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AGL LOY YANG EMISSIONS MONITORING PROGRAM – CLASS 3 INDICATORS - RESULTS

Prepared for	AGL Loy Yang Pty Ltd
Report No.	HLC/2022/055
Date	March 2022
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Executive Summary

HRL Technology Group (HRL) was retained by AGL Loy Yang Pty Limited (AGL Loy Yang) to report on the outcomes of an Emissions Monitoring Program – Class 3 Indicators (Class 3 Program) completed for Loy Yang A Power Station (LYA). As required by condition LI_DA4.4 of EPA Licence No. 11149 (Licence):

> *You must establish and implement a program for a 12-month period to monitor the discharge to air, at discharge point(s) 1 to 4, of all class 3 indicators listed in Schedule A of State Environment Protection Policy (Air Quality Management), as agreed in writing with EPA. The results of this program must be made available to EPA on request and must be published to the publicly accessible website required by condition LI_DA4.2 by 31 March 2022.*

A Class 3 monitoring program was developed following guidance from EPA Publication 440.1 *A guide to the sampling and analysis of air emissions and air quality* and EPA Publication 1322.9 *Licence Management.* The program scope of work was informed by outcomes of previous studies and historic LYA analytical results (e.g. coal analysis data, stack test reports and ash analysis data), to identify which Class 3 Indicators should be excluded from the Class 3 Program. From that assessment, seven (7) Class 3 Indicators were excluded from the Class 3 Program, on the basis that they are not associated with the combustion of brown coal at LYA.

The proposed Class 3 Program scope of work, which was submitted to the EPA on 1 July 2021, included sampling and testing of all relevant Class 3 Indicator emissions from a representative Unit at LYA (Unit 4), supplemented by routine annual National Pollutant Inventory (NPI) monitoring which included Unit 3. The NPI monitoring program includes Class 3 Indicator metals (Arsenic, Beryllium, Cadmium and Nickel). On 3 August 2021, the EPA confirmed in writing that the proposed scope of work for the Class 3 Program was appropriate for the purpose of complying with the new condition LI_DA4.4 but recommended that emissions testing for mercury (a Class 2 Indicator) also be included in the monitoring program.

Stack emission testing was conducted by a third-party specialist stack emission testing service provider, Ektimo Pty Ltd (Ektimo), on Units 3 and 4 (corresponding to Licence air emission discharge points 3 and 4 at LYA), in accordance with the approved Class 3 Program.

The analytical results for most organic Class 3 Indicators sampled were below the limit of detection for the applicable analytical measurement methods. For the few organic Class 3 Indicators that were detected as present in emissions (e.g. Dioxins & Furans and Poly Aromatic Hydrocarbons (PAHs)) each of these were present at low concentrations. This result is expected given the high temperature conditions and residence time within the boiler furnace.

The inorganic Class 3 Indicators that were detected in the sampling program are primarily associated with residual particulate matter emissions downstream of the Electrostatic Dust Precipitators (EDPs). These included Arsenic, Beryllium, Cadmium and Nickel, and Respirable Crystalline Silica (as cristobalite), which were present above detection limits for some, but not all, of the stack tests conducted during the Class 3 Program. The Class 3 Program also utilised recent emission testing data for Class 3 metals from the routine annual NPI monitoring, also undertaken on Units 3 and 4 at LYA.

Of the 26 Class 3 Indicators listed in Schedule A of *State Environment Protection Policy (Air Quality Management)* (SEPP AQM) only seven (7) Class 3 Indicators were detected i.e. found to be present in the flue gas at levels above the analytical limit of detection.

To assess whether the analytical results from the Class 3 Program are of concern to human health and the environment, it is necessary to compare the 'in-stack' concentrations of Class 3 Indicators (if detected) with ground level concentrations (GLCs), to facilitate comparison with appropriate GLC standards. The former SEPP AQM Schedule A GLC design criteria for Class 3 Indicators has recently been replaced by EPA Publication 1961, which includes risk-based air pollution assessment criteria (referred to as APACs). The new risk-based air pollution assessment criteria provide a benchmark to understand potential risks and to assist in the assessment of whether an emitter is complying with the general environmental duty, which requires persons engaging in an activity that may give rise to risks of harm to human health or the environment from pollution or waste to minimise those risks, so far as reasonably practicable.

HRL compared the in-stack measurements to the new ground level APACs listed in Table 3 of EPA Publication 1961 by using a calculated 'Dilution Ratio' based on the maximum 3-minute average ground level concentration for Total Solid Particles (TSP) obtained from modelling of the Latrobe Valley Air Shed, prepared for the EPA Licence Review (GHD, 2018). The calculated Dilution Ratio (1513:1) was determined from the results of atmospheric dispersion modelling using estimated Total Solid Particle (TSP) emissions from LYA, LYB and Yallourn power stations operating simultaneously at maximum emission rates and the predicted the maximum grid (ground level) 3-minute average result for TSP, under worst case ambient conditions. The Dilution Ratio for TSP was utilised for the assessment of Class 3 Indicator emissions as TSP and (Total) mercury emissions were the only two results presented as 3-minute average results (for comparison with both APACs and SEPP AQM benchmark ground level concentration assessment criteria), and TSP yielded the lowest and hence, the most conservative, dilution ratio. Furthermore, most Class 3 Indicator emissions that were above the limit of detection are typically associated with particulate matter.

