CASTLE ENVIRONMENTAL

2.3.2.17

Method Statement

Hazardous Waste Recycling Process

Version 3.0

The purpose of this document is to describe the plant, process and methodology with respect to the APC Treatment Process in operation at Castle Environmental Cardiff Waste Treatment and Transfer Facility.

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Introduction:

Industrial thermal processes such as incineration and power generation give rise to residual wastes such as Boiler Fly Ashes and Bottom Ashes, in addition to wastes generated from the scrubbing of off gases such as Air Pollution Control residues (APCr).

These residues may be generated separately or as a single waste stream. These residues are often strongly alkaline materials that contain high concentrations of soluble metal chlorides, lime and other calcium compounds and often have pozzolanic properties.

Whether utilised for the stabilisation of other wastes, pre-treated or directly disposed, historically the majority of APC residues produced are routed to landfill.

However, more recently, these residues are now treated to generate materials that are suitable for use in the construction sector, for example as aggregates or replacement for raw materials in bound applications.

Castle Waste Services provide a range of options for the treatment of APCr, this document describes the process used to wash APCr using a filter press. In addition, the method statement details the measures in place to reduce the pH of the APCr slurry within the process. This can be achieved either by addition of liquid acid or by the use of carbon dioxide.

Treatment Processes:

The Recycling Process operated at the Castle Cardiff site incorporates reaction vessel named Press Feed Tank (PFT). Within this process the APCr can undergo a washing process or a neutralisation process. Each of these options begins with generation of a slurry. The process is described in process flow document P2403-PFD-001 which is contained within Appendix 1.

Slurrying phase:

The APC residues are mixed in to water in mixing tank B1, this dissolves the undesirable chlorides (and any other leachable components) so that they may be removed from the solid waste in solution.

Thermal residues may contain a number of alkaline species. Typically the alkalinity of such wastes is accounted for by a mixture of calcium oxide [CaO], calcium hydroxide [$Ca(OH)_2$] and calcium carbonate [$CaCO_3$].

Generally the CaO content is negligible as the species is readily hydrated to $Ca(OH)_2$.

During the slurrying treatment any lime content persisting in the waste as the basic anhydride becomes fully hydrated.

$$\mathbf{CaO_{(s)} + H_2O \leftrightarrow Ca(OH)_{2\,(s)}}$$

ΔH_f: (-635.5) (-285.8) (-986.6) $\Delta H_r = (-65.3)$ kJ/mol [1]

In the washing process, the insoluble solid residues can then be recovered from the slurry by means of a filter press. The filter press in place at Castle Environmental Cardiff incorporates a further aqueous washing system to ensure complete removal of the dissolved chlorides and a high-pressure air drying system to produce cake with minimised moisture content. The solid residues generated are suitable for use in the construction sector.

Mains water is used for the purposes of this slurrying stage however the opportunity for using recovered rainwater or other aqueous effluents exists. Should this option be utilised, all proposed aqueous inputs shall be subject to any required pre-acceptance procedures including full technical assessment and process modelling to ensure compatibility. Further to that, effluent is reused within the process as far as is practicable.

The process generates an aqueous effluent and a solid filter cake. The effluent undergoes additional treatment at the site in order to generate an effluent that is suitable for discharge to sewer under the terms of a trade effluent consent. The filter cake may be utilised as a replacement for fines aggregate within the construction sector. It may also be disposed of as a waste either to landfill or a suitable third-party recovery process. In each case, the residue will be sampled and analysed to ensure it is able to meet the specification of the receiving facility.

[1] All stated enthalpies of reaction are expressed per mole of alkaline species neutralised.

Additional Treatment:

Depending on the specification of the receiving facility, it may also be necessary to carry out a further step in the process to neutralise the solid residue, therefore reducing the calcium hydroxide content of the material and altering the minerology of the final solid residue.

In the event that neutralisation is required, this can be achieved by introduction of a neutralising agent directly into the reaction vessel prior to the dewatering step. The neutralising agent can be in the form of aqueous based acids such as sulphuric, hence resulting in the formation of calcium sulphate (gypsum) within the solid residue. As an alternative, carbon dioxide can be utilised as a neutralising agent. Where this is the case, the resulting minerology change will be the generation of calcium carbonate within the residue.

