DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Broken Hill Environmental Lead Study 2016-2020 Summary Report

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Broken Hill Environmental Lead Study Summary

Background

The Broken Hill Environmental Lead Study (BHELS) was commissioned by the Broken Hill Environmental Lead Program (BHELP) to determine likely source areas contributing to the amount of lead that is in the air and deposited at various locations representative of lead exposure across Broken Hill.

The BHELS is a five-year program, being conducted over the 2016 to 2020 period, including a sampling program spanning over three calendar years (January 2017–March 2020).

Specific study objectives include:

- Determine likely source areas contributing to airborne lead levels in Broken Hill based on a year of wind-directional measurements of ambient air lead at selected locations and analyse the data to identify the direction of sources contributing to airborne lead.
- Monitoring of airborne and deposited lead levels for a further two years to evaluate the effectiveness of remediation works in reducing lead levels.

This brief report summarises the BHELS results from Year 1 (**Jan 2017 – Jan 2018**), Year 2 (**Jan 2018 – Feb 2019**) and Year 3 (**Feb 2019 – Mar 2020**) reports. The BHELS Year 1 report details the study design, choice of dust sampler, monitoring site locations, and quality assurance procedures. The BHELS Year 2 Report provides an update of lead monitoring results covering the period 16 January 2018 to 20 February 2019. Based on the Year 1 study results, the sampling wind sectors were adjusted to better differentiate lead-bearing TSP from mining and non-mining areas of Broken Hill. The Year 2 report also presents the monthly dust deposition gauge sampling results covering March 2018 to February 2019.

The final report of the current study has been subject to an independent review to:

- evaluate the scientific robustness of the study;
- assess whether the evidence supports the results and conclusions;
- determine whether the study objective has been adequately addressed;
- recommend any additional work as may be necessary to address the study objective;
- note any inconsistencies or significant gaps within the overall report.

Study Aim

Broken Hill is an inland mining city known to have one of the world's largest silver, lead, zinc minerals deposits. The Broken Hill study area is known for accommodating one of the largest lead mining operations in the region including exploration, processing and transport. Lead is one of the major pollutants that has been widely investigated to identify the contributions of local sources to the measured lead pollution occurring in the area.

This study aimed to establish a relationship between lead emissions sources that can be attributed to mining activities at Broken Hills and the surrounding lead concentrations recorded in the selected areas.

Introduction

Lead is an environmental contaminant that can result from naturally occurring deposits, from historical and current mining activities and from its utilisation. Depending on the prevailing meteorological conditions, airborne transport has the greatest potential to disperse pollutants. Determining the sources of lead at the existing sites in Broken Hill is complicated because of the following aspects:

- the area has a long history of lead mining activities that continue to this day.
- Broken Hill is rich in naturally occurring lead-ore deposits that are at or near the surface.
- different amounts of waste known as tailings have been produced as a result of mining operations with some of the waste may continue to disperse from their original deposit by natural factors such as winds and rain.

Mining activities can produce dust that has the potential to cause adverse health impacts on people living in the vicinity and downwind areas. Dust from mining activities consists primarily of larger particles generated through the handling of rock and soil, as well as through wind erosion of stockpiles and exposed ground. Larger particles (measured as dust deposition and TSP) are mostly associated with dust nuisance or amenity impacts in residential areas, through settling or deposition of the particles. Smaller particles such as PM10 (particles less than 10 micrometers in diameter) and PM2.5 (particles less than 2.5 micrometers in diameter) can also be generated through mining activities. Elevated levels of PM10 and PM2.5 have the potential to affect human health as these particles can be trapped in the nose, mouth or throat, or be drawn into the lungs. Fine particles (i.e., PM2.5) are typically generated through combustion processes.

A fundamental characteristic of suspended particulate matter (PM) that affects transport is its size distribution, often expressed as a function of the particle's aerodynamic diameter. The size distribution affects aerosol physics, chemistry, and transport, and environmental and health effects.

Coarse particles (greater than 2.5 μm) are generated by mechanical action, such as crushing, grinding, material handling, wind erosion, or vehicular traffic. Large particles have high gravitational settling velocities and can deposit onto a surface within a few minutes to a few hours after suspension. For example, stockpiles that consist of large particles are unlikely to become suspended and transported long distances by direct wind action except during extreme weather events. Particles that have diameters of a few micrometers, can remain suspended for several days and can therefore be transported long distances. Atmospheric turbulence plays an important role in lofting suspended particles from near the ground to higher altitudes, thereby facilitating long-distance transport.

