

Lead Health Report 2015

– Children less than 5 years old in Broken Hill –



This work is copyright. It may be reproduced in whole or part for study or training purposes subject to the inclusion of an acknowledgement of the source. It may not be reproduced for commercial usage or sale. Reproduction for purposes other than those indicated above requires written permission from the NSW Ministry of Health.

© NSW Ministry of Health 2016

Contact

For further information please contact:

Population Health Unit

Western NSW & Far West Local Health Districts

Centre for Remote Health Research, University of Sydney

Corrindah Court, Morgan St

PO Box 457

Broken Hill NSW 2880

Phone: 08 8080 1278

Fax: 08 8080 1258

Date: March 2016

AUTHORS

Margaret Lesjak

Thérèse Jones

AFFILIATIONS

Population Health, Western NSW & Far West Local Health Districts

Child and Family Health Service, Broken Hill

University Department of Rural Health, University of Sydney

SUGGESTED CITATION

Population Health Unit, Western NSW & Far West Local Health District. *Lead Health Report – children less than 5 years old in Broken Hill*. Broken Hill, 2016.

EXECUTIVE SUMMARY

- This annual report provides an update on the ongoing issue of elevated blood lead levels in Broken Hill children with an epidemiological focus. The data deliver a near real-time review, measuring the impact of ongoing environmental and health service focused strategies, as well as public health actions aiming for all children in Broken Hill to maintain blood lead levels at or below 5µg/dL, the new National Health and Medical Research Council (NHMRC) level for investigation.
- All children 1-4 years residing in Broken Hill have been offered blood lead testing since 1991. This testing is voluntary and offered by the Broken Hill Child and Family Health Centre Service and Maari Ma Primary Health Care Service.
- From 2011 several strategies have been implemented to improve the participation rates for voluntary blood lead level screening including:
 - alignment of lead testing with childhood immunisation clinics;
 - introduction of mobile text message (SMS) reminders to reduce 'did not attend rates';
 - development of partnerships to improve initial testing and case management of children with high blood lead levels and;
 - restarting promotion of lead screening through pre-schools visits and community events with the Lead Ted Junior mascot.

The significant outcomes for 2015 are:

- There were 679 children (178 Aboriginal and 501 non-Aboriginal) tested, 40 children fewer than in 2014.
- The population age-sex standardized geometric mean blood lead level was 5.8µg/dL, a slight increase from 2014 but similar to the 2013 mean.
- The Aboriginal age-sex standardized population geometric mean blood lead level was 9.3µg/dL, an increase from previous years.
- Of 177 babies' cord bloods tested, the geometric mean was 1.1µg/dL.
- The proportion of all children, Aboriginal and non-Aboriginal children with blood lead levels above the current NHMRC benchmark of ≤5µg/dL was 47%, 79% and 35% respectively.
- The proportion of all children, Aboriginal and non-Aboriginal children with blood lead levels above the then NSW Health notifiable level of ≥10µg/dL was 24%, 49% and 14% respectively. The current notifiable level has changed to 5µg/dL from February 2016.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	3
INTRODUCTION	5
DEMOGRAPHIC DATA AND PARTICIPATION RATES IN BROKEN HILL	7
SCREENING OF NEWBORNS.....	8
SCREENING OF CHILDREN AGED 1 TO 4 YEARS	9
SCREENING OF ABORIGINAL CHILDREN AGED 1 TO 4 YEARS	15
CONCLUSION.....	20
APPENDIX 1 HIGH RISK BIRTHING CRITERIA.....	21
BIBLIOGRAPHY	22

INTRODUCTION

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

A serological survey of school-aged children in 1982, found that all had blood lead levels below 40µg/dL, the then level of concern in Australia.¹ A survey of 1-4 year-old Broken Hill children in 1991 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.²

Since 1991, all 1-4 year old children in Broken Hill have been offered voluntary blood lead screening. The combination of a reminder letter, linking lead testing to attendance for immunisations, promotions and advertising in the local media is used to encourage attendance at the lead screening clinic for at least one blood lead test each year. Population-based blood lead screening is used to measure the impact of lead in childhood development and to orientate the delivery of health services and guide research questions to achieve the goal of all children in Broken Hill recording and maintaining a blood lead level within current health guidelines. In 1993 the National Health and Medical Research Council (NHMRC) set a goal for all Australians to have a blood lead level of less than 10µg/dL.

In 1994, the NSW State Government funded a lead management program to address high blood lead levels in Broken Hill children.³ Activities included an active research and evaluation project coupled with extensive land remediation work which began in 1997, with final works completed in 2003 and 2004. In addition this funding allocation included health promotion campaigns, active case finding and management, remediation of land, planting of hardy native shrubs and grasses and urban development of vacant blocks and cemented footpaths.⁴

The effort of the Broken Hill community and the NSW Government resulted in a major reduction of blood lead levels among young children during the 1990s. At the same time as blood lead levels dropped so was attendance at screening with the lowest numbers in 2008-2010. This was recognised as more than just a reflection of the decreasing population⁵⁻⁷.

¹ 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.

² 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.

³ 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

⁴ 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

⁵ Kardamanidis K, Lyle DM, Boreland F. Addressing decreasing blood lead screening rates in young children in Broken Hill, NSW. *NSW Public Health Bulletin* 2008; 19(9-10):180-182

⁶ Boreland F, Lyle D. Using performance indicators to monitor attendance at the Broken Hill blood lead screening clinic. *Environmental Research* 2009; 109:267-272

⁷ Thomas S, Lyle D, Boreland F. Improving access to and outcomes of blood lead screening for Aboriginal children in Broken Hill NSW *NSW Public Health Bulletin* 2012; 23(11-12):234-238

From July 2006 the management of lead has been integrated with the Broken Hill Child and Family Health Centre. At the time of the integration, several public health activities were recommended to minimise the impact of lead in Broken Hill children including:

- cord blood analysis offered for all babies born to women who reside in Broken Hill;
- blood lead level surveillance for children under 5 years;
- case management of children with lead levels above the recommended levels;
- educational and health promotion activities for families in the Broken Hill community.

The Broken Hill Community Reference Group, founded in 2008, is led by the Broken Hill City Council and consists of community interest groups, mining companies and government agencies representing and advocating for the Broken Hill community regarding lead as a community issue. The Broken Hill Lead Steering Committee, also founded in 2008, 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.

Since October 2008 parents have had the option of having their child(ren) screened with the less invasive capillary sampling (fingerprick) method. A child's first test in a calendar year has always been used for the blood lead analysis for the annual report. If a child has both a fingerprick and venous test the venous test is used.

From 2011 additional strategies successfully introduced to further improve the health outcomes of children in Broken Hill, included:

- alignment of lead testing with the childhood immunisation clinics;
- introduction of SMS reminders to reduce 'did not attend' rates;
- development of a collaborative partnership with Maari Ma Health Aboriginal Corporation, an Aboriginal community controlled health service, where the Healthy Start team tests blood lead levels in children and provides follow-up care and case management of children with high lead levels.
- promotion of lead screening through pre-schools visits and community events with the Lead Ted Junior mascot.

Since 1993 blood lead levels aimed to be less than 10µg/dL, however, in May 2015, the NHMRC issued the following statement: "a blood lead level greater than 5 micrograms per decilitre suggests that a person has been, or continues to be, exposed to lead at a level that is above what is considered the average 'background' exposure in Australia" (Evidence on the Effects of Lead on Human Health⁸). Five µg/dL has been used as the benchmark level for this report to enable insight into the extent of lead as an issue for children in Broken Hill, though ≥10µg/dL was the NSW Health notifiable blood lead level during 2015.

From July 2015, following significant planning and advocacy and working with a number of Ministers, the NSW Government funded the Broken Hill Environmental Health Program (BHELP) with \$13 million allocated to lead abatement over 5 years. Five people have been recruited to the BHELP program. under the auspices of the Environmental Protection Agency.(EPA). The steering committee is made up of representatives from EPA, Far West LHD and Broken Hill Lead Reference Group.

⁸NHMRC: Evidence on the Effects of Lead on Human Health ref # EH58 May 2015
http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/eh58_nhmrc_statement_lead_effects_human_health_a.pdf

Notable outcomes for 2015 have been:

- There were 679 children (178 Aboriginal and 501 non-Aboriginal) tested, 40 children fewer than in 2014.
- The population age-sex standardized blood lead level mean was 5.8µg/dL, a small increase from 2014 (5.2µg/dL) but similar to the 2013 mean.
- The Aboriginal age-sex standardized population blood lead level mean was 9.3µg/dL, an increase from previous years.
- Of 177 babies' cord bloods tested, the geometric mean was 1.1µg/dL.

Future challenges for managing blood lead levels in Broken Hill children that are above the guidelines include:

- meeting the lower NHMRC recommended threshold of blood lead levels in children, particularly for Aboriginal children;
- maintaining long term momentum in the community to support childhood screening in the first five years of life once the NSW government funded Broken Hill Environmental Lead Program finishes in 2020; and
- ensuring the community continues to engage in lead action activities.

DEMOGRAPHIC DATA AND PARTICIPATION RATES IN BROKEN HILL

Over the course of each census (1991-2011) there has been a decrease in the overall number of children under the age of 5 years residing in the Broken Hill Local Government Area (**Table 1**). Census data were used as the denominator for the analysis to measure the impact of the voluntary blood lead screening program. The next census is in 2016 with data available in 2017.

To measure any potential differences within the population, a separate analysis is undertaken to monitor any inequitable burden of high lead levels that might be evident in Aboriginal children. Denominator data on Aboriginality are sourced from the census and are based on self-identification. The number and proportion of Aboriginal identified children has increased from 1996 to 2011 (**Table 1**).

