with their immunisation schedule or health check appointments. Those children found to have BLLs above the guideline are managed and treated in accordance with the *Lead in Blood Control Guidelines*. Blood lead testing is voluntary and offered free of charge to parents and carers through the Broken Hill Child and Family Health Service and the Maari Ma Primary Health Care Service. Children are screened every 6 months until the age of 2 years, and where upon it is recommended annually until they turn 5 years of age. Screening of umbilical cord BLLs of newborns, born to Broken Hill resident mothers, is also included in the Program.

The Program is intended to monitor children's BLLs as they interact with their physical environment across three developmental stages, through which children go from being completely dependent to being physically independent. The *Lead Program Annual Report 2023* presents an update on trends in BLLs over time following the 2023 screening of children, according to these three stages of development: newborns, 6 months to less than 12 months of age and 1 year to less than 5 years of age. As a child may undergo multiple blood lead tests in the same year, the first BLL is used for analyses for each of the three categories.

The *Lead Program Annual Report 2023* presents trends in BLL screening for newborns and children aged 1 year to less than 5 years from 2014; and, for babies aged from 6 months to less than 12 months from 2018, due to there being no testing for this age group during the years 2013 to 2017. Reports summarising data from the commencement of the Program in 1991 are available on request.

Results

Newborns, 2014 to 2023

In 2023, umbilical cord blood from 152 newborns of Broken Hill resident mothers were tested for BLLs. Of these newborns, 24% (n=36) are Aboriginal and 76% (n=116) are non-Aboriginal. Of the

152 umbilical cord bloods screened:

- 99% had BLLs within the guideline (less than 5 µg/dL).
- The geometric mean of all BLLs was 0.6 µg/dL.

There was no difference between the geometric mean of BLLs for Aboriginal newborns compared to that for non-Aboriginal newborns.

Over the 10 years from 2014 to 2023, the proportion of newborns screened for BLLs increased slightly (1%), from 82% to 83% respectively. Over the 8 years of comparable resulting, from 2016 to 2023, the annual geometric mean declined, from 0.8 µg/dL to 0.6 µg/dL respectively.

Children aged 6 months to less than 12 months, 2018 to 2023

In 2023, there were 200 children screened aged from 6 months to less than 12 months. Of these children:

- 13% (n=26) had BLLs above the guideline, which was marginally less than in 2022 (14%).
- 20% (n=40) are Aboriginal and 80% (n=160) are non-Aboriginal.
- 33% (n=13) of Aboriginal children had BLLs above the guideline compared to 8% of non-Aboriginal children (n=13).
- The geometric mean of all BLLs was 2.4 µg/dL.
- The geometric mean for Aboriginal children, while within the guideline, was 1.0 µg/dL higher than for non-Aboriginal children, that is 3.3 µg/dL and 2.3 µg/dL, respectively.

Over the six years from 2018 to 2023, the number of screened children aged 6 months to less than 12 months increased by 28% (from 156 to 200 respectively). At the same time, there was an overall small decrease in the annual geometric mean (from 2.7 µg/dL to 2.4 µg/dL respectively) and the percentage of children with blood lead levels above the guideline (from 15% to 13% respectively).

Children aged 1 year to less than 5 years, 2014 to 2023

In 2023, there were 711 children aged 1 year to less than 5 years screened for BLLs. Of these children:

- 27% (n=190) were Aboriginal and 72% (n=515) were non-Aboriginal, with 1% (n=6) having no record for this indicator.
- Using the ABS 2021 Census population count for Broken Hill resident children aged 1 to less than 5 years as the denominator, the estimated participation rate in the Program for all children was 91%.
- Participation rates increased across all age groups, with the exception of the 3 year olds for whom it remained unchanged.
- 74% of Aboriginal children screened had BLLs above the guideline.
- 9% of Aboriginal children screened had high or very high BLLs (≥ 20 µg/dL) compared to less than 1% of non-Aboriginal children.

Applying the age-sex standardised calculations to the Broken Hill ABS population for children aged 1 year to less than 5 years, the annual geometric mean was 4.4 µg/dL, which is below the guideline. Nonetheless, there were 43% of Broken Hill children with BLLs above the guideline in 2023, and

proportionally this was highest in the 2 year old age group.

Over the 10-year period from 2014 to 2023, the number of screened children aged 1 year to less than 5 years decreased by 1% (from 719 to 711 respectively), and the average annual estimated participation rate over that time equated to 84%. As such, the 2023 rate of 91% is above the reporting period average, and continues the increasing trend in participation since the impact of COVID-19 in 2021.

From 2014 to 2023, the annual age-sex standardised geometric mean for all children in this age group fell by 0.8 µg/dL i.e., from 5.2 µg/dL (above the guideline) to 4.4 µg/dL (below the guideline) respectively, and the percentage of children with BLLs above the guideline decreased from 48% to 43% respectively. Conversely, the annual age-sex standardised geometric mean for Aboriginal children increased by 0.4 µg/dL over this 10-year reporting period, from 7.5 µg/dL to 7.9 µg/dL respectively, and remains above the guideline. However, the percentage of Aboriginal children with BLLs above the guideline decreased slightly, from 76% to 74%, respectively.

For the 10-year reporting period, 2014 to 2023, there was a consistent disproportionality between the proportion of BLLs above the guideline for Aboriginal and non-Aboriginal children aged 1 year to less than 5 years. The average annual percentage over this reporting period for the Aboriginal children with BLLs above the guideline was 74%, which was almost double the 37% recorded for non-Aboriginal children.

Seasonal trends, 2023

In 2023, the quarters with the higher geometric means correlated with the warmer months, there was no correlation for the quarters with the higher rainfalls or testing numbers.

Conclusion

Over the reporting period, participation rates in the Program decreased marginally for the screening of newborns and children aged 6 to less than 12 months. Conversely, the participation rate for children aged 1 year to less than 5 years was at its highest for the past 5 years. The annual BLL geometric mean for 2023 was unchanged for the cord blood screening and marginally decreased for children aged 6 months to less than 12 months, but both of these were well below the guideline. Notably, the geometric mean for children aged 6 months to less than 12 months was higher for Aboriginal children than for non-Aboriginal children. For children aged 1 year to less than 5 years, there was an increase in geometric mean for the total number of children screened, although the level remained below the guideline. Importantly, annual geometric mean for Aboriginal children in this age group continues to be above the guideline, with a greater proportion of their results in the high to very high BLL categories.

Background

Broken Hill is a town located in the far west of New South Wales (NSW) and experiences the hot, dry and windy climate associated with this region. It was founded in 1883 following the discovery of the world's largest deposit of lead-silver-zinc. The ore body known as the 'Line-of-Lode', has been mined continuously since 1884, and the city has grown out around this.¹ Onsite smelting activities and waste management practices in the early years of mining and the impact of wind and water erosion on lead-contaminated sites has resulted in the ubiquitous distribution and concentration of lead in soil and dust throughout the city.

Consequently, Broken Hill residents, miners, industry workers and their families experience long term environmental lead exposure. Changes to mining practices, including underground extraction, off-site smelting, capping of waste dumps along the Line of Lode, storm water control on the mining leases and waste disposal regulation, have seen a large reduction in atmospheric lead emissions over time.² However, ore continues to be brought to the surface for processing and concentration, so mining emissions are an ongoing issue.³ Furthermore, the predicted climate changes for Far West NSW forecasting an increase in temperatures and decrease in rainfall over the 20 years from 2020 to 2039 will potentially increase the frequency of dust storms, soil dispersion and therefore elevate lead dust loading into the environment.⁴

Lead is a naturally occurring element found in a variety of compounds and remains in the earth until physically removed through mining. As a result of long-term mining and widespread industry use including house paint and petroleum, lead can be found throughout the Australian environment.⁵ People absorb lead into the body by ingesting or breathing in lead-contaminated dust. As such, most people have some level of lead in their system. The average 'background' blood lead level (BLL) is estimated to be less than 5 micrograms per decilitre ($\mu\text{g}/\text{dL}$).

The effect of lead exposure on health varies according to age, dose, and length of exposure. The ill-health risk for children and babies (including in utero) exposed to lead is higher than in adults, because their bodies are smaller, and their bodies and brains are growing and developing at a rapid rate.⁵ Children are more likely to breathe in or ingest lead-contaminated dust and dirt as they explore and physically interact with their environment and frequently touch their mouths. Lead toxicity can affect a range of molecular processes, partly due to its ability to inhibit and mimic the actions of calcium. This in turn impacts the function of many organs and systems within the body.

It is well established that BLLs greater than 10 $\mu\text{g}/\text{dL}$ can lead to adverse effects on digestive, cardiovascular, renal, reproductive, and neurological functions.⁶ However, the evidence for a causal link between BLLs of 5 to 10 $\mu\text{g}/\text{dL}$ is less clear, despite the identification of potential associations with adverse cognitive effects and behavioural problems in children, delays in sexual maturation in adolescents and increased blood pressure in adults. Currently, BLLs equal to or above 5 $\mu\text{g}/\text{dL}$ are notifiable under the 2016 Public Health Amendment to the NSW Public Health Act 2010.⁷ For the purposes of this report, 'guideline' will refer to BLLs less than 5 $\mu\text{g}/\text{dL}$.

Broken Hill Lead Program

A 1991-1993 survey of Broken Hill children aged from 1 year to less than 5 years of age found that 86% of these children had BLLs of $10\mu\text{g}/\text{dL}$ or above and that 38% had very high lead levels of $20\mu\text{g}/\text{dL}$ or above.⁸ Following these findings, a targeted program designed to monitor BLLs in children aged under 5 years of age in Broken Hill was instituted.⁹ Between 1991 and 2012, the age-sex standardized geometric mean blood lead level reduced by about two-thirds (from $16.7\mu\text{g}/\text{dL}$ to $4.5\mu\text{g}/\text{dL}$) and has since ranged between $3.6 - 5.9\mu\text{g}/\text{dL}$ during 2014-2023.¹⁰

The Broken Hill Lead Program has evolved over time to collect blood lead samples from three groups of children aged less than 5 years. The three groups are based on the developmental progression of children from being completely dependent to being physically independent, and include¹¹:

1. Newborns, whose umbilical cord blood is tested at birth to determine the impact of lead transfer from the mother to the child and is considered a proxy baseline for the child.
2. Children aged 6 months to less than 12 months, who are learning to explore their environment by putting objects into their mouths and have limited mobility through crawling but may be restrained outside.
3. Children aged between 1 year and less than 5 years, who are moving towards independence and can more freely interact with their environment, often with decreasing hand to mouth play and increasing autonomy with activities such as handwashing.