The suspension of fugitive dust particles depends on particle sizes, surface loadings, surface conditions, wind speeds, atmospheric and surface moisture, and the existence of dust-generating activities, such as vehicular traffic. Windblown dust occurs when the wind exceeds a threshold velocity. The minimum threshold wind velocity is often found to be about 5–10 m/s when extrapolated to 10 m above the surface (the standard height for reporting wind speed). However, the threshold can vary widely because of such factors as surface roughness, moisture content, vegetative cover, and particle size.

The project is attempting to examine the extent to which various sources contribute to environmental lead contamination at selected sites in the Broken Hill area. This investigation includes extensive sampling, analysis, and interpretation to attempt providing evidence needed to identify lead sources contributing to the lead concentrations measured at the selected sites. Specific instruments have been deployed such as directional sampling instruments to distinguish between sectors.

Meteorology and Climate

Meteorological parameters such as winds, rain and temperature influence the rate of emissions and dispersion of dust from selected sources. Wind speed also dictate the amount of dust lifted into the air by wind erosion. Temperature can affect air quality as it can influence the movement of air. For example, during a hot summer day, the air near the surface can be much warmer than the air above. Sometimes large volumes of warm air near the surface rises, which results in vigorous mixing of compounds. The amount of precipitation controls the amount of fugitive dust and the removal of contaminants from the air.

- Wind roses were plotted for different years to determine the dominant feature of prevailing winds for each selected year. Regional wind patterns in 2017-2020 were very similar to previous years (2000-2016). The dominant feature of each of these wind roses is the high frequency of winds associated with southerly components. Other notable features are the occasional occurrences of north-easterly winds, and the relative lack of winds associated with westerly components.
- Annual average wind speed in 2019 was higher by 6.73% than previous measurements in 1017 and 2018.
- The monthly maximum temperatures in 2017, 2018 and 2019 were above the long-term average monthly maximum temperatures (1960-2017) for the most months.
- The highest maximum monthly temperature was 38.3°C in January 2019.
- The annual average rainfall was 91 mm in 2017-2019, and 68 mm in 2019 which was the lowest since 1997.
- Extreme heatwaves and drought conditions intensified the frequency of the dust storms in 2019.

Sampling Overview

Wind directional high-volume air samplers (D-HVAS) were installed at five sites representative of community exposure to lead in Broken Hill. Dust deposition samplers were installed at the same sampling sites to provide information on total dust deposition and deposited lead levels.

Each sampler continuously measured the wind speed and direction, air temperature and barometric pressure, and logged the volume of air sampled. The sampler collected total suspended particulates (TSP) over a 7-day period before being sent to a NATA accredited independent laboratory for analysis. The wind speed and direction data in combination with the lead concentration data was used to indicate the likely sources of lead-rich airborne dust.

D-HVAS sampling was undertaken at five sites: three sites in North Broken Hill (National Parks Building, Wetlands, and the Sewerage Pumping station) and two sites in South Broken Hill (Waterboard and Silver City Hwy). The placement of monitoring sites is shown in Figure 1. it should be noted that Alma Oval site was operational for nine months in Year 1, which was then decommissioned due to low wind speeds and the sampling duration being too low. This samples were then re-located to the Silver City Highway site.

Two D-HVAS were deployed at each sampling site. One unit samples during periods when the prevailing wind is blowing from ‘Sector A’ (which places a D-HVAS downwind of predominantly mining areas), and the second unit samples during periods when the wind is blowing from the remaining sector or Sector B. One sampler in Sector A at Waterboard site was operated until 3 October 2018. Schematic diagrams in Figure 2 presents the wind sectors for Sector A and Sector B at each site.