In 2015 the participation rate for all children aged 1-4 was 77% and for Aboriginal children was 122%. Since 2012 there has been an over 100% participation rate for Aboriginal children in the Broken Hill blood lead level screening program. This may be due to the under reporting of self-identified Aboriginal status during census collection or perhaps indicative of migration of families with Aboriginal children to the Broken Hill Local Government Area.

The number of children screened has increased significantly over the last few years. Increasing the proportion of children tested will improve the accuracy of the population estimate for mean blood lead levels among Broken Hill children.

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

Age in years	1996		2001		2006		2011	
	All	Aboriginal	All	Aboriginal	All	Aboriginal	All	Aboriginal
0-4	1427	112(8%)	1255	165(13%)	1191	177(15%)	1070	176(16%)

Source: ABS Census data.

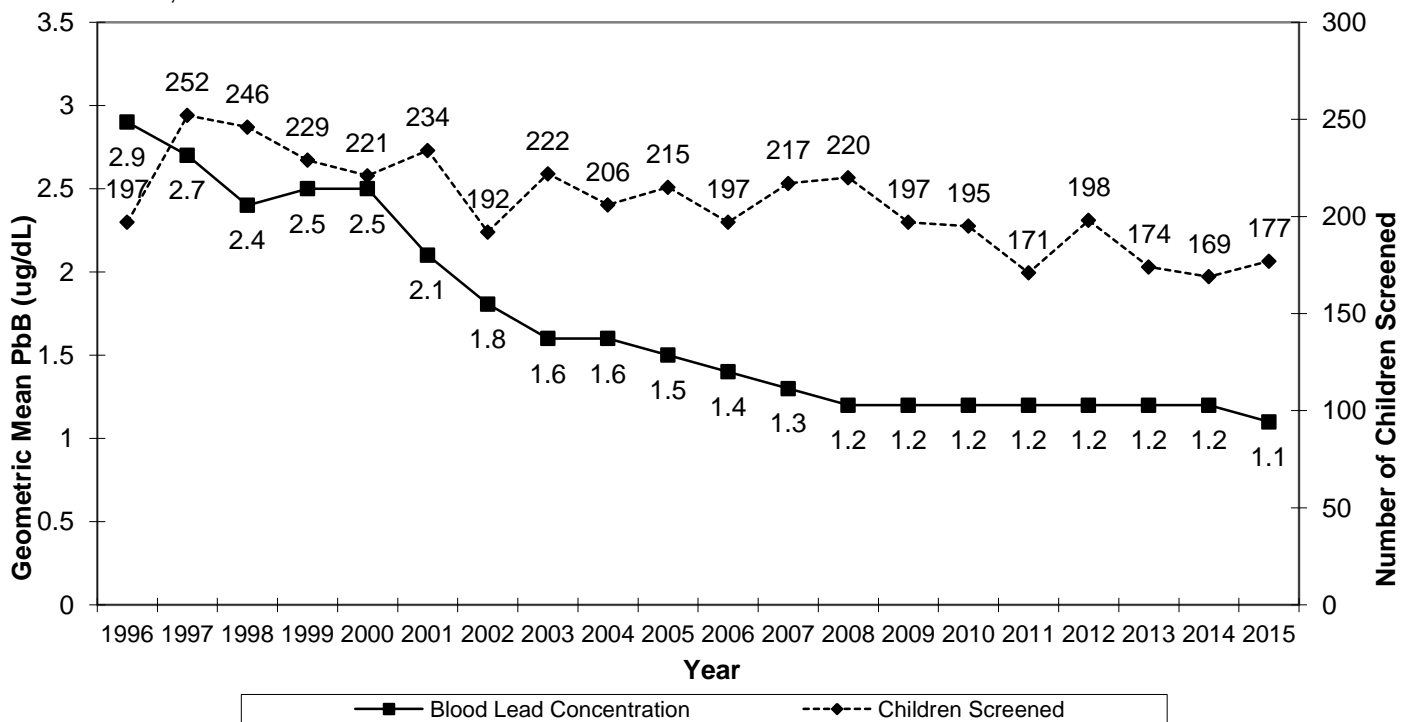
SCREENING OF NEWBORNS

The introduction of newborn screening assists in determining the impact of lead transfusion from the mother to the unborn child. To test the lead levels in newborns, a sample of venous blood from the umbilical cord is used. Screening of cord blood samples commenced in 1996; the aims being to determine blood lead levels in children at birth and to identify those exceeding the guidelines. Cord blood lead levels have been falling from 2.9µg/dL in 1996, levelling out from 2008 at 1.2µg/dL and in 2015 decreasing further to 1.1µg/dL. In 2015, 187 babies were born at Broken Hill Hospital to Broken Hill mothers, with 95% having their cord blood tested. As for all children under 5 years of age, there has been a decline in newborns in Broken Hill. In addition, for mothers to give birth at Broken Hill hospital in recent years they must be considered low risk (**Appendix 1**). If they do not meet the criteria for a low risk birth they are referred to Flinders Medical Centre or Women’s and Children’s Hospital, Adelaide. Approximately 1-2 women each month birth elsewhere either because they are referred due to being high risk or they have chosen to birth at another hospital. This affects the number of cord bloods tested.

Cord bloods are tested in the same way as a venous sample, with a minimum reading possible of 1µg/dL (**Figure 1**). The geometric mean is used because blood lead values are clustered at one end of the range with most being under 10µg/dL. The arithmetic mean is not appropriate to use in this situation because it is only accurate when values are spread evenly along the range or clustered in the middle.

Umbilical Cord Blood Screening in Broken Hill 1996-2015

Figure 1. Geometric mean blood lead concentration and number of resident newborns screened at Broken Hill Health Service, 1996-2015.



⁹CDC. Fourth national report on human exposure to environmental chemicals. Updated tables, September 2013. Atlanta, GA: US Department of Health and Human Services, CDC; 2012. Available at http://www.cdc.gov/exposurereport/pdf/fourthreport_updatedtables_sep2013.pdf

SCREENING OF CHILDREN AGED 1 TO 4 YEARS

A child's first test in a calendar year is used for the following analyses. If a child has both a fingerprick and venous test, only the results of the venous test are used. Over the duration of the voluntary blood lead screening program there has been a trend of decreasing average blood lead levels in children aged 1-4 years since 1991, from a high of 16.7µg/dL in 1991 to an adjusted mean of 5.8µg/dL in 2015 (**Figure 2**). This small increase from 5.2µg/dL in 2014 mirrors the rise in both non Aboriginal (from 4.4µg/dL to 4.9µg/dL) and Aboriginal (from 8.0µg/dL to 9.3µg/dL) children's adjusted means. The results for Aboriginal children are discussed separately but presented with all children's results in **Figure 2** for ease of comparison.

The number of all children tested peaked in 1994, with 948 children screened, as a result of a major, labour-intensive doorknocking campaign in 1994 to raise awareness in the wider community. In 1998, four years after the commencement of environmental and health promotion initiatives, a second peak was observed where 814 children were tested. There was no apparent specific intervention responsible for this second peak. From 1998 there had been a progressive decline in the number of children voluntarily undertaking blood lead screening. From 2011 this falling participation rate was reversed with the inclusion of blood lead screening with routine immunisation at the Broken Hill Child and Family Health Centre and expansion of testing at Maari Ma Primary Health Care service. In 2015 a total of 679 children had at least one test, 40 fewer than 2014. Each census since 1991 has counted fewer children aged 1-4 years living in Broken Hill. Data collected in the 2016 census will be available in 2017. Anecdotally blood lead testing has increased at GP practices although blood lead results for 2015 did not need to be reported to the Child and Family Health Centre; or notified to the Public Health Unit when <10µg/dL.

Because children's blood lead levels vary by age and sex, 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. Usually that proportion changes a little each year. Therefore age-sex standardisation is used to account for this change and calculates what the blood lead level would be if all children in Broken Hill were tested using the proportion of children in each age-sex group from the most recent census. This age-sex adjusted population mean is the one reported over time for children aged 1-4 years.

In May 2015, the NHMRC issued the following statement:

"a blood lead level greater than 5 micrograms per decilitre suggests that a person has been, or continues to be, exposed to lead at a level that is above what is considered the average 'background' exposure in Australia" (*Evidence on the Effects of Lead on Human Health*).

The proportion of children with blood lead levels ≤5µg/dL has risen from 24% in 2000 to 53% in 2015 (**Figure 3**). At the same time the population mean has fallen from 8.4µg/dL to fluctuate since 2005 between 5-6µg/dL. Fluctuations in the geometric mean in part reflect the proportion under 5µg/dL as well as the number of children tested (i.e. the greater the proportion of children under 5µg/dL the lower the geometric mean).

While the NHMRC changed their benchmark in 2015, the notifiable blood lead level to NSW Health for 2015 was 10µg/dL or more. The change to 5µg/dL was implemented in February 2016. The proportion of all children with a blood lead level ≥10µg/dL in 2015 was 24%.

