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Boral Cement Works

Use of Solid Fuel in Kiln 6

Human Health Risk Assessment - Response to Peer Review

Report Number 610.15875.00000.0020 HRA

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Boral Cement Limited

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Use of Solid Fuel in Kiln 6

Human Health Risk Assessment - Response to Peer Review

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Executive Summary

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Boral Cement Limited (Boral) to assess the potential impacts of the proposed application to modify the development consent for Kiln 6 at Berrima Cement Works. The modification seeks to support the sustained and viable use of waste derived fuels.

This report presents the methodology and findings of the Health Risk Assessment completed for the application to modify the development consent for Kiln 6 at Berrima Cement Works, undertaken by SLR Consulting on behalf of Boral Cement.

The objective of the Human Health Risk Assessment is to contribute to the analysis of toxicity of by-products associated with the use of Solid Waste Derived Fuels (SWDF) in Kiln 6 to surrounding communities and provide an assessment of the risk to human health associated with the use of SWDF.

Risk assessments of the nature performed here do not provide definitive assessments of the acceptability of risk for specific individuals. Risk assessments should only be applied on a probabilistic basis to a population of exposed persons.

The communities chosen for the purposes of this assessment were the residents of New Berrima, Berrima, Burradoo and Moss Vale. The local communities in closest proximity to the Boral Cement live in New Berrima (approximately 0.5 km), and the furthest live in Burradoo (approximately 5 km). Outside these population areas the land is rural in nature with scattered houses generally on farmland.

Boral proposed two Solid Waste Derived Fuels (SWDF) for use in the Kiln 6 subject of this modification (modification 9).

- Wood Waste - material left over from industrial processes like milling, furniture making, and building and construction; and

- Refuse Derived Fuel (RDF) - fuel made from the combustible materials recovered and processed from waste streams, such as papers, cardboards, packaging, and construction and demolition materials

The Contaminants of Potential Concern (COPC) associated with the use of SWDF as fuels in Kiln 6 were identified as the following: Fine particulates (TSP, PM_{10}, $PM_{2.5}$), SO_2, NO_X, CO, VOCs, PAHs, heavy metals, hydrogen chloride, hydrogen fluoride, chlorine, sulphuric acid mist/sulphur trioxide and dioxins.

The Primary exposure pathways relating to the operations of the Berrima Cement works were determined to be via the airborne pathway and inhalation and ingestion of the COPC. This was due to the anticipated mass of airborne COPC emissions being the dominant source for both point sources (such as Kiln 6 and fugitive sources). The Secondary exposure pathway was considered to be the indirect pathway in which COPC emissions are transported off site through environmental forces such as wind and then partition into settled dusts or soils and are remobilised when the soil or dusts are disturbed, at which point human exposure may take place via inhalation, ingestion or dermal absorption.

Executive Summary

The majority of COPCs identified in the Issue Identification stage of the risk assessment were assessed as unlikely to be present at concentrations likely to impact on the health risks to receptors in the surrounding communities. This was based on comparisons of predicted COPC concentrations at or near receptor sites in communities with relevant air quality assessment criteria, such as NSW EPA criteria or health based benchmarks. This group of COPCs included fine particulates (TSP, PM_{10}, $PM_{2.5}$), SO_2, NO_X, CO, VOCs, PAHs, heavy metals, hydrogen chloride, hydrogen fluoride, chlorine, and dioxins. The exception to this was sulphuric acid mist/sulphur trioxide which required further assessment.

The predicted peak Ground Level Concentrations (GLC) of sulphuric acid mist / sulphur trioxide were 24.2µg/m^3 which exceed the EPA Criteria of 18µg/m^3. Therefore the potential for health risks, if any, to the local communities was assessed further.

The principal benchmark used in this assessment was the lowest concentration of airborne sulphuric acid reported to illicit a physiological response, being transient changes in pulmonary function, in the population group reported as most sensitive to sulphuric acid inhalation, adolescent asthmatic children with that concentration being 70µg/m^3.

In the current study, the maximum exposure concentration for sulphuric acid was predicted to occur at receptors near the site boundary and was 24.2µg/m^3. The exposure is less than half the lowest concentration of airborne sulphuric acid reported to illicit a response, that is 70µg/m^3.

Furthermore the actual exposure concentration of the surrounding communities is likely to be less than 24.2µg/m^3. This is based on two considerations, firstly the dilution of emissions as they travel away from the facility boundary to a receptor. Secondly, the conservative nature of the air modelling which allowed predicted concentrations to be possibly as much as ninety times higher than the probable concentrations as set out in section 2.3.3.

Based on this, the Primary Exposure pathway was considered unlikely to lead to receptor exposure at concentrations likely to increase the health risk to receptors. Therefore the predicted sulphuric acid emissions during the operation of Kiln 6 were not expected to lead to an increase health risk to the surrounding communities.

Therefore, predicted concentrations of identified COPC at or near receptor sites were unlikely to be present at concentrations likely to impact on the health risks to receptors in the surrounding communities. Accordingy, the use of SWDF as fuels in Kiln 6 under the conditions proposed by Boral are considered unlikely to increase the human health risk to surrounding communities.

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1 INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Boral Cement Limited (Boral) to assess the potential impacts of the proposed application to modify the development consent for Kiln 6 at Berrima Cement Works. The modification seeks to support the sustained and viable use of waste derived fuels.

The application relates to the Cement Works at New Berrima (the Works) in the Wingecarribee Local Government Area (Lot 1 DP 582277, Lot 2 DP 774598, Lot 22 DP 582276, Lot 100 DP 882139, Taylor Avenue, New Berrima). The cement works operate subject to development approval issued by the Department of Planning and Environment (DA 401-11-2002, May 2003 and DA 85-4-2005, Aug 2005). Eight subsequent modifications have also been issued by DP&E. The location of the site in relation to New Berrima is shown in Photograph 1.

Photograph 1 Aerial photograph showing site proximity to New Berrima

This report presents the methodology and findings of the Health Risk Assessment completed for the proposed application to modify the development consent for Kiln 6 at Berrima Cement Works, undertaken by SLR Consulting on behalf of Boral Cement.

The Health Risk Assessment was conducted as per the recommendations contained in *Environmental Health Risk Assessment. Guidelines for assessing human health risks from environmental hazards*. (enHealth, 2012).

1.1.1 What is Risk Assessment

Risk assessments have been defined in many ways but all share the concept of a process for estimating and characterising the potential risks associated with various agents or activities.

The National Research Council (1983) definition is:

Risk assessment is the systematic scientific characterisation of potential adverse health effects resulting from human exposures to hazardous agents or situations.

The underlying concept to risk assessment is the Conceptual Site Model (CSM) whereby risk is assessed using the concept of the links between source – pathway – receptor. This can include the source of Contaminants of Potential Concern (COPC) which may impact on the communities in question and transport mechanisms whereby COPC can be moved to exposure points (human receptors). If any of these links are missing then an exposure pathway in incomplete and human exposure will not occur. If the exposure pathway is potentially complete then likely impact on the receptor may need to be assessed.

The exposure pathway describes the course a COPC takes from the source to an exposed receptor. This pathway is unique for specific situations involving particular COPC and specific communities or individuals.

Once a COPC has travelled along the exposure pathway to the receptor, it may then be exposed to the COPC through a number of exposure routes. The basis of these routes are:

- Inhalation of contaminants, either as gases, mists, fumes or airborne particulates,
- Ingestion of contaminants, through food, drink or through secondary transfer from skin to mouth through poor hygiene practices, and
- Direct contact leading to absorption through skin (dermal absorption).

The exposure pathway and exposure route through which contaminants exposure can potentially occur will depend on the chemical characteristics of a contaminant and how the contaminant behaves in the environment. If the normal form of a chemical in the environment is a gas then the likely exposure route will be through inhalation. In contrast if the contaminant usually binds to particulate matter such as dust, soils or sediments, then the exposure routes may be inhalation of contaminated dusts, ingestions of soils or possible direct contact with contaminated soils.

The most common approach to risk assessment is a simple comparison of site specific data on COPC concentrations against relevant guidelines such as regulatory limits, investigation levels or screening levels. In most cases if the COPC meets the adopted guidelines, then the risk is considered low and acceptable. If the COPC exceeds the adopted guidelines then further evaluation is usually required.

1.1.2 Risk Assessment Approach

The methodology adopted in the conduct of the Human Health Risk Assessment is consistent with that used to evaluate risks to human health associated with a population's exposure to a hazardous agent. The current study pertains to the application for the Project to use of SWDF in the Kiln 6 at Berrima Cement Works. Therefore this health risk assessment is focused on potential by-products associated with the use of SWDF as fuels in cement kilns.

The approach to the assessment of risk to human health is based on the protocols/guidelines recommended by the enHealth Council. These are detailed in the document "*Guidelines for assessing human health risks from environmental hazards*. June, 2012."

Identification and assessment of the potential risks to human health within the site have been undertaken by implementing four prime tasks. These tasks are:

1. **Issue Identification** – This involves an evaluation of the available information on the key issues amenable to risk characterisation relating to the use of SWDF in Kiln 6.

2. **Hazard Assessment** – This task provides a review of the current understanding of the toxicity issues to humans associated with the use of SWDF as fuels in Kiln 6 and the identifies hazards associated with exposure to by-products from the use of SWDF.

3. **Exposure Assessment** – This task draws on the evaluation undertaken as part of the "Issue Identification" stage identifying the groups of people in surrounding communities who may be exposed to by-products associated with the use of SWDF as fuels in Kiln 6 and quantifying exposure concentrations.

4. **Risk Characterisation** – This task provides the qualitative evaluation of potential risks to human health. The characterisation of risk is based on the review of toxicity of by-products associated with the use of SWDF as fuels in Kiln 6 and assessment of the magnitude of exposure.

1.2 Objectives

The objective of the Human Health Risk Assessment is to contribute to the analysis of toxicity of by-products associated with the Project to use of SWDF as fuels in Kiln 6 to surrounding communities and provide an assessment of the risk to human health associated with the use of SWDF.

The risk assessment aims to:

- Identify the any COPC associated with the use of SWDF as fuels in Kiln 6,
- Identify the groups of people who may be exposed to any COPC associated with the use of SWDF as fuels in Kiln 6,
- Compare exposure concentrations with contemporary health standards (where available),
- Identify the health risks associated with exposure should it occur; and
- Assess and communicate the identified risks.

Risk assessments of the nature performed here do not provide definitive assessments of the acceptability of risk for specific individuals. Risk assessments should only be applied on a probabilistic basis to a population of exposed persons.

It should be noted that the scope of this Human Health Risk Assessment is limited to potential by-products associated with the use of SWDF as fuels in Kiln 6 and does not include any other agents of potential concern (if any).

1.3 Details of Local Communities

The local communities in closest proximity to the Berrima Cements Works live in for state suburb areas of New Berrima (SSC 11711), Berrima (SSC 10196), Moss Vale (SSC 11604) and Burradoo (SSC 10396). From the 2011 Census, the usual population size for these state suburb areas, the areas and the approximate distance of the urban areas from the site has been set out below in **Table 1.**

Table 1 Details of communities in proximity to Berrima Cement Works

Community	Population (Australian Bureau of Statistics (2012)	Area (sq Kms)	Approximate Distance and Direction of Urban Area from Kiln 6
New Berrima (SSC 11711)	542	3	0.3 km north
Berrima (SSC 10196)	600	23.1	2 km north
Moss Vale (SSC 11604)	7,305	92.2	3.5 km south east
Burradoo (SSC 10396)	2,555	12.4	5 km east

1.3.1 Community Demographic

The demographics of the state suburb areas New Berrima (SSC 11711), Berrima (SSC 10196), Moss Vale (SSC 11604) and Burradoo (SSC 10396) have been set out in **Figure 1 to Figure 4**.

Figure 1 New Berrima population by age, 2011

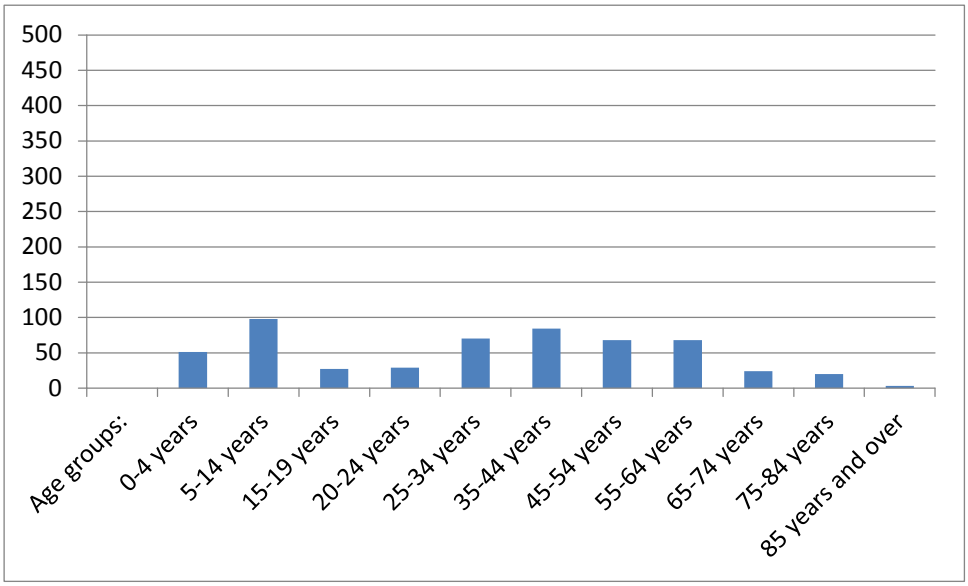


Figure 2 Berrima population by age, 2011

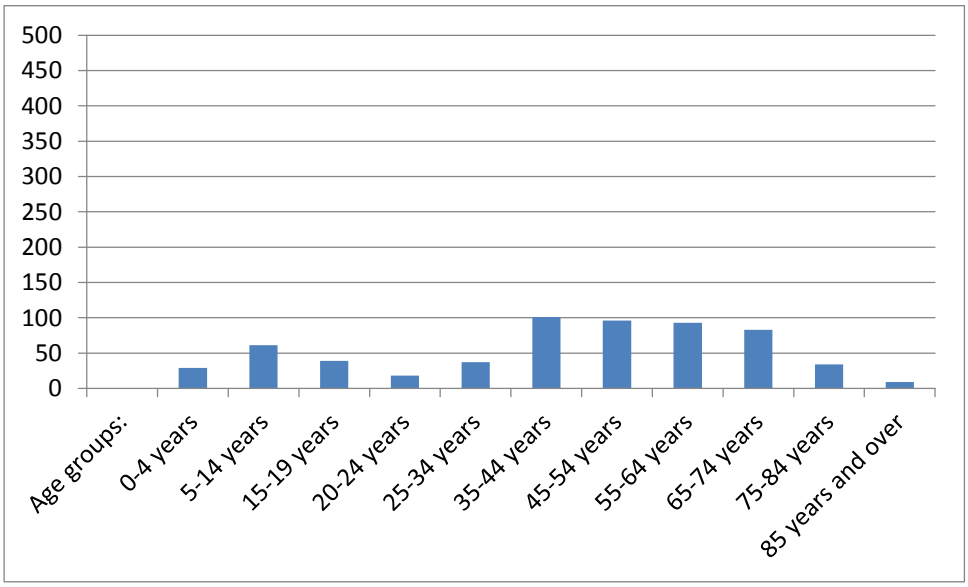


Figure 3 Moss Vale population by age, 2011

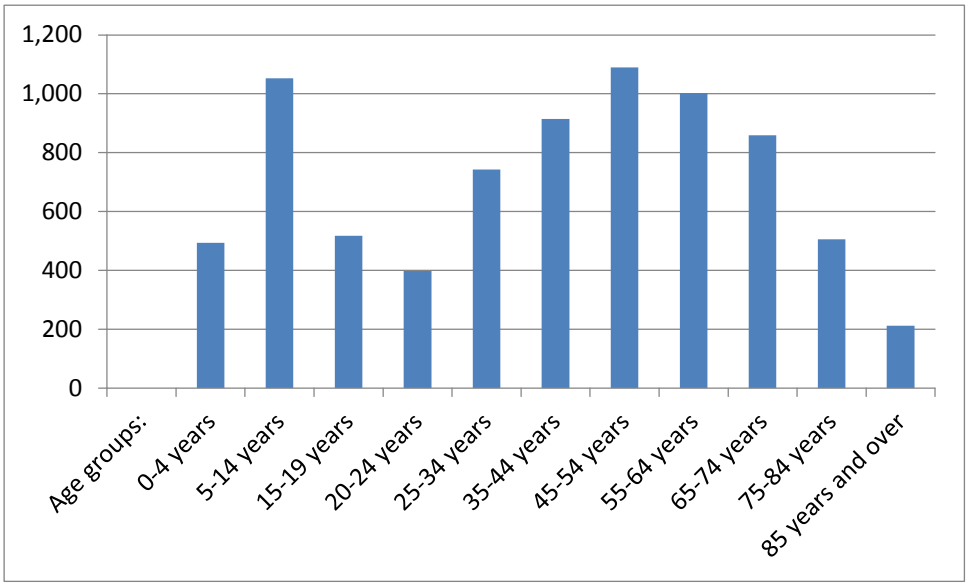
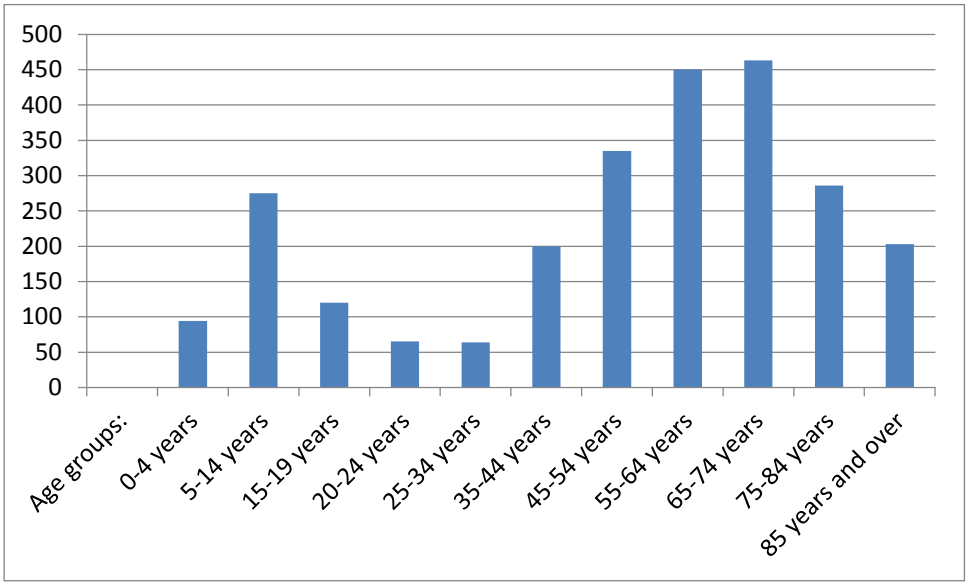


Figure 4 Burradoo population by age, 2011



1.3.2 Special Populations

Special populations are sub groups within the community who may be at greater risk of adverse health effects. The increased risk may be due to factors such as age, ill health or close proximity to an identified hazard, in this case the potential pollutants from the Berrima Cement Works.

Children or teenagers under eighteen years of age are considered at higher risk than older members of the population. In this age group humans are considered to have not reached maturity. Therefore their bodies may respond differently to adults when exposed to a toxic or carcinogenic threat. In many cases they will be at higher risk from the exposure compared to adults. Details of the special populations based on age of the communities chosen for the assessment have been set out in **Table 2.**

Table 2 Details of special populations based on age, within communities in proximity to Berrima Cement Works

Community	Population Under 18 years of Age	Population Over 74 years of Age*
New Berrima (SSC 11711)	176	23
Berrima (SSC 10196)	129	43
Moss Vale (SSC 11604)	2,065	718
Burradoo (SSC 10396)	489	489

* Elderly taken to be over 74 years of age due to limitations of Census data.

1.3.3 Community Health Data

Health data on small populations, such as New Berrima or Berrima, may lack epidemiological power to detect health effects (enHealth, 2001). Accordingly the health statistics for NSW were utilised in this report as a basis for the risk determinations in later sections of the report.

It is anticipated that there may slight differences in the local community health data compared with the overall NSW health data. However, differences are likely to be small and therefore the NSW statistics may be used in the assessment.

The health statistics set below in **Table 3** were chosen for their relevance to the health risk assessment of airborne particulates later in the report.

Table 3 NSW Community Health Summary – Indicators Relevant to Airborne Particulates

Health Indicator	Incidence Rate per 100,000 Population
Mortality	
All causes-all ages	670*
All causes - ≥ 30 years	1087*
Cardiopulmonary - ≥ 30 years	490*
Cardiovascular – All ages	164*
Respiratory – All ages	57*
Hospital Admissions	
Cardiovascular - ≥ 65 years	2335.2[#]
Respiratory - ≥ 65 years	8807[#]

Data from *=2005-2007; [#]=2009-2011; [+]=2010-2011 (EnRiskS, 2014)

1.4 BERRIMA CEMENT WORKS PROCESS INFORMATION SOURCES

The background information on site processes at Berrima Cement Works and potential contamination sources, used in the current report was based on a desktop review of existing reports including

Air Quality Professionals, 2015. *Boral Cement Berrima Works Use of Solid Waste Derived Fuels in Kiln 6 Air Quality Assessment*. 24 April 2015

SLR, 2015 *Use of Solid Waste Derived Fuels Kiln 6, Berrima Cement Works DA 401-11-2002-Modification 9 Environmental Assessment July 2015*. Report Number 610.14460. SLR Consulting Australia Pty Ltd

1.5 EXISTING ENVIRONMENT

1.5.1 Topography

The Berrima region is flanked by hills on all sides within about 10-20km of the Works. These hills rise to an elevation of about 60-130m above local ground level at the cement works, which is about 675m above mean sea level. The Australian coastline is 50km to the east of the works. (Air Quality Professionals, 2015)

The cement works site is flat and the immediate surrounding area is characterised by gently rolling shallow hills and valleys with some flat areas. The topographical elevation information is shown **Figure 5.**