Since the APACs have longer time averaging periods (i.e. typically 1-hour averages, or annual averages) rather than the 3-minute average design criteria in SEPP AQM Schedule A, the 1-hour APACs were converted to a 3-minute averaging time basis[1] prior to applying the Dilution Ratio. For those Class 3 Indicators with APAC time averaging periods greater than 1-hour, SEPP AQM Schedule A 3-minute average design criteria was conservatively used for the benchmarking assessment.

The analytical results for Class 3 metals, PAHs, Dioxins & Furans and Respirable Crystalline Silica were found to be 1 – 4 orders of magnitude below the benchmark in-stack concentration assessment criteria. This assessment was based on the calculated Dilution Ratio and after correction of in-stack concentrations to benchmark assessment criteria reference conditions[2].

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[1] From EPA Publication 1965 page 56: Using the function $Ct = C_{60} \times (60/t)^{0.2}$, where 't' is an averaging time (in minutes) that is shorter than 60 minutes.

[2] EPA Publication 1961 APACs and the SEPP AQM both report concentrations using gas volumes expressed at 25°C, wet and an atmospheric pressure of 101.325 kPa, while stack testing results are typically reported using gas volumes expressed as dry, 0°C and 101.325 kPa.

The results of the emissions testing for metals classified as Class 3 Indicators (As, Be, Cd & Ni) demonstrate that the Class 3 Indicators largely remain in the fly ash captured by the EDPs or in the boiler bottom ash. Of those measurements which were not below the measurement detection limit, calculations indicate Class 3 metal removal rates of 97.2 – 99.97% in recovered EDP fly ash or boiler bottom ash. As a result, flue gas emissions of those Class 3 Indicators are between one and several orders of magnitude below the estimated benchmark in-stack emission concentrations, which means that ground level concentrations for each would be well below applicable benchmark APACs or SEPP (AQM) design criteria.

Calculations indicate removal rates of 40 – 80% for the more volatile Class 2 Indicator, Mercury (Total), in recovered EDP fly ash or boiler bottom ash. Despite the higher proportion of Mercury in flue gas, the results for mercury emissions obtained during the monitoring campaigns were also several orders of magnitude below the benchmark in-stack concentration assessment criteria, based on SEPP AQM Schedule A 3-minute average design criteria for total mercury (inorganic + organic mercury) and using an estimated dilution ratio (1619:1) for Total Mercury emissions obtained from modelling of the Latrobe Valley Air Shed, prepared for the EPA Licence Review (GHD, 2018).

Overall, the Class 3 Program has demonstrated that, despite typical variable coal quality observed over the Class 3 stack testing campaign and routine annual stack testing, the high temperature combustion conditions (which destroy organic compounds) are effective in eliminating or limiting the emission of Class 3 Indicators such as VOCs, dioxins and furans, and Poly Aromatic Hydrocarbons (PAHs), while the EDPs are effective in removing Class 3 Indicators that are present within the solid fly ash by-product. Consequently Class 3 Indicators were found to be either below measurement detection limits or, if detected, one to several orders of magnitude below benchmark in-stack concentration assessment criteria, based on EPA Publication 1961 APACs or SEPP AQM design criteria, which is established to protect human health and the environment. This finding is consistent with the results of past Class 3 Indictor monitoring activities at LYA and for other large Latrobe Valley brown coal combustion processes.

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Table of Contents

List of Tables

List of Figures

1 Introduction

HRL Technology Group (HRL) was retained by AGL Loy Yang Pty Limited (AGL Loy Yang) to report on the outcomes of an Emissions Monitoring Program – Class 3 Indicators (Class 3 Program) completed for Loy Yang A Power Station (LYA). As required by condition LI_DA4.4 of EPA Licence No. 11149 (Licence):

> *You must establish and implement a program for a 12-month period to monitor the discharge to air, at discharge point(s) 1 to 4, of all class 3 indicators listed in Schedule A of State Environment Protection Policy (Air Quality Management), as agreed in writing with EPA. The results of this program must be made available to EPA on request and must be published to the publicly accessible website required by condition LI_DA4.2 by 31 March 2022.*

At the time condition LI_DA4.4 was imposed on the Licence, Class 3 Indicators were a group of substances listed in Schedule A of *State Environment Protection Policy (Air Quality Management)* (SEPP AQM). Following the commencement of the new *Environment Protection Act 2017* (Vic) on 1 June 2021, SEPP AQM no longer has formal legal status. Rather, Class 3 Indicators are now regulated under the *Environment Protection Regulations 2021* (Vic) (EP Regulations) and the *Guideline for Assessing and Minimising Air Pollution in Victoria* (EPA Publication 1961). Schedule 4 of the EP Regulations lists all substances which are classified as Class 3 Indicators. The Class 3 Indicators listed in Schedule 4 of the EP Regulations are identical to those listed in Schedule A of SEPP AQM except for Asbestos, which is no longer listed (though it is still classified as Class 3 in EPA Publication 1961).

2 Class 3 Program Methodology

EPA Publication 1322.9 *Licence Management* requires sampling and analysis to be conducted in accordance with EPA Publication 440.1 *Guide to Air Quality Sampling and Analysis*. The Class 3 Program developed to address Licence condition LI_DA4.4 was prepared following guidance from EPA Publication 440.1 and was informed by outcomes of previous studies and historic analytical results (e.g. coal analysis data, stack test reports and ash analysis data) provided by LYA.

