Ormeau/Yatala air quality investigation

Queensland Government

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Executive summary

The Department of Science, Information Technology and Innovation (DSITI) was commissioned by the Department of Environment and Heritage Protection (DEHP) to conduct an investigation of air quality in residential suburbs bordering hard rock quarries in the Ormeau and Yatala areas. The aim of the monitoring program was to obtain data to assess community concern about potential risks to human health, in particular respirable crystalline silica and asbestos, from emissions from local quarry operations.

Monitoring was conducted at residential properties in relatively close proximity to quarrying operations where highest pollutant levels resulting from quarrying activities were expected to be experienced. Monitoring took place between September 2015 and November 2016.

Monitoring found no evidence that quarry dust emissions were resulting in pollutant levels in the community that would lead to adverse health effects. Levels of PM_{10} (particles less than 10 micrometres in diameter), $PM_{2.5}$ (particles less than 2.5 micrometres in diameter), TSP (total suspended particles), respirable crystalline silica and asbestos all complied with relevant air quality guidelines for protection of human health at all monitoring locations during the investigation period.

In relation to the air pollutants of particular concern, respirable crystalline silica concentrations were less than two per cent of the assessment criterion for protection of human health. More than 85 per cent of particle samples contained no crystalline silica. No asbestos was detected in any of the particle samples collected during the investigation.

Dust emissions from quarrying activities did not lead to any exceedences of dust nuisance criteria during the monitoring period. While there were infrequent exceedences of nuisance criteria for TSP and deposited dust, in all cases quarrying activities were found not to be the primary cause of the exceedance. However, extensive dust complaints received by DEHP over two days in July 2016 highlights that the current dust nuisance assessment method based on a monthly average dust deposition rate may not adequately capture nuisance impacts from infrequent high dust episodes that are of relatively short duration.

Contents

List of tables

List of figures

Introduction

Six large quarries operate in the northern Darlington Range region located to the west of Ormeau and south of Yatala in South East Queensland. The quarried rock is used for concrete and asphalt aggregates and crushed road base. Manufactured sand is also produced in substantial volumes. The resource in the northern Darlington Range will provide the main long-term source of aggregates for markets in the Brisbane-Gold Coast growth corridor, and has been identified as a Key Resource Area under the *State Planning Policy 2/07 – Protection of Extractive Resources*[1].

The geological composition of the Ormeau/Yatala area in which these quarries exist consist of regionally metamorphosed sedimentary and volcanic rocks containing siliceous compounds. It is therefore expected that dust from quarrying operations in this area may include crystalline silica, however it is important to note that only respirable crystalline silica (i.e. found in particles less than 4 micrometres in diameter) is associated with adverse human health effects. The non-fibrous form of actinolite (acicular actinolite) is also present in trace amounts[2]. While the fibrous form of actinolite (asbestiform actinolite) is an asbestos material, acicular actinolite poses a low risk to human health and is not considered hazardous.

The Department of Environment and Heritage Protection (DEHP) regulates emissions to air, land and water from industrial activities designated as Environmentally Relevant Activities (ERAs) through conditions attached to development approvals issued in accordance with the *Environmental Protection Act 1994*. When directed by DEHP, industries must monitor air quality to show compliance with these conditions, set to protect sensitive receptors from nuisance and health-related impacts. The six significant quarry operations in the Ormeau/Yatala area hold Environmental Authorities to conduct ERAs, under which they are required to conduct monthly dust deposition monitoring.

In 2014–15, DEHP received numerous complaints from Yatala residents and the Yatala Residents Association regarding silica and asbestos impacts from these hard rock quarrying activities. Although the dust monitoring conducted by the quarries indicated that the dust deposition criterion was being met, the respirable fraction of any dust emitted (including the amount of respirable crystalline silica) could not be determined.

In response to these concerns, the Ormeau/Yatala air quality monitoring investigation was initiated by the DEHP to obtain data to assess community concern about the impact of quarry dust emissions on air quality and human health in residential areas of Ormeau and Yatala.

DEHP commissioned the Department of Science, Information Technology and Innovation (DSITI) to conduct a monitoring program to gather air quality data at residential sites in the Ormeau/Yatala area that were likely to experience highest impacts from quarrying activities based on proximity and prevailing wind directions. The program was designed to measure levels of deposited dust, suspended particles, and respirable crystalline silica and asbestos. The monitoring program ran from 3 September 2015 to 14 November 2016. This report details the results of the investigation.

[1] available at https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0015/114171/dme-stateplan-policy-1.pdf

[2] Holcim, *Actinolite Questions and answers*, 2015, available at http://www.holcim.com.au/fileadmin/templates/AU/doc/Community_Link/Beenleigh/QAsBeenleighActinolite.pdf

Monitoring program design

Impacts of airborne particles are closely related to particle size. Human health effects are generally associated with particles less than 10 micrometres (µm) in diameter (called PM_{10}) which are small enough to be inhaled in to the lower respiratory tract. Of the total PM_{10} fraction of airborne particles, particles less than 2.5 µm in diameter (called $PM_{2.5}$) are now understood to be the primary size fraction of concern with regard to adverse human health effects. Airborne particles larger than 10 µm in diameter are generally associated with impacts on amenity (e.g. dust nuisance).

PM_{10} may be generated by both combustion processes (e.g. motor vehicle engines) and mechanical processes (e.g. rock crushing and windblown dust). While $PM_{2.5}$ is primarily formed by combustion processes, emissions from mechanical processes can contain some $PM_{2.5}$.

The composition of these small airborne particles may also be of concern. Of particular relevance to particle emissions from hard rock quarries are silica and asbestos. Silica can exist in both crystalline and non-crystalline forms, with only long-term exposure to crystalline silica particles in the respirable size fraction (less than 4 µm in size) being associated with adverse health effects. Silicate materials can also exist in fibrous and non-fibrous forms. Asbestos is the term for six naturally occurring fibrous silicate materials that, when inhaled, may lead to adverse human health effects. When bonded with other materials (e.g. cement) and undisturbed, asbestos generally does not pose a risk to human health.

DSITI's air quality monitoring program in the Ormeau/Yatala area was conducted over a 14-month period, from September 2015 to November 2016. To assess the potential for human health impacts, the monitoring program collected information on levels of:

- respirable crystalline silica
- particles less than 10 µm in diameter (PM_{10})
- particles less than 2.5 µm in diameter ($PM_{2.5}$)
- asbestos

To assess the potential for dust nuisance impacts, the monitoring program collected information on levels of:

- total suspended particles (TSP)
- deposited dust

Measurement of local meteorology (wind speed and direction, rainfall) was also undertaken to assist with assessment of possible sources of monitored particle levels and contributing factors.

Assessment criteria

In this study, assessment of possible health and amenity effects associated with particle levels and composition was conducted by comparing measured levels against recognised ambient air quality criteria. These criteria are summarised in Table 1.

Table 1. Air quality assessment criteria.

Pollutant	Criteria	Averaging period	Criteria source
Crystalline silica	3 µg/m³	Annual	EPA Victoria
PM_{10}	50 µg/m³	24-hour	EPP Air and AAQ NEPM
	25 µg/m³	Annual	AAQ NEPM
$PM_{2.5}$	25 µg/m³	24-hour	EPP Air and AAQ NEPM
	8 µg/m³	Annual	EPP Air and AAQ NEPM
TSP	90 µg/m³	Annual	EPP Air
	60 µg/m³† 200 µg/m³†	24-hour 1-hour	NZ MfE
Deposited dust	120 mg/m² per day	Month	DEHP
Asbestos	0.1 fibres/mL	8-hour time-weighted average*	Safe Work Australia

EPA Victoria = Environment Protection Authority Victoria
EPP Air = Queensland Environmental Protection (Air) Policy 2008
AAQ NEPM = Commonwealth National Environment Protection (Ambient Air Quality) Measure
NZ MfE = New Zealand Ministry for the Environment
† applicable to high sensitivity receiving environments such as residential areas

While there are standards for occupational exposure, there are no Queensland or national criteria for ambient (i.e. in the community) respirable crystalline silica concentrations. In the absence of Queensland or national criteria for crystalline silica, measured respirable (as $PM_{2.5}$) crystalline silica concentrations in the Ormeau/Yatala area were compared against the annual assessment criterion in EPA Victoria's *Protocol for Environmental Management: Mining and Extractive Industries (PEMMEI)*.[3] The criterion in this document was adopted from the California EPA Office for Environmental Health Hazard Assessment Reference Exposure Levels (RELs) for respirable crystalline silica.