Aqueous sulphuric acid can be added to the reaction vessel from one of the bulk acid storage tanks T13, T14 or T15 or can be added direct from a container using a bulking up pump.

If sulphuric acid [H_2SO_4] is used:

$$H_2SO_{4\,(aq)} + Ca(OH)_{2\,(s)} \leftrightarrow CaSO_{4\,(s)} + 2H_2O$$

ΔH_f: (-907.5) (-986.6) (-1432.7) (-571.6) ΔH_r = (-110.2) kJ/mol

$$H_2SO_{4\,(aq)} + CaCO_{3\,(s)} \leftrightarrow CaSO_{4\,(s)} + CO_{2\,(g)} + H_2O$$

ΔH_f: (-907.5) (-1207.0) (-1432.7) (-393.5) (-285.8) ΔH_r = (-2.5) kJ/mol

The alkaline species are treated out in similar fashion however instead of calcium chloride, calcium sulphate [$CaSO_4$], also known as gypsum, is produced. Gypsum has a low solubility and therefore partitions into the solid state and is removed by the filter press.

Secondary gypsum has potential reuse applications in various industries including as an alternative raw material for the cement industry.

[redacted]

Carbon dioxide is stored in a liquidised form in holding tank C1. Prior to introduction to the process it is passed through a vaporiser, [redacted] The adsorption of carbon dioxide neutralises the calcium hydroxide and hence reduces the pH of the slurry. The addition of carbon dioxide continues until the target pH is achieved.

$$CO_{2\,(g)} + Ca(OH)_{2\,(s)} \leftrightarrow CaCO_{3\,(s)} + H_2O_{(l)}$$

ΔH_f = (-393.5) (-986.6) (-1207.4) (-285.8) ΔH_r = (-113.5) kJ/mol

In the case of carbon dioxide being added to the reaction vessel, Castle will purchase carbon dioxide that is generated as a byproduct of waste processes such as anaerobic digestion (AD) or landfill of waste. The carbon dioxide generated from these sources is known as biogenic. In the case of AD, where a plant generated a biomethane stream for injection into the grid, it is necessary to purify the methane, this requires the removal of carbon dioxide which makes up approximately 40% of the volume of off gasses generated by the AD process. Whilst a number of AD plant capture this waste CO2, the majority do not, and it is released to atmosphere. [redacted]

In each case, once the target pH has been achieved within the reaction vessel, the slurry is pumped to the filterpress where it is initially dewatered. The dewatered solids undergo a washing and drying step within the filterpress.

The dry solid cake is then transferred directly from the press into road transport vehicles or skips and removed from site.

Atmospheric carbon dioxide

In addition to carbon dioxide injection into the reaction vessel, it should also be noted that a non-neutralised or partially neutralised filter cake will naturally adsorb carbon dioxide from the atmosphere in accordance with the above reaction scheme. It is possible to determine the degree of CO_2 adsorbed by weathering by laboratory analysis.

This is a widely understood process generally known as 'weathering'. It is the process that results in the pH of Incinerator Bottom Ash (IBA) falling from >12 to circa 9 as part of the process of generating Incinerator Bottom Ash Aggregate (IBAA).

Filtrate treatment

Depending upon the degree of carbonation, the filtrate generated from the washing process may require additional treatment in order to achieve the specification of the trade effluent discharge consent. Although the total alkalinity of such filtrate is very low, the pH will often be outside the range permissible for direct sewer discharge. Filtrate may also be generated that is suitable for third party use / treatment.

Filtrate will initially be captured within storage tank Tank 8. From here, the effluent can either be added directly to one of the aqueous treatment reaction tanks R1 or R2, or it can be utilised in the slurrying of other alkaline powders to generate a slurry for treatment via the aqueous treatment process. Utilising the material as a slurrying aid serves to reduce the demand for mains water.