The Class 3 Program proposed by AGL Loy Yang included conducting stack emission testing on licenced air emission discharge points (3 and 4) for all Class 3 Indicators except the following, which are not known to be associated with the combustion of brown coal or a component of brown coal from the Latrobe Valley:

- Asbestos
- Ethylene Oxide
- Propylene Oxide
- Epichlorohydrin
- MDI (Diphenylmethane diisocyanate)
- TDI (toluene-2,4-diisobyanate and toluene-2,6-diisocyanate)
- Phosgene

The Class 3 Program proposed that physical stack emission sampling would utilise the normal sampling location on each flue which is utilised for routine annual Licence compliance monitoring.

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AGL Loy Yang engaged a National Association of Testing Authorities (NATA) accredited specialist stack emission sampling and testing service provider, Ektimo Pty Ltd (Ektimo) to:

- Select the appropriate sampling and analysis methods for each Class 3 Indicator, considering the approved methods in EPA Publication 440.1,
- Implement the physical sampling and testing aspects of the Class 3 Program using NATA accredited methods and laboratories, and
- Prepare reports for each sampling and testing campaign, to inform the assessment of Class 3 Indicator emissions to the atmosphere at LYA.

The sampling and analysis methods and the NATA accreditation status each analyte in relation to the specified sampling or analysis method are summarised in Table 1.

Table 1: Selected sampling and analysis methods for Class 3 analytes

Parameter	Sampling Method	Analysis Method	Uncertainty*	NATA Accredited	
				Sampling	Analysis
Sampling points - Selection	AS 4323.1	NA	NA	✓	NA
Flow rate, temperature and velocity	ISO 10780	ISO 10780	8%, 2%, 7%	NA	✓
Moisture	USEPA Method 4	USEPA Method 4	8%	✓	✓
Molecular weight	NA	USEPA Method 3	not specified	NA	✓
Carbon dioxide and oxygen	USEPA Method 3A	USEPA Method 3A	13%	✓	✓
Aldehydes and ketones	Ektimo 330	Ektimo 330	16%	✓	✓†
Cyanide	Ektimo 270	Envirolab in-house method Inorg-014	14%	✓	✓‡
Speciated volatile organic compounds	Ektimo 200	Ektimo 345b	not specified	✓	✓†
Volatile organic compounds	Vic EPA 4230	Ektimo 344	19%	✓	✓†
Hexavalent chromium	CARB 425	Envirolab in-house method Inorg-024	16%	✓	✓‡
Dioxins and furans (PCDDs and PCDFs)	USEPA Method 23A	NMI in-house method AUTL_MET_02	16%	✓	✓¶
Polycyclic aromatic hydrocarbons (PAHs)	USEPA SW-846 0010	NMI in-house method NGCMS 11.27	21%	✓	✓¶
Crystalline silica	USEPA Method 201A (Modified)	SafeWork NSW EPA in-house method WCA.220	16%	×	✓[b]
Benzyl chloride (Alpha-chlorotoluene)	Vic EPA 4230	Ektimo 344	19%	×	×†
Pentachlorophenol	USEPA Method 23A	NMI in-house method NGCMS 11.27	21%	×	✓¶
Total (gaseous & particulate) metals (Non-USEPA 29) (Th, U)	USEPA Method 29	NMI in-house methods NT2.47, NT2.44 & NT2.52	15%	×‡‡	✓¶
Total (gaseous & particulate) metals (As, Be, Cd, Ni)	USEPA Method 29	NMI in-house methods NT2.47, NT2.44 & NT2.52	15%	✓	✓¶

As shown in Table 1, Ektimo is NATA accredited for sampling all the Class 3 Indicator analytes selected for inclusion in the Class 3 Program except for Respirable Crystalline Silica and Radionuclides (Thorium and Uranium), neither of which are typically sampled from flue gas stacks in Australia, and Alpha chlorinated toluenes and benzoyl chloride. As both Respirable Crystalline Silica and Radionuclides analytes are primarily associated with particulate matter, Ektimo employed approved particulate matter sampling standards for collecting samples from flue gas at LYA.

Ektimo has noted in its reports that NATA accredited laboratories undertook the analysis of all samples for the relevant Class 3 Indicator analytes. However, due to the unusual requirement to test brown coal combustion flue gas emissions for the presence of one of the Class 3 Indicator analytes (Alpha chlorinated toluenes and benzoyl chloride), the NATA accreditation for the analytical methods (if available), does not specifically include those analytes.

A Dilution Ratio methodology, based on the maximum 3-minute average ground level concentration for Total Solid Particles (TSP) obtained from modelling of the Latrobe Valley Air Shed, prepared for the EPA Licence Review (GHD, 2018), was proposed for the purposes of comparing measured 'in-stack' concentrations with applicable ground level concentration (GLC) criteria.

The proposed Class 3 Program scope of work, which was submitted to the EPA on 1 July 2021, included sampling and testing of all applicable Class 3 Indicators from the emissions from a single representative Unit (Unit 4), supplemented by routine annual National Pollutant Inventory (NPI) monitoring which included Unit 3. The NPI monitoring program includes Class 3 Indicator metals (Arsenic, Beryllium, Cadmium and Nickel).