24-hour PM_{10}, and 24-hour average and annual average $PM_{2.5}$ concentrations were compared with air quality objectives in the Queensland Environmental Protection (Air) Policy 2008 (EPP Air)[4]. Annual average PM_{10} concentrations were compared with the air quality standard in the Commonwealth National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM).[5]

Annual average TSP concentrations were compared with the EPP Air objective for assessment of human health risk. TSP is, however, mainly associated with dust nuisance impacts. Dust nuisance can be experienced at TSP levels below the health protection criterion, with the result that guidelines designed for avoidance of dust nuisance are set at lower levels and for shorter averaging periods. There are no Queensland or national TSP dust nuisance guidelines, so the high sensitivity receiving environment dust nuisance trigger levels for 24-hour and one-hour average TSP concentrations provided in the New Zealand Ministry for the Environment (NZ MfE) document

[3] EPA Victoria, *Protocol for Environmental Management: Mining and Extractive Industries (PEMMEI)*, Publication 1191, Victoria, Australia, December 2007, available at http://www.epa.vic.gov.au/our-work/publications/publication/2007/december/1191

[4] available at https://www.legislation.qld.gov.au/LEGISLTN/CURRENT/E/EnvProtAirPo08.pdf

[5] available at https://www.legislation.gov.au/Details/F2016C00215

Good practice guide for assessing and managing the environmental effects of dust emissions[6], as recommended by DEHP[7] have been used to assess dust nuisance potential in this investigation. The MZ MfE document applies the high sensitivity criteria to residential areas.

The dust deposition limit value commonly applied to environmentally relevant activities by DEHP[8] was used to assess the potential for nuisance dust impacts resulting from measured levels of deposited dust.

The results of asbestos monitoring at Ormeau and Yatala were compared with Safe Work Australia's Workplace Exposure Standards for Airborne Contaminants.[9]

Monitoring data collection methods

$PM_{2.5}$ and crystalline silica filter-based monitoring

In this study crystalline silica concentrations were determined from $PM_{2.5}$ samples collected over seven-day periods. Collection of filter samples over seven-day periods was necessary to collect sufficient $PM_{2.5}$ material for the crystalline silica laboratory analysis method.

It was necessary in this investigation to use ambient particle samplers designed for ongoing outdoor use, which were not capable of collecting the respirable particle fraction (particles less than 4 µm in diameter, or PM_4) commonly sampled in occupational exposure monitoring, but instead collected particles less than 2.5 µm in diameter, or $PM_{2.5}$. The measured $PM_{2.5}$ crystalline silica concentrations were compared with EPA Victoria's PEMMEI criterion for crystalline silica present in $PM_{2.5}$, which has been set at a level that provides equivalent protection to respirable crystalline silica guidelines.

Seven-day sampling was conducted using Partisol® Model 2025 sequential low-volume air samplers operated in accordance with the Australian/New Zealand Standard *AS/NZS 3580.9.10:2006 Method 9.10: Determination of suspended particulate matter—$PM_{2.5}$ low-volume sampler—Gravimetric method*. These samplers drew air through a $PM_{2.5}$ size-selective inlet (which removed particles larger than $PM_{2.5}$) and then through pre-weighed 47 millimetre diameter Teflon® filters over a seven-day period. The sampler automatically inserted a new pre-weighed filter in the air stream every seven days. The filters were weighed again after sampling and the difference in the weight was the mass of the $PM_{2.5}$ particles collected. From this, the mass concentrations of $PM_{2.5}$ were calculated by dividing the mass of collected particles by the volume of air drawn through the sampler.

The $PM_{2.5}$ particles collected on Partisol® sampler filters were analysed for crystalline silica content by infrared spectroscopy using a method based on the NHMRC *Method for Measurement of Quartz in Respirable Airborne Dust by Infrared Spectroscopy and X-Ray Diffractometry*[10] and

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[6] available from http://www.mfe.govt.nz/publications/air/good-practice-guide-assessing-and-managing-environmental-effects-dust

[7] DEHP, *Application requirements for activities with impacts to air*, 2015, available at http://www.ehp.qld.gov.au/assets/documents/regulation/era-gl-air-impacts.pdf

[8] DEHP, *Common conditions – Prescribed environmentally relevant activities*, 2016, available at https://www.ehp.qld.gov.au/assets/documents/regulation/pr-co-common-conditions-prescribed-eras.pdf

[9] available at http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/workplace-exposure-standards

[10] National Health and Medical Research Council, Canberra, ACT, 1984.

NIOSH Method 7602 Silica, Crystalline by IR (KBr pellet)[11]. The crystalline silica analysis was conducted by the NATA-accredited Queensland Government Safety In Mines Testing and Research Station (Simtars) laboratory.

PM_{10}, $PM_{2.5}$ and TSP continuous monitoring

Over the course of the investigation, continuous suspended particle monitoring was conducted using two different methods: TEOM® analysers and DustMasterPro™ instruments.

Continuous PM_{10} and $PM_{2.5}$ measurements were collected at the Yatala monitoring site from 3 September 2015 to 6 May 2016 using a Model 1405-DF dichotomous TEOM® analyser fitted with a Filter Dynamics Measurement System (FDMS) unit, operated in accordance with the Australian/ New Zealand Standard *AS/NXS 3580.9.13:2013 Method 9.13: Determination of suspended particulate matter—$PM_{2.5}$ continuous direct mass method using a tapered element oscillating microbalance analyser*. The TEOM® analyser drew air through a PM_{10} size-selected inlet (which removed particles larger than PM_{10}), then through a very sharp cut cyclone (VSCC) which separated the particle stream into two; one of particles less than 2.5 µm in diameter ($PM_{2.5}$) and the other of particles between 2.5 and 10 µm in diameter ($PM_{2.5-10}$). The separated particle streams then passed through separate filters mounted on vibrating glass tubes. Particle mass was measured by the change in oscillating frequency of each glass tube following particle deposition on the filter. PM_{10} mass was calculated as the sum of simultaneous mass measurements from both particle streams.

Continuous TSP monitoring was conducted at the Yatala monitoring site over the same period using an a Model 1405 TEOM® analyser operated in accordance with the above Australian Standard method, but without an FDMS unit and fitted with a TSP size-selective inlet in place of the PM_{10} inlet.

The TEOM® analysers were removed from the Yatala monitoring site on 7 May 2016 (required for other DSITI monitoring investigations) and a DustMasterPro™ 6000 series instrument was used to continuously monitor PM_{10} only for the remainder of the monitoring investigation. The DustMasterPro™ instrument was operated in accordance with the manufacturer's operating instructions. For the month prior to the removal of the TEOM® analysers, the DustMasterPro™ instrument was operated in conjunction with the TEOM® analysers to ensure data continuity following the change in instrumentation. From 8 July 2016, a second DustMasterPro™ 6000 series instrument was operated at the Ormeau monitoring site to provide continuous PM_{10} measurements at this site.

The DustMasterPro™ instruments measured PM_{10} by first drawing air through a PM_{10} size-selective inlet (which removed particles larger than PM_{10}). Inside the instrument, the air stream was illuminated with the beam from a laser light source, and reflected light scattered by particles in the air stream measured by a detector. The electrical signal from the detector was proportional to the amount of scattered light, which was, in turn, multiplied by an internal calibration factor to give the PM_{10} mass concentration.

Deposited dust monitoring

Levels of deposited dust – the amount of dust that settles out of the air over time – were measured at Ormeau and Yatala using dust deposition gauges, which comprised a funnel and collection

[11] National Institute for Occupational Safety and Health, Issue 3, NIOSH Manual of Analytical Methods (NMAM) Fourth Edition, 2003, available at https://www.cdc.gov/NIOSH/DOCS/2003-154/pdfs/7602.pdf

bottle to catch dust settling over a fixed area (the internal area of the funnel) over a one-month sampling period. Following sampling, the collected dust and rainwater was passed through a sieve to remove any extraneous matter greater than 1 mm in size (e.g. leaves, insects). The sieved sample was separated into insoluble and soluble fractions by filtration and dried, then the dried solids weighed. The results of the dust deposition analysis were expressed as the weight of dried solids per unit of surface area for the sampling period (e.g. mg/m^2/day averaged over a 30-day period).

The insoluble solids were further analysed and identified as:

- ash – the mass of the insoluble portion which remained after heating the sample to a temperature of 850 degrees Celsius for 30 minutes
- combustible matter – the mass of the insoluble portion of particles deposited which was lost on heating the sample to a temperature of 850 degrees Celsius for 30 minutes.

Deposited dust samples were collected and analysed in accordance with the Australian/New Zealand Standard *AS/NZ 3580.10.1:2016 Method 10.1 Determination of particulate matter—Deposited Matter—Gravimetric Method*.

Asbestos sampling

Particle samples for asbestos analysis was collected by residents living in suburbs surrounding the quarries over an eight-hour period when the resident considered they were experiencing dust impacts from quarrying operations. Residents were supplied with a personal air sampling unit (SKC Aircheck Model 224-PCXR8 sampler), together with track-etched membrane filter cowls supplied by the laboratory undertaking the asbestos analysis. The sampling units were configured with a flow rate of 1 L/min, which equated to an air volume of about 500 litres over the eight hour collection period. This sample volume was as recommended by the laboratory to maximise the detection of asbestos fibres. Four particle samples were received for asbestos analysis.

