Appendix E

Ash management study

VEOLIA ENVIRONMENTAL SERVICES (AUSTRALIA) PTY LTD

ASH MANAGEMENT STUDY

WOODLAWN ADVANCED ENERGY RECOVERY CENTRE

OCTOBER 2022

PUBLIC

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Ash Management Study
Woodlawn Advanced Energy Recovery Centre

Veolia Environmental Services (Australia) Pty Ltd

WSP
Level 12, 900 Ann Street
Fortitude Valley QLD 4006
GPO Box 2907
Brisbane QLD 4001

Tel: +61 7 3854 6200
Fax: +61 7 3854 6500
wsp.com

	NAME	DATE	SIGNATURE
Prepared by:	Daniel Burton	04/10/2022	
Reviewed by:	David Harris	04/10/2022	
Approved by:	Helen Jones	04/10/2022	

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ABBREVIATIONS

ABS	Australian Bureau of Statistics
ADC	Alternative Daily Cover
APCr	Air Pollution Control residues
ARC	Advanced Energy Recovery Centre
AS	Australian Standard
BAT	Best Available Techniques
C&D	Construction & Demolition Waste
C&I	Commercial & Industrial Waste
COAG	Council of Australian Governments
CT	Contaminant Threshold
DPE	Department of Planning and Environment (NSW)
EfW	Energy from Waste
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
FA	Fly or boiler Ash
FGT	Flue Gas Treatment
GIA	General Immobilisation Approval
GSW	General Solid Waste
HW	Hazardous Waste
IBA	Incinerator Bottom Ash
IED	Industrial Emissions Directive
LGA	Local Government Area
MEP	Multiple Extraction Procedure
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
MUD	Multi-Unit Development
MWRRG	Metropolitan Waste and Resource Recovery Group
POEO	Protection of the Environment Operations
PIW	Prescribed Industrial Waste
POPs	Persistent Organic Pollutants
RSW	Restricted Solid Waste
SCC	Specific Contaminant Concentration

SEARs	Secretary's Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
SIA	Specific Immobilisation Approval
TCLP	Toxicity Characteristic Leaching Procedure
tpa	Tonnage Per Annum
UCL	Upper Confidence Limit
WtE	Waste to Energy

EXECUTIVE SUMMARY

Veolia Environmental Services (Australia) Pty Ltd (Veolia) is seeking to develop an Advanced Energy Recovery Centre (ARC) at its Woodlawn Eco-Precinct in New South Wales (NSW). The proposed ARC will generate residual ash by-products from the waste combustion and flue gas treatment processes that requires management, treatment and/or repurposing. To address these ash management issues and inform the reference design of the proposed waste management infrastructure at the site, WSP Australia Pty Ltd (WSP) were engaged to prepare this ash management study for inclusion in the Environmental Impact Statement (EIS) for the project.

This report aims to provide a likely compositional scenario and appreciation of the ARC by-product waste streams, likely to be generated via the energy from waste (EfW) process. Consideration has been given to the management requirements (i.e. disposal options) of these waste streams and where applicable, potential mechanisms for waste treatment and/or recovery / beneficial reuse opportunities within a NSW legislative context.

The analysis and assumptions derived in this report are based on both privately supplied and publicly available information and WSP's in-house project experience gained through similar studies. It is noted that given the current lack of operating EfW plants in Australia, data from overseas reference plants has been utilised.

The scope of works addressed in this report is summarised as follows:

- Comparison of the ARC feedstock to the provided reference data and a commentary on likely output waste;
- Assessment of incinerator bottom ash (IBA) and air pollution control residue (APCr) reference data contaminant concentrations against the NSW Environment Protection Authority (EPA) Waste Classification Guidelines (2014a and 2014b);
- Discussion of potential immobilisation process requirements to allow APCr to be disposed of within the proposed encapsulation cell;
- Description of the different stabilisation, treatment and disposal options for the output waste streams and recommendations for a preferred stabilisation methodology for inclusion in the EIS; and
- Summary of key findings based on data, assumptions, parameters, and key design and management considerations for each waste residue stream.

Based on the compiled and reviewed reference data and the discussion presented within this report, the following key conclusions have been drawn from this study:

- The IBA generated in the Woodlawn ARC would likely be classified as General Solid Waste (GSW) and hence would be suitable for disposal in the existing Woodlawn Bio-Reactor Landfill;
- The APCr would likely be initially classified as Hazardous Waste (HW) and hence would require treatment to immobilise leachable contaminants, subject to a specific immobilisation approval (SIA) from NSW EPA;
- Following treatment via immobilisation, the APCr would then be classified as Restricted Solid Waste (RSW) and hence would be suitable for disposal into the proposed encapsulation cell;
- The most suitable treatment option for the APCr for the purposes of this study and associated reference design considerations is Portland cement stabilisation, however alternative treatment options such as phosphate stabilisation would be further considered as the project develops;
- Although all waste output by-products from the Woodlawn ARC would be disposed to landfill initially, there are various potential beneficial re-use options for IBA which should be considered as soon as the plant is commissioned. Despite a lack of guidance in NSW currently, there is a well-established history of IBA reuse overseas and it is expected that there will be increasing market demand in future for this product; and

— Potential reuse strategies for both IBA and APCr should be reviewed periodically (e.g. at least every 5 years) as the EfW and associated recycling industries in Australia develop.

Based on the above findings, the key design and management considerations for the development of the proposed maturation pad and encapsulation cell are presented in Table ES.1 below. As noted throughout this report, many of the assumptions made will be subject to NSW EPA approval and the specific properties of the waste materials generated.

Table ES.1 Key design and management considerations

PARAMETER	IBA	APCR
Waste classification	General solid waste	Hazardous waste (restricted solid waste following stabilisation)
Required disposal facility	Licensed GSW landfill (existing Bioreactor Landfill)	Licensed RSW encapsulation cell (doubled lined)
Annual mass produced	76,000 tpa	15,200 tpa
Density of final waste product	1.4 (1.2-1.7) t/m^3	0.7-1.5 t/m^3 including post-treatment bulking (0.4 t/m^3 pre-treatment)
Specific infrastructure required	Storage pad (to accommodate up to 3 months production capacity) with leachate collection and management	Treatment batching plant (sufficient capacity for 5 days waste production) and mixing unit, with appropriate reagent storage
Transport / handling requirements	Dust suppression and sediment controls associated with general waste management	Dust suppression and sediment controls associated with general waste management
Potential beneficial re-use options	— Landfill daily cover material — Road sub-base material — Construction material production (e.g. bricks, pavers, concrete, ceramics, etc.)	— Cement clinker production — Light weight aggregates / concrete — Zeolite production

1 INTRODUCTION

1.1 BACKGROUND

Veolia Environmental Services (Australia) Pty Ltd (Veolia) is seeking to develop an Advanced Energy Recovery Centre (ARC) at its Woodlawn Eco-Precinct in New South Wales (NSW). The project is classified as a State Significant Development (SSD). The proposed ARC will generate residual biproduct from the waste combustion and flue gas treatment processes that requires management, treatment and/or repurposing. The waste residue by-products include:

- Incinerator bottom ash (IBA); and
- Mixed boiler ash and air pollution control residues (APCr).

Golder Associates Pty Ltd (A Member of WSP) (Golder) and WSP Australia Pty Ltd (WSP) were engaged to prepare supporting documentation for inclusion in the Environmental Impact Statement (EIS) to be prepared by EMM Consulting Pty Ltd (EMM). The EIS will then be submitted to the NSW Department of Planning and Environment (DPE) for review and approval. Specifically, the following documents were required:

- Preliminary Site Investigation (PSI) (Golder)
- Ash management study – this document (WSP)
- IBA storage and maturation pad reference design (Golder)
- APCr encapsulation cell reference design (Golder)

1.2 PURPOSE

This report aims to provide a likely compositional scenario and appreciation of the ARC by-product waste streams, likely to be generated via the energy from waste (EfW) process. Consideration will be given to the management requirements (i.e. disposal options) of these waste streams and where applicable, identify potential mechanisms for waste treatment and/or recovery / beneficial reuse opportunities within a NSW legislative context.

This ash management study report has therefore been prepared to inform the reference designs for both the IBA storage / maturation pad (the storage pad) and APCr encapsulation cell (the encapsulation cell), as well as to meet the general requirements and address the key issues outlined in the Planning Secretary's Environmental Assessment Requirements (SEARs).

1.3 SCOPE OF STUDY

The analysis and assumptions derived in this report are based on both privately supplied and publicly available information and WSP's in-house project experience gained through similar studies. It is noted that given the current lack of applicable EfW plants in Australia, the data for similar studies WSP have undertaken has typically been derived from overseas reference plants.

This approach has been adopted for this study with base data used in the preparation of this report referenced throughout as appropriate. A full reference list is included in Section 5.

The specific scope of works addressed in this report are summarised as follows:

- Compare the ARC feedstock to the provided reference data and provide commentary on likely output waste;
- Complete an assessment of waste product reference data contaminant concentrations against the NSW EPA Waste Classification Guidelines (2014a and 2014b);

- Specify potential immobilisation process requirements to allow APCr to be disposed of within the proposed encapsulation cell;
- Define parameters for the assessment of different stabilisation, treatment and disposal options for the output waste streams and provide recommendations for each, including a preferred stabilisation methodology for inclusion in the EIS; and
- Provide a summary of key findings based on data, assumptions, parameters, and key design and management considerations for each waste residue stream.

This scope of works is considered sufficient to meet the requirements of the SEARs, in particular the specific items listed under the "Waste Management" section. These items are summarised in Table 1.1 below.

Table 1.1 Summary of relevant SEARs – Waste Management (solid waste)

SEAR – KEY ISSUE	REPORT SECTION
Solid waste generated: quantities, composition and classification	Section 4
Solid waste storage, treatment and disposal	Section 5
Re-use suitability and potential options	Section 6
Immobilisation process for APCr	Section 5.2
Encapsulation cell design	Encapsulation Cell Design Report
Waste stockpile design and location	IBA Pad Design Report

2 TECHNICAL FRAMEWORK AND LEGISLATIVE OVERVIEW

Energy from Waste (EfW) is very well established overseas, however in Australia the first EfW projects have only just been approved in recent years and of these projects two facilities are currently under construction (East Rockingham and Kwinana, both in Western Australia (WA)). In the past a lack of legislative drivers along with other considerations such as: adequate landfill capacity, poor financial incentives, unfavourable public perceptions and lack of government policy support, have combined to prevent any meaningful EfW projects from gaining traction.

This position is now changing with many Australian States and Territories having EfW position statements and strategy-drivers that promote the technology, some of which are summarised below.

2.1 POLICY DOCUMENTS

The following policy documents are applicable to EfW projects:

- 2018 National Waste Policy: less waste, more resources (Commonwealth of Australia, 2018)
- NSW Energy from Waste Policy Statement (EPA, 2021)
- NSW Waste and Sustainable Materials Strategy 2041 – Stage 1: 2021-2027 (Department of Planning, Industry and Environment (DPIE), 2021)

These documents are summarised below or else referenced as applicable throughout this report.

2.1.1 2018 NATIONAL WASTE POLICY

Underpinning waste policy at all levels of government is the Waste Hierarchy, which identifies a set of priorities for the efficient use of resources. In recent years, all levels of government have identified the urgent requirement to improve their performance in relation to waste management with the current **circular economy approach** getting increasing traction across Australia.

This framework is reflected in the objectives of each state's Environmental Protection Act.