Sampling from a single Unit was proposed since all Units receive the sample coal supply and are essentially identical in both operation and controls. A second and more targeted campaign was proposed to occur if the assessment of 'in-stack' concentration results from the Unit 4 campaign, using the Dilution Ratio methodology, identified any Class 3 Indicators with concentrations greater than 10% of the relevant GLC criteria.

On 3 August 2021, the EPA confirmed in writing that the proposed scope of work for the Class 3 Program was appropriate for the purpose of complying with the new condition LI_DA4.4 but recommended that emissions testing for mercury (a Class 2 Indicator) also be included in the monitoring program. This recommendation was implemented in finalising the scope of work for the Class 3 Program.

The overall Class 3 Program implementation schedule is illustrated in Figure 1.

Figure 1: Emissions Monitoring Program – Class 3 Indicators Implementation Schedule

	2021							2022		
Activity	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Development of Class 3 Indicators Program										
EPA Review and Approval of Class 3 Indicators Program Scope										
1st Campaign (Screening) with NPI Suite and Compliance testing for Unit 4		Unit 4	Unit 4							
Coal sampling (during 1st Campaign)										
2nd Campaign (Targeted) [If required] with scheduled NPI Suite and Compliance testing for Unit 3						Unit 3	Unit 3			
Coal sampling (during Unit 3 / 2nd Campaign)										
Analysis of Results										
Publish on Website										

3 Class 3 Program Results Summary & Assessment

During stack testing for Class 3 Indicators, it is desirable for the Unit undergoing testing to be operating stably and near to nameplate generation capacity (subject to the direction of the Australian Energy Market Operator, AEMO), with corresponding coal consumption and the potential for maximum emission rates. 30-minute average generation data obtained from the Unit data historian confirmed that the Units undergoing testing for Class 3 Indicators was operating between 88 – 100% capacity, except for one afternoon, when capacity was reduced to 70%. In addition, analysis results from coal feedstock grab samples collected during the testing campaigns indicated typical coal quality, with the variability in coal quality during the testing campaigns remaining typical of normal operation at LYA.

Table 2 summarises the maximum in-stack concentrations measured for the Class 3 Program. Analytical results for non-metal Class 3 Indicators other than Dioxins & Furans, PAHs and Respirable Crystalline Silica (as cristobalite) are below detection levels, as expected, given that the high temperature residence time conditions within the boiler furnace will destroy organics that may be present in the coal or may form during the combustion process. The presence of detectable quantities of Class 3 metals and Respirable Crystalline Silica are dependent on coal composition, boiler performance and EDP performance.

Table 2: Analytical results from the Emissions Monitoring Program - Class 3 Indicators

Class 3 Indicators	Included in Monitoring Program?	Maximum In-Stack Concentration from Unit 4 (& Unit 3 for Class 3 Metals), for 2021/22 testing campaigns (mg/m^3, Dry, STP)	Comment
Acrolein	Yes	BDL (<0.008)	
Acrylonitrile	Yes	BDL (<0.2)	
Alpha chlorinated toluenes and benzoyl chloride	Yes	BDL (<0.2)	
Arsenic and compounds	Yes	0.00042 (U4) / 0.00092 (U3)	
Asbestos	No	Not Tested	Unlikely in coal fired combustion emissions.
Benzene	Yes	BDL (<0.2)	
Beryllium and compounds	Yes	BDL (<0.0004) (U4) / BDL (<0.0006) (U3)	
1,3-butadiene	Yes	BDL (<0.005)	
Cadmium and compounds	Yes	0.00037 (U4) / BDL (<0.0004) (U3)	
Chromium VI compounds	Yes	BDL (<0.0004)	
1,2-dichloroethane (ethylene dichloride)	Yes	BDL (<0.2)	
Dioxins and Furans (as TCDD I-TEQs)	Yes	Lower Bound (Note 2) 1.5E-09 Middle Bound 2.1E-09 Upper Bound 2.8E-09	
Epichlorohydrin	No	Not Tested	Unlikely in coal fired combustion emissions.
Ethylene Oxide	No	Not Tested	Unlikely in coal fired combustion emissions. Also, unlikely given reactivity, mainly associated with polymer manufacture.
Hydrogen cyanide	Yes	<0.02	
MDI (Diphenylmethane diisocyanate)	No	Not Tested	Unlikely in coal fired combustion emissions. Also, unlikely given reactivity, mainly associated with foam manufacture.
Nickel and compounds	Yes	0.0023 (U4) / 0.032 (U3)	

Class 3 Indicators	Included in Monitoring Program?	Maximum In-Stack Concentration from Unit 4 (& Unit 3 for Class 3 Metals), for 2021/22 testing campaigns (mg/m³, Dry, STP)	Comment
PAH (as BaP)	Yes	Lower Bound (Note 2) 1.9E-06 Middle Bound 9.9E-06 Upper Bound 1.8E-05	
Pentachlorophenol	Yes	<0.00009	
Phosgene	No	Not Tested	Unlikely in coal fired combustion emissions. Not expected to be present at temperatures >200°C and requires specialised equipment.
Propylene oxide	No	Not Tested	Unlikely in coal fired combustion emissions. Also, unlikely given reactivity, mainly associated with polymer manufacture.
Radionuclides	Yes	Thorium: BDL (<0.0004) (U4) / 0.00032 (U3) Uranium: BDL (<0.0003) (U4) / BDL (<0.0006) (U3)	
Respirable crystalline silica (inhaled in the form of quartz or cristobalite) (measured as PM2.5)	Yes	0.063 – alpha quartz and BDL (<0.03) - cristobalite	
TDI (toluene-2,4-diisobyanate and toluene-2,6-diisocyanate)	No	Not Tested	Unlikely in coal fired combustion emissions. Also, unlikely given reactivity, mainly associated with foam manufacture.
Trichloroethylene	Yes	BDL (<0.2)	
Vinyl chloride	Yes	BDL (<0.006)	