Comparisons of BLLs across the groups inform both intervention needs and monitoring of the Program. Program participation is free of charge and voluntary, and screening is aligned with the immunisation schedule so that children are tested at 6 months, 12 months, 18 months, and 2 years and then at 3 years and again at 4 years. The Program is promoted via reminder phone text messaging to parents and carers, promotions and advertising through local media. If BLLs are found to be above the guideline, children are recalled for repeat testing, management and treatment as per the NSW Health's [Lead in Blood Control Guidelines](#).

Broken Hill Local Government Area Population Profile

The Australian Bureau of Statistics (ABS) census population data for the years since the commencement of Broken Hill Lead Program (1996, 2001, 2006, 2011, 2016 and 2021) has shown a decline in both the number and the proportion of children under the age of 5 years residing in the Broken Hill Local Government Area, overall and for each of the 1 year age groups (Table 1).¹² Analysis of blood lead levels for annual reporting is stratified by Aboriginality to monitor any inequitable burden in high BLLs which may exist. Counts of the Aboriginal children population are sourced from the Census data, and so are reliant on self-identification. The number of Aboriginal children aged under 5 years has increased by 71% from 1996 to 2021. Conversely, over the same period, the number of all Broken Hill children aged under 5 years has decreased by 31%.

Table 1: ABS Usual Resident Population 0-4 years from 1996 to 2021, total population and stratified by age and Aboriginality, 1996 to 2021

Census Year	1996	2001	2006	2011	2016	2021	1996-2021 % change
All children 0-4 years (% of total population)	1,403 (6.6%)	1,297 (6.4%)	1,184 (6.1%)	1070 (5.8%)	977 (5.5%)	972 (5.5%)	-31%
Children aged 0 years (% of total population)	247 (1.2%)	236 (1.2%)	228 (1.2%)	186 (1.0%)	196 (1.1%)	192 (1.1%)	-22%
Children aged 1 year (% of total population)	280 (1.3%)	247 (1.2%)	222 (1.1%)	230 (1.2%)	189 (1.1%)	186 (1.1%)	-36%
Children aged 2 years (% of total population)	282 (1.3%)	250 (1.2%)	227 (1.2%)	236 (1.3%)	183 (1.0%)	205 (1.2%)	-27%
Children aged 3 years (% of total population)	306 (1.4%)	280 (1.4%)	228 (1.2%)	197 (1.1%)	217 (1.2%)	175 (1.0%)	-43%
Children aged 4 years (% of total population)	288 (1.3%)	284 (1.4%)	279 (1.4%)	221 (1.2%)	196 (1.1%)	218 (1.2%)	-24%
Aboriginal children 0-4 years (% of 0-4yr population)	112 (8.0%)	165 (13.0%)	177 (17.0%)	176 (16.0%)	182 (19.0%)	191 (20.0%)	71%

Source: Australian Bureau of Statistics, Usual Resident Population, Census and Housing.

Methods

Collection of blood samples

For newborn babies born at the Broken Hill Health Service, an umbilical cord blood sample is taken for laboratory testing. BLLs for children less than 5 years are taken as either a finger prick (capillary) or venous test (considered more invasive). Since blood lead screening is aligned with the childhood immunisation schedule, testing may occur at 6 months, 12 months, 18 months and 4 years of age. Children aged 2 and 3 years of age are encouraged to be presented for testing to ensure each child is monitored at least once every year until they turn 5 years old.

Data collation and analysis of blood lead levels

Where a child has had multiple BLL tests in the same calendar year, only the first test for the year is used for analysis. Exceptions to this include situations where a child is tested at age 6 months to less than 12 months and then turns 1 in the same year; they will be included in the analysis twice i.e., in the 6 months to less than 12 months age group and then in the 1 year to less than 5-year age group. Where a venous test and capillary test have been collected in the same calendar year for a child, the venous test, considered to be a more accurate test, is included in the analysis over the capillary test(s).

The geometric mean, as opposed to an average or arithmetic mean, is used to report BLLs. This is because the majority of children have lower BLLs, and only a small number have very high levels. The arithmetic mean is strongly affected by the very high values whereas the geometric mean normalises the values being averaged so that no value dominates the weighting.¹³

Up until 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. From 2016, all results were recorded with decimal places, so geometric means will not be exactly comparable to previous years. This particularly affects low results such as those recorded for cord blood analysis. Also, the minimum reading possible for capillary sampling is 3µg/dL compared to <1µg/dL for venous sampling. A “low result” reading is also possible for capillary testing and is recorded as 2 µg /dL. This affects the geometric means by slightly raising the average compared to those for the years where capillary testing was not available (before 2009). During 2022 and 2023, there were three brief time periods where a recall or ruptures of the LeadCare II analyser’s Point of Care testing strips disrupted on-site testing, impacting the two testing sites differently.^a A different testing method was used when the Point of Care strips were unavailable, so its lower cut off level may have also affected the geometric mean during that period. However, as population levels are reported here, these impact of the testing and resulting differences are likely to be slight and the trends in BLLs will still be meaningful.

Age-sex standardisation of results

Children’s BLLs can vary by age and gender, hence, it is difficult to compare BLLs from year to year unless the same proportion of children in each age group is tested for the successive years. Therefore age-sex standardisation is used to account for this variation. Effectively, this determines what the BLL 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 data. This age-sex

^a Offsite testing was used by one testing site for 3 months from the end of January to the end of April 2022 and then for 5 weeks during July to September 2023.

adjusted population mean is reported for children aged 1 year to less than 5 years. Unadjusted means with 95% confidence intervals (2014 to 2023) are available in [Appendix 1](#).

Data source

Until 2017, all children’s demographics and BLLs were stored on a standalone Access® database. NSW Health ceased using Access® software and all data was loaded onto the new platform, the Powerchart/Community Health Outpatient Care (CHOC) application of the Electronic Medical Records from Cerner Systems Solutions. Maari Ma Aboriginal Health Corporation have continued to provide their blood lead screening results for loading onto the CHOC application.

Results

Screening of umbilical cord blood of newborns, 2014 to 2023

Newborns screened

In 2023 there were 184 live births at the Broken Hill Health Service, 170 of which were identified as belonging to residents of Broken Hill and the immediate surrounds (postcode 2880)^b. In this same year, umbilical cord blood lead screening was completed on 152 newborns^c, which equated to a participation rate of 83% for cord blood lead screening in 2023. However, this level of participation is not unexpected given that any residents who birthed outside of Broken Hill do not have opportunity to participate in cord blood lead testing and in some cases a cord blood result was not able to be obtained for local births.

Of the 152 newborns tested, 24% (n=36) identified as Aboriginal and/or Torres Strait Islander and 76% (n=116) were non-Aboriginal. For the 10 years from 2014 to 2023, there was a marginal increase of 1% in the proportion of all newborns screened for BLLs, from 82% to 83% respectively (Table 2).

Table 2: Annual total of Broken Hill newborns screened and annual total of live births for 2014-2023, with the percentage of newborns screened given as a proportion of the total live births.

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
No. of newborns screened	169	177	165	165	153	156	122	160	157	152
No. of live births	206	196	209	188	176	185	166	201	203	184
% Newborns screened	82%	90%	79%	88%	87%	84%	73%	80%	77%	83%

Blood lead levels

On the 152 newborn cord bloods tested in 2023, 99% (n=150) had BLLs within the guideline (<5 µg/dL), 1% (n=2) had BLLs between 5.0 and 10.1 µg/dL. Overall, this equated to an annual geometric mean of 0.6 µg/dL, which was unchanged from the geometric mean for 2022 (0.6 µg/dL). Due to a change in the recording of BLLs from 2016 onwards, comparisons to annual geomeans prior to 2016 is not possible (see Methods section for more information). As such, looking at the

^b The number of live births for 2023 and the number which were live births for women with a postcode of 2880 (Broken Hill and immediate surrounds), was obtained from the manager of Maternity and Newborn Services at the Broken Hill Base Hospital.

^c Of the 152 cord blood lead samples tested, 7 also had an address outside of Broken Hill’s immediate surrounds.

trend from 2016 to 2023, annual geometric means have decreased overall, from 0.8 µg/dL to 0.6 µg/dL respectively (Figure 1).

There was no difference in geometric means between Aboriginal and non-Aboriginal newborns in 2023.

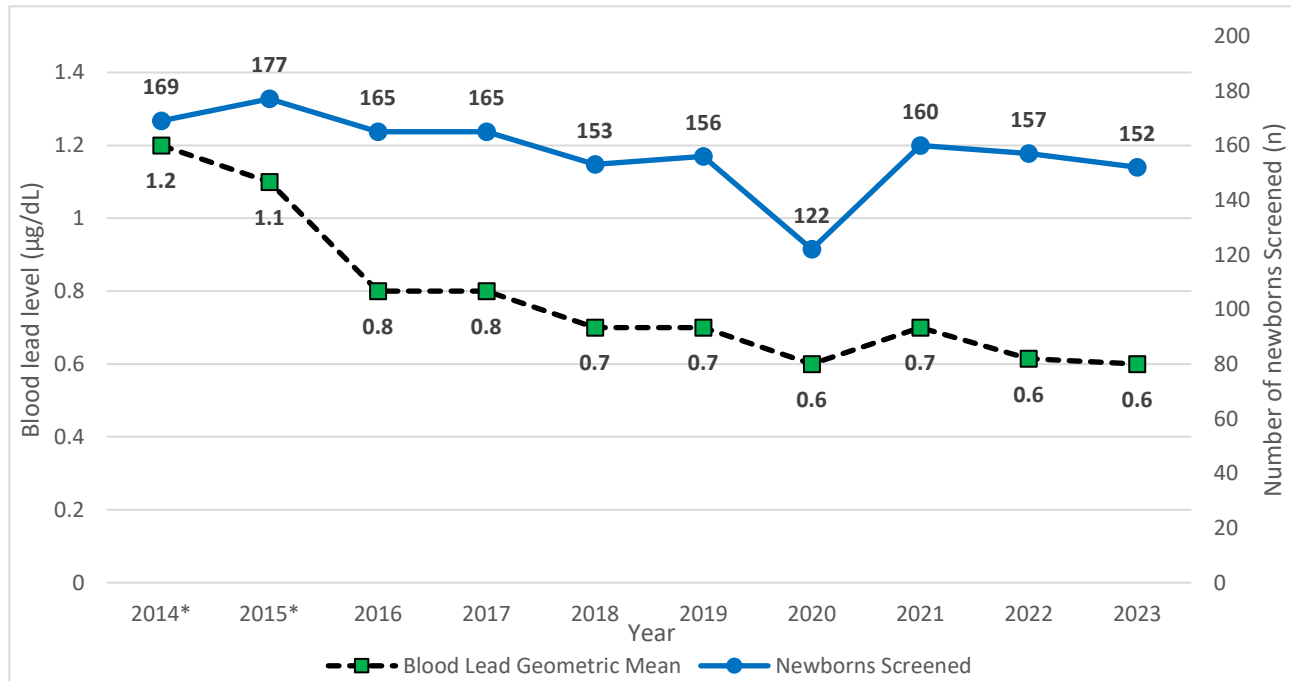


Figure 1: Annual total of Broken Hill newborns screened and annual blood lead level geometric mean, 2014-2023. *Prior to 2016, BLLs were rounded up or down which particularly affects low results. As such 2014-2015 geometric means are not comparable to those from 2016 onwards where decimal points were recorded.