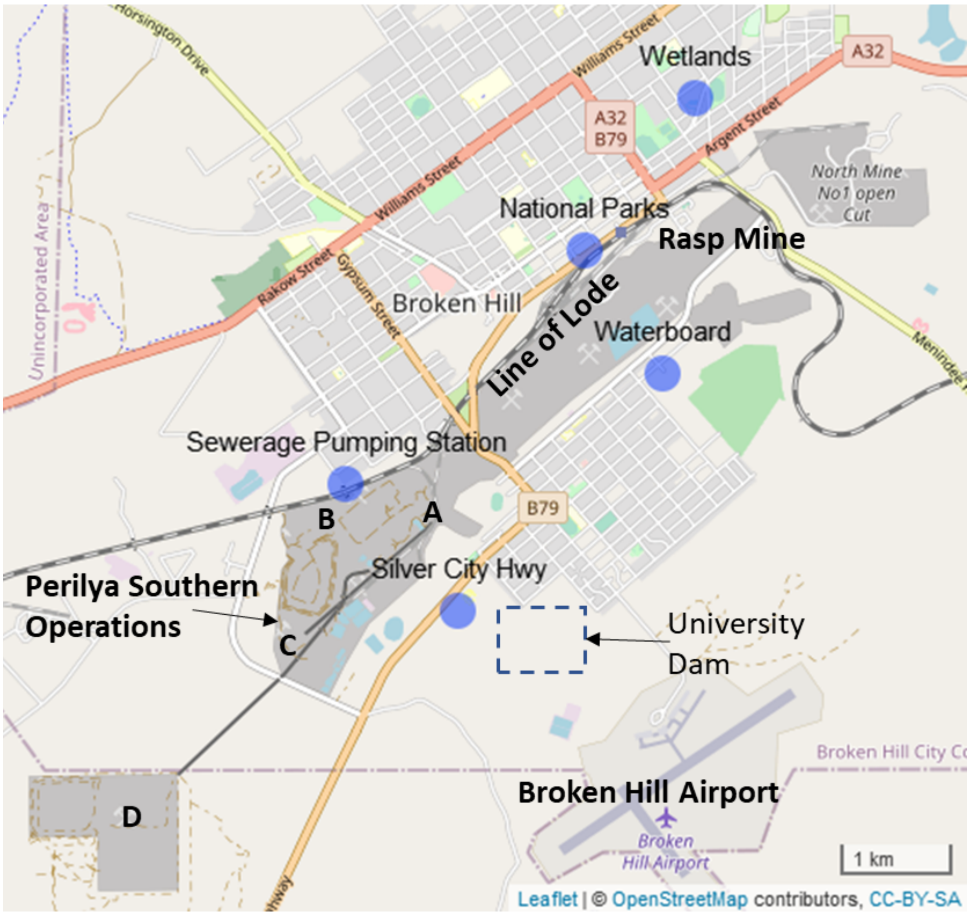

Figure 1 **Sampling site locations around Broken Hill indicated by the blue dots. A, B, C, and D represents tailings storage facilities for the Perilya Southern Operations (PSO).**

Data availability

In order for the D-HVAS to switch on, the wind must blow in-sector for a minimum of 90 seconds and the wind speed must be above 0.2 ms^{-1}.Based on the quality assurance procedure developed for the study, the D-HVAS samples were valid when the sampling duration was more than 480 minutes.

The major reason for invalidation of the collected D-HVAS filter samples were low sampling volume due to the low frequency of in sector winds. The Silver City Highway site received significantly lower valid sampling days' in Sector B compared to the rest of the sites caused by low sampling duration resulting from the low frequency of in sector winds.