Notes:

1. BDL = Below Detection Limit
2. Dioxins & Furans and PAHs consist of groups of similar compounds which are expressed as a total based on a reference compound i.e. 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) in the case of Dioxins & Furans and Benzo(a)pyrene (BaP) in the case of PAHs. Since some of the individual compounds may not be detected, the following convention is used by Ektimo to report the analytical test results for these groups of compounds:
   Lower bound: those compounds whose concentrations are below their respective detection limits are set to zero.
   Middle bound: those compounds whose concentrations are below their respective detection limits are assumed to be present at half of the detection limit concentration.
   Upper bound: those compounds whose concentrations are below their respective detection limits are assumed to be present at the detection limit concentration.

Of the 26 Class 3 Indicators listed in Schedule A of SEPP AQM only seven (7) Class 3 Indicators were detected i.e. found to be present in the flue gas at levels above the analytical limit of detection.

3.1 Assessment of Class 3 Indicator Emissions Against Benchmark Ground Level Assessment Criteria

To assess whether the analytical results from the Class 3 Program are of concern to human health and the environment, it is necessary to compare the in-stack concentrations of Class 3 Indicators (if detected) with ground level concentrations (GLCs), to facilitate comparison with appropriate GLC standards. The former SEPP AQM Schedule A design GLC criteria for Class 3 Indicators has recently been replaced by EPA Publication 1961, which includes risk-based air pollution assessment criteria (referred to as APACs). The new risk-based air pollution assessment criteria provide a benchmark to understand potential risks and to assist in the assessment of whether an emitter is complying with the general environmental duty, which requires persons engaging in an activity that may give rise to risks of harm to human health or the environment from pollution or waste to minimise those risks, so far as reasonably practicable. As such, the APACs can be used to benchmark the performance of the boilers and air pollution controls i.e. the EDPs.

HRL compared the stack test results to the new ground level APACs listed in Table 3 of EPA Publication 1961 by using a calculated Dilution Ratio[3] based on the maximum 3-minute average ground level concentration for Total Solid Particles (TSP) obtained from modelling of the Latrobe Valley Air Shed, prepared for the EPA Licence Review (GHD, 2018). The calculated dilution ratio (1513:1) was determined from the results of atmospheric dispersion modelling using estimated Total Solid Particle (TSP) emissions from LYA, LYB and Yallourn power stations operating simultaneously at maximum emission rates and the predicted the maximum grid (ground level) 3-minute average result for TSP, under worst case ambient conditions. The Dilution Ratio for TSP was utilised for the assessment of Class 3 Indicator emissions as TSP and (Total) mercury emissions were the only two results presented as 3-minute average results (for comparison with both APACs and SEPP AQM benchmark ground level concentration assessment criteria), and TSP yielded the lowest and hence, the most conservative, dilution ratio. Furthermore, most Class 3 Indicator emissions that were above the limit of detection are typically associated with particulate matter.

Since the APACs have longer time averaging periods (i.e. typically 1-hour averages, or annual averages) rather than the 3-minute average design criteria in SEPP AQM Schedule A, the 1-hour APACs were converted to a 3-minute averaging time basis[4] prior to applying the Dilution Ratio. For those Class 3 Indicators with APAC time averaging periods greater than 1-hour, SEPP AQM Schedule A 3-minute average design criteria was conservatively used for the benchmarking assessment. Using criteria for the shorter time averaging period is more conservative than using a longer time averaging period, where the ground level concentration design criteria is lower than that for the longer averaging period.

It is also noted that actual measured in-stack concentrations are typically presented as mg/m^3 Dry STP (i.e. Gas volumes and concentrations are expressed on a dry basis at Standard Temperature and

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[3] The Dilution Ratio is the ratio of the concentration of a substance in the flue gas stack (in-stack concentration) compared to the maximum predicted ground level concentration of that substance, after dispersion in the atmosphere. The level of atmospheric dispersion and therefore dilution is affected by many factors such as: flue gas stack height, exit temperature and velocity, wind speed and other ambient atmospheric conditions, as well as topographical features of the surrounding landscape and nearby buildings.

[4] From EPA Publication 1961 page 56: Using the function $Ct = C_{60} \times (60/t)^{0.2}$,where 't' is an averaging time (in minutes) that is shorter than 60 minutes.

Pressure (STP), 0°C and an absolute pressure of 101.325 kPa), while for EPA Publication 1961 Table 3 APACs (and SEPP AQM design criteria) are expressed at 25°C, one atmosphere pressure and on a wet basis. To allow comparison between the actual measured in-stack concentrations and the estimated benchmark in-stack concentration assessment criteria, the stack measurements are converted from 'Dry STP' to 'Wet 25°C' using a correction factor of ~0.71[5].