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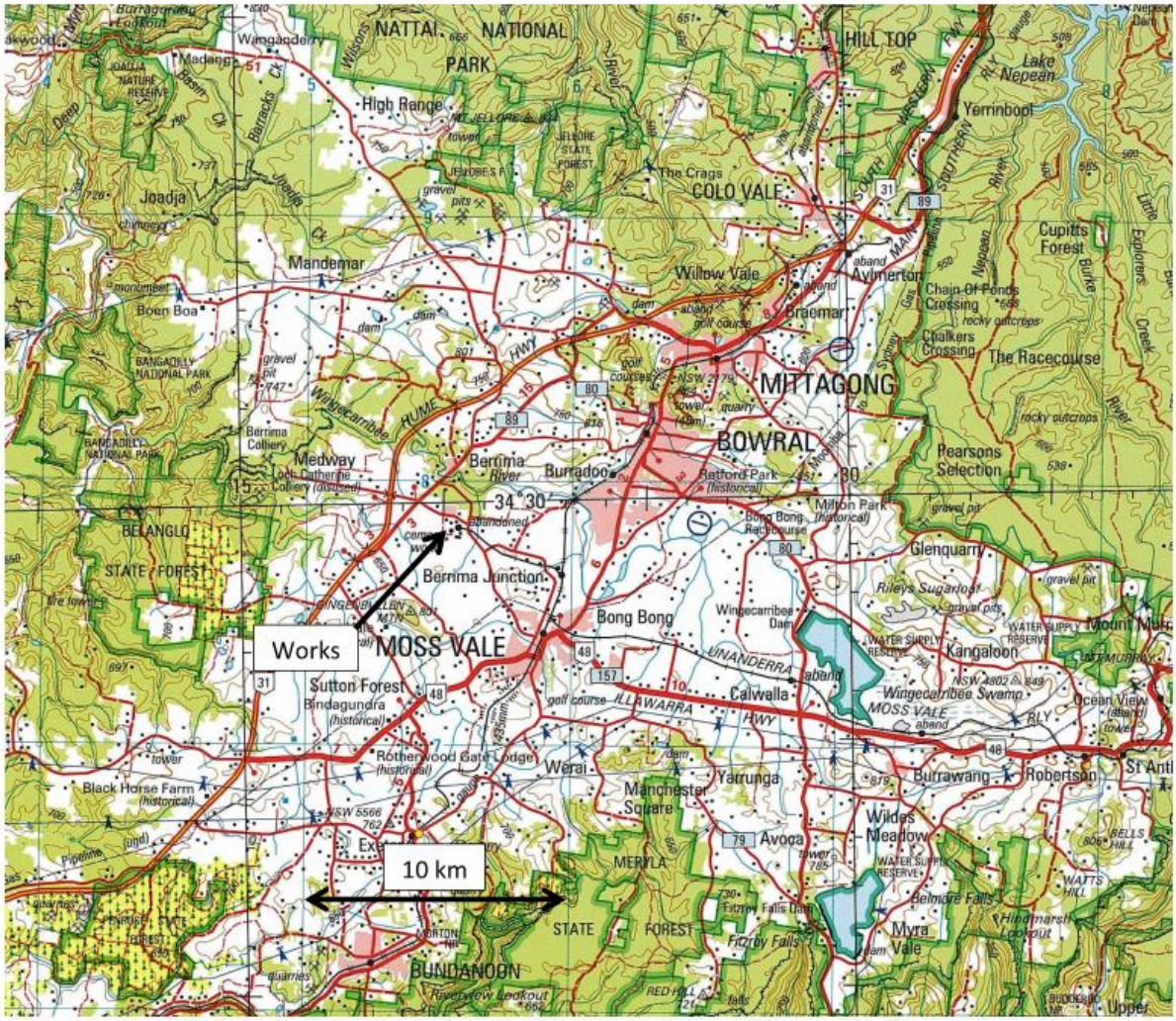
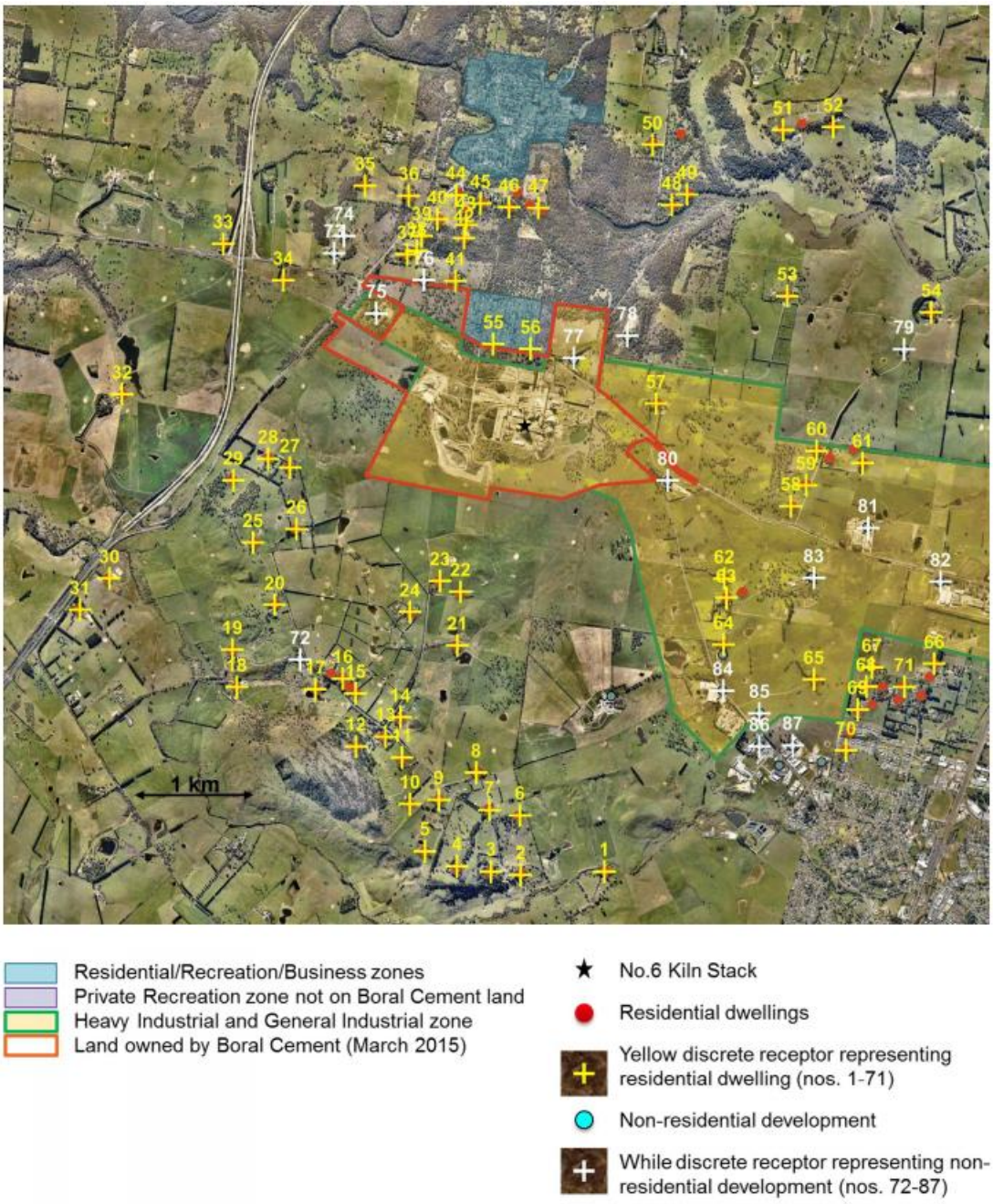
Figure 5 Topographical map of region around Berrima works (Air Quality Professionals, 2015)



1.5.2 Surrounding Land Use

Figure 6 shows the surrounding land uses, residential dwellings and sensitive Receptors used in the air quality modelling study of Air Quality Professionals, (2015). It should be noted that Receptor 88 is not shown on the map but is located at the corner of Howard St and Taylor Ave New Berrima, west of Receptor 55, approximately 300m from the cement works boundary.

Figure 6 Surrounding land uses around Berrima works (Air Quality Professionals, 2015)



1.6 EXISTING OPERATIONS

Berrima Cement Works has been operating since 1929 and produces cement products (cement and clinker) for sale in NSW, the ACT and for export. The Cement Works is approved to produce up to 1.56 million tonnes per annum of cement products which has historically represented 60% of cement sold for building and construction in NSW. Cement products are dispatched to domestic customers by train and truck and international customers through Port Kembla.

The facility operates one kiln and two cement mills, along with storage and stockpile facilities, and a substantial fleet of heavy vehicles for transportation.

The clinker, which looks like small balls of pumice, is stored before being passed to the grinding mill where it is ground into cement. The cement is stored on site before being loaded for transport off-site.

Cement manufacture is an energy intensive process due to the high temperatures required for the production of clinker. Currently 220,000 tonnes per year of coal is used to heat the kiln to a temperature of up to 1500°C. Up until 2013 coal was sourced from the nearby Medway Colliery but since the colliery's closure, coal is currently sourced from the Illawarra area by road. This reliance on coal contributes to the total energy cost at the facility, which represents 40% of Boral's costs in the cement production process.

The facility supports a direct workforce of 130 employees, a further 20 in engineering and procurement, as well as many indirect jobs in the region through logistics, contractors and suppliers.

Some of the pressures on the facility's existing operation include:

- increased energy prices,
- increased costs of raw materials, and
- increased affordability in importing clinker from overseas.

Boral has implemented a number of efficiency measures over the years to address these pressures and reduce its operating costs. The use of SWDF is another such measure which would reduce energy costs and help secure the commercial and environmental sustainability of the Cement Works into the future.

Figure 7 shows the site layout and **Figure 8** provides a flow diagram of the current operating process at the facility. The main raw material inputs are limestone, sourced from the Marulan mine, and shale, sourced on site. Limestone is transported via rail and combined with the shale. The blended material is passed through a raw milling and gas cleaning system and into the rotary kiln where the material elements are combined at very high temperature to form clinker.

Figure 7 Aerial photograph of Berrima Works with locations of various activities indicated. Aerial photography from nearmap, imagery dated 22 May 2014 (source: Air Quality Professionals, 2015).

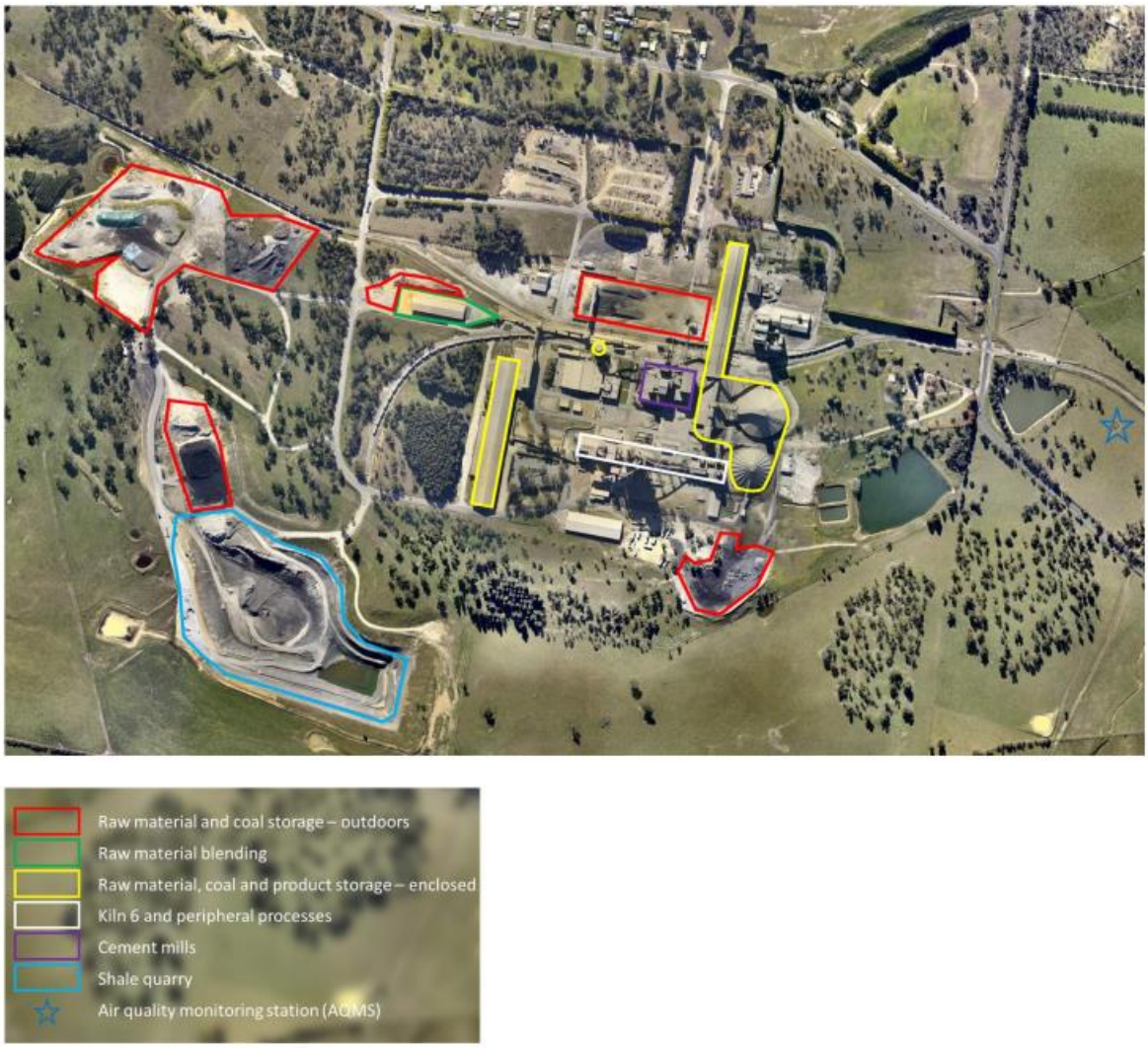
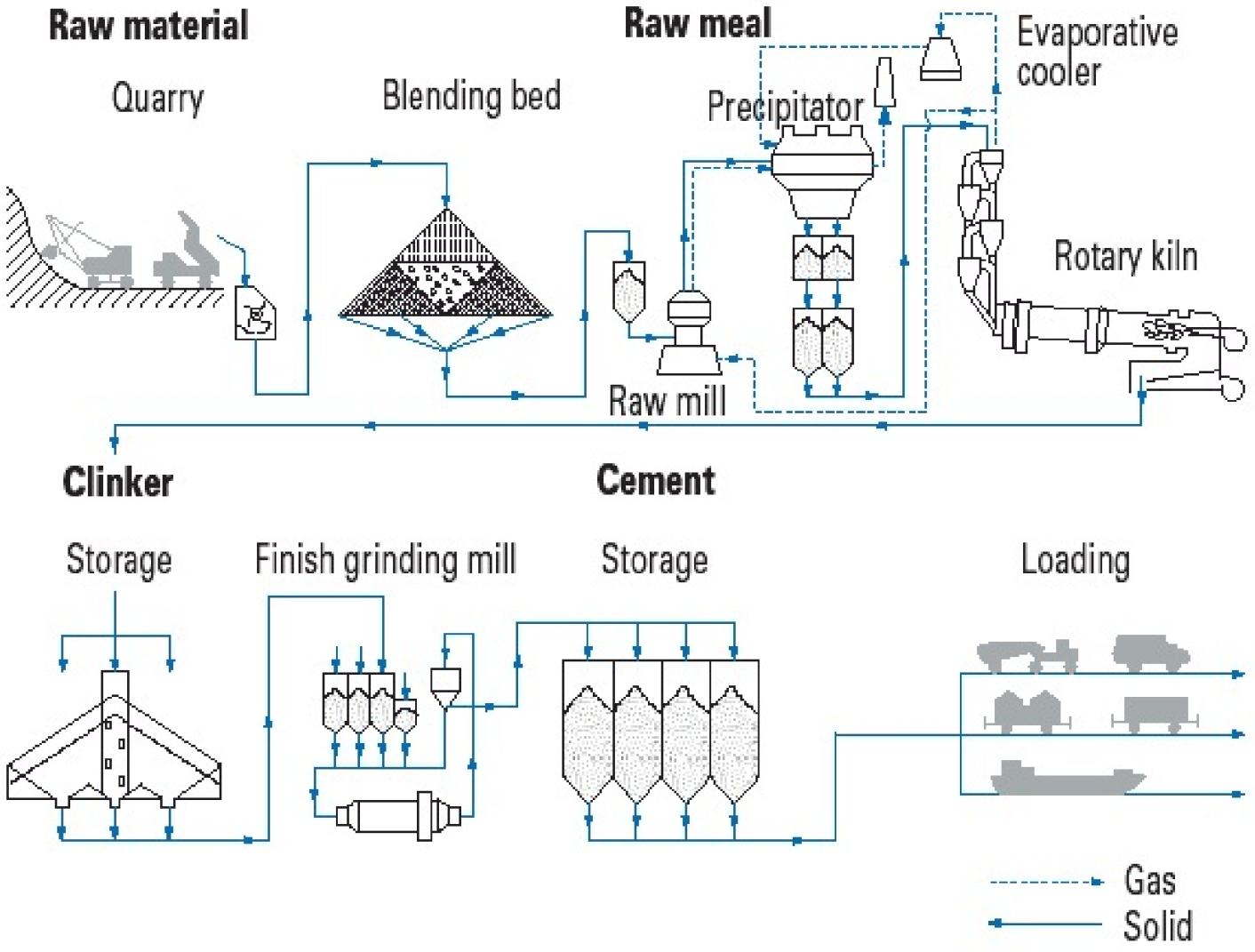


Figure 8 Flow chart describing current process operations



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Current Process Operations

FIGURE 8

1.7 Existing emission control equipment

Cement kilns offer a superior solution for handling wastes due to high temperatures and residence times with no solid residues. In 2004, Boral upgraded Kiln 6 and installed additional equipment specifically suited to the burning of SWDF.

The key features of this equipment are:

- a large volume pre-calciner combustion vessel, which gives fuels longer time to burn out (>6 seconds) at high temperatures (>800^{o}C). This means that all of the solid fuel is given the chance to burn out and eliminates residues like smoke;

- the raw mill dust collector, which filters kiln exhaust gas particulates and provides additional high efficiency cleaning capacity to minimise stack emissions; and

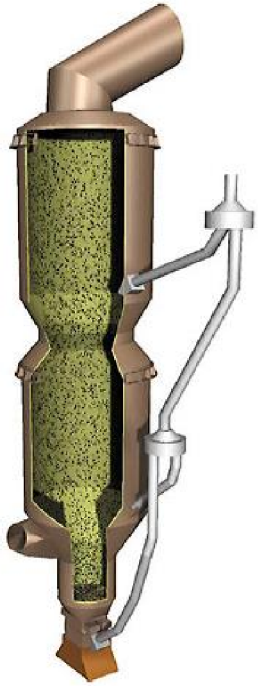
- the installation of continuous monitoring equipment for key gaseous pollutants, which allows prompt response to any adverse trends in stack emissions.

Figure 9 illustrates some of this equipment and the emissions benefits.

Figure 9 Existing emission control equipment

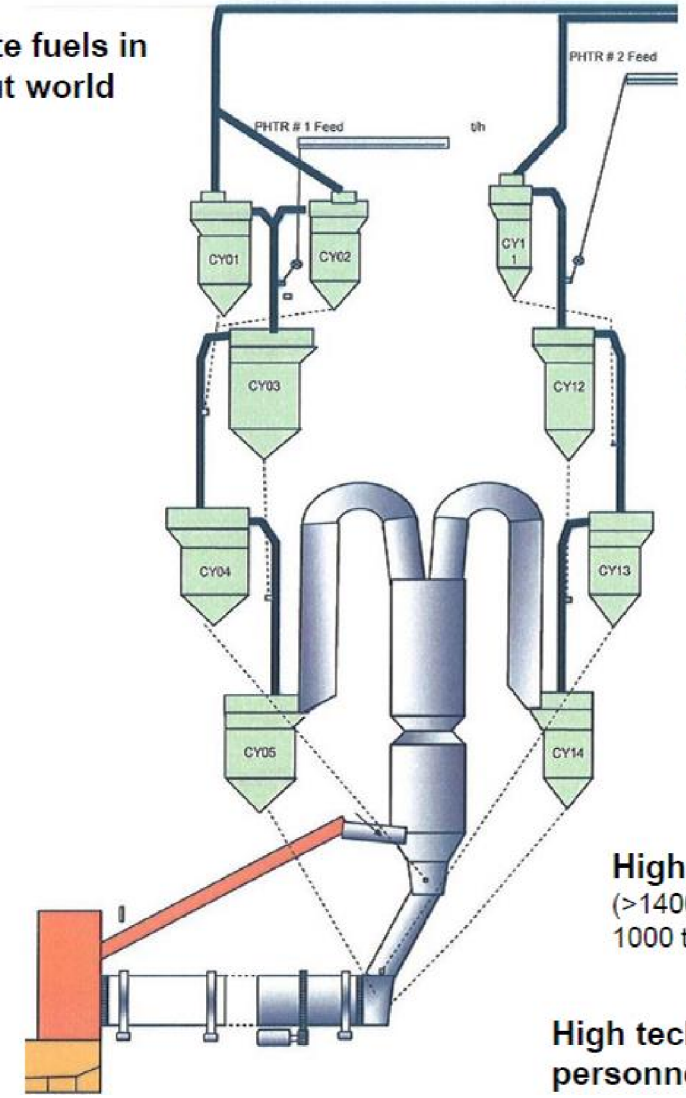
Use of wide range of solid waste fuels in cement kilns proven throughout world

Reduces CO2 emissions with biomass fuels



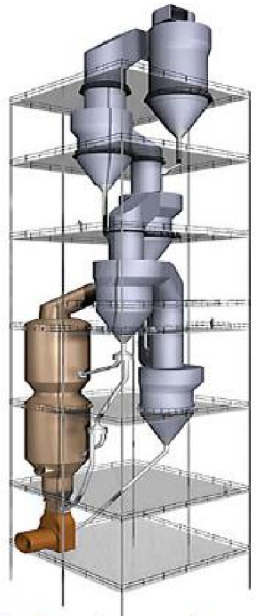
High combustion residence time in kiln and pre-calciner (>6 seconds gas residence time @>800 Deg C) in calciner)

No solid residues to dispose of (ash combined in clinker)



High efficiency filtration of kiln exhaust gas particulates (ash combined in clinker)

High level of automated combustion and chemistry control



Preheater acts as efficient acid gas scrubber (high limestone/lime environment)

High gas temperatures (>1400 deg C in kiln 1000 to 800 deg C in calciner)

High technical competency of personnel

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Existing Emissions Control Equipment

FIGURE 9

1.8 SCOPE OF MONITORING OF EXISTING EMISSIONS

Details of the historic and current air quality testing regime in place at the cement works was detailed in the report Air Quality Professionals (2015). This report stated:

A range of sampling and analysis programmes are conducted at the Berrima site to monitor air discharges from the four discharge points. These programmes are as follows:

Monitoring required by the EPL during combustion of standard fuels:

a. *Annual stack testing. This applies to all four discharge points.*

b. *Continuous measurement in No.6 Kiln stack of total suspended particulate (TSP) (required in EPL since 30 March 2012, although the measurement has been conducted for several years outside of this EPL requirement as a voluntary process control measure).*

Additional monitoring that is only required by the EPL during combustion of NSF (Non Standard Fuels) *(a requirement that has not been initiated yet because the site hasn't been using any NSF) – this testing is currently carried out voluntarily by the site during combustion of standard fuels as well:*

a. *Additional annual testing on discharges from No.6 Kiln stack, as would be required if NSF were being used, as well as testing of PAHs.*

b. *Continuous measurement in No.6 Kiln stack of nitric oxide (NO), nitrogen dioxide (NO_2), NMHCs, methane, oxygen, carbon monoxide (CO), and sulfur dioxide (SO_2).*

All monitoring is carried out or equipment is maintained and calibrated by independent, suitably qualified contractors. In accordance with Special Condition E2 of the EPL and condition 4.1B of the DA (required only when NSF are used, currently undertaken on a voluntary basis), Boral Cement also operates an ambient air quality monitoring station (AQMS) beyond the site boundary which records meteorological data continuously and TSP, PM_{10} and heavy metals on a one-day-in-six basis.

1.9 BERRIMA CEMENT WORKS PROPOSED MODIFICATION

1.9.1 Current Approvals and Recent Modifications

Berrima Cement Works operates under two development consents that were granted by the Minister in 2003 (Kiln 6) and 2005 (Mill 7). Boral Cement is permitted to produce up to 1.56 million tonnes of cement a year at the facility. These consents have since been modified as per **Table 4**.

Table 4 Modifications to the original development approvals

Modification	Reference/Date	Scope
1	MOD 2-1-2004 Sept 2005	Use of non-standard fuels, including used tyres, liquid oil residues and spent aluminium electrode carbon
2	MOD 109-9-2006 Sep 2006	Removal of hazardous waste prohibition
3	MOD 12-2-2007 Feb 2007	Trial use of tyre chips
4	MOD 4 April 2008	Varying usage of coke fines
5	MOD 5 Aug 2009	Coal deliveries by rail
6	MOD 6 June 2012	Stockpiling of coal for sale and transport to Port Kembla
7	MOD 7 April 2012	Trial and use of blast furnace slag
8	MOD 8 July 2012	Administrative changes to align DA and EPL conditions

1.9.2 Non-Standard Fuels

Boral has been investigating the use of non-standard fuels in Kiln 6 since 1999. The types of non-standard fuels considered included: carbon anode dust, used tyres, recycled oils and grease, and waste wood with preliminary trials conducted in 2000 and 2001.

On 12 May 2003 the Minister for Infrastructure and Planning approved a development application for an upgrade to Kiln 6 at the existing Cement Works. The Minister's consent only permitted the use of standard fuels at the upgraded development as no assessment had been undertaken as part of the application for use of any non-standard fuels.

Further trials were conducted in 2003 to inform a modification application seeking approval for the use of non-standard fuels at Berrima (MOD 2-1-2004). The Modification application sought approval for:

- use of three non-standard fuels (being used tyres (AKF5), liquid oily residues (AKF1) and carbon anode dust (Hi Cal 50) which had been trialled and tested in accordance with an EPA licence; and

- a protocol describing the trialling, testing and approval procedures for possible new fuels at the upgraded Kiln 6.

The Department granted approval for the use of the three trialled and tested non-standard fuels, subject to stringent environmental controls, but did not grant approval to the implementation of any protocol. This would result in any future proposal to use additional non-standard fuels requiring further approvals under the Environmental Planning and Assessment Act 1979.

Approval for used tyres (AKF5) was granted subject to the necessary approvals under the Act being obtained for storage facilities and kiln feeding infrastructure. No AKF5 is permitted to be received at the site until the necessary storage facilities and kiln feeding infrastructure have been constructed in accordance with any such approvals.

Approval for Hi Cal 50 and AKF1 was granted subject to the detailed design for any necessary storage facilities and kiln feeding infrastructure being approved by the Director-General.

A subsequent modification application (MOD 12-2-2007) granted approval for Boral to undertake a single operational trial of chipped tyres in the development, ahead of the construction of storage facilities and kiln feeding infrastructure for AKF5, subject to a number of requirements.