Blood lead levels in all children and children identifying as Aboriginal aged 1 – 4 years in Broken Hill, 1991-2015

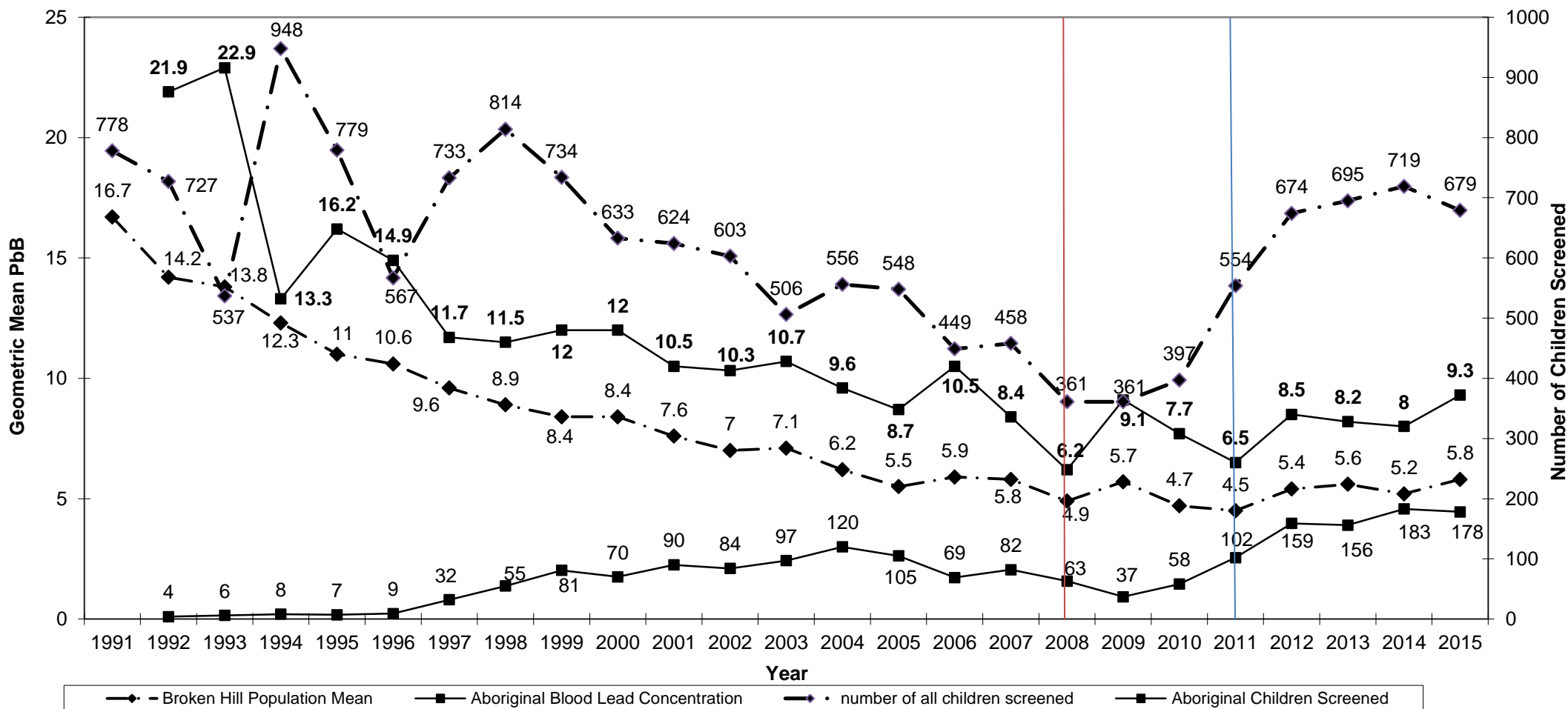


Figure 2. Population age-sex standardised geometric mean blood lead concentration and number of all children and Aboriginal* children screened aged between 1-4 years in Broken Hill, 1991-2015. The red line indicates the point in which both venous and capillary samples are reported together and the blue 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.

Percentage of children aged 1 – 4 years in Broken Hill by category of blood lead level and geomean by year

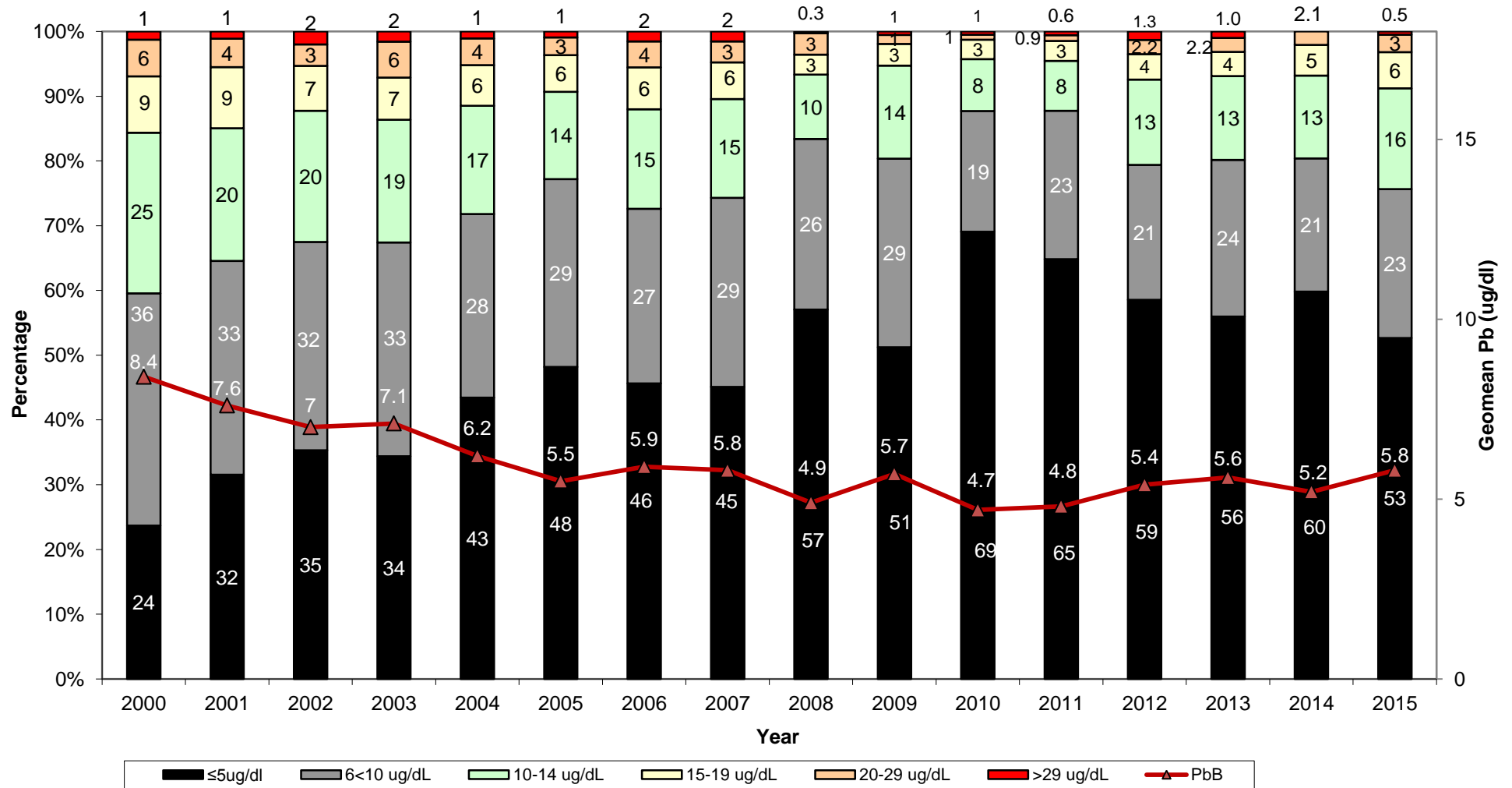


Figure 3. Population age sex standardised percentage of Broken Hill children in each blood lead category including ≤5ug/dl, aged between 1 and 4 years, and population age sex standardised age-sex geometric mean (geomean), 2000-2015.

Aligning blood lead screening with immunisation has resulted in more children aged 1 to less than 3 years being screened for lead. Capturing more children for screening is important as children aged 1-3 years are considered particularly at risk of increasing blood lead levels as they start to crawl and become more mobile with increasing hand to mouth activity.

While the overall number of children screened has decreased from the peak in 1994, it is apparent that previous interventions and strategies have been successful in reducing blood lead levels and the number of children with blood lead levels $\leq 5\mu\text{g/dL}$ has increased from 2000. In 2015, however, the number of children has fallen in this category (**Figure 4**) and the number of children in the 6-<10 $\mu\text{g/dL}$, 10-14 $\mu\text{g/dL}$ and 15-19 $\mu\text{g/dL}$ categories increased compared to 2012-2014. There are no apparent explanations for these increases and on a population basis (**Figure 3**) the proportional increases are small. Note that the data in Figure 3 are population age-sex standardised percentages and the data in Figure 4 are raw numbers. Consequently, there will be minor discrepancies between the two results due to rounding of the numbers to determine percentages.

Blood lead levels and the number of children tested are both higher in the first half of the year (**Figure 5**). Children presenting for testing also drops over the winter months. As the immunisation schedule occurs at 12 months, 18 months, 2 years and 4 years of age, a child may present at 12 months and 18 months or 18 months and 2 years 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. This also explains the success in capturing those aged between 12 months and less than 3 years.