Table 3 summarises the results of the benchmarking assessment of analytical results from the 2021-22 Class 3 Program against benchmark in-stack concentration assessment criteria. The green font colour is used to indicate that the actual measured value (or the limit of detection) is suitably below the estimated benchmark in-stack concentration assessment criteria. The analytical results for Class 3 metals, PAHs, Dioxins & Furans and Respirable Crystalline Silica were found to be 1 – 4 orders of magnitude below the benchmark in-stack concentration assessment criteria based on the calculated Dilution Ratio and after correction of in-stack concentrations to APAC reference conditions. This means that ground level concentrations would be well below the EPA Publication 1961 APACs (or SEPP AQM Schedule A design criteria, where EPA Publication 1961 does not specify applicable APACs). As such, further targeted follow-up testing of Class 3 Indicators other than Class 3 metals, planned to be undertaken during the Unit 3 stack testing campaign in November/December 2021, was not warranted.

Table 3: Summary of benchmarking emission assessment results from the Class 3 Program

Class 3 Indicators	EPA Publication 1961 APACs or SEPP AQM Design Criteria Toxicity, both using (3-minute time averaging) (mg/m³) (Note 2)	Est. Benchmark In-Stack Concentration Assessment Criteria using a calculated Dilution Ratio (3-minute average basis) (Note 3)	Maximum of Actual Measured In-Stack Concentration from Unit 4 / Unit 3 2021 testing campaigns, after correction (Note 4) (mg/m³)	Comment
Acrolein	0.020	**30**	BDL (<0.006)	
Acrylonitrile	0.014*	21	BDL (<0.14)	Unlikely in coal fired combustion emissions
Alpha chlorinated toluenes and benzoyl chloride	0.017*	**26**	BDL (<0.14)	
Arsenic and compounds	0.018	27	0.000419 / 0.000923	29,000 - 65,000 times lower than the benchmark assessment criteria
Asbestos				Unlikely in coal fired combustion emissions
Benzene	1.056	1,598	BDL (<0.14)	
Beryllium and compounds	0.000007*	0.011	BDL (<0.0003) / BDL (<0.0004)	
1,3-butadiene	1.202	1,818	BDL (<0.0035)	Unlikely in coal fired combustion emissions
Cadmium and compounds	0.033	50	0.000263 / BDL (<0.0004)	189,000 times lower than the benchmark assessment criteria
Chromium VI compounds	0.0024	3.58	BDL (<0.0003)	
1,2-dichloroethane (ethylene dichloride)	4.005	6,061	BDL (<0.14)	
Dioxins and Furans (as TCDD I-TEQs)	3.7E-09*	5.6E-06	Lower Bound (Note 5) 1.1E-09 Middle Bound 1.5E-09 Upper Bound 2.0E-09	2,800 times lower than the benchmark assessment criteria

[5] Based on a calculated annual average actual stack moisture content of 22.5% in flue gas and a temperature correction from 0°C to 25°C.

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Class 3 Indicators	EPA Publication 1961 APACs or SEPP AQM Design Criteria Toxicity, both using (3-minute time averaging) (mg/m³) (Note 2)	Est. Benchmark In-Stack Concentration Assessment Criteria using a calculated Dilution Ratio (3-minute average basis) (Note 3)	Maximum of Actual Measured In-Stack Concentration from Unit 4 / Unit 3 2021 testing campaigns, after correction (Note 4) (mg/m³)	Comment
Epichlorohydrin	2.367	3,582	Not Tested	Unlikely in coal fired combustion emissions
Ethylene Oxide	0.006*	9.1	Not Tested	Unlikely in coal fired combustion emissions.
Hydrogen cyanide	0.619	937	BDL (<0.014)	Unlikely in coal fired combustion emissions
MDI (Diphenylmethane diisocyanate)	0.00007*	0.11	Not Tested	Unlikely in coal fired combustion emissions.
Nickel and compounds	0.00036	0.55	0.00163 / 0.023	24 – 337 times lower than the benchmark assessment criteria
PAH (as BaP)	0.00073*	1.10	Lower Bound (Note 5) 1.3E-06 Middle Bound 7.0E-06 Upper Bound 1.3E-05	86,000 times lower than the benchmark assessment criteria
Pentachlorophenol	0.0017*	2.57	BDL (<0.000064)	
Phosgene	0.00728	11	Not Tested	Unlikely in coal fired combustion emissions.
Propylene oxide	5.64	8,541	Not Tested	Unlikely in coal fired combustion emissions.
Radionuclides	As Low As Reasonably Achievable*	-	BDL (i.e. Th <0.00028, U <0.00021) / Th 0.00023, U BDL (i.e. U <0.00043)	Uranium (U) and Thorium (Th), were sampled along with other metals in the USEPA Method 29 sampling train for analysis.
Respirable crystalline silica (inhaled in the form of quartz or cristobalite) (measured as PM2.5)	0.00033*	0.50	0.044 – alpha quartz BDL <0.02 - cristobalite	11 times lower than (or 9% of) the benchmark assessment criteria
TDI (toluene-2,4-diisobyanate and toluene-2,6-diisocyanate)	0.00364	5.51	Not Tested	Unlikely in coal fired combustion emissions.
Trichloroethylene	0.9*	1,362	BDL (<0.14)	
Vinyl chloride	124	187,340	BDL (<0.004)	

* Retains SEPP AQM design GLC criteria, since EPA Publication 1961 APAC averaging period is greater than 1 hour.