1.9.3 Outcome of trials involving non-standard fuels

As part of Modification 2-1-2004-i of the Kiln 6 Development Consent, trials of waste-derived fuels were conducted on two days in August 2003 and two days in October 2003.

Blends of the waste-derived fuels were tested against a baseline of coal and 5% coke as follows:

- Coal/coke + HiCal 1.3 tph (Trial Blend 1);
- Coal/coke + HiCal + Waste Oil (AKF1) 1 tph (Trial Blend 2); and
- Coal/coke + HiCal 1.3 tph+ Waste Oil (AKF1) 1 tph + chipped tyres (AKF5) 4.5 tph (Trial Blend 3).

The stack emissions were monitored during the trial by the external provider, Air Labs (report dated 4 December 2004). The trial was regarded as a success. This success was measured in terms of:

- No adverse impact on emissions, land, noise and traffic;
- No adverse impact on clinker quality; and
- No community complaints or adverse comments.

1.9.4 Stack emission testing summary

Most of the parameters tested were well below the safe emission limits imposed later in the modified consent for the combustion of waste-derived fuels. The only exceptions were Total Particulate and Nitrogen Oxides.

During the trials, Total Particulates were measured at 40, 44 and 51 mg/m^3 for the trial blends 1, 2 and 3, respectively against the limit of 30 mg/m^3 that was later applied to the Consent. For MOD 9, Boral is proposing to change this limit to 50 mg/m^3 in line with the NSW Energy from Waste Policy, 2014. Total Particulate levels measured during the past year have been well below this proposed limit.

Nitrogen Oxides were at the level of 1700 mg/m^3 for the baseline (coal and coke), dropping down to approximately 1200 mg/m^3 which was still higher than the limit of 800 mg/m^3 that was applied in the consent. For MOD 9, Boral is proposing to change this limit to 1000 mg/m^3 being the same level currently being complied with for standard fuels.

The potential for Dioxin and Furan emissions was a key concern for the community at the time. The baseline measurement was 0.0034 ng/m^3 while blend 1 was 0.0049 and blend 3 was 0.013 ng/m^3. There was no adequate sample obtained for blend 2 due to a process upset during the 6-hr timeframe required for dioxin sample collection. The highest level recorded during blend 3 was nearly 8 times below the limit of 0.1 ng/m^3 that was later applied to the consent. The trials demonstrated that even with all three waste-derived fuels being fed into the kiln simultaneously, there were no potentially unsafe dioxin emissions.

Heavy metal emissions were at a similar level to the baseline or lower, including the more volatile metals such as cadmium and mercury.

VOC emissions were up to two times higher with the use of waste-derived fuels but still well within the applicable emission limit. Due to the marked variability of VOC emissions observed over the years from the contribution of blue shale, in MOD 9 Boral are proposing to change this limit to 40 ppm when waste-derived fuels are used.

1.9.5 Proposed Activities of the Project

This modification, Modification 9, seeks approval for the following:

- use of Solid Waste Derived Fuel (SWDF) as an energy source;
- changes to the air emission limits of particulate matter (PM), nitrous oxides (NOx) and volatile organic compounds (VOC); and
- construction of a fuel storage and kiln feeding system.

The fuels that are the subject of this modification are the following SWDF:

- Wood Waste - material left over from industrial processes like milling, furniture making, and building and construction; and
- Refuse Derived Fuel (RDF) - fuel made from the combustible materials recovered and processed from waste streams, such as papers, cardboards, packaging, and construction and demolition materials

These fuels are considered to be an ideal fuel source for Kiln 6 and would be sorted, tested and shredded off-site by authorised waste suppliers to maintain compliance with relevant specifications.

Boral proposes to use up to 100,000 tonnes per year of SWDF in Kiln 6 operations. This would replace 20-30% of the coal used in the facility. **Table 5** compares the quantities of fuel that Boral currently has approval to use with the quantities proposed by this modification.

Table 5 Approved and proposed classes and quantities of standard and waste derived fuel

Fuel	Category	Tonnes per annum	% of total fuel (by mass)	Tonnes per annum	% of total fuel (by mass)
		Current		Proposed	
Natural Gas, Fuel Oil, Diesel	Standard Fuel	No Limit		No change	
Coal	Standard Fuel	No Limit	≥ 60.0	No Limit	No Limit
Coke Fines	Standard Fuel	No Limit	≤ 30.0	No Limit	≤ 30.0
Aluminium electrode carbon (Hi Cal 50)	SWDF	10,000	≤ 6.0	10,000	≤ 6.0
Liquid Oil Residues (AKF1)	LWDF	20,000	≤ 4.7	20,000	≤ 4.7
Waste Tyres (AKF5)	SWDF	30,000	≤ 21.0	100,000	≤ 50
Wood Waste	SWDF	Not currently approved			
RDF	SWDF				

Boral would only source feedstock from suppliers that have agreed to meet the requirements of the EPA guidelines, including the resource recovery criteria for energy recovery facilities set out in the NSW EPA Energy from Waste Policy (2014). This would be a prerequisite when establishing supply contracts for kiln feedstock.

The policy specifies what is considered to be an ‘eligible waste fuel’ which would be reviewed over time.

Boral proposes to adopt a risk based approach to minimise any potential environmental impact of using SWDF. Boral's approach would involve four levels of risk protection as follows:

Detailed fuel specifications

Boral has developed detailed fuel specifications for the proposed SWDF based on established European and USA standards. The levels of contaminants, such as heavy metals, in these standards are low enough to ensure that when used as a fuel in the cement kiln, emissions are unlikely to exceed the limits defined in the Energy from Waste Policy and the sites EPL. The fuel specifications would be the basis of acceptance of deliveries of fuels from suppliers.

Supplier control systems

Suppliers of SWDF to Berrima would be required to establish rigorous Quality Assurance / Quality Control procedures to ensure the SWDF products produced from their operations meet Boral's specifications. The QA/QC of suppliers would be subject to regular audit by Boral or external parties.

Check sampling and testing of waste fuels supplied

Regular statistical check sampling and testing of dispatched waste fuel products would be established based on the European standards. Using this methodology, samples of fuel would be taken at either the supplier's site or at the Cement Works on a regular basis and analysed to determine compliance with the fuel specification. This will provide a regular check of the effectiveness of the supplier's quality assurance processes. Analysis of test results would be undertaken by suitably accredited laboratories using standard test methods.

Inherent capture efficiency of the cement kiln process

Boral and industry data demonstrates that cement kilns have inherently high capture efficiency for contaminants such as heavy metals which are captured as a stable component of the kilns clinker product. Therefore in the unlikely event that the preceding three stages fail to prevent out-of-specification fuels being fed into the kiln, the risk of a significant environmental impact resulting from such an event is low.

Concrete is an artificial stone made of cement, aggregates, sand and water and is known for its high environmental performance. This performance is not impaired when waste derived fuels are used for cement production. Concrete made from cement manufactured using waste derived fuels has the same properties as concrete made from cement manufactured using fossil fuels.

One aspect of the environmental performance of concrete is the behaviour of heavy metals in concrete. These trace elements are found in various concentrations in the raw materials and fuels used in the manufacture of cement and may be found at a slightly higher proportion in the waste-derived fuels. However, high temperatures maintained in the clinker kiln and the kiln's highly alkaline environment cause most of the metals to precipitate becoming irreversibly bound into the newly-formed clinker. The metals will not solubilise again which is a pre-requisite for leaching to occur; with the clinker matrix acting as a permanent immobiliser. As heavy metals are found in raw materials and fuels used in clinker manufacture only at trace concentrations, the added quantities are negligible in comparison with the bulk of the cement material produced.

The heavy metals bound in the cement are further chemically bound in the alkaline reaction between the cement and water which produces concrete. This fixation as well as the high density and low permeability of concrete result in a very low potential for heavy metals to be released from the concrete structures.

The leaching of heavy metals from concrete has been examined in a number of investigations (Alternative Fuels in Cement Manufacture, Cembureau, Brussels 1997; M.T. Webster and R.C. Loehr, Long-Term Leaching of Metals from Concrete Products, Journal of Environmental Engineering, Vol. 122, No. 8, 1996; S.R. Hilliera, C.M. Sangha, B.A. Plunkettb, P.J. Walden, Long-term leaching of toxic trace metals from Portland cement concrete, Cement and Concrete Research, Vol. 29, No.4, 1999). They all show that the release is very low, independently of the kind of fuels used for cement clinker production. The leached quantities have always been found to be either not measurable or significantly below allowable environmental and/or public health limits. The only benchtop leaching tests that can demonstrate any extent of leaching of heavy metals from cement or concrete are those based on acid extraction.

European Union countries have been using waste derived fuels extensively in cement manufacture for around 50 years now. Many concrete structures in Europe have therefore been built using cement that incorporates heavy metals from the waste derived fuels, with no evidence of any environmental impacts that may have originated from heavy metals that have leached out of concrete.

1.9.6 Emission changes

Emission limits

Boral seeks a modification to the emission limits of three air pollutants to align with the requirements of the EPA's NSW Energy from Waste Policy (2014).

Boral Cement holds the Development Consent (DA 401-11-2002) for Kiln 6, last modified in August 2012, and the EPL 1698 for the site, last updated May 2013. The DA and EPL regulate the discharges of contaminants to air from the burning of standard fuels (such as coal, diesel, and heavy oil). From 2005, the DA and EPL also allow for the burning of "non-standard fuels" (NSF) in the kiln with specific air discharge conditions. These conditions associated with the burning of NSF are onerous and difficult to meet. As a result, the NSF programme has never been implemented.

Condition 3.10, Table 3 of the Development Consent and Conditions L3.1 and L44-L3.5 in EPL 1698 define permitted contaminant **emission limits for the four discharge points during the burning of standard fuels, and are shown in Table 6** and **Table 7**.

Table 6 Emissions limits for particulate matter for burning of standard fuels

Discharge point (and EPL point reference number)	Particulate matter 100 percentile concentration limit
No. 6 Kiln Stack (2)	95 mg/Nm^3
No. 6 Cement Mill (4)	100 mg/ Nm^3
No. 6 Kiln Cooler (5)	100 mg/ Nm^3
No. 7 Cement Mill (10)	20 mg/ Nm^3

Table 7 Emission limits for other contaminants from No. 6 Kiln Stack for burning of standard fuels

Contaminant	100 percentile concentration limit
Nitrogen oxides	1000 mg/ Nm^3

Condition 3.10 Table 4 of the Development Consent and Conditions L3.6 to L3.8 of EPL 1698 define permitted contaminant emission limits for the No.6 Kiln Stack during the burning of NSF, as shown in **Table 8**.

Table 8 Emission limits for particulates, NOx and VOCs from No. 6 Kiln Stack for burning of non-standard fuels

Contaminant	100 percentile concentration limit
Nitrogen oxides	800 mg/ Nm^3
Particulate matter	30 mg/ Nm^3
Volatile organic compounds	20 ppm

Table 9 provides a comparison of the current emission limits for particulate matter, NOx and VOCs for burning of Standard Fuels and Non-Standard Fuels.

Table 9 Comparison of current emission limits for Particulates, NOx and VOCs from No. 6 Kiln Stack for burning of standard fuels and non-standard fuels

Contaminant	Non-Standard Fuels 100 percentile concentration limit	Standard Fuels 100 percentile concentration limit
Nitrogen oxides	800 mg/ Nm^3	1000 mg/ Nm^3
Particulate matter	30 mg/ Nm^3	95 mg/ Nm^3
Volatile organic compounds	20 ppm	No limit specified

Boral has undertaken monitoring and annual reporting on air emissions from the No. Kiln 6 stack, which demonstrates that the Cement Works complies with the emission limits for standard fuels. However, the more onerous conditions with regard to WDF would be more difficult to comply with, and therefore Boral has never progressed the use of WDF.

Additionally, and of relevance to this proposed modification, is the release of the EPA's NSW Energy from Waste Policy (2014), which defers to the emission limits specified in the Protection of the Environment Operations Regulation (Clean Air) 2010. To align with the regulation and policy, as well as to facilitate the use of SWDF, Boral proposes changes to the emission limits of particulate matter (PM), nitrogen oxides (NOx) and volatile organic compounds (VOCs). **Table 10** details the current air emission limits and the proposed changes.

Table 10 Proposed emission limits for burning non-standard fuel

Emission types	Limit using standard fuel	Current limit using non standard fuel	Proposed limit using non standard fuel
Particulate matter (PM)	95 mg/m^3	30 mg/ m^3	50 mg/ m^3 *
Nitrogen Oxides (NOx)	1000 mg/ m^3	800 mg/ m^3	1000 mg/ m^3 **
Volatile Organic Compounds (VOCs)	N/A	20 ppm	40 ppm **

* NSW Group 6 emission criteria as per *Energy from Waste Policy 2014*
** Alternative emission standards applied for as per Clause 36 of *POEO (Clean Air) Regulation 2010*

These proposed emission limits are considered safe with regards to public health and environmental impacts (Air Quality Professionals, 2015) and are also realistic for Boral to achieve at a commercially acceptable cost.

Emissions reporting

Boral also seeks minor changes in the development consent to the way two emissions are reported. The changes sought are:

- the definition of Volatile Organic Compounds to be changed to Non-Methane Volatile Organic Compounds; and
- the averaging period for the reporting of Nitrogen Oxides changed from 1-hour averaging, to 24-hour averaging.

The reasons for these changes are outlined below.

Volatile Organic Compounds

Within Kiln 6, it can be demonstrated that VOC emissions are not associated with the combustion of fuels. Rather, the VOC's are associated with the natural composition of onsite blue shale used as a raw material in Kiln 6.

In Europe, where there is widespread use of WDF in cement kilns, there is recognition in their policy document (Waste Incineration Directive, 2000 (WID)) that VOC emissions are not necessarily linked to the use of waste-derived fuels. Rather, it is recognised that these emissions may be caused by other factors, therefore providing the regulator with discretion to allow exemptions based on other parameters such as Total Organic Carbon (TOC).

The WID states:

"*Exemptions may be authorised by the competent authority in cases where TOC (i.e. VOC) and SO_2 do not result from incineration of waste*".

Boral seeks recognition of established practices used in WID and submits that Non-Methane Volatile Organic Compounds as Propane (C3) are the appropriate VOC to measure compliance to account for the inherent VOC levels within the blue shale. Accordingly, Boral seeks modification of Condition 3.10A, Table 4 in the consent to acknowledge Non-Methane Volatile Organic Compounds as Propane.

Averaging period for Nitrogen Oxides

Continuous monitoring results for Nitrogen Oxides (NO_x) are currently required to be averaged over a 1 hour period when burning non-standard fuels. However, other pollutants, like particulate matter, are required to be averaged over 24 hours.

Interactions between fuel combustion and chemical processes in a cement kiln can result in significant hourly variations in NO_x which are not reflective of the environmental impact of the kiln emissions. This is important from a regulatory and community point of view, so that reporting is consistent and an accurate reflection of potential environmental impact, rather than short term variations.

Boral seeks consistency of averaging periods across monitoring of all pollutants when using non-standard fuels and requests that the averaging period for NO_x be changed to a 24-hour average, counted from midday to midday.

1.9.7 Fuel storage and feeding system

The following sections discuss the design, construction and operation of the necessary fuel storage and feeding system to enable the use of SWDF at the Cement Works.

The SWDF that are proposed to be used at Berrima would be transported by road from tier one waste management facilities and unloaded directly into an onsite enclosed purpose built steel clad building on the Berrima Cement works site.

Design

The storage and handling facility is designed to store and handle SWDF such as waste tyre chips (AKF5), wood waste and RDF. The SWDF fuel storage, handling and feeding system comprises:

- a receival and storage building located on the southern side of the Kiln 6 pre-heater tower. The building would be 33m long, 50m wide and 13m high;

- a RDF bale feed conveyor to feed bales into the receival shed;
- a de-baler/shredder and feed system at the back end of the storage shed;
- an enclosed conveyor from the storage building to the existing pre-calciner vessel located in the preheater tower;
- a screw conveyor and air sealing device around the pre-calciner within the preheater tower; and
- a designated ground outdoor storage area for SWDF received in the form of covered (plastic wrapped) bales or within covered delivery vehicles.

Potential suppliers of SWDF have nominated bales as the preferred method of transporting in the short term. However, in the future, as the market develops, transportation may move to using shipping containers, which would necessitate an alternate feeding system. This would be subject to future development assessment.

The daily SWDF would require approximately ten (10) truck deliveries per day with the planned trucks to be covered tippers.

The SWDF receiving and storage building has provision to accommodate the necessary buffer tyre (TDF) and (C&I) wood chips stockpile on site at Berrima in order to cater for weekends. The intended onsite stockpile for TDF would be up to 350m^3 and for C&I wood chips the onsite stockpile of 1,110m^3.

The SWDF bales would be unloaded and stored in the SWDF building until required to be transferred by the SWDF material handling system to the Kiln 6. To cater for weekends, the intended onsite stockpile would include provision for 850 SWDF 1 m^3 bales.

1.10 Traffic and Access

1.10.1 Existing Environment

Traffic travelling to and from the Cement Works use the following roads:

- Taylor Avenue – a local road that runs in an east-west direction and which connects Berrima Road in the east to Old Hume Highway in the west. It carries approximately 2,795 vehicles per day and provides a key link for the Cement Works with the majority of heavy vehicles using it to access the Hume Highway (M31 Motorway) to the west;
- Berrima Road – a RMS Main Road (MR372) that runs in a north-south direction and which connects Berrima in the north with Moss Vale in the south. It carries approximately 3,700 vehicles per day; and
- Hume Highway (M31 Motorway) – a national highway that runs in a generally north east-south west direction which connects the Sydney and Melbourne metropolitan area. It carries approximately 9,850 vehicles per day.

Existing site characteristics

The Cement Works operates 24 hours a day and seven days a week, however, a typical transport day occurs mainly for a 12-hour period during weekdays (4.00am to 4.00pm), and on Saturdays for a 6 hour period (7.00am to 1.00pm). Limited heavy traffic volumes are generated outside of these periods.

Access to the site is via :

- Gate 1: On Argyle Street, used for access to administration, reception and stores; and
- Gate 2: On Perth Street, used for all truck deliveries and dispatches.

A private railway line also operates through the site which enters the site at Berrima Road.

Existing traffic generation

An average total of 207 loads are required to be transported to and from the Cement Works daily. Due to the efficiency benefits of backloading trucks, whereby a truck arrives carrying a load of material (i.e. aggregate) and departs carrying a load of another material (i.e. clinker product), these 207 individual loads translates to only approximately 297 truck movements (arrival trips and departure trips) per weekday. It is also worth noting that raw materials, clinker and cement products are also delivered and dispatched via the privately operated railway line.

The 297 truck movements generally occur uniformly throughout an average 12-hour weekday, therefore on average the works site generates 24.8 movements (trips) per hour. There are 90 truck movements on Saturdays translating into an average of 15.0 movements (trips) per hour over the 6-hour operating period.

Deliveries and dispatches of materials by road to and from the Cement Works can be broken down as follows:

- deliveries of raw materials used for production of clinker and cement: 375,000 tonnes/year;
- deliveries of fuels for energy to operate the Kiln: 220,000 tonnes/year;
- dispatch of manufactured clinker: 300,000 tonnes/year; and
- dispatch of manufactured cement: 550,000 tonnes/year.

The majority of Cement Works truck traffic accesses the New Berrima area via the Hume Highway (M31 Motorway) to the west of the site. The remainder travel east along Berrima Road to the Concrete Plant in Moss Vale. To access the Hume Highway, trucks depart via Gate 2 and travel west through New Berrima along Taylor Avenue to the roundabout intersection at its western termination. From this roundabout, trucks travel either west along Medway Road or south west along the Old Hume Highway.

All additional waste fuel delivery truck traffic would use the same local truck routes as existing cement works trucks; that is, accessing the Hume Highway via Taylor Avenue and Medway Road or the Old Hume Highway. Accordingly, the proposal would not increase truck movements on roads that do not already support cement works trucks.

Proposed Operation Traffic

The proposal seeks to use solid waste fuel to supplement and partially replace the existing use of coal to generate energy for the operation of Kiln 6. Provision of up to 100,000 tonnes of solid waste fuel is proposed to be sourced per year, which would reduce the reliance on coal from 220,000 tonnes consumed per year to 170,000 tonnes. Due to the lower caloric value of the solid waste fuel compared to coal, an extra 50,000 tonnes of solid waste fuel would be required to service the existing energy needs of the site. The solid waste-derived fuels intended for Berrima would also have lower bulk density, translating into more trucks for the same tonnage. As a result there would be minor additional truck loads and movements to the site as a result of the proposed modification.

The changes to the existing truck movements as a result of the shift to waste derived fuel would be:

- coal and coke breeze: the reduction in coal required would result in five (5) fewer truck loads to 18 truckloads per day with 36 associated truck movements per day, a reduction from the 46 trips per typical weekday. On Saturdays, there would be approximately 18 trips; and

- waste derived fuel: the waste fuel is to be delivered by either truck and dog trailer vehicles or B-Double trucks with 24 tonne payload capacity. Based on this, 15 truckloads would need to be transported daily, resulting in 30 truck movements per day now needed. On Saturdays, there would be approximately 15 trips.

As staffing levels remain unchanged, no additional parking is required.

All heavy vehicle traffic, include deliveries of solid waste derived fuel, would be weighed upon site entry and exit.

Details of the existing operational traffic for the Berrima Cement Works and future operation traffic anticipated for the Cement Works following the proposed modification are summarised in **Table 11** along with the net increase in traffic volumes.

Table 11 Existing and proposed operational truck traffic

Scenario	12-hour weekday		6-hour Saturday	
	Daily	Hourly	Daily	Hourly
Existing (trucks)	297	24.8	90	15.0
Future (trucks)	317	26.4	100	16.7
Net increase (trucks)	20	1.6	10	1.7
Net increase (%)	6.7%	6.5%	11.1%	11.3%

The assessment indicates that the net increase in traffic generation as a result of the proposed modification would be:

- weekday: 20 additional trips on an average 12-hour working weekday, equivalent to 1.6 additional trucks per hour or an increase in truck trips of approximately 6.5%; and

- Saturday: 10 additional trips on an average 6-hour working Saturday, equivalent to 1.7 additional trucks per hour or an increase in truck trips of approximately 11.3%.

This demonstrates that the forecast increase in traffic generation as a result of the proposed modification would be minor.

As all additional waste fuel delivery truck traffic would use the same local truck routes as existing Cement Works trucks, the proposed modification would not lead to truck movements on roads that do not already support Cement Works trucks.

Details of the existing traffic flow volumes on Taylor Avenue (recorded by tube count survey) and the anticipated net increase in traffic as a result of the proposed modification are summarised in **Table 12.**.

Table 12 Traffic implications for Taylor Avenue

Scenario	Weekday		Saturday	
	Daily	12-hour day,	Daily	6-hour day
Existing (vehicles)	2,795	2,025	1,866	698
Net increase (vehicles)	20	20	10	10
Net increase (%)	0.7%	1.0%	0.5%	1.4%

The assessment indicates that the impacts to Taylor Avenue traffic as a result of the proposed modification would be:

- weekday: An increase of just 1% in Taylor Avenue traffic volumes during the typical 12-hour working weekday and just 0.7% across all 24-hours on an average weekday; and
- Saturday: An increase of just 1.4% in Taylor Avenue traffic volumes during the typical 6-hour working Saturday and just 0.5% across all 24-hours of an average Saturday.

The increases in traffic on the local road network as a result of the proposed modification are of such a low order that they would have no material impact on the performance or safety of the local road network and therefore no external infrastructure upgrades are required.