In all cases, pH adjustment will occur in one of the reaction vessels and will be achieved by the addition of acidic wastes, either from bulk storage tanks or from batches of containerised wastes. The pH adjustment will cause some precipitation to occur in addition to the solids precipitated from the treatment of the alkaline powder slurry and acids. The batch will be prepared to a target specification, once achieved, the slurry will be directed through the aqueous treatment press. The solids from this process will be collected in a roll-on-off skip beneath the press. The effluent will initially be collected in a small filtrate bath, before transfer to an effluent holding tank. Samples of effluent are collected during treatment to ensure it has hit the target specification.

Further details on this process are contained within document 2.3.2.8 'Aqueous Waste Treatment Process'.

Environmental Permitting:

The APC Treatment Process is operated under Environmental Permit LP3337ML (the permit).

The schedule 1 listed activities (as per the PPC regulations) granted by the permit with respect to the APC Treatment Process are:

- S5.3 A(1) (a)(ii) – The recovery or disposal of hazardous waste.

  (including Waste Framework Directive Annex IIA and IIB operations):

D9	Physico chemical treatment including storage of residues.
D13	Blending or mixing prior to submission of the operations numbered D1 to D12
D14	Repackaging prior to submission to any of the operations numbered D1 to D13
D15	Storage pending D9
R5	Recycling/reclamation of inorganic materials
R7	Recovery of components used for pollution abatement

and

- Section 5.4 Part A (1) (b) Recovery or a mix of recovery and disposal of non-hazardous waste.

(including Waste Framework Directive Annex IIA and IIB operations):

D9	Physico chemical treatment including storage of residues.
D13	Blending or mixing prior to submission of the operations numbered D1 to D12
D14	Repackaging prior to submission to any of the operations numbered D1 to D13
D15	Storage pending D9
R5	Recycling/reclamation of inorganic materials
R7	Recovery of components used for pollution abatement

Operation of the Process also utilises the following Directly Associated Activity (DAA):

- D6 – Release to sewer from blending of aqueous effluents

The list of permitted waste types for the Hazardous Waste Recycling Process is given in table S2.4 and S2.5 of the permit.

Ancillary Plant:

Below is a list of the main items of plant that make up the hazardous waste treatment process. They are marked site layout plan P2326-LAYOUT-001 which is contained within Appendix 1. Location references are indicated in parentheses below.

Bulk powder storage:

All powder inputs to the APC Treatment Process are stored in a bulk silo designated Silo 2. (Ref 28)

The residues are transported to site in appropriately designed powder tankers. The residues are blown into the silo under pressure generated by the tanker.

Silo 2 has an 110 cubic metre capacity (3.5m diameter, 8.0m body length plus coned bottom).

The silo is fitted with reverse jet filter system and a pressure/vacuum relief valve.

The silo is fitted with level indication equipment linked to an automated audible alarm system and linked to an automated shut off valve.

The silo is fitted with pressure sensors which are linked to an audible alarm and will trigger an automated value to prevent over pressurisation of the silo.

The silo also benefits from emergency venting arrangements via a pressure relief valve.

The silo is fitted with load cells which are uses to measure fill weights, values are fed into the process PLC.

Powders are transferred directly to slurry tanks B1 & B2 vessel Silo 2 by means of a screw conveyor (the auger).

Slurry tanks

There are two slurry holding tanks in place at the Cardiff site, B1 and B2, (Ref 16, 17). These are both 19 cubic metre tanks of mild steel construction. Each of the tanks are fed alkaline powder from powder storage silo 2 by a screw feed auger.

Liquids may be added to the tanks from various holding vessels. Tank B1, which is dedicated to this process can receive inputs of either mains water or recycled treated effluent from tanks T6 or T8 respectively.

Both tanks are fitted with a large stirrer in order to maintain the solids in the slurry form.

Both tanks are fitted with pressure/vac relief. Level transmitters are installed and connected to independent high-level alarms.

Batches are prepared utilising the process PLC and making use of the various I/O available from the feed and input values.

Reactor vessel

The process has a dedicated reaction vessel named the Press Feed Tank (PFT) (Ref 18), this is a 30 cubic metre tank of stainless steel construction. The tank is fitted with a mixer, pressure/vacuum relief,level indication and pressure transmitter. The vessel feeds slurry to the filter press via a variable speed warman pump controlled by the process PLC.