Screening of children aged 6 months to less than 12 months, 2018 to 2023

Children screened

In 2023, 200 children aged 6 months to less than 12 months were screened for BLLs^d. Of these children, 20% (n=40) are Aboriginal and 80% (n=160) are non-Aboriginal.

From 2013 to 2017, there was no screening of children aged 6 months to less than 12 months. For the six years from 2018 to 2023, the overall annual number of children screened for BLLs in this age group increased by 28%, i.e., from 156 to 200 (Figure 2), but there was a 4% decrease in the number of children screened from 2022 to 2023. The low number of children tested during 2021 is suggestive of the COVID-19 pandemic's impact on the Program^e.

^d Participation rates have not been reported for this age group as an ABS Census denominator by six months is not available.

^e Following a steep drop off in the number of children screened in 2021, but participation increased by 30% in 2022. This is suggestive of a COVID19 pandemic artefact on the Program participation, due to reduced testing carried out from 13th September 2021 to 24th January 2022.

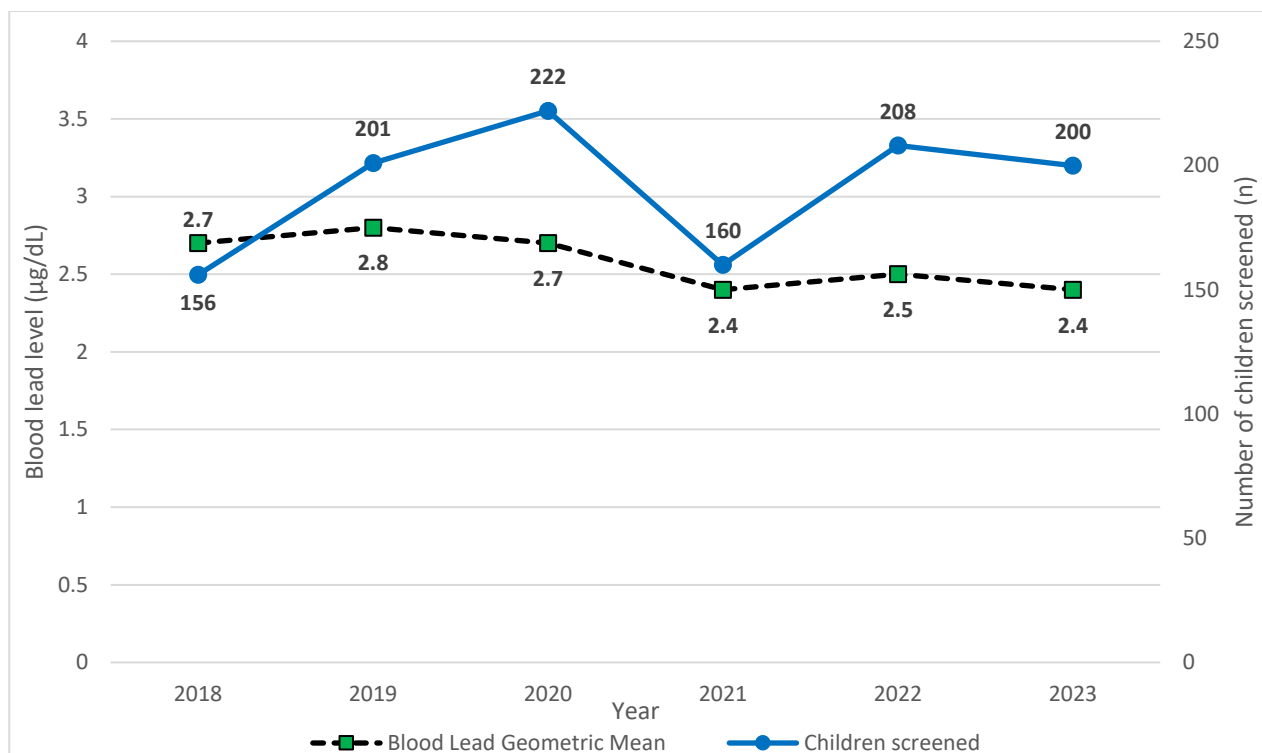


Figure 2: Annual number of Broken Hill children screened aged 6 months to less than 12 months and annual blood lead level geometric mean, 2018-2023.

Blood lead geometric mean and elevated blood lead levels

In 2023, the annual geometric mean for all children aged 6 months to less than 12 months was 2.4 µg/dL, which was a 4% decrease from 2022 (Figure 2)^f. Looking at the overall trend from 2018 to 2023, there was a slight downturn in the annual blood lead geometric means over this period, from 2.7 µg/dL to 2.4 µg/dL respectively. The geometric mean for Aboriginal children aged 6 months to less than 12 months was higher than that for non-Aboriginal children, that is 3.3 µg/dL compared to 2.3 µg/dL respectively.

In 2023, 13% (n=26) of all children aged from 6 months to less than 12 months had BLLs above the guideline, which was just below that for 2022 (14%), as well as the average proportion for three years 2018 to 2020 (14%) (Figure 3)^g. The percentage of Aboriginal children with BLLs above the guideline in 2023 was four times that for non-Aboriginal children, that is 33% (n=13) compared to 8% (n=13) respectively.

^f As per the methods, offsite testing was used during certain time periods of 2022/2023 following recalls or ruptures of the Point of Care testing strips; for 3 months from the end of January to the end of April 2022 and then for 5 weeks during July to September 2023. As this different testing method had a lower cut off level, this may have influenced the geometric mean during these times. Although the small number of test results at the lower level during those periods would suggest that the overall effect would likely be minimal.

^g The proportion of all children aged from 6 months to less than 12 months that had BLLs above the guideline in 2021 was 7%, half of that of the years prior (2018-2020) and the years since (2022-2023).

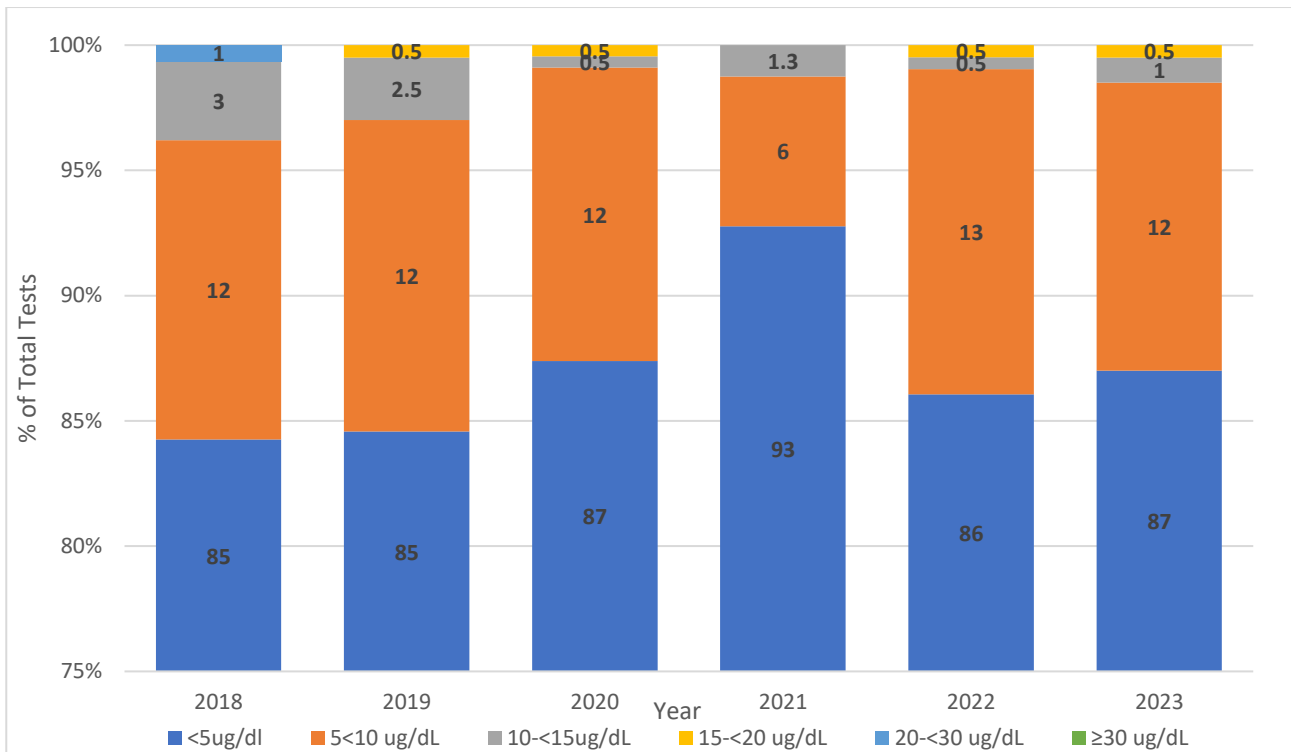


Figure 3: Percentage of Broken Hill children aged 6 months to less than 12 months blood lead levels by category, 2018-2023. NB: totals may vary slightly due to rounding.

Screening of children aged 1 year to less than 5 years, 2014 to 2023

Children screened

In 2023 there were 711 children screened, an increase of 15% in the number of children screened from 2022. Over the 10-year reporting period from 2014 to 2023, there was a 1% decrease in the number of screened children aged 1 year to less than 5 years, from 719 to 711 respectively (Figure 4), indicating a return to pre-pandemic testing levels. As with the 6 months to less than 12 months age group, the low number of children tested during 2021 was suggestive of the COVID-19 pandemic's impact on the Program^h.

Of the 711 children screened, 27% (n=190) were Aboriginal and 72% (n=515) were non-Aboriginal, with a small number (n=6, 1%) having no record for this indicator. From 2014 to 2023 the number of Aboriginal children screened for BLLs increased by 4%, from 183 to 190 respectively (Figure 4), while the number of non-Aboriginal children screened (including those children where there was no record for this indicator) decreased by 3%, from 536 to 521 respectively.