2 RISK ASSESSMENT

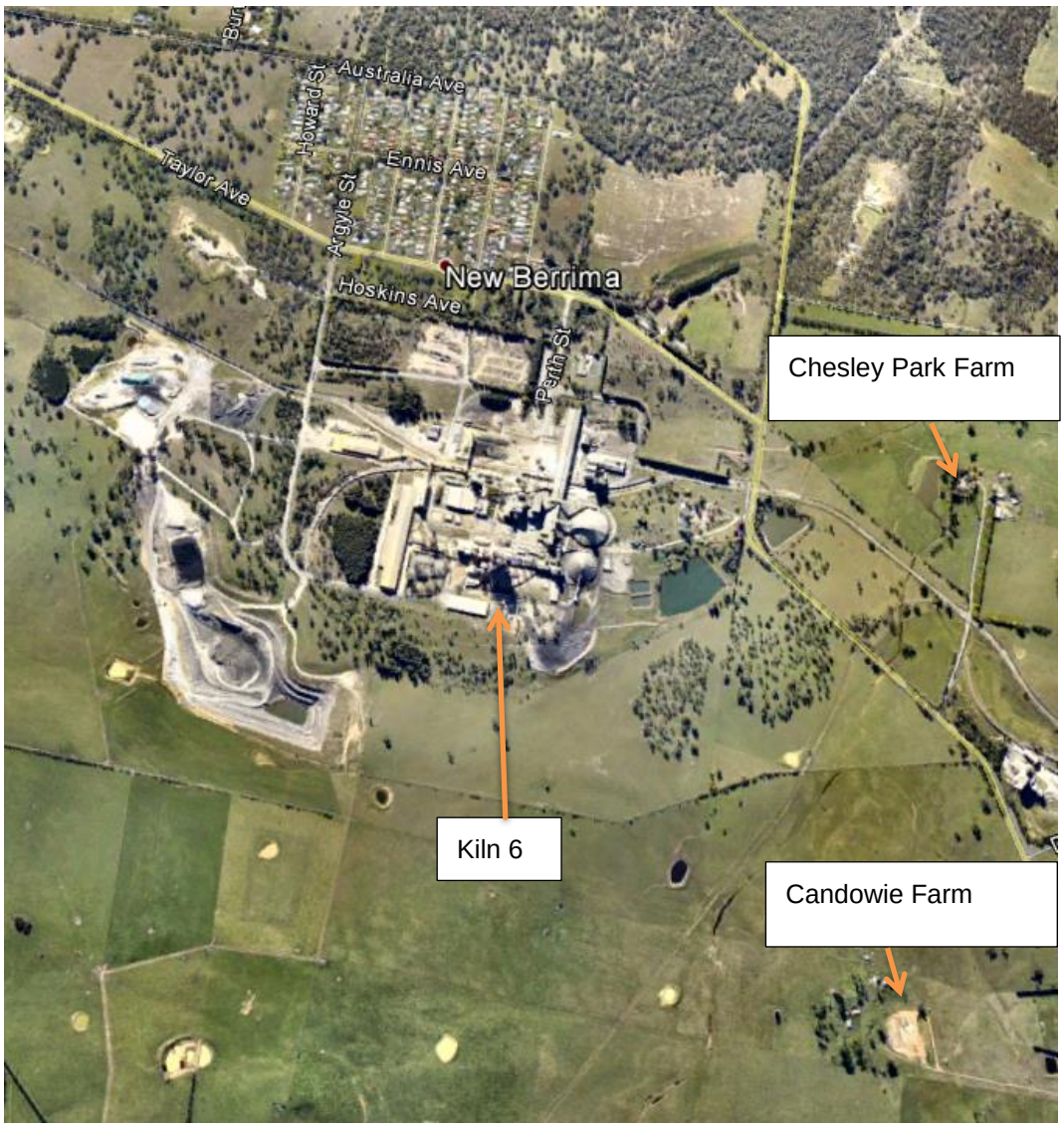
2.1 Issue Identification

2.1.1 Community Chosen for Assessment

The communities chosen for the purposes of this assessment were the residents of New Berrima, Berrima, Burradoo and Moss Vale. The local communities in closest proximity to the cement works live in New Berrima (approximately 0.5 km), and the furthest live in Burradoo (approximately 5 km). Outside these population areas the land is rural in nature with scattered houses generally on farmland.

The location of the site in relation to New Berrima is shown in **Photograph 2.**

Photograph 2 Aerial photograph showing site proximity to New Berrima



2.1.2 Solid Waste Derived Fuels (SWDF)

Boral proposes two SWDF for use in the Kiln 6 subject of this modification (modification 9):

- Wood Waste - material left over from industrial processes like milling, furniture making, and building and construction; and
- Refuse Derived Fuel (RDF) - fuel made from the combustible materials recovered and processed from waste streams, such as papers, cardboards, packaging, and construction and demolition materials

Table 13 provides an indicative breakdown of the waste streams that make up Wood Waste and Refuse Derived Fuel based on information provided by potential suppliers. It should be noted that the actual breakdown could vary from the data presented here, depending on the final product specification prepared by each supplier and the ability to tailor the specification to the specific requirements of the Berrima site.

Table 13 Indicative breakdown of Solid Waste Derived Fuels waste streams

Wood Waste				Refuse Derived Fuel			
Supplier 1		Supplier 2		Supplier 1		Supplier 2	
Component	% (range)	Component	% (range)	Component	% (range)	Component	% (range)
Plastics	5-15%	Plastics and textiles	5-10%	Plastics	35%	Plastics	45% (+/- 15%)
Paper and cardboard	5- 20%	Furniture (lacquered / painted MDF and Wood	10-15%	Paper and Cardboard	20%	Paper / cardboard	35% (+/- 15%)
Wood	60-80%	Untreated boards	30-40%	Organic materials	14%	Wood	5-10%
Other (textiles, fines)	5-15%	MDF / chipboard	30-40%	Textiles	11%	Other	0-5%
				Other including fines	20%		

2.1.3 Potential Contaminant Emission Sources at the Cement Works

The source of potential contaminant release into the environment at the Berrima Cement Works can be divided into two broad classes, point sources, such as kiln number 6 stack, and fugitive sources from more diffuse sources such as that caused by truck movements. The list of potential point emission sources and controls has been set out below in **Table 14**.

Table 14 Potential emission sources – point sources and controls

Point Source	Description	Particulate Control Equipment
Kiln No 6 stack	Stack discharging exhaust gases from kiln	Full exhaust gas flow split between electrostatic precipitator (ESP) and bag filter
Cement Mill No 6	Vent discharging from side of Cement Building No 6	Bag filter
Kiln No 6 Cooler	Stack discharging large volume of air used to cool clinker after it comes out of kiln	Bag filter
Cement Mill No 7	Vent at end of a large duct coming out of the side of Cement Building No 7	Bag filter

Fugitive sources are more diffuse in nature and generally relate to activities. The reported fugitive sources were reported by Air Quality Professionals (2015) to be the following:

- Stockpiles of bulk dry materials such as coal, blue shale, yellow shale, steel or blast furnace slag, cement fibreboard, and gypsum.
- Trucks and loaders generating dust from vehicle tracks and movement of materials.

- Unpaved roads and dusty surfaces in stockpile areas.
- Quarry area.
- Crushing and mixing of materials prior to kiln processing.

The report went on to note the predicted new emission sources but concluded fugitive emissions of odour from within the storage building are the only potential new air emission identified within the Project. This conclusion was based on the design of the new storage and handling facilities. A key control feature of this was that the SWDF was wrapped in plastic for transport to the works and only unwrapped once inside the storage building. Details of the proposed design features have been set out previously in the current report section 1.9.7.

2.1.4 Emissions from the Co-Processing of SWDF in Cement Kilns

The European Commission (2013) Industrial Emissions Directive 2010/75/EU sets out a general indicative list of the main air-polluting substances to be taken into account, if they are relevant for fixing emission limit values, for the co-processing of waste derived fuels such as SWDF in cement kilns.

Emissions relevant to cement manufacture including the use of waste are:

• Oxides of nitrogen (NOx) and other nitrogen compounds

• Sulphur dioxide (SO2) and other sulphur compounds

• Dust

• Total organic compounds (TOC) including volatile organic compounds (VOC)

• Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD and PCDF) (dioxins and furans)

• Metals and their compounds

• Hydrogen fluoride (HF)

• Hydrogen chloride (HCl)

• Carbon monoxide (CO)

2.1.5 Conceptual Site Model

Conceptual Site Model (CSM) uses the concept of the links between source – pathway – receptor to assess risk. This can include the source of Contaminants of Potential Concern (COPC) which may impact on the communities in question and transport mechanisms whereby COPC can be moved to exposure points (human receptors). If any of these links are missing then an exposure pathway in incomplete and human exposure will not occur. If the exposure pathway is potentially complete then likely impact on the receptor may need to be assessed.

The CSM development indicated that following factors:

- Potential COPCs

- The release mechanism whereby the COPCs may be released into the environment
- The transport pathways moving the COPCs through the environment
- Exposure pathways
- Exposure Routes whereby the a person takes in the COPC
- Location of potential receptors
- Significant pathways by which exposure may occur
- Minimal exposure pathways, considered as less likely to led to human exposure
- Primary exposure pathways considered to be the pathway by which the largest quantities of emissions of a identified COPC move
- Secondary exposure pathways considered to be the pathway by which lessor quantities (compared to the Primary exposure pathway) of the emissions of a identified COPC move

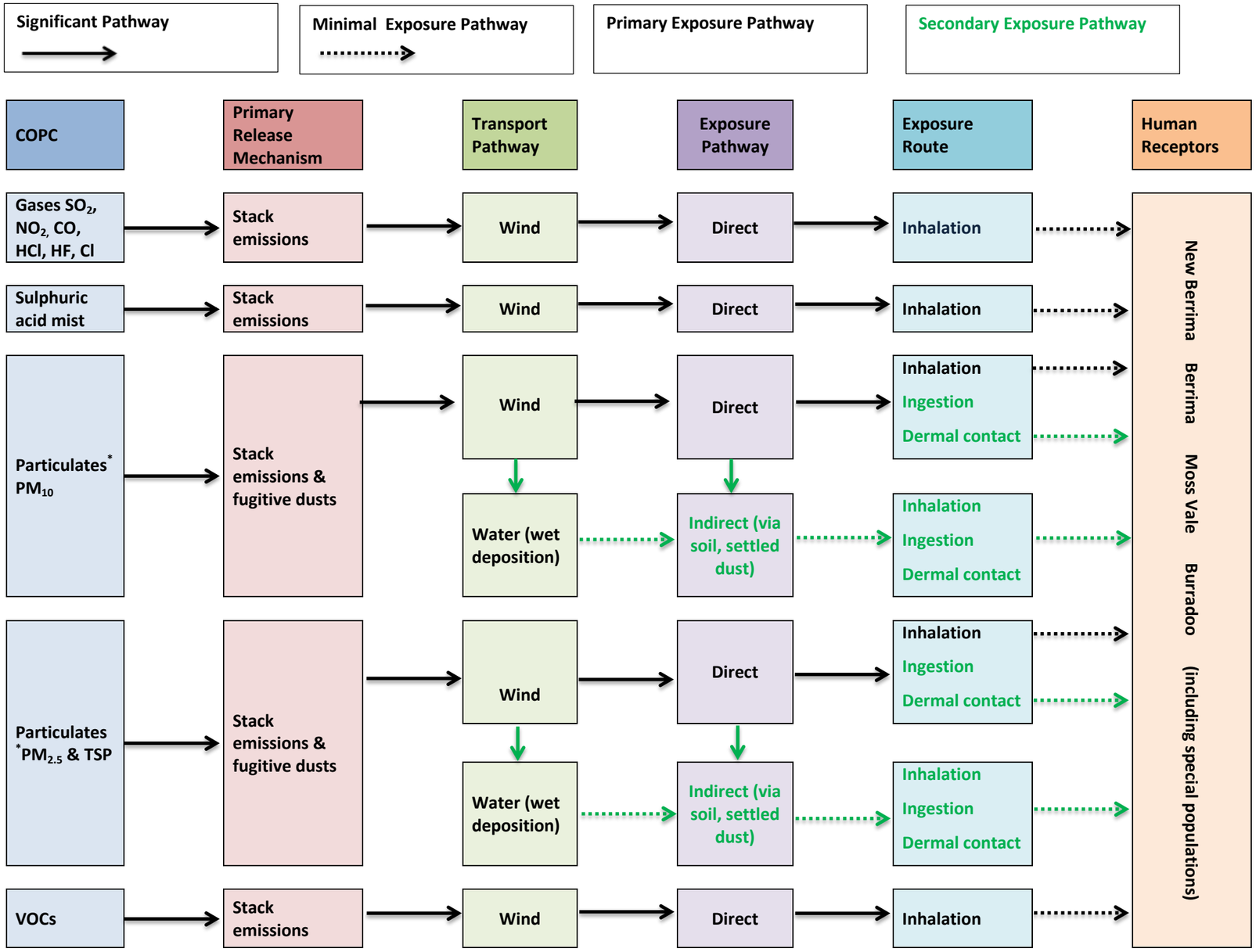
The Primary exposure pathway relating to the operations of the Berrima Cement works were determined to be via the airborne pathway. This was due to the anticipated mass of airborne COPC emissions being the dominate source for both point sources (such as the kiln and fugitive sources. The Secondary exposure pathway was considered to be the indirect pathway in which COPC emissions are transported off site through environmental forces such as wind, the COPC then settle into dusts or soils and are subsequently remobilised when the soil or dusts are disturbed, at which point human exposure may take place.

In the current study, it was determined that if the Primary exposure pathway was found to be unlikely to cause a risk to humans then the Secondary exposure pathway was also similarly excluded. This conclusion was drawn due to the Secondary exposure pathway being considered to transport significantly less mass of a COPC compared with the Primary exposure pathway.

The CSM diagram has been set out in **Figure 10**.

Figure 10 Conceptual Site Model - Berrima Cement Works

Figure 10 Conceptual Site Model - Berrima Cement Works



Note * Includes particle associated COPCs such as dioxins, PAHs & heavy metals

2.1.6 Contaminants of Potential Concern (COPC)

The groups of substances relevant to the Co-Processing of SWDF in Boral Kiln 6 were detailed in *Boral Cement Berrima Works Use of Solid Waste Derived Fuels in Kiln 6 Air Quality Assessment* (Air Quality Professionals, 2015). These groups of substances form the COPC for the health risk assessment and have been set out below in **Table 15**.

Table 15 Contaminants of Potential Concern (COPC), sources and potential exposure pathways

COPC	Source	Exposure Transport Pathways or Environmental Sink	Exposure Routes[#]
Fine Particulates PM_{10} and $PM_{2.5}$	Combustion processes and dry goods handling / milling processes	airborne	Inhalation Ingestion
Sulphur dioxide	Combustion processes	airborne	Inhalation
Nitrogen oxides	Combustion processes	airborne	Inhalation
Carbon monoxide	Combustion processes	airborne	Inhalation
Volatile organic compounds VOCs	Combustion processes and dry goods handling / milling processes	airborne	Inhalation
Polycyclic aromatic hydrocarbons PAHs	Combustion processes and dry goods handling / milling processes	airborne & soils	Inhalation Ingestion Dermal absorption
Heavy metals	Combustion processes and dry goods handling / milling processes	airborne & soils	Inhalation Ingestion Dermal absorption
Hydrogen halides – hydrogen chloride, hydrogen fluoride, chlorine	Combustion processes	airborne	Inhalation
Sulphuric acid mist / sulphur trioxide	Combustion processes	airborne	Inhalation
Dioxins	Combustion processes and dry goods handling / milling processes	airborne & soils	Inhalation Ingestion Dermal absorption

Note [#] Examples of these exposure Pathways and Routes are listed below:

Inhalation – Inhalation of airborne gases and particulates from point sources like Kiln 6 or fugitive sources. This is a primary route of potential exposure highlighted in **Table 15**.

Ingestion – Ingestion of particulate matter, from point sources like Kiln 6 or fugitive sources, either travelling directly from the source to the receptor or indirectly where the particulates have settled into settled dust or soils then are ingested through contamination of food, drink or through poor hygiene practices. This is the secondary route of potential exposure highlighted in **Table 15**.

Dermal Absorption – Absorption into the body through skin after contact with contaminated particulates either travelling directly from the source to the receptor or indirectly where the particulates have settled into dust or soils then are ingested through contamination of food, drink or through poor hygiene practices. This is a secondary route of potential exposure highlighted in **Table 15**.

2.1.7 Exposure Concepts

To assess the potential health impact of a COPC on a population the exposure can be assessed in two broad concepts, acute exposure and chronic exposure.

Acute exposure refers to short term exposures of up to 14 days, often with immediate effects on the exposed individuals. This may be due to the inherent toxicity of a contaminant or the physiological response the contaminate elicits such as irritation to an individual's airways.

Examples of parameters used to assess acute exposure can include peak concentrations of a contaminate, predicted 24 hour average concentrations and the like.

Chronic exposure refers to long term exposures based on exposure all day every day for a lifetime. An example of a parameter used to assess chronic exposure is the annual average concentrations of air pollutants.

2.1.8 Fine Particulates

Fine particulates refer to any particles likely to be potentially airborne. In terms of human health risk, the issues may arise from physical damage to the respiratory system from inhaled particles. Total Suspended Particulates (TSP) includes particles with an approximate aerodynamic diameter of 50µm and less. Particles at the larger end of this size range may be inhaled but do not as a rule penetrate far into the respiratory system. Accordingly the larger particulates may have little role in health impacts associated with inhaled particulates. The smaller particles such as PM_{10} and $PM_{2.5}$ are more of a health hazard as their size allows the particle to penetrate deeply into the respiratory system. Aside from physical damage, the particulates may also act as carriers of chemical contaminants, bound to the particulates, transporting the chemical into the lungs where absorption of the chemical into the body is more likely or into the gut if contaminated particulates are ingested. The current study will focus on the potential health impacts associated with the smaller particles (PM_{10} and $PM_{2.5}$) that can potentially penetrate deep in to the lungs and therefore have the greatest potential for adverse health impacts.

Air Quality Professionals (2015) state that the particulate matter discharged from various sources at the site, including Kiln 6 and Cement Mill stacks as well as stockpiles and open sources, will be comprised of a variety of size fractions that will vary for each source. These size fractions are listed as:

- Larger depositable dust generally greater than 50µm in diameter.
- Total Suspended Particulates (TSP), which his finer than the depositional dust.
- PM_{10}, that is the fraction of TSP less than 10µm in diameter
- $PM_{2.5}$, that is the fraction of TSP less than 2.5µm in diameter

The report goes on to comment that Kiln 6 and Cement Mill stacks are fitted with particulate control equipment that traps the majority of depositable dusts. Thus the majority of the particulates discharged from these stacks are likely to be in the PM_{10} and $PM_{2.5}$ size range. Annual stack testing of the existing facility between 2011, 2013 & 2014 has confirmed this showing the particulate emissions to consist of approximately 61-74% PM_{10} and 30-33% $PM_{2.5}$.

2.1.8.1 National Airborne Particulates Air Quality Goals and Health Based Criteria.

The current national air quality goals for particulates were set with a view to be protective of health and achievable for industry, based on the scientific evidence available at the time of setting the goals. With the advancement of scientific knowledge, there has been some debate as to whether the national goals need to be revised and on the adequacy of current national air quality goals for particulate matter for health risk assessments. The review by NEPC (2011) reported current national air standards were not meeting the requirements for adequate protection of human health. The review further commented that there was substantial new evidence on both short-term and long-term effects for particles (PM_{10} and $PM_{2.5}$) associated with increases in mortality and morbidity, with much stronger evidence now for cardiovascular outcomes. Therefore it is likely that future revision of the goals may lead to a lowering of the acceptable concentrations for PM_{10} and $PM_{2.5}$.

It is widely considered there is no lower threshold concentrations for the health effects of air pollution. That is to say there is no known lower limit threshold concentrations below which health impacts will definitely not occur in sensitive individuals. This does not mean that health impacts will definitely occur rather it indicates there may be a risk to health and that the risk of an incidence of adverse health impact will decrease as the concentrations of PM_{10} and $PM_{2.5}$ decrease. Therefore there may be some residual health risk associated with national air quality standards (NEPC, 2010). The question then becomes what is an acceptable level of health risk? This will be discussed below.

The current national air quality goals for airborne particulates have been set out below in **Table 16.**

Table 16 Particulate Matter Air Quality Goals

Particulate Class	Averaging Period	Goal (µg/m^3)
TSP	Annual	90$^{\#}$
PM_{10}	24 hours	50* (maximum of 5 days exceedances per year)
	Annual	30*
$PM_{2,5}$	24 hours	25*
	Annual	8*

* NEPC (2003), $^{\#}$ DEC (2005)

The current national air quality goals are set as total airborne particulates concentrations. Referred to as cumulative airborne particulate concentrations in air quality modelling predictions. Comparison of total airborne particulate concentrations, over the relevant averaging periods such as 24 hours or annual averages, to standards or goals can demonstrate potential for health risks. However, the natural fluctuations in background concentrations can make it difficult to determine the extent of potential risks associated with particulate emissions from a proposed development. That is, the additional contribution locally to the already existing health risks from airborne particulates in a particular geographical area.

The accepted method to investigate additional contribution to health risk from airborne particulates, as PM_{10} and $PM_{2.5}$, is to determine the increase in risk associated with the increase in airborne particulates (PM_{10} and $PM_{2.5}$.) predicted from a proposed development. In this, the predicted incremental airborne particulates concentrations from modelling, that is the likely change in local concentrations caused by the proposed development are utilised rather than the predicted total concentrations. Established risk calculations are used to determine the potential increase in health risk to a community. The basis of these risk calculations have been set out in **Appendix A.**

The quantification of risk is an imprecise practise, based on available evidence, estimating level of risk within generally accepted ranges rather that absolute risk. The level of negligible / acceptable risk is generally considered to be less than 1 in 1,000,000 (i.e 1×10^{-6}) for contaminates with health effects considered to non-threshold in nature or carcinogenic chemicals (enHealth, 2012). At this level of risk, it is considered essentially non-existent. The level of risk is considered unacceptable at greater than 1 in 10,000 (1×10^{-4}). Tolerable risk occurs in the range between 1×10^{-6} and 1×10^{-4} (DEC, 2005). Tolerable risks are considered acceptable when best practise for minimising air toxics has been utilised.

2.1.8.2 TSP

As previously stated, it is the finer particles in TSP (PM_{10} and $PM_{2.5}$) that are associated with health impacts. Accordingly the current health risk assessment will focus on the PM_{10} and $PM_{2.5}$ size particles in the next sections.

However with regards to the TSP it was noted that the predicted cumulative annual average concentrations were reported to be all below the Approved Methods assessment criteria of 90 µg/m^3 at each of the discrete receptors with the highest concentration being 15.2 µg/m^3 at Receptor 75 (Air Quality Professionals, 2015).

Furthermore the authors considered the predictions to be highly conservative in nature, stating that:

In addition, TSP concentrations occurring beyond the site boundary due to emissions from the Works are very insensitive to changes in TSP emission rates from the Kiln 6 stack.

The model results and calculated cumulative GLCs (Ground Level Concentrations) *are very conservative as the model was run using a constant (365 days per year, 24 hours per day) 1-hour average emission concentration that represents the peak 1-hour average concentration that might occur within the maximum 24-hour average concentration proposed in the EPL modification for the burning of NSF.*

Therefore it is concluded that adverse air quality impacts will not arise due to TSP emissions due to the Project.

2.1.8.3 PM_{10}

Cumulative Concentrations PM_{10}

The modelling of Air Quality Professionals (2015) concluded that there will be no adverse changes in annual average PM_{10} concentrations, due to the Project, stating that:

Cumulative annual average concentrations of PM_{10} from both fugitive and point sources at the Works, including background concentrations, are below the Approved Methods assessment criteria of 30 µg/m^3 at each of the discrete receptors even with the conservative assumption that the Works operates continuously for 365 days per year.

However, with regards to PM_{10} 24 hour average concentrations the report found some exceedances, stating that:

For most of the discrete receptors, no additional exceedances of the 24-hour average PM_{10} air quality criteria are generated due to PM_{10} emissions from the Works. However a small number of discrete receptors near the site boundary do show some possible additional exceedances. For receptors 23 and 57, GLC exceedances are highly dependent on background data. For receptors 75 and 88, and to an extent receptor 57 as well, the number of cumulative GLCs exceeding 50 µg/m^3 is highly dependent on the modelled incremental concentrations, and therefore highly dependent on the magnitude of the fugitive dust concentrations. Those fugitive dust concentrations are considered to be over-estimates of actual maximum incremental GLCs at receptors close to the site boundary because of the assumptions required for the fugitive dust dispersion analysis. In most cases, the cumulative GLCs that exceed 50 µg/m^3 are only 10-20% greater than that threshold concentration, so overestimates of fugitive dust concentrations will play a large role in the number of predicted exceedances.

The receptors potentially affected by the exceedances have been set below in **Table 17** and are also displayed on **Figure 6.** Receptor 88, which is not noted on Figure 6, is located on the corner of corner of Howard St and Taylor Ave New Berrima.

Table 17 Location of potentially impacted receptors in relation to Berrima Cement Works

Receptor	Approximate Distance from Site Boundary	Direction from Site
23	790m	south west
57	1000m	north east
75	700m	north west
88	300m	north

To put the exceedances attributed to the facility in perspective, it should be noted these exceedances are similar in number but at lower concentrations (maximum 69.7µg/m^3) than exceedances due to general environmental conditions excluding the influence of the facility (maximum 177.5µg/m^3).

Fugitive dust from the works has been determined as the main source of airborne dust as PM_{10} exceedances attributed to the facility. However, background environmental conditions (excluding dust emissions from the facility) are predicted to give rise to PM_{10} 24 hour averages approximately eight times greater than those attributed to the facility alone.