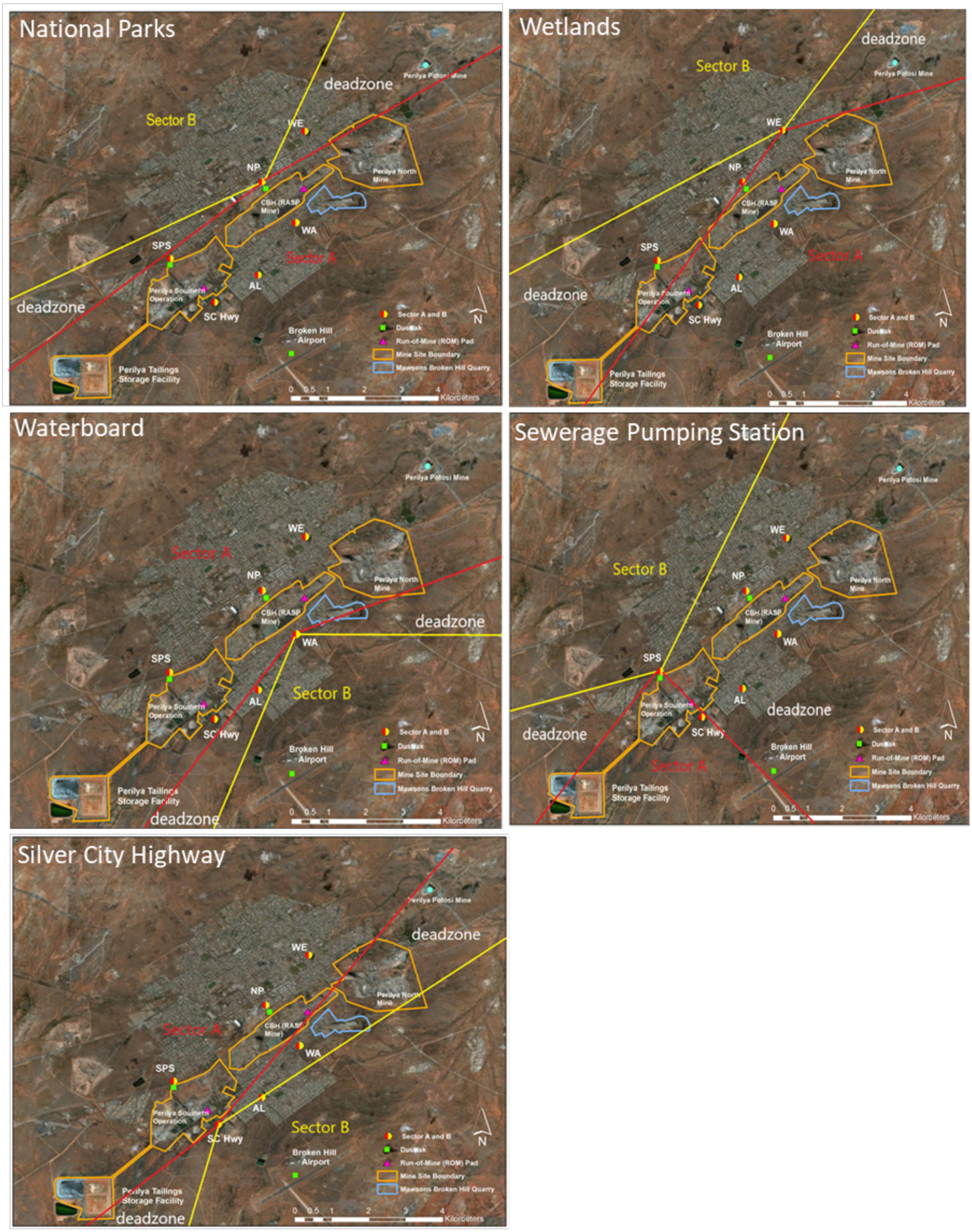

Figure 2 Wind sectors for Sector A and Sector B at each monitoring site. On 29 August 2019 the wind sectors were modified to better separate active mining sources from non-mining sources.

Ambient lead concentrations and mass fractions

- The measurement campaign carried out during 2017-220 showed that, the median ambient[1] lead concentrations for Sector A, were varying between 0.08 and 0.91 µg/m^3. Silver City Highway measurements recorded the highest median ambient lead concentrations, ranging between 0.50 µg/m^3 in Year 1 and 0.91 µg/m^3 in Year 3. Figure **3** presents the median ambient concentration range recorded during this project.
- The lowest lead levels recorded in the area was measured at the Wetlands site. This site is the farthest site away from the major mining activities. Knowing that the closest source is the Rasp mine which is 1.4 km to the south-west.
- The median ambient lead levels in Sector B measured during 2017-2020 measurement campaign were generally below 0.09 µg/m^3 at all sites, except at Silver City Highway (0.06 – 0.37 µg/m^3). Note that the small number of samples for Sector B at at Silver City Highway site could have biased the median concentrations due to the low frequency in the relevant wind sectors resulting in low sampling volumes.
- The median lead mass fraction levels (lead-in-TSP) were higher in Year 3 sampling period than in Year 2 and lower in Year 3 than in Year 1. Silver City Highway site recorded the highest median lead-in-TSP levels consistently over all four monitoring periods. The highest Sector A median lead-in-TSP level was 10,823 mg/kg at Silver City Highway site measured in Year 3. Figure 4 presents the median lead-in-TSP recorded during this project.
- It is important to highlight that the weekly average ambient lead concentration in Sector B was 0.95 µg/m^3, which was twice as high as in Sector A during this episode (8–15 January 2019). At this stage, the reasons for this trend have not been assessed. at this stage. is result has been e reason for such occasional high Sector B lead levels is unknown.