Bulk water storage:

Mains water is used for the cross-wash cycle of the filter press system and also may be used as make up water for the slurrying stage.

The press wash cycle is fed from a bulk water storage tank designated T6 (Ref 22).

T6 is a HDPE tank of 10 cubic metre capacity.

Bulk alkali/effluent storage:

The alkali effluent generated from the washing process is stored in tank T8 (Ref 21). Tank 8 is a stainless steel construction with a capacity of 40 cubic meters. The effluent stored within this tank may be reused in the slurrying stage where it is deemed suitable. Spend effluent will be transferred from this tank into the aqueous waste treatment process. The tank is fitted with level indication linked to audible alarms along with pressure / vacuum relief.

Bulk acid storage:

The PFT tank may be dosed with acid where a reduced pH solid residue is required. In this case, acid may be transferred from one of the bulk storage tanks T13, T14, T15 (Ref 24, 25, 26). Each is a 33 cubic metre HDPE tank. Additions are controlled by PLC and all additional undergo modelling in the laboratory to ensure a known and specified volume is added.

Carbon Dioxide Storage:

Product liquified carbon dioxide will be stored in tank C1 (Ref 33). This is a vehicle tank with capacity to hold 24 tonnes of material. The tank is provided on a hire agreement from a specialist company. The tank is sited on a purpose designed civils infrastructure located within Yard 5 of the Cardiff site. Filling will be by specialist road tanker with a specific offloading point located in Yard 5. Liquified carbon dioxide will pass through a vaporiser. [redacted]

Filter-press:

The press in place at Castle Cardiff is a recess and membrane filter press. It is located in press house (Ref 6).

The press is fitted with a membrane squeeze facility to optimise the de-watering capability. Every second filter has an integral membrane that can be pressurised by the external air supply. This membrane, when pressurised, squeezes the adjacent filter cake to press additional filtrate water out of the cake.

The press installation includes a hydraulic power unit. This is used to operate the press clamp cylinder (open/close filter pack), turn the plate shifter hydraulic motor (forward/reverse) and to extend and maintain chain tension on the tensioning cylinder.

Operations of the press not controlled by the hydraulic system are controlled by the external compressed air system. This air system is used to control operations including cross blow, core blow and membrane squeeze. A secondary compressor is used for instrumentation and control such as the operation of actuated valves.

All plant operations are programmed and controlled from the control panel situated beside the press in the press house structure, there is a second HMI which allows some limited functionality located within the process area bund. The control panel also houses the emergency stop trigger which may be used to cease all plant operations instantly in the event of an emergency.

The Press is fed by the variable speed drive (VSD) pump detailed above. The VSD is controlled based on the backpressure presented by the press as it fills.

As the slurry is fed to the press under pressure, the solids are collected by the filter cloths and trapped in the recesses between the plates. The aqueous filtrate is forced through the cloths and is discharged from the press.

Once full, the press is left under maximum pressure for such a time as to allow consolidation of the cake.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

On completion [redacted] the pack of filter plates is opened to allow the filter cake to drop into a vehicle (or skip) below the press. Each plate in the pack is opened individually to drop out the filter cake. The filter cloth is then inspected and manually scraped to remove any residual filter cake from the cloth. This is repeated for each plate with the effect of transferring the pack of filter plates from one end of the filter to the other.

Once the press has been emptied of filter cake, all the filter plates will have been transferred to the clamp end of the press. The hydraulic cylinder then closes the press.

Once the press is closed the filter is then ready for refilling with slurry.

Process control:

Batching of carbon dioxide is achieved by a small modular siemens PLC which allows the operator to set batch recipes and monitor key process parameters. [redacted] In process sampling and analysis is undertaken to ensure key parameters are achieved.

Addition of acids is controlled by sampling, analysis, modelling and assessment undertaken by site chemists. Volumes of material added are then controlled by monitoring changes in tank levels to ensure correct volumes of material are added. The washing process is operated via an Allen Bradley PLC. There are two HMIs that can be used to access the controls and make batches.