The predicted exceedances of PM_{10} 24 hour average concentrations and frequency have been set out below in **Table 18.**

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Table 18 Dust PM_{10} Emissions from Berrima Plant that may exceed regulatory criteria

Airborne Pollutant	Regulatory Criteria	Predicted Concentrations at Ground Level	Comments
Dust PM_{10} 24 hour average – Additional exceedances beyond background	50µg/m^3 GLC* Maximum of 5 exceedances per year	50 – 69.7µg/m^3 When background environmental dust levels are less than 47µg/m^3	Ground level receptors, limited number affected near boundary (R23, R57, R75, R88). Source expected to be fugitive dust not kiln emissions. Frequency 2 to 5 times per year.
Dust PM_{10} 24 hour average Background exceedances due to environmental conditions	50µg/m^3 GLC*	52 – 177.5µg/m^3 Background environmental dust levels only	Ground level receptors, near boundary (R23, R57, R75, R88). Source background dust unrelated to Berrima Plant. Frequency 2 to 7 times per year.

2.1.8.4 $PM_{2.5}$

Cumulative Concentrations $PM_{2.5}$

The modelling of Air Quality Professionals (2015) concluded that with regards to $PM_{2.5}$ concentrations there will be no effective change to off-site local air quality impacts of $PM_{2.5}$ due to the Project, stating that:

Cumulative annual average concentrations of $PM_{2.5}$ from both fugitive and point sources at the Works, including background concentrations, are below the Approved Methods assessment criteria of 8 µg/m^3 at each of the discrete receptors even with the conservative assumption that the Works operates continuously for 365 days per year.

24-Hour average - No additional exceedances of the NSW EPA criteria arise from the cumulative assessment of $PM_{2.5}$ emissions from the site combined with contemporaneous background data. Therefore it is concluded that adverse air quality impacts will not arise from 24-hour average $PM_{2.5}$ concentrations due to the Project.

2.1.8.5 Health Risk Assessment of Changes in PM_{10} & $PM_{2.5}$ Concentrations

As discussed above in **2.1.8.1** while the current NEPC (2003) air quality goals for PM_{10} and $PM_{2.5}$ were established to be protective of health it is widely recognised concentrations below these levels may impact on health. Moreover the natural background fluctuations unrelated to a Project also may impact on health outcomes in the community. Therefore to determine if the Project will generate changes in PM_{10} and $PM_{2.5}$ community exposure that may impact on community health, risk assessments were undertaken based on the incremental changes predicted at the Receptors identified in the air quality report.

The quantified risk assessment of predicted incremental increases in total PM_{10} and $PM_{2.5}$ concentrations combining all point sources and fugitive sources, based on annual average concentrations, (maximums: PM_{10} = 5.2 µg/m^3; $PM_{2.5}$ = 1 µg/m^3) found that the risks were in the negligible (risk = ≤ 1 x 10^{-6}) to tolerable risks (risk = ≤1 x 10^{-4} to ≥1 x 10^{-6}) range at Receptor locations. That is, risks may be considered acceptable when best practise for minimising air toxics have been utilised.

At locations other than Receptors, the predicted maximum incremental increases in total PM_{10} and $PM_{2.5}$ based on annual average concentrations, (maximums: PM_{10} = 18 µg/m^3; $PM_{2.5}$ = 3 µg/m^3, Air Quality Professionals, 2016), found at these maximum concentrations there were potentially unacceptable risks (risk = ≥ 1 x 10^{-4}) with regards to $PM_{2.5}$ particulates (risk = 1 x 10^{-4} & 2 x 10^{-4}). This equates to 1 – 2 extra incidents of the chosen health endpoints per population of 10,000 people. However, the location where these maximum concentrations occur was just outside a small section of the western boundary of the site and not in an area of habitation. As such, it is unlikely to be a realistic exposure scenario for the community.

The potential risk caused by changes in PM_{10} & $PM_{2.5}$ associated with the Project was assessed as set out above in **2.1.8.1.** The results of the assessments have been set out in **Table 19.**

Table 19 Summary of incremental risks for exposure at off site receptors from PM_{10} & $PM_{2.5}$ from fugitive dusts & combined point sources,

Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5
Health Endpoint	Mortality - All causes Long Term ≥ 30 years	Hospitalisations - Cardiovascular Short Term ≥ 65 years	Hospitalisations - Respiratory Short Term ≥ 65 years	Mortality - All causes Short Term all ages	Mortality - All causes Short Term all ages	Mortality - Cardiopulmonary Long Term ≥ 30 years	Mortality - Cardiovascular Short Term all ages	Mortality - Respiratory Short Term all ages
Receptor	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
Maximum	**6×10^{-5}**	**2×10^{-5}**	**4×10^{-5}**	**2×10^{-5}**	**6×10^{-6}**	**6×10^{-5}**	**2×10^{-6}**	**1×10^{-6}**
1	7×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	7×10^{-7}	7×10^{-6}	2×10^{-7}	1×10^{-7}
2	9×10^{-6}	3×10^{-6}	5×10^{-6}	2×10^{-6}	9×10^{-7}	9×10^{-6}	2×10^{-7}	2×10^{-7}
3	1×10^{-5}	3×10^{-6}	6×10^{-6}	2×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
4	1×10^{-5}	4×10^{-6}	7×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
5	1×10^{-5}	3×10^{-6}	6×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
6	1×10^{-5}	3×10^{-6}	6×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
7	1×10^{-5}	4×10^{-6}	7×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
8	1×10^{-5}	4×10^{-6}	8×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	4×10^{-7}	2×10^{-7}
9	1×10^{-5}	4×10^{-6}	8×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
10	1×10^{-5}	4×10^{-6}	8×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
11	2×10^{-5}	5×10^{-6}	9×10^{-6}	4×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
12	2×10^{-5}	6×10^{-6}	1×10^{-5}	5×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
13	2×10^{-5}	5×10^{-6}	1×10^{-5}	5×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
14	2×10^{-5}	6×10^{-6}	1×10^{-5}	5×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
15	2×10^{-5}	7×10^{-6}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
16	2×10^{-5}	7×10^{-6}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
17	2×10^{-5}	6×10^{-6}	1×10^{-5}	6×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}

Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5
Health Endpoint	Mortality - All causes Long Term ≥ 30 years	Hospitalisations - Cardiovascular Short Term ≥ 65 years	Hospitalisations - Respiratory Short Term ≥ 65 years	Mortality - All causes Short Term all ages	Mortality - All causes Short Term all ages	Mortality - Cardiopulmonary Long Term ≥ 30 years	Mortality - Cardiovascular Short Term all ages	Mortality - Respiratory Short Term all ages
Receptor	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
18	1×10^{-5}	3×10^{-6}	6×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
19	1×10^{-5}	3×10^{-6}	6×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
20	2×10^{-5}	6×10^{-6}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
21	2×10^{-5}	7×10^{-6}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
22	4×10^{-5}	1×10^{-5}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	1×10^{-6}	6×10^{-7}
23	4×10^{-5}	1×10^{-5}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	1×10^{-6}	7×10^{-7}
24	3×10^{-5}	9×10^{-6}	2×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-5}	8×10^{-7}	5×10^{-7}
25	2×10^{-5}	6×10^{-6}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
26	3×10^{-5}	8×10^{-6}	2×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}
27	3×10^{-5}	9×10^{-6}	2×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}
28	2×10^{-5}	7×10^{-6}	1×10^{-5}	9×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
29	2×10^{-5}	6×10^{-6}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
30	6×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	6×10^{-7}	6×10^{-6}	2×10^{-7}	1×10^{-7}
31	6×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	6×10^{-7}	6×10^{-6}	2×10^{-7}	1×10^{-7}
32	8×10^{-6}	2×10^{-6}	5×10^{-6}	3×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
33	1×10^{-5}	4×10^{-6}	7×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
34	2×10^{-5}	6×10^{-6}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
35	2×10^{-5}	5×10^{-6}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
36	2×10^{-5}	5×10^{-6}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
37	3×10^{-5}	8×10^{-6}	1×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-5}	7×10^{-7}	4×10^{-7}

Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5
Health Endpoint	Mortality - All causes Long Term ≥ 30 years	Hospitalisations - Cardiovascular Short Term ≥ 65 years	Hospitalisations - Respiratory Short Term ≥ 65 years	Mortality - All causes Short Term all ages	Mortality - All causes Short Term all ages	Mortality - Cardiopulmonary Long Term ≥ 30 years	Mortality - Cardiovascular Short Term all ages	Mortality - Respiratory Short Term all ages
Receptor	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
38	2×10^{-5}	7×10^{-6}	1×10^{-5}	9×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
39	2×10^{-5}	6×10^{-6}	1×10^{-5}	8×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
40	2×10^{-5}	5×10^{-6}	1×10^{-5}	6×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
41	3×10^{-5}	8×10^{-6}	1×10^{-5}	9×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	4×10^{-7}
42	2×10^{-5}	5×10^{-6}	9×10^{-6}	5×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
43	1×10^{-5}	4×10^{-6}	8×10^{-6}	5×10^{-6}	1×10^{-6}	1×10^{-5}	4×10^{-7}	2×10^{-7}
44	1×10^{-5}	4×10^{-6}	7×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
45	1×10^{-5}	3×10^{-6}	6×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
46	9×10^{-6}	3×10^{-6}	5×10^{-6}	3×10^{-6}	9×10^{-7}	9×10^{-6}	2×10^{-7}	2×10^{-7}
47	8×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
48	7×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	7×10^{-7}	7×10^{-6}	2×10^{-7}	1×10^{-7}
49	7×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	7×10^{-7}	7×10^{-6}	2×10^{-7}	1×10^{-7}
50	6×10^{-6}	2×10^{-6}	3×10^{-6}	1×10^{-6}	6×10^{-7}	6×10^{-6}	1×10^{-7}	1×10^{-7}
51	7×10^{-6}	2×10^{-6}	4×10^{-6}	1×10^{-6}	7×10^{-7}	7×10^{-6}	2×10^{-7}	1×10^{-7}
52	6×10^{-6}	2×10^{-6}	4×10^{-6}	1×10^{-6}	6×10^{-7}	6×10^{-6}	2×10^{-7}	1×10^{-7}
53	2×10^{-5}	5×10^{-6}	9×10^{-6}	4×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
54	2×10^{-5}	4×10^{-6}	9×10^{-6}	4×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
55	4×10^{-5}	1×10^{-5}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	1×10^{-6}	7×10^{-7}
56	4×10^{-5}	1×10^{-5}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	9×10^{-7}	6×10^{-7}
57	6×10^{-5}	2×10^{-5}	4×10^{-5}	2×10^{-5}	6×10^{-6}	6×10^{-5}	2×10^{-6}	1×10^{-6}

Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5
Health Endpoint	Mortality - All causes Long Term ≥ 30 years	Hospitalisations - Cardiovascular Short Term ≥ 65 years	Hospitalisations - Respiratory Short Term ≥ 65 years	Mortality - All causes Short Term all ages	Mortality - All causes Short Term all ages	Mortality - Cardiopulmonary Long Term ≥ 30 years	Mortality - Cardiovascular Short Term all ages	Mortality - Respiratory Short Term all ages
Receptor	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
58	2×10^{-5}	6×10^{-6}	1×10^{-5}	6×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
59	2×10^{-5}	7×10^{-6}	1×10^{-5}	6×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
60	3×10^{-5}	8×10^{-6}	1×10^{-5}	7×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	4×10^{-7}
61	2×10^{-5}	6×10^{-6}	1×10^{-5}	5×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
62	2×10^{-5}	5×10^{-6}	9×10^{-6}	5×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
63	2×10^{-5}	4×10^{-6}	9×10^{-6}	4×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
64	1×10^{-5}	4×10^{-6}	7×10^{-6}	4×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}
65	9×10^{-6}	3×10^{-6}	5×10^{-6}	2×10^{-6}	9×10^{-7}	9×10^{-6}	2×10^{-7}	2×10^{-7}
66	8×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
67	8×10^{-6}	2×10^{-6}	5×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
68	8×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
69	7×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	7×10^{-7}	7×10^{-6}	2×10^{-7}	1×10^{-7}
70	6×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	6×10^{-7}	6×10^{-6}	2×10^{-7}	1×10^{-7}
71	8×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
72	2×10^{-5}	6×10^{-6}	1×10^{-5}	7×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
73	2×10^{-5}	7×10^{-6}	1×10^{-5}	9×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}
74	2×10^{-5}	6×10^{-6}	1×10^{-5}	9×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}
75	5×10^{-5}	1×10^{-5}	3×10^{-5}	2×10^{-5}	5×10^{-6}	5×10^{-5}	1×10^{-6}	9×10^{-7}
76	3×10^{-5}	9×10^{-6}	2×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-5}	8×10^{-7}	5×10^{-7}
77	4×10^{-5}	1×10^{-5}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	1×10^{-6}	7×10^{-7}

Particulate Fraction	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5
Health Endpoint	Mortality - All causes Long Term ≥ 30 years	Hospitalisations - Cardiovascular Short Term ≥ 65 years	Hospitalisations - Respiratory Short Term ≥ 65 years	Mortality - All causes Short Term all ages	Mortality - All causes Short Term all ages	Mortality - Cardiopulmonary Long Term ≥ 30 years	Mortality - Cardiovascular Short Term all ages	Mortality - Respiratory Short Term all ages
Receptor	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
78	3×10^{-5}	8×10^{-6}	2×10^{-5}	9×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}
79	2×10^{-5}	6×10^{-6}	1×10^{-5}	5×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}
80	4×10^{-5}	1×10^{-5}	2×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-5}	1×10^{-6}	7×10^{-7}
81	1×10^{-5}	4×10^{-6}	8×10^{-6}	4×10^{-6}	1×10^{-6}	1×10^{-5}	4×10^{-7}	2×10^{-7}
82	9×10^{-6}	3×10^{-6}	5×10^{-6}	2×10^{-6}	9×10^{-7}	1×10^{-5}	2×10^{-7}	2×10^{-7}
83	1×10^{-5}	4×10^{-6}	8×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
84	1×10^{-5}	3×10^{-6}	8×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}
85	9×10^{-6}	3×10^{-6}	5×10^{-6}	2×10^{-6}	9×10^{-7}	1×10^{-5}	2×10^{-7}	2×10^{-7}
86	8×10^{-6}	2×10^{-6}	5×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}
87	8×10^{-6}	2×10^{-6}	4×10^{-6}	2×10^{-6}	8×10^{-7}	8×10^{-6}	2×10^{-7}	8×10^{-7}
88	4×10^{-5}	1×10^{-5}	3×10^{-6}	2×10^{-6}	4×10^{-6}	5×10^{-5}	1×10^{-6}	8×10^{-7}

2.1.9 Sulphur Dioxide (SO_2)

Sulphur dioxide is a colourless gas with a pungent odour. Sulphur dioxide in the air results primarily from activities associated with the burning of fossil fuels (coal, oil) such as at power plants or from copper smelting. In nature, sulphur dioxide can be released to the air, for example, from volcanic eruptions (ASTDR, 1998a). In the environment sulphur dioxide will normally be found in the gaseous phase.

Air Quality Professionals (2015) comment that sulphur dioxide emissions from dry process kilns are mostly linked to sulphur in raw material feed rather than fuel sulphur. The report goes onto state that up to 95% of potential sulphur dioxide emissions are not released into the environment but rather become physically bound up in clinker product. This is due to the highly alkaline nature of the cement kiln systems.

Sulphur dioxide can easily and rapidly enter the bloodstream through lungs. At elevated concentrations, SO_2 can cause irritation to the airways. Once in the body, it breaks down to sulphate and leaves through the urine (ASTDR, 1998a).

The acute LOAEL for sulphur dioxide has been reported as low as 0.1ppm (286µg/m^3) in sensitive asthmatics, however healthy non asthmatics respond to higher concentrations equal to or greater than 1.0ppm (2,860µg/m^3) (ASTDR, 1998a).

NEPC (2003) set air quality guidelines for sulphur dioxide considered to be protective of adverse health impacts for acute exposure and chronic exposure. The acute guidelines have been set at 0.2ppm (572 µg/m^3) for one hour exposure, 0.08ppm (246 µg/m^3) for a 24 hour exposure. The chronic exposure guidelines have been set at 0.02ppm (57 µg/m^3). These guidelines are in line with the NSW EPA Criteria of 570 µg/m^3, 288 µg/m^3 and 60 µg/m^3, respectively.

The air quality modelling of the proposed use of SWDF at the cement works predicted the cumulative SO_2 concentrations, as 1 hour, 24 hour and annual averages, to be significantly less than the health based criteria. These concentrations have been set out below in **Table 20.**

Table 20 Highest predicted cumulative SO_2 concentrations at off site receptors

Averaging Period	Cumulative SO_2 Concentration (µg/m^3)	NSW EPA Criteria (µg/m^3)	Acute Health Based Guideline (NEPC) (µg/m^3)	Chronic Health Based Guideline (NEPC) (µg/m^3)
1 hour	37.4	570	572	N/A
24 hour	10.6	288	286	N/A
Annual	0.84	60	N/A*	60

* N/A = not applicable

Therefore it is concluded the SO_2 from the operations are unlikely to increase the health risks to the local communities. Accordingly SO_2 can be excluded from further risk assessment.

Based on this the Primary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore SO_2 will not require further risk assessment.

2.1.10 Nitrogen Oxide (NO_x)

Oxides of nitrogen are a group of chemical compounds produced during the combustion process. The gaseous compounds produced by combustion include a range of oxides of nitrogen. Making up the majority of nitrogen oxides is the compound nitrogen oxide (NO) which accounts for roughly 90-95% of nitrogen oxides released with combustion of fossil fuels. The second most prolific combustion compound is nitrogen dioxide (NO_2) accounting for 5 -10% of nitrogen oxides. However, nitrogen dioxide concentrations rise over time as atmospheric reactions convert NO in to NO_2 in the time frame of several hours after emission into the environment.

Amongst this group, the main compounds of concern for human health are NO and NO_2. Only the concentration of NO_2 is regulated in ambient air (Air Quality Professionals, 2015).

The primary route of exposure to nitrogen oxides is by inhalation; however exposure by any route can cause systemic effects. Low levels of nitrogen oxides in the air are irritating to the eyes, skin, mucous membranes and respiratory tract (ATDSR 2002).

Populations that may be particularly sensitive to nitrogen oxides include asthmatics and those with chronic obstructive pulmonary disease or airway disease (ATSDR 2002).

NEPC (2003) set air quality guidelines for nitrogen dioxide considered to be protective of adverse health impacts for acute exposure and chronic exposure. The acute guideline has been set at 246 $\mu g/m^3$. Based on the lowest observed adverse effect level (LOAEL) of 409 to 613 $\mu g/m^3$ derived from statistical reviews of epidemiological data suggesting an increased incidence of lower respiratory tract symptoms in children and aggravation of asthma with an uncertainty factor of two added to protect susceptible individuals (EnRiskS, 2014).

The chronic guideline has been set at 62 $\mu g/m^3$. Based on the lowest observed adverse effect level (LOAEL) of 75 to 150 $\mu g/m^3$ during early and middle childhood which may lead to recurrent upper respiratory tract symptoms, with an uncertainty factor of two added to protect susceptible individuals (EnRiskS, 2014).

The air quality modelling of the proposed use of SWDF at the cement works predicted the offsite maximum NO_2 concentrations, as 1 hour maximums and mean annual concentrations, at discrete receptors. These concentrations were calculated using two methods for conversion of NO to NO_2 and two sources of background data, from Bargo and Camden. The results have been set out below in **Table 21**.

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Table 21 Highest predicted cumulative NO_2 concentrations at offsite receptors (Air Quality Professionals, 2015)

NO to NO_2 Calculation	Source of Background Data	Maximum Predicted 1 Hour Concentration ($\mu g/m^3$)	Maximum Predicted Annual Concentration ($\mu g/m^3$)
Method 2 (Ozone Limiting Method)	Bargo (excluding peaks 17-21 October 2013)	180	13.2
	Camden	188	11.3
Method 3 (Janssen Method)	Bargo (excluding peaks 17-21 October 2013)	128	10.7
	Camden	135	8.9
Acute Health Based Guideline		**246**	N/A
Chronic Health Based Guideline		N/A*	**62**

* N/A = not applicable

The predicted concentrations of NO_2 are below both acute and chronic health based criteria. Therefore it is concluded the NO_2 from the operations are unlikely to increase the health risks to the local communities. Accordingly NO_2 can be excluded from further risk assessment.

Based on this, the Primary Exposure pathway was considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore NO_2 will not require further risk assessment.

Receptors 65-70 have some of the highest incremental impacts in the NO_2 assessment. This may be due to the modelling methods utilised. The NO_2 assessment is a special case because the incremental concentration is a function of background ozone concentration (for the "ozone-limiting method") and also is a function of distance from the discharge source (for the "Janssen method"). It may be that ozone concentrations are higher under northwesterly winds, meaning higher NO_2 conversion rates. Another reason that receptors 65-70 show higher concentrations of NO_2 under the "Janssen method" is they are further from the stack than most of the other receptors

The higher predicted concentrations of NO_2 generally occur to the south and southeast of the Works. The model results show some elevated concentrations of NO_2 near Mossvale, well to the southeast of the Works (receptors 65 to 71). This is largely due to the coincidence of high concentrations of ozone in the Bargo ozone data at the same time as maximum GLCs of NO occur at those receptors. In addition, the larger distance between the Works and the receptors increases the percentage conversion of NO to NO_2 compared with receptors closer to the Works (Air Quality Professionals, 2016).

2.1.11 Carbon Monoxide (CO)

Carbon monoxide is an odourless colourless gas produced to varying extents during the fuel burning processes. Carbon monoxide quickly enters the blood when inhaled into the lungs. Levels normally present in the atmosphere are unlikely to cause ill effects. Carbon monoxide concentrations may reach harmful levels in poorly ventilated rooms during operation of unflued gas heaters or in the passenger compartment of vehicles with defective exhaust systems.

In the current situation, Air Quality Professionals (2015) considered that the only source of CO was the kiln stack. The report further went on to comment that industrial burning of fuels in the presence of sufficient oxygen has very minor potential to cause adverse effects because of the high combustion efficiency and the relatively high air quality impact criteria for CO. The NEPC ambient air quality guideline of 10,000 µg/m^3 over an 8 hour period, have been considered to provide protection from both acute and chronic exposure (EnRiskS, 2014). Furthermore the NEPC guidelines are in line with the WHO (2005) recommendations for derived guidelines in ambient air (WHO, 1999).

Therefore CO was not considered as part of the air quality assessment. For similar reasons CO is not considered further in the current risk assessment.

Based on this, the Primary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore CO will not require further risk assessment.

2.1.12 Volatile Organic Compounds (VOCs)

Volatile organic compounds or VOCs are organic chemical compounds, that is, compounds (that contain carbon) whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure. VOCs thus comprise a broad grouping of compounds with varying reactivity with other atmospheric components and varying impacts on human health.

Air Quality Professionals (2015) reported that VOCs were emitted as trace amounts in gaseous combustion products and therefore may be discharged from Kiln 6.

As set out in the Environmental Assessment (SLR, 2015), Boral is seeking for current VOC criteria of 20ppm to be changed to NMHC of 40ppm. The reason being the major source of VOCs in the emission has been demonstrated to be the blue shale mined on site. NMHC are considered appropriate VOCs to measure compliance to account for the inherent VOC levels within the blue shale.

Air Quality Professionals (2015) reported that:

As NMHC represents a wide collection of organic compounds there is no single generic representative assessment threshold. An indicative breakdown of organic compounds in emissions from Portland cement kilns is provided in USEPA (1995). In this breakdown, a large proportion of the organic emission is comprised of benzene and benzoic acid, with smaller amounts of other constituents. Further breakdown of NMHC constituents is not considered to be useful unless chemical composition data is collected at the Berrima site.

The assumed breakdown of organic compounds from Portland cement kilns from USEPA (1995) has been set out below in **Table 22.**

Table 22 Assumed breakdown of organic compounds from Portland cement kilns from USEPA (1995)

Individual organic compounds	Mass percentage of organic compounds as per USEPA (1995)
acetone	3.7%
benzene	31.4%
benzoic acid	35.3%
carbon disulfide	1.1%
chloromethane	3.7%
formaldehyde	4.5%
methylene chloride	4.9%
naphthalene*	2.2%
phenanthrene*	3.9%
toluene	2.0%
xylenes	1.3%
others	4.7%

* Included in PAH assessment as BaP-TEQ rather than NMHC assessment for this report.

Modelling using the proposed 40ppm criteria indicated that the highest one hour maximum NMHC concentration occurring beyond the site boundary GLC was 21µg/m^3. The report goes onto use the VOC species assumed to be present in the total NMHC mix for comparisons against available regulatory criteria for specific VOCs.