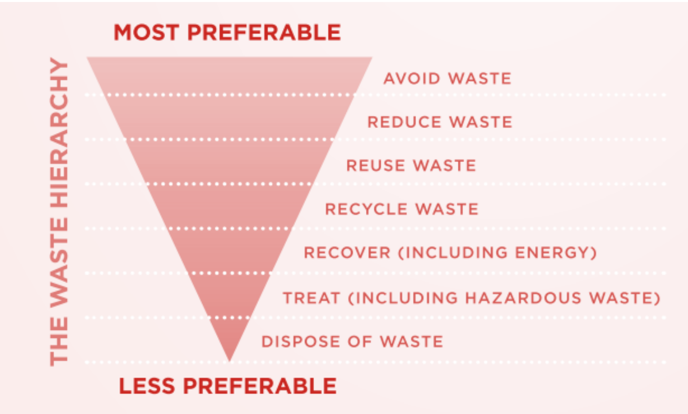

Figure 1: Waste Hierarchy - National Waste Policy (2018)

The Waste Hierarchy clearly identifies that **recovery** including via **Waste to Energy** is a preferred and higher-level performer than traditional waste disposal to landfill.

2.1.2 NSW ENERGY FROM WASTE POLICY STATEMENT 2021

The NSW EPA outlined in its *Energy from Waste Policy Statement 2021* that it encourages the recovery of energy from waste if this can deliver positive outcomes for the community and the environment. However, it specifies that energy recovery from waste proposals must represent the most efficient use of the resource and demonstrate they are ensuring air quality and human health are being protected.

Assessment of potential EfW proposals put forward to the NSW Government must comply with the *Protection of the Environment Operations Act 1997* and must also feature collaborative consultation with key stakeholders as well as addressing the potential impacts of all stages of development.

Whilst the NSW government encourages proposals regarding potential waste to energy facilities, the *Waste Avoidance and Resource Recovery Act 2001* aims to ensure that avoidance of unnecessary resource consumption is the first preference with resource recovery the second preference. The NSW Government has committed to work with industry to anticipate the array of new technologies likely to enter the market and will provide regulatory certainty by continually updating guidance notes that set out regulatory requirements for new EfW technologies.

2.1.3 NSW WASTE AND SUSTAINABLE MATERIALS STRATEGY 2041

In this strategy document the NSW Department of Planning, Industry and Environment (DPIE) state that recovering energy from waste can be a legitimate and necessary residual waste management option where it can deliver positive outcomes for the community and the environment and assist in lowering carbon footprint and reducing the need for landfill.

Energy recovery can also reduce emissions by replacing more carbon-intensive fuels and by stopping harmful methane emissions from materials in landfill. However, it is noted that general waste reduction, recycling and beneficial re-use are priorities over EfW recovery.

> *"We want to support energy recovery where it makes sense to do so and where it is used to manage residual waste, not as an alternative to recycling." (DPIE)*

2.2 LEGISLATION AND GUIDANCE DOCUMENTS

The following legislative and guidance documents are applicable to EfW projects and the generation and management of EfW derived waste products:

- NSW Protection of the Environment Operations (POEO) Act 1997
- NSW Protection of the Environment Operations (POEO) (Waste) Regulation 2014
- Waste Classification Guidelines – Part 1: Classifying waste (NSW EPA, 2014a)
- Waste Classification Guidelines – Part 2: Immobilisation of waste (NSW EPA, 2014b)
- Environmental Guidelines – Solid waste landfills (NSW EPA, 2016a)
- Eligible Waste Fuels Guidelines (NSW EPA, 2016b)
- Waste Levy Guidelines (NSW EPA, 2018)

These documents are summarised below or else referenced as applicable throughout this report.

2.2.1 WASTE CLASSIFICATION GUIDELINES – PARTS 1 & 2

The Waste Classification Guidelines Part 1: Classifying waste and Part 2: Immobilisation of waste (NSW EPA, 2014a and 2014b) are the relevant guidance documents for the classification of waste in order to determine the appropriate management and/or disposal options for that waste in NSW.

Part 1 outlines the methodology to be followed in order to classify waste under one of the following categories:

- Special waste;
- Liquid waste;
- Hazardous waste (HW);

- Restricted solid waste (RSW);
- General solid waste (GSW) (putrescible); and
- General solid waste (GSW) (non-putrescible).

Part 2 outlines the process to obtain EPA approval for the treatment of hazardous waste via immobilisation of contaminants, in order to allow for legal disposal of the waste to landfill. Material classified as hazardous waste cannot otherwise be disposed of to landfill in NSW.

2.2.2 ENVIRONMENTAL GUIDELINES – SOLID WASTE LANDFILLS

The *Environmental Guidelines – Solid Waste Landfills 2016* were introduced by the NSW EPA to provide guidance for environmental management of landfills in NSW by providing a series of minimum standards. These standards cover the requirements for leachate barriers, storage & disposal; stormwater management and water quality monitoring, odour, dust, noise and other amenity controls; waste acceptance and management; daily waste cover and final capping.

A landfill must be suitably designed for both the conditions associated with its setting/location, as well as the type of wastes it is intended to contain, in order to minimise impacts to the environment, human health and general amenity.

2.2.3 ELIGIBLE WASTE FUELS GUIDELINES

The Eligible Waste Fuels Guidelines were developed in conjunction with the NSW Energy from Waste Policy Statement (NSW EPA, 2021) to outline the criteria and regulatory framework applicable to potential EfW fuel sources. A number of "eligible waste fuels" are specified, along with guidance on characterisation of waste material and the process for applying to EPA for a resource recovery order or exemption in order to use the waste as a fuel source.

2.2.4 WASTE LEVY GUIDELINES

The Waste Levy Guidelines (NSW EPA, 2018) contain specific legal requirements which occupiers of scheduled waste facilities must meet in addition to their obligations under the POEO Act and the Waste Regulation. The Guidelines include how waste is measured to calculate levy liability, when certain levy deductions can be claimed, and how records, surveys and reports are required to be made, kept and provided to the EPA in order for the occupier to fulfil their obligations under the Waste Regulation.

2.3 OTHER PLANNING DOCUMENTS

The EfW plant will require a works approval application to comply with all relevant legislation, regulations and planning strategies/instruments/plans. These documents establish a framework to ensure that waste treatment infrastructure is appropriately located, designed, constructed, operated and managed to minimise risks to the environment and public health.

The following State Environmental Planning Policies (SEPPs) and protocols for environmental management were detailed in the SEARs provided by EMM for the proposed Woodlawn ARC:

- SEPP (Infrastructure) 2007
- SEPP (State and Regional Development) 2011
- SEPP (Sydney Drinking Water Catchment) 2011
- SEPP No. 33 – Hazardous and Offensive Development
- SEPP No. 55 – Remediation of Land
- Draft Remediation of Land SEPP
- Goulburn Mulwaree Local Environmental Plan 2009

2.4 FUTURE TRENDS / LEGISLATION CONSIDERATIONS

The Australian energy landscape is increasingly shifting towards the renewables sector and this is being driven from all levels of government. As part of this shift EfW is increasingly being seen as a viable option with multiple projects under way across the country and several more in the planning and approvals stages.

EfW technology has the potential to contribute to renewable energy targets, divert waste away from landfill, and reduce carbon emissions but it does not entirely eliminate waste. The positive advantages of moving to a circular economy society also present a cost risk to EfW plants as the by-product waste streams can form a reasonable percentage of the input waste and in some instances can contain concentrated levels of contamination. By-product ash therefore requires careful consideration in order that residual waste management costs do not jeopardize the beneficial EfW process.

However, there is a strong precedent for the safe management of EfW by-products overseas, and in fact the potential for beneficial re-use of IBA is also well established. So while there are currently no specific guidelines in Australia for management of EfW by-products to ensure that contaminants potentially present in waste streams (whether they are historically known or emerging contaminants) are identified and procedures are implemented to ensure they are appropriately managed, it is likely that steps will be taken to develop such a framework in the near future. In fact it is understood that regulators in WA and Victoria are currently working on this and a processing facility to recycle IBA is currently under construction in WA.

As such proactive beneficial re-use of by-products should be considered at the planning phase of any new EfW project, given the numerous successful examples of this overseas and the likely positive market for such products in Australia.

3 REFERENCE DATA SUMMARY

3.1 ADOPTED REFERENCE PLANTS

As noted earlier, no EfW projects have been commissioned to date in Australia and hence no ash chemical composition data from the combustion of Australian wastes is currently available. Data from the following international reference plants was therefore used to support the discussion presented within this report:

- United Kingdom (UK):
  - Veolia Staffordshire
  - Veolia Leeds
  - Veolia Battlefield (Shropshire)
  - Viridor Exeter
  - Viridor Peterborough
- Canada:
  - Metro Vancouver
- France:
  - Veolia Monthyon
  - Veolia Ivry Sur Seine
  - Veolia Saint Ouen
  - Veolia Sovalem
  - Veolia Isseane

Veolia has provided data from their international facilities in relation to the solid and leachable chemical composition of the different waste ash by-products produced from the EfW process. The following should be noted with regards to the reference data used:

- UK plants typically combine boiler ash with IBA for management/disposal purposes, with APCr managed separately;
- French and Canadian plants combine boiler ash with APCr for treatment/disposal (this is also proposed for the Woodlawn ARC plant), while IBA is a separate waste stream; and
- The European testing standard for leachability used in waste classification (EN 12457-2:2004) is significantly different from the standard used in other jurisdictions including Canada, Australia and the United States of America (USA) and so leachability data from the UK and French reference datasets cannot be directly assessed against relevant waste characterisation guidelines in Australia.

This means that the solid contaminant IBA data for the UK plants is a conservative measure of chemical concentrations likely to be produced in IBA at the Woodlawn ARC, i.e. concentrations would typically be lower. Hence the UK data should be considered a worst-case scenario for the IBA management required at Woodlawn ARC.

Likewise, the contaminant data for IBA from the French plants is representative of the likely concentrations to be produced at the Woodlawn ARC, however it is noted that a smaller sample set was provided for this data. As such the UK data has been included to supplement the French dataset, despite the differences in processing and handling of the waste by-products. Similar solid contaminant data for the Canadian plant, Metro Vancouver, along with leachability data for key contaminants of concern, was sourced from publicly available documents published on the plant website, which are reported as per local regulatory requirements.

As stated above, the UK and French leachability data cannot be directly compared to Australian (and specifically for this project NSW) guidelines, however it can be used to indicate the primary leachable contaminants in EfW by-products and the effectiveness of various treatment options to limit leachability. The method for leachate analysis adopted in Vancouver is however consistent with the requirements of the NSW EPA, i.e. it follows the United States EPA (USEPA) procedure. It is noted that the leachability data provided for the mixed boiler ash/APCr material is from post-treatment analysis, i.e. following chemical treatment using soluble phosphate to immobilise leachable contaminants. As such this data should be considered as a measure of the effectiveness of the treatment process utilised at the Vancouver plant, which is discussed further in Section 5.2.

It is understood that the technology proposed for the Woodlawn ARC is similar to these reference plants and hence the Woodlawn output waste streams are likely to be consistent with the reference data from these plants (noting the different approach to boiler ash management in the UK). It is noted that the input waste feedstock also varies between regions, due to differing waste management and recycling policies, which is discussed in the following section.

3.2 INPUT WASTE FEEDSTOCK COMPOSITION

For the purposes of this study and based on information provided by Veolia, it is assumed that the annual general waste feedstock composition for Woodlawn ARC will comprise approximately 80% residual municipal solid waste (MSW) and 20% residual commercial and industrial waste (C&I). Veolia have also provided indicative input waste feedstock data for the Woodlawn ARC, based on waste characterisation audits of MSW and C&I waste from across the greater Sydney region. It is understood that this data represents residual waste following the resource recovery process required by various national and NSW waste management policies, as discussed in Section 2.1.

Current waste feedstock data has also been compiled for the two primary reference plants detailed in Section 3.1, all of which is summarised in Table 3.1 below.