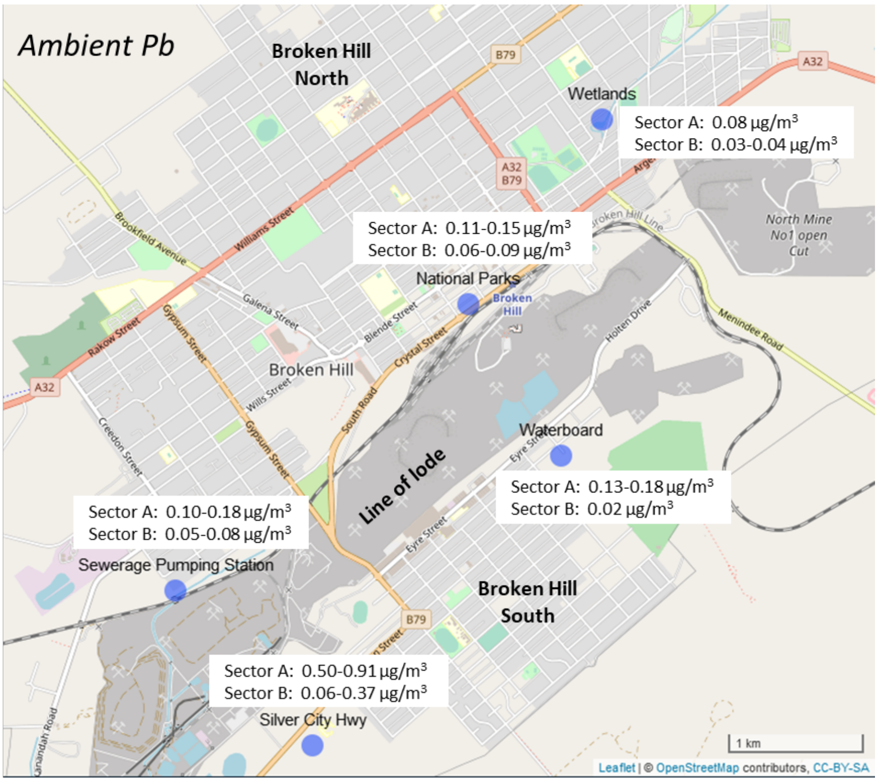

Figure 3 **Spatial distribution of median ambient lead concentration measured in all sampling period.**