This comparison indicated that NHMCs likely to be present in the emissions were all below applicable criteria and mostly at concentrations at least two orders of magnitude below the regulatory criteria (Air Quality Professionals, 2015).

For the purpose of this health risk assessment the predicted maximum concentrations of individual NHMCs were compared against health based criteria, such as TCEQ ESLs.

The Texas Commission on Environmental Quality (TCEQ) lists Effects Screening Levels (ESLs) for various chemicals. ESLs are chemical concentrations in the air that are considered safe. ESLs protect human health in the general public, including children, the elderly, pregnant women, and people with pre-existing health conditions (TCEQ, 2010). These ESLs are considered reputable by many organisations, both local and international. Accordingly ESLs are often used as part of health risk assessments.

To assess the potential for health risks for individual NHMCs the concept of Hazard Quotients (HQ) for each was utilised. To assess the potential for health risks from the mixture of NHMCs predicted to be present, a cumulative Hazard Index (HI) made up of the summed Hazard Quotients (HQ) for individual NHMCs was utilised. The definitions of HQ and HI have been set out below.

Hazard Quotient (HQ)

The ratio of the potential exposure to the substance and the level at which no adverse effects are expected. A hazard quotient less than or equal to 1 indicates that adverse noncancer effects are not likely to occur, and thus can be considered to have negligible hazard. HQs greater than 1 are not statistical probabilities of harm occurring. Instead, they are a simple statement of whether (and by how much) an exposure concentration exceeds the reference concentration (RfC) (USEPA, 2016). The reference concentration used in the current assessment is the chosen health based criteria.

Hazard Index (HI)

The sum of hazard quotients (HQ) for substances that affect the same target organ or organ system. The hazard index (HI) is only an approximation of the aggregate effect on the target organ (e.g., the lungs) because some of the substances might cause irritation by different (i.e., non-additive) mechanisms. As with the HQ, aggregate exposures below an HI of 1will not result in adverse non-cancer health effects over a lifetime of exposure and would ordinarily be considered acceptable. An HI equal to or greater than 1, however, does not necessarily suggest a likelihood of adverse effects. Because of the inherent conservatism of the reference concentration (RfC) methodology, the acceptability of exceedances must be evaluated on a case-by-case basis (USEPA, 2016).

Regarding the current report, the predicted one hour peak concentrations and annual average concentrations for VOC species assumed to be present in the NMHC emissions mix were compared with the relevant acute and chronic health based criteria. The determination of HQ and HI values for both acute and chronic exposures indicated that there was unlikely to be a health risk to the community. The detailed information has been set out in **Table 23 and Table 24**.

Table 23 Evaluation of potential acute impacts based on incremental individual NMHC species GLCs, 99.9th percentile one hour maximum concentrations predicted outside works boundary (Air Quality Professionals, 2015)

Individual NMHC species	Mass percentage assumed in total NMHC	Incremental 1 hour max GLC calculated pro-rata from total GLC of 21µg/m^3	NSW EPA (2005) ambient air quality (µg/m^3)	TCEQ Acute ESL (µg/m^3)	Health Based Acute criteria adopted* (µg/m^3)	Acute Hazard Quotient (HQ)
acetone	3.7%	0.78	22000	7800	7800	<0.01
benzene	31.4%	6.6	29	170	29	0.23
benzoic acid	35.3%	7.4		500	500	0.01
carbon disulfide	1.1%	0.23		750	7500	<0.01
chloromethane	3.7%	0.78	1900	1030	1030	<0.01
formaldehyde	4.5%	0.95	20	15	15	0.06
methylene chloride	4.9%	1.0	3200	3600	3600	<0.01
toluene	2.0%	0.42		4500	4500	<0.01
xylenes	1.3%	0.27		2200	2200	<0.01
						Acute Hazard Index (HI)
					TOTAL	**0.31**

* The lowest of the two health based criteria was utilized in the assessment.

Table 24 Evaluation of potential chronic impacts based on Incremental individual NMHC species GLCs, annual average concentration predicted outside works boundary (Air Quality Professionals, 2015)

Individual NMHC species	Mass percentage assumed in total NMHC	Annual average GLC (µg/m^3)	Health Based Chronic criteria (µg/m^3)	Chronic Hazard Quotient (HQ)
acetone	3.7%	0.018	4800	<0.01
benzene	31.4%	0.15	1.7	0.089
benzoic acid	35.3%	0.17	50	<0.01
carbon disulfide	1.1%	0.01	32	<0.01
chloromethane	3.7%	0.02	103	<0.01
formaldehyde	4.5%	0.02	3.3	0.01
methylene chloride	4.9%	0.02	350	<0.01
toluene	2.0%	0.01	1200	<0.01
xylenes	1.3%	0.01	180	<0.01
				Chronic Hazard Index (HI)
			TOTAL	**0.10**

The predicted concentrations of NHMCs were significantly below both the acute and chronic health based criteria. Therefore it is concluded the NHMCs from the operations are unlikely to increase the health risks to the local communities.

Based on this, the Primary Exposure and Secondary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore NMHCs will not require further risk assessment.

2.1.13 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled meat. PAHs are ubiquitous environmental pollutants formed from both natural and anthropogenic sources. The latter are by far the major contributors. Natural sources include forest fires, volcanic eruptions, and degradation of biological materials, which has led to the formation of these compounds in various sediments and fossil fuels. Major anthropogenic sources include the burning of coal refuse banks, coke production, automobiles, commercial incinerators, and wood gasifiers. PAHs are usually found as complex mixtures containing two or more of these compounds, such as soot (ASTDR,1995, U.S. Geological Survey, 2015).

In the environment, PAHs are often attached to particulates such as dusts, soils and sediments. Some PAHs are volatile and become gases in the air. PAHs cover a broad class of chemicals and accordingly the differing nature of the chemicals is reflected in the toxicity, carcinogenicity and breakdown of PAHs. Some PAHs breakdown relatively quickly in the environment whereas others can persist for weeks or months. The toxicity and carcinogenicity varies greatly across the class of chemicals. Most of the carcinogenic potential of PAHs resides with four to seven ringed compounds (WHO, 2013).

Benzo (a) pyrene (BaP) is the most studied PAH. However, many other PAHs present with BaP in complex mixtures, such as tobacco smoke and diesel exhaust, are also potential carcinogens. In order to address the carcinogenicity of PAHs in ambient air as a class, potency equivalency factors (PEFs) for some PAHs relative to BaP have been developed using carcinogenesis studies in experimental animals. (OEHHA, 1994) These PEFs are used to calculate a BaP-Toxicity Equivalency for the mixture of PAHs.

The air quality modelling of the proposed use of SWDF at the cement works predicted the highest ground level concentrations of PAHs beyond the site boundary to be 0.000017$\mu g/m^3$ as BaP-TEQ 1 hour incremental GLC. To put this concentration in a health based context, WHO (2013) noted that with regards to risk of lung cancer from lifetime exposure to inhaled PAHs associated with airborne particles, a concentration of 0.000012$\mu g/m^3$ gave a lifetime risk of 1×10^{-6}. This level of risk is classed as a negligible risk of cancer. The document went on to state a concentration of 0.0012$\mu g/m^3$ as BaP-TEQ equated to a lifetime risk of 1×10^{-4}. (However it should be noted there was some discussion as to whether the EC guideline of 0.001$\mu g/m^3$ as BaP-TEQ was more appropriate.) This level of risk (1×10^{-4}) is generally considered to be lower limit of an unacceptable risk of cancer. Accordingly with regards to current project, the maximum predictions of 0.000017$\mu g/m^3$ as BaP-TEQ 1 hour incremental GLC indicate in most cases a negligible lifetime risk of cancer ($\leq 1 \times 10^{-6}$) and in the worst case scenarios a tolerable lifetime risk of cancer ($\leq 1 \times 10^{-4} \geq 1 \times 10^{-6}$).

Moreover the highest ground level concentrations of PAHs beyond the site boundary to be 0.000017$\mu g/m^3$ as BaP-TEQ 1 hour incremental GLC are only 0.004% of the NSW EPA air quality criteria of 0.4 $\mu g/m^3$ (Air Quality Professionals, 2015).

The predicted airborne concentrations of PAHs are significantly below both NSW EPA criteria and health based criteria. Therefore it is concluded the PAHs from the operations are unlikely to increase the health risks to the local communities. Accordingly airborne PAHs can be excluded from further risk assessment.

PAH exposure through ingestion of contaminated particulate matter, such as dusts or soils is possible in the surrounding communities. However, given the general background levels of PAHs from multiple sources, for example fires, vehicle exhausts, industrial sources, unrelated to the cement works the very low concentrations of PAHs predicted to be emitted from the kiln, it is more likely that in most cases the sources of PAHs in soils are unrelated to the kiln.

Based on this, the Primary Exposure and Secondary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore PAHs will not require further risk assessment.

2.1.14 Heavy Metals

The term, heavy metals, is used to describe a number of metallic elements with high atomic weights such as mercury, chromium, cadmium, arsenic, and lead. However the term heavy metals is considered by some to be too ill defined and not necessarily reflecting all toxic metals. Accordingly metals and metallic compounds are the focus of the current report.

Regarding the metals associated with the cement kilns, Air Quality Professionals (2015) state:

Emissions of metal compounds from cement kilns can be grouped into three general classes:

- *Volatile metals, including mercury (Hg) and thallium (Tl);*
- *Semivolatile metals, including antimony (Sb), cadmium (Cd), lead (Pb), selenium (Se), zinc (Zn), potassium (K), and sodium (Na); and*

- *Refractory or non-volatile metals, including barium (Ba), chromium (Cr), arsenic (As), nickel (Ni), vanadium (V), manganese (Mn), copper (Cu), and silver (Ag).*

Although the partitioning of these metal groups is affected by kiln operating conditions, the refractory metals tend to concentrate in the clinker, while the volatile and semivolatile metals tend to be discharged to air (USEPA, 1995).

Metals in feed and fuel are volatile at high temperatures experienced in the kiln burning zone but then condense as temperatures decrease. In general, the more volatile metals condense on small dust particles, and the high boiling point metals tend to remain in the clinker. This, to a large degree, depends on the quantities of metals present in the feed and fuel, the manufacturing process, and the chloride content. Volatile metals such as thallium and mercury tend to remain unbonded and are emitted to atmosphere primarily in elemental form.

*Chromium can be present as either the hexavalent (+6) oxidation state or the less toxic trivalent (+3) oxidation state. In the Berrima kiln, the hexavalent chromium emission has been measured in each of the annual stack testing programmes in addition to total chromium (*Air Quality Professionals, 2015).

The scope of historic and current emissions testing, as set out in Section 1.8, included analysis of particulate matter for a range of heavy metals. Monitoring results from 2011 to 2014 found all heavy metals tested were consistently below the applicable threshold criteria. Furthermore in the case of arsenic, beryllium, cadmium, cobalt, nickel, selenium and mercury, all results were less than the detection limit of the analysis (Air Quality Professionals, 2015).

The summary of heavy metal testing from 2011 to 2014 has been set out below in **Table 25**.

Table 25 Summary of results of heavy metal testing at AQMS, 2011-2014. 24 hour average concentrations measured in particulate during 1 day in 6 testing programme (no samples = 243) (source *Air Quality Professionals, 2015*).

Metal	Number of times the test result was higher than the MDL[#]	Concentrations when test results were higher than MDL (µg/m^3)			Air Quality Threshold Criteria (µg/m^3)
		Minimum measured concentrations	Maximum measured concentrations	Average concentration	
Antimony	16	0.007	0.104	0.025	9 [2]
Arsenic	0	<0.007	<0.01	n/a*	0.009 [2]
Beryllium	0	<0.004	<0.01	n/a*	0.004 [2]
Cadmium	0	<0.004	<0.005	n/a*	0.018 [2]
Chromium (total)	98	0.004	0.021	0.0055	9 [2]
Chromium VI	1	0.008	0.008	0.008	0.09 [2]
Cobalt	0	<0.004	<0.01	n/a*	n/d[%]
Copper	103	0.004	0.026	0.0053	18 [2,3]
Lead	5	0.008	0.019	0.013	0.50 [1,2]
Manganese	240	0.004	0.147	0.029	18 [2]
Mercury	0	<0.00015	<0.0005	n/a*	1.8 [2]
Nickel	0	<0.004	<0.01	n/a*	0.18 [2]
Selenium	0	<0.007	<0.01	n/a*	20 [6,8]
Thallium	3	0.004	0.005	0.0047	n/d[%]
Tin	7	0.009	0.027	0.015	n/d[%]
Vanadium	39	0.004	0.012	0.0063	30 [5,6,7]
Zinc	243	0.005	0.779	0.034	90 [2,4]

Notes:[#] MDL = method detection limit of analysis; * n/a = not calculated as all results < MDL; [%] n/d= no data- no standards or guidelines;[1]= Air NEPM 91998), annual average; [2] = NSW EPA Approved Methods (2005) Impact Assessment Criteria, 1 hour average; [3] = Dust associated copper; [4] = Zinc oxide fume; [5] = Vanadium pentoxide; [6] = Office of Environmental Health Hazard Assessment (OEHHA) California Reference Exposure Level (REL); [7] = Acute OEHHA REL, annual average; [8] = Chronic OEHHA REL, annul average

The air quality modelling of the proposed use of SWDF at the cement works predicted the ground level concentrations of a range of metals beyond the site boundary. The emission rates used for modelling metals was equal to ten times the maximum measured concentrations from 2011 to 2014. The study reported all metals investigated, both by modelling and from historic monitoring data, were significantly below NSW EPA assessment criteria.

The Air Quality Professionals (2015) states:

Lead emissions are assessed separately from other heavy metals due to the requirement for lead to be assessed as an annual averaging period. NSW EPA requires 100th percentile lead GLCs to be assessed at the nearest existing or likely future off-site sensitive receptor, and background concentrations must be included.

A mean 24-hour background concentration for lead of 29.9 ng/m (0.0299 µg/m^3) was identified in the NSW. The equivalent annual average background concentration is expected to be lower than this value, however for the purpose of this assessment this concentration of 0.0299 µg/m^3 has been adopted as representing the background annual average as well.

The highest incremental annual average GLCs occurring anywhere beyond the site boundary is 0.00033 µg/m^3. This occurs in the industrial-zoned area to the east of the Works, and does not occur near one of the discrete receptors 1-87.

The maximum cumulative lead concentration of 0.030 µg/m^3 (sum of maximum background plus maximum GLC) is only 6% of the NSW EPA criteria of 0.5 µg/m^3. Therefore adverse impacts from discharges of lead from the Works are anticipated to be negligible.

For metals other than lead, as stated above the GLC were significantly below NSW EPA Assessment criteria. The predicted concentrations of the majority of metals were less than 1% of the relevant assessment criteria. The exceptions were cadmium and nickel, still less than the criteria, with predicted concentrations at 34% and 10% respectively of assessment criteria.

Comparison of predicted metal concentrations against health based criteria, both acute and chronic, found that concentrations were all significantly below adopted criteria. Furthermore the Hazard Index for the mixture of metals present was less than 1, which indicated the health risks were unlikely from the mixture of metals present. These results have been set out below in **Tables 26 and 27**.

Table 26 Evaluation of potential acute impacts based on incremental individual metal species GLCs, 99.9th percentile one hour maximum concentrations predicted outside works boundary (Air Quality Professionals, 2015)

* The lowest of the two health based criteria was utilized in the assessment. # Hazard Quotient rounded off to 2 decimal places.

Individual Heavy Metal species	Highest 99.9th Percentile incremental 1 hour GLC beyond site boundary (µg/m^3)	NSW EPA (2005) ambient air quality (µg/m^3)	TCEQ Acute ESL (µg/m^3)	Health Based Acute criteria adopted* (µg/m^3)	Acute Hazard Quotient (HQ)#
Antimony	0.036	9	5	5	<0.01
Arsenic	0.0015	0.02	3	0.02	0.08
Beryllium	0.0015	0.02	0.02	0.02	0.08
Cadmium	0.0061	0.018	0.1	0.018	0.34
Chromium (total)	0.01	9	-	9	<0.01
Chromium VI	0.0061	0.09	0.39	0.09	0.07
Cobalt	0.0036	0.2	0.2	0.2	0.02
Copper	0.031	18	10	10	<0.01
Manganese	0.17	18	2	2	0.09
Mercury	0.012	1.8	0.25	0.25	0.05
Nickel	0.019	0.18	0.33	0.18	0.11
Selenium	0.007	2	2	2	<0.01
Thallium	0.0061	1	1	1	0.01
Tin (inorganic)	0.015	20	20	20	<0.01
Vanadium	0.0058	0.5	20	0.5	<0.01
					Acute Hazard Index (HI)
				TOTAL	**0.66**

Table 27 Evaluation of potential chronic impacts based on incremental individual metal species annual average concentrations predicted outside works boundary (Air Quality Professionals, 2015)

* The lowest of the two health based criteria was utilized in the assessment. . # Hazard Quotient rounded off to 2 decimal places.

Individual Heavy Metal species	Annual Average GLC beyond site boundary (µg/m^3)	NSW EPA (2005) ambient air quality (µg/m^3)	TCEQ Chronic ESL (µg/m^3)	Health Based Chronic criteria adopted* (µg/m^3)	Chronic Hazard Quotient (HQ)#
Antimony	0.000825	9	0.5	0.5	<0.01
Arsenic	0.000033	0.02	0.67	0.02	<0.01
Beryllium	0.000033	0.02	0.002	0.002	0.02
Cadmium	0.0001375	0.018	0.01	0.01	0.01
Chromium (total)	0.00022	9	-	9	<0.01
Chromium VI	0.0001375	0.09	0.0039	0.0039	0.04
Cobalt	0.0000825	0.2	0.02	0.02	0.04
Copper	0.000715	18	1	1	<0.01
Manganese	0.003905	18	0.2	0.2	0.02
Mercury	0.000275	1.8	0.025	0.025	0.01
Nickel	0.000429	0.18	0.059	0.059	0.01
Selenium	0.0001595	2	0.2	0.2	<0.01
Thallium	0.0001375	1	0.1	0.1	<0.01
Tin (inorganic)	0.00033	20	0.2	0.2	<0.01
Vanadium	0.000132	0.5	0.2	0.2	<0.01
					Chronic Hazard Index (HI)
				TOTAL	**0.15**

The majority of metals released from the operations will be associated with particulate matter. Therefore the ultimate environmental fate of these metals will be to de deposited in soils or sediments. As metals are elements, the metals will not breakdown but rather will be buried over time, unless disturbed. Therefore there is potential for localised build-up of metals in soils, the extent of which is unclear. The likelihood of this will be dependent on how far particulate matter that becomes airborne travels and disperses before settling out. However, significant metal enrichment of local soils may be unlikely given the predicted metal emissions are significantly below NSW EPA assessment criteria and the adopted chronic health based criteria.

Based on the historic emissions monitoring by Boral and the predicated metal emissions from Kiln 6 it is concluded that heavy metals from the operations are unlikely to increase the health risks to the local communities. Accordingly, heavy metals can be excluded from further risk assessment.

Based on this, the Primary Exposure and Secondary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the receptors health risk. Therefore heavy metals will not require further risk assessment.

2.1.15 Hydrogen Halides & Sulphuric Acid Mist / Sulphur Trioxide

The COPC in this category listed in the Air Quality Professionals(2015) report were hydrogen chloride, chloride, hydrogen fluoride, sulphuric acid mist and sulphur trioxide. All of these are potentially emitted from Kiln 6 during operations. It should be noted that the report does not specify at which receptor GLC of sulphuric acid mist / sulphur trioxide exceeded the regulatory criteria.

The predicted emissions of sulphuric acid / sulphur trioxide as well as chlorine and hydrogen chloride were considered to be highly conservative overestimations. Calculations based on data from four years of annual testing at the site indicated the overestimations are possibly as much as ninety times, one hundred and eighty times or thirty times, respectively, higher than actual emissions (Air Quality Professionals, 2015).

It is worth quoting the Air Quality Professionals (2015) in detail to demonstrate the basis of these overestimations.

Chlorine, hydrogen chloride and sulfuric acid mist/sulfur trioxide GLCs were assessed as incremental 99.9th percentile 1-hour average concentrations at or beyond the site boundary in accordance with the "Approved Methods" guidelines ……. For each of these species, the emission concentration used in the model was the maximum specified in the current EPL for burning of NSF – i.e. 200, 10, and 100 mg/Nm^3 for chlorine, hydrogen chloride and sulfuric acid mist/sulfur trioxide respectively.

The maximum GLC for each of these species was calculated by adjusting the GLCs in proportion with emission rate relative to the maximum GLC for a unitary emission rate of 1 g/s. ……...

The GLC for emissions of sulfuric acid mist/sulfur trioxide exceeds the NSW EPA assessment criteria for sulfuric acid. This GLC was derived from an assumed discharge at the emission concentration limit specified in the EPL, which is 100 mg/Nm^3 (at 10% O_2) yielding a mass emission rate of 20 g/s. In reality, emissions of sulfuric acid mist/sulfur trioxide are much lower than this……... From the four years of annual testing, sulfuric acid mist/sulfur trioxide has only been detected on one occasion, with an emission concentration of 1.5 mg/Nm^3 (at 10% O_2) and a mass emission rate of 0.23 g/s. If that emission rate was applied to the dispersion model, the maximum GLC beyond the site boundary would be 0.28 mg/m^3 which is 1.5% of the NSW EPA assessment criteria. The reason for the low acidic emissions is the nature of the cement kiln which acts as a large alkaline scrubber neutralising acid gases.

The GLC for emissions of chlorine at the EPL limit of 200 mg/Nm^3 (at 10% O_2) is close to exceeding the NSW EPA assessment criteria. In reality, emissions of chlorine are much lower than this. ……... From the four years of annual testing, chlorine has only been detected on two occasions, with a maximum emission concentration of 0.32 mg/Nm^3 (at 10% O_2) and a mass emission rate of 0.18 g/s (compared to 40 g/s used in the model). If that emission rate was applied to the dispersion model, the maximum GLC beyond the site boundary would be 0.22 µg/m^3 which is 0.4% of the NSW EPA assessment criteria. Chlorine is a carefully controlled operational parameter in the feed as it impacts clinker quality and marked increases in emission concentrations for this element are unlikely.

The GLC for hydrogen chloride is small compared to the NSW EPA assessment criteria. However the emission rate that this GLC is derived from is also large compared with measured results. ……. From the four years of annual testing, hydrogen chloride was detected on all but one occasion, with a maximum emission concentration of 0.25 mg/Nm^3 (at 10% O_2) and a mass emission rate of 0.12 g/s. If that emission rate was applied to the dispersion model, the maximum GLC beyond the site boundary would be 0.15 µg/m^3 which is 0.1% of the NSW EPA assessment criteria.

The predicted maximum emissions have been set out in **Table 28.**

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Table 28 Halide and other chemical species GLCs and comparison to assessment criteria (source Air Quality Professionals, 2015).

Chemical	Highest 99.9th Percentile incremental GLC beyond site boundary (µg/m^3)	NSW EPA Air quality assessment criteria (µg/m^3) (DEC, 2005)	GLC as a percentage of air quality assessment criteria (µg/m^3)
Sulphuric acid mist and/or sulphur trioxide	24.2	18	134
Hydrogen chloride	2.4	140	17
Chlorine	48.4	50	97
Hydrogen Fluoride	**Highest 100th Percentile incremental GLC beyond site boundary (µg/m^3)**	**Air quality assessment criteria – 24 hour average (µg/m^3)**	
Hydrogen fluoride	0.11	1.5	7.3

Health effects and health based criteria for hydrogen chloride, chloride, hydrogen fluoride, sulphuric acid mist and sulphur trioxide are set out below.

Hydrogen Chloride (HCl)

Hydrogen chloride is a by-product from combustion of many materials, especially materials with high chlorine content (OEHHA, 2015a). In the atmosphere, HCl aggregates into aerosols and is removed from the atmosphere by rainfall.

The acidic nature of HCl means that at elevated concentrations HCl can irritate human tissue for example respiratory tract, skin, eyes, etc. Regarding acute exposure, the lowest concentration at which inhalation of HCl is likely to impact on humans has been reported as 1.4ppm (2,100 µg/m^3) over a 1 hour period based on an acute NOAEL (no observed adverse effect level, based on experimental data) of 1.8ppm (2,100 µg/m^3) over a 45 minute period (OEHHA, 2015b).

The data relating to chronic exposure of humans to HCl via the respiratory route is more limited than that available for acute exposures. OEHHA (2015b) calculated the concentration unlikely to impact on humans 0.06ppm (9 µg/m^3) as a Chronic Reference Exposure Level (REL) which is an airborne level of a chemical that is not anticipated to present a significant risk of an adverse non-cancer health effect.