Table 3.1 Input waste feedstock composition summary

Plant	Woodlawn[1]			Staffordshire[2]	Vancouver[3]		
Category	**MSW**	**C&I**	**Average Input**	**Average Input**	**MSW**	**C&I**	**Average Input**
Organics	39.9%	38.3%	39.6%	25.0%	28.4%	38.0%	35.7%
Paper/Cardboard	15.6%	20.3%	16.5%	24.1%	16.7%	15.2%	14.2%
Plastics	7.7%	5.3%	7.2%	17.9%	24.7%	14.9%	18.5%
Textiles	7.8%	2.1%	6.7%	9.5%	0.0%	0.0%	0.0%
Nappies/Hygiene	15.8%	16.9%	16.0%	5.3%	13.3%	4.4%	7.9%
Non Combustible/Inert	1.2%	3.0%	1.6%	2.7%	6.3%	12.5%	9.8%
Glass	1.5%	3.5%	1.9%	1.8%	2.0%	2.0%	2.2%
Metals	1.7%	1.9%	1.7%	3.4%	4.9%	5.1%	4.5%
Ewaste	0.3%	3.3%	0.9%	1.3%	1.8%	2.4%	1.9%
Other Combustible (not specified)	0.8%	1.8%	1.0%	3.4%	0.0%	0.0%	0.1%
Hazardous Material	0.9%	0.7%	0.9%	0.5%	0.6%	2.1%	1.1%
Other (not specified)	6.7%	3.0%	6.0%	5.2%	1.5%	3.3%	4.1%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%

(1) Woodlawn average input composition based on 80% MSW and 20% C&I from Banksmeadow audit (Source: Veolia, 2022)

(2) Staffordshire average input composition provided as the average of combined MSW and C&I data over a three-month period (Source: Veolia, 2022)

(3) Vancouver average input composition based on 2020 summary statistics for combined MSW and C&I (Source: Metro Testing & Engineering Ltd, 2021)

It is noted that the Vancouver waste composition data did not utilise all of the same categories as for the Woodlawn and Staffordshire data, e.g. the Vancouver data did not include textiles as a separate category. As such the Vancouver data has been compiled to fit the most relevant categories in Table 3.1, based on the descriptions provided in the source document. The data presented is considered to provide an appropriate level of detail for preliminary analysis and is a relatable data set for comparison of the input feedstock for each plant.

As illustrated in Chart 1 below, the general proportion of different waste types between the reference plants is broadly consistent, with organics, paper/cardboard and plastics making up the bulk of the feedstock for each plant (i.e. greater than 66% of total for each plant). However, some key differences are noted, which are summarised as follows:

- Organics comprise a higher proportion of the feedstock for Woodlawn than the reference plants, by up to 15%;
- Paper/cardboard content varies by up to 10% between plants, with Woodlawn in the mid-range of the dataset;
- Plastics comprise a significantly lower proportion of the feedstock for Woodlawn compared to the other plants, while nappies/hygiene products comprise a higher proportion;
- Metals comprise a lower proportion of feedstock for Woodlawn compared to the other plants, in particular the proportion is half that of the Vancouver data; and
- As previously noted textile content was not included in the Vancouver dataset, however a significantly larger proportion of the waste stream was designated as non-combustible/inert.

Given the input feedstock composition is generally consistent between the plants, it is considered that reference data of the output waste streams (e.g. IBA, boiler ash and APCr) for Staffordshire and Vancouver are comparable. The reference data from those plants will therefore likely be applicable to what could be expected from the proposed Woodlawn ARC, given it will utilise similar technology. In particular it is noted that the proportion of both e-waste and hazardous materials is similar between all plants, which is significant given that these waste streams are the primary source of key contaminants (e.g. heavy metals) in the IBA and APCr generated.

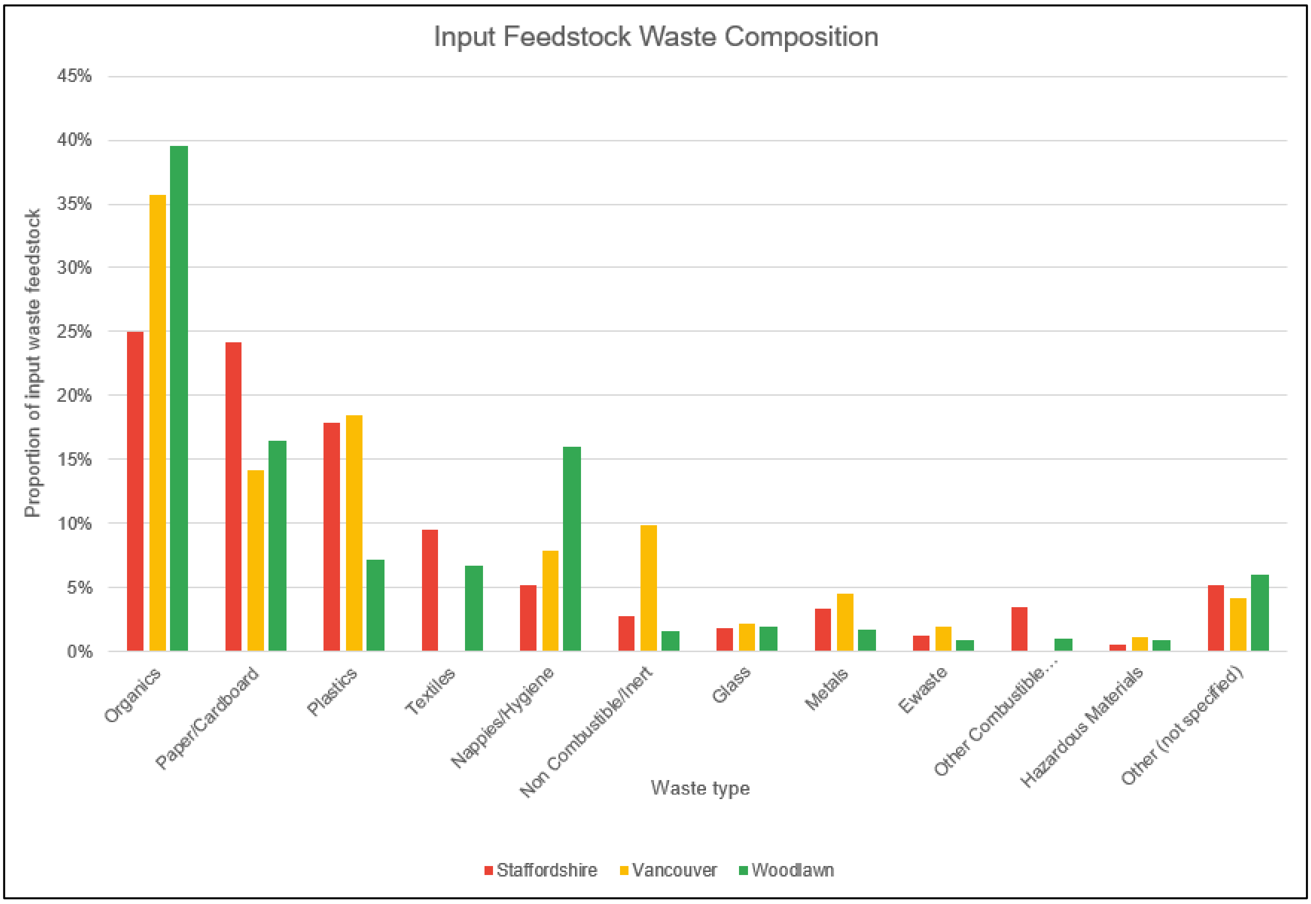

Chart 1: Feedstock Waste Comparison

3.3 COMPOSITIONAL RISKS

As noted in Section 3.2 above, the composition of waste likely to be utilised as feedstock at Woodlawn is generally comparable to the waste composition utilised by the reference plants. However, the composition of waste by-products resulting from any plant is site and feedstock specific. A risk relating to by-product composition, treatment requirements and potential future beneficial reuse viability will therefore exist until a data set of actual waste by-product chemical composition can be established and assessed (i.e. during the commissioning phase of the project).

In addition, changes to input feedstock over time due to additional recycling or resource recovery activities has the potential to vary the output waste by-product characteristics. For this reason additional testing / waste characterisation should be considered in future, whenever significant changes to the input feedstock occurs.

4 ASH PROPERTIES ASSESSMENT

4.1 OUTPUT WASTE SUMMARY

The typical waste combustion process produces three types of output waste residues:

- Incinerator bottom ash (IBA);
- Boiler ash; and
- Air Pollution Control residues (APCr).

IBA is material discharged from the combustion grate and collected below the furnace / combustion chamber. IBA is formed from the inorganic content of the waste feed and contains varying quantities of non-combustible materials such as glass, ceramics, brick, concrete and metals (ferrous and non-ferrous) in addition to clinker and ash, depending on the composition of the waste being combusted.

Waste combustion processes may also produce boiler ash, which is the particulate matter removed from the flue gas stream in the boiler passes. The flue gas treatment (FGT) system produces APCr, which comprises ash and residue products from the flue gas cleaning process recovered in the baghouse filter system (dry and semi-dry scrubbing systems) and/or sludge recovered from wet scrubbing systems. The boiler ash and APCr are typically mixed at the plant prior to being sent for treatment and disposal, as such throughout the following sections this material will be referred to simply as APCr.

Data provided by Veolia indicate that using a waste feedstock input of 380,000 tonnes per annum (tpa) at Woodlawn ARC, the predicted annual ash waste volumes are:

- IBA: 76,000 tpa (20% of feedstock); and
- APCr: 15,200 tpa (4% of feedstock).

As discussed in Section 3.1 the reference data relating to characterisation and ash chemistry has been sourced from several reference plants in the UK, France and Canada. At the UK plants IBA and boiler ash are mixed and re-purposed for use as an alternative aggregate material in the construction industry, whereas at the French and Canadian plants the boiler ash and APCr material is mixed together for the purposes of testing, treatment and disposal / management (as proposed for Woodlawn ARC). The chemical analysis data in this study is therefore presented with appropriate discussion on differences between these reference datasets (including differences in the leachability testing standards) and the relevant outcomes for the Woodlawn ARC.

4.2 WASTE CLASSIFICATION PROCEDURE

As discussed in Section 2.2.1, the Waste Classification Guideline – Part 1 (NSW EPA, 2014a) is the principle document for classification of waste materials in NSW. The guideline details a six-step process for classifying waste, which is summarised in Table 4.1, along with the applicable designation for the waste products detailed in this study for each step.

Table 4.1 Waste characterisation procedure

STEP	DESCRIPTION	IBA	APCr
1	Is the waste special waste? (as defined in the guideline)	No	No
2	Is the waste liquid waste? (as defined in the guideline)	No	No
3	Is the waste pre-classified? (i.e. has it been pre-classified by the EPA?)	No	No

STEP	DESCRIPTION	IBA	APCr
4	Does the waste possess hazardous characteristics? (i.e. is it a dangerous good under the Transport of Dangerous Goods Code?)	No	No
5	Determining a waste's classification using chemical assessment	Refer 4.3	Refer 4.4
6	Is the waste putrescible or non-putrescible? (as defined in the guideline)	Non-putrescible	Non-putrescible

The process for classification of waste using chemical assessment (Step 5) outlined in the guidelines involves comparison of contaminant concentrations (as either solid or leachable concentration) to different threshold values for various waste categories. Solid contaminant data is referred to as the specific contaminant concentration (SCC) value, while leachable contaminant data is expressed as the toxicity characteristics leaching procedure (TCLP) value.

The process for comparison of the SCC and/or TCLP values to the various threshold values is presented as Chart 2 below, along with the relevant waste categories.