Number of children aged 1 – 4 years in Broken Hill by category of blood lead level by year

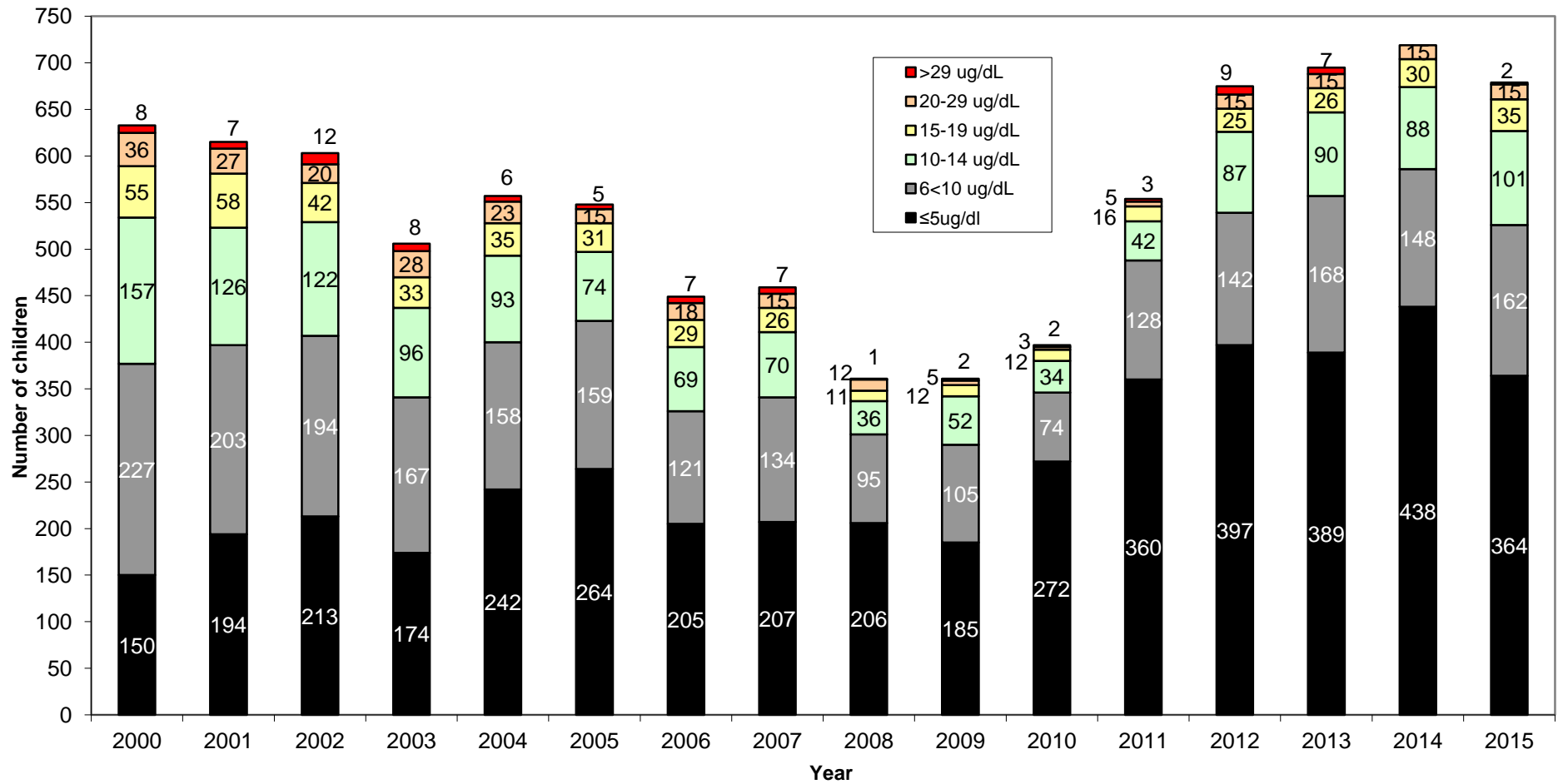


Figure 4. Count of all tested Broken Hill children in each blood lead category, aged between 1 and 4 years, 2000-2015.

Monthly mean blood lead levels of children aged 1 – 4 years in 2015

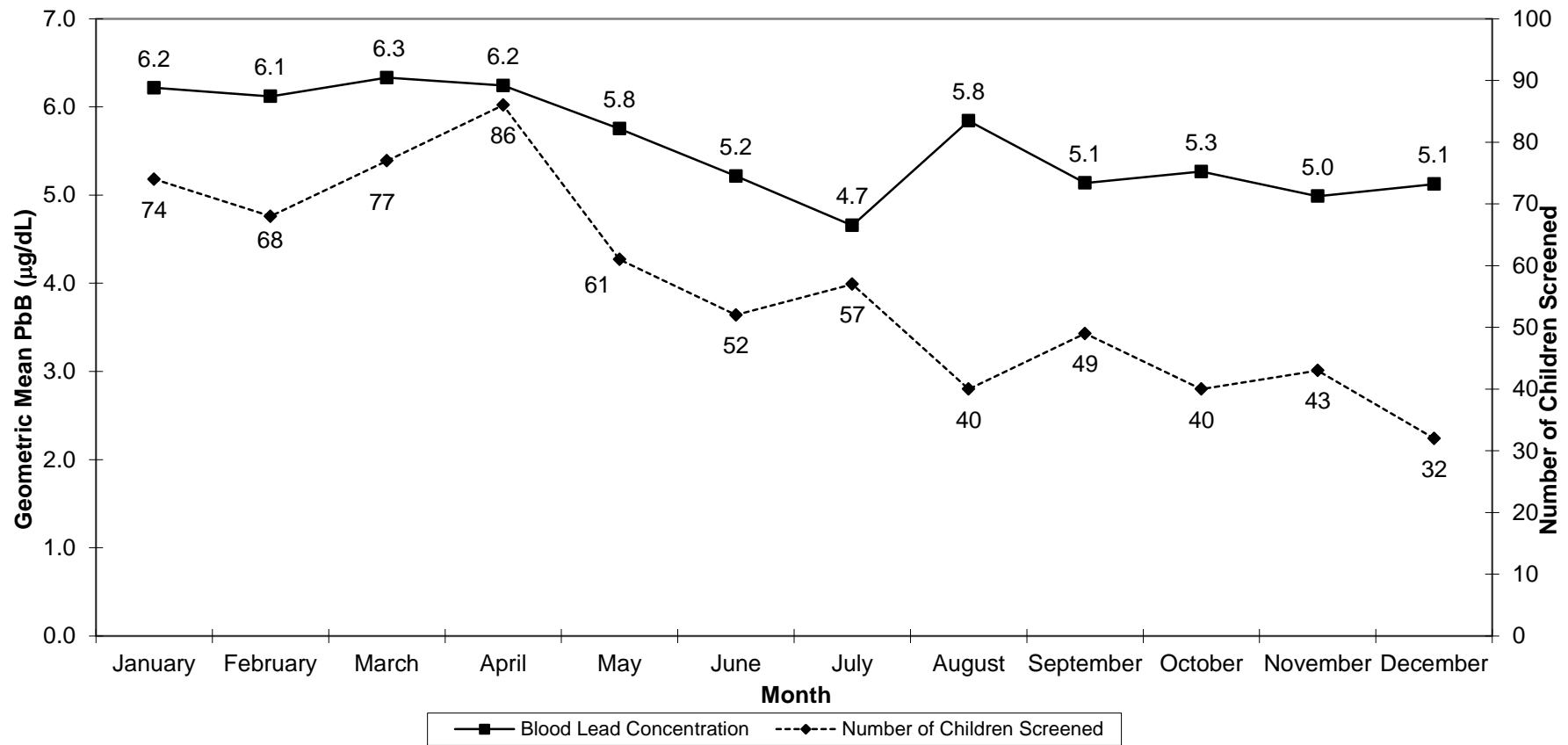


Figure 5. Monthly geomean comparison of first visit blood lead levels for Broken Hill children aged between 1 to 4 years of age for 2015.

SCREENING OF ABORIGINAL CHILDREN AGED 1 TO 4 YEARS

Although blood lead level for Aboriginal children is higher than the overall geometric mean for all Broken Hill children, this level has also been slowly decreasing. There has been an historical burden of high blood lead levels in children identified as Aboriginal in Broken Hill. The gap between Aboriginal and non-Aboriginal children blood lead levels has ranged from 9.1µg/dL in 1993 (when only 6 children tested were recorded as Aboriginal) to a low of 1.3µg/dL in 2008 (with an estimated 44% of Aboriginal children screened). From 2011, when aligning blood lead testing with immunization began and the proportion of children tested markedly increased, the average gap is 2.8µg/dL (**Figure 2**).

This year saw an increase of 1.3µg/dL in the Aboriginal population age-sex standardized geomean, from 8.0µg/dL in 2014 to 9.3µg/dL in 2015 (**Figure 2**). The unadjusted geomean for the 178 children tested was 8.6µg/dL. In previous years the unadjusted and adjusted geometric means have been comparable. While the proportion of children tested is high the number of children in any given age-sex cohort is small. This year one age-sex cohort recorded few tests all with blood lead levels over the current NHMRC benchmark. The cohort's calculated age-sex geomean had a noticeable effect on the adjusted population geometric mean. When the cohort's geomean was replaced with a value in line with the other cohorts the adjusted geomean decreased and was closer to the unadjusted geomean. Further examination of the data showed this observation was likely due to fewer children in this age group tested than expected as well as an artefact of the screening process and analysis method, in this case the age at their first test that is counted in the analysis. Some in 2015 were still considered in the 1 year cohort (as were 18 months old at first test in 2015) or in 2015 were in the next age cohort (3 Yrs). There were also children expected in the age-sex cohort (from 2014 records) who had no test recorded in 2015.

While the geomean for individual years does fluctuate the marked overall decrease in the geometric mean of blood lead in Aboriginal children from 1994 can be attributed to the expansion of the blood lead screening program by screening and active case management of children through Maari Ma Aboriginal health service including at the time of immunisation, as well as education around reducing lead exposure. As well Aboriginal children will have benefited from general public health action to reduce the health impacts of high blood lead levels, past remediation work, and health promotion activities undertaken as part of a broad range of activities to reduce the potential environmental exposure to lead in Broken Hill.