The TCEQ (2015) listed ESLs for HCl are the following: Short term ESL, (equivalent to an acute exposure) of 190 µg/m^3 and a Long term ESL, (equivalent to a chronic exposure) of 7.9 µg/m^3.

In the current project, the modelled HCl concentrations were reported as 2.4 µg/m^3 (see table 22 above). This concentration is below both chronic and acute health based criteria listed above. Therefore HCl was not considered further in the current risk assessment.

Chlorine (Cl_2)

Chlorine is a heavier-than-air, greenish-yellow reactive gas with a pungent, irritating odour (ATSDR, 2010). Chlorine is a very reactive gas and as such after release into the environment does not persist but quickly reacts with other chemicals in the environment. The main human exposure route is via inhalation with eyes also affected, however the dermal exposure only a minor route. The affect of chlorine on the respiratory tract and other tissue, is to act as an irritant at low concentrations, such as 1ppm to 3ppm (1,583 to 4,748 µg/m^3) (ASTDR, 2010).

The TCEQ (2015) listed ESLs for Cl_2 are the following: Short term ESL, (equivalent to an acute exposure) of 15 µg/m^3 and a Long term ESL, (equivalent to a chronic exposure) of 1.5 µg/m^3.

The air quality modelling of the proposed use of SWDF at the cement works predicted the maximum Cl_2 concentration as 48.4 µg/m^3. This concentration exceeds both the acute health based criteria, but significantly higher than chronic health based criteria. The predicted Cl_2 concentration is also close to the NSW EPA Criteria of 50 µg/m^3 (DEC, 2005). These concentrations have been set out below in **Table 29.**

Table 29 Highest predicted incremental Cl_2 concentrations at off site receptors

Highest 99.9th Percentile incremental GLC beyond site boundary (µg/m^3)	NSW EPA Criteria (µg/m^3)	Acute Health Based Guideline (TCEQ) (µg/m^3)	Chronic Health Based Guideline (TCEQ) (µg/m^3)
48.4	50	15	1.5

Air Quality Professional (2015) considers their modelling to be overly conservative for Cl_2 emissions, based on a Cl_2 emission rate roughly two hundred times higher than the measured Cl_2 emissions. Air Quality Professional (2015) reported Cl_2 has only been detected in kiln 6 emissions twice from four years of annual monitoring data. Moreover the concentrations detected were significantly less than the concentration used in the air quality modelling. If the measured emission concentrations were used in the modelling then the maximum concentrations beyond the boundary was predicted to be 0.22µg/m^3. This concentration is within both the acute and chronic health based guideline of 1.5ug/m^3.

It should also be noted that the results of test burns of non standard fuels in 2003 reported no significant differences in measured Cl_2 emission from kiln 6 when non standard fuel was tested compared with routinely used fuels (Air Quality Professional, 2015).

Therefore it is concluded the Cl_2 from the operations are unlikely to increase the acute or chronic health risks to the local communities. This is based on the lack of change in measured Cl_2 emissions when SWDF was tested and the overly conservative nature of the modelling.

Therefore further risk assessment of predicted Cl_2 concentrations is not required.

Hydrogen Fluoride

Hydrogen fluoride is a colourless, corrosive gas or liquid (it boils at 19.5 °C) that is made up of a hydrogen atom and a fluorine atom. It fumes strongly, readily dissolves in water, and both the liquid and vapour will cause severe burns upon contact (ASTDR, 2003).

Health based criteria for acute and chronic hydrogen fluoride exposure via inhalation have been determined, based on the LOAEL of 0.5 ppm (446 µg/m^3) fluoride for upper respiratory tract irritation. ASTDR (2003) determined the acute Minimal Risk Levels (MRL) to be 0.02ppm (17.8 µg/m^3). This was in line with the TCEQ listed ESLs for hydrogen fluoride as Short term ESL, (equivalent to an acute exposure) of 18 µg/m^3 and a Long term ESL, (equivalent to an chronic exposure) of 8.7 µg/m^3 (TCEQ, 2015).

The air quality modelling of the proposed use of SWDF at the cement works predicted the maximum hydrogen fluoride concentration as 0.11µg/m^3. This concentration is within both the acute health based criteria, and chronic health based criteria. Therefore hydrogen fluoride will not require further risk assessment.

Sulphuric acid mist / Sulphur trioxide

Sulphur trioxide in the pure form is a colourless liquid but can also exist as crystals or a gas. When exposed to air sulphur trioxide quickly reacts with water to form sulphuric acid. It is unlikely to exist in the atmosphere except as a transitory compound prior to conversion to sulphuric acid. Furthermore any sulphur trioxide inhaled by a person reacts with water and converts to sulphuric acid in the upper respiratory tract (ASTR, 1998b). Accordingly, the focus of this toxicity assessment will be on sulphuric acid.

Sulphuric acid in pure form is a clear colourless liquid and a strong acid. Much of the atmospheric sulphuric acid forms when sulphur dioxide degrades to sulphur trioxide which reacts with water in the air to form sulphuric acid. Sulphuric acid vapours can condense and form airborne particles, nuclei, which can grow in size overtime with the inclusion of water in the particles (ATSDR, 1998; WHO, 2006).

ATSDR (1998) did not set either acute or chronic MRLs for sulphuric acid. It was felt the methodology for derivation did not incorporate all the variables in addition to concentration that determine the response to sulfuric acid.

However the California Government Office of Environmental Health Hazard Assessment (OEHHA) set health based Reference Exposure Levels (REL) for both acute and chronic exposures of 120 µg/m^3 and 1 µg/m^3 respectively. REL are defined as "*The concentration level at or below which no adverse health effects are anticipated for a specified exposure duration is termed the reference exposure level (REL). RELs are based on the most sensitive, relevant, adverse health effect reported in the medical and toxicological literature. RELs are designed to protect the most sensitive individuals in the population by the inclusion of margins of safety*." (OEHHA, 1999).

Regarding the chronic REL it should be noted that the derivation of this was based on one small study. Therefore chronic REL may be overly conservative to take into account the limited data on which it is based.

The air quality modelling of the proposed use of SWDF at the cement works predicted the maximum sulphuric acid concentration as 24.2 µg/m^3. This concentration is within the acute health based criteria, but significantly higher than chronic health based criteria. The predicted sulfuric acid concentration was also above to the NSW EPA Criteria of 18 µg/m^3 (DEC, 2005). These concentrations have been set out below in **Table 30.**

Table 30 Highest predicted incremental sulfuric acid concentrations at off site receptors

Highest 99.9th Percentile incremental GLC beyond site boundary (µg/m^3)	NSW EPA Criteria (µg/m^3)	Acute Health Based Guideline (REL) (µg/m^3)	Chronic Health Based Guideline (REL) (µg/m^3)
24.2	18	120	1

Therefore it is concluded the sulphuric acid mist / sulphur trioxide from the operations is within the acute health based criteria. However the predicted concentrations exceed the NSW EPA criteria and the chronic health criteria. Therefore further risk assessment of predicted sulphuric acid mist / sulphur trioxide concentrations is required in Sections 2.3 and 2.4 of the current report.

2.1.16 Dioxins

The term Dioxins is generally used to refer to both dioxins and furans. Dioxins are a family of toxic chemicals that all share a similar chemical structure and a common mechanism of toxic action. This family includes seven of the polychlorinated dibenzo dioxins (PCDDs), ten of the polychlorinated dibenzo furans (PCDFs) and twelve of the polychlorinated biphenyls (PCBs) (USEPA, 2015).

The toxicity of different dioxins in a mixture can be considered to be additive. To help represent the overall toxicity of complex mixtures of dioxins, the concept of Toxicity Equivalent (TEQ) is used. The TEQ is based on concentrations of various dioxin species in the mixture each multiplied by a relative toxicity factor and added together to give a single TEQ, expressed in grams.

Dioxins are not commercial chemical products but are trace level unintentional by-products of most forms of combustion and several industrial chemical processes. Dioxins are generally formed as a result of poorly controlled or uncontrolled combustion (Bawden *et al,* 2004). The formation of dioxins is complex and many factors are important, including the material being burned, the conditions of combustion, the composition of the particulate matter generated, and the design and operation of the burners all exert influence over dioxin formation (Air Quality Professionals, 2015). However dioxin formation tends to occur in a zone where combustion gases cool from approximately 450^{o}C to 250^{o}C (UNEP,1999).

Controlling and limiting the formation of dioxins in an industrial process, such as cement kilns, depends significantly on temperature control. In cement kilns the nature of the combustion and necessary pollution control processes limit the production of dioxins. Furthermore, the presence of chlorine is required for dioxin formation. In the operations of Kiln 6, chlorine is a carefully controlled operational parameter in the feed as it impacts clinker quality (Air Quality Professional, 2015).

Air Quality Professional (2015) state that:

A review report released by the United National Environment Programme (UNEP, 2005) notes that provided combustion is good and excess oxygen is present in the exhaust gases, the main factor controlling dioxin emissions in the air discharge from a cement kiln is the temperature of the dust collection device in the gas cleaning system. The UNEP report highlights the importance of stack gas temperature of less than 200°C into the particulate control equipment (electrostatic precipitator or bag filter). The UNEP report also states that in a dry process kiln with preheater (such as that at the Berrima Works), this prerequisite is inherent in the process.

The emissions of dioxins from Australian cement kilns has been noted to be well controlled by current practises over a range of processes and fuels. The Australian Inventory of Dioxin Emissions 2004 (Bawden *et al,* 2004) state that:

Australian dioxin emission testing data were provided by the CIF for all Australian cement kilns. The emissions testing data provided were the results of repeated measurements over the period 1991 – 2003 and were obtained from all cement kilns in Australia using a range of process conditions, primary fuels and raw materials. Both wet and dry processes are represented as were plants using gas, coal and alternative fuels.

All measured dioxin concentrations for the period 1991-2003 were well below 0.1 ng TEQ/Nm³ (@ 11% O_2) indicating a high level of dioxin control at Australian cement production facilities.* (note * ng = nanogram that is 0.000000001g)

The air quality modelling of the proposed use of SWDF at the cement works predicted the highest ground level concentrations of dioxins beyond the site boundary to be 0.000024ng/m^3. That is 83,000 times less than the NSW EPA air quality criteria of 2 ng/m^3 (Air Quality Professionals, 2015).

The predicted airborne concentrations of airborne dioxins are significantly below criteria. Therefore it is concluded the airborne dioxins from the operations are unlikely to increase the health risks to the local communities. Accordingly airborne dioxins can be excluded from further risk assessment.

In the environment, dioxins are often attached to particulates such as dusts, soils and sediments. Breakdown of dioxins occurs slowly if at all in the environment and dioxins can persist for years in soils. Therefore it is possible for soil to be enriched with dioxins over time in areas with a history of dioxin production such as might have occurred in areas of many industries.

In the case of Berrima Cement Works, with the predicted airborne concentrations beyond the site boundary being 83,000 times less than the NSW EPA air quality criteria, it is unlikely that these emissions will lead to a significant impact on soil dioxin levels in the communities surrounding the works.

Based on this, the Primary Exposure and Secondary Exposure pathways were considered unlikely to lead to receptor exposure at concentrations likely to increase the health risk to receptors. Therefore Dioxins will not require further risk assessment.

2.1.17 Summary of COPC Emissions Exceeding Regulatory or Health Based Criteria

The emissions predicted to periodically exceed the criteria include dust as PM_{10} 24 hour average, sulphuric acid mist / sulphur trioxide, and VOCs. The predicted concentrations of these emissions and number of predicted exceedances per year have been set out below in **Table 31**.

Table 31 Emissions from Berrima Cement Works that may exceed regulatory criteria

Airborne Pollutant	Regulatory Criteria	Predicted Concentrations at Ground Level	Comments
Dust PM_{10} 24 hour average – Additional exceedances beyond background	50µg/m^3 GLC*	50 – 69.7µg/m^3 When background environmental dust levels are less than 47µg/m^3	Ground level receptors, limited number affected near boundary (R23, R57, R75, R88). Source expected to be fugitive dust not kiln emissions. **Frequency 2 to 5 times per year.**
Dust PM_{10} 24 hour average Background exceedances due to environmental conditions	50µg/m^3 GLC*	52 – 177.5µg/m^3 Background environmental dust levels only	Ground level receptors, near boundary (R23, R57, R75, R88). **Source background dust unrelated to Berrima Plant.** **Frequency 2 to 7 times per year**.
Sulphuric acid mist / Sulphur trioxide	18µg/m^{3*} GLC* (99th Percentile) 1µg/m^3^ Chronic Health Guideline	24.2µg/m^3	Maximum predicted concentration at any receptor.
Volatile Organic Compounds (VOC) 24 hour average	20 ppm$^{\#}$ Emission criteria	Not applicable	EPA Current Criteria is VOC 20ppm. Boral is requesting a change to NMHC 40ppm

Source: Air Quality Professionals (2015); * GLC = Ground Level Concentration; $^{\#}$ VOC criteria of 40 ppm as NMHC proposed by Boral; * NSW EPA (DEC, 2005); ^ OEHHA (1999)

Fugitive dust has been determined as the main source of airborne dust as PM_{10} exceedances attributed to the facility. To put the exceedances attributed to the facility in perspective, it should be noted these exceedances are similar in number but at lower concentrations (maximum 69.7µg/m^3) than exceedances due to general environmental conditions excluding the influence of the facility (maximum 177.5µg/m^3).

Accordingly, environmental conditions (excluding dust emissions from the facility) are predicted to give rise to PM_{10} 24 hour averages approximately eight times greater than those attributed to the facility alone.

The quantification of potential health risk associated with PM_{10} and $PM_{2.5}$ determined the increased risk to the surrounding community to be negligible to tolerable (as set out in **Section 2.1.8.5**).

Therefore it is considered that dust exceedances associated with the facility are unlikely to increase the risk to local communities, beyond that already present from current environmental conditions. As such further risk assessment is not required.

As previously stated Boral is requesting the VOC criteria of 20ppm be changed to NMHC of 40ppm. The reason being the major source of VOCs in the emission has been demonstrated to be the blue shale mined on site. NMHC are considered appropriate VOCs to measure compliance to account for the inherent VOC levels within the blue shale.

Modelling using the proposed 40ppm criteria indicated that the highest NMHC concentration occurring beyond the site boundary GLC was 21µg/m^3. The VOC species assumed to be present in the total NHMC mix were compared against available regulatory and health based criteria for individual VOCs. This comparison indicated that NHMCs likely to be present in the emissions were all below applicable criteria. Therefore, it is considered that the NHMC emissions beyond the site boundary will be unlikely to pose an unacceptable health risk to the surrounding communities. As such further risk assessment is not required.

2.2 Issue Identification Summary

The main issues identified relating to the use of SWDF in Kiln 6 and the local populations are the following:

- The air quality modelling in this document indicated that the majority of emissions from the proposed use of SWDF would be within the relevant regulatory and health based criteria.

- Fugitive dusts from the facility are likely to lead to two to five incidents of airborne dust as PM_{10} 24 hour average, exceeding the EPA criteria of 50µg/m^3, with predicted concentrations of 50 – 69.7µg/m^3 at four receptors close to the facility. However concentrations of these exceedances are less than that caused by exceedances due to general environmental conditions excluding the influence of the facility. Moreover quantification of potential increased risk to the surrounding community demonstrated negligible to tolerable risk. Therefore it is considered that dust exceedances associated with the facility are unlikely to increase the risk to local communities, beyond that already present from current environmental conditions.

- Emissions of NHMC in the range of 40ppm or less from Kiln 6 are predicted to lead to GLC concentrations of individual VOC species below applicable regulatory and health based criteria and therefore unlikely to pose an unacceptable health risk to the surrounding communities.

- Emissions from Kiln 6 are predicted to lead to peak GLC concentrations of sulphuric acid mist / sulphur trioxide of 24.2µg/m^3 which exceed the EPA Criteria of 18µg/m^3 and the chronic health based criteria of 1µg/m^3. Therefore the potential for health risks, if any, to the local communities will be detailed in the following sections.

2.3 Toxicity Assessment

The only COPC carried through into the risk assessment was sulphuric acid / sulphur trioxide. All other COPCs were eliminated in the preceding Hazard Identification stage.

2.3.1 Sulphuric Acid / Sulphur Trioxide

Sulphur trioxide in the pure form is a colourless liquid but can also exist as crystals or a gas. When exposed to air sulphur trioxide quickly reacts with water to form sulphuric acid. It is unlikely to exist in the atmosphere except as a transitory compound prior to conversion to sulphuric acid. Furthermore any sulphur trioxide inhaled by a person reacts with water and converts to sulphuric acid in the upper respiratory tract (ASTR, 1998b). Accordingly, the focus of this toxicity assessment will be on sulphuric acid.

Sulphuric acid in pure form is a clear colourless liquid and a strong acid. Much of the atmospheric sulphuric acid forms when sulphur dioxide degrades to sulphur trioxide which reacts with water in the air to form sulphuric acid. Sulphuric acid vapours can condense and form airborne particles, nuclei, which can grow in size overtime with the inclusion of water in the particles. (ATSDR, 1998; WHO, 2006)

Sulphuric acid has a direct action on the tissues it contacts. Once absorbed sulphuric acid converts to salts of the sulphate ion which are excreted from the body in urine as organic sulphates, neutral sulphur or neutral sulphur compounds such as amino acids. The low toxicity of these metabolites means the main health impact from inhaled sulphuric acid will be the direct irritation of the respiratory tract (OEHHA, 2001).

Asthmatics and particularly adolescent asthmatics are the most sensitive group to the impacts of inhaled sulphuric acid. The lowest concentrations reported to illicit a physiological response in asthmatics has been 70µg/m^3, being transient changes in pulmonary function in adolescent children after 40 to 45 minutes exercise, with other studies reporting 100µg/m^3 as the lowest observable effect limit (ATSDR, 1998). In contrast, in healthy adults few lung function responses have been documented below 500µg/m^3 (Folinsbee, 1992).

The action of inhaled sulphuric acid on a person's respiratory system is dependent on the acid buffering capacity of the respiratory mucous layer. It has been estimated that a person with normal mucous buffering capacity and protein content can accommodate an exposure of approximately 300ug/m^3 for 30 minutes. In contrast asthmatics' mucous has been reported to be of lower pH and buffering capacity when compared with a healthy individual. This may explain asthmatics greater sensitivity to inhaled sulphuric acid (ATSDR, 1998).

Children's Susceptibility

The impact of a chemical exposure on children may vary from that experienced by adults. Children, from conception to 18 years old, are actively growing and some of their biological systems may still be developing. Children are not small adults and moreover children's behaviour may lead to different exposures to that of adults.

A number of studies have concluded that adolescent asthmatics may be more susceptible to transient sulphuric acid induced changes in respiratory function than adult asthmatics (ATSDR, 1998).

2.4 Exposure Assessment

In general, an exposure assessment aims to provide the magnitude, frequency, extent, character and duration of exposures to a chemical or material of concern. An exposure assessment also aims to identify human populations or groups who may be exposed and potential exposure pathways, which in this case is inhalation.

2.4.1 Exposure Pathways and Receptors

An exposure pathway describes the mechanism by which persons may be exposed to airborne sulphuric acid emissions originating from Kiln 6. Each exposure pathway must include a source, in this case Kiln 6, and a transport mechanism for sulphuric acid to enter the breathing zone, in this case environmental air movement. The exposure pathway is incomplete if any of these factors are not present, and therefore no additional risks are associated with that activity as the COPC does not reach the receptor.

Receptors

Receptors are similar groups of people from the defined communities. In this assessment, receptors are considered to be individuals who usually reside in the communities within close proximity to the facility. For the purposes of this study a nominal 5km cut off distance has been used to delineate these communities. These communities were set out above in **Table 1** and included the following:

- New Berrima
- Berrima
- Moss Vale
- Burradoo

2.4.2 Assessment of Exposure Concentration

The exposure concentration used for the current study was based on results of air quality modelling as previously mentioned.

The maximum exposure concentration for sulphuric acid was predicted to occur near the site boundary and was 24.2µg/m^3. It would be expected that exposure concentration for sulphuric acid for communities away from the facility boundary would be less than 24.2µg/m^3 due to the effective dilution of emissions from Kiln 6 with distance from the source to receiver. Moreover the conservative nature of the air quality modelling leads to predicted concentrations that are probably much higher than actual concentrations. This aspect will be discussed in detail below.

To put the predicted concentration of airborne sulphuric acid in context, the maximum exposure concentration for sulphuric acid of 24.2µg/m^3 is less than half the lowest concentration of airborne sulphuric acid reported to illicit a physiological response, being transient changes in pulmonary function, in the population group reported as most sensitive to sulphuric acid inhalation. The most sensitive group to this exposure being adolescent asthmatic children and the lowest concentration reported to affect this group being 70µg/m^3.

Regarding the current project, it should be noted that modelling may be overly conservative for sulphuric acid mist / sulphur trioxide emissions, based on an emission rate roughly one hundred times higher than the measured emissions. Air Quality Professional (2015) reported sulphuric acid mist / sulphur trioxide emissions have only been detected in kiln 6 emissions once in four years of annual monitoring data. Moreover the concentrations detected were significantly less than the concentration used in the air quality modelling. If the measured emission concentrations were used in the modelling then the maximum concentrations beyond the boundary was predicted to be 0.28µg/m^3. This concentration is within chronic health based guideline of 1ug/m^3.

It should also be noted that the results of test burns of non standard fuels in 2003 reported no significant differences in measured sulphuric acid mist / sulphur trioxide emissions from kiln 6 when no standard fuels was tested compared with routinely used fuels (Air Quality Professional, 2015). This would indicate use of SWDF in operations was unlikely to change the concentrations of sulphuric acid local communities are exposed to from current operations of the kiln 6.

3 RISK CHARACTERISATION

Risk characterisation involves the incorporation of the exposure assessment and the hazard assessment to provide an overall evaluation and assessment of risk. Risk assessment is used extensively in Australia and overseas to assist decision making on project acceptability and chemical use. Risk is the probability of an unwanted event happening and is often expressed as a multiple of its consequences and frequency. Risks can be defined to be acceptable or tolerable if the population will bear them without undue concern. The quantification of risk is an imprecise practise, based on available evidence, estimating level of risk within generally accepted ranges rather that absolute risk. The level of negligible / acceptable risk is generally considered to be less than 1 in 1,000,000 (i.e 1 x 10^{-6}) for contaminates with health effects considered to non-threshold in nature or carcinogenic chemicals (enHealth, 2012). At this level of risk it is considered essentially non-existent. The level of risk is considered unacceptable at greater than 1 in 10,000 (1 x 10^{-4}). Tolerable risk occurs in the range between 1 x 10^{-6} and 1 x 10^{-4} (DEC, 2005). Tolerable risks are considered acceptable when best practise for minimising air toxics has been utilised.

Regulatory limits are set at points deemed 'acceptable' by the regulator, taking into account objective evidence of harm and the general views of society. However in some cases, health based guidelines from reputable sources may be more appropriate in determining risk.

As with any risk assessment there is always a degree of uncertainty associated with the assessment. The factors involved in this uncertainty and the implications are discussed in **Appendix B**

Negligible risks are those so small that there is no cause for concern, or so unlikely that there is no valid reason to take action to reduce them. Humans continually expose themselves to, or have imposed upon them, the risk of injury or fatality. Self-imposed risk is known as voluntary risk and includes everyday events such as smoking, swimming and driving. Each has an associated risk that people voluntarily accept when weighed against the perceived benefits.

A simple comparison of an air measurement and a health benchmark can be thought of as a "screening" exercise, that is, the risk assessor is screening for possible problems. If the majority of samples are much less than the benchmark, then in a majority of cases it would be appropriate to conclude that a health impact is unlikely.

The majority of COPCs identified in the Issue Identification stage of the risk assessment were assessed as unlikely to be present at concentrations likely to impact on the health risks to receptors in the surrounding communities. This was based on comparisons of predicted COPC concentrations at or near receptor sites with relevant air quality assessment criteria, such as NSW EPA criteria or health based benchmarks. This group of COPCs included fine particulates (TSP, PM10, PM2.5), SO2, NOX, CO, VOCs, PAHs, heavy metals, hydrogen chloride, hydrogen fluoride, chlorine, and dioxins. The exception to this was sulphuric acid mist/sulphur trioxide which required further assessment.

The principal benchmark used in this assessment was the lowest concentration of airborne sulphuric acid reported to illicit a physiological response, being transient changes in pulmonary function, in the population group reported as most sensitive to sulphuric acid inhalation, adolescent asthmatic children with that concentration being 70µg/m^3.

In the current study, the maximum exposure concentration for sulphuric acid was predicted to occur at receptors near the site boundary and was 24.2µg/m^3. The exposure is less than half the lowest concentration of airborne sulphuric acid reported to illicit a response, that is 70µg/m^3.