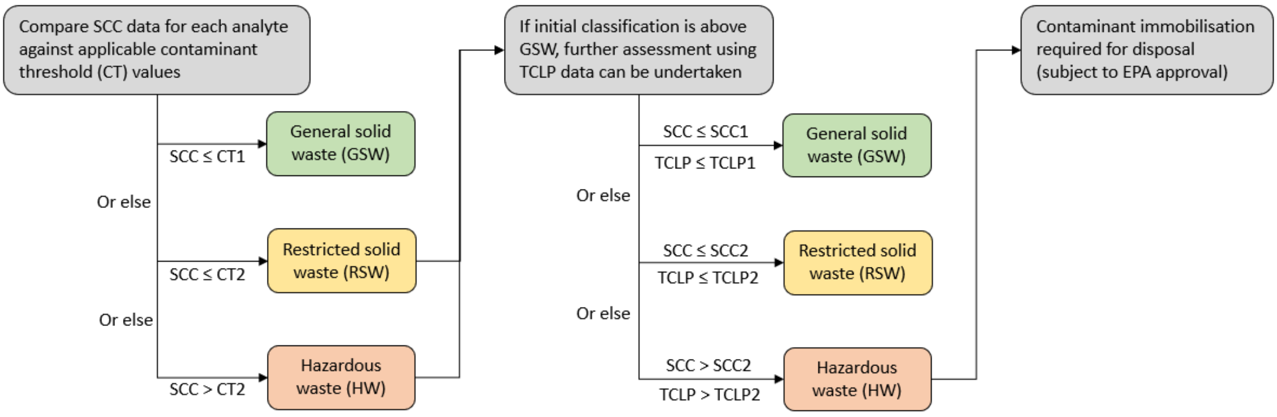

Figure 2: Waste Characterisation Process Using Chemical Assessment

The key takeaway from this process is that leachability of contaminants is the main determining factor in the characterisation of the waste. SCC values can be used without TCLP values, however the applicable threshold values in that case (CT1 & CT2) are more conservative than the values applied when TCLP data is also used (SCC1 & SCC2). As such leachability testing is always recommended to assist with waste characterisation and approval for disposal, particularly for wastes with higher contaminant concentrations.

It is also noted that the guidelines recommend the calculation of sample mean, standard deviation and 95% upper confidence limit (UCL) of the mean for each contaminant in a dataset where possible when undertaking waste characterisation. This ensures a representative waste classification is applied, which is not affected by anomalous data, e.g. a statistically high concentration or "hot spot" for a contaminant in one sample which could change the classification from GSW to RSW.

This process was applied to the ash waste data obtained from the reference plants where possible (i.e. if sufficient data was provided to calculate the summary statistics) and the characterisation of each waste product is discussed in the following sections.

4.3 TYPICAL IBA COMPOSITION

Summary statistics for the compiled IBA solid composition data and calculated 95% UCLs for the reference plants compared against the applicable threshold values is presented in Table 1, Appendix A. As leachability data was not available for the UK plants, those SCC values have been compared against the CT1/2 values, whereas the Vancouver data has been compared against the SCC1/2 values, in accordance with the process detailed in Section 4.2.

Compiled TCLP data and calculated 95% UCLs for the Vancouver and French plants compared against the applicable threshold values (TCLP1/2) is presented in Table 2, Appendix A.

Note only compounds/elements for which waste categorisation values exist, or that are considered potentially relevant to future waste disposal and/or reuse approvals are included in the summary tables.

4.3.1 UK PLANTS

The combined IBA data for the UK plants are summarised as follows:

- Mean and 95% UCL SCC for lead typically exceeded the CT2 value;
- Mean and 95% UCL SCCs for chromium and nickel typically exceeded the CT1 value; and
- SCC for all other contaminants were less than the CT1 values.

Based on this data alone, the IBA would be classified as HW, due to the boiler ash mixed into the IBA resulting in increased metals levels (particularly lead).

It is noted however that the SCC values for these heavy metals do not exceed the applicable SCC1 threshold values, indicating that if the leachability of these contaminants was assessed and determined to be below the TCLP1 threshold values, the material could be classified as GSW. This is the case for the Vancouver data as detailed below.

4.3.2 VANCOUVER, CANADA

The Vancouver IBA data are summarised as follows:

- SCCs for all contaminants were less than the applicable SCC1 values; and
- TCLPs for all contaminants were less than the applicable TCLP1 values.

Based on this data, the IBA would be classified as GSW.

4.3.3 FRENCH PLANTS

The IBA data for the French plants are summarised as follows:

- TCLPs for all contaminants were less than the applicable TCLP1 values.

Solid contaminant data was not available for the French reference plants, however this data supports the classification of the IBA as GSW, given the low leachability.

4.3.4 SUMMARY

It is noted that the Vancouver dataset has significantly higher heavy metals concentrations that the UK plants dataset. This indicates that the Vancouver leachability data is likely a conservative representation of the likely leachability of the typical UK IBA, i.e. leachable metals concentrations from the UK IBA would be lower.

This summary indicates that although solid concentrations of certain heavy metals are potentially of concern within the IBA, the leachability of these elements from the material is low enough to not pose an issue for disposal. As such the applicable classification of the IBA based on the reference data is **General Solid Waste**. Based on this classification the IBA generated at the Woodlawn ARC would therefore be suitable for disposal into the existing Woodlawn Eco-Precinct Bioreactor landfill, without any pre-treatment required.

It is also noted that based on this likely classification of the IBA there is significant potential for beneficial reuse options such as the production of recycled aggregates (IBAA – incinerator bottom ash aggregates) by means of mechanical processing and maturation, which is commonly done in Europe and other regions (refer Section 6.3). Alternatively, IBA could be used as alternative cover material at the Woodlawn Bioreactor landfill and/or proposed encapsulation cell, subject to regulatory approval (refer Section 6.1).

4.4 TYPICAL APCR COMPOSITION

Summary statistics for the compiled APCr solid composition data and calculated 95% UCLs for the reference plants compared against the applicable threshold values is presented in Table 3, Appendix A. As leachability data was only available for the Vancouver plant, the SCC values for the UK and French plants have only been compared against the CT1/2 values, whereas the Vancouver data has been compared against the SCC1/2 values.

Compiled TCLP data and calculated 95% UCLs for the Vancouver plant compared against the applicable threshold values (TCLP1/2) is presented in Table 4, Appendix A.

Note only compounds/elements for which waste categorisation values exist, or that are considered potentially relevant to future waste disposal and/or reuse approvals are included in the summary tables.

4.4.1 UK PLANTS

The APCr data for the UK plants are summarised as follows:

- Mean and 95% UCL SCCs for lead and cadmium exceeded the CT2 value;
- Mean and 95% UCL SCC for mercury exceeded the CT1 value; and
- SCC for all other contaminants were less than the CT1 values.

Based on this data, the APCr would be classified as HW and hence would require analysis of leachability and potential treatment to immobilise the contaminants prior to disposal to a suitably licensed landfill.

It is noted that the SCC values for these heavy metals do not exceed the applicable SCC2 threshold values, indicating that if the leachability of these contaminants was assessed and determined to be below the TCLP2 threshold values, the material could be classified as RSW. In that case treatment prior to disposal to landfill would not be required.

4.4.2 VANCOUVER, CANADA

The Vancouver combined APCr data are summarised as follows:

- SCCs for lead and cadmium exceeded the SCC1 values;
- SCCs for all other contaminants were less than the applicable SCC1 values; and
- TCLPs for all contaminants were less than the applicable TCLP1 values.

Based on this data, the APCr would be classified as RSW. It is noted that despite the elevated solid concentrations, the leachable concentrations are very low, indicating that the treatment process used at the plant is effectively immobilising these contaminants.

4.4.3 FRENCH PLANTS

The combined APCr data for the French plants are summarised as follows:

- 95% UCL SCCs for lead, cadmium and mercury exceeded the CT2 value;
- 95% UCL SCC for chromium and fluoride exceeded the CT1 value; and
- SCC for all other contaminants were less than the CT1 values.

Based on this data, the APCr would be classified as Hazardous Waste and hence would require analysis of leachability and potential treatment to immobilise the contaminants prior to disposal to a suitably licensed landfill. This is consistent with the UK dataset and again demonstrates that the leachability of heavy metals is the key concern with regards to management of this material.

It is again noted that the SCC values for these heavy metals do not exceed the applicable SCC2 threshold values, indicating that if the leachability of these contaminants was assessed and determined to be below the TCLP2 threshold values, the material could be classified as RSW. In that case treatment prior to disposal to landfill would potentially not be required.

4.4.4 SUMMARY

The conservative classification of the APCr material likely to be generated at Woodlawn ARC based on the reference data is **Hazardous Waste.**

Based on this classification the APCr would require treatment to immobilise the contaminants (particularly lead and cadmium), in order to reduce the classification to **Restricted Solid Waste** and allow disposal to an appropriate landfill facility. The specific treatment requirements would be subject to actual characterisation of the generated APCr material during the commissioning phase of the plant, however likely treatment options are discussed in Section 5.2. The Woodlawn ARC project includes development of a suitable encapsulation cell at the Woodlawn Eco-Precinct for the specific purpose of containing the APCr material, regardless of the treatment requirements.

It should be noted that pre-treatment leachability data was not available for any of the reference plants and hence the classification presented here is conservative. Various literature on APCr material does however suggest that high leachable metals concentrations are commonplace in the material. Veolia have stated that they intend to manage the APCr as hazardous waste requiring treatment, with appropriate controls in place throughout the generation, transport & handling, treatment and disposal process, to ensure the protection of human health and the environment.

4.5 ASH WASTE CHARACTERISATION SUMMARY

The outcomes of the waste characterisation based on the adopted reference plant data is summarised as follows:

- The IBA would be classified as GSW and hence would be suitable for disposal in the existing Woodlawn Bio-Reactor Landfill and/or proposed encapsulation cell;
- In addition, based on the likely classification of the IBA there is significant potential for beneficial reuse options such as an alternative daily cover material at the Bio-Reactor, and/or for the production of recycled aggregates and other construction materials;
- The APCr would likely be initially classified as HW and hence would require treatment to immobilise leachable contaminants; and
- Following treatment via immobilisation, the APCr would then be classified as RSW and hence would be suitable for disposal into the proposed encapsulation cell.

5 MANAGEMENT AND TREATMENT OPTIONS REVIEW

This section outlines the proposed generation, storage, treatment and/or management of the output waste products intended at the Woodlawn ARC. A review of additional potential treatment/management processes applicable to the IBA and APCr material to allow for various beneficial reuse options is also detailed in the following sections.

5.1 IBA MANAGEMENT

As stated in Section 4.3 the waste classification of the IBA based on the reference data is GSW and as such is suitable for disposal to an appropriately licenced landfill without treatment. However, some processing/management of the IBA may be considered in future to enhance the potential for beneficial re-use of the material (e.g. to produce IBAA and other products) and these processes are outlined as follows.

5.1.1 CRUSHING

Although not required for landfill disposal, crushing is a general pre-treatment technique for reuse applications and is undertaken to refine the particle size distribution of the IBA, making it more usable in construction materials. The timing of crushing is critical and should be carried out before weathering; crushing after weathering changes the characteristics of IBA by breaking the carbonated surfaces of the ash and potentially negating the benefits of carbonation.

It is understood that the proposed IBA management process at Woodlawn will not initially include crushing, however this may be considered in future as beneficial re-use opportunities are explored.

5.1.2 SCREENING OR SEPARATION

There are three basic elements to the separation process:

— Removal of ferrous metals;

— Removal of non-ferrous metals; and

— Separation of oversized particles.

IBA is fed into a semi-enclosed structure where it is processed by a series of trommels, screens and conveyors, together with magnets (for ferrous metals) and eddy current separators (for non-ferrous metals), to recover metals for recycling and grade the material according to particle size.