In all years, except 2009, the proportion of Broken Hill children identifying as Aboriginal that have been screened has been higher than that for non-Aboriginal children (**Figure 6**). The marked increase in attendance of Aboriginal children from 2011 is probably attributed to blood lead screening being offered with immunisation services, as well as the additional opportunity offered for screening through Maari Ma Aboriginal health service. Using the 2011 ABS Census data as the denominator, the proportion of resident Aboriginal children screened in 2015 was 122%. The population of Aboriginal children at the time of the 2011 ABS Census is clearly an underestimate and the testing rate may be explained by the significant migration of families with Aboriginal children into Broken Hill and/or an overall under reporting of Aboriginal status during the census.

Almost half (49%) of Aboriginal children had a blood lead level $\geq 10\mu\text{g/dL}$ the NSW Health notifiable level for 2015.

Based upon the new NHMRC benchmark of $\leq 5\mu\text{g/dL}$, 91% of Aboriginal children would have exceeded this in 2000 and in the intervening period the proportion has fluctuated but overall has decreased, to 79% in 2015 (**Figure 7**). The most noticeable reductions have occurred in the 20-29 $\mu\text{g/dL}$ and $\geq 29\mu\text{g/dL}$ categories. The Aboriginal population is small and numbers of children tested have fluctuated widely over this period (particularly 2006-2010), (**Figure 2**). The most recent years may be more indicative of blood lead levels in the Aboriginal population than those between 2006-2010.

The discrepancies in blood lead levels between Aboriginal and non-Aboriginal children are greatest in the $\leq 5\mu\text{g/dL}$ category (**Figure 8**). The proportion of non-Aboriginal children with blood lead levels $\leq 5\mu\text{g/dL}$ is 65% compared to 21% of Aboriginal children. Using these proportions and the 2011 census data an estimated 259 non Aboriginal and 115 Aboriginal children are above $5\mu\text{g/dL}$. If the 178 Aboriginal children tested in 2015 is considered closer to the current Aboriginal population aged 1-4 years then the number would be 141. A significant discrepancy for the $\geq 10\text{-}14\mu\text{g/dL}$ category is also noted, with 31% of Aboriginal children having this level compared to only 9% of non-Aboriginal children. Corresponding discrepancies were also noted in 2013 and 2014.

The expansion of the blood lead screening program has resulted in a more accurate depiction of the burden of blood lead level among Aboriginal children. This more accurate picture can better inform public health action to reduce the blood lead level discrepancy between Aboriginal and non-Aboriginal children in Broken Hill.

Proportion of children identifying as Aboriginal aged 1 – 4 years screened for blood lead levels in Broken Hill, 1991-2015

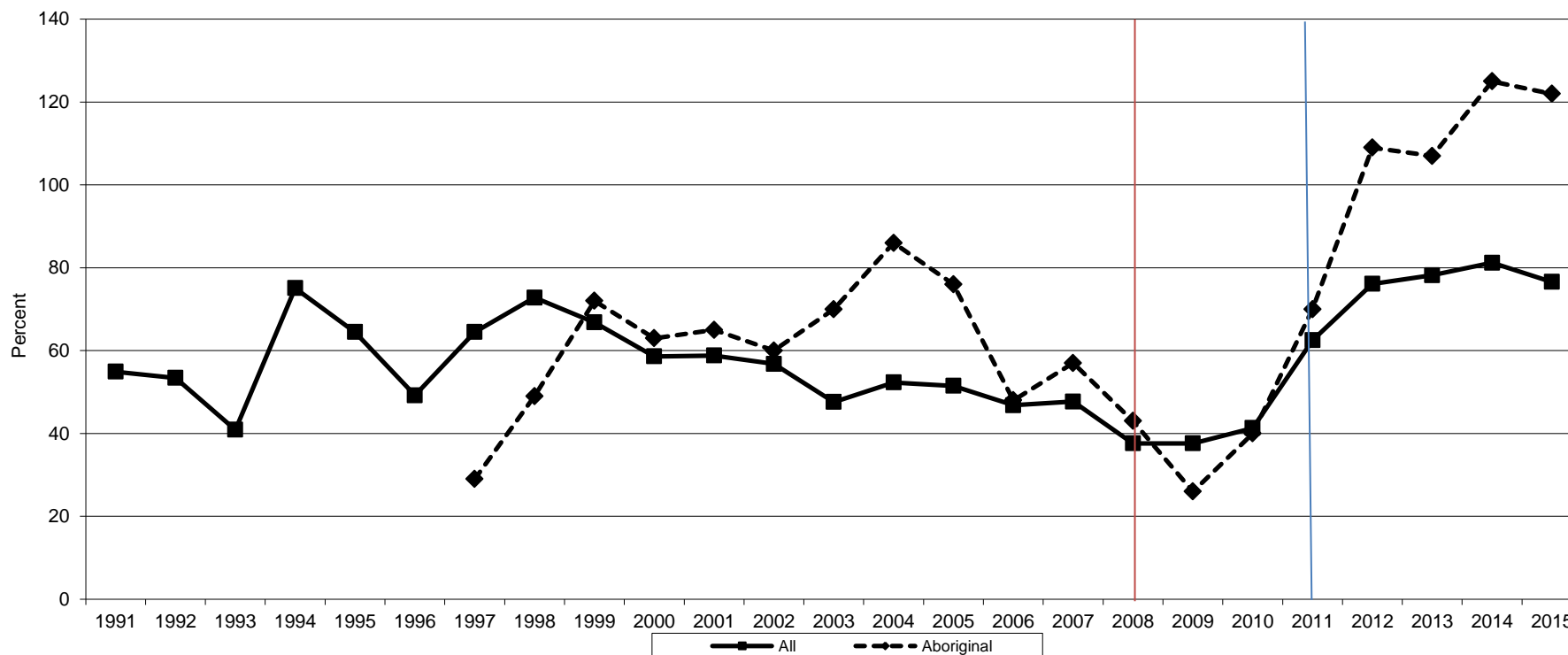


Figure 6. Adjusted response rate* of all children and Aboriginal children aged 1 to 4 years attending lead testing clinics, 1991-2015. The red line indicates the point in which both venous and capillary samples are reported together; the blue line indicated commencement of linking of screening with Immunisation program and expansion when Maari Ma offered blood lead screening.

*Calculated on a 1.6% decline of children aged 1 to 4 years for period 1996 - 2001. Calculations for 2002-2005 based on 2001 census data, 2006-2010 on 2006 census data, 2011-2015 based on 2011 census data.

Percentage of Aboriginal identified children aged 1 – 4 years for each category of blood lead level, 2000-2015

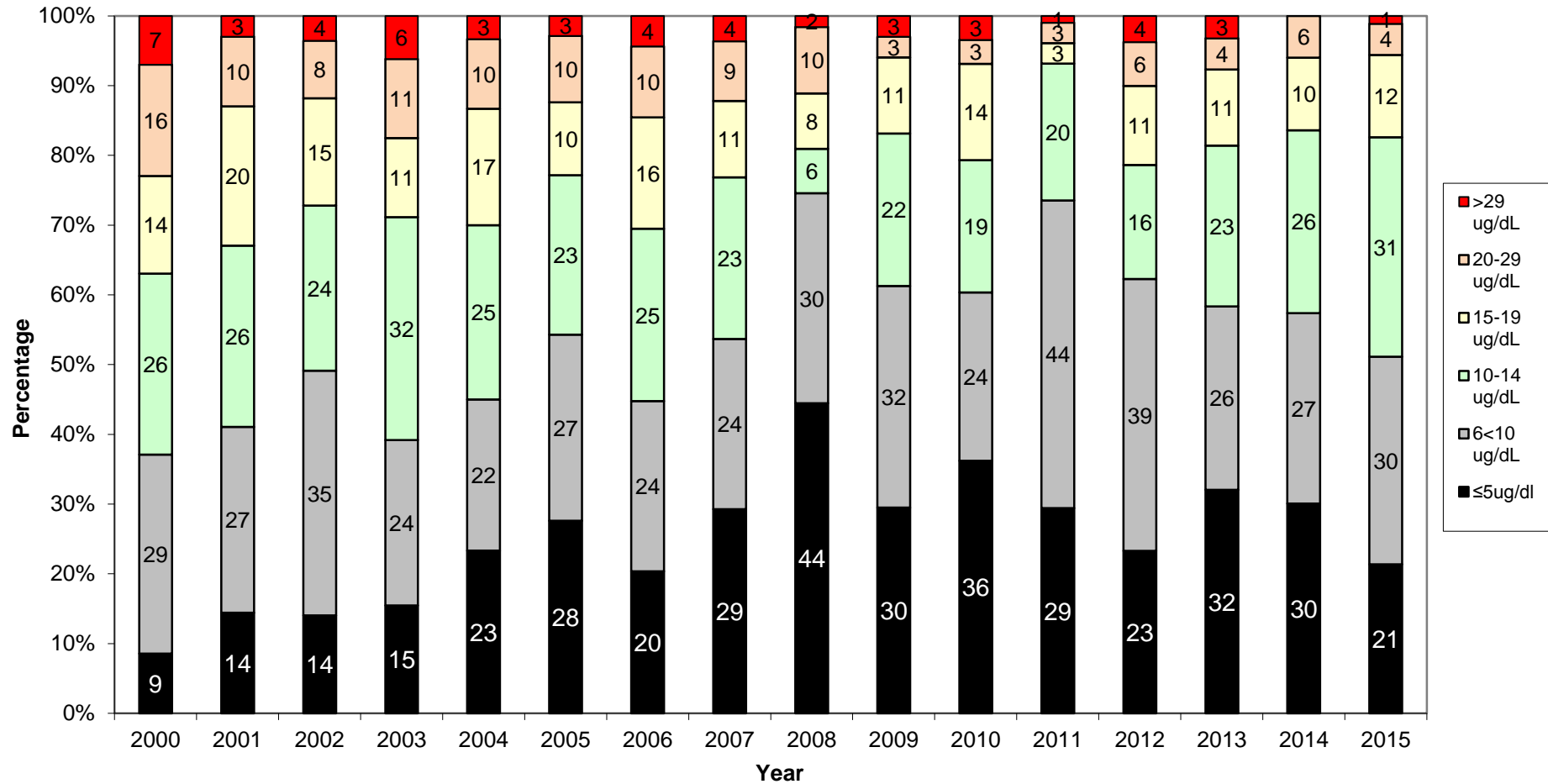


Figure 7. Percentage of Broken Hill Aboriginal children in each blood lead category, aged between 1 and 4 years, 2000-2014. Data is presented from 2000 as before that the proportion and number of Aboriginal children tested was small, additionally caution should be used with the 2006 – 2010 results as this was also a period of low attendance by Aboriginal children.