^h Following a 18% decline in the number of children screened in 2021, participation increased by 17% in 2022. As with the 6 to less than 12 month age group, this is suggestive of a COVID19 pandemic artefact on the Program participation, due to reduced testing carried out from 13th September 2021 to 24th January 2022.

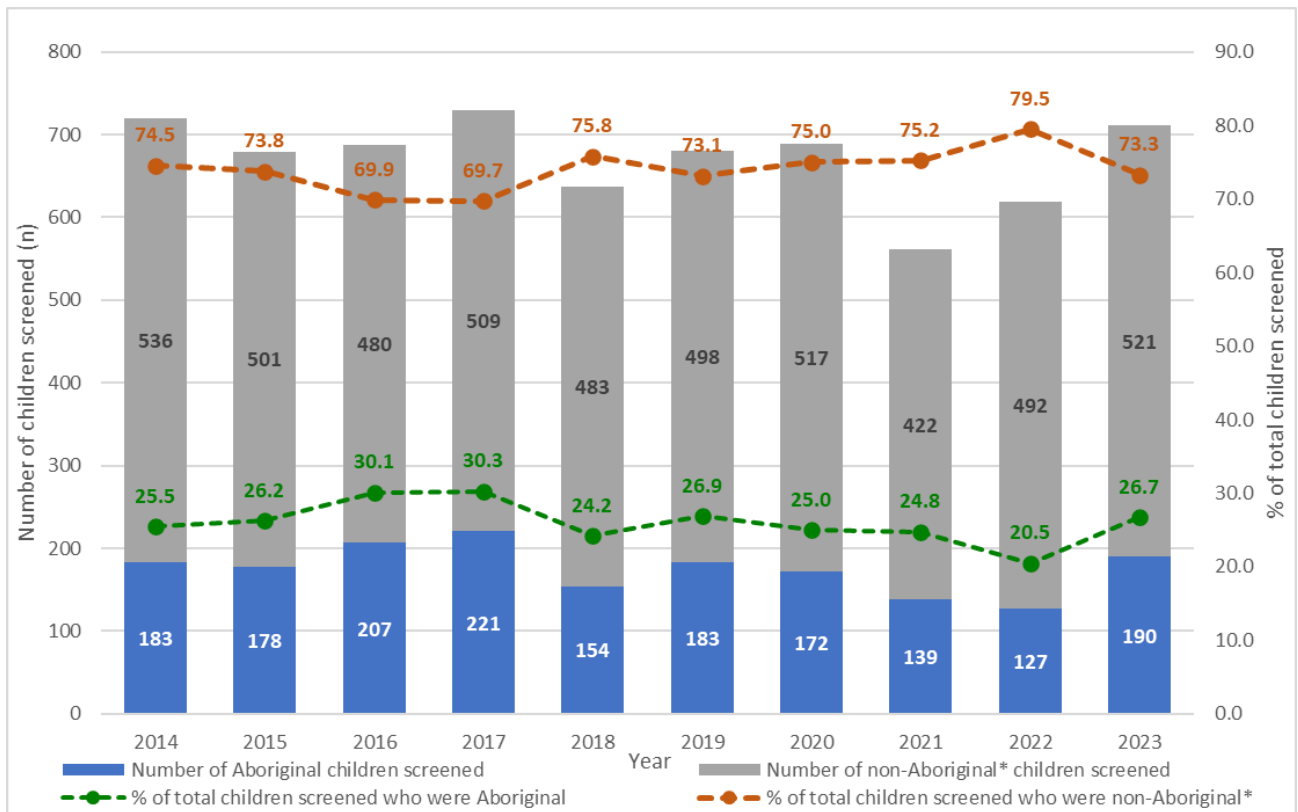


Figure 4: Total annual number of children aged 1 year to less than 5 years screened for blood lead levels during 2014 to 2023, shown as numbers of Aboriginal and non-Aboriginal children screened, with the proportion of the total number of children screened by Aboriginal and non-Aboriginal status in percentage. *Non-Aboriginal screened include those children where this indicator was not recorded.

Estimated participation rate

Participation rates are based on the population by age counts from the ABS 2021 census data as compared to the number of children screened.ⁱ The participation rate of all children aged 1 year to less than 5 years for 2023 was 91%, a 15% increase from the previous year, 2022 (Figure 5). Looking at the trends in participation for this age group over time, there was a 10% increase seen from 2014 to 2023, from 81% to 91% respectively, with the 10-year average annual participation rate equating to 84%.

The estimated participation rate for Aboriginal children aged 1 year to less than 5 years has fluctuated over the past 10 years and frequently exceeded 100%. While the under reporting of Aboriginality in the Census has improved over time, the 2011 and 2016 counts are less than the total Aboriginal children tested in Broken Hill for the years 2014 to 2017, 2019 to 2020 and 2023. Consequently, a 10-year average rate was not calculated and participation rates for years 2018, 2021 and 2022 must be used with caution.

²⁰ Participation rates should be interpreted with caution due to data limitations with using the most recent ABS Usual Resident Population (URP) as total population or denominator. This is not ideal as census requires a minimum residency period to be counted as a resident, but in Broken Hill the mining related workforce (and family) can ebb and flow depending on ore prices and Aboriginal families may be more transient in their movements between extended family.

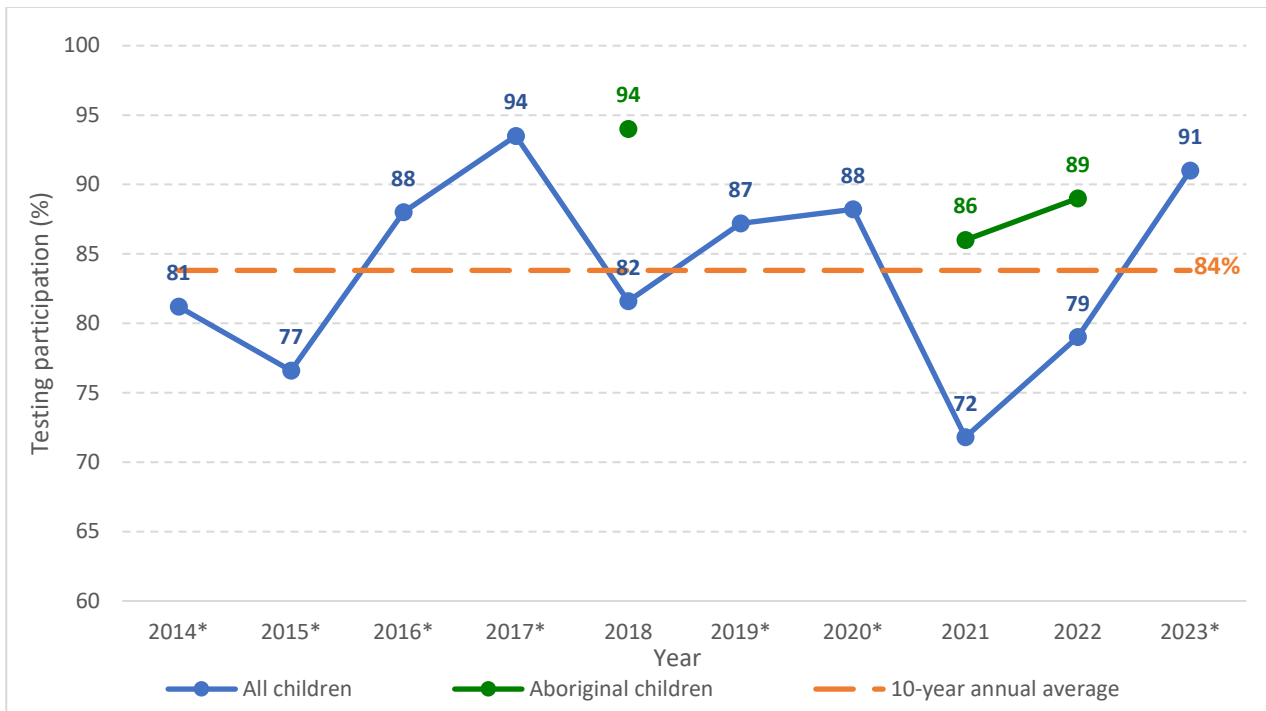


Figure 5: Annual lead screening participation rate for all Broken Hill children and Aboriginal children aged between 1 and less than 5 years old, 2014-2023. *Participation rate for Aboriginal children exceeded 100%.

Stratifying the annual participation rate by 1 year age groups for 2018 to 2023 demonstrates the fluctuation in participation across the 2, 3 and 4 year old age groups from 2018 to 2020. The generalised decline for all age groups in 2021 is again suggestive of the COVID-19 pandemic's impact (Table 3). However, since 2022, there has been an increase in participation across the age groups, with the exception of the 2 year olds which only began to improve in 2023. The proportion of 1 year old children screened each year has consistently been above 100%, with an additional 26% increase seen from 2022 to 2023, 139% to 175% respectively.^j In 2023, the participation rate for the 2 year old and 4 year old age groups also increased, by 35% and 7% respectively, but it remained unchanged for the 3 year olds at 63%. As blood lead testing is aligned with the childhood immunisation schedule, the lower participation for the 2 and 3 year olds may be influenced by there being no scheduled vaccinations on the National Childhood Immunisation Program for these two age groups.

Table 3: Annual lead screening participation rate for all Broken Hill children aged between 1 and less than 5 years old, 2018-2023, stratified by age group.

Year	1 year	2 years	3 years	4 years	All 1-4 years
2018	131%	75%	53%	76%	83%
2019	134%	72%	55%	86%	87%
2020	154%	61%	57%	82%	74%
2021	126%	51%	49%	66%	72%
2022	139%	40%	63%	70%	79%
2023	175%	54%	63%	75%	91%

²¹ Preliminary investigations into the reason for this increase in the participation rate for 1 year olds, did not reveal any definitive conclusions other than that previously outlined in terms of the limitation of using the most recent ABS Usual Resident Population (URP) as total population or denominator in the Broken Hill context.

Blood lead geometric mean

In 2023, the annual age-sex standardised BLL geometric mean^k for children aged from 1 year to less than 5 years was 4.4 µg/dL, equating to an increase of 0.3 µg/dL from 2022 (Figure 6)^l. Over the 10 years from 2014 to 2023 the standardised BLL geometric mean decreased by 0.8 µg/dL, from being above the guideline at 5.2 µg/dL to below the guideline at 4.4 µg/dL. In 2021, the standardised geometric mean for this age group decreased to a record low of 3.6 µg/dL, which corresponded to the record low number of children screened that year and the different method of testing used during the last four months.

