Caulmert Limited

Engineering, Environmental & Planning Consultancy Services

Knottingley Waste to Resource Facility

FCC Recycling (UK) Limited

Environmental Permit Variation Application

Process Description and BAT Review for the Physico-chemical and Biological Treatment of Leachate and Aqueous Wastes

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DISCLAIMER

Process Description and BAT Review for the Physico-chemical and Biological Treatment of Leachate and Aqueous Wastes

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1.0 INTRODUCTION

1.1 Overview

1.1.1 FCC Recycling (UK) Limited ('the Operator') (a subsidiary of FCC Environment (UK) Limited) have appointed Caulmert Limited to prepare an environmental permit variation application to vary its existing permit ref. EPR/JP3547JL to include additional activities at the Knottingley Waste to Resource Facility on Weeland Road, Knottingley, West Yorkshire, at postcode WF11 8DZ (hereafter referred to as 'the Site').

1.1.2 FCC Recycling (UK) Limited currently operates the Knottingley Waste to Resource Facility, which is dedicated to the storage, transfer, treatment, and recovery of industrial wastes. The site is located in Knottingley occupying a location historically associated with chemical processing, notably coal tar and related products dating back to the mid-Victorian era. The site falls within a larger area previously occupied by coal tar processing activities (to the East and West), now a mix of industrial and low-grade agricultural land. The Bank Dole Cut and Lock (part of Aire and Calder Navigation canal) and the River Aire lies to the North, and the A645 road to the South. Approximately 300m to the West, over the canal, lies an industrial area including a glassworks beyond which are residential areas.

1.1.3 The Operator proposes adding new activities to the existing permit, consisting of physico-chemical and biological treatment of landfill leachate and other aqueous wastes imported to site. This will involve reverse osmosis (RO) and biological treatment plants, ammonia recovery unit, including ultrafiltration and nanofiltration, with the resultant treated effluent discharged to sewer or surface water where appropriate.

1.1.4 The leachate and aqueous waste treatment activities will be a self-contained treatment operation carried out within fully bunded areas in the following plants:

- Two reverse osmosis plants will cumulatively treat approx. 700 tonnes of imported leachate daily before discharging the permeate into the river. Concentrate from the RO process will then pass through an ammonia stripping plant to recover ammonia, where the remainder of the concentrate with less ammonium will undergo biological treatment followed by, where required, ultrafiltration and nanofiltration before discharge to sewer. There will be a point source emissions to surface water for the RO plants' permeate (combined with uncontaminated site surface waters) via the proposed discharge point 'SW1'. The existing discharge point to sewer will be used to discharge wastewater remaining after the ammonia recovery and biological treatment processes (permitted by the Trade Effluent Discharge Consent currently in place at the site (YW/973/93C).

- The biological treatment plant, which includes an ultrafiltration component (and may include nanofiltration and activated carbon filtration components) will process approx. 300 tonnes of concentrate from the RO plants and directly received wastes per day. After initial biological treatment and ultrafiltration, the effluent will undergo further polishing if required (i.e. nanofiltration and/or carbon filtration) to produce an effluent that may be discharged to sewer following the Discharge Consent in place at the site or transferred off-site. These biological treatment processes employed are nitrification and de-nitrification, supported by ultrafiltration and nanofiltration if required and provision is made for dewatering of excess biomass using a decanter centrifuge.

- An ammonia recovery unit will pre-treat approx. 200 tonnes of landfill leachate, leachate concentrate from the RO installation, and similar ammonia-rich wastes daily prior to biological treatment. The process will involve thermal stripping of ammonia and scrubbing of the liberated ammonia and a concentration stage to generate a recovered ammonia solution which will be stored prior to transfer from site. The strength of this solution will be between 15 – 20 % wt/wt so as to be suitable for reuse. The contingency exists to remove the solution for further treatment or disposal if no user is available.

- The installation process is phased so that the RO units may be installed and the concentrate produced, subject to ammonia recovery, with the resulting wastewater available for biological treatment or tankered from site to a suitable treatment plant. Alternatively, if ammonia solution is desired not to be produced, the biological process can be used to treat RO concentrate without the ammonia removal.

- An option exists in the future to replace the biological treatment plant with a drying unit so as to convert the liquid waste into a solid waste and steam, the latter may be condensed and discharge as trade effluent. The solid waste may be subject to further processing on site as part of the physico-chemical treatment activities or removed from site to a suitable treatment facility. The drying unit may also incorporate the ammonia recovery activity.

1.2 Report Context

1.2.1 This report provides a process description and the Best Available Technique review of the following proposed waste treatment activities:

- **Leachate and Aqueous Wastes Treatment** – the physico-chemical and biological treatment of landfill leachate and similar aqueous wastes with a combination of reverse osmosis, ammonia recovery, biological treatment, ultrafiltration, nanofiltration, centrifugation and activated carbon or similar adsorption. The deployment of these processes will depend upon input composition and effluent quality requirements to achieve BAT for this activity. The combination of these techniques provides the following advantages:
  - Reverse osmosis delivers excellent effluent quality and is robust to changing feed quality;

- The use of an MBR results in a good quality effluent which if required, can be further polished by nanofiltration or activated carbon;
- The ammonia recovery stage creates a useful resource and reduces the complexity and reagent use for the final stage of biological treatment;
- Suitable effluents may be discharged to the river or sewer or, with other residues, removed from site for further treatment at a suitable facility elsewhere.

1.2.2 These activities involve the following listed activities:

- *Section 5.4 A(1)(a)(ii) 'Disposal of non-hazardous waste with a capacity exceeding 50 tonnes per day involving physical-chemical treatment;*
- *Section 5.4 A(1)(b)(i) 'Recovery or a mix of recovery and disposal of non-hazardous waste with a capacity exceeding 75 tonnes per day involving biological treatment'.*

1.2.3 The following waste operation is being proposed to be added to the leachate and aqueous waste treatment operation:

- *Physical treatment of non-hazardous waste for recovery – Ammonia stripping & scrubbing;*

1.3 BAT Assessment

1.3.1 The above operations are assessed in line with the following BAT conclusions and guidance:

- 'Best Available Techniques (BAT) Conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament and of the Council', from the Official Journal of the European Union;[1]
- Environment Agency (EA) guidance 'Chemical waste: appropriate measures for permitted facilities' published 18 November 2020.[2]

1.3.2 The technical standards for the proposed site operations against the relevant BAT Conclusions are detailed within this report, including the general process description for the treatment activities.

1.4 Additional Reports within this Permit Variation Application

1.4.1 The other activities to be added to the permit as part of this permit variation have been assessed against the relevant BAT and appropriate measures in the following reports:

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.208.01.0038.01.ENG&toc=OJ%3AL%3A2018%3A208%3ATOC
[2] https://www.gov.uk/guidance/chemical-waste-appropriate-measures-for-permitted-facilities

- 5827-CAU-XX-XX-RP-V-0306 – Process Description and BAT Review for RDF Preparation.

- 5827-CAU-XX-XX-RP-V-0308 - Process Description and BAT Review for the Physical and Physico-chemical Treatment of Aqueous and Inorganic Wastes, Solids and Sludges.

1.4.2 Other documents included as part of this application are as follows:

- 5827-CAU-XX-XX-RP-O-0300 H1 - Surface Water Pollution Risk Assessment (this also includes the Sewer Discharge Assessment as part of the H1 assessment);
- 5827-CAU-XX-XX-RP-V-0302 - Environmental Risk Assessment;
- 5827-CAU-XX-XX-RP-V-0310 - Odour Management Plan;
- 5827-CAU-XX-XX-RP-V-0311 - Noise Management Plan.

2.0 PROCESS DESCRIPTION

2.1 Waste Pre-acceptance and Waste Acceptance

2.1.1 Before any waste is accepted onto site, the site operator will complete a pre-acceptance assessment, which involves gathering information through an enquiry and a pre-acceptance evaluation of samples. The treatability assessment is particularly significant, as it confirms the characteristics and composition of the waste (requiring recovery or disposal) relevant to the process route. This process underscores an integral part of the waste acceptance process.

2.1.2 Following this, a waste acceptance phase begins, where all wastes are pre-booked/booked into the site, weighed using the on-site weighbridge, and directed to the tanker holding (see permit boundary plan - 5827-CAU-XX-XX-DR-V-1804 in the drawing section of this report for more details). The site operatives scrutinise the necessary documents, at which point the vehicle is either accepted or the load will be rejected. In report ref. 5827-CAU-XX-XX-RP-V-0308, more details on waste pre-acceptance and waste acceptance procedure are presented as part of the permit variation application.

2.1.3 Bulk waste in tankers are off-loaded in the designated areas following the relevant procedure for that particular activity.

2.2 Leachate and Aqueous Waste Treatment

2.2.1 As mentioned in **Section 1.1.4** above, the Operator proposes to install two reverse osmosis treatment plants, an ammonia recovery unit and a biological treatment plant with ultrafiltration and nanofiltration plants, to treat non-hazardous leachate and aqueous wastes brought onto the site following waste acceptance, having undergone the necessary waste pre-acceptance and waste acceptance assessment stages.

2.2.2 The process area referred to as Waste Processing 07 on the Sampling and Emissions Point Plan ref. 5827-CAU-XX-XX-DR-V-1809 will house two RO plants, one ultrafiltration and one nanofiltration plant linked to the biological treatment plant and an ammonia recovery unit. These activities will be carried out within the designated leachate and aqueous wastes treatment area which will be a self-contained aqueous leachate treatment operation with segregated bunded tank areas, a process building and process area.

2.2.3 The aim of these processes is to treat landfill leachate and similar aqueous wastes in order to remove ammonia, biodegradable organic components as well as trace metals, to produce an effluent that may be discharged to sewer (permitted under the existing Discharge Consent in place), or to surface water (in the case of the RO plants' permeate), or for reuse in other processes. See the schematic process flow diagram in **Figure 1** below. Where practicable, the process will include ammonia recovery from the received wastes so as to recover an ammonia solution for reuse by end users.