The Woodlawn ARC facility will use purpose built ash extractors to efficiently cool down the ash and optimise its moisture content, and then coarse fraction ferrous/non-ferrous metal extraction as previously described will be undertaken. Extracted metals will then be sent for recycling in accordance with waste reduction and resource recovery policies. Veolia have estimated that the annual volume of metal waste extracted will be approximately 5,700 tonnes of ferrous metals (1.5% of annual feedstock) and 1,900 tonnes of non-ferrous metals (0.5% of annual feedstock).

Further grading of material has not initially been proposed at Woodlawn ARC, however again this may be considered in future as beneficial re-use opportunities are explored.

5.1.3 WEATHERING OR MATURATION

Weathering or maturation is carried out by exposing stockpiles of IBA to the atmosphere for an extended period, after which it is ready for processing/disposal/re-use. Weathering or ageing is a general pre-treatment technique for reuse applications as opposed to disposal requirements for landfilling.

When IBA leaving the combustion process is exposed to the atmosphere this results in significant stabilisation reactions such as hydration and carbonation, which reduces the pH of IBA and reduces leachability by generation of more stable (less soluble) compounds.

The time required to stabilise the ash residues depends upon the stockpile conditions and ash composition. Periods of three to six months are often necessary before weathering reactions produce significant changes in IBA characteristics (Kosson *et al* 1994), although the UK Environment Agency refers to a typical six to 12-week process. The Metro Vancouver management strategy involves stockpiling for one to three months prior to disposal and hence three months capacity has been assumed for the Woodlawn ARC storage pad.

Weathering requires additional stockpile space, leachate collection and management, prior to disposal or re-use of the IBA. It is noted however that generation of leachate is very limited and this can generally be managed through reuse in the ash discharger process. Stockpile requirements will vary based on the site weather conditions (e.g. rainfall and wind) and ash composition and this will require further consideration when investigating this treatment method in detail, however the operational logistics of managing the material is the main consideration. Specifically, ensuring that the size and layout of stockpiles is manageable, safe and that sufficient runoff and dust controls are in place is generally of greater concern than other factors, as regardless of the stockpiling process adopted the maturation process will effectively occur.

It is proposed that at the Woodlawn ARC IBA will be transported via covered conveyors from the ARC to a purpose built storage pad for stockpiling and maturation. The pad will be a sealed surface (i.e. concrete slab) with leachate collection infrastructure (e.g. perimeter bunds, drains) feeding back into the ash discharger system, to ensure that leachate from the stockpiles is contained during the maturation period (typically up to 3 months). The pad will be of sufficient size to contain up to 3 months of production volume (19,000 tonnes), with space to manage separate stockpiles to allow for periodic sampling to confirm suitability for disposal/re-use. The dimensions of each stockpile (particularly length) will vary depending on the volume of material to manage and the layout of the pad area, however it is estimated that the maximum stockpile dimensions will be 55 m long by 18 m wide by 5 m high in a trapezoidal cross-section (i.e. angled slopes), for an estimated total stockpile capacity of approximately 20,400 m^3.

The unloading area from the conveyor system and processing equipment will be enclosed on three sides by walls and/or covered with a roof structure, to assist with managing moisture content and wind-blown dust generation during the initial handling / pre-treatment and stockpiling process. The structure will be constructed at sufficient height to allow for the aforementioned stockpile volumes, facilitate safe access with machinery (e.g. front-end loaders) when handling material and allow sufficient ventilation. This arrangement meets the requirements of the Best Available Techniques Conclusions (BAT-C), relating to the European Industrial Emissions Directive (IED) as being representative of international best practice, specifically BAT 24.

Initially all IBA at Woodlawn will be stockpiled at the storage pad and then sent to the existing Bioreactor Landfill for disposal as dictated by the production rate, i.e. IBA will be transported from the pad to the landfill as required to ensure sufficient space for newly generated IBA. During the commissioning phase and following sufficient maturation and testing of the material, Veolia intend to consider beneficial re-use of the IBA, including the use of IBA as alternative daily cover (ADC) material at the Bioreactor Landfill and/or the proposed encapsulation cell.

Other potential beneficial reuse options include using IBA in various construction materials such as road base, paving or concrete, which are discussed further in Section 6.3. Any potential reuse of IBA would be managed from the maturation pad area as far as practical, and may require additional processing, e.g. sorting/grading, mixing with other materials, etc. depending on the intended reuse option.

5.1.4 SUMMARY OF PROPOSED IBA MANAGEMENT PROCESS

The proposed management process for the IBA generated at the Woodlawn ARC is based on proven technologies and methods used at the various reference plants as previously discussed. The process from generation to disposal is presented on Figure 1 and summarised as follows:

1 Generation: IBA is produced by the ARC through combustion of waste;

2 Quenching: IBA is quenched through a wet process to reduce the ambient temperature, and to optimise the moisture content for further processing / handling;

3 Metals extraction: IBA is transported along covered conveyors where it is screened and coarse ferrous and non-ferrous metals are extracted using a series of vibrating screens, a trommel, overband and eddy current separators. Extracted metals are sent off site to a metal recycler;

4 Maturation: Following metals extraction IBA is transported via covered conveyors and then stockpiled using a front-end loader on the storage pad. Approximately one-month of production volume will be stored in each stockpile, which will be left for up to 3 months to mature (actual duration will be subject to testing undertaken during the commissioning phase of the plant);

5 End use: Following maturation the IBA will be ready for either disposal or beneficial re-use as detailed below:

   a Disposal: During the initial operation phase of the plant (nominally 6 months) and once laboratory analysis confirms that the material is suitable for characterisation as GSW, the IBA will be transported by trucks to the existing Woodlawn Bioreactor landfill for disposal as required;

   b Alternative cover: After the actual physical and chemical characteristics of the material can be established, Veolia intend to seek approval for the use of the IBA as alternative cover material at the Woodlawn Bioreactor landfill and/or proposed APCr encapsulation cell (refer to Section 6.1);

   c Beneficial re-use: In addition, following the initial waste characterisation phase, Veolia intend to investigate the potential for beneficial re-use of the IBA (refer to Section 6.3). Options for beneficial re-use of the IBA would be revisited periodically (e.g. at most 5-year intervals), as the Australian EfW and associated resource recovery industries develop.

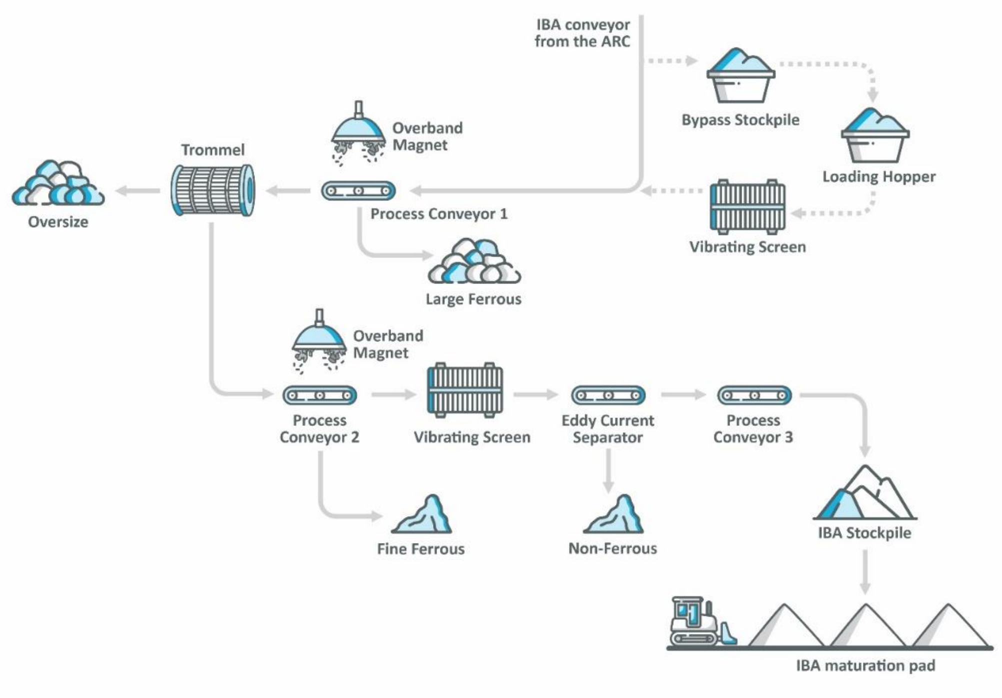

Figure 3: IBA management process

5.2 APCR MANAGEMENT

The ash categorisation results in Section 4.5 indicate that treatment of APCr will almost certainly be required to make the material suitable for landfill disposal. Treatment of EfW APCr is well-established in Europe and North America, whereas ash treatment in Australia is limited to less-hazardous fly ash from coal fired power stations.

5.2.1 TREATMENT OPTIONS REVIEW

Treatment processes are available to treat EfW APCr to remove (leach) potentially harmful elements and/or reduce their leachability prior to disposal or use. The technical performance of the treatment process and the potential environmental impact of the final product would determine how the processed EfW APCr be utilised. The stabilisation of APCr does not reduce the physical amount of solid metal within the APCr (although a dilution factor occurs due to the addition of treatment material) or necessarily remove its toxicity (Ferreira *et al* 2003), but it should reduce the ability for the entrained metals to mobilise from the APCr in a liquid or gaseous form.

The concentration of soluble salts and heavy metals makes disposal of APCr challenging, and hence a common strategy for waste management is treatment followed by landfilling in either hazardous or non-hazardous facilities. This process may create a new pollution source with potential environmental impacts at the landfill site if not appropriately managed and therefore the long-term leachability of the treated APCr is an important consideration for treatment option selection. It is noted that the Woodlawn Eco Precinct contains integrated waste management infrastructure which provides an opportunity to mitigate this impact by retaining the waste on-site in an appropriate designed landfill facility as part of the ARC project.

A summary of ash treatment methodologies, including their technological maturity and availability in Australia, is provided in Table 5.1. A detailed description of the preferred treatment methodology is included in Section 5.2.3 with descriptions of alternative treatment options potentially under consideration included in Section 6.2.

Table 5.1 APCr treatment options

TECHNOLOGY	SPECIFIC PROCESS	DESCRIPTION	MATURITY OF TECHNOLOGY	WORLDWIDE FEASIBILITY	AVAILABILITY IN AUSTRALIA[1]
Waste Acid Treatment	NA	Mixing of EfW ash with industrial waste acids to generate a less hazardous neutral sludge.	Used by several waste companies in the UK.	Yes, but only where specific industries exist generating sufficient material to warrant the process.	No. Unlikely to be specific industries generating sufficient material to warrant process.
Washing	Washing with water	Extraction of salts by addition of water as a leachate.	Used in Europe for salt extraction and as first step for various stabilisation techniques in Europe and UK	Yes, used throughout Europe and UK.	No, but feasible.
	Washing with magnesium sulphate ($MgSO_4$)	Leaching with $MgSO_4$ lowers pH and forms gypsum and Sorel cement which binds chloride ions and heavy metals	Research stage only	No	No
	Acid leaching with nitric acid (HNO_3)	Leaching with HNO_3 neutralises the ash and removes readily leachable metals and ions.	Used by several companies in the UK to treat ash and generate residue suitable for reuse.	Yes, limited use in UK.	No, but feasible depending on availability of nitric acid.
Chemical Stabilisation	Phosphate injection	Inject phosphate into ash stream to immobilise heavy metals. pH can be lowered by subsequent injection of MgO.	Wes-PHix used at over 50 EfW plants in North America and Japan. Revasol process used in Asia. Other processes either at pilot plant stage or not proven on EfW ash.	Yes, used throughout North America and Japan.	Yes, used for Pb stabilisation in contaminated soils.
	Ferrox	Addition of ferrous sulphate solution to ash which immobilises	In use at one EFW plant in Denmark.	No, limited availability of reagent.	No.

		heavy metals by an undisclosed process.			
	Gypsum mixing	Active mixing of ash with gypsum matrix that stabilises contaminants by an undisclosed process	In use at one facility in Norway that treats fly ash from ~80 EfW and coal plants in Scandinavia.	No.	No.
Solidification	Cement based processes	Creation of cement with APCr as a limestone replacement to reduce leachability to make suitable for landfill disposal.	In use globally.	Yes, commonly used.	Yes, not used for coal fired ash, but feasible.
	Concrete production	Encapsulation of APCr particles in the concrete matrix (i.e. monolithic encapsulation)	In use globally	Yes, commonly used.	Yes, unspecified locations.
	Bitumen encapsulation	Encapsulation of ash in bitumen to reduce leachability for landfill disposal.	Widely used in Netherlands and Belgium. Isolated use elsewhere.	Yes, limited use.	No
	Carbonation	Mixing ash with elevated concentrations of CO_2 gas forming calcium carbonate, which reduces pH and encapsulates heavy metals.	At least one company in UK (Carbon8) commercially treating EfW ash.	Not common, but feasible.	No. Feasible.
	Geopolymer	Encapsulation of ash and slag by proprietary technology to create a geopolymer concrete.	Technology patented by Zeobond and used in Australia	Yes. Designed to generate usable product replacing concrete but requires slag, sand and gravel. Efficacy of metals immobilisation not clear in literature.	Yes. Designed to generate usable product replacing concrete but requires slag, sand and gravel. Efficacy of metals immobilisation not clear in literature.