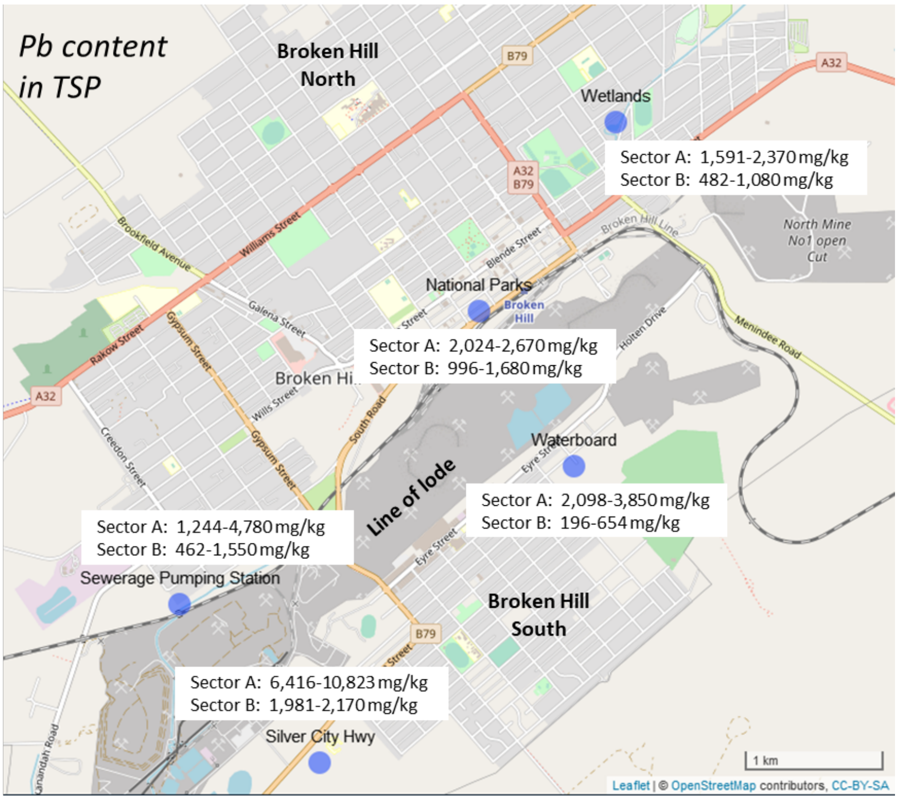

Figure 4 **Spatial distribution of median lead-in-TSP measured in all sampling period.**

Lead levels in dust deposition gauges

- Lead mass fraction in TSP was calculated at each site based on the monthly lead deposition data of DDGs.
- The average lead level measured by DDGs at Silver City Highway was 3,430 mg/kg, which is much higher than other sites.
- The maximum and minimum lead-in-TSP levels were 9,763 mg/kg in July 2018 at Silver City Highway and 30 mg/kg in July 2019 at Wetlands site, respectively.
- The frequent dust storms that occurred during 2019 have influenced the monthly dust deposition measured in the area.
- During elevated dust levels, the measured lead-in-TSP levels were lower than the other sampling periods. This could be related to the dilution of lead mass fraction with non-lead bearing dusts.

Conclusion

This report summarises the results from TSP monitoring by D-HVAS. Three detailed reports have been published to analyse the results.

Since the beginning of the BHELS, the lowest ambient lead concentration in Sector A at Wetlands site, as the site is the farthest away from the major mining sources compared to the rest of the sites. Overall average median ambient lead concentrations across all sites and sampling period estimate that the Sector A lead level was about three times higher than in Sector B, where the leading contributor of the lead levels to each monitoring period was the Silver City Highway site (both Sector A and Sector B).

While the BHELS results provide a quantitate understanding of lead levels at Broken Hill and its relationship with the local wind flow pattern, the major challenge is that the results cannot be compared with the regulatory standard.

Recommendation

The measurements campaign confirmed the qualitative relationships between high lead levels measured at selected sites with selected wind directions. This qualitative assessment requires additional information linking sources and receptors. Additional work is still needed to quantify the contributions of each source to the recorded lead levels. To successfully achieve this objective, it is important to:

- Determine a baseline level of lead for the areas that can cover the background levels of lead emissions away from mines operations.
- Define and carry out modelling scenarios to determine the likely source-receptor relationships for different operations.
- Ambient Air Quality National Environment Protection Measure (AAQ NEPM)[1] compliant sampling requires sampling and analysis of TSP and lead for 24 hours every sixth day (i.e., 1 day in 6). The NEPM goal for lead is 0.5 µg/m^3 based on the mean of lead concentrations over a calendar year.
- Utilising the existing instruments, four high D-HVAS can be established in the residential areas of north and south Broken Hill to measure AAQ NEPM compliant lead levels

It is recommended that a monitoring network be implemented that is compliant with the Ambient Air Quality National Environment Protection Measure (AAQ NEPM)[2]. This network will assess community exposure and allow comparison with the health standard for lead.

AAQ NEPM compliant sampling requires sampling and analysis of TSP and lead for 24 hours every sixth day (i.e., 1 day in 6). The NEPM goal for lead is 0.5 µg/m^3 based on the mean of lead concentrations over a calendar year. The network would make use of the instruments purchased for the BHELS study and would only require on-going operational and analysis costs.

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[1] National Environment Protection (Ambient Air Quality) Measure as amended, National Environment Protection Council, 7 July 2003, Canberra.

https://www.legislation.gov.au/Details/C2004H03935 - refer Schedule 2, Standards and Goals.

[2] National Environment Protection (Ambient Air Quality) Measure as amended, National Environment Protection Council, 7 July 2003, Canberra.

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