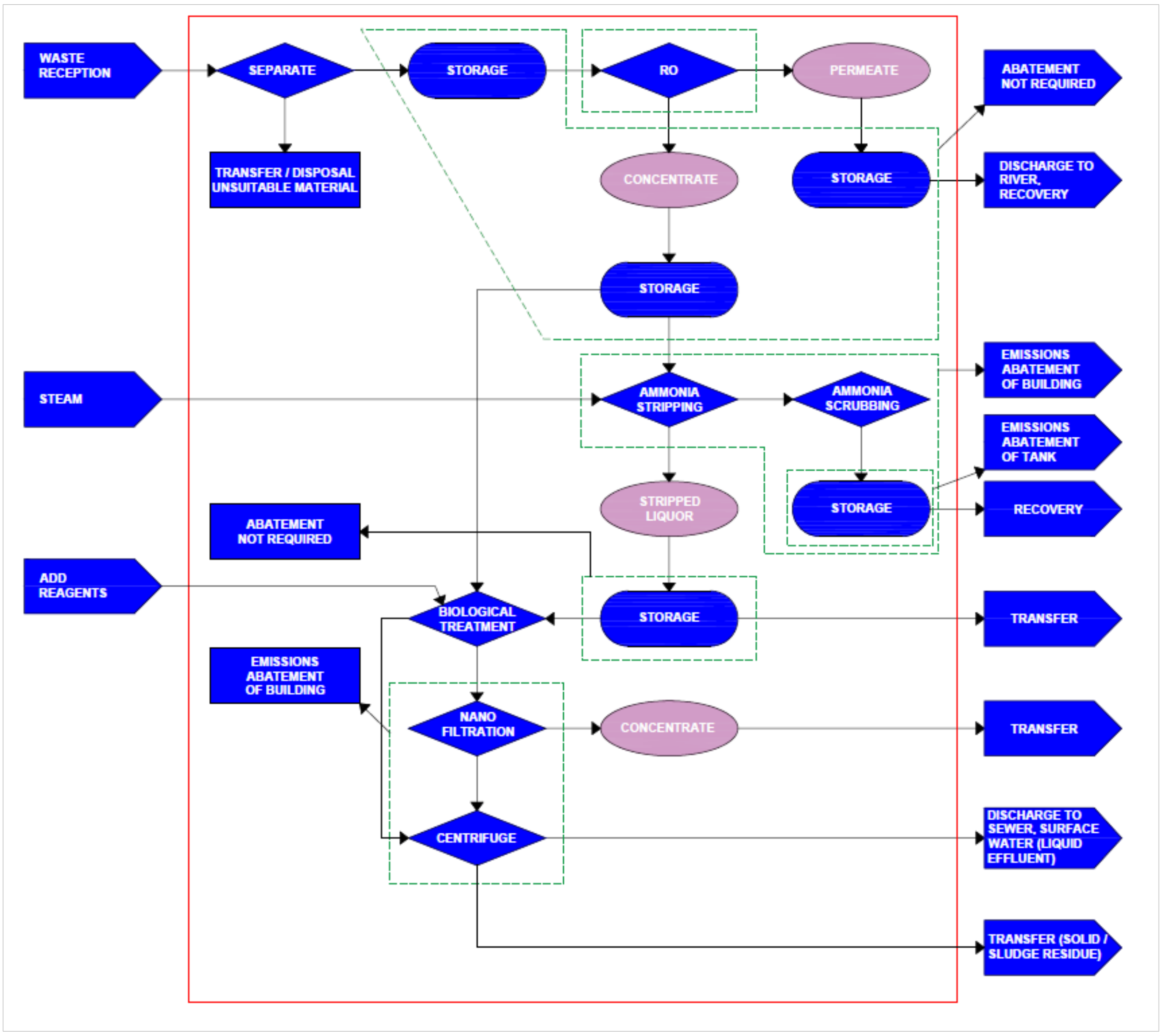

Figure 1: Schematic Flow Diagram for the Leachate and Aqueous Waste Treatment Process Outputs.

2.2.4 The proposed leachate and aqueous waste treatment area will have one stack emission point (i.e., EP07) as indicated on Sampling and Emissions Point Plan – Waste Processing 07 (ref. 5827-CAU-XX-XX-DR-V-1809) showing the various infrastructure within the LTP-T1 and one air handling unit (with Tag No. P07-AP-01) equipped with carbon filter, responsible for regulating and distributing air throughout the building. **Table 1** below summarises the list of tanks, their capacities and emission points for the proposed self-contained aqueous leachate treatment operation.

2.2.5 A balance tank (i.e., P07-TP-01) will be provided for the leachate and aqueous waste treatment processes. The tank's design will meet the relevant plants' requirements according to the sequence of operation, helping to even out variations in leachate quality and buffer fluctuations in inlet flow, thereby ensuring a consistent feed for the treatment plants.

Table 1: List of Tanks within the proposed Leachate and Aqueous Waste Treatment area (Waste Processing 07).

Item purpose	Item type/function	Capacity	Tag Number[3]	Emission Points[4]
Process	Leachate Treatment building	n/a	P07-ZP-1 1	n/a
Storage	Discharge tank	435m^3	P07-TS-0 3	EP56
Storage	Offload tank	600m^3	P07-TS-0 2	EP57
Storage	Offload tank	600m^3	P07-TS-0 1	EP58
Process	Denitrification tank	180m^3	P07-TP-1 1	EP59
Process	Balance tank	250m^3	P07-TP-0 1	EP60
Process	Denitrification tank	180m^3	P07-TP-2 1	EP61
Process	Nitrification tank	500m^3	P07-TP-1 2	EP62
Process	Nitrification tank	500m^3	P07-TP-2 2	EP63
Process	Nitrification tank	500m^3	P07-TP-1 3	EP64
Process	Nitrification tank	500m^3	P07-TP-2 3	EP65
Process	Post Denitrification tank	50m^3	P07-TP-1 5	EP66
Process	Post Aeration tank	180m^3	P07-TP-1 4	EP67
Process	Post Aeration tank	180m^3	P07-TP-2 4	EP68
Process	Post Denitrification tank	50m^3	P07-TP-2 5	EP69
Storage	Ammonia Solution tank	50m^3	P07-TS-0 6	EP70
Process	Scrubbing column	n/a	P07-TP-3 2	EP71
Storage	Acetic Acid tank	30m^3	P07-TS-0 4	n/a
Storage	Sulphuric Acid tank	30m^3	P07-TS-0 5	n/a
Process	Stripping column	n/a	P07-TP-3 1	n/a
Process	Concentrating column	n/a	P07-TP-3 3	n/a
Process	Humidification vessel	n/a	P07-TP-3 4	n/a
Process	Air Handling Unit	n/a	P07-AP-0 1	EP07

2.3 Context of Reverse Osmosis

2.3.1 The Operator intends to install two RO plants at the Knottingley Waste to Resource Facility on Weeland Road, Knottingley, West Yorkshire, to facilitate the treatment of non-hazardous leachate to remove organic and inorganic contaminants.

2.3.2 The RO plants will be a 3-stage filtration process to meet the effluent quality required for discharge to river, based on the expected contamination levels to be dealt with and minimising electricity and reagent use. The operator already employs this technology for this use in preparing effluents from landfill leachates for surface water and sewer discharges at other sites. These plants will be capable of achieving clean and consistent permeate quality, which will be suitable for discharge to river .

[3] *Refer to Knottingley Equipment Tag spreadsheet in **Appendix 2** of this report for the associated item type in the Permit Boundary Plan ref. 5827-CAU-XX-XX-RP-V-1804.*

[4] *See **Appendix 3** of this report for emission points and their corresponding grid references*

2.3.3 The proposed the RO plants at Knottingley will be similar in scale and operations to the treatment capabilities of the RO Plant at the Dogsthorpe facility and the biological treatment plant at Marstonvale, therefore the permeate (Dogsthorpe facility) and effluent (Marstonvale facility) were reviewed to assess and identify pollutants that may be released from the RO treatment plants, post treatment discharge. See **Table 2** below for the parameters assessed to be present within the RO plant discharge. A full detail of the results is discussed in the H1 assessment (see report. ref 5827-CAU-XX-XX-RP-O-0300). The maximum concentration of each parameter was included within the assessment as a worst-case scenario.

Table 2: Parameters assessed to be present within the RO plant discharge.

Parameter	Concentration (ug/l)		EQS-AA (ug/l)
	Avg.	Max	
Ammoniacal Nitrogen	1270	4000	620
Chloride	2600	13000	250000
Arsenic	4	20	50
Cadmium	0.08	0.2	0.09
Chromium	2.5	4	4.7
Copper*	7	48	1
Iron	17	70	1000
Zinc*	22.4	227	13.8
Phosphate	34.6	170	113
Sulphate	5300	10000	400000

*Bioavailable EQS

2.3.4 **Table 3** is an indicative discharge concentration of RO permeate and uncontaminated (clean) site surface water (combined) before discharge into the river. These values reflect surface water worst case scenarios (e.g., due to storm conditions) with no permeate present.

Table 3: Indicative discharge concentration of RO permeate and clean site surface water combined

Parameter	Concentration (mg/l)*
Chloride	200
Suspended solids	50
Phosphate	1
Sulphate	100
Arsenic	0.1
Cadmium	0.1
Chromium	0.3
Copper	0.5
Iron	-
BOD	-
Zinc	2

*Maximum values have been quoted

2.4 Approach to the selection of RO Treatment Plant

2.4.1 The attached 'Technical Proposal' in **Appendix 1** is provided as an indicative Reverse Osmosis (RO) Plant only and the proposed scheme may be this, or similar.

2.4.2 The selection of wastewater management options by the Operator has, in accordance with the principles outlined in BAT Reference document for Waste Treatment, IED, 2010/75/EU IPPC (updated October 2018), been based on thorough characterisation of the non-hazardous leachate and assessment of the most appropriate treatment option for the leachate, taking into account leachate quality data to-date, water balance calculations that provide predictions for future waste water production, the site setting, physical constraints on the site, costs, and the proposed receiving river for the permeate discharge.

2.4.3 Reverse Osmosis (RO) is regarded in BAT Reference document for Waste Treatment, IED, 2010.75/EU IPPC (updated October 2018) and the SGN5.06 Guidance document as:

"the finest physical separation method known in contrast to normal filtration where solids are eliminated from a liquid, reverse osmosis succeeds in removing solutes."

2.4.4 The RO plant is a state-of-the-art membrane plant for leachate treatment and is characterized by a high degree of automatization. As a technology, RO is well established in wastewater treatment applications where the RO membranes can retain >98% of large molecules dissolved in waste waters and are frequently used in waste and potable water desalination operations.

2.4.5 Both plants will be designed to cumulatively treat up to 700 tonnes per day of non-hazardous leachate and will operate continuously for 24-hours and capable of expected annual throughput of ~255,000 tonnes per year in total. In practice, throughput is dictated by availability of inputs and maintenance periods.

Leachate Characterisation

2.4.6 The proposed reverse osmosis units will treat imported landfill leachate that will be well-characterised. Quality data of the raw leachate will be obtained and assessed during the pre-acceptance and waste acceptance stage, where necessary, further sampling and testing of the waste load will be conducted by the laboratory chemist to assess suitability and process route.

2.4.7 The removal rates within the RO Plants (based on the treatment capabilities within a similar sized RO Plant at FCC-operated Dogsthorpe site) was applied to the data within the H1 Assessment (document ref. 5827-CAU-XX-XX-RP-O-0300) to ascertain if the treated leachate (permeate) can be discharged to river.

2.4.8 The most common leachate indicator parameters were ammoniacal nitrogen and chloride. Ammoniacal nitrogen concentrations within the permeate were reported at a maximum of 4 mg/l and an average of 1.27 mg/l. The average concentration of this parameter within the raw leachate was 805 mg/l and a maximum of 1520 mg/l, which indicates after treatment in the RO plant, the removal rate for ammoniacal nitrogen was approximately between 99.7% and 99.8%.