<u>Notes:</u>

1. BDL = Below Detection Limit
2. Gas volumes are expressed at 25°C and at an absolute pressure of one atmosphere (101.325 kPa).
3. Based on a dilution ratio of 1513:1, which has been calculated from the maximum grid (ground level) result for the 3-minute average Total Solid Particle (TSP) emissions, obtained from modelling of the Latrobe Valley Air Shed prepared for the EPA Licence Review (GHD, 2018).
4. Gas volumes converted from dry Standard Temperature and Pressure (STP) reference conditions to wet, 25°C and at an absolute pressure of one atmosphere (101.325 kPa), for comparison with the APACs and SEPP AQM design GLCs and the estimated benchmark in-stack concentration assessment criteria. The calculated correction factor of ~0.71 is based on an annual estimated moisture content of 22.5% (at stack oxygen content) and a temperature correction from 0°C to 25°C.
5. Dioxins & Furans and PAHs consist of groups of similar compounds which are expressed as a total based on a reference compound i.e. 2,3,7,8-TCDD in the case of Dioxins & Furans and BaP in the case of PAHs. The following convention is used for reporting analytical test results for these groups of compounds:
   Lower bound: those compounds whose concentrations are below their respective detection limits are set to zero.
   Middle bound: those compounds whose concentrations are below their respective detection limits are assumed to be present at half of the detection limit concentration.
   Upper bound: those compounds whose concentrations are below their respective detection limits are assumed to be present at the detection limit concentration.

3.2 Assessment of Mercury Emissions

While Mercury is listed as a Class 2 Indicator under SEPP (AQM) and Schedule 4 of the EP Regulations (2021), the EPA requested that Mercury emissions testing be included in the Class 3 Program objectives. The monitoring of Mercury and Mercury compounds is already included in the regular NPI monitoring and testing program for AGL LY. The in-stack concentration results from the Class 3 stack testing campaigns for Units 3 and 4 are presented in Table 4.

Taking a similar approach to benchmarking in-stack concentrations as was undertaken for Class 3 Indicators, the results of the 2021/22 emissions monitoring campaign are presented in Table 4. The 2021 stack test results are several orders of magnitude below the estimated benchmark in-stack concentration assessment criteria based on a calculated Dilution Ratio (see Table 4 Note 2) and SEPP AQM 3-minute averaging time design criteria for ground level concentrations[6]. This means that actual ground level concentrations will be well below the SEPP AQM Schedule A design criteria for (Total) Mercury. However, it is noted that Mercury emissions are directly related to the Mercury content of coal and the nature of the Mercury (organic or inorganic), since Mercury is more volatile than the Class 3 Indicator metals, and therefore more likely to be present in vapour/gaseous form at stack temperatures (also see Section 3.3).

Table 4: Summary of analytical results and benchmarking assessment for Mercury emissions

Class 3 Indicators	SEPP (AQM) Design Criteria Toxicity (mg/m^3) (Note 1)	Est. Benchmark In-Stack Concentration Assessment Criteria using a calculated Dilution Ratio (3-minute average basis) (Note 2)	Actual Measured In-Stack Concentration from Unit 3 & 4 2021/22 testing campaigns, after applying a correction factor of ~0.71 (Note 3) (mg/m^3)		Comment
			U3	U4	
Mercury - Organic	0.00033	0.53	Not separately identified		
Mercury - Inorganic	0.0033	5.34	Not separately identified		
Mercury – Total	0.00363	5.88	Max. 0.0049 Ave. 0.0045 Min. 0.0039	Max. 0.0034 Ave. 0.0028 Min. 0.0021	Maximum in-stack measurements are 1,729 (U4) & 1,200 (U3) times lower than the benchmark assessment criteria.

Notes:

1. Gas volumes are expressed at 25ºC and at an absolute pressure of one atmosphere (101.325 kPa).
2. Based on a dilution ratio of 1619:1, which has been calculated from the maximum grid (ground level) result for the 3-minute average (total) Mercury emissions, obtained from modelling of the Latrobe Valley Air Shed prepared for the EPA Licence Review (GHD, 2018).
3. Gas volumes converted from dry Standard Temperature and Pressure (STP) reference conditions to wet, 25ºC and at an absolute pressure of one atmosphere (101.325 kPa), for comparison with the SEPP (AQM) DGLCs and the estimated benchmark in-stack concentration assessment criteria. The calculated correction factor of ~0.71 is based on an annual estimated moisture content of 22.5% (at stack oxygen content) and a temperature correction from 0ºC to 25ºC.

[6] SEPP (AQM) Schedule A design criteria for (Total) Mercury is used rather than EPA Publication 1961 APAC for Mercury, which uses a 1-year averaging time, rather than a 1-hour or 3-minute averaging time required for application of the Dilution Ratio for comparing in-stack concentration with benchmark ground level concentration assessment criteria.

3.3 Assessment of Coal Quality on Class 3 Metal and Mercury Emissions

Table 5 summarises the heavy metals of interest (i.e. Class 3 metals and Mercury (Class 2)) from the analysis of coal grab samples collected during the stack testing campaigns. The coal analysis results show that Beryllium and Cadmium are typically only present at low levels or below the analytical detection limit. In this table, HRL has estimated the concentration of each analyte in the flue gas upstream of the EDPs using a known relationship between coal calorific value and volumetric flue gas emissions from the combustion of coal at LYA. These estimated concentrations are then compared to the actual analytical results from the emissions testing, to provide an indication of the portion of metals in the coal that report to the flue gas stack, and the portion which remains in the fly ash captured by the EDPs.