Thermal Treatment	Vitrification	Melting of the ash with glass precursors to form an amorphous glassy material encapsulating contaminants.	In use mainly in Japan, Asia and a few plants in USA and Europe.	Yes.	No. High energy costs.
	Melting	Melting of ash with extraction of different metals at different temperatures.	In use in Japan and Asia.	Yes, limited use.	No. High energy cost.
	Sintering	Heating to bind particles together reducing leachability.	In use in a small number of European plants.	Limited use.	No. High energy cost.

1 No EfW ash has been generated in Australia to date. Availability in Australia refers to the process being commercially available for coal fired power station fly ash.

Treatment options for EfW APCr for the Woodlawn project are limited by the following factors:

- Local availability of treatment material (e.g. waste acid washing);
- Mature technology likely to gain regulatory approval;
- Energy efficiency and sustainability;
- Final destination and subsequent required leachability values for the treated APCr; and
- Creation of unwanted by-products / waste (e.g. washing).

Based on a comparison of the options presented above and the various benefits vs limitations, the most practical treatment options for further consideration of use at the proposed Woodlawn ARC are:

1. Portland cement solidification; and
2. Phosphate (or other chemical) stabilisation.

The preferred treatment option for the purposes of the reference design and the EIS is stabilisation of the ash in a Portland cement mix to reduce leachability. Portland cement stabilisation is a widely used and accepted method for management of leachate from various hazardous wastes, and the required input products and application technology are readily available in Australia.

The final selection of treatment option would be subject to a cost-benefit analysis as part of ongoing design development, as well as actual analysis results of the ash waste composition and the results of treatment trials during the commissioning phase, as required for regulatory approval (see Section 5.2.2 below).

5.2.2 IMMOBILISATION APPROVAL

As stated in the Waste Classification Guideline – Part 1 (NSW EPA, 2014a), hazardous waste cannot be disposed of in NSW without first treating the material. Treatment typically involves some sort of immobilisation to reduce the leachability of contaminants once the material is landfilled.

The Waste Classification Guideline – Part 2 (NSW EPA, 2014b), outlines the procedure to obtain an immobilisation approval from the EPA as defined in the POEO (Waste) Regulation 2014 (Part 10), to allow for treatment and management of hazardous wastes. Various types of immobilisation are possible, some of which were discussed above in Section 5.2.1 such as chemical fixation to convert contaminants to a stable form (e.g. phosphate injection) and micro-encapsulation to physically lock up contaminants within the structure of the waste (e.g. cement stabilisation).

Based on the guidance in this document the APCr material generated at Woodlawn ARC would require a specific immobilization approval (SIA) for a non-naturally immobilised waste. An SIA is required where no general immobilization approval (GIA) has previously been issued by the EPA for the hazardous waste generated, as is the case for EfW output by-products.

The application process for an SIA requires the applicant to:

- Address the proposed treatment and immobilisation mechanism in the form of a report. Information to be provided includes evidence that it is not possible to reprocess the waste in order to reuse or recycle it. Details on quantity, form, background information and chemical composition of the waste should be provided. The applicant should also describe the proposed treatment methods or process, if applicable, to be used, the equipment to be used and evidence of quality assurance/quality control.
- Provide details about ‘treatability’, including total concentration of the contaminants and the leaching performance based on ‘toxicity characteristics leaching procedure’ (TCLP) tests or other relevant tests. It should be noted, however, that TCLP results alone are not generally accepted as proof of immobilisation. The scientific basis and relevant reaction chemistry for claiming immobilisation must also be included in an application for a specific immobilisation approval. Where appropriate conduct additional leaching test such as the USEPA Multiple Extraction

Procedure Test Method 1320 (MEP Test) to demonstrate long term leaching performance of the contaminants of concern. The MEP Test involves TCLP analysis every day for a period of 10 days to simulate weathering conditions.

— Where the waste is not naturally immobilised or is being macro-encapsulated, it may be necessary to undertake treatment trials to determine the effectiveness of the proposed treatment. Attention should be paid to addressing scale-up issues between laboratory trials and the actual treatment. Laboratory trials, for example, often do not reproduce the conditions needed to achieve effective mixing during full scale treatment.

It is therefore proposed that during the commissioning phase at Woodlawn ARC a preliminary waste characterisation and treatment trial would be undertaken to allow an SIA application to be submitted to EPA in accordance with the POEO (Waste) Regulation 2014. The general process for the treatment trial and SIA application is outlined in Figure 4 below.

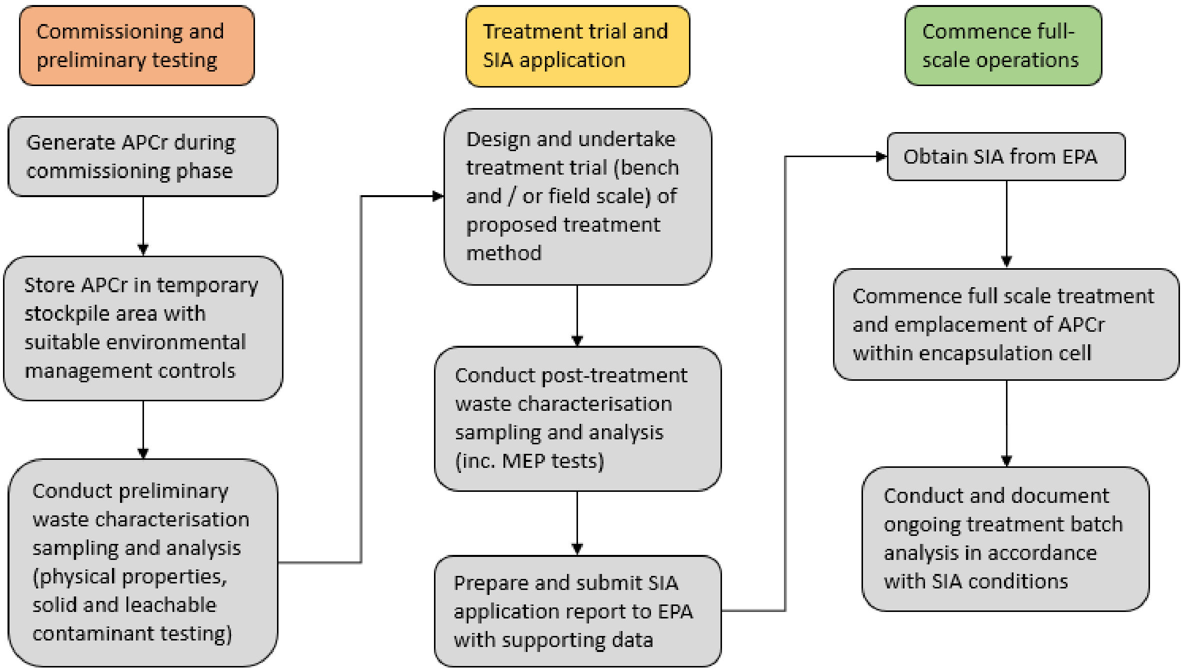

Figure 4: Immobilisation approval process

Given the timescale required to undertake the treatment trial and SIA application during the commissioning phase, it is considered that a practical approach would be to submit a preliminary SIA report prior to the trial. This preliminary report would present reference data similar to this document, outlining specific details of the proposed treatment option, chemical analysis data and management processes, in order to obtain "in principle approval" from EPA along with any conditions applicable to the commissioning phase operations. Following this the treatment trial can be completed and the resulting data used to support the final SIA for full-scale operation.

Prior to issue of the final SIA the APCr material generated would be treated and deposited within the encapsulation cell, following the proposed management procedures. If the EPA determine that additional treatment / processing is required to satisfy the conditions of the final SIA, the APCr generated during commissioning could then be extracted and re-treated. Through this process the APCr would be appropriately managed in accordance with the Waste Classification Guidelines and in compliance with the POEO (Waste) Regulation 2014 requirements.

In addition, once the SIA is granted by EPA, the ongoing testing required would generally be limited to typical waste characterisation analysis, e.g. solid and TCLP analysis on a batch by batch basis to demonstrate that treatment is not actually required (i.e. the material is classified as RSW), or else that the treatment undertaken is effectively immobilising the contaminants and hence disposal to the encapsulation cell is acceptable.

5.2.3 SUMMARY OF PROPOSED APCR TREATMENT AND MANAGEMENT PROCESS

The available chemical information from the reference plants (Section 4.4) indicates that stabilisation and/or solidification will be required to allow landfill disposal of APCr. The treatment options review determined that stabilisation of the APCr using a Portland cement mix is the preferred option, based on current data and with consideration of the risks/limitations of various options.

The process from generation to disposal is summarised as follows:

1. Generation: APCr is produced through combustion of waste and collection from settled residue at the boiler and from filtration bags prior to the stack.
2. Storage of ash: APCr will be transported by conveyor to dedicated silos with sufficient storage capacity for 5 days production (approximately 180 m^3), located adjacent to the combustion and boiler hall.
3. Stabilisation: APCr is conveyed from the silos to the adjacent stabilisation facility, which will involve the mixing of Portland cement with the APCr plus water[1]. A specifically designed mixer will be used to combine the APCr with the Portland cement.
4. Disposal: The treated APCr will be transported from the plant using an articulated dump truck or tractor & bin, and will be unloaded in the encapsulation cell (monocell).
5. Compaction and curing: To minimise the storage volume of the treated FA / APCr, post-placement compaction will be conducted within the encapsulation cell. Compaction will also increase material shear strength and reduce permeability and leachability following in-situ curing (Tang et al, 2016). The process may involve moisture adjustment followed by spreading and compaction/densification with appropriate plant such as bulldozers or front-end loaders.

[1] Mixing ratios for ash:cement in international reference plants range from 1:4 to 1:2, which vary with leachability and the required stability/strength of the final product. However, the exact mixing ratio required to adequately limit leachability of the Woodlawn APCr will be ascertained during the testing for the immobilisation approval process.

6 FUTURE CONSIDERATIONS

6.1 IBA AS ALTERNATIVE DAILY COVER

As discussed in Section 5.1, Veolia intend to dispose all IBA to landfill as necessary for an initial period likely to be in the order of 6 months. During this time, options for potential re-use for the IBA will be explored, in particular whether the IBA can be utilised as alternative daily cover (ADC) material at the existing Woodlawn Eco-Precinct Bioreactor landfill and/or the proposed APCr encapsulation cell.