Blood lead level categories by Aboriginal status for children aged 1 – 4 years, Broken Hill, 2015

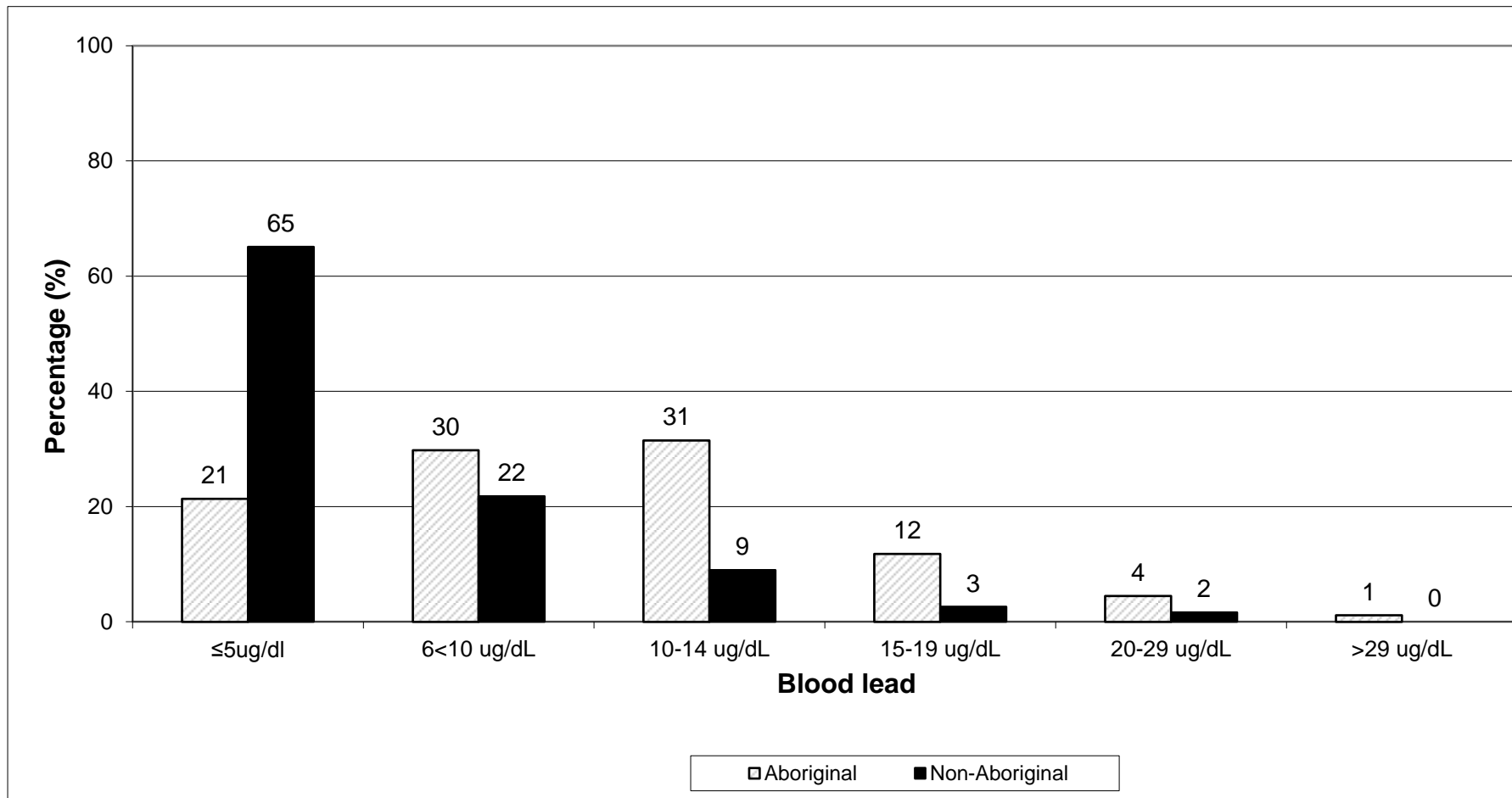


Figure 8. Comparison of Aboriginal versus non-Aboriginal aged 1-4 years by Blood Lead Categories, including ≤5ug/dl, for 2015

CONCLUSION

In 2015 the age-sex standardised mean for all children and Aboriginal children rose slightly, especially when compared to results since 2012. The proportion of all children above the new NHMRC benchmark of $\leq 5\mu\text{g/dL}$, was 47% and for Aboriginal children 79%. While these findings are reflective of the new benchmark and present new challenges, screening participation is still high, cord blood levels decreased and average population blood lead levels for children aged between 1 and under 5 years have remained within a 5-6 $\mu\text{g/dL}$ range.

The alignment of immunisation and blood lead testing, as well as the strengthening of the partnership between the Child and Family Health Centre and Maari Ma have been major factors in reversing the previous decline in children's participation in screening. These initiatives may have also contributed to the decrease in blood lead levels.

Reducing blood lead levels among Aboriginal children to match those of non-Aboriginal children remains a challenge. The 2015 results indicate that 65% of non-Aboriginal children in Broken Hill had a blood lead level of $\leq 5\mu\text{g/dL}$ compared to only 21% of Aboriginal children. The statement issued by the NHMRC in May 2015 recommends that "If a person has a blood lead level greater than 5 micrograms per decilitre ... the source of exposure should be investigated and reduced, particularly if the person is a child or pregnant woman. Identifying and controlling the source of lead exposure will reduce the risk of harm to the individual and to the community". In light of this statement, reducing blood lead levels among children, especially Aboriginal children in Broken Hill, will continue to be a challenge for some time to come.

The emphasis of the Broken Hill Environmental Lead Program, set up in mid-2015, on further lead abatement and environmental activities adds an extra dimension to the current prevention and management strategies. This renewed program should also help maintain long term momentum in the community to support childhood screening and engage in lead reduction activities, with the primary aim of decreasing blood lead levels in children.

APPENDIX 1 HIGH RISK BIRTHING CRITERIA

The criteria for birthing in Broken Hill is that they have to be low risk.

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

- <37 weeks gestation
- BMI > 45 at 36 weeks gestation
- 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 I 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.

BIBLIOGRAPHY

Lead and Health in Broken Hill

Published Research

Year	Publication
------	-------------

- | | |
|-------|--|
| 2016 | <ul style="list-style-type: none">○ Sullivan M & Green D Misled about lead: an assessment of online public health education material from Australia's lead mining and smelting towns <i>Environmental Health</i> (2016) 15:1 DOI 10.1186/s12940-015-0085-9 |
| 2015 | <ul style="list-style-type: none">○ Boreland F, Lyle D, Brown A, Perkins D. Effectiveness of introducing point of care capillary testing and linking screening with routine appointments for increasing blood lead screening rates of young children: a before-after study. <i>Archives of Public Health</i> 2015, 73 :60 (29 December 2015)○ Dong, C., Taylor, M.P., Kristensen, L.J. Zahran, S. Environmental contamination in an Australian mining community and potential influences on early childhood health and behavioural outcomes. <i>Environmental Pollution</i> (2015) 207: 345-356.○ Kristensen LJ, Taylor MP, Morrison AL Lead and zinc dust depositions from ore trains characterised using lead isotopic compositions <i>Env Science: processes & impacts</i> 2015 (in press) |
| 2014 | <ul style="list-style-type: none">○ 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.... <i>Environ. Res.</i>(2014),135: 296-303 http://dx.doi.org/10.1016/j.envres.2014.08.036i○ Boreland F, Lyle D. Putting the genie back in the bottle: protecting children from lead in the 21st century. A report from the field. <i>Public Health Research and Practice</i> 2014; 25(1): :e2511403 |
| 2012 | <ul style="list-style-type: none">○ Thomas S, Lyle D, Boreland F. Improving access to and outcomes of blood lead screening for Aboriginal children in Broken Hill NSW <i>NSW Public Health Bulletin</i> 2012; 23(11-12):234-238 |
| 2009: | <ul style="list-style-type: none">○ Boreland F, Lesjak M, Lyle D Evaluation of home lead remediation in an Australian mining community <i>Sci Tot Environment</i> 2009; 408:202-208○ Boreland F, Lyle D. Using performance indicators to monitor attendance at the Broken Hill blood lead screening clinic. <i>Environmental Research</i> 2009; 109:267-272. |
| 2008: | <ul style="list-style-type: none">○ Boreland F, Lesjak MS, Lyle DM. Managing environmental lead in Broken Hill: a public health success. |