The membrane filters were analysed using Scanning Electron Microscopy (SEM) in accordance with International Organization for Standardization Method: *ISO 14966 – Ambient air – Determination of numerical concentration of inorganic fibrous particles – Scanning electron microscopy method* to count the respirable fibres collected on the filters (respirable fibres are less than 3 µm wide, greater than 5 µm long, and have an aspect ratio of length to width greater than 3:1). The composition of these respirable fibres were then assessed using X-ray Energy Dispersive Spectroscopy (EDS) to identify fibres as organic or inorganic, with additional characterisation of the inorganic fibres.

The reporting limit of detection of the sampling and analysis method was 0.001 fibres per millilitre (f/mL).

The asbestos analysis was conducted by COHLABS in conjunction with Glossop Consultancy. COHLABS is a NATA-accredited laboratory for asbestos identification and airborne fibre counting analysis.

Monitoring site locations

Monitoring site locations were chosen in relatively close proximity to quarrying operations to obtain a measure of the highest concentrations likely to be experienced in residential areas of Yatala and Ormeau. The locations of these monitoring stations in relation to local quarries are shown in Figure 1.

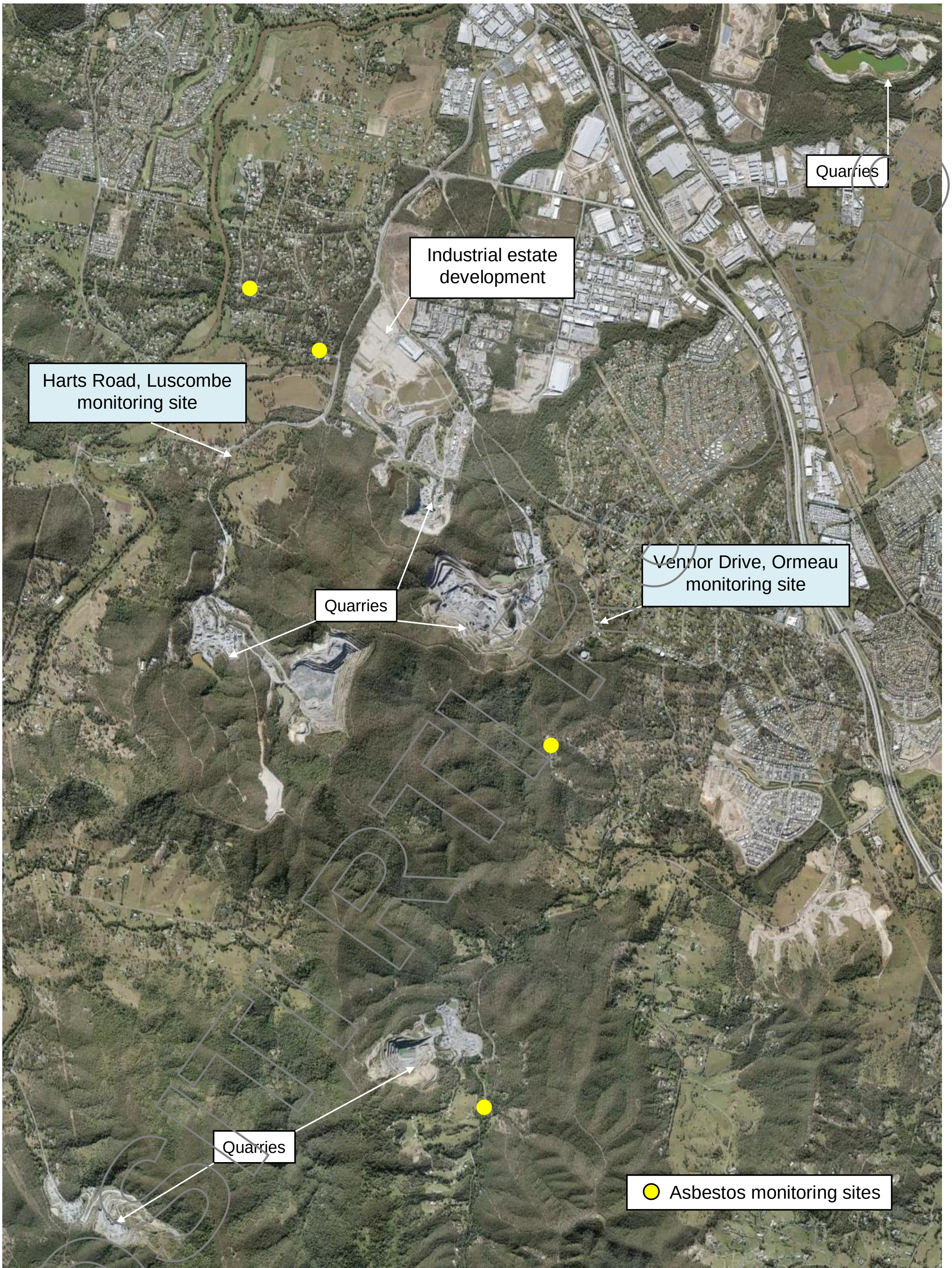

Figure 1. Monitoring site and quarry locations.

For Yatala residential areas, monitoring equipment was sited at a private residence on Harts Road in Luscombe, approximately 1.5km north of the nearest quarry and 150m from the road used by trucks transporting quarry products.

For Ormeau residential areas, monitoring equipment was sited at a private residence on Vennor Drive in Ormeau, approximately 500m east of the nearest quarry.

At both monitoring sites, collection of weekly $PM_{2.5}$ samples for crystalline silica analysis and monthly deposited dust samples were collected.

At the Harts Road, Luscombe monitoring site, continuous measurement of PM_{10}, $PM_{2.5}$, TSP and meteorological parameters was also undertaken (scaled back to just PM_{10} and meteorology from May 2016). The Vennor Drive, Ormeau monitoring was upgraded to include continuous measurement of PM_{10} and meteorology from July 2016.

Asbestos sampling was conducted at four additional residential locations, two in Yatala, one in Ormeau Hills and one in Kingsholme.

Results and discussion

Meteorology

For dust generated at quarries to impact on the Harts Road, Luscombe monitoring site, the wind had to blow from an east to south-west direction. During the monitoring period there were also extensive earthworks associated with the development of an industrial estate taking place approximately 1.5km from the Harts Road, Luscombe monitoring site. During north-east to east winds dust from these earthworks could impact on the monitoring site.

For dust generated at quarries to impact on the Vennor Drive, Ormeau monitoring site, the wind had to blow from a south-west to a north-west direction.

In the assessment of the potential sources of elevated particle concentrations in this report, pollution roses (diagrams showing pollutant concentration frequency and wind direction relationships) and the proportion of winds from the direction of the quarries have been included in the pollutant analyses.

Rainfall can impact particle emissions and concentrations. Rainfall totals during the individual monitoring periods were generally low (predominantly less than 10 mm in any seven-day sampling period), so it is unlikely that particle concentrations would have been significantly affected by rainfall events during the majority of the investigation period. Particle levels monitored during this period are therefore likely to include conditions representative of worst-case scenarios.

Wind direction and rainfall summaries for each seven-day monitoring period at the Harts Road, Luscombe and Vennor Drive, Ormeau monitoring sites are shown in the Appendix to this report.

Crystalline silica

Summary statistics for the seven-day average $PM_{2.5}$ crystalline silica concentrations measured at the Harts Road, Luscombe and Vennor Drive, Ormeau monitoring sites are shown in Table 2. Data for individual seven-day monitoring periods can be found in the Appendix to this report.

Table 2. $PM_{2.5}$ crystalline silica statistics at the Harts Road, Luscombe and Vennor Drive, Ormeau monitoring sites.

Statistic	Harts Road Luscombe	Vennor Drive Ormeau
Monitoring period	3 September 2015 to 2 November 2016	10 September 2015 to 2 November 2016
Number of valid 7-day average values	56 (92%)	60 (100%)
Number of 7-day average values greater than the detection limit value (0.06 µg/m³)	8	5
Maximum 7-day average concentration (µg/m³)	0.13	0.07
Average concentration (µg/m³)*‡	0.04	0.03

* The EPA Victoria Protocol for Environmental Management: Mining and Extractive Industries (PEMMEI) assessment criterion for respirable crystalline silica (as $PM_{2.5}$) is an annual average of 3 µg/m³.

‡ In calculating the average concentration over the monitoring period, a concentration of 0.03 µg/m³ (50% of the detection limit of the sampling and analysis method) has been assumed for those 7-day sampling periods where the crystalline silica concentration was below the detection limit.

Measured $PM_{2.5}$ crystalline silica levels were very low. The maximum seven-day crystalline silica concentrations measured in this study were 0.13 µg/m³ at the Harts Road, Luscombe monitoring site and 0.07 µg/m³ at the Vennor Drive, Ormeau monitoring site. A crystalline silica content above the detection limit of the sampling and analysis method (0.06 µg/m³) was only measured in 14 per cent of samples collected at the Harts Road, Luscombe monitoring site and 8 per cent of samples collected at the Vennor Drive, Ormeau monitoring site.

In the absence of a Queensland or national ambient air quality guideline for crystalline silica, measured concentrations of crystalline silica were compared against the annual assessment criterion of 3 µg/m³ in EPA Victoria's *Protocol for Environmental Management: Mining and Extractive Industries* (PEMMEI). The EPA Victoria criterion is based on crystalline silica present in $PM_{2.5}$.