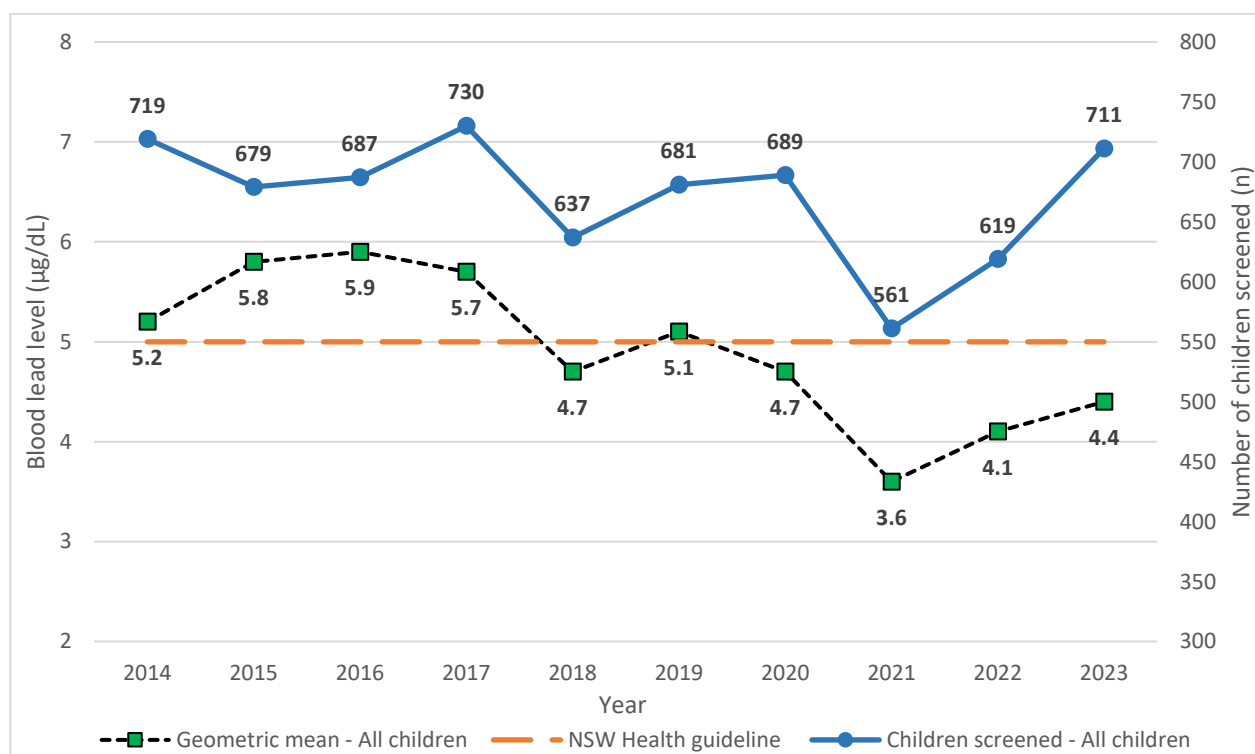


Figure 6: Annual number of Broken Hill children screened aged 1 to less than 5 years and population age-sex standardised geometric mean blood lead level compared to the NSW Health recommended guideline (<5.0 µg/dL), 2014 to 2023.

The annual age-sex standardised blood lead geometric mean for Aboriginal children aged from 1 year to less than 5 years in 2023 of 7.9 µg/dL was above the guideline. While the standardised geometric mean for this population group from 2014 to 2023 increased by 0.4 µg/dL, from 7.5 µg/dL to 7.9 µg/dL respectively, it has risen by 0.8 µg/dL from the level in the previous year, 2022 (Figure 7).

^k See Appendix 1 for Unadjusted geometric means plus 95% confidence intervals and age-sex standardised geometric means for all children aged 1 to <5years in Broken Hill, 2014-2023.

^l As with the 6 to less than 12 month age group, the lower cut-off level of the alternate testing method, used from the end of January to the end of April 2022 and then for 5 weeks during July to September 2023, may have influenced the geometric mean during these times. Although the small number of test results at the lower level during those periods would suggest that the overall effect would likely be minimal.

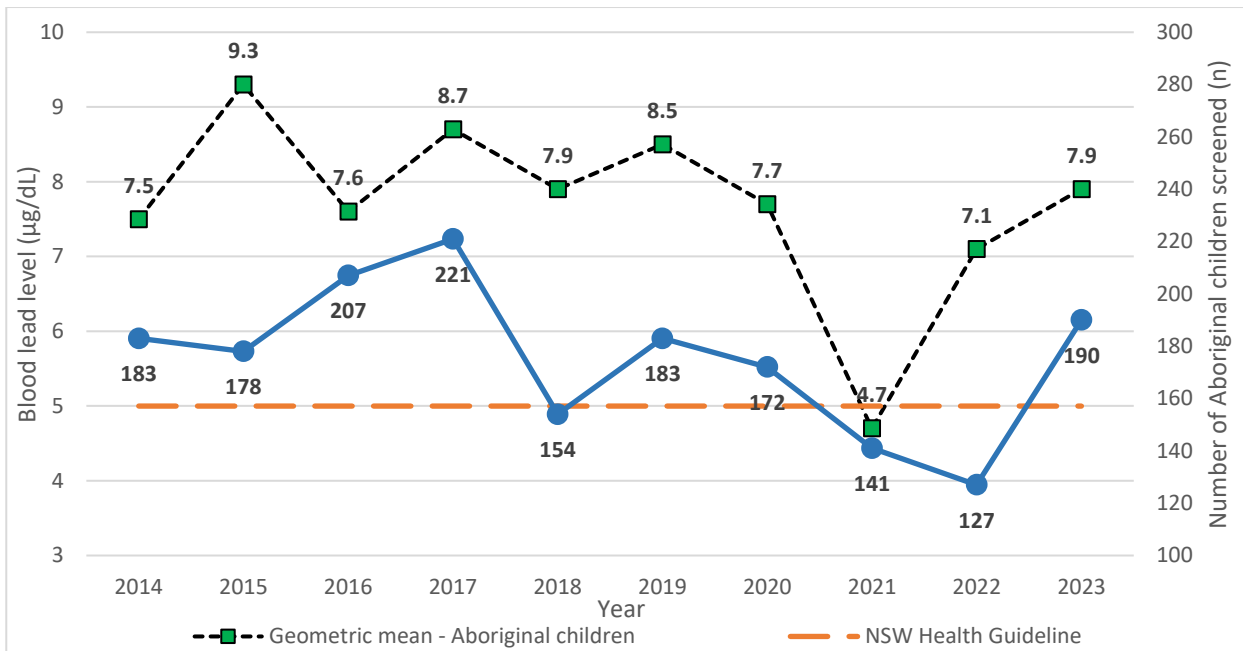


Figure 7: Annual number of Broken Hill Aboriginal children aged 1 to less than 5 years screened and the Aboriginal population age-sex standardised geometric mean blood lead level compared to the NSW Health recommended guideline (<5.0 µg/dL), 2014 to 2023.

Stratifying the 2023 population age-sex standardised geometric mean by 1 year age group demonstrates the geometric means for all age groups were below the guideline (Figure 8); highest in 2 year old children, followed by 3 then 4 years olds, and the lowest level in the 1 year olds. This pattern of geometric mean levels for these age groups has been relatively consistent since 2019, with the 2 year olds always highest.^m The geometric mean for all year groups have been below the guideline since 2018, with the exception of 2 year olds in both 2019 and 2020, and 3 and 4 year olds in 2019.

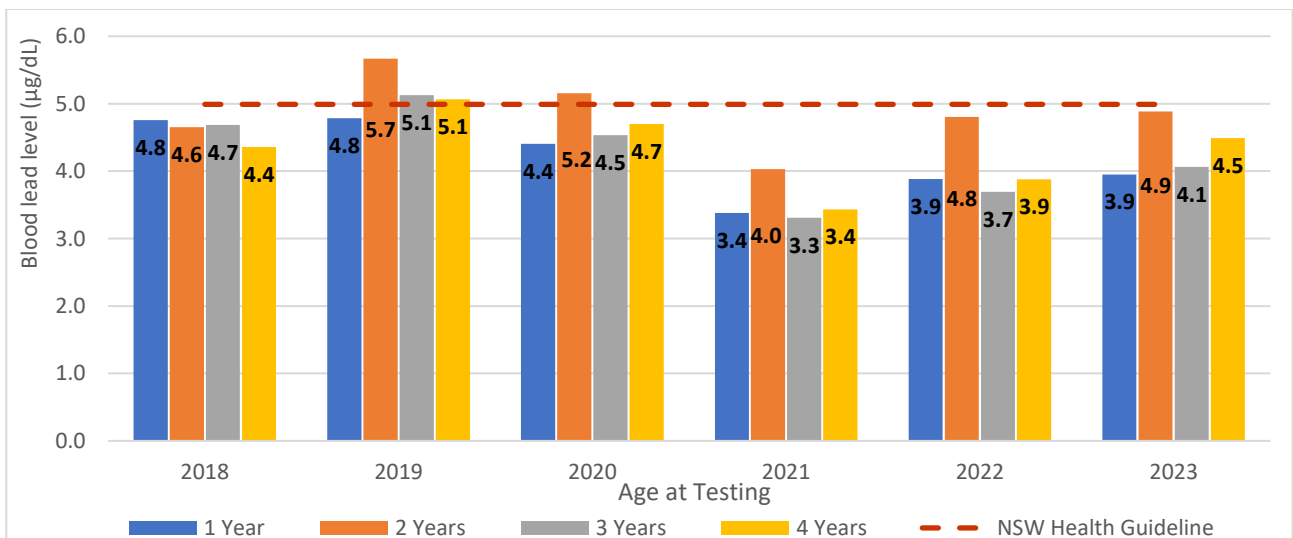


Figure 8: Annual population age-sex standardised geometric mean blood lead level for children screened aged 1 to less than 5 years, stratified by 1 year age groups and compared to the NSW Health recommended guideline (<5.0 µg/dL), 2018 to 2023.

^m The blood lead screening data for years prior to 2018 is held in an archived database and so was not available to evaluate by 1 year groups prior to 2018 and provide further information about the change in pattern between 2018 and 2019.

Elevated blood lead levels

In 2023, the age-sex standardised percentage of all children aged from 1 year to less than 5 years with BLLs above the guideline was 43%, which equates to 324 children, based on the 2021 ABS census data. The standardised percentage of Aboriginal children aged from 1 year to less than 5 years with BLLs above the guideline was 74%, which equates to 105 children. This represents an increase in the proportion of children screened with BLLs above the guideline from the previous year 2022, for both all children screened (10%) and Aboriginal children (12%).