Year	Publication
	<i>NSW Public Health Bulletin</i> 2008; 19(9-10):174-179.
	○ Boreland F, Lyle D. Screening children for elevated blood lead – Learnings from the literature. <i>Science of the Total Environment</i> 2008, 390:13-22
	○ Kardamanidis K, Boreland F, Lyle D. <i>Review of blood lead screening in Broken Hill pre-school aged children.</i> Broken Hill University Department of Rural Health, University of Sydney. ISBN 978-0-9752257-2-1
	○ Kardamanidis K, Lyle DM, Boreland F. Addressing decreasing blood lead screening rates in young children in Broken Hill, NSW. <i>NSW Public Health Bulletin</i> 2008; 19(9-10):180-182.
	○ Lesjak M, Boreland F. Protecting children from lead in Broken Hill. <i>In Touch: the newsletter of the Public Health Association of Australia</i> , 2008. 25(11): 5.
	○ Misan G, Lesjak M , Fragar L. Health of rural populations. In: <i>A Textbook of Australian Rural Health.</i> Eds Haw S-T & Kilpatrick S. Australian Rural Health Education Network, Canberra, 2008. pp 71-81.
2006:	○ Boreland F, Lyle DM. Lead Dust in Broken Hill Homes: Effect of remediation on indoor lead levels. <i>Environmental Research</i> 2006, 100:276-283.
	○ Boreland F, Lyle DM, Wlodarczyk J, Balding WA. Lead Dust in Broken Hill Homes: relationship between house dust and children's blood lead levels. <i>Environmental Health</i> 2006, 6(4):15-24.
	○ Lyle DM, Phillips AR, Balding WA, Burke H, Stokes D, Corbett S, Hall J. Dealing with lead in Broken Hill – trends in blood lead levels in young children 1991 – 2003. <i>Science of the Total Environment</i> 2006, 359:111-119.
2005:	○ Low C, Gore D, Taylor MP, Louie H. Black bluebush and old man saltbush biogeochemistry on a contaminated site: Broken Hill, New South Wales, Australia. In: Roach I.C. ed, 2005. <i>Regolith 2005 – Ten Years of CRC LEME.</i> CRC LEME, pp 213-218.
2003:	○ Burke H, Balding B, Lyle D. Reducing lead exposure in children in Broken Hill. <i>New South Wales Public Health Bulletin</i> 2003, 14(3):52-54.
2002:	○ Boreland F, Lyle DM, Wlodarczyk J, Balding WA, Reddan S. Lead Dust in Broken Hill Homes –a potential hazard for young children? <i>Australian and New Zealand Journal of Public Health</i> 2002, 26(3):203-207.
2001:	○ Lyle D, Balding B, Burke H, Begg S. NSW Lead Management Program in Broken Hill. <i>New South Wales</i>

Year	Publication
	<i>Public Health Bulletin</i> 2001, 12:165-167.
1999:	<ul style="list-style-type: none"> ○ McGee, T. Private responses and individual action: community responses to chronic environmental lead contamination. <i>Environment and Behavior</i> 1999, 31(1):66-83.
1998:	<ul style="list-style-type: none"> ○ Gulson BL, Yui LA, Howarth D. Delayed visual maturation and lead pollution. <i>Science of the Total Environment</i> 1998, 224:215-219.
1997:	<ul style="list-style-type: none"> ○ Balding B, Reddan R. Lead and environmental health in Broken Hill. <i>New South Wales Public Health Bulletin</i> 1997, 8(14-12):97.
1996:	<ul style="list-style-type: none"> ○ Gulson BL. Tooth analyses of sources and intensity of lead exposure in children. <i>Environmental Health Perspectives</i> 1996, 104(3):306-312. ○ Gulson BL, Mizon KJ, Korsch MJ, Howarth D. Non-orebody sources are significant contributors to blood lead of some children with low to moderate lead exposure in a major lead mining community. <i>Science of the Total Environment</i> 1996, 181:223-230. ○ Gulson BL, Mizon KJ, Korsch MJ, Howarth D. Importance of monitoring family members in establishing sources and pathways of lead in blood. <i>Science of the Total Environment</i> 1996, 188:173-182. ○ Gulson BL, Mizon KJ, Korsch MJ, Howarth D, Phillips A, Hall J. Impact on blood lead in children and adults following relocation from their source of exposure and contribution of skeletal tissue to blood lead. <i>Bulletin of Environmental Contamination and Toxicology</i> 1996, 56:543-550.
1995:	<ul style="list-style-type: none"> ○ Gulson, B. L., Davis, J. J., Mizon, K. J., Korsch, M. J., Korsch, M. J. & Bawden-Smith, J. 1995, 'Sources of lead in soil and dust and the use of dust fallout as a sampling medium.' <i>Science of the Total Environment</i>, vol. 166, pp. 245-62. ○ Gulson B, Mahaffey K, Mizon K, Korsch M, Cameron M, Vimpani G. Contribution of tissue lead to blood lead in adult female subjects based on stable lead isotope methods. <i>Journal of Laboratory and Clinical Medicine</i> 1995, 125:703-712.
1994:	<ul style="list-style-type: none"> ○ Gulson B, Davis J, Mizon K, Howarth D. Lead bioavailability in the environment of children: blood lead levels in children can be elevated in a mining community. <i>Archives of Environmental Health</i> 1994, 49:326-331. ○ Gulson BL, Howarth D, Mizon KJ, Law AJ, Korsch MJ & Davis JI. Sources of lead in humans from Broken Hill mining community. <i>Environmental Geochemistry and Health</i>

Year	Publication
	1994, 16(1):19-25.
	<ul style="list-style-type: none"> ○ Gulson B, Mizon K, Law A, David J, Howarth D. Sources and pathways of lead in humans from Broken Hill mining community – an alternative use of exploration methods. <i>Economic Geology</i> 1994, 89:889-908. ○ Gulson BL, Wilson D. History of lead exposure in children revealed from isotopic analysis of teeth. <i>Archives of Environmental Health</i> 1994, 49:279-283.
1986:	<ul style="list-style-type: none"> ○ Koh TS, Babidge PJ. A comparison of blood lead levels in dogs from a lead mining, lead smelting, urban and rural island environment. <i>Australian Veterinary Journal</i> 1986, 63(9): 282-285.

Year	Reports and conference presentations
2015	<ul style="list-style-type: none"> ○ Boreland F. Management strategies: Broken Hill. Presentation to Forum: management of lead exposure in lead endemic communities. Hosted by National Health and Medical Research Council on behalf of enHealth. QT Hotel, Canberra, ACT. 31st March 2015. ○ Boreland F. Blood lead screening: Broken Hill. Presentation to Forum: management of lead exposure in lead endemic communities. Hosted by National Health and Medical Research Council on behalf of enHealth. QT Hotel, Canberra, ACT. 31st March 2015. ○ Boreland F. Case management: Broken Hill. Presentation to Forum: management of lead exposure in lead endemic communities. Hosted by National Health and Medical Research Council on behalf of enHealth. QT Hotel, Canberra, ACT. 31st March 2015. ○ Boreland F, Lesjak M, Lyle D, Jones T, Johnson D. Translating research into action: renewing the Broken Hill Environmental Lead Program. <i>One vision, many voices. Population Health Congress 2015.</i> Hotel Grand Chancellor, Hobart, 6-9 September 2015. ○ Boreland F, Lyle D, Perkins D, Brown A. Enhancing collaboration in a resource constrained environment: Broken Hill Lead Reference Group. <i>One vision, many voices. Population Health Congress 2015.</i> Hotel Grand Chancellor, Hobart, 6-9 September 2015. (Poster) ○ Boreland F, Lyle D, Perkins D, Brown A. Reducing community lead exposure: identifying and prioritising points for intervention. <i>One vision, many voices. Population Health Congress 2015.</i> Hotel Grand Chancellor, Hobart, 6-9 September 2015. (Poster) ○ Boreland F, Lyle D, Perkins D, Brown A. Reducing community lead exposure: identifying and prioritising points for intervention. <i>Different perspectives, working together. School of Public Health Research Presentation Day.</i> Eastern Avenue Complex, Camperdown Campus, University of Sydney, Camperdown, 28th September 2015.
2014	<ul style="list-style-type: none"> ○ Boreland F, Lyle D, Brown A, Perkins D. Reducing community lead exposure: where to from here? <i>Emerging Health Policy Research Conference,</i> Menzies Centre for Health Policy Research, Sydney. 2nd October 2014
2013	<ul style="list-style-type: none"> ○ Boreland F, LyleD, Brown A, Perkins D. Access and acceptability: Improving participation in blood lead screening among young children in Broken Hill. <i>Innovation and Achievement - making the difference in rural health.</i> NSW