The Environmental Guidelines – Solid waste landfills (NSW EPA, 2016) outline the requirements for daily cover material, which is typically certified virgin excavated natural material (VENM) or excavated natural material (ENM), however alternative cover materials can be used, subject to EPA approval. The application for an ADC material requires the following:

- A specification describing the waste component fractions, particle size distribution and limits on foreign / unsuitable matter;
- Chemical analysis demonstrating the material is general solid waste (non-putrescible); and
- A program for monitoring ongoing compliance of the material with the specification.

A trial of the cover material may be undertaken to demonstrate that the cover can perform satisfactorily and meet the required outcomes of daily cover. The trial would include observations of amenity indicators such as odour, dust, litter and presence of scavengers / vermin, and a comparison of these observations with conditions using typical clean fill daycover.

Specific parameters required for ADC materials are not detailed in the guidelines as they are determined on a case by case basis, however examples of typical parameters include:

- No coarse or harmful waste material such as asbestos, food waste, animal waste, rubber, plastic, bitumen, metal, etc;
- Maximum particle dimension of 50 mm, with >50% by mass of material at <1 mm particle size; and
- Rainfall runoff in contact with the alternative cover must be managed as landfill leachate.

Based on the reference data reviewed for this report, it is considered that the IBA produced at Woodlawn would be a viable candidate for ADC. Some additional crushing, grading and/or separation may be required to produce a suitable aggregate, which would be investigated during the initial operation period of the ARC, along with the waste characterisation testing.

Given that currently a significant amount of daily cover material used at Woodlawn Bioreactor is imported from off site, reducing this volume would result in a significant reduction in the carbon footprint of the landfill operation, in addition to preventing otherwise clean fill material from being wasted and reducing the overall capacity and hence lifespan of the landfill. Use of the IBA as daily cover would therefore be in accordance with the principles of the NSW Waste and Sustainable Materials Strategy 2041, and the Waste Avoidance and Resource Recovery Act 2001.

6.2 ALTERNATIVE TREATMENT OPTIONS

As detailed in Section 5.2.1, the alternative to cement stabilisation for treatment of the APCr material considered potentially viable for the Woodlawn ARC is phosphate stabilisation. Other stabilisation reagents may also be explored as the project develops and as specific waste characterisation data becomes available (as other reagents may be deemed more effective).

The treatment process using the phosphate stabilisation option is similar to the cement stabilisation option in that it involves mixing of a stabilising agent with the material prior to disposal into a doubled-lined landfill. The key difference is that instead of physically immobilising the leachable contaminants (as per cement), the phosphate solution chemically fixes the contaminants into a more stable (less leachable) form. The exact process and treatment rates, etc. are dependent on the specific chemistry of the waste generated and so would need to be developed during the commissioning phase of the plant, once specific waste characterisation data is available.

The general treatment process from generation to disposal is summarised as follows:

1. Generation: APCr is produced through combustion of waste and collection from settled flue gas residue at the boiler and from filtration bags prior to the stack.
2. Storage of ash: APCr will be transported by conveyor to dedicated silos with sufficient storage capacity for 5 days production (approximately 180 m^3), located adjacent to the combustion and boiler hall.
3. Stabilisation: APCr is conveyed from the silos to the adjacent stabilisation facility, which will involve the mixing of a liquid phosphate solution with the APCr. A specifically designed mixer will be used to combine the APCr with the phosphate solution.
4. Disposal: The treated APCr will be transported from the plant using an articulated dump truck or tractor & bin, and will be unloaded in the encapsulation cell.
5. Compaction: To minimise the storage volume of the treated APCr, post-placement compaction will be conducted within the encapsulation cell. Compaction will also increase material shear strength and reduce permeability and hence leachability. The process may involve moisture adjustment followed by spreading and compaction / densification with appropriate plant such as bulldozers or front-end loaders.

6.3 POTENTIAL BENEFICIAL REUSE - IBA

As previously mentioned, opportunities exist to recycle EfW IBA, provided contamination issues are appropriately managed. In the UK, recycling IBA into aggregate material has been common practice for many years and the process is regulated in the UK Standard Rules SR2012 No. 13 of the *Environmental Permitting (England & Wales) Regulations 2010*. Some statistics suggest that more than half of all IBA generated across Europe is reused in the construction industry (Blasenbauer et al, 2020).

As with recycling of construction and demolition (C&D) waste (e.g. bricks, concrete, etc.) the use of IBAA is a prime example of a circular economy whereby reuse is maximised, while waste to landfill is minimised. The use of IBAA also means a reduction in the need for extraction and processing of raw materials from virgin sites (e.g. quarrying of sand, gravel, etc.), and a subsequent reduction in environmental impact and carbon footprint associated with those activities.

Options for potential beneficial reuse that have been identified internationally include the use of IBAA in:

- Road base and structural platform construction;
- Pipe bedding and drainage material;
- Aggregate in general concrete or bitumen mixes; and
- Brick/paver production.

The limiting factor to any potential reuse lies with the specific chemistry of the by-products (see Section 4), however as previously stated the IBA generated at Woodlawn ARC would likely be classified as GSW and hence would be suitable for many applications. The options above are further detailed in the following sections.

No specific guidance from regulators currently exists in relation to EfW IBA reuse in NSW, however it is understood that both Victoria and WA are currently developing frameworks and a number of industry bodies including the Australian Road Research Board (ARRB) and Cement Concrete & Aggregates Australia (CCAA) have produced documents supporting the future use of IBAA for various industries. In addition, as previously explained IBAA has been used for decades in the UK, Europe and North America, and specifically the UK Environmental Agency has developed a regulatory position statement (RPS) on *Using unbound incinerator bottom ash aggregate (IBAA) in construction activities: RPS 247* (UKEA, 2022).

It is therefore considered that beneficial reuse of IBA is a practical option that should be explored at the earliest opportunity, as it supports the principles of the waste hierarchy and circular economy (i.e. recycling over landfilling), and the demand for such products will only increase over time.

6.3.1 ROAD BASE AND STRUCTURAL PLATFORM CONSTRUCTION

Of the beneficial reuse options considered above, it is recommended that reuse options of road base and structural platform construction be considered further as these options present the best opportunity for the material to be utilised in an application that is effectively capped (via pavement). The reuse of IBAA within road construction (including pavements and maintenance) is well established overseas (as per RPS 247 in the UK).

An important mechanism in Australia for the use of IBAA in road base is the ***Transport Infrastructure Product Evaluation Scheme*** (TIPES) supported by the Australian Road Research Board (ARRB). The process aims at providing an independent fit-for-purpose assessment of innovative road construction products. TIPES is intended for the evaluation of products that fall outside the scope of established standards and specifications, and is a national scheme endorsed by all Australian State and Territory road agencies. In the recently published *Best Practice Expert Advice on the Use of Recycled Materials in Road and Rail Infrastructure* report by ARRB (2022), the use of IBAA in road base is considered to be the “best practice approach in bottom ash management” and has the potential to deliver significant cost savings to future infrastructure projects.

6.3.2 PIPE BEDDING AND BRICKS/PAVERS

Reuse of EfW IBA for pipe bedding or bricks/pavers are considered higher risk reuse options in that these applications could be used more widely in a sensitive environment (e.g. residential setting). However, following appropriate testing it is likely that regulatory approval for such reuse options would be granted, so ultimately the key driver is simply whether a market exists for such products. It is noted that using IBAA for pipe bedding / drainage material is included in the UK RPS 247. As with any of the options detailed in this document, potential beneficial reuse of the waste by-products should be considered from a cost-benefit and resource recovery / waste reduction perspective.

6.3.3 CONCRETE / BITUMEN MIXES

The other primary use of IBAA overseas is in the production of concrete or bitumen mixes. These applications are particularly suitable as they produce a stabilised bound product. The *Use of Recycled Aggregates in Construction* report by CCAA (2008) supports the use of IBAA for a variety of concrete mixes and applications.

Some additional processing of the IBA, e.g. crushing and grading/sorting (refer to Section 5.1), would likely be required to meet the physical standards required for aggregates used in concrete, however that is unlikely to pose a significant barrier to re-use of the material.

6.3.4 PERIODIC REVIEW OF OPTIONS

Although there is a current lack of specific guidance on beneficial re-use of IBA in Australia, this is changing and with a number of EfW projects underway the market demand for IBAA will only grow with time. Given the well-established use of IBAA overseas Veolia have indicated that in accordance with Australian and NSW waste reduction and resource recovery policies, the potential beneficial re-use of IBA will be considered periodically once the Woodlawn ARC plant is operating and specific information on the chemical and physical products of the output waste ash is ascertained.

It is recommended that reviewing potential beneficial re-use options at least every 5 years would be appropriate as the Australian EfW and associated resource recovery industries develop.

6.4 POTENTIAL BENEFICIAL REUSE – APCR

Given the more hazardous classification of typical APCr as detailed in Section 4.4, options for potential beneficial reuse of this material are more limited. Overseas most APCr is treated and sent to suitable landfills for disposal, which is the proposed approach for Woodlawn ARC. The following beneficial reuse options are potentially viable for APCr however are subject to further testing and have not been widely adopted:

- Cement clinker production;
- Zeolite production; and
- Cement replacement in light weight concrete.

Similar to IBA however, Veolia have indicated that in accordance with Australian and NSW waste reduction and resource recovery policies, the potential beneficial re-use of APCr will be considered periodically once the Woodlawn ARC plant is operating and specific information on the chemical and physical products of the output waste ash is ascertained. This process would be undertaken approximately every 5 years as the Australian EfW industry and APCr treatment / processing technologies develop.

7 CONCLUSION

7.1 KEY FINDINGS

The following key conclusions have been drawn from this study:

- The IBA generated in the Woodlawn ARC would likely be classified as GSW and hence would be suitable for disposal in the existing Woodlawn Bio-Reactor Landfill as waste, but subject to appropriate trials and approvals it could be used as ADC in landfilling operations (at both the existing Bioreactor landfill or the proposed encapsulation cell);
- The APCr would likely be initially classified as HW and hence would require treatment to immobilise leachable contaminants, subject to a specific immobilisation approval (SIA) from NSW EPA;
- Following treatment via immobilisation, the APCr would then be classified as RSW and hence would be suitable for disposal into the proposed encapsulation cell;
- The most suitable treatment option for the APCr for the purposes of this study and associated reference design considerations is Portland cement stabilisation, however alternative treatment options such as phosphate stabilisation would be further considered as the project develops; and
- Although all waste output by-products from the Woodlawn ARC would be disposed to landfill initially, there are various potential beneficial re-use options for IBA which should be considered as soon as the plant is commissioned. Despite a lack of guidance in NSW currently, there is a well-established history of IBA reuse overseas and it is expected that there will be increasing market demand in future for this product.

7.2 KEY DESIGN AND MANAGEMENT CONSIDERATIONS

Based on the findings of this report, the key design and management considerations for the development of the proposed maturation pad and encapsulation cell are presented in Table 7.1. As noted throughout this report, many of the assumptions made will be subject to NSW EPA approval and the specific properties of the waste materials generated.