2.4.9 Chloride concentrations within the permeate recorded an average concentration of 2.6 mg/l and a maximum of 13 mg/l. It was observed that chloride was often detected below the detection limit (<1 mg/l) within the permeate (32 out of 52 samples). The raw leachate reported an average concentration of 1317 mg/l and maximum of 2110 mg/l, this indicated a removal rate approximately between 99.4% and 99.8% within the RO plant.

2.4.10 As part of the H1 Assessment, a number of parameters were screened out following treatment at the RO plants, prior to the surface water screening assessment, as concentrations were below the relevant EQS values before discharge into the river. All other parameters passed the surface water assessment and therefore, this assessment demonstrated that concentrations within the discharge are acceptable with respect to the Surface Water Pollution Assessment Methodology.

2.5 Principles of the reverse osmosis treatment process

2.5.1 Reverse osmosis is a technique well-established in wastewater treatment applications which aims to extract clean water from aqueous solution of organic and inorganic contaminants found in wastewaters. The technique is also used for the desalination of saline or seawaters to produce potable water.

2.5.2 The process is designed around the natural osmosis principles that facilitate movement of dilute solutions across a semi-permeable membrane into a higher concentrated solution on the opposite side of the membrane until both solutions display the same concentration.

2.5.3 In reverse osmosis, pressure is applied to the run-off against a semi-permeable membrane forcing water molecules through the membrane to form a clean ‘permeate’ solution. The solutes or contaminants that are retained are collected as a ‘concentrate’ for further treatment or disposal.

2.6 RO Plant design selection

2.6.1 The proposed technology aims to effectively treat the non-hazardous leachate to produce clean permeate before discharging to the river; the anticipated influent and required effluent concentrations will be crucial in designing the proposed plants.

2.6.2 The operator is proposing to install two reverse osmosis systems similar to plants successfully operating at other FCC sites within the United Kingdom.

2.7 RO Plant size calculations

2.7.1 The RO plants will be designed for the treatment of predicted non-hazardous leachate that will be imported onto the Knottingley Site to produce a permeate that can be discharged into the river.

2.7.2 Their design treatment capacity will be up to 300 tonnes per day (equivalent to approximately 300 m^3 per day) each, and a maximum operating pressure of 80 bar. The RO plants will treat non-hazardous leachate primarily to reduce chloride and ammoniacal nitrogen and also metals which are present at much lower levels.

2.7.3 In light of the imported leachate strength/composition and destination of the permeate (river), the manufacturer of the RO plants have specified that a 3-stage RO plant will be required, with three purification stages to treat the leachate and guarantee a high permeate quality for discharge into the river.

2.8 RO Plant design details

2.8.1 The RO plants will treat leachate imported from other sites. A flow diagram illustrating the reverse osmosis process, based on the indicative proposal in **Appendix 1**, is provided in Figure 2 below.

2.8.2 The RO plants are a state-of-the-art membrane plant for wastewater treatment and characterized by a high degree of automatization

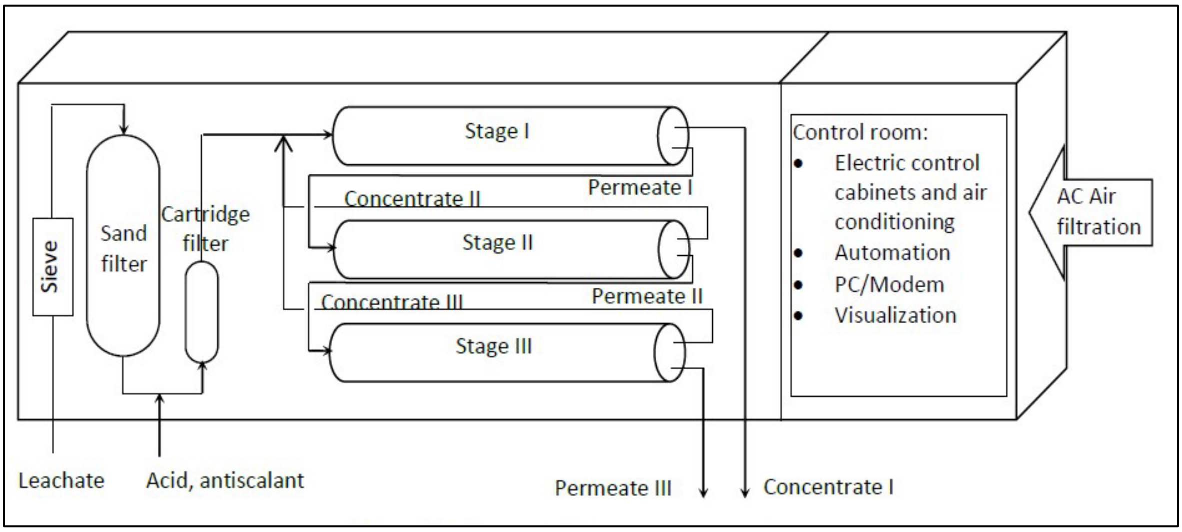

Figure 2: Schematic of a 3-stage Containerised Reverse Osmosis System.

Input Quality

2.8.3 The input quality of leachate to be brought onto sit to meet the indicative design specification of the proposed RO plants is as follows:

- Quantity of imported leachate - 700 T/d
- COD - 6000 mg/l
- Ammonia - 2000 mg/l
- Conductivity - 21,500 µS/cm

Treatment Stages

2.8.4 The main treatment stages that will be integrated in the RO plants container are as follows:

- Sieve with a 1.5mm mesh
- Pre-filtration by a pressurised sand filter
- Control of pH by dosing of sulphuric acid
- Addition of antiscalent
- Pre-filtration by microfiltration 10µm (1-10µm)
- 1st stage of Reverse Osmosis
- 2nd Stage of Reverse Osmosis
- 3rd Stage of Reverse Osmosis

2.8.5 To control the quality of permeate at the outlet, the conductivity value will be measured inline. The permeate can be discharged to the environment, or alternatively be used for irrigation or as process water, etc.

Pre-Filtration

2.8.6 Based on the indicative proposal in **Appendix 1**, as a pre-treatment and for the protection of the pumps and membranes, there will be a sieve with a 1.5mm mesh, a sand filtration stage and two microfiltration stations. Sand filtration will be carried out in pressurized filters. The sand filters will be cleaned by applying a liquid (automatism included), the cleaning liquid is leachate. The frequency of cleaning of the filters will depend on the content of suspended solids in the leachate and is usually weekly.

2.8.7 After the sand filtration, there are two filtration stations with 10µm cartridge (microfiltration, porosity adjustable to the sort of leachate between 20 to 1µm) to avoid the entry of small particles which may damage the membranes. Each station takes various filtrating cartridges adapted on the size of the plant. In the case of blockage, a message appears on the system's screen. Replacement of cartridges is fast, simple, and economical and due to the parallel system, it can be executed during operation.

Chemical Dosing System

2.8.8 The chemicals that the RO plants will use in this process are to favour the ionic form of ammonia (other than the dissolved gas form) to allow effective removal, to subsequently, post filtration to bring the pH back to a near neutral level and cleaning chemicals, predominately antiscalents, to clean the membranes of inorganic scale, thus maintaining their efficiency:

- pH adjustment with acid
- pH adjustment with alkali
- Antiscalent

2.8.9 Acidification is done with 96-98% concentrated sulphuric acid, which is the most efficient means of achieving the aims. The transportation and dosage pump are integrated in the container. For safety reasons, the acid injecting system is completely sealed in a chemically resistant box and equipped with a overfill sensor that switches the system off, in case of a spillage.

2.8.10 The pH of the leachate entering the separation stages is controlled by the sulphuric acid dosage system, before passing through the membranes. The acid is injected directly into the piping with a dosing valve. The advantage of this solution is injection in a closed and pressurized system allows avoidance of production of foaming and strong odours.

2.8.11 The pH of effluent is raised by the use of sodium hydroxide solution.

2.8.12 During cleaning cycles, antiscalant and dispersant is added inline at a dosing station. Depending on the leachate composition, there are suitable products which are added to the process to improve the performance of the plant in terms of treatment, washing cycles and lifetime of the membranes.

2.8.13 The pre-treatment system is equipped with pressure, flow, conductivity, temperature, and pH sensors used for control and monitoring of the process.

Membrane System

2.8.14 The three stages of the Reverse Osmosis (RO) system are equipped with pressure sensors for process control. In case of a malfunction (under- or over-pressure), the process shuts down automatically. In addition, there is an over-pressure safety valve in the first stage to avoid damage to the system. The stages are as follows (and shown in **Figure 2**):

1st Stage

- Downstream the filtration stage, a piston pump increases the pressure according to the operating parameters (which depend on the characteristics of the leachate).
- Several membrane modules are installed in a high-pressure tube, forming a block. In addition, each block is equipped with a recirculation pump which maintains the velocity at a high level, and thus, a turbulent flow over the membrane surface, to reduce the effects of “scaling and fouling.” The high-pressure pump and a pneumatic pressure control valve create and control the pressure inside the blocks. The flow of the final concentrate is measured by an electromagnetic flow meter and controlled according to the adjusted efficiency by a special anti-cavitation pneumatic control valve with highly resistant satellite components. Depending on the type of operation, the plant can be controlled also by the pressure. Each block can be switched off separately (by-passed), to adapt the plant to different operating conditions.
- The concentrate that results from the first stage can be sent to a storage tank to await further processing, at the remaining pressure of the modules (max. 5bar).

2nd and 3rd Stage

- To ensure a proper treatment of the leachate and to guarantee the compliance of the limit values of the existing Trade Effluent Consent or Discharge Consent, the reverse osmosis system is equipped with a second and a third treatment stage
- The operation of the process of the 2nd stage is identical to the 1st stage, only that the pressure is naturally reduced due to the lower osmotic pressure (max. 35bar) in this 2nd stage.
- The concentrate of the 2nd stage is recirculated and sent to the inlet tank of the leachate in the inside of the container. This concentrate is treated together with the incoming leachate to maximise permeate production.
- In the final stage, further filtration takes place with permeate being collected and concentrate being returned to the start of the process.
- To ensure that there is no problem with the membrane system, the permeate is monitored at the outlet by the conductivity value which gives an early indication of membrane damage.

RO Plant Infrastructure

2.8.15 The self-contained aqueous leachate treatment area will have the following infrastructure:

- Two RO plants;
- Raw leachate reception tank that will feed directly into the plants;
- Wash and permeate tanks;
- Reagent tanks (i.e., for sulphuric and sodium hydroxide) (see **Table 1** in **Section 2.2.5** above for more details);
- A dosing station;
- Chemical storage (see Sampling and Emissions Point Plan - 5827-CAU-XX-XX-DR-V-1809 for a closer view of all the RO infrastructures within the LTP-T1 complex);
- Concentrate is collected in a tank with Tag No. P07-TP-01, for the next treatment stage;
- Bunded areas for all the listed tanks, pipework and manifolds – minimum 110% of largest tank capacity with impermeable concrete surfacing (a kerbed concrete slab). Bunding and storage will comply with CIRIA C736. Details of the secondary containment calculations for the applicable tank capacity and bund associated with the relevant buildings has been provided in **Appendix 4** of this report;
- The plant will be designed for a minimum operational life of 20 years;
- All tanks and vessels will be appropriately labelled and clearly signed as to their contents and capacity, each given a unique identifier (e.g., tag number as shown in **Table 1** above). Labelling of tanks and process pipework will differentiate between waste water and raw process waters including direction of flow;
- Emergency showers are provided close to areas offloading or handling hazardous reagents.