Year	Reports and conference presentations
	<i>Rural Health and Research Congress 2013</i> . Glasshouse Port Macquarie, 21 - 23 October 2013
2012	<ul style="list-style-type: none"> ○ Gough N, Lesjak MS, Kirby S, The Broken Hill Aboriginal Community Working Party, Lyle D The Impact of Lead and a change in Lead Guidelines for Broken Hill An inquiry into community concern and desire for action. Broken Hill University Department of Rural Health, 2012: Broken Hill NSW.
2011	<ul style="list-style-type: none"> ○ Thomas S, Lyle D, Boreland F. (2011) <i>Review of Blood Lead Screening in Aboriginal Children in Broken Hill</i>, Broken Hill Centre for Remote Health Research, University of Sydney, Broken Hill NSW. ○ Thomas S, Boreland F, Lyle D. Improving access to blood lead level screening for Aboriginal Children in Broken Hill. Submitted to <i>Sustaining Rural Health Through Research</i>, 4th Rural Health research Colloquium, Dubbo RSL Club Retreat Conference Centre, Dubbo, NSW, 11-13 October 2011
2010	<ul style="list-style-type: none"> ○ Boreland F, Lesjak M *, Lyle D Evaluation of home lead remediation in an Australian mining community Are you remotely interested? –the 2010 Mt Isa Remote Health Conference, 20-22 August 2010
2009:	<ul style="list-style-type: none"> ○ Boreland F, Lyle D, Perkins D. Protecting children from lead in environments with multiple lead sources. Submitted to <i>Rural Health: the place to be...</i> 10th National Rural Health Conference, Cairns Convention Centre, Cairns, Qld, 17-20 May 2009. (Poster)
2008:	<ul style="list-style-type: none"> ○ Boreland F. <i>Patterns of attendance at the Broken Hill blood lead screening clinic</i>. MPH (Hons) treatise, School of Public Health, University of Sydney, July 2008.
2007:	<ul style="list-style-type: none"> ○ Boreland F, Lesjak M, Lyle D. Managing environmental lead in Broken Hill; a public health success. <i>Standing up for rural health: learning from the past, action for the future</i>. 9th National Rural Health Conference, 7-10 March 2007. Albury, NSW. (Poster) ○ Boreland F, Lesjak M, Lyle D. Managing environmental lead in Broken Hill; a public health success. <i>Building a healthier future through research</i>. 2nd Rural health Research Colloquium, 15-17 May, 2007. UDRH Centre, Tamworth Rural referral Hospital, NSW.
2006:	<ul style="list-style-type: none"> ○ Boreland F, Lyle D. Factors affecting attendance at the Broken Hill Child and Family Health blood lead screening clinic. <i>Optimising Impact</i>, 2006 GP & PHC Research Conference, 5-7 July, Perth Convention and Exhibition Centre. (Conference presentation)

Year	Reports and conference presentations
2005:	<ul style="list-style-type: none"> ○ Boreland F, Lyle D, Heading G. Factors affecting attendance at the Broken Hill Child and Family Health blood lead screening clinic: a study proposal. <i>Cultivating Capacity: Building a research community in primary health care.</i> 3rd Annual NSW Primary Health Care Research Evaluation Conference, Carlton Crest hotel, Sydney, 1-2 December 2005. (Conference presentation)
2003:	<ul style="list-style-type: none"> ○ Corbett S, Morgan G, Balding W, Reddan S, Beggs S, Lyle D, Burke B. An evaluation and randomised trial of home lead remediation in Broken Hill, a lead mining community in far western New South Wales. <i>Local Solutions, Smart Future:</i> 2003 conference and celebration Port Pirie, South Australia, 29-30 Sept 2003. (Conference presentation)
2002:	<ul style="list-style-type: none"> ○ Boreland F. Lead management in Broken Hill: the importance of research and evaluation in targeting a community based program. <i>Research from the ground up.</i> 2002 NSW Primary Health Care Research Conference, Sydney, 20-21st September, University of Sydney, Holme Building, Sydney. (Conference presentation) ○ Boreland F. Lead management in Broken Hill: the importance of research and evaluation in targeting a community based program. <i>Our Community – answers from within.</i> 3rd Victorian Small Rural Communities Health Conference, Hepburn Springs, 16-17th October, 2002. The Springs Retreat, Hepburn Springs, Victoria. (Conference presentation) ○ Boreland F & Lyle D. Effect of remediation on indoor lead levels in Broken Hill homes. <i>Research – making a difference to health and health care.</i> 2002 General Practice and Primary Health Care Research Conference, Melbourne, 30th & 31st May 2002, Carlton Crest Hotel, Melbourne. (Poster) ○ Boreland F, Lyle DM, Wlodarczyk J & Balding WA. Relationship between house dust and children's blood lead levels in Broken Hill. <i>Research – making a difference to health and health care.</i> 2002 General Practice and Primary Health Care Research Conference, Melbourne, 30th & 31st May 2002, Carlton Crest Hotel, Melbourne. (Poster) ○ D. Lyle, A. Phillips, W. Balding & H. Burke. Trends in blood lead levels among young Broken Hill children 1991 to 1999. <i>Research – making a difference to health and health care.</i> 2002 General Practice and Primary Health Care Research Conference, Melbourne, 30th & 31st May 2002, Carlton Crest Hotel, Melbourne (Poster)
2000:	<ul style="list-style-type: none"> ○ Balding B. <i>The decline in the blood lead levels of children in Broken Hill: a report on children aged 6 to 59 months of age from 1991-1997.</i> MPH Treatise, University of Sydney, 2000. ○ Boreland F, Lyle DM, Wlodarczyk J, Balding B & Reddan S.

Year	Reports and conference presentations
	<p><i>Lead dust in Broken Hill homes: a potential hazard for young children?</i> Broken Hill Environmental Lead Centre Scientific Report Series 2000.</p> <ul style="list-style-type: none"> ○ Corbett, S., Balding, W., Lyle, D. Evaluation of a randomized trial of home remediation, Broken Hill, Australia. In: International Conference on Lead Remediation, Coeur d'Alene, ID, USA, May 2000. (Conference presentation) ○ Lesjak M & Lyle DM. <i>1994 community survey of risk factors for children with elevated blood lead levels.</i> Broken Hill Environmental Lead Centre Short Report Series 2000. ○ Lively M, Balding B. The decline in the blood lead levels of children in Broken Hill: a report on children aged 6 to 59 months of age from 1991 to 1997. In: International Conference on Lead Remediation, Coeur d'Alene, ID, USA, May 2000. (Conference presentation) ○ Lyle DM, Balding B, Burke H, Corbett S, Begg S & Kerr C. <i>Dealing with lead in Broken Hill – a public health approach.</i> Broken Hill Environmental Lead Centre Scientific Report Series 2000 ○ Phillips A, Lyle DM, Reddan S, Balding B, Stokes D & Boreland F. <i>Dealing with lead in Broken Hill – trends in blood lead levels in young children 1991-1999.</i> Broken Hill Environmental Lead Centre Scientific Report Series 2000.
1998:	<ul style="list-style-type: none"> ○ Chompikul, J. 1998, <i>Impact of environmental lead pollution on children: Studies from Thailand and Australia.</i> Submitted for degree of Doctor of Philosophy, Department of Public Health and Community Medicine, University of Sydney. ○ Phillips A. <i>Trends in and factors for elevated blood lead concentration in Broken Hill pre-school children in the period 1991-1993.</i> Thesis, Master of Medical Science (Clinical Epidemiology), University of Newcastle Nov 1998. ○ Stokes D, Boreland F, Pickering B, Reddan S, Begg S, Kennedy B. (1998). Lead in house dust: a legacy of the past. <i>Celebrating Public Health: Decades of Development, Decades of Opportunity.</i> 30th Annual Conference of the Public Health Association of Australia Inc. 13-16th September 1998, West Point Hotel Casino, Hobart. (Poster)
1997:	<ul style="list-style-type: none"> ○ Burke M. <i>Childhood blood lead levels in Broken Hill 1991 – 1996 – a descriptive analysis.</i> Unpublished report. 1997?
1996:	<ul style="list-style-type: none"> ○ McGee T. <i>Shades of grey: Community responses to chronic environmental lead contamination in Broken Hill, New South Wales.</i> PhD Thesis, Centre for Resource and Environmental Studies, The Australian National University, Canberra.
1994:	<ul style="list-style-type: none"> ○ Phillips A, Hall J. <i>Risk factors for blood lead levels in preschool children in Broken Hill 1991-1993.</i> Western NSW

Year	Reports and conference presentations
	Public health Unit Report, Vols 1 & 2. 1994.
1993:	<ul style="list-style-type: none"> ○ AGC Woodward Clyde Pty Ltd. <i>Evaluation of environmental lead in Broken Hill.</i> Sydney. Report to the Environment Protection Authority. 1993. ○ Gulson BL, Mizon KJ, Law AJ, Korsh MJ, Davis JJ, Howarth D. <i>Sources and pathways of lead in humans from the Broken Hill mining community. Part 1. Lead Isotope Fingerprinting.</i> CSIRO Division of Exploration Geoscience, Open File Report IR415R, CSIRO, 1993, 108pp.
1991:	<ul style="list-style-type: none"> ○ van Alphen M. <i>The history of smelting and ore dressing in Broken Hill and the potential for mine derived lead contamination in Broken Hill.</i> Unpublished report, 1991.
1990	<ul style="list-style-type: none"> ○ Division of Analytical Laboratories, NSW Health Department. Annual Report 1990. (survey of lead levels in water collected from rooves of private homes in Broken Hill)
1982:	<ul style="list-style-type: none"> ○ Western NSW Public Health Report
1921:	<ul style="list-style-type: none"> ○ New South Wales Technical Commission of Inquiry into the Prevalence of Miners' Phthisis, Lead Poisoning and Hookworm at Broken Hill <i>Report of the technical commission of inquiry appointed upon the recommendation of the New South Wales Board of Trade to investigate the prevalence of miner's phthisis and pneumoconiosis in the metalliferous mines at Broken Hill,</i> Sydney : Government Printer, 1921
1920	<ul style="list-style-type: none"> ○ Workmen's Compensation (Broken Hill) Act Act No. 36, 1920
1914:	<ul style="list-style-type: none"> ○ NSW Legislative Assembly, <i>Report of the Royal Commission on the Mining Industry at Broken Hill,</i> Sydney, Government printer
1893:	<ul style="list-style-type: none"> ○ Thompson AJ. <i>Report of Board appointed to inquire into the prevalence and prevention of lead poisoning at the Broken Hill Silver-Lead Mines.</i> NSW Legislative Assembly Government Printer Sydney. 1893.