From 2014 to 2023, the age-sex standardised percentage of all children aged 1 year to less than 5 years screened with BLLs above the guideline has decreased, from 48% to 43%, respectively. Over this 10-year reporting period, there was a marginal increase in the percentage of children with BLLs ranging from 5 to less than 10 µg/dL, from 28% to 29% respectively, but a decrease from 10 to less than 15 µg/dL, from 13% to 7% respectively (Figure 9). The percentage of children with levels of 30 µg/dL or above increased from 0% to 1% (n=7) since 2014 but had decreased from 2% (n=6) in 2022. Overall, this indicates that very high BLLs in this age group persist for a small number of children.

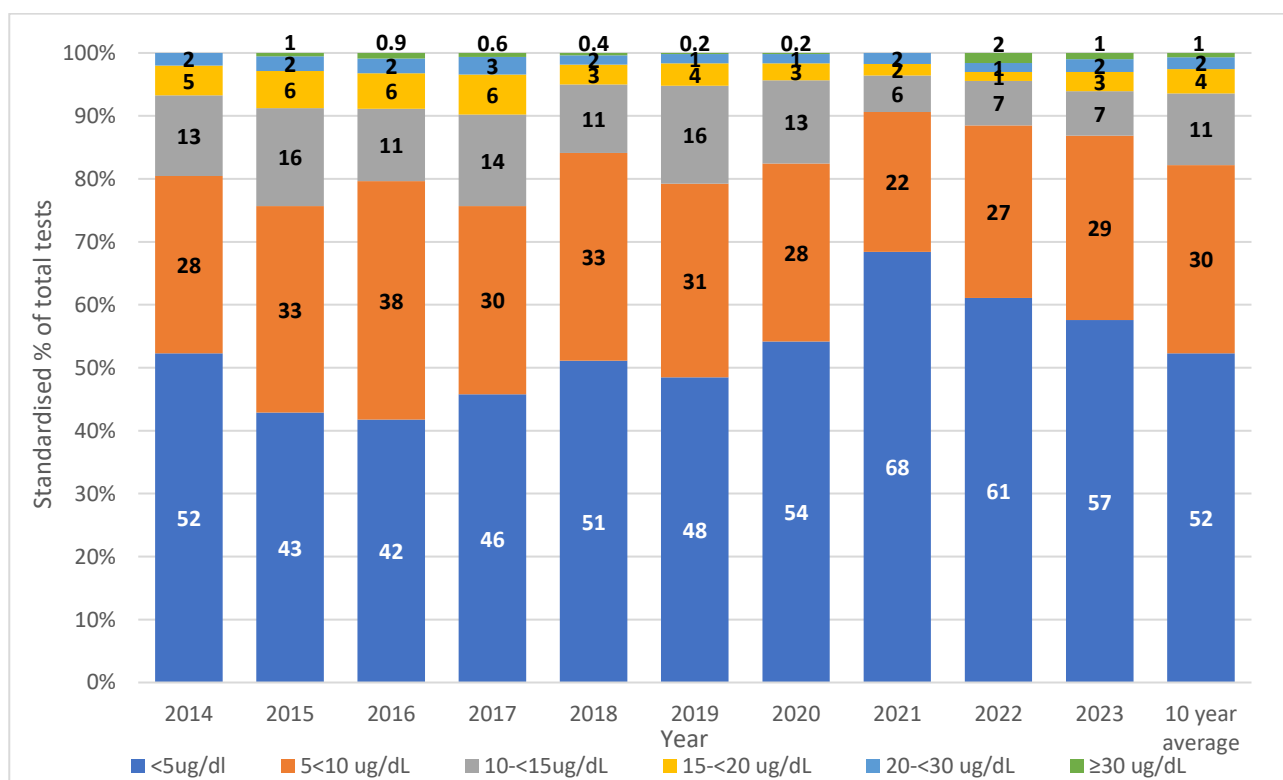


Figure 9: Blood lead levels of all children aged 1 to less than 5 year by category as a percentage of total annual tests, (age-sex standardised percentage), Broken Hill, 2014-2023. NB: totals may vary due to rounding.

Over the same reporting period (2014 to 2023), a comparison of the annual proportions of BLLs above the guideline between Aboriginal and non-Aboriginal children aged 1 years to less than 5 years evidences the disproportionality that exists between these populations (Figure 10). The 10-year average proportion of children with BLLs above the guidelines was 74% for Aboriginal children, in contrast to 37% for the non-Aboriginal children in this age group. Nonetheless, the percentage of Aboriginal children screened with BLLs above the guideline has decreased marginally, from 76% in 2014 to 74% in 2023. Over this period, the percentage of Aboriginal children with BLLs ranging from 5 to less than 10 µg/dL has increased (from 33% to 42%), but the

percentage with BLLs from 10 to less than 15 µg/dL has decreased (from 26% to 16%). Importantly, the proportion of Aboriginal children with very high BLLs, 30 µg/dL, has increased from 0% (n=0) in 2014 to 4% (n=7) in 2023, showing the persistence of the heightened level seen in 2022 (5%).

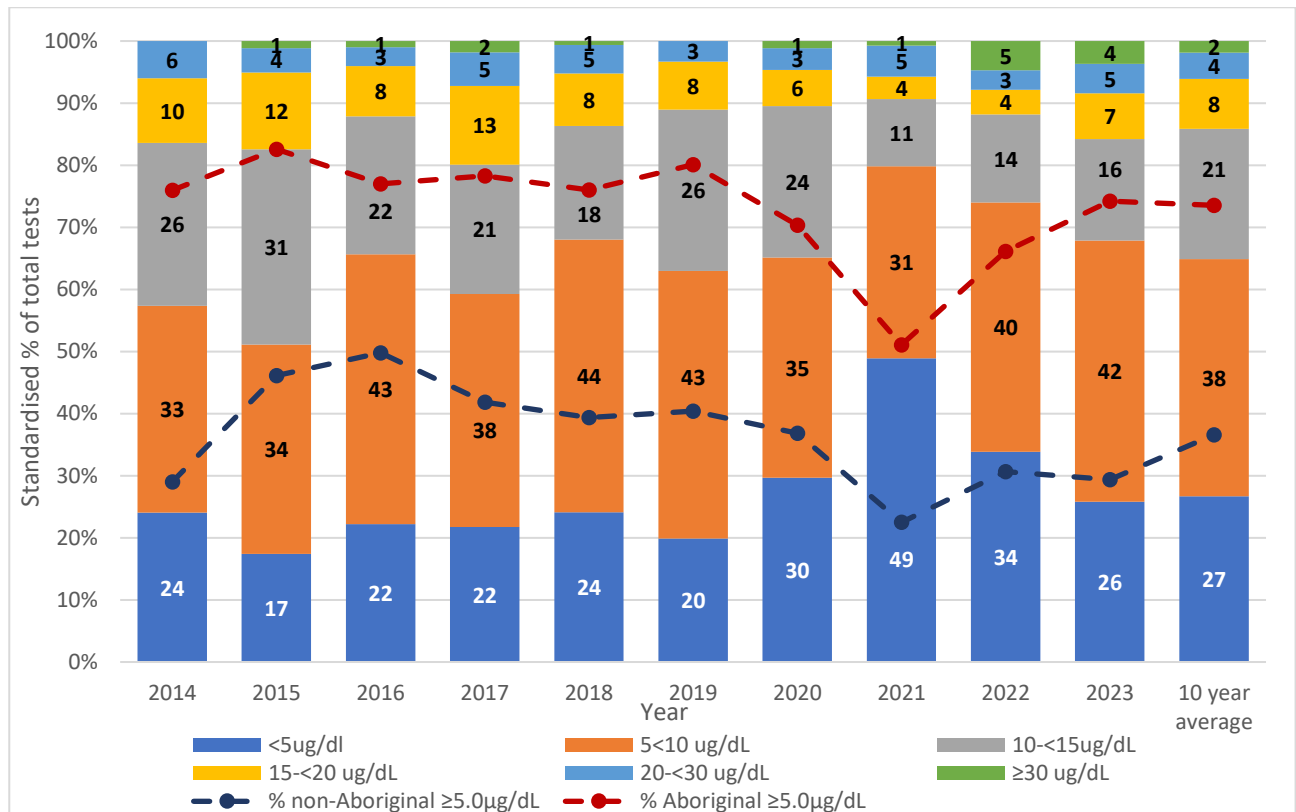


Figure 10: Blood lead levels of Aboriginal children aged 1 to less than 5 years by category as a percentage of total annual tests, with the annual proportions (%) of children testing over the NSW Health guideline (≥5.0 µg/dL) for non-Aboriginal and Aboriginal children, Broken Hill, 2014-2023. NB: totals may vary due to rounding.

In 2023, the proportion of children with levels above the guideline was 29% of non-Aboriginal children as compared with 74% of Aboriginal children (Figure 11). For all other categories where BLLs were above the guideline, the proportions for Aboriginal children were greater than those for non-Aboriginal children. In particular, 9% of Aboriginal children (n= 16 children) were found to have high or very high BLLs (≥20 µg/dL) compared to less than 1% of non-Aboriginal children (n= 1 child).

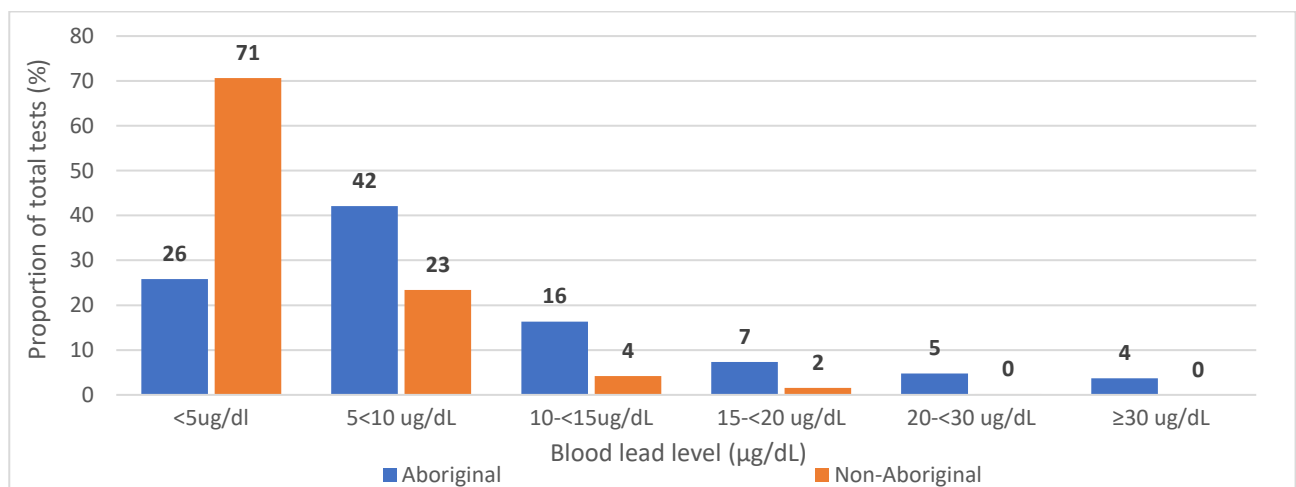


Figure 11: Comparison of Aboriginal versus non-Aboriginal children aged 1 to less than 5 years, stratified by blood lead category percentage, 2023.