Average crystalline silica concentrations monitored in this study were less than two per cent of the EPA Victoria criterion. The average crystalline silica concentration measured at the Harts Road, Luscombe monitoring site was 0.04 µg/m³. At the Vennor Drive, Ormeau monitoring site, the average crystalline silica concentration was 0.03 µg/m³.

The monitoring conducted at Harts Road, Luscombe and Vennor Drive, Ormeau demonstrates that dust emissions from local quarry operations contain very low levels of respirable crystalline silica. This finding is in line with that of a previous quarry dust investigation conducted by DSITI at Mount Cotton[12].

Based on the very low levels of respirable crystalline silica relative to the health risk assessment criterion measured in the air at the two monitoring sites in close proximity to quarrying operations, it is not expected that ambient exposure in residential areas in Yatala and Ormeau would lead to adverse health impacts.

[12] available at https://www.qld.gov.au/environment/pollution/monitoring/air-programs/

PM_{10}

Summary statistics for PM_{10} concentrations measured at the Harts Road, Luscombe and Vennor Drive, Ormeau monitoring sites are shown in Table 3.

Table 3. PM_{10} concentration statistics at the Harts Road, Luscombe and Vennor Drive, Ormeau monitoring sites.

Statistic	Harts Road Luscombe	Vennor Drive Ormeau
Monitoring period	3 September 2015 to 14 November 2016	8 July 2016 to 14 November 2016
Number of valid 1-hour average values	10,129 (96%)	2784 (90%)
Number of valid 24-hour average values	422 (96%)	116 (90%)
Maximum 24-hour average concentration (µg/m^3)	37.9	32.2
Exceedences of EPP Air 24-hour objective†	0	0
Average concentration (µg/m^3)‡	12.0	18.9
Exceedences of AAQ NEPM annual standard*	0	0
Median 24-hour average concentration (µg/m^3)	11.2	18.3
Minimum 24-hour average concentration (µg/m^3)	2.3	11.6

† The EPP Air objective (and AAQ NEPM standard) for 24-hour average PM_{10} concentration is 50 µg/m^3.
* The AAQ NEPM standard for annual average PM_{10} concentration is 25 µg/m^3.
‡ Average concentration for the study period calculated from 1-hour average concentrations.

Twenty-four hour average PM_{10} concentrations did not exceed the EPP Air objective at either monitoring site during the period of monitoring at each site.

The average PM_{10} concentration at the Harts Road, Luscombe monitoring site over the study period was less than 50 per cent of the AAQ NEPM annual standard. The average PM_{10} concentration over the four-month period during which PM_{10} monitoring was undertaken at the Vennor Drive, Ormeau monitoring site was also less than the AAQ NEPM annual standard value.

As many processes (both mechanical and combustion-related) can give rise to PM_{10} emissions, the continuous PM_{10} monitoring data from both the Harts Road, Luscombe and Vennor Drive, Ormeau monitoring sites was checked against wind direction to identify potential sources of elevated PM_{10} concentrations. The results of this analysis are displayed below as pollution roses showing the frequency of measured one-hour average PM_{10} concentrations for ten degree wind direction ranges (direction being where the wind is blowing from).

Pollution roses for one-hour average PM_{10} concentrations at the Harts Road monitoring site are shown in Figure 2 and Figure 3. The pollution rose in Figure 2 includes PM_{10} concentrations for the whole of the study period. The pollution rose in Figure 3**Error! Reference source not found.** ncludes only PM_{10} concentrations measured during the hours of operation of the quarries (7am to 5pm, Monday to Friday). The red lines in the two figures indicate the wind direction range where quarry dust emissions could impact on the Harts Road, Luscombe monitoring site. The black vertical scale indicates the percentage of total measurements.

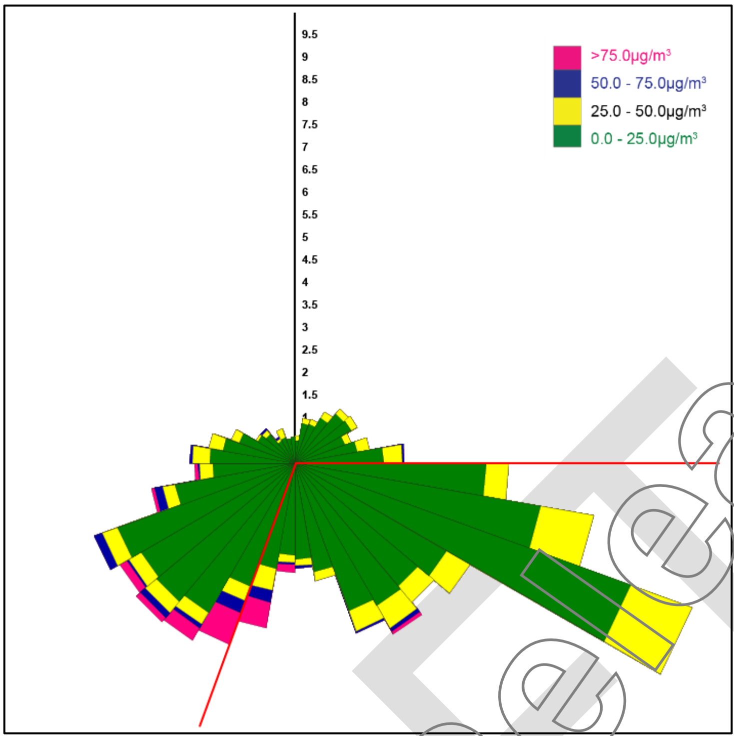

Figure 2. PM_{10} pollution rose for the Harts Road, Luscombe monitoring site for all hours during the monitoring period.

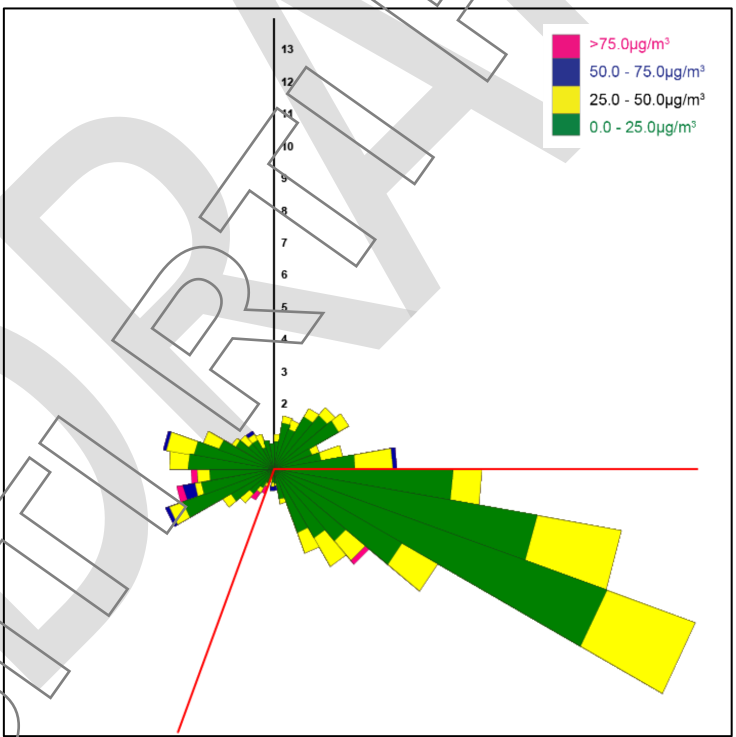

Figure 3. PM_{10} pollution rose for the Harts Road, Luscombe monitoring site during quarry operating hours (7am-5pm, Monday–Friday).

These pollution roses show that during the period from September 2015 to November 2016 winds blew predominantly from the south to south-east, while the highest one-hour average PM_{10} concentrations at the Harts Road, Luscombe monitoring site occurred during south to south-westerly winds. Comparison of Figure 2 (all hours) with Figure 3 (quarry operating hours only) indicates that the majority of the elevated one-hour average PM_{10} concentrations (>50 µg/m^3)

occurred outside of quarry operating hours and were therefore due to sources other than quarrying activities. Other possible PM_{10} sources contributing to these elevated concentrations could have been windblown dust from dry ground and vegetation burning.

In Figure 3 the spread of one-hour average PM_{10} concentrations observed for wind directions associated with quarry dust emissions is similar to that seen for non-quarry wind directions. This indicates that for the Harts Road, Luscombe monitoring site (located greater than 1.5 km from quarrying operations) PM_{10} impacts resulting from quarrying activities are comparable to those coming from other PM_{10} sources.

Corresponding pollution roses for one-hour average PM_{10} concentrations at the Vennor Drive, Ormeau monitoring site are shown in Figure 4 and Figure 5. The pollution rose in Figure 4 includes PM_{10} concentrations for the whole period PM_{10} monitoring was undertaken at the site, and shows that during this period winds blew predominantly from either the east or the west. Elevated one-hour average PM_{10} concentrations (>50 µg/m^3) occurred mainly during winds from the west, but also on winds from the east and south to a lesser extent. This suggests that a variety of sources, including quarries, windblown dust, vehicles, vegetation burning, domestic and commercial sources, contribute to overall PM_{10} concentrations.