Table 7.1 Key design and management considerations

PARAMETER	IBA	APCR
Waste classification	General solid waste	Hazardous waste (restricted solid waste following stabilisation)
Required disposal facility	Licensed GSW landfill	Licensed RSW encapsulation cell (doubled lined)
Annual mass produced	76,000 tpa	15,200 tpa
Density of final waste product	1.4 (1.2-1.7) t/m^3	0.7-1.5 t/m^3 including post-treatment bulking (0.4 t/m^3 pre-treatment)
Specific infrastructure required	Storage pad (to accommodate up to 3 months production capacity) with leachate collection and management	Treatment batching plant (sufficient capacity for 5 days waste production) and mixing unit, with appropriate reagent storage
Transport / handling requirements	Dust suppression and sediment controls associated with general waste management	Dust suppression and sediment controls associated with general waste management

PARAMETER	IBA	APCR
Potential beneficial re-use options	— Landfill daily cover material — Road sub-base material — Construction material production (e.g. bricks, pavers, concrete, ceramics, etc.)	— Cement clinker production — Light weight aggregates / concrete — Zeolite production

7.3 IDENTIFIED RISKS

Risks identified during the assessment are detailed within Table 7.2 below. This list is provided based on the experience of WSP with similar projects, however it is provided for information only and cannot be considered an exhaustive list of risks associated with this specific project.

Table 7.2 Identified Risks

RISK	COMMENTS AND POTENTIAL IMPACT
Variation of input waste feedstock	WSP considers that the input waste feedstock information presented in this report suggests that there is a low risk of significant volumes of hazardous materials entering the plant. A number of controls apply to the waste management process, such as feedstock inspections / audits, waste testing and characterisation, etc. which further reduce the risk of undesirable materials entering the plant. The inclusion of waste streams that have an inherent risk of containing problem chemistry including emerging chemicals of concern such as persistent organic pollutants would therefore pose a risk to the waste characterisation discussed in this report. It is however noted that many potential contaminants would be destroyed by the combustion process.
Applicability of reference data	WSP considers that the data from the adopted reference plants provides a conservative summary of the likely waste characterisation of the output by-products from the Woodlawn ARC. As such there is a risk that the reference data provides an exaggerated view of the likely by-product chemistry. It is also noted that limited data is available in relation to Australian waste by-products. The input waste feedstock data reviewed does however suggest a general correlation with the adopted reference plants, and hence the likelihood of significant variation from the reference data due to differences in Australian waste streams is low (or at least unlikely to present a risk to the conservative characterisation adopted in this report). It is also noted that variations in the adopted leachability testing standards between Europe and other jurisdictions mean that reference data on leachable contaminant levels cannot necessarily be directly compared to NSW guidelines. In any case, it is likely that NSW EPA will require adequate testing of output waste by-products and the effectiveness of the proposed treatment methodology during the commissioning phase of the Woodlawn ARC, prior to granting a final immobilisation approval. It is noted that any such testing requirements would be detailed under the environmental licence issued for the site following project approval.
Federal/State/Local Government policy and/or regulatory changes	While effort has been made to anticipate changes in government policy to the extent of publicly available information, a risk exists with unforeseen changes which may affect waste composition, management and disposal mechanisms. Unpublicised Federal/State/Local Government policy or regulatory changes have the ability to influence waste management capacity including adding environmental regulatory impact on end

	disposal area or reuse markets thus influencing landfill void space availability and gate fee, or the ability to recover and reuse IBA material.

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APPENDIX A

TABLES

Table 1: IBA Solid Contaminant Concentrations

NSW EPA Waste Classification Guidelines Part 1: Classifying Waste (2014)						Veolia Staffordshire (2017)			Veolia Leeds 2016			Veolia ES Shropshire 2016		
Element	Unit	CT1	CT2	SCC1	SCC2	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL
Arsenic	mg/kg	100	400	500	2000	7.30	0.56	7.84	4.77	1.11	5.40	12.45	3.81	16.17
Cadmium	mg/kg	20	80	100	400	6.05	1.31	7.34	9.20	8.85	14.21	8.40	3.71	12.04
Chromium VI	mg/kg	100	400	1,900	7,600	93.20	17.33	110.18	68.18	24.04	81.77	101.88	6.50	108.24
Lead	mg/kg	100	400	1,500	6,000	618.25	249.94	863.19	346.92	79.84	392.09	834.00	352.83	1179.76
Mercury	mg/kg	4	16	50	200	0.39	0.02	0.41	0.44	0.03	0.46	0.38	0.02	0.40
Nickel	mg/kg	40	160	1,050	4,200	81.60	12.20	93.56	58.26	11.30	64.65	98.48	16.68	114.82

	Veolia Exeter (2016)			Viridor Peterborough 2016			Metro Vancouver (2018)			Metro Vancouver (2019)		
Element	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL
Arsenic	18.30	4.03	22.25	17.03	9.59	22.46	33.87	11.69	34.80	31.21	9.58	31.96
Cadmium	38.50	10.15	48.45	23.28	14.24	31.34	18.82	44.90	22.37	21.89	112.02	30.68
Chromium VI	158.75	23.26	181.54	145.69	47.81	172.74	218.61	293.14	241.83	215.78	238.17	234.47
Lead	566.25	106.24	670.36	834.18	548.65	1144.60	1210.18	2225.15	1386.48	1117.80	1702.73	1251.40
Mercury							0.14	0.17	0.15	0.13	0.24	0.15
Nickel	121.25	2.63	123.83	93.81	38.40	116.50	223.47	243.25	242.74	271.70	622.23	320.52

Notes:
1- CT1/CT2 values applied to UK data as no leachate data was available
2- SCC1/SCC2 values applied to Vancouver data as leachate data was available, refer to Table 2 for details
3- Only summary statistics are presented for each site due to the large dataset utilised. Full dataset can be provided on request.

Table 2: IBA Leachable Contaminant Concentrations

NSW EPA Waste Classification Guidelines Part 1: Classifying Waste (2014)				Metro Vancouver (2018)			Metro Vancouver (2019)			Veolia Monthyon (2020)			Veolia Ivry Sur Seine (2020)			Veolia Saint Ouen (2020)			Veolia Sovalem (2020)			Veolia Isseane (2020)		
Element	Unit	TCLP1	TCLP2	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL
F	mg/L	150	600							0.500	0.000	0.500	0.500	0.000	0.500	0.500	0.000	0.500	0.500	0.000	0.500	0.500	0.000	0.500
As	mg/L	5	20	<1	<1	<1	<2.5	<2.5	<2.5	0.010	0.000	0.010	0.010	0.000	0.010	0.010	0.000	0.010	0.010	0.000	0.010	0.013	0.005	0.016
Cd	mg/L	1	4	0.28	0.41	0.31	0.28	0.03	0.31	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Cr	mg/L	5	20	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0.011	0.002	0.013	0.010	0.000	0.010	0.013	0.003	0.016	0.013	0.002	0.014	0.013	0.004	0.016
Pb	mg/L	5	20	0.44	0.90	0.51	0.33	0.05	0.38	0.020	0.016	0.032	0.010	0.000	0.010	0.016	0.006	0.022	0.016	0.006	0.021	0.023	0.023	0.039
Hg	mg/L	0.2	0.8	0.02	0.40	0.05	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mo	mg/L	5	20							0.020	0.000	0.020	0.020	0.000	0.020	0.021	0.001	0.022	0.020	0.000	0.020	0.024	0.008	0.029
Ni	mg/L	2	8	0.58	0.25	0.60	0.59	0.02	0.60	0.010	0.000	0.010	0.010	0.000	0.010	0.010	0.000	0.010	0.010	0.000	0.010	0.010	0.000	0.010
Se	mg/L	1	4							0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001
PCB total	mg/L	NA	NA							0.007	0.000	0.007	0.007	0.000	0.007	0.007	0.000	0.007	0.007	0.000	0.007	0.007	0.000	0.007
Total PAH	mg/L	NA	NA							0.081	0.001	0.082	0.081	0.001	0.082	0.087	0.002	0.088	0.098	0.015	0.113	0.080	0.001	0.081

Notes:
1 - Only summary statistics are presented for each site due to the large dataset utilised. Full dataset can be provided on request.

Table 3: FA/APCr Solid Contaminant Concentrations

NSW EPA Waste Classification Guidelines Part 1: Classifying Waste (2014)						Metro Vancouver	Veolia Staffordshire (2017)			Veolia ES Shropshire (2016)			Veolia Exeter 2016			Veolia Leeds 2016			Viridor Petersborough 2016			French Plants (multiple sites) 2020		
Element	Unit	CT1	CT2	SCC1	SCC2	(May-June 2021)	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL	Mean	Std Dev	95%UCL
Arsenic	mg/kg	100	400	500	2000	160	45.43	2.92	48.28	70.55	13.61	83.88										4.6	6.1	9.5
Beryllium	mg/kg	20	80			0.51																		
Cadmium	mg/kg	20	80	100	400	195	165.75	25.05	190.30	174.25	63.93	236.90	100.00	27.34	126.79	175.00	16.48	191.15	293.50	41.33	334.00	65.7	20.8	82.3
Chromium	mg/kg	100	400	1,900	7,600	140	74.95	3.70	78.57	113.83	26.56	139.85	108.50	26.51	134.48	39.23	1.71	40.90	38.88	7.15	45.89	159.7	108.6	246.5
Cyanide	mg/kg	320	1,280																					
Fluoride	mg/kg	1,200	3,000	10,000	40,000																	1166.7	205.5	1331.1
Lead	mg/kg	100	400	1,500	6,000	1,620	1083.25	107.13	1188.23	1757.75	570.46	2316.79	2776.25	462.68	3229.67	1269.25	231.15	1495.77	1727.75	357.23	2077.83	1078.3	503.9	1481.5
Mercury	mg/kg	4	16	50	200	7.03	6.65	0.52	7.16	10.10	1.09	11.17	155.00	16.02	170.70	6.80	0.32	7.12	15.77	6.73	22.37	14.9	10.2	23.0
Molybdenum	mg/kg	100	400	1,000	4,000	13																10.0	0.0	10.0
Nickel	mg/kg	40	160	1,050	4,200	49	23.35	1.84	25.15	60.75	24.84	85.10	44.75	12.81	57.31	16.03	3.62	19.57	13.90	2.70	17.64	21.0	15.3	33.2
PCB total (TEQ)	mg/kg	<50	<50													1.9E-03	1.9E-03	3.8E-03	1.0E+00	1.8E+00	2.8E+00			
Sellenium	mg/kg	20	80	50	200	2.68																10.0	0.0	10.0
Silver	mg/kg	100	400	180	720	18																		

Notes:
1- CT1/CT2 values applied to UK data as no leachate data was available
2- SCC1/SCC2 values applied to Vancouver data as leachate data was available, refer to Table 4 for details
3- Only summary statistics are presented for each site (except Vancouver) due to the large dataset utilised. Full dataset can be provided on request.

Table 4: FA/APCr Leachable Contaminant Concentrations

NSW EPA Waste Classification Guidelines Part 1: Classifying Waste (2014)				Metro Vancouver	Metro Vancouver Oct-Dec 2017			Metro Vancouver 2018			Metro Vancouver 2019			Metro Vancouver 2020			Metro Vancouver 2021 (Jan-April)		
Element	Unit	TCLP1	TCLP2	May-June 2021	Mean	Stdev	95% UCL	Mean	Stdev	95% UCL	Mean	Stdev	95% UCL	Mean	Stdev	95% UCL	Mean	Stdev	95% UCL
As	mg/L	5	20	<1.0															
Cd	mg/L	1	4	<0.050	0.210	0.155	0.302	0.165	0.102	0.202	0.152	0.119	0.200	0.155	0.109	0.196	0.089	0.028	0.121
Cr	mg/L	5	20	<0.25															
Pb	mg/L	5	20	<0.25	1.072	0.945	1.690	1.126	0.893	1.296	1.234	1.122	1.458	1.497	1.361	1.775	1.769	1.302	2.119
Hg	mg/L	0.2	0.8	<0.0001															
Ni	mg/L	2	8	<0.25															
Se	mg/L	1	4	<0.1															
Ag	mg/L	5	20	<0.050															

Notes:
1 - Only summary statistics are presented for each site due to the large dataset utilised. Full dataset can be provided on request.