Technical Description of the RO System

2.8.16 The RO technology works with semi permeable membranes and high pressure to separate the substances from the water. The pressure of the system must be higher than the osmotic pressure caused by the total dissolved salts (TDS) in the leachate in order for the purified water to pass through the membrane. The higher the salt content, the higher the required osmotic pressure with respect to the trans-membrane pressure of the system to achieve a high flux rate.

2.8.17 While water can pass through the membrane, organic substances and even small ions cannot pass through and will be rejected. The leachate will be separated into cleaned water (permeate) and a highly concentrated reject aqueous solution (concentrate).

2.8.18 The raw leachate will be pumped from the storage tanks to small pH adjust tanks, which will be used for the injection of sulphuric acid. From the pH adjustment tanks, the run-off is fed to a sand filter stage to remove suspended solids that may be present in the leachate. From this process, the leachate is then put through a reverse osmosis process which means each litre of wastewater is filtered by a reverse osmosis membrane.

2.8.19 The RO plants will be completely automated with security systems capable of switching them off in the event of a problem arising, and all aspects of the process, including process parameters, can be monitored and controlled. All data will be registered by the on-board software.

2.8.20 In summary, the proposed system of reverse osmosis integrates a three-stage treatment process to ensure a high quality of the treated effluent and with a higher operating pressure, up to 80 bar, to optimize the permeate flow. The systems will be equipped with “wide spacer” spiral membranes. The three-stage purification process proposed has the advantage of being able to treat heavy loads of leachate and be more adaptable to future situations in terms of variations of flow and quality of the leachate effluent.

2.8.21 The feeding of the system consists of an external pump, placed inside the leachate reception tank and controlled by the reverse osmosis module. The leachate is pumped to the container by the external supply pump. The pump is controlled by the level signal of the leachate reception tank in the osmosis. The leachate enters the container, passes a sieve, and flows into the leachate reception tank which is equipped with two level-sensors: one sensor for controlling the feed pump and the other sensor to avoid spillages.

Cross-flow Filtration

2.8.22 Modern membrane processes are based on the “cross-flow” dynamic filtration, instead of the ordinary “dead-end” statistic filtration (see **Figure 3**). During the “cross-flow” filtration, there is a high flow (volume) of the liquid that passes through the filtering membrane, to avoid the accumulation of particles on the membrane surface. The cross-flow filtration is a process that separates the liquid flow at the entrance into two types of effluent: permeate and concentrate. The relationship between the two flows is the result of the concentration factor, one of the indicators of the separation efficiency.

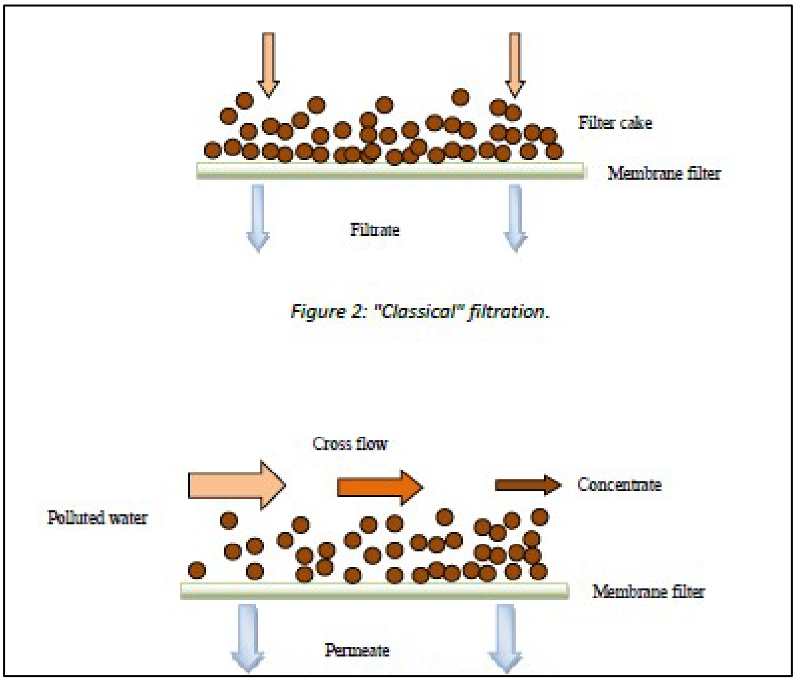

Figure 2: "Classical" filtration.

Figure 3: Cross-flow Filtration

Diffusion and Osmosis

2.8.23 The phenomenon of diffusion is defined as being a process in which different concentrations have the tendency to equilibrate and homogenise or mix together, because of the random movement of its components: atoms, molecules, or ions. If there is a separation of two liquids through one semi-permeable membrane with the selection only for the molecules of the solvent, the result is an unidirectional diffusion of the solvent through this semi-permeable membrane. The movement of the solvent molecules takes place via the membrane, in the direction of the more concentrated solution. The resulting pressure on the membrane is called **osmotic pressure**.

2.8.24 When a high pressure is applied on the solution, with high concentration, the solvent diffuses through the membrane, starting from the more concentrated solution to the more diluted. This process is called **reverse osmosis**. The membrane process by cross-flow filtration, based on this effect of the reverse osmosis, allows the separation of nearly 100% of molecules with a molecular weight higher than 100g/mol and between 95% and 99% of salt retention. Individual effects are depending on the form and charge of the molecules.

Types of Membranes

2.8.25 Membranes used in reverse osmosis systems have high selectivity, as they should retain nearly all dissolved substances, allowing only the diffusion of water molecules and a very small fraction of these substances. The retention amount depends on the type of substance, varying between 85 and 100%. The membranes normally used in leachate treatment are tubular, disk or spiral-type membranes.

2.8.26 Structurally, the spiral of the membrane is constructed by "gluing" the membrane sheets in the form of an envelope inserting the open side into a central tube. The permeate enters the space in the envelope-like form where it is conducted until the central tube. The channels in between the membrane sheets are created by the utilization of "spacers". The spiral membranes of "wide-spacer" type which are used in the proposed system show the best relation of price/handling/space/performance in the leachate treatment and are, for these reasons, selected for this RO system. The active material in the membrane surface is polyamide with a high mechanical and chemical resistance. There are several types of membrane surfaces which influence, specifically, the higher or lower salt passage. The used membranes are of the "high rejection" type (of salts) to improve the permeate quality.

2.8.27 Main characteristics and advantages of applied "wide-spacer" spiral membranes, compared to other current types include:

- Considerably lower replacement costs.
- Lower maintenance costs, due to the easy accessibility - fast control and change.
- Optimization of space, due to the good relation of membrane area/volume.
- Optimized hydraulic characteristics with a tangential flow at high velocity on the membrane surface, resulting in a turbulent flow.
- Reduction of the blocking risk (phenomena of "Fouling and Scaling"), resulting in a lower washing frequency and the increase of lifetime.
- The membrane type is a high rejection membrane to allow a better quality of the permeate.
- TFC (Thin film composite) - type with an active surface of polyamide, resistant to a wide temperature and pH range.

2.9 RO Flow

2.9.1 The RO plants will ensure an adequate treatment with a maximum entry flow at each plant of 350 m^3 per day (constant 24 hours per day) each of leachate. For the balance of the masses, the system will be calculated based on leachate with 21,500 µS/cm conductivity. The annual capacity of the system must be calculated by the availability which is typically 90%. The complete system is assembled in a 40-foot container. The plant can also accept leachate with different conductivity values, with adapted operating parameters.

2.10 RO Raw Materials

2.10.1 Raw materials will be required as part of the RO plant treatment process. Below is an indicative list of raw materials which will be used for the RO treatment process, including the overall leachate and aqueous waste treatment.

- Sodium hydroxide;
- Sulphuric acid;
- Cleaning chemicals.

2.10.2 The operator will select the least harmful products to use in the operation wherever possible.

2.10.3 The operator will keep Safety Data Sheets (SDS) for all products used and will monitor the quantity of materials used. This will provide data for regular reviews of raw materials usage.

2.11 Ammonia Recovery

2.11.1 The proposed process for treating leachate and aqueous waste includes an ammonia recovery stage (see Figure 1 in **Section 2.2** of this report for the schematic flow diagram). This will involve the treatment of concentrate from the reverse osmosis operation employing stripping and scrubbing to recover ammonia as a 15 – 20 % solution and the remaining wastewater, which contains less ammonia, will be processed in a biological treatment plant with a nanofiltration stage to produce an effluent that may be discharged to sewer or transferred off-site for further treatment.

2.11.2 The Operator plans to adopt the thermal ammonia recovery technology which requires heat, preferably waste-heat, though this is not proposed at the outset, during treatment to achieve over 98.5% ammonia removal from the leachate.[5]

2.11.3 The benefits of this technology are as follows:

- Low chemical requirements for operation. The only chemical addition required in normal circumstances is anti-foam agent measured in litres per day. Organic antifoam agents are used;

- Small footprint. The first plant commissioned in 1998 was able to remove 12 tonnes of ammonia per day in a single location of 20m by 20m;

- Predictable performance. As the system is based upon physical chemistry, there is no need to maintain bacterial colonies for performance;

- The materials selected can give long term, reliable duty

2.11.4 The proposed ammonia recovery will be a standalone system within the self-contained leachate and aqueous waste treatment complex.

2.11.5 Figures 4 and 5 below highlights the process flow configuration of the ammonia recovery and conversion to aqueous ammonia of the proposed LTP-T1 activities.

[5]Eden, R. *et al.* (2019) 'The Role of Ammonia Stripping in the Enhancement of Anaerobic Digestion ', *European Biosolids and Organic Resources Conference, 19th - 20th November, 2019* [Corresponding Author Email: keith.richardson@organics.co.uk].

2.11.6 Heated water will be passed directly into the top of the ammonia stripper column. From the base of the ammonia stripper, hot water will then be passed into a cooling tower, to reduce its temperature prior to release. A final cooling and heat recovery stage will be included to achieve the specific effluent temperature. It may be extended as an extra/over to produce lower temperatures, if required.