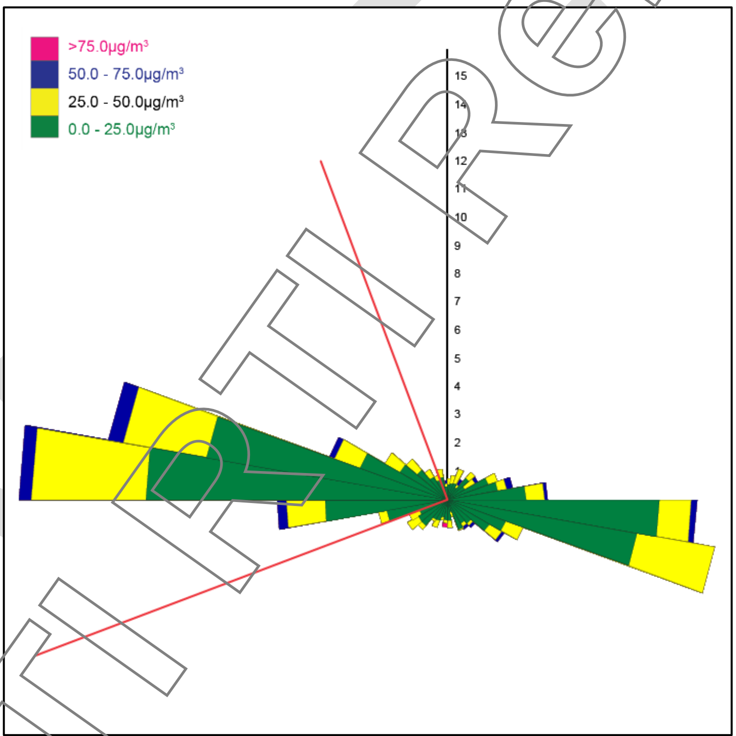

Figure 4. PM_{10} pollution rose for the Vennor Drive, Ormeau monitoring site for all hours during the PM_{10} monitoring period.

The pollution rose in Figure 5 includes only PM_{10} concentrations measured during the hours of operation of the quarries (7am to 5pm, Monday to Friday). Within these periods one-hour average PM_{10} concentrations greater than 25 µg/m^3 were highly correlated with winds from the west, indicating that quarry dust emissions made up a significant proportion of overall PM_{10} at the Vennor Drive, Ormeau monitoring site when quarry activities were taking place. This result is likely to be influenced to a significant degree by the local topography and proximity to the closest quarry of this monitoring site (located on a ridge overlooking the quarry approximately 500m away). Residential areas in Ormeau further from the quarries and below the ridge line are expected to experience lesser impacts from quarry dust emissions.

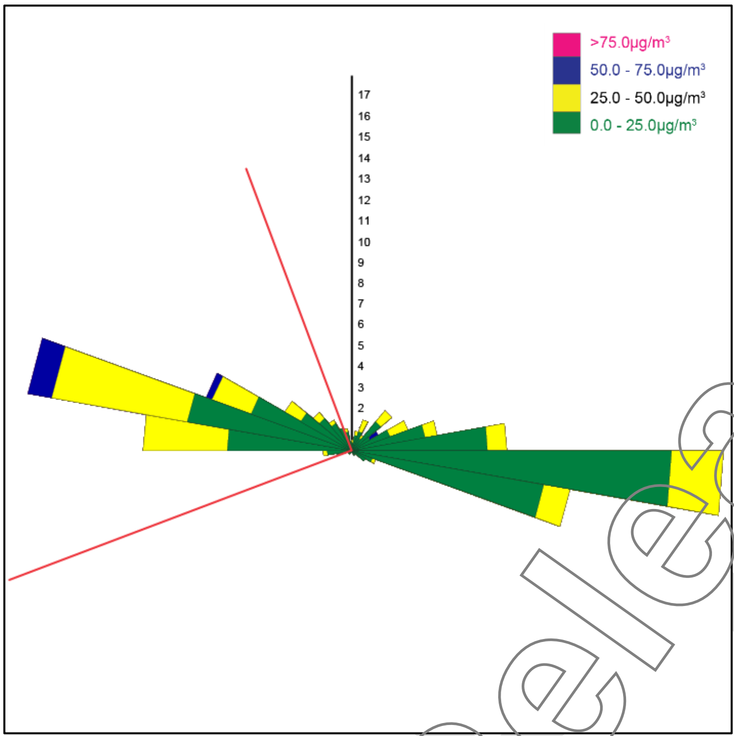

Figure 5. PM_{10} pollution rose for the Vennor Drive, Ormeau monitoring site during quarry operating hours (7am–5pm, Monday–Friday).

While the monitoring data points to quarry operations noticeably impacting on PM_{10} concentrations at the Vennor Drive, Ormeau monitoring site, quarry dust emissions did not cause PM_{10} concentrations to exceed air quality guideline values during the monitoring period.

$PM_{2.5}$

Summary statistics for $PM_{2.5}$ concentrations measured at the Harts Road, Luscombe and Vennor Drive, Ormeau monitoring sites are shown in Table 4.

Assessment of $PM_{2.5}$ levels against the EPP Air 24-hour objective was only possible at the Harts Road, Luscombe site during the eight-month period the TEOM® instrument was located at this site (September 2015 to May 2016). No exceedances of the EPP Air objective for 24-hour average $PM_{2.5}$ concentrations were measured during this period.

The seven-day $PM_{2.5}$ concentration data collected by the Partisol® samplers over the period September 2015 to November 2016 was used to assess compliance with the EPP Air annual objective. The average $PM_{2.5}$ concentrations at the Harts Road, Luscombe and Vennor Drive, Ormeau monitoring sites (as measured by the Partisol® samplers) over the monitoring period were 56 per cent and 54 per cent respectively of the EPP Air annual objective.

Local quarry operations did not lead to levels of $PM_{2.5}$ above guideline values at the two monitoring sites during the monitoring period. This is in line with the general understanding that dust emissions from mechanical processes such as blasting and rock crushing predominantly contain particles larger than 2.5 µm in size.

Table 4. $PM_{2.5}$ concentration statistics at the Harts Road, Luscombe and Vennor Drive, Ormeau monitoring sites.

Statistic	Harts Road, Luscombe		Vennor Drive, Ormeau
Monitoring instrument	TEOM®	Partisol®	Partisol®
Monitoring period	3 September 2015 to 5 May 2016	3 September 2015 to 2 November 2016	10 September 2015 to 2 November 2016
Number of 1-hour average values	5875 (99%)	n/a	n/a
Number of 24-hour average values	245 (99%)	n/a	n/a
Maximum 24-hour average concentration (µg/m³)	13.9	n/a	n/a
Exceedences of EPP Air 24-hour objective†	0	n/a	n/a
Median 24-hour average concentration (µg/m³)	5.7	n/a	n/a
Minimum 24-hour average concentration (µg/m³)	2.0	n/a	n/a
Number of 7-day average values	n/a	56 (92%)	60 (100%)
Maximum 7-day average concentration (µg/m³)	n/a	16.0	8.6
Average concentration (µg/m³)	5.0‡	4.5	4.3
Exceedences of EPP Air annual average objective value*	0	0	0

n/a = not applicable
† The EPP Air objective (and AAQ NEPM standard) for 24-hour average $PM_{2.5}$ concentration is 25 µg/m³.
* The EPP Air objective (and AAQ NEPM standard) for annual average $PM_{2.5}$ concentration is 8 µg/m³.
‡ Average concentration for the monitoring period calculated from 1-hour average concentrations.

TSP

Summary statistics for TSP concentrations measured at the Harts Road, Luscombe monitoring site between September 2015 and May 2016 are shown in Table 5.

The New Zealand Ministry for the Environment has developed guidelines for TSP to trigger when action to control dust is needed to minimise offsite impacts. For high sensitivity receiving environments such as residential areas, a trigger level of 200 µg/m³ over a one-hour period and 60 µg/m³ over a 24 hour period have been suggested. At the Harts Road, Luscombe monitoring site, TSP levels complied with the one-hour trigger level for the entire monitoring period, except for a two-hour period on 11 April 2016. The 24-hour dust trigger level was also exceeded on this day. The elevated TSP concentrations on this day occurred during southerly winds, which is consistent with possible impact from quarry dust emissions. However, as the high TSP levels were measured between 5:00pm and 10:00pm it is likely that another source was responsible.

Table 5. TSP concentration statistics at the Harts Road, Luscombe monitoring site.