Metals classified as Class 3 Indicators (As, Be, Cd & Ni) exhibit a medium level of volatility and as expected, the Class 3 Indicators largely remain in the fly ash captured by the EDPs or in the boiler bottom ash. Of those measurements which were not below the measurement detection limit, the calculations and test results indicate estimated removal rates of 97.2 – 99.97% in recovered EDP fly ash or boiler bottom ash, thus demonstrating the capability of the EDPs to reduce the emission of the Class 3 Indicators so far as reasonably practicable. Consequently, the calculations and test results demonstrate that the Class 3 Indicator metals are well below the estimated benchmark in-stack concentration assessment criteria (as summarised in Table 3).

Table 5: Estimated removal of Class 3 Indicator metals & Mercury present in coal

Analyte in Coal	Coal Analyte Concentration Results (mg/kg)	Estimated Analyte Concentration in Flue Gas before EDP (mg/m³, STP, Dry, Stack O_2)	Ektimo Average Measured Emission Concentration in Flue Gas from a Single Flue (mg/m³, STP, Dry, Stack O_2)	Portion of Analyte to Flue Gas Emissions (Note 1) (%)	Portion of Analyte to Fly Ash & Bottom Ash (%)
			U4 Flue 1		
As	9.14	0.978	0.00053	0.05%	99.95%
Be*	0.1	0.011	0.0002	1.87%	98.13%
Cd*	0.05	0.005	0.00015	2.80%	97.20%
Ni	1.94	0.208	0.0019	0.92%	99.08%
Hg	0.15	0.016	0.0032	19.68%	80.32%
			U4 Flue 2		
As*	9.68	1.103	0.0003	0.03%	99.97%
Be*	0.1	0.011	0.0002	1.75%	98.25%
Cd*	0.05	0.006	0.00036	6.32%	93.68%
Ni	1.0	0.114	0.0021	1.84%	98.16%
Hg	0.13	0.015	0.0048	31.75%	68.25%
			U3 Flue 1		
As*	0.5	0.060	0.000245	0.41%	99.59%
Be*	0.05	0.006	0.00015	2.48%	97.52%
Cd*	0.05	0.006	0.00015	2.48%	97.52%
Ni	2	0.226	0.0016	0.71%	99.29%
Hg	0.10	0.012	0.0068	57.01%	42.99%

Analyte in Coal	Coal Analyte Concentration Results (mg/kg)	Estimated Analyte Concentration in Flue Gas before EDP (mg/m^3, STP, Dry, Stack O_2)	Ektimo Average Measured Emission Concentration in Flue Gas from a Single Flue (mg/m^3, STP, Dry, Stack O_2)	Portion of Analyte to Flue Gas Emissions (Note 1) (%)	Portion of Analyte to Fly Ash & Bottom Ash (%)
			U3 Flue 2		
As	0.4	0.046	0.0013	2.81%	97.19%
Be*	0.05	0.006	0.0003	5.19%	94.81%
Cd*	0.05	0.006	0.0002	3.46%	96.54%
Ni	1.3	0.150	0.0032	2.14%	97.86%
Hg	0.08	0.010	0.0058	59.96%	40.04%

* Values below the limit of detection for either the analyte concentration in coal or the analyte concentration in the flue gas are assumed to be half of the limit of detection.

Notes:

1. Assumes equal emission rates from flues 1 & 2.

Due to its higher volatility, Mercury is expected to be more prevalent in the gaseous phase, rather than in the fly ash, as shown in Table 5. Despite the higher portion of Mercury reporting to the gaseous phase, the sampling and testing results (see Table 4) still demonstrate that Total Mercury emissions from LYA are very low and well below benchmark assessment criteria.

4 References

Environment Protection Regulations 2021 (Vic) (EP Regulations)

EPA Publication 440.1 *Guide to Air Quality Sampling and Analysis*

EPA Publication 1322.9 *Licence Management*

EPA Publication 1961 *Guideline for Assessing and Minimising Air Pollution in Victoria*

EPA Licence No. 11149 AGL Loy Yang Pty Ltd

GHD (2018) AGL Loy Yang, Loy Yang B and Energy Australia Yallourn, Latrobe Valley Coal Fired Power Stations Licence Review Community Summary Report, 3136071

The following Ektimo stack testing reports were referenced when preparing this report:

Ektimo Report No.	Report Title	Comment
R009707	2021-22 Financial Year Boiler Unit 4 – EPA Compliance + NPI Monitoring, AGL Loy Yang, Traralgon South	Includes Class 3 Indicator metals and mercury for Unit 4 Flues 1 & 2
R011370	2021 - Class 3 Indicator Programme Boiler Unit 4 - Flue 1 AGL Loy Yang, Traralgon South	Includes Class 3 Indicators for Unit 4 – Flue 1
R011865	AGL Loy Yang, Traralgon South, 2021-22 Financial Year, Boiler Unit 3 – EPA Compliance + NPI Monitoring	Includes Class 3 Indicator metals and mercury for Unit 3 Flues 1 & 2