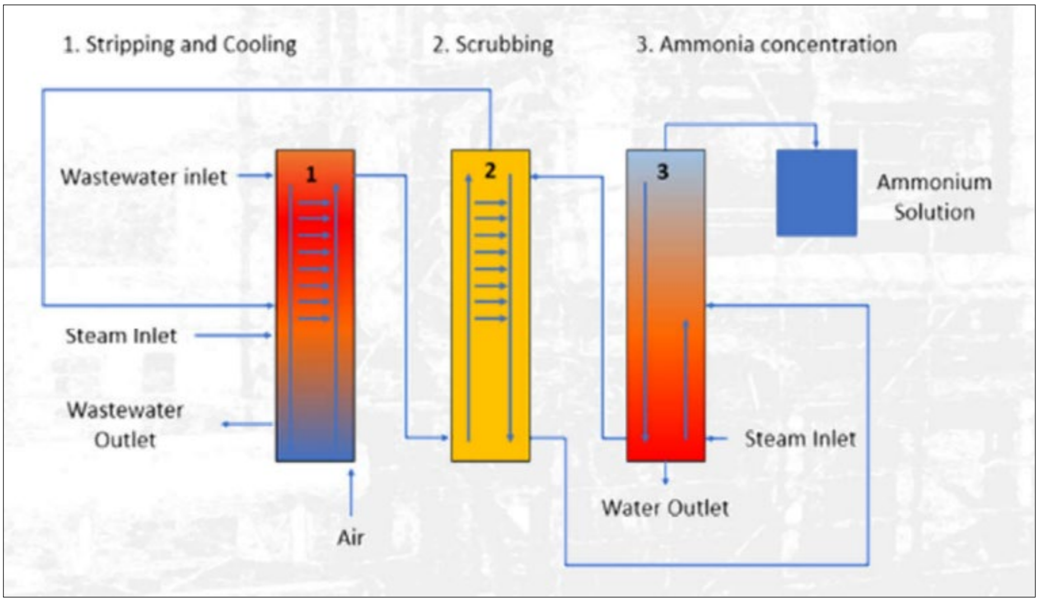

Figure 4: Process flow configuration of the proposed ammonia recovery facility.

2.11.7 Stripper-air will be drawn from the atmosphere and passed through the cooling tower into the ammonia stripper. Steam will be injected into the stripper-air after the cooling tower to bring the stripper-air to the correct operational conditions.

2.11.8 Ammoniated air will be drawn from the top of the ammonia stripper and passed through a condenser and cooled in the scrubbing column.

2.11.9 In the scrubbing column, cold water will be used to capture the ammonia and commence the process of concentration. Air from the scrubber is returned to the inlet of the stripper. It is not released to atmosphere. A small make-up air flow is drawing into the inlet to compensate for losses in the ammonia concentrator and vented gases. Vented gases are passed via a cold-water trap, followed by an acid trap, to ensure ammonia is not released to atmosphere.

2.11.10 Captured ammonia is then passed from the scrubber column to the concentrator column where it is taken to the final specified ammonia concentration.

2.11.11 Ammonium hydroxide liquid stored in suitable container (e.g., 50m^3 sized tanks per **Table 1 in Section 2.2** above) for transport off-site.

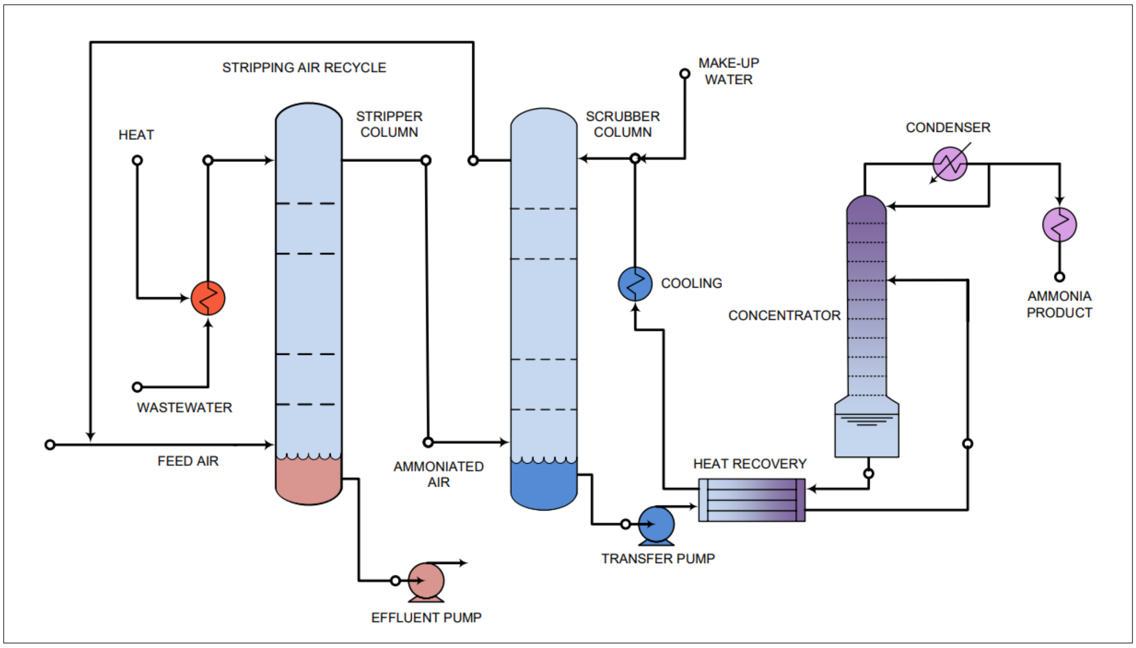

Figure 5: Process Flow Diagram of Aqueous Ammonia Product.

2.11.12 **Table 4** below summarises the key performance parameters for the proposed ammonia recovery operation.

Table 4: Design Parameters for ammonia recovery

Parameter		Value
Liquid flow rate		150 m^3/day
Influent concentration (NH_4)		6,000 mg/l
Effluent concentration (NH_4)		<150 mg/l
Effluent temperature		40 °C max
Influent pH		8.0
Ambient air temperature	Maximum	35 °C
	Minimum	0 °C
Relative humidity	Maximum	85 %
	Minimum	60 %
Product type		Ammonia hydroxide
Ammonia concentration		15 % to 20 %
Utility requirements		
Electricity		54 kWe
Heat		0.8 MW_{th}
Water		1 m^3/hour
Chemical requirements		
Antiform agent		0.5 litres/hour (organic biodegradable)

Theory behind Thermal Ammonia Stripping

2.11.13 Ammonia stripping involves passing a gas, usually air, through a liquid stream to release and remove ammonia gas. Because ammonia will typically be present as (NH_4^+) ion in wastewater (or effluent) at near-neutral pH levels, the bond of the ammonium ion will not break, thus preventing the release of ammonia gas, (NH_3) and making it remain "fixed" in the solution. To break the ammonium ion bond, either the pH or temperature of the waste water, or both, will need to be raised to facilitate the release of ammonia gas into the solution, which will be ready for removal.

Basic Equation

2.11.14 The equation governing the relationship between ammonia gas and the ammonium ion may be written as follows:

$$NH_4^+ + OH^- \leftrightarrow NH_3 + H_2O$$

2.11.15 As the temperature of the water increases, so the amount of free ammonia gas also increases.

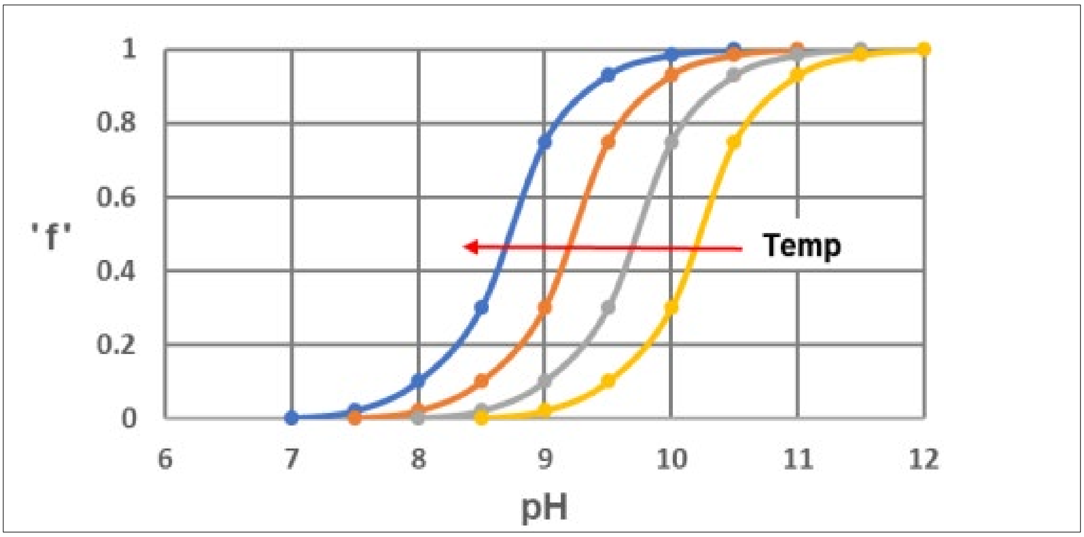

Figure 6: Relationship between pH, temperature and 'f'

Where 'f' represents the ratio of ammonia in the gas phase to the total ammoniacal nitrogen.

2.11.16 From the graph, the following reactions are taking place:

- The conversion of the ammonium ion to ammonia gas;
- The removal of the ammonia gas from the effluent by air-stripping/scrubbing.

2.11.17 Figure 6 depicts that as pH increases, the propensity of ammonia to occupy the gas phase also increases. However, the graph also shows that as temperature increases the gas phase can equally be achieved even at a neutral pH.

2.11.18 Often, air stripping of ammonia first requires a significant increase to the pH in order to remove the gas and then large amounts of air to strip off the ammonia, but by adding heat to the process, raising of the pH will not be required for typical waste water streams. As a result, relatively less air is required to remove the ammonia with the thermal ammonia stripping process. FCC believe the thermal route is the most appropriate technique and have selected this as their preferred technology.

Input Quality

2.11.19 The input quality of concentrate treated by the proposed RO plants prior to ammonia stripping to meet the indicative design specification of the proposed RO plants is as follows:

- Concentrate - 160 T/d
- COD - 18000 mg/l
- Ammonia - 6000 mg/l

2.11.20 The operation of the ammonia recovery facility will requirement the following equipment:

- Wastewater feed pump (in duty/standby configuration);
- Wastewater feed heater x 1(heat exchanger);
- Ammonia stripper column x 1 (stripper column, column packing, column insulation and packing cleaning systems);
- - Condenser heat recovery system x 1 (condenser to recover heat from ammoniated air into the wastewater, air blast cooler);
- Effluent heat recovery system x 1 (wastewater cooler/heat recovery unit, plate-type heat exchanger);
- Effluent cooling system (air blast cooler to ensure maximum discharge temperature);
- Waste heat boiler x 1 (steam generator, intermediary high pressure hot water circuits and equipment. safety valves, built to ASME code and third party approved by a recognised body);
- Air delivery and control x1 (suitably rater air blower, associated ducting, valves and controls);
- Scrubber column x 1 (scrubber column, column packing, column insulation, packing cleaning systems, feed water cooling systems);
- Ammonia concentrator column (Concentrator column, column trays, column insulation, tray cleaning systems, reboiler, condenser, reflux drum);

- Aqueous ammonia storage (correctly rate ammonia storage vessel with capacity for one day’s product and transfer facilities to transport container);
- Ancillaries (control valves, control panel, PLC, SCADA, instrumentation).