Statistic	Harts Road, Luscombe
Monitoring period	3 September 2015 to 5 May 2016
Number of 1-hour average values	5843 (99%)
Number of 24-hour average values	245 (99%)
Maximum 1-hour average concentration (µg/m³)	491.8
Exceedences of NZ MfE 1-hour dust nuisance trigger value+	2
Maximum 24-hour average concentration (µg/m³)	71.7
Exceedences of NZ MfE 24-hour dust nuisance trigger value†	1
Median 24-hour average concentration (µg/m³)	22.2
Minimum 24-hour average concentration (µg/m³)	6.1
Average concentration (µg/m³)‡	23.7
Exceedences of EPP Air annual objective*	0

+ The NZ MfE criterion for 1-hour TSP concentrations is 200 µg/m³.
† The NX MfE criterion for 24-hour average TSP concentrations is 80 µg/m³.
* The EPP Air objective for annual average TSP concentrations is 90 µg/m³.
‡ Average concentration for the study period calculated from 1-hour average concentrations.

Based on the dust nuisance assessment criteria used and the monitoring results, levels of suspended particles generated by quarry activities would not be considered to constitute a dust nuisance at distances from quarry operations comparable to that of the Harts Road, Luscombe monitoring site (greater than 1.5km).

Although a full year of data was not collected, the average TSP concentration over the eight-month monitoring period was just 26 per cent of the EPP Air annual average objective of 90 µg/m³, indicating that long-term TSP exposure at the monitoring location would almost certainly be below the objective for protection of human health.

Deposited dust

Monthly deposited dust levels measured at the Harts Road, Luscombe monitoring site are displayed in Figure 6 and collated in The DEHP guideline was exceeded at the Harts Road, Luscombe monitoring site in November 2015 only. During this sampling period, about half of all winds blew from the direction of the quarries. In Figure 6 it can be seen that this sample contained a significantly higher than usual amount of combustible matter, while the ash content, although slightly elevated, was still well below the DEHP guideline value. This indicates that quarry dust emissions were not the major reason for the exceedance of the DEHP guideline. In other dust deposition monitoring undertaken by DSITI, a similar elevated combustible matter content at the same time of year was found to be due to high levels of plant material in the deposited dust, possibly from an annual flowering event.

The DEHP guideline was exceeded at the Vennor Drive, Ormeau monitoring in March 2016 only. While this sample had a very high ash content indicative of quarry dust contribution, the proportion of winds blowing from the direction of the quarries was very low – only six per cent of the sampling period (see Table 7). For this result to have been caused by quarry dust emissions, dust levels during the times winds blew from the direction of the quarries would have been extremely high and dust complaints would have been expected. As no complaints were received by DEHP during this period, other dust sources (most likely in the immediate vicinity of the sampler) were considered to have been responsible.

Table 6. Corresponding data for the Vennor Drive, Ormeau monitoring site are displayed in Figure 7 and collated in Table 7. In Figures 6 and 7 the ash and combustible matter content of the collected insoluble solids is shown by the divisions in each column. Being rock in origin, dust from quarrying operations would appear in the ash fraction of the insoluble solids.

At both locations average insoluble dust deposition rates were typically less than half the DEHP guideline value. The ash content (indicative of quarry contributions) was typically less than 30 per cent of the DEHP guideline.

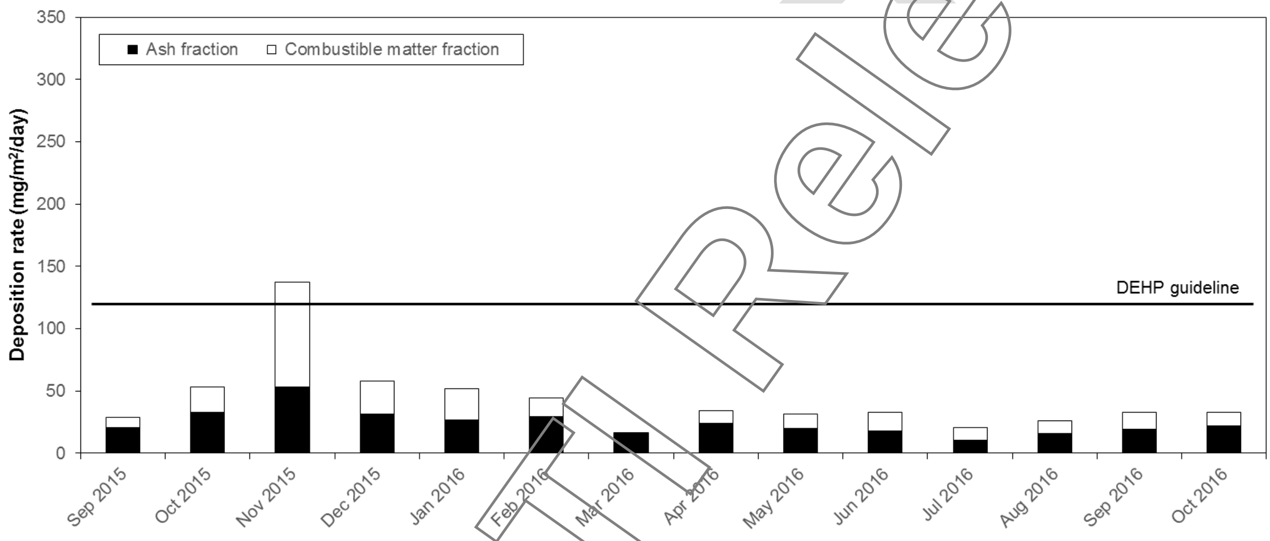

Figure 6. Insoluble dust deposition rates at the Harts Road, Luscombe monitoring site.

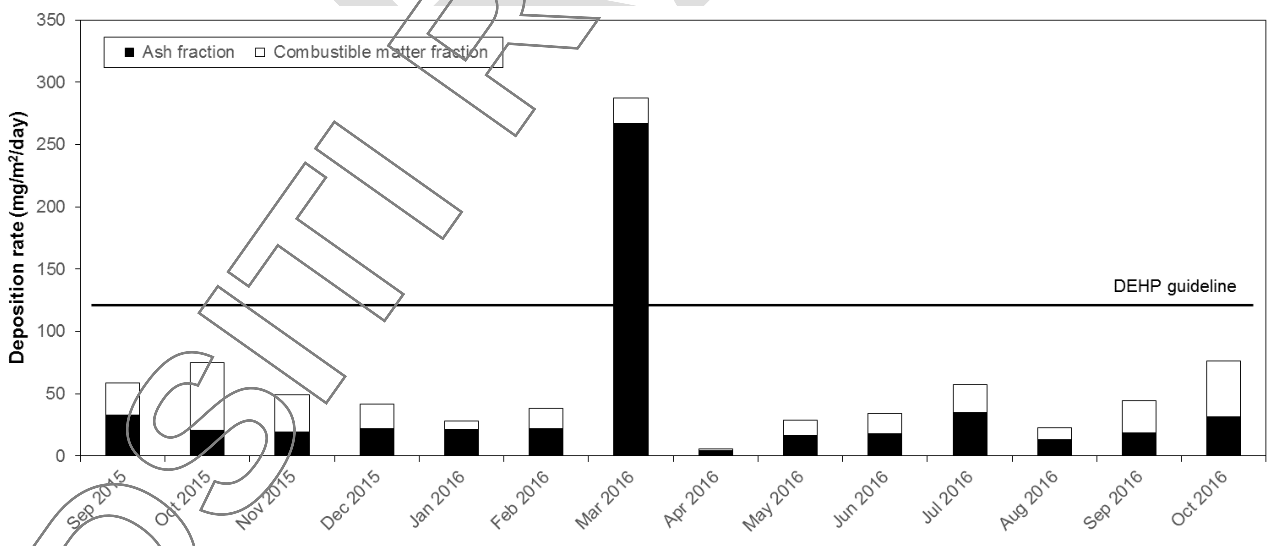

Figure 7. Insoluble dust deposition rates at the Vennor Drive, Ormeau monitoring site.

The DEHP guideline was exceeded at the Harts Road, Luscombe monitoring site in November 2015 only. During this sampling period, about half of all winds blew from the direction of the quarries. In Figure 6 it can be seen that this sample contained a significantly higher than usual amount of combustible matter, while the ash content, although slightly elevated, was still well below the DEHP guideline value. This indicates that quarry dust emissions were not the major reason for the exceedance of the DEHP guideline. In other dust deposition monitoring undertaken by DSITI, a similar elevated combustible matter content at the same time of year was found to be due to high levels of plant material in the deposited dust, possibly from an annual flowering event[13].

The DEHP guideline was exceeded at the Vennor Drive, Ormeau monitoring in March 2016 only. While this sample had a very high ash content indicative of quarry dust contribution, the proportion of winds blowing from the direction of the quarries was very low – only six per cent of the sampling period (see Table 7). For this result to have been caused by quarry dust emissions, dust levels during the times winds blew from the direction of the quarries would have been extremely high and dust complaints would have been expected. As no complaints were received by DEHP during this period, other dust sources (most likely in the immediate vicinity of the sampler) were considered to have been responsible.

Table 6. Deposited dust levels monitored at the Harts Road monitoring site, September 2015 to October 2016.