The PLC sequences the various steps within the batch preparation and treatment process. There are various parameters that can be edited in order to optimise the process depending upon the variability of individual process inputs. For example, the membrane squeeze pressures, wash volumes and dry time can all be optimised for different wastes.

The PLC also manages the safe / unsafe conditions for the process with all alarms routed via the panel to sounders located in the process area. There are hard safety locks integral in the panel such as trapped key interlocks which prevent access to dangerous parts of the filter press whilst it is in operation. The e-stop circuit also runs through the panel.

Front end control:

The APC treatment process operates under a rigorous system of front-end control that regulates inputs such that all treatment targets are consistently achieved.

All waste streams are subject to full technical assessment at the pre-acceptance stage.

Waste streams may be excluded from the process based on physical/chemical characteristics.

Upon arrival to site all wastes are subject to laboratory analysis, confirming their suitability for the proposed treatment route. The analytical suite conducted is tailored to each specific waste stream however as a minimum, wastes assigned hazard codes as irritant, or corrosive are subject to total alkalinity/acidity (as appropriate) prior to processing in order to ensure that the strength of acid/alkaline is with the working parameters of the plant.

Each neutralisation/treatment batch is modelled on laboratory scale prior to full scale processing.

Control of any liquid alkaline feed stock is maintained by the use of a make-up tank. Suitable alkaline waste streams are bulked into the make-up tank in order to maintain a consistent input.

Reaction monitoring:

The Hazardous Waste Recycling process incorporates electrically powered equipment that is controlled by programmable logic control (PLC) systems.

Due to the nature of the environment within the reaction vessels, pH probes do not survive for a practicable period of time. Hence, continuous pH monitoring is not feasible. Both tanks are fitted with sampling points facilitating a spot-checking system to verify pH of the contents any anytime.

Both reaction vessels are fitted with level indication equipment and linked to audible high level alarm sirens.

There is also a pressure/vacuum release vent incorporated into each reaction vessel. The sizing of pressure / vacuum venting is in accordance with a venting study conducted by third-party chemical engineer.

Residue Analysis:

Samples of solid residues are collected from the holding skips. Samples are taken at random from a number of locations and are used to generate a composite sample.

Samples are labelled and despatched to a laboratory for testing. Laboratories used include the on-site laboratory, other laboratories within group and third-party external laboratories.

The analysis undertaken is targeted to ensure the material is able to achieve the specification of the receiving facility. Typical test may include, pH, moisture, alkalinity, metal ion content, anion content.

Outputs

Aggregate replacement

The process has the capacity to generate a filter cake that can be utilised as a replacement for fines aggregate in the construction industry. This material has been assessed to achieve end of waste status subject to achieving a defined product specification. The material is suitable for use in bound applications. The material is dispatched to customers as a product with all deliveries to third parties requiring a delivery note detailing the transfer. The material is not sold to members of the public and is only provided to trusted third party partners.

Waste output

Where the process aims to generate a waste product, either a hazardous or a non-hazardous final specification can be targeted. The hazardous / non-hazardous status is dependant on the concentration of dangerous substances within the solid residue. The material is assessed in accordance with Environment Agency guidance document WM3 to determine whether the material is hazardous or not.

The waste residue may be disposed of to landfill, either non-hazardous or hazardous depending upon the process inputs, process target and confirmatory analysis and assessment. It may also be used by third parties in recycling or recovery processes. Where this is the case a specification and suite of analysis will be generated to ensure suitability. This analysis will be undertaken in addition to an assessment of hazardous properties to ensure the waste is suitable for acceptance by any third party.

Aqueous effluent

Aqueous fractions collected from the dewatering operations are either transferred to the final effluent holding tank, are re-used in the process or undergo further treatment prior to transfer to the final effluent tank. Effluents discharged to sewer under the terms of a trade effluent agreement but may also be investigated for alternative uses where deemed appropriate.

Appendix 1 - Process Flow Document P2403-PFD-001

[redacted]

Appendix 2 – P2403-LAYOUT-001