2.12 Principles of the biological treatment (BT) processes

2.12.1 As mentioned in **Section 1.1.4** of this report, the biological treatment plant, which includes an ultrafiltration stage and allows for nanofiltration and/or an activated carbon filtration component will process approx. 300 tonnes of wastewater per day to produce an effluent that may be discharged to sewer. This process will also involve nitrification, denitrification.

2.12.2 The effluent parameters must meet the Discharge Consent in place at the site, as well as those listed within the Industrial Emissions Directive Best Available Techniques Reference Document that have associated BAT-AELs (Acceptable Emission Limits) for indirect discharge to water for treatment of water based liquid waste. See Table 11 of the H1 Assessment report ref. which is part of this application document for a summary of the BAT-AELs for treatment of water-based liquid waste.

2.12.3 The two main contaminants for treatment in this process are ammoniacal nitrogen and COD and the well-established optimum process for achieving this is by anaerobic and aerobic biodegradation. This process utilises two processes:

2.12.4 The first stage is denitrification under anoxic conditions. This is a natural process using the available organic material. Heterotrophic bacteria reduce nitrate to molecular nitrogen.

$$4\,NO_3^- + 5\,C + 4\,H^+ \xrightarrow{\text{heterotrophic bacteria}} 2\,N_2 + 2\,CO_2 + 4\,H_2O$$

2.12.5 The second stage is nitrification, where the ammonium compounds are oxidized from nitrites to nitrates. First, ammonia-oxidizing bacteria (Nitrosomonas) oxidize ammonia to nitrite. Then nitrite-oxidizing bacteria (Nitrobacter) oxidize nitrite to nitrate. At the same time COD is biologically removed.

$$2\,NH_4^+ + 3\,O_2 \xrightarrow{\text{Nitrosomonas}} 2\,NO_2^- + 2\,H_2O + 4\,H^+$$
$$2\,NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} 2\,NO_3^-$$

2.12.6 The dissolved oxygen will be provided by an aeration system which also provides adequate mixing.

2.12.7 It is anticipated that an additional carbon source (i.e., acetic acid) will be required to optimise the biological processes. This will be used initially for this purpose, although sugar-based or waste derived will also be assessed for appropriateness for use and used if suitable and so replace a hazardous reagent.

2.12.8 The nitrification process generates acidity and it is often necessary to dose caustic soda solution in order to maintain the correct pH level. Although the denitrification process will act as a buffer to this process, the addition of caustic soda is not anticipated during normal operations. Regardless, a caustic soda dosing system will be included in case pH adjustment is required.

2.12.9 Temperature will be maintained by the heat generated within the biological treatment processes, particularly from the denitrification process. In addition, heat exchangers will be employed to transfer heat from the permeate liquor into the untreated leachate before it enters the denitrification tank.

2.12.10 Uniformity will be provided by blending the leachates in a balance tank prior to treatment and close control of input rates. See **Section 2.2.5** above for reference.

2.12.11 Typically, this process will give rise to the creation of foams, which will be controlled by dosing with antifoam solution where necessary.

2.13 Biological treatment Plant design selection

2.13.1 Several different types of plant are suitable for treating this type of effluent including:

- Sequencing Batch Reactor (SBR)
- Membrane Reactor (MBR)
- Moving Bed Bioreactor (MBBR)

2.13.2 The membrane reactor (MBR) is being proposed for the treatment operation as it is considered to provide highly efficient biological treatment and reliable ultrafiltration for biomass separation for the effective treatment of leachate and aqueous waste. This process is considered to be more energy-efficient compared to other biological processes (e.g., SBR), and the denitrification stage eliminates the requirement for caustic soda addition during normal operating conditions.

2.13.3 Provision is made for the use of a nanofiltration plant and/or activated carbon filtration to polish the effluent from the biological treatment plant if required to meet regulatory requirements with regard to trace metals removal or specific, trace organics.

2.14 Biological treatment Plant size calculations

2.14.1 The proposed biological treatment plant will be designed to accept predominately concentrate from the RO operations, with or without ammonia recovery having taken place. Capacity within the design allows for untreated leachate to be accepted, the proportion predominately being determined by whether ammonia recovery is being undertaken (and the availability of biological treatment capacity to achieve ammonia removal). The indicative design load for the biological treatment process includes:

- Leachate - 300 T/d
- COD - 18000 mg/l
- Ammonia - 2000 mg/l

2.14.2 See Table 2 in **Section 2.2.5** above showing the typical range of leachate parameters that will be brought onto site, followed by blending of leachates in a balance tank prior to biological treatment in the biological treatment plant.

2.15 Biological treatment Plant design details

2.15.1 In addition to **Section 2.13.2**, a brief description of the proposed MBR process and main advantages is presented below.

2.15.2 This MBR plant is a well-proven technology for leachate treatment. It is fully automated and can be monitored and controlled remotely via telemetry.

2.15.3 The plant layout can be seen in the Sampling and Emissions Point drawing ref. 5827-CAU-XX-XX-DR-V-1809, and the process flow diagram displayed in **Figure 1** of **Section 2.2** above highlights the stage of biological treatment within the overall leachate and aqueous waste treatment activities.

2.15.4 Below is an illustrative process flow diagram of the proposed biological treatment.

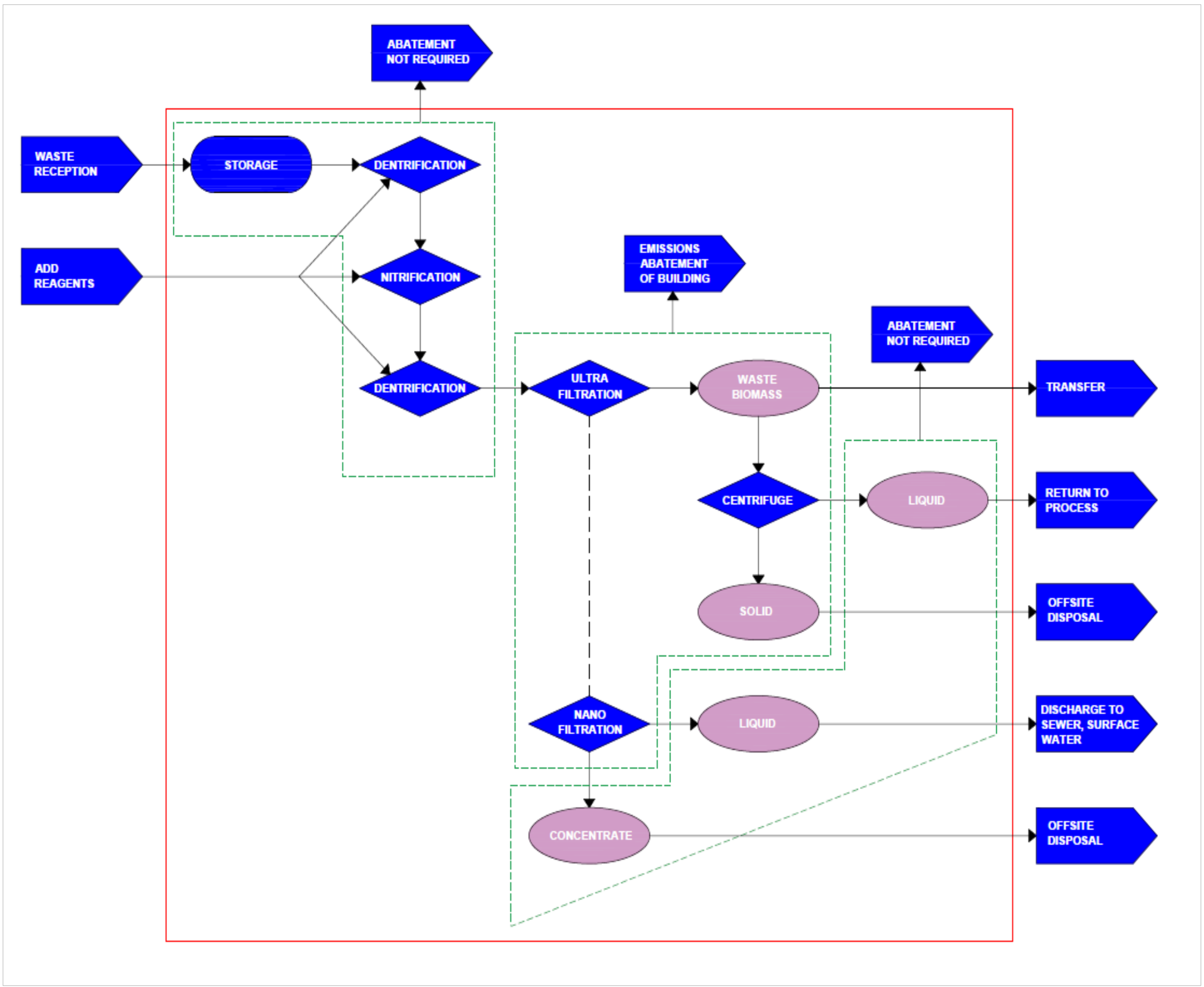

Figure 7: Process flow diagram of the proposed Biological Treatment (see process details in the following section).

Blending

2.15.5 As mentioned in **Section 2.2.5** above, blending of leachate and similar aqueous wastes for the proposed treatment processes will take place in a balance tank following the prescribed operation sequence in order to even out leachate quality variations and buffer fluctuations in inlet flow to ensure a consistent feed for the biological treatment plant.

Biological Treatment

2.15.6 Leachate and similar aqueous wastes will be pumped into bioreactors, which will be tanks containing high concentration of activated sludge (bacteria).

2.15.7 The first stage is denitrification under anoxic conditions. This is a natural process using the available organic material; heterotrophic bacteria to reduce nitrate to molecular nitrogen.

2.15.8 This denitrification process will create energy savings opportunities and significantly reduce the requirement for caustic soda as a reagent. Since easily degradable organic material will be used up during denitrification, this will reduce the amount of aeration required in the nitrification stage. In addition, alkalinity will increase during denitrification thus saving caustic soda that would have been used for pH-stabilization.

2.15.9 Since leachate usually do not contain sufficient easily biodegradable organics, a carbon source (e.g., acetic acid) can be dosed to the system. This reagent may be replaced by suitable wastes containing easily biodegradable organics and no other significant contaminants.

2.15.10 A gravity overflow pipe will allow the wastewater/biomass mixture to be routed into a separate nitrification tank. In the nitrification tank, ammonium compounds will be oxidized from nitrites to nitrates. First, ammonia-oxidizing bacteria (Nitrosomonas) oxidize ammonia to nitrite. Then nitrite-oxidizing bacteria (Nitrobacter) oxidize nitrite to nitrate. At the same time COD is biologically removed.