Month	Deposited dust at Harts Road, Luscombe (mg/m²/day)			Proportion of winds from quarries (%)	Rainfall (mm)
	Insoluble solids*	Ash	Combustible matter		
September 2015	29	20	8	41	26.2
October 2015	53	33	20	52	22.8
November 2015	**137**	53	84	48	91.2
December 2015	58	31	27	54	41.1
January 2016	52	26	26	52	23.2
February 2016	45	30	15	71	74.3
March 2016	17	15	1	67	24.7
April 2016	34	24	10	56	21.8
May 2016	31	20	12	28	0.9
June 2016	33	18	15	30	121.9
July 2016	20	10	10	26	16.4
August 2016	26	16	10	38	18.3
September 2016	33	19	14	38	21.4
October 2016	33	22	11	40	29.6

* Deposited dust levels above the DEHP guideline are shown in **bold** text.
The DEHP guideline for deposited dust is 120 mg/m²/day, averaged over 1 month.

13 DSITI, *Western-Metropolitan Rail System Phase 2 Coal Dust Monitoring Program. Phase 2 monitoring report: February 2014 to December 2015*, 2016, available at http://www.ehp.qld.gov.au/management/coal-dust/pdf/phase2-rail-coal-dust-monitoring-report-feb2014-dec2015.pdf

Table 7. Deposited dust levels monitored at the Vennor Drive monitoring site, September 2015 to October 2016.

Month	Deposited dust at Harts Road, Luscombe (mg/m²/day)			Proportion of winds from quarries (%)	Rainfall (mm)
	Insoluble solids*	Ash	Combustible matter		
September 2015	58	33	25	17	26.2
October 2015	75	21	54	7	22.8
November 2015	49	19	30	14	91.2
December 2015	41	22	20	8	41.1
January 2016	28	21	7	10	23.2
February 2016	38	22	16	5	74.3
March 2016	**287**	267	21	6	24.7
April 2016	6	4	2	8	21.8
May 2016	29	17	12	21	0.9
June 2016	34	18	16	34	121.9
July 2016	57	35	23	54	16.4
August 2016	23	13	10	45	18.3
September 2016	44	18	26	45	21.4
October 2016	76	31	45	38	29.6

* Deposited dust levels above the DEHP guideline are shown in **bold** text.
The DEHP guideline for deposited dust is 120 mg/m²/day, averaged over 1 month.

The dust deposition monitoring results indicate that quarry dust emissions did not cause exceedences of the dust nuisance assessment criterion at the two monitoring sites during the period from September 2015 to October 2016. However, it is recognised that dust nuisance impacts from quarries often relate to short-duration episodes of high dust levels which may not be captured in an assessment method based on a monthly average deposition rate if dust levels are low at other times during the sampling period. A case in point is the July 2016 result for the Vennor Drive, Ormeau monitoring site. DEHP received a number of complaints of dust nuisance from Vennor Drive residents during westerly winds over a two day period, yet average dust deposition over the whole month was only 48 per cent of the DEHP guideline.

Asbestos

In this investigation sampling for airborne asbestos was undertaken by residents living in suburbs surrounding the quarries. Residents were supplied with a personal sampling pump and specially prepared membrane collection filter, and asked to operate the sampler when they considered quarry dust impacts were being experienced. A total of four particle samples were received for testing for the presence of asbestiform minerals. The results of the particle sample analysis are shown in Table 8.

Table 8. Asbestos monitoring results.

Sample location	Concentration (fibres/mL)*	Respirable fibres detected	
		Count	Composition
Glen Osmond Road, Yatala	<0.001	8	mica (×5), quartz (×2), halite
Enkleman Road, Yatala	<0.001	4	mica (×3), actinolite
The Plateau, Ormeau Hills	<0.001	3	mica, organic, chlorite
Upper Ormeau Road, Kingsholme	<0.001	4	mica (×2), quartz, halite

* The Safe Work Australia criterion for asbestos is 0.1 fibres/mL.

No asbestos materials were detected in any of the four particle samples collected in residential areas surrounding the quarries.

One of the particle samples collected in Yatala was found to contain a cleavage fragment of non-asbestiform actinolite. This non-fibrous form of actinolite is present in trace amounts in the rock quarried in the Ormeau and Yatala areas[14].

The other types of respirable fibres detected in the particle samples were consistent with inorganic minerals that could be expected in a suburban housing environment.

In all particle samples the concentration of respirable fibres was below the reporting limit of detection of 0.001 fibres/mL. This concentration is less than 1/100th of the Safe Work Australia eight-hour exposure standard.

[14] Holcim, *Actinolite Questions and answers*, 2015, available at http://www.holcim.com.au/fileadmin/templates/AU/doc/Community_Link/Beenleigh/QAsBeenleighActinolite.pdf

Conclusions

In relation to the main objective of the investigation – to determine if air pollutant levels at residential locations in Ormeau and Yatala were likely to impact on human health – the monitoring results obtained between September 2015 and November 2016 found no evidence that this would be the case. Levels of PM_{10}, $PM_{2.5}$, TSP, respirable crystalline silica and asbestos all complied with relevant air quality guidelines for protection of human health at all monitoring sites.

Measured PM_{10} concentrations did not exceed 76 per cent of the EPP Air 24-hour objective and 73 per cent of the AAQ NEPM annual standard. Annual and maximum 24-hour $PM_{2.5}$ concentrations were both only 56 per cent of the EPP Air objectives. The average TSP concentration at the Harts Road, Luscombe monitoring site was just 26 per cent of the EPP Air annual objective.

Average $PM_{2.5}$ crystalline silica concentrations measured at the Yatala and Ormeau monitoring sites were both less than two per cent of the EPA Victoria annual assessment criterion. The highest seven-day average concentration recorded during the 14-month investigation period was just 0.13 $\mu g/m^3$ (or 4.3 per cent of the annual criterion). Crystalline silica was only detected in 14 per cent of weekly samples at the Harts Road, Luscombe monitoring site and 8 per cent of weekly samples at the Vennor Drive, Ormeau monitoring site.

No asbestos was detected in the particle samples collected at residential sites during this investigation.

The relationship between one-hour average PM_{10} concentrations and wind direction demonstrated a definite contribution from quarrying operations to PM_{10} levels at the Vennor Drive, Ormeau monitoring site during winds blowing from the direction of the quarries. However, at the Harts Road, Luscombe monitoring site which was located further from quarrying activities, PM_{10} concentrations measured during winds coming from the direction of the quarries were comparable to those measured on other wind directions. This suggests that in terms of PM_{10} exposure, quarry dust emissions are only likely to be significant for residents living in close proximity to quarries, such as residents of Vennor Drive, Ormeau located on the ridge line overlooking one of the quarries. For the majority of Yatala and Ormeau residents living further from the quarries, PM_{10} exposure from quarry emissions would be unlikely to be any greater than that from other urban PM_{10} sources.

The monitoring also determined that quarrying activities did not result in exceedences of the criteria commonly used that assess dust nuisance potential at the two monitoring locations during the investigation period. While there were infrequent exceedences of TSP and deposited dust criteria, in all cases quarrying activities were found not to be the primary cause of the exceedance. However, complaints about quarry dust impacts from Vennor Drive, Ormeau residents in July 2016 highlights that the dust nuisance assessment method based on a monthly average dust deposition rate may not adequately capture nuisance impacts from infrequent high dust episodes that are of relatively short duration.

Appendix

Table 9. Seven-day average $PM_{2.5}$ crystalline silica concentration monitoring results at the Harts Road, Luscombe monitoring site, 3 September 2015 to 2 November 2016.

Weekly sampling period	Harts Road, Luscombe		
	7-day average $PM_{2.5}$ crystalline silica concentration* (µg/m³)	Proportion of winds from direction of quarries (%)	Rainfall during sampling period (mm)
3 Sep to 9 Sep 2015	**0.06**	34	5.0
10 Sep to 16 Sep 2015	<0.06	49	6.3
17 Sep to 23 Sep 2015	<0.06	52	11.7
24 Sep to 30 Sep 2015	<0.06	32	3.2
1 Oct to 7 Oct 2015	<0.06	30	0.0
8 Oct to 14 Oct 2015	<0.06	58	5.7
15 Oct to 21 Oct 2015	<0.06	58	0.0
22 Oct to 28 Oct 2015	<0.06	54	17.1
29 Oct to 4 Nov 2015	<0.06	51	58.2
5 Nov to 11 Nov 2015	<0.06	63	25.2
12 Nov to 18 Nov 2015	<0.06	53	6.6
19 Nov to 25 Nov 2015	<0.06	39	1.1
26 Nov to 2 Dec 2015	<0.06	39	4.4
3 Dec to 9 Dec 2015	**0.06**	58	0.0
10 Dec to 16 Dec 2015	<0.06	54	4.6
17 Dec to 23 Dec 2015	<0.06	52	0.8
24 Dec to 30 Dec 2015	<0.06	57	13.9
31 Dec to 6 Jan 2016	<0.06	61	22.1
7 Jan to 13 Jan 2016	<0.06	52	0.6
14 Jan to 20 Jan 2016	<0.06	56	0.1
21 Jan to 27 Jan 2016	<0.06	57	3.2
28 Jan to 3 Feb 2016	<0.06	26	14.0
4 Feb to 10 Feb 2016	<0.06	82	2.1
11 Feb to 17 Feb 2016	<0.06	70	2.8
18 Feb to 24 Feb 2016	<0.06	74	1.3
25 Feb to 2 Mar 2016	<0.06	80	56.5
3 Mar to 9 Mar 2016	<0.06	83	15.7
10 Mar to 16 Mar 2016	<0.06	84	18.4
17 Mar to 23 Mar 2016	<0.06	63	0.7

Table 9 (cont.). Seven-day average $PM_{2.5}$ crystalline silica concentration monitoring results at the Harts Road, Luscombe monitoring site, 3 September 2015 to 2 November 2016.