Stratifying the 2023 age-sex standardised percentages of all children aged 1 year to less than 5 years by 1 year age groups reveals that the 2 year olds have the highest proportion (50%) of children screened with BLLs above the recommended guideline of <5 µg/dL (Figure 12). This is consistent with the higher geometric mean recorded for this year group in 2023 (Figure 8). The proportion of children with high (20-<30 µg/dL) or very high BLLs (30 µg/dL) was highest in 2 year old age group (n=5), although 3 year olds had the highest proportion of children with very high levels (n=3).

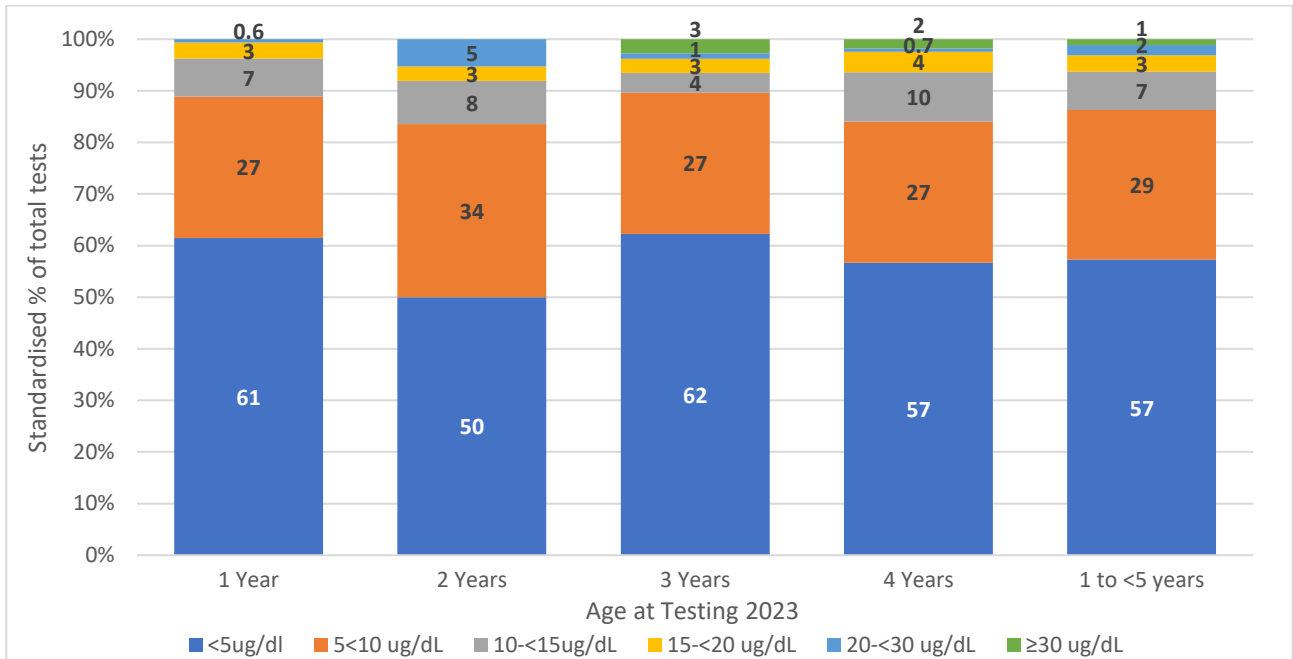


Figure 12: Blood lead levels by category as a percentage of total tests (age-sex standardised percentage) and by 1 year age group for children aged 1 to less than 5 years in Broken Hill, 2023. NB: totals may vary due to rounding.

Looking at the age-sex standardised percentage of children aged 1 year to less than 5 years, screened annually from 2018-2023 and with high BLLs (20 µg/dL and above), it can be seen that 2 years olds have consistently had the highest proportion of children with BLLs (Figure 13), with the exception of 2021 where this was marginally higher in 3 year olds. As identified earlier, Aboriginal children are overrepresented in these proportions of children with high BLLs.

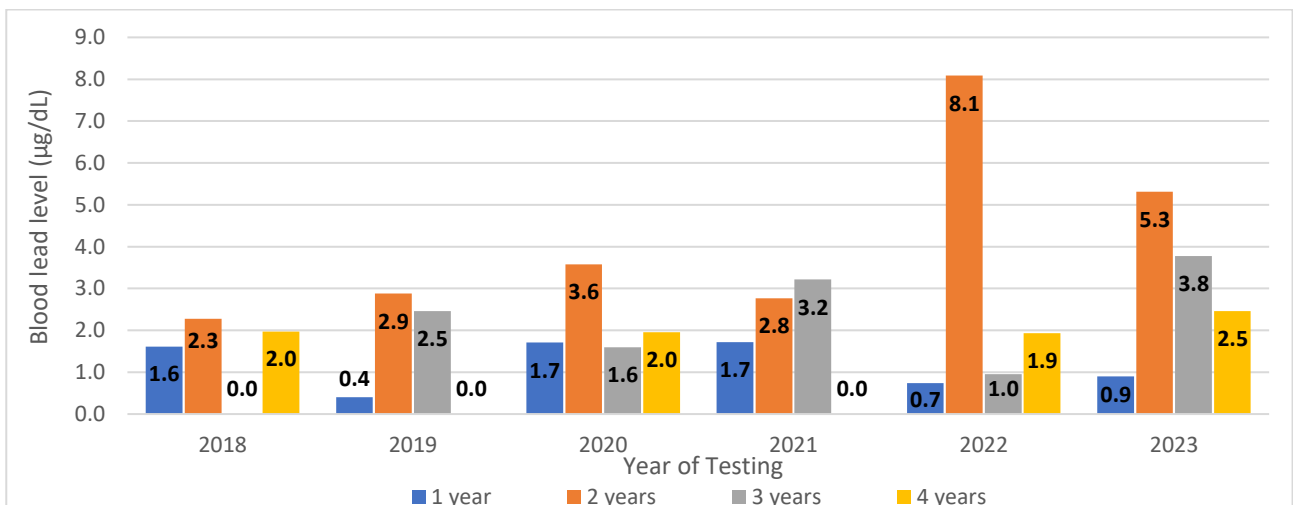


Figure 13: Blood lead levels of 20 µg/dL and above as a percentage of total annual tests (age-sex standardised percentage) and stratified by 1 year age group for children aged 1 to less than 5 years in Broken Hill, 2018-2023. NB: totals may vary due to rounding.

Seasonal trends in blood lead levels of all children aged 1 to < 5 years, 2023

A study by Liu et al, 2021¹⁴ of BLLs in Broken Hill children aged under 5 years from 1991 to 2015 found that higher BLLs were associated with the warmer months (October to March) and lower BLLs in the colder months (April to September). Unlike the year before, this seasonal association was more apparent in 2023, with BLL geometric means for children aged 1 year to less than 5 years highest in the first (January to March) and fourth (October to December) quarters, i.e. 5.1 µg/dL and 4.6 µg/dL respectively, as compared to the second (April to June) and third (July to September) quarters, i.e. 3.4 µg/dL and 3.8 µg/dL respectively. For the 10-year average of the monthly geometric means, the higher geometric means generally tended to occur during the first quarter of the year followed by the fourth quarter, which includes the warmer months of the year (Figure 14). December is the exception to this, as both testing numbers and geometric means are consistently lower in this month.

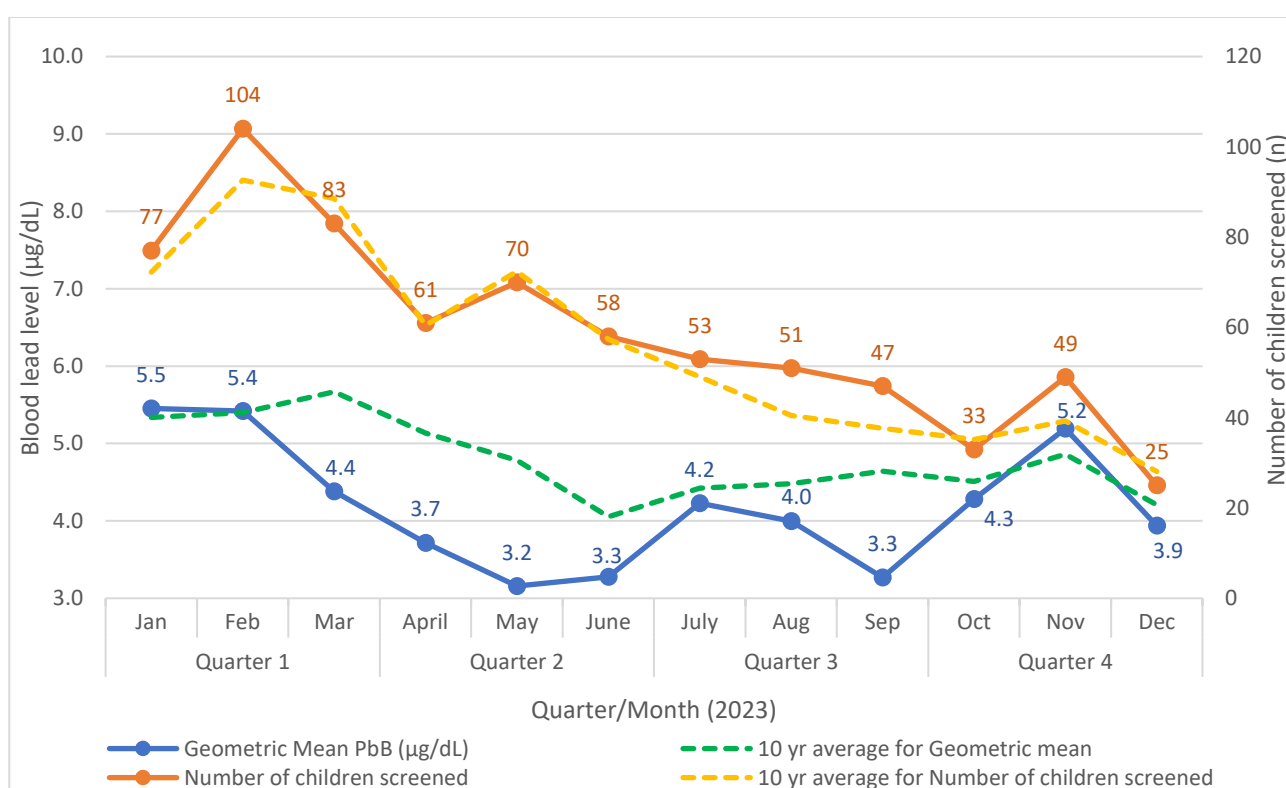


Figure 14: Monthly geometric mean blood lead level comparison of first visit blood lead levels for Broken Hill children aged between 1 to less than 5 years of age, 2023.