2.15.11 An aeration system will be located inside the bioreactor continuously aerating the biomass with air being provided by an external blower through ejectors.

2.15.12 Ejectors provide an efficient and reliable oxygen transfer system in effluent and sewage treatment. On account of the high oxygen demands of organically polluted wastewater and the increasing height of modern biological wastewater treatment plants, it is more energy efficient, to pre-compress air mechanically and supply it through an ejector.

2.15.13 Oxygen transfer does not only depend on bubble size (contact surface between gas and water), but also on the distribution of water over the gas bubble contact surface. Therefore, ejectors – with their permanent circulation of the wastewater – achieve a far larger oxygen efficiency than other aerators.

2.15.14 They are relatively maintenance free and so the shutdown of the plant due to issues such as exchange of blocked membrane aerators will be eliminated.

2.15.15 The dissolved oxygen (DO), pH and temperature in the bioreactor will be monitored to control the operation of the blowers to maintain the desired residual DO. The treated sludge from the nitrification process will be fed into the ultrafiltration plant under a continuous, rather than a batch process.

2.15.16 This process will operate at a temperature of around 30 - 35 ^{o}C, no additional heating will be required which reduces the energy requirements compared to a typical SBR system.

2.15.17 The potential for odour emissions will be reduced as there are no open tanks and much of the process is within an enclosed system.

Excess Sludge

2.15.18 All biological treatment processes create surplus ‘sludge’ which is bacteria/biomass that results from the wastewater treatment process and is a by-product of the bio-oxidation of the ammonia and carbohydrates contained in the wastewater. The surplus sludge will be removed on a regular basis to maintain the desired sludge concentration and sludge age.

2.15.19 The operator plans to add a dewatering stage within the self-contained aqueous leachate treatment operation, to handle excess biomass through the use of centrifuge depending on future regulatory requirements. Hence, excess sludge created from the biological treatment process will be dewatered on-site or transferred to other FCC-operated sites for further treatment. See Figure 7 above.

Ultrafiltration (UF) Separation

2.15.20 The proposed ultrafiltration plant will be based on a side-stream crossflow membrane filtration process that will use true UF tubular membranes modules.

2.15.21 The use of the tubular membrane modules provides the complete retention of biomass. The ‘mixed liquor’ of activated sludge and effluent will be pumped from the bioreactor via the tubular membranes in order to separate the treated wastewater from the activated sludge. All bacteria and any COD due to suspended solids material plus macro-molecules and colloidal matter will be safely retained within the system and is continuously fed back, as retentate, into the ring main and returned back to the bioreactor for more biological treatment.

2.15.22 The tubular membrane module allows the operation at a much higher mixed liquor solids concentration compared to other membrane systems. The benefits being, smaller bioreactors and reduced volume of the waste sludge to dewater.

2.15.23 The UF system typically consists of 2 - 6 tubular membrane modules connected in series to form a UF-loop. The ultrafiltration plan can consist of several UF-loops operating parallel, depending on the required throughput.

2.15.24 Each UF-loop will have a dedicated circulation pump, sized to provide the required cross flow velocity along the membrane, to reduce fouling and maintain a high permeate flux.

2.15.25 Occasionally, the UF membrane modules will need to be rinsed or cleaned. This is achieved via the wash pump by using water or permeate stored in the wash tank. Any chemicals needed to clean the membranes can be dosed into the wash tank. The individual UF loops can be rinsed or cleaned while the remaining loops are in operation.

2.15.26 Compared to other membrane systems, the ultrafiltration plant is designed as a closed loop system and will be located within the LTP-T1 building.

2.15.27 The treated effluent from the ultrafiltration may be transferred into the nanofiltration plant and/or activated carbon filtration unit as a polishing stage if not suitable for discharge as trade effluent. Here any residual (trace) metals and organics in the treated effluent will undergo further removal in order for the resultant effluent to meet both the requirements of the existing Discharge Consent and what is believed may be required in the foreseeable future.

2.15.28 Such future planning also allows for the nanofiltration plant to be upgraded to an RO unit with its associated effluent quality. The final effluent will then be pumped into a holding/balancing tank before discharge to sewer from the public sewer connection. Concentrate from the nanofiltration unit containing the removed metals and/or activated carbon will be removed offsite for disposal at a suitable facility, where practicable spent carbon will be regenerated at a suitable facility.

3.0 REVIEW AGAINST BAT CONCLUSIONS

3.1 Overview

3.1.1 This section (**Table 5**) is a review against 'Establishing Best Available Techniques (BAT) Conclusions for Waste Treatment, under Directive 2010/75/EU of the European Parliament and of the Council' (2018).

3.1.2 In addition, Sector Guidance Note (SGN IPPC 5.06) 'Guidance for the Recovery and Disposal of Hazardous and Non-Hazardous Waste' has also been used as reference for this BAT review.

Table 5: Review Against BAT Conclusions

BAT Conclusion Number	Description	Applicable to LTP-T1	Brief comments on how compliance with BAT will be achieved.
	Overall Environmental Performance		
1	In order to improve the overall environmental performance, BAT is to implement and adhere to an environmental management system (EMS) that incorporates all of the following features: I) Commitment of the management, including senior management; II) Definition, by the management, of an environmental policy that includes the continuous improvement of the environmental performance of the installation; III) Planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment; IV) The implementation of procedures; V) Checking performative and taking corrective action; VI) Review, by senior management, of the EMS and its continuing suitability, adequacy and effectiveness; VII) Following the development of cleaner technologies; VIII) Consideration for the environmental impacts from the eventual decommission of the plant at the stage of designing a new plant, and throughout its operating life; IX) Application of sectoral benchmarking on a regular basis; X) Waste stream management; XI) An inventory of waste water and waste gas streams; XII) Residues management plan;	Yes	• The site operates under an ISO 14001 accredited environmental management system (EMS); audits of the performance of key plants, and all maintenance will be carried out in compliance with the standard requirements and reviewed at the required frequency by senior management to demonstrate top management engagement with the management system and to drive continual improvement in its overall environmental performance. • The site's management system is audited externally as part of the ISO 9001 and ISO 14001 accreditation. It also operates and is audited against ISO 45001 and ISO 50001.

	XIII) Accident management plan; XIV) Odour management plan; XV) Noise and vibration management plan.		
2	In order to improve the overall environmental performance of the plant, BAT is to use all of the techniques detailed in 'BAT 2 Table 'best available techniques (BAT) conclusions for waste treatment industries (BREF), under Directive 20/10/75/EU, from the Official Journal of the EU' summarised below: I) Pre-acceptance procedures II) Waste Acceptance procedures III) Waste tracking and inventory IV) Output quality management system V) Ensure waste segregation VI) Waste compatibility prior to mixing or blending of waste VII) Sorting of incoming solid waste	Yes	<u>Pre-acceptance and Waste Acceptance procedures</u> • See **Section 2.0** of this report ref. 5827-CAU-XX-XX-RP-V-0308 for details on pre-acceptance and waste acceptance procedures the operator has as part of its management system. <u>Waste tracking and inventory</u> • See **Section 2.0** of this report ref. 5827-CAU-XX-XX-RP-V-0308 for details on this as part of the operator's management system. <u>Output Quality Management System</u> • As mentioned in BAT 1 above, the site's management system is externally verifiable to ISO 9001 standards. • Treatability studies and associated analytical work undertaken by the operator will be to good laboratory standards (e.g., existing EN standards where applicable) allowing tracking of samples and results against the relevant enquiry, selection of appropriate test methods and appropriate calibration of equipment used. • Where third party analyses are required, this shall be to recognised standard and where practicable undertaken by a UKAS or MCERTS accredited laboratory. Analytical details shall be maintained for six years. <u>Ensure waste segregation</u> • Waste storage will be provided in appropriate areas, segregating incompatible materials to ensure only compatible materials are stored near each other. Waste deemed not acceptable will be stored within a quarantine area pending removal from site.

			• Where storage is in the open, the operator will adequately store the wastes within either packaging or larger containers suitable for the contents. • Additional storage for wastes, reagents and residues in skips will be provided in bunded areas with appropriate segregation. • See **Section 2.0** of the report ref. 5827-CAU-XX-XX-RP-V-0308 for more details on how the Operator segregates wastes. Waste Compatibility • Waste pre-acceptance and waste acceptance procedures, sampling, testing and analysis procedures will be in place to ensure that only waste types permitted are accepted onto site. • On-site verification, storage and control procedures will be undertaken to ensure that the materials accepted are consistent with the analysis and description supplied at the pre-characterisation stage. • Samples of all waste received and used for acceptance assessment shall be retained for two weeks. • More details have been provided in **Section 2.0** of the report ref. 5827-CAU-XX-XX-RP-V-0308 for more details on how the operator segregates wastes. Sorting of Incoming waste • Following full pre-acceptance of the waste on-site prior to off-loading bulk wastes in tankers, appropriate sample/samples representative of the waste load as a whole or targeted will be analysed to confirm its characteristics and composition against the initial enquiry and suitability for the intended process route to be confirmed. • Compatible tankered wastes such as leachate shall be received into tanks and blended to even out variations in leachate quality

			and buffer fluctuations to create a consistent feed for the proposed treatment. • See **Section 2.0** of the report ref. 5827-CAU-XX-XX-RP-V-0308 for more details on how the Operator sorts overall incoming waste.
3	In order to facilitate the reduction of emissions to water and air, BAT is to establish and to maintain an inventory of waste water and waste gas streams, as part of the environmental management system.	Yes	• Existing inventory with be updated to capture any waste water and waste gas streams associated with the addition of the new activities, where applicable. • In addition, the proposed stack air emission points will be equipped with appropriate scrubber to minimise emissions into the atmosphere. See **Appendix 3** of this report for details of the proposed emission points and corresponding grid references, and **Appendix 6** for summary document providing justification for the identification and selection of emission control equipment and how it meets BAT. Upon commencement of operations for each process, monitoring of air emissions will be undertaken to confirm effectiveness of abatement and to undertake an Air Emissions Risk Assessment. • Discharge to sewer will be in line with the existing Trade effluent discharge consent in place at the site. • Treated effluent (i.e., RO permeate) to be discharged to surface water will undergo a pre- and post- assessment where applicable, using appropriate controls to minimise unwanted emissions into the environment. See H1 Assessment report ref. 5827-CAU-XX-XX-RP-O-0300 for inventory of waste water emissions.