Weekly sampling period	Harts Road, Luscombe		
	7-day average $PM_{2.5}$ crystalline silica concentration* (µg/m³)	Proportion of winds from direction of quarries (%)	Rainfall during sampling period (mm)
24 Mar to 30 Mar 2016	<0.06	34	2.2
31 Mar to 6 Apr 2016	<0.06	53	0.0
7 Apr to 13 Apr 2016	**0.06**	40	0.4
14 Apr to 20 Apr 2016	<0.06	55	2.0
21 Apr to 27 Apr 2016	<0.06	71	0.7
28 Apr to 4 May 2016	<0.06	46	18.7
5 May to 11 May 2016	**0.13**	37	0.0
12 May to 18 May 2016	Sampling fault	21	0.0
19 May to 25 May 2016	**0.06**	35	0.0
26 May to 1 Jun 2016	<0.06	23	0.1
2 Jun to 8 Jun 2016	**0.06**	29	62.3
9 Jun to 15 Jun 2016	<0.06	54	3.2
16 Jun to 22 Jun 2016	**0.06**	23	52.5
23 Jun to 29 Jun 2016	<0.06	11	0.5
30 Jun to 6 Jul 2016	Sampling fault	16	4.2
7 Jul to 13 Jul 2016	<0.06	21	0.0
14 Jul to 20 Jul 2016	<0.06	55	4.0
21 Jul to 27 Jul 2016	**0.06**	15	0.0
28 Jul to 3 Aug 2016	Sampling fault	23	12.5
4 Aug to 10 Aug 2016	<0.06	48	3.2
11 Aug to 17 Aug 2016	<0.06	46	0.3
18 Aug to 24 Aug 2016	<0.06	35	14.0
25 Aug to 31 Aug 2016	<0.06	27	0.0
1 Sep to 7 Sep 2016	<0.06	49	7.0
8 Sep to 14 Sep 2016	Sampling fault	48	6.9
15 Sep to 21 Sep 2016	<0.06	17	7.0
22 Sep to 28 Sep 2016	Sampling fault	25	0.1
29 Sep to 5 Oct 2016	<0.06	27	14.8
6 Oct to 12 Oct 2016	<0.06	45	0.1
13 Oct to 19 Oct 2016	<0.06	54	9.9
20 Oct to 26 Oct 2016	<0.06	29	0.0

Table 9 (cont.). Seven-day average $PM_{2.5}$ crystalline silica concentration monitoring results at the Harts Road, Luscombe monitoring site, 3 September 2015 to 2 November 2016.

Weekly sampling period	Harts Road, Luscombe		
	7-day average $PM_{2.5}$ crystalline silica concentration* (µg/m³)	Proportion of winds from direction of quarries (%)	Rainfall during sampling period (mm)
27 Oct to 2 Nov 2016	<0.06	35	5.8

* Samples containing measurable crystalline silica content are shown in bold text.

Table 10. Seven-day average $PM_{2.5}$ crystalline silica concentration monitoring results at the Vennor Drive, Ormeau monitoring site, 10 September 2015 to 2 November 2016.

Weekly sampling period	Vennor Drive, Ormeau		
	7-day average $PM_{2.5}$ crystalline silica concentration* (µg/m³)	Proportion of winds from direction of quarries† (%)	Rainfall during sampling period (mm)*
10 Sep to 16 Sep 2015	<0.06	13	6.3
17 Sep to 23 Sep 2015	<0.06	14	11.7
24 Sep to 30 Sep 2015	<0.06	15	3.2
1 Oct to 7 Oct 2015	<0.06	10	0.0
8 Oct to 14 Oct 2015	<0.06	7	5.7
15 Oct to 21 Oct 2015	<0.06	5	0.0
22 Oct to 28 Oct 2015	<0.06	9	17.1
29 Oct to 4 Nov 2015	<0.06	11	58.2
5 Nov to 11 Nov 2015	<0.06	11	25.2
12 Nov to 18 Nov 2015	<0.06	8	6.6
19 Nov to 25 Nov 2015	<0.06	20	1.1
26 Nov to 2 Dec 2015	**0.07**	19	4.4
3 Dec to 9 Dec 2015	<0.06	5	0.0
10 Dec to 16 Dec 2015	<0.06	9	4.6
17 Dec to 23 Dec 2015	<0.06	7	0.8
24 Dec to 30 Dec 2015	<0.06	7	13.9
31 Dec to 6 Jan 2016	<0.06	7	22.1
7 Jan to 13 Jan 2016	<0.06	9	0.6
14 Jan to 20 Jan 2016	**0.07**	4	0.1
21 Jan to 27 Jan 2016	**0.07**	12	3.2
28 Jan to 3 Feb 2016	**0.07**	25	14.0

Table 10 (cont.). Seven-day average $PM_{2.5}$ crystalline silica concentration monitoring results at the Vennor Drive, Ormeau monitoring site, 10 September 2015 to 2 November 2016.

Weekly sampling period	Vennor Drive, Ormeau		
	7-day average $PM_{2.5}$ crystalline silica concentration* (µg/m³)	Proportion of winds from direction of quarries† (%)	Rainfall during sampling period (mm)*
4 Feb to 10 Feb 2016	<0.06	2	2.1
11 Feb to 17 Feb 2016	<0.06	2	2.8
18 Feb to 24 Feb 2016	<0.06	3	1.3
25 Feb to 2 Mar 2016	<0.06	1	56.5
3 Mar to 9 Mar 2016	<0.06	5	15.7
10 Mar to 16 Mar 2016	<0.06	6	18.4
17 Mar to 23 Mar 2016	<0.06	5	0.7
24 Mar to 30 Mar 2016	<0.06	10	2.2
31 Mar to 6 Apr 2016	<0.06	10	0.0
7 Apr to 13 Apr 2016	<0.06	12	0.4
14 Apr to 20 Apr 2016	<0.06	4	2.0
21 Apr to 27 Apr 2016	<0.06	3	0.7
28 Apr to 4 May 2016	<0.06	20	18.7
5 May to 11 May 2016	<0.06	17	0.0
12 May to 18 May 2016	<0.06	12	0.0
19 May to 25 May 2016	<0.06	18	0.0
26 May to 1 Jun 2016	<0.06	36	0.1
2 Jun to 8 Jun 2016	<0.06	48	62.3
9 Jun to 15 Jun 2016	<0.06	11	3.2
16 Jun to 22 Jun 2016	<0.06	46	52.5
23 Jun to 29 Jun 2016	<0.06	37	0.5
30 Jun to 6 Jul 2016	<0.06	38	4.2
7 Jul to 13 Jul 2016	**0.06**	73	0.0
14 Jul to 20 Jul 2016	<0.06	28	1.3
21 Jul to 27 Jul 2016	<0.06	70	0.0
28 Jul to 3 Aug 2016	<0.06	64	6.9
4 Aug to 10 Aug 2016	<0.06	40	7.0
11 Aug to 17 Aug 2016	<0.06	41	0.5
18 Aug to 24 Aug 2016	<0.06	32	10.8
25 Aug to 31 Aug 2016	<0.06	54	0.0

Table 10 (cont.). Seven-day average $PM_{2.5}$ crystalline silica concentration monitoring results at the Vennor Drive, Ormeau monitoring site, 10 September 2015 to 2 November 2016.

Weekly sampling period	Vennor Drive, Ormeau		
	7-day average $PM_{2.5}$ crystalline silica concentration* (µg/m³)	Proportion of winds from direction of quarries† (%)	Rainfall during sampling period (mm)*
1 Sep to 7 Sep 2016	<0.06	36	4.0
8 Sep to 14 Sep 2016	<0.06	15	8.5
15 Sep to 21 Sep 2016	<0.06	60	7.8
22 Sep to 28 Sep 2016	<0.06	55	0.1
29 Sep to 5 Oct 2016	<0.06	74	13.8
6 Oct to 12 Oct 2016	<0.06	30	0.3
13 Oct to 19 Oct 2016	<0.06	18	7.3
20 Oct to 26 Oct 2016	<0.06	33	0.2
27 Oct to 2 Nov 2016	<0.06	26	5.9

* Samples containing measurable crystalline silica content are shown in bold text.
† Wind and rainfall data was only collected at Vennor Drive, Ormeau monitoring site from 7 July to 15 November 2016. Prior to 7 July 2015, wind and rainfall data collected at the Harts Road, Luscombe monitoring site were used.