In 2023, quarters with the highest rainfall were the second quarter (24.7 millimeters) followed by the first quarter (12.9 millimeters), but these did not correlate to the quarters with similar geometric means. The annual rainfall for 2023 (156.8 millimeters) was around half that of the average for 1952-2023 (249.6 millimeters), and a quarter of that from the previous year 2022, which had the highest rainfall on record (558.8 millimeters).¹⁵ Comparing annual geometric means with annual rainfalls for Broken Hill over the past 10 years gave no clear indication of an association between lower BLLs and high rainfall (Figure 15).

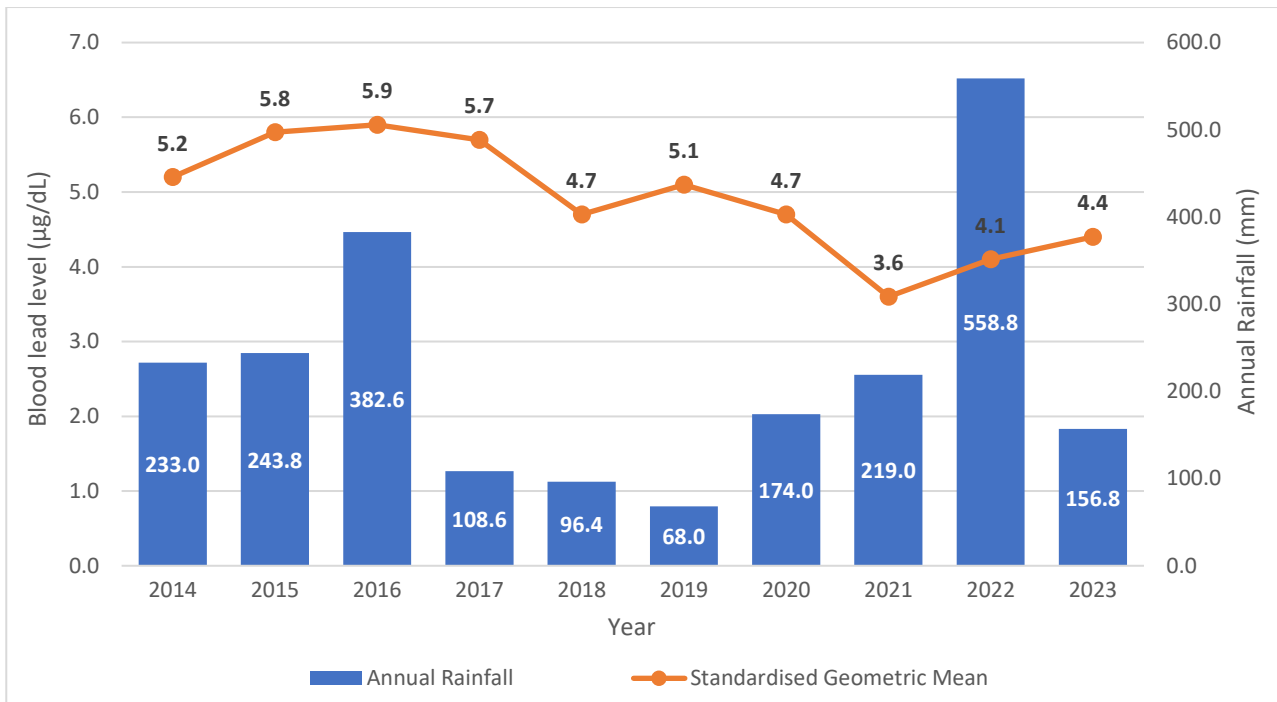


Figure 15: Annual standardised geometric mean of first visit blood lead levels for Broken Hill children aged between 1 to less than 5 years of age, and annual Broken Hill rainfall for 2014-2023.

In 2023, the highest numbers of first tests occurred in the first (n=264) and second (n=189) quarters of the year, which is consistent with findings for previous years. However, there was no obvious association between high testing numbers and higher geometric means (Figure 14).

Conclusion

In 2023, the Broken Hill Lead Program saw a minimal decrease in the number of children screened across two of the three developmental groups, as compared to that seen in 2022. The number of newborns screened fell minimally in 2023, as did the number of children screened aged 6 months to less than 12 months. The proportion of newborns screened from the Broken Hill's residents live births has seen a small increase since 2016 but the fluctuation in this proportion over that time makes an overall trend more difficult to discern. Similarly for the number of children screened aged 6 months to less than 12 months since 2018, the fluctuating screening numbers are not indicative of an overall trend for this period. In contrast, the number of children screened for the aged 1 to less than 5 years age group saw further improvement from the 2022 increase, with the highest participation rate for the past 5 years. Looking at this by 1 year breakdown, this increase in participation was seen in all age groups except the 3 year olds, although screening rates are lowest for the 2 and 3 year olds.

Analyses of geometric means across the developmental groups confirm that for newborns the geometric mean continues to be low, with no difference seen between Aboriginal and non-Aboriginal newborns. This measure acts as a proxy baseline for children as they grow and develop, but with their increased interaction with the environment, when rolling, crawling and grabbing at objects, the geometric mean begins to rise. For children aged 6 months to less than 12 months the geometric mean remains within the guideline, for both Aboriginal and non-Aboriginal children alike. However, the geometric mean for Aboriginal children was higher. As children transition into

the toddler stage (1 year and older), they develop greater autonomy, allowing them more freedom to roam and explore their surroundings. This increases children's exposure to lead and is when their BLLs can rise close to or above the guideline. The 10-year trend for children aged 1 year to less than 5 years has seen the overall geometric mean for this age group fall from above the guideline to below the guideline, although for Aboriginal children it remains above. In 2023, the geometric mean for children aged 1 to less than 5 years old remained below the guideline, with the 2 year old age group found to have both the highest age-group specific geometric mean and proportion of children with high BLLs.

The numbers of Aboriginal children aged 1 year to less than 5 years being screened for BLL increased during 2023, after the decline of previous years. However, the annual geometric means for this population, except in 2021, have remained above the guideline, and the higher proportion of Aboriginal children with high or very high blood levels persists.

Appendix 1: Unadjusted geometric means, with 95% CI

Table 4: Broken Hill children aged 1 year to less than 5 years. Unadjusted annual geometric means with 95% confidence intervals and age-sex standardized geometric means (std GM), 2014-2023.

Year	Children tested	Unadjusted geomean	95 CI+	95 CI -	age-sex std GM
2014	719	5.1	5.53	4.87	5.2
2015	679	5.7	6.16	5.44	5.8
2016	687	5.8	6.31	5.49	5.9
2017	730	5.5	6.09	5.31	5.7
2018	637	4.6	5.08	4.32	4.7
2019	681	5.1	5.45	4.75	5.1
2020	689	4.7	5.04	4.36	4.7
2021	561	3.5	3.82	3.16	3.6
2022	619	3.9	4.39	3.44	4.1
2023	711	4.2	4.66	3.78	4.4

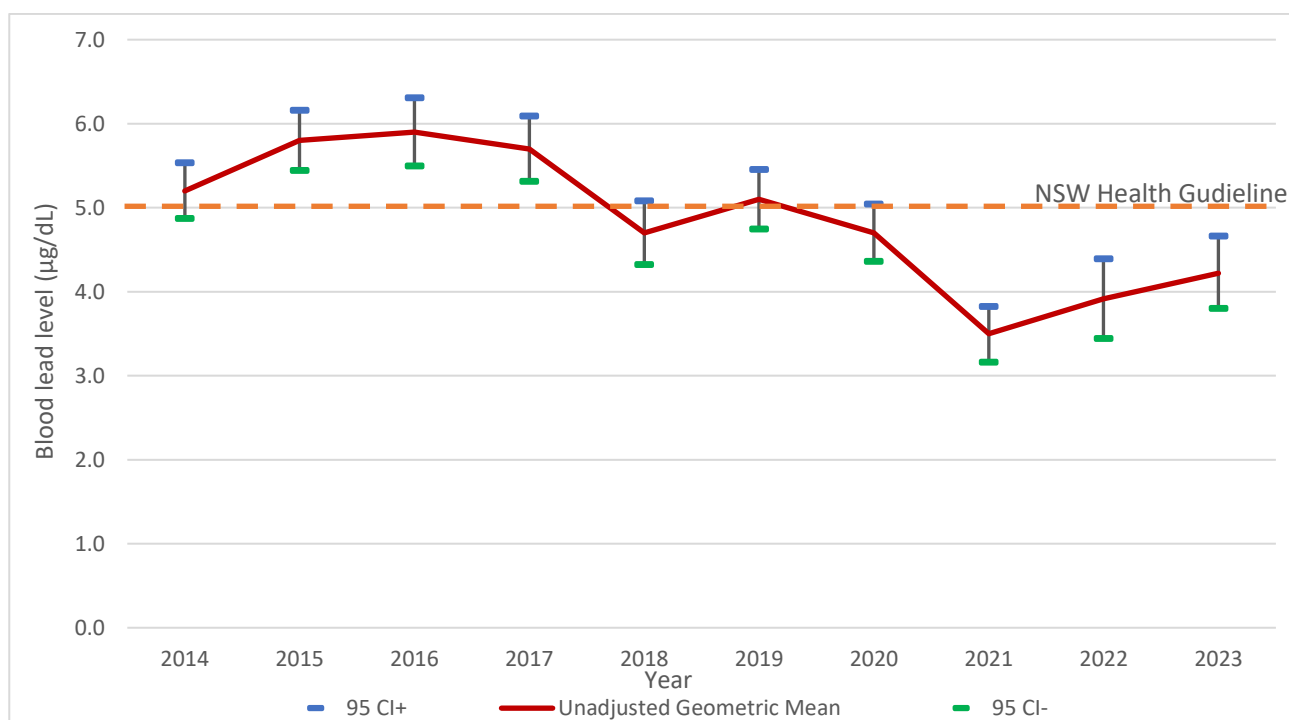


Figure 16: Children aged 1- less than 5 years, unadjusted annual geometric means with 95% confidence intervals, 2014-2023, and NSW Health guideline (<5µg/dL).

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