Furthermore the actual exposure concentration of the surrounding communities is likely to be less than 24.2µg/m^3. This is based on two considerations, firstly the dilution of emissions as they travel away from the facility boundary to a receptor. Secondly the conservative nature of the air modelling which allowed predicted concentrations to be possibly as much as ninety times higher the probable concentrations as set out in section 2.3.3. If the measured emission concentrations were used in the modelling then the maximum concentrations beyond the boundary was predicted to be 0.28µg/m^3. This concentration is within chronic health based guideline of 1ug/m^3.

Therefore the predicted sulphuric acid emissions during the operation of Kiln 6 are not expected to lead to an increased health risk to the surrounding populations.

Based on this the Primary Exposure pathway of inhalation was considered unlikely to lead to receptor exposure at concentrations likely to increase the health risk to receptors. Therefore sulphuric acid mist/sulphur trioxide is not considered to require further risk assessment.

4 CONCLUSIONS

SLR assessed the potential exposure pathways for human health from contamination during the operations of Kiln 6 at the Berrima Cement Works while using SWDF. The assessment was based on a desktop review of available documents including environmental assessment and air quality report as set out in section 1.4.

A desktop evaluation it is considered appropriate given the limited scope of the proposed works.

As this project involves only minor physical changes in process, the potential impact on the surrounding communities is limited.

Taking available information sources into account and considering the nature and scope of the proposed works, it is considered that the proposed works are sufficiently characterised to enable an assessment of risks.

From the information available, it was concluded that:

- The communities who may be exposed to any COPCs associated with the use of SWDF as fuels in Kiln 6 were identified as New Berrima, Berrima, Moss Vale and Burradoo.

- The COPC associated with the use of SWDF as fuels in Kiln 6 were identified as fine particulates (TSP, PM_{10}, $PM_{2.5}$), SO_2, NO_X, CO, VOCs, PAHs, heavy metals, hydrogen chloride, hydrogen fluoride, chlorine, sulphuric acid mist/sulphur trioxide and dioxins

- Comparisons of predicted COPC concentrations at or near receptor sites with relevant air quality assessment criteria or health based benchmarks determined that none of the identified COPCs were likely to be present at concentrations likely to impact on the health risks to receptors in the surrounding communities.

Emission control measures to minimise any potential impacts have been noted in section 1.7.

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Appendix A

QUANTIFICATION OF RISK ASSOCIATED WITH AIRBORNE PARTICULATES AS PM_{10} & $PM_{2.5}$

The methodology regrading quantification of risk followed that outlined by the WHO (Ostro, 2004). This method has been utilised to quantify health risks associated with airborne particulates (PM_{10} & $PM_{2.5}$) in recent major developments in NSW where airborne particulate pollution has been as a significant concern for the community, such as the WestConnex M4 East and NorthConnex motorway tunnels proposed for the Sydney roads system (EnRiskS, 2014 & EnRiskS, 2014).

In the WestConnex M4 East and NorthConnex reports EnRiskS (2014 & 2015) provided extensive and detailed background to the use and development of the risk quantification methodology as well as the chosen health endpoints associated with the risk. Furthermore those projects required agreement with the NSW Department of Health with regards to the appropriateness of methodology. An example of this can be seen in NorthConnex reports (EnRiskS, 2014) which states "*The health impact functions presented in this table* (referring to Table 5-1) *have been discussed and agreed with NSW Health as the most current and appropriate for the quantification of potential health effects for the health endpoints considered in this assessment."* This indicates a level of robustness in the methodology and functions chosen.

Based on this acceptance health impact functions in those previous reports, it was decided the current report would use the same health impact functions. This would then follow previous practise on major developments and if required allow comparison with risks levels from previous major developments

The NorthConnex report (EnRiskS, 2014) succinctly summarised the adopted health impact functions and exposure response relationships used in the risk assessment. As such the table has been quoted in full below as Table B-1.

The risk equation utilised in the WestConnex M4 East and NorthConnex reports to calculate annual risk for individuals exposed to increased PM emission from the project at specific locations (such as maximum, or at specific sensitive receiver locations) has ben set out below (EnRiskS, 2014).

Risk = β x ∆X x B

Where

β = slope coefficient relevant to the per cent change in response to a 1 $\mu g/m^3$ change in particulate matter exposure (as per Table B-1)

ΔX = change (increment) in PM10 or PM2.5 exposure concentration in $\mu g/m^3$ relevant to the project at the point of exposure

B = baseline incidence of a given health effect per person (eg annual mortality rate)

Table B-1 Adopted health impact functions and exposure response relationships (source: EnRiskS, 2014)

Health endpoint	Exposure period	Age Group	Published relative risk (95% confidence interval) per 10 µg/m^3	Adopted β coefficient (as %) for 1 µg/m^3 increase in PM	Reference
Primary assessment health endpoints					
$PM_{2.5}$: Mortality, all causes	Long Term	≥30yrs	1.06 [1.04-1.08]	0.0058 (0.58%)	Relationship derived for all follow-up time periods to the year 2000 (for approx. 500 000 participants in the US) with adjustment for seven ecologic (neighbourhood level) covariates (Krewski et al. 2009). This study is an extension (additional follow-up and exposure data) of the work undertaken by Pope (2002), is consistent with the findings from California (19992002) (Ostro et al. 2006) and is more conservative than the relationships identified in a more recent Australian and New Zealand study (EPHC 2010).
$PM_{2.5}$: Cardiovascular hospital admissions	Short term	≥65yrs	1.008 [1.0059-1.011]	0.0008 (0.08%)	Relationship established for all data and all seasons from US data for 1999 to 2005 for lag 0 (exposure on same-day)(strongest effect identified) (Bell, M. L. 2012; Bell, Michelle L. et al. 2008)
$PM_{2.5}$: Respiratory hospital admissions	Short Term	≥65yrs	1.0041 [1.0009-1.0074]	0.00041 (0.041%)	Relationship established for all data and all seasons from US data for 1999 to 2005 for lag 2 (exposure 2 days previous)(strongest effect identified) (Bell, M. L. 2012; Bell, Michelle L. et al. 2008)

Table B-1 Adopted health impact functions and exposure response relationships (source: EnRiskS, 2014) (con't)

Health endpoint	Exposure period	Age Group	Published relative risk (95% confidence interval) per 10 µg/m^3	Adopted β coefficient (as %) for 1 µg/m^3 increase in PM	Reference
Secondary assessment health endpoints					
PM_{10}: Mortality, all causes	Short Term	All ages*	1.006 [1.004-1.008]	0.0006 (0.06%)	Based on analysis of data from European studies from 33 cities and includes panel studies of symptomatic children (asthmatics, chronic respiratory conditions) (Anderson et al. 2004)
$PM_{2.5}$: Mortality, all causes	Short Term	All ages*	1.0094 [1.0065-1.0122]	0.00094 (0.094%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)
$PM_{2.5}$: Cardiopulmonary Mortality	Long Term	≥30yrs	1.14 [1.11-1.17]	0.013 (1.3%)	Relationship derived for all followup time periods to the year 2000 (for approx. 500 000 participants in the US) with adjustment for seven ecologic (neighbourhood level) covariates (Krewski et al. 2009).
$PM_{2.5}$: Cardiovascular mortality	Short Term	All ages*	1.0097 [1.0051-1.0143]	0.00097 (0.097%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)
$PM_{2.5}$: Respiratory mortality (including lung cancer)	Short Term	All ages*	1.0192 [1.0108-1.0278]	0.0019 (0.19%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)

* Relationships established for all ages, including young children and the elderly

Regarding the current project, the calculated changes in health risk from incremental changes in both PM10 and PM2.5 at each Receptor identified by Air Quality Professional (2015) have been set out below in Table B-2. All of the Receptor locations the increased risk were calculated to be within the range considered to be negligible to tolerable risk as set out in DEC (2005). None of the Receptor locations showed unacceptable risks.

Table B-2 Calculated changes in health risk from changes in PM_{10} & $PM_{2,5}$ concentrations at each receptor location

Fugitive Dusts & Combined Point Sources			Primary Assessment Health End Points			Secondary Assessment Health End Points				
Particulate Fraction			**PM2.5**	**PM2.5**	**PM2.5**	**PM10**	**PM2.5**	**PM2.5**	**PM2.5**	**PM2.5**
Endpoint			**Mortality - All causes**	**Hospitalisations - Cardiovacular**	**Hospitalisations - Respiratory**	**Mortality - All causes**	**Mortality - All causes**	**Mortality - Cardiopulmonary**	**Mortality - Cardiovacular**	**Mortality - Respiratory**
Effect Exposure Duration			Long Term	Short Term	Short Term	Short Term	Short Term	Long Term	Short Term	Short Term
Age Group			≥ 30 years	≥ 65 years	≥ 65 years	all ages	all ages	≥ 30 years	all ages	all ages
β			0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019
Baseline Incidence per 100,000			1087	2335.2	8807	670	670	490	164	57
Baseline Incidence per person			0.01087	0.023352	0.08807	0.0067	0.0067	0.0049	0.00164	0.00057
Sensitive Receiver	**Change in annual average PM10 concentration (µ/m3)**	**Change in annual average PM2.5 concentration (µ/m3)**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**
Maximum Receptor	5.2	1	6E-05	2E-05	4E-05	2E-05	6E-06	6E-05	2E-06	1E-06
Individual Receptors										
1	0.4	0.11	7E-06	2E-06	4E-06	2E-06	7E-07	7E-06	2E-07	1E-07
2	0.51	0.14	9E-06	3E-06	5E-06	2E-06	9E-07	9E-06	2E-07	2E-07
3	0.6	0.17	1E-05	3E-06	6E-06	2E-06	1E-06	1E-05	3E-07	2E-07
4	0.68	0.2	1E-05	4E-06	7E-06	3E-06	1E-06	1E-05	3E-07	2E-07
5	0.69	0.18	1E-05	3E-06	6E-06	3E-06	1E-06	1E-05	3E-07	2E-07
6	0.67	0.18	1E-05	3E-06	6E-06	3E-06	1E-06	1E-05	3E-07	2E-07
7	0.75	0.2	1E-05	4E-06	7E-06	3E-06	1E-06	1E-05	3E-07	2E-07
8	0.9	0.23	1E-05	4E-06	8E-06	4E-06	1E-06	1E-05	4E-07	2E-07
9	0.82	0.21	1E-05	4E-06	8E-06	3E-06	1E-06	1E-05	3E-07	2E-07
10	0.84	0.21	1E-05	4E-06	8E-06	3E-06	1E-06	1E-05	3E-07	2E-07
11	1.06	0.25	2E-05	5E-06	9E-06	4E-06	2E-06	2E-05	4E-07	3E-07
12	1.33	0.33	2E-05	6E-06	1E-05	5E-06	2E-06	2E-05	5E-07	4E-07
13	1.25	0.29	2E-05	5E-06	1E-05	5E-06	2E-06	2E-05	5E-07	3E-07
14	1.32	0.31	2E-05	6E-06	1E-05	5E-06	2E-06	2E-05	5E-07	3E-07
15	1.68	0.36	2E-05	7E-06	1E-05	7E-06	2E-06	2E-05	6E-07	4E-07
16	1.8	0.37	2E-05	7E-06	1E-05	7E-06	2E-06	2E-05	6E-07	4E-07
17	1.61	0.32	2E-05	6E-06	1E-05	6E-06	2E-06	2E-05	5E-07	3E-07
18	0.94	0.18	1E-05	3E-06	6E-06	4E-06	1E-06	1E-05	3E-07	2E-07
19	0.93	0.18	1E-05	3E-06	6E-06	4E-06	1E-06	1E-05	3E-07	2E-07
20	1.64	0.3	2E-05	6E-06	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
21	1.72	0.39	2E-05	7E-06	1E-05	7E-06	2E-06	2E-05	6E-07	4E-07
22	2.83	0.6	4E-05	1E-05	2E-05	1E-05	4E-06	4E-05	1E-06	6E-07
23	3.13	0.64	4E-05	1E-05	2E-05	1E-05	4E-06	4E-05	1E-06	7E-07
24	2.38	0.49	3E-05	9E-06	2E-05	1E-05	3E-06	3E-05	8E-07	5E-07
25	1.77	0.3	2E-05	6E-06	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
26	2.68	0.44	3E-05	8E-06	2E-05	1E-05	3E-06	3E-05	7E-07	5E-07
27	2.88	0.46	3E-05	9E-06	2E-05	1E-05	3E-06	3E-05	7E-07	5E-07
28	2.22	0.36	2E-05	7E-06	1E-05	9E-06	2E-06	2E-05	6E-07	4E-07

Fugitive Dusts & Combined Point Sources			Primary Assessment Health End Points			Secondary Assessment Health End Points				
Particulate Fraction			**PM2.5**	**PM2.5**	**PM2.5**	**PM10**	**PM2.5**	**PM2.5**	**PM2.5**	**PM2.5**
Endpoint			**Mortality - All causes**	**Hospitalisations - Cardiovacular**	**Hospitalisations - Respiratory**	**Mortality - All causes**	**Mortality - All causes**	**Mortality - Cardiopulmonary**	**Mortality - Cardiovacular**	**Mortality - Respiratory**
Effect Exposure Duration			Long Term	Short Term	Short Term	Short Term	Short Term	Long Term	Short Term	Short Term
Age Group			≥ 30 years	≥ 65 years	≥ 65 years	all ages	all ages	≥ 30 years	all ages	all ages
β			0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019
Baseline Incidence per 100,000			1087	2335.2	8807	670	670	490	164	57
Baseline Incidence per person			0.01087	0.023352	0.08807	0.0067	0.0067	0.0049	0.00164	0.00057
Sensitive Receiver	**Change in annual average PM10 concentration (µ/m3)**	**Change in annual average PM2.5 concentration (µ/m3)**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**
Individual Receptors (con't)										
29	1.81	0.31	2E-05	6E-06	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
30	0.51	0.1	6E-06	2E-06	4E-06	2E-06	6E-07	6E-06	2E-07	1E-07
31	0.49	0.1	6E-06	2E-06	4E-06	2E-06	6E-07	6E-06	2E-07	1E-07
32	0.78	0.13	8E-06	2E-06	5E-06	3E-06	8E-07	8E-06	2E-07	1E-07
33	1.04	0.19	1E-05	4E-06	7E-06	4E-06	1E-06	1E-05	3E-07	2E-07
34	1.77	0.3	2E-05	6E-06	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
35	1.63	0.29	2E-05	5E-06	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
36	1.63	0.29	2E-05	5E-06	1E-05	7E-06	2E-06	2E-05	5E-07	3E-07
37	2.5	0.41	3E-05	8E-06	1E-05	1E-05	3E-06	3E-05	7E-07	4E-07
38	2.33	0.39	2E-05	7E-06	1E-05	9E-06	2E-06	2E-05	6E-07	4E-07
39	1.91	0.34	2E-05	6E-06	1E-05	8E-06	2E-06	2E-05	5E-07	4E-07
40	1.45	0.27	2E-05	5E-06	1E-05	6E-06	2E-06	2E-05	4E-07	3E-07
41	2.28	0.41	3E-05	8E-06	1E-05	9E-06	3E-06	3E-05	7E-07	4E-07
42	1.36	0.26	2E-05	5E-06	9E-06	5E-06	2E-06	2E-05	4E-07	3E-07
43	1.17	0.23	1E-05	4E-06	8E-06	5E-06	1E-06	1E-05	4E-07	2E-07
44	0.96	0.19	1E-05	4E-06	7E-06	4E-06	1E-06	1E-05	3E-07	2E-07
45	0.87	0.18	1E-05	3E-06	6E-06	3E-06	1E-06	1E-05	3E-07	2E-07
46	0.63	0.14	9E-06	3E-06	5E-06	3E-06	9E-07	9E-06	2E-07	2E-07
47	0.48	0.12	8E-06	2E-06	4E-06	2E-06	8E-07	8E-06	2E-07	1E-07
48	0.46	0.11	7E-06	2E-06	4E-06	2E-06	7E-07	7E-06	2E-07	1E-07
49	0.44	0.11	7E-06	2E-06	4E-06	2E-06	7E-07	7E-06	2E-07	1E-07
50	0.32	0.09	6E-06	2E-06	3E-06	1E-06	6E-07	6E-06	1E-07	1E-07
51	0.36	0.11	7E-06	2E-06	4E-06	1E-06	7E-07	7E-06	2E-07	1E-07
52	0.35	0.1	6E-06	2E-06	4E-06	1E-06	6E-07	6E-06	2E-07	1E-07
53	1.09	0.25	2E-05	5E-06	9E-06	4E-06	2E-06	2E-05	4E-07	3E-07
54	1	0.24	2E-05	4E-06	9E-06	4E-06	2E-06	2E-05	4E-07	3E-07
55	3.59	0.67	4E-05	1E-05	2E-05	1E-05	4E-06	4E-05	1E-06	7E-07
56	3.11	0.58	4E-05	1E-05	2E-05	1E-05	4E-06	4E-05	9E-07	6E-07
57	4.54	1.01	6E-05	2E-05	4E-05	2E-05	6E-06	6E-05	2E-06	1E-06
58	1.42	0.34	2E-05	6E-06	1E-05	6E-06	2E-06	2E-05	5E-07	4E-07

Fugitive Dusts & Combined Point Sources			Primary Assessment Health End Points			Secondary Assessment Health End Points				
Particulate Fraction			**PM2.5**	**PM2.5**	**PM2.5**	**PM10**	**PM2.5**	**PM2.5**	**PM2.5**	**PM2.5**
Endpoint			**Mortality - All causes**	**Hospitalisations - Cardiovacular**	**Hospitalisations - Respiratory**	**Mortality - All causes**	**Mortality - All causes**	**Mortality - Cardiopulmonary**	**Mortality - Cardiovacular**	**Mortality - Respiratory**
Effect Exposure Duration			Long Term	Short Term	Short Term	Short Term	Short Term	Long Term	Short Term	Short Term
Age Group			≥ 30 years	≥ 65 years	≥ 65 years	all ages	all ages	≥ 30 years	all ages	all ages
β			0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019
Baseline Incidence per 100,000			1087	2335.2	8807	670	670	490	164	57
Baseline Incidence per person			0.01087	0.023352	0.08807	0.0067	0.0067	0.0049	0.00164	0.00057
Sensitive Receiver	**Change in annual average PM10 concentration (µ/m3)**	**Change in annual average PM2.5 concentration (µ/m3)**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**
Individual Receptors (con't)										
59	1.51	0.35	2E-05	7E-06	1E-05	6E-06	2E-06	2E-05	6E-07	4E-07
60	1.68	0.41	3E-05	8E-06	1E-05	7E-06	3E-06	3E-05	7E-07	4E-07
61	1.34	0.33	2E-05	6E-06	1E-05	5E-06	2E-06	2E-05	5E-07	4E-07
62	1.14	0.25	2E-05	5E-06	9E-06	5E-06	2E-06	2E-05	4E-07	3E-07
63	1.05	0.24	2E-05	4E-06	9E-06	4E-06	2E-06	2E-05	4E-07	3E-07
64	0.89	0.2	1E-05	4E-06	7E-06	4E-06	1E-06	1E-05	3E-07	2E-07
65	0.57	0.14	9E-06	3E-06	5E-06	2E-06	9E-07	9E-06	2E-07	2E-07
66	0.44	0.12	8E-06	2E-06	4E-06	2E-06	8E-07	8E-06	2E-07	1E-07
67	0.48	0.13	8E-06	2E-06	5E-06	2E-06	8E-07	8E-06	2E-07	1E-07
68	0.46	0.12	8E-06	2E-06	4E-06	2E-06	8E-07	8E-06	2E-07	1E-07
69	0.45	0.11	7E-06	2E-06	4E-06	2E-06	7E-07	7E-06	2E-07	1E-07
70	0.4	0.1	6E-06	2E-06	4E-06	2E-06	6E-07	6E-06	2E-07	1E-07
71	0.43	0.12	8E-06	2E-06	4E-06	2E-06	8E-07	8E-06	2E-07	1E-07
72	1.73	0.33	2E-05	6E-06	1E-05	7E-06	2E-06	2E-05	5E-07	4E-07
73	2.29	0.37	2E-05	7E-06	1E-05	9E-06	2E-06	2E-05	6E-07	4E-07
74	2.16	0.34	2E-05	6E-06	1E-05	9E-06	2E-06	2E-05	5E-07	4E-07
75	5.25	0.8	5E-05	1E-05	3E-05	2E-05	5E-06	5E-05	1E-06	9E-07
76	3.01	0.49	3E-05	9E-06	2E-05	1E-05	3E-06	3E-05	8E-07	5E-07
77	3.46	0.64	4E-05	1E-05	2E-05	1E-05	4E-06	4E-05	1E-06	7E-07
78	2.17	0.42	3E-05	8E-06	2E-05	9E-06	3E-06	3E-05	7E-07	5E-07
79	1.29	0.32	2E-05	6E-06	1E-05	5E-06	2E-06	2E-05	5E-07	3E-07
80	3.22	0.64	4E-05	1E-05	2E-05	1E-05	4E-06	4E-05	1E-06	7E-07
81	0.94	0.23	1E-05	4E-06	8E-06	4E-06	1E-06	1E-05	4E-07	2E-07
82	0.6	0.15	9E-06	3E-06	5E-06	2E-06	9E-07	1E-05	2E-07	2E-07
83	0.85	0.22	1E-05	4E-06	8E-06	3E-06	1E-06	1E-05	3E-07	2E-07
84	0.72	0.17	1E-05	3E-06	6E-06	3E-06	1E-06	1E-05	3E-07	2E-07
85	0.62	0.15	9E-06	3E-06	5E-06	2E-06	9E-07	1E-05	2E-07	2E-07
86	0.53	0.13	8E-06	2E-06	5E-06	2E-06	8E-07	8E-06	2E-07	1E-07
87	0.49	0.12	8E-06	2E-06	4E-06	2E-06	8E-07	8E-06	2E-07	1E-07
88	4.27	0.71	4E-05	1E-05	3E-05	2E-05	4E-06	5E-05	1E-06	8E-07

Appendix B

UNCERTAINTIES AND LIMITATIONS

Uncertainties are present in all risk assessments and this reinforces the need for a systematic and rigorous approach. The enHealth human health risk assessment process attempts to estimate risk as accurately as possible, however there are various sources of uncertainty in the process that should be examined. Understanding these uncertainties places the risk estimates in a proper perspective allowing them to be applied in practice with an appropriate level of confidence.

In general, the uncertainties and limitations of human health risk assessment can be classified into the following categories:

- Personnel exposure assessment.
- Toxicological assessment.
- Risk characterisation.

Various sources of uncertainty are briefly discussed below.

Uncertainty related to Exposure Assessment

The uncertainties that may exist in exposure assessment include the estimation of concentrations in the air:

- Uncertainties relating to air modelling.
- Models are generally conservative and overestimate concentrations

Uncertainty related to Toxicity Assessment

In general, the available scientific literature is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals or materials to which humans may be exposed. It is necessary therefore, to extrapolate these properties from data obtained under other conditions of exposure and involving experimental laboratory animals. This may introduce two types of uncertainties into the risk assessment, as follows:

- Those related to extrapolation from one species to another
- Those related to extrapolating from high exposure doses, usually in experimental animal studies, to the lower doses usually estimated for human exposure situations

Safety factors are introduced to compensate for these uncertainties. The use of safety factors and extrapolating from high exposure concentrations typically leads to a conservative over-estimation of dose response relationships.

Uncertainties in Site Specific Data and Modelling.

Much of the data relied upon in this report was based on Boral's historic air quality and stack testing data from existing operations and also predicted COPC concentrations from the air quality modelling outlined by Air Quality Professionals (2015). The uncertainty associated with Boral's air quality testing data is expected to be distributed around the actual concentration and no different from measured data any air monitoring programme. The uncertainty associated with the air quality modelling predictions is more directed as the modelling deliberately chooses conservative parameters which are more likely to overestimate COPC concentrations. Therefore the predicted data used for exposure assessments in the risk assessment were likely to be much higher than what the actual concentrations will be when the Cement Works is in operation.

Uncertainties Conclusion

While a number of parameters used within the risk assessment have a moderate degree of uncertainty associated with them, values used to define these parameters have been selected to be conservative. This has resulted in estimates of risk which tend towards a conservative overestimation.

Data Gaps

There is limited information on background soil concentrations of persistent COPCs, for example PAHs, dioxins and heavy metals, in general soils around the chosen communities, relating to historic deposition. This gap adds to the uncertainty associated with the assessment of secondary exposure from existing and future emissions. Accordingly ingestion and dermal pathways could not be fully accessed.

The actual composition of the VOC mixture present in the Kiln 6 emissions is unknown at this time.