4	In order to reduce the environmental risk associated the with storage of waste, BAT is to use all of the techniques given below a) Optimised storage location b) Adequate storage capacity c) Safe storage operations d) Separate area for storage and handling of packaged hazardous waste	Yes	<u>Adequate storage capacity</u> • The total storage in the Leachate and Aqueous Wastewater treatment area will be up to 4795m^3 within 17 tanks, which includes 30m^3-sized tanks for reagents storage and a further 25m^3 of biomass residues skips. These will be within fully bunded segregated storage areas. Details of the secondary containment calculations for the applicable tank capacity(ies) and bund associated with the relevant buildings has been provided in **Appendix 4** of this report. <u>Safe storage operations</u> • Wastes and regents received in bulk are stored in appropriate tanks suitable for their storage. Wastes are not received in packages, but packaged reagents are used, segregated and stored appropriately. Storage areas will be fully bunded. <u>Optimised storage location</u> • The reagents to be used are stored close to the point of use and in conditions for a lifetime in line with manufacturers recommendations/good practice.
5	In order to reduce the environmental risk associated with the handling and transfer of waste, BAT is to set up and implement handling and transfer procedures. Handling and transfer procedures aim to ensure that wastes are safely handled and transferred to the respective storage or treatment. Including the following elements: I) Handling and transfer of waste are carried out by competent staff; II) Handling and transfer of waste are duly documented;	Yes	<u>Handling and transfer of waste are carried out by competent staff</u> • Only staff trained and authorised to complete this task may do so. • Staff undertaking the pre-acceptance and acceptance assessment of wastes shall have a minimum qualification of HNC in chemistry or a related subject or be supervised by such an individual. <u>Handling and transfer of waste are duly documented</u> • The Operator has developed an Enquiry system where it documents/records details of the waste characteristics,

	III) Measures are taken to prevent, detect and mitigate spills; IV) Operation and design precautions are taken when mixing or blending wastes;		process route and any special instructions, including details of consignment notes, and associated weight records which shall be maintained for six years. Measures are taken to prevent, detect and mitigate spills • The Environmental Risk Assessment report ref. 5827-CAU-XX-XX-RP-V-0302 prepared for the proposed activities, highlights an emergency spillage pads and/booms will be provided should a spillage or leak occur, including spillage action plan with training of all relevant staff on implementing the plan and in the use of spill pads and booms, which will be available. • Also, a Planned Preventative Maintenance (PPM) programme will be put in place for all critical equipment and infrastructure. Regular inspection of surface integrity, container and bunding integrity. All tanks and pipework will be below ground and will undergo routine visual inspections to identify any leaks (this is covered in the document ref. **IMS-4-04-01-02-KETP procedure specifying waste storage tank and pipework inspection regime.** • See **Appendix 7** of this report for summary document on Leak detection and Repair protocol. Operation and design precautions are taken when mixing or blending wastes • This is not applicable to the Leachate and Aqueous Waste Treatment of the wastes to be accepted.
	Monitoring		
6	For relevant emissions to water as identified by the inventory of waste water streams, BAT is to monitor key process parameters at key locations (e.g. at the inlet and/or outlet of the pretreatment, at the inlet to the final treatment, at the point where the emission leaves the installation).	Yes	• See response to BAT 3 above.

7	BAT is to monitor emissions to water with at least the frequency detailed in BAT 7 'best available techniques (BAT) conclusions for waste treatment industries (BREF), under Directive 20/10/75/EU, from the Official Journal of the EU'	Yes	• See response to BAT 3 above.
8	BAT is to monitor channelled emissions to air with at least the frequency detailed in BAT 8 'best available techniques (BAT) conclusions for waste treatment industries (BREF), under Directive 20/10/75/EU, from the Official Journal of the EU' and in accordance with EN Standards. If EN standard are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.	Yes	• See response to BAT 3 above.
9	BAT is to monitor diffuse emissions of organic compounds to air from the regeneration of spent solvents, the decontamination of equipment containing POPs with solvents, and the physico-chemical treatment of solvents for the recovery of their calorific value, at least once per year using one or a combination of the techniques given (refer table).	No	• Not applicable to the Leachate and Aqueous Wastes Treatment process.
10	BAT is to periodically monitor odour emissions.	Yes	• Odour risk from the Leachate and Aqueous Waste Treatment building is addressed in the 'Environmental Risk Assessment' report ref. 5827-CAU-XX-XX-RP-V-0302 and considered a low risk to receptors if control measures are implemented. • Daily on-site olfactory monitoring will occur as part of routine site inspections (or more frequently following odour complaints), and monitoring will be undertaken by staff trained by Site Management. • Refer to the Odour Management plan report ref. 5827-CAU-XX-XX-RP-V-0310 included in this application for more details.

11	BAT is to monitor the annual consumption of water, energy and raw materials as well as the annual generation of residues and waste water, with a frequency of at least once per year.	Yes	The Operator will keep Safety Data Sheets (SDS) for the types of reagents that will be used and will monitor the quantity of materials used, including the volume of waste generated This will provide data for regular reviews of raw materials usage. All product documentation will be checked against that expected prior to acceptance.
	Emissions to air		
12	In order to prevent, or where that is not practicable, to reduce odour emissions, BAT is set up, implement and regularly review an odour management plan, as part of the environmental management system, that includes all of the following elements: a) Protocol for containing actions and timelines; b) Protocol for conducting odour monitoring as set out in BAT 10; c) Protocol for response to identified odour incidents, e.g. complaints d) An odour prevention and reduction programme designed to identify the source(s); to characterise the contributions of the sources; and to implement prevention and/or reduction measures.	Yes	• See response to BAT 10 above.
13	In order to prevent or, where that is not practicable, to reduce odour emissions, BAT is to use one of more a combination of the following techniques given below: a) Minimise residence time of potentially odorous waste in storage or in handling systems (e.g., pipe, tank containers) in particular in anaerobic conditions b) Using chemical treatment c) Optimising aerobic treatment	Yes	• See response to BAT 10 above.

14	In order to prevent or, where that is not practicable, to reduce emissions to air, in particular of dust, organic compounds and odour. BAT is to use an appropriate combination of the techniques given below: a) Minimizing the number of potential diffuse emissions sources b) Selection and use of high integrity equipment c) Corrosion prevention d) Containment, collection and treatment of diffuse emissions e) Dampening f) Maintenance g) Cleaning of waste treatment and storage areas h) Leaks detection and repair (LDAR) programme		Minimizing the number of potential diffuse emissions sources • Emission points have been minimised. See **Appendix 3** of this report for summary of the emission points and their grid references. • Housekeeping measures (e.g., closing doors, windows, etc) will be adopted. • Speed limits are in place at the site to control traffic and dust generation. Speed ramps are also in place to enforce speed limit. • Dust created due to vehicular movements around site will be supressed with water where required. Containment, collection and treatment of diffuse emissions • Enclosed self-bunded building will have an air extraction system (such as wet scrubber and VOCs scrubber) in place for this purpose. • Vents on outside tanks for the displacement of air during infilling of effluent. Emissions not considered to be significant due to low displacement volumes and therefore no treatment proposed. • See **Appendix 6** of this report for the summary document providing justification for the identification and selection of emission control equipment and how it meets BAT. Maintenance • Plants will be maintained following the manufacturer's recommendations. Emissions of particulates will be controlled in accordance with Site management procedures (see BAT 10 response for reference).

			Dampening • Dust created due to vehicular movements around site will be dampened/supressed with water where required. Cleaning of waste treatment and storage areas • A housekeeping checks procedure will be created for this purpose as part of the management system in place for the site.
15	BAT is to use flaring only for safety reasons or for non-routine operation conditions (e.g. start-ups, shutdowns) by using techniques below a) correct plant design b) Plant management	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
16	In order to reduce emissions to air from flares when flaring is unavoidable, BAT is to use the techniques detailed below: a) Correct design of flaring devices b) Monitoring and recording as part of flare management	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	Noise and Vibration		
17	In order to prevent, or where that is not practicable, to reduce noise and vibration emissions, BAT is to set up, implement and regularly review a noise and vibration management plan as part of the environmental management system.	Yes	• Noise and vibrations assessed in the 'Environmental Risk Assessment' document ref. 5827-CAU-XX-XX-RP-V-0302, indicates that noise and vibration impacts from the activities of the Leachate and Aqueous Waste Treatment processes are likely to be of low impact to sensitive receptors if control measures are implemented. The report referenced will be added to this application. • The control of noise and vibration shall be considered when purchasing and installing new equipment to minimise any impact on staff or off-site receptors.

			• Waste processing activities will be carried in a manner that minimises off-site noise from the processing activities. Equipment such as the pumps, scrubber fans, compressors and heat exchangers that may generate noise will be of low noise type and positioned and operated in a manner that will minimise the impact of noise on any off-site receptors. • A Noise Management Plan document ref. 5827-CAU-XX-XX-RP-V-0311 has been prepared as part of this variation application to demonstrate how BAT 17 will be met.
18	In order to prevent or where that is not practicable, to reduce noise and vibration emissions, BAT is to use one or a combination of the techniques given below. a) Appropriate location of equipment and buildings b) Operational measures c) Low-noise equipment d) Noise and vibration control equipment e) Noise Attenuation	Yes	See response to BAT 17 above.
	Emissions to water		
19	In order to optimise water consumption, to reduce the volume of waste water generated and to prevent or, where that is not practicable, to reduce emissions to soil and water, BAT is to use an appropriate combination of the techniques given below: a) Water management b) Water recirculation c) Impermeable surface d) Technique to reduce the likelihood and impact of overflows and failures from tanks and vessels	Yes	<u>Water management</u> Not applicable to the Leachate and Aqueous Wastes Treatment processes. <u>Impermeable surface</u> • All tanks or a combination of tanks in this area shall be self-bunded or within bunded areas on impermeable concrete, designed in line with the CIRIA ‘Containment systems for the prevention of pollution: Secondary, tertiary and other measures for industrial and commercial premises’

	e) Roofing of waste storage and treatment areas f) Segregation of water streams g) Adequate drainage infrastructure h) Design and maintenance provisions to allow detection and repair of leaks i) Appropriate buffer storage capacity		(C736;2014) and HSE standards for storing chemicals. See **Appendix 4** of this report for details on secondary containment with the relevant calculation where applicable. • The bunded areas will have sumps for collecting rainwater and any contaminated liquid from spillages/leaks and disposed of appropriately (this is addressed in the document ref. **IMS-4-04.19.02-KETP for procedure on Sump Integrity Check**). The bunds will be inspected regularly (this is covered in the document ref. **IMS-4.02.04.02-BM procedure for Daily Site Checks that covers bund inspection**). All surface water collected in bunds will pass through the treatment facility. <u>Techniques to reduce the likelihood and impact of overflows and failures from tanks and vessels</u> • Storage tanks will be equipped with online level monitoring, using radar or ultrasonics with three alarm levels for alerting staff when maximum capacity is reached, including an Automatic Feed Shut Off (AFSO) system to protect against tank overflow or, power failure. <u>Roofing of waste storage and treatment areas</u> • The appropriate roofing style will be constructed, including storing and treating wastes in such manner that will prevent contact with rainwater and thus minimise the volume of contaminated run-off water where applicable. <u>Segregation of water streams</u> • Uncontaminated (clean) site surface waters from site roads and non-waste areas are collected in existing storage tanks for reuse or discharge to surface water via an interceptor. • Following the H1 assessment, the Operator can discharge some, or all of the treated effluent (i.e., RO permeate) to the

			river. See the H1 Assessment report (ref. 5827-CAU-XX-XX-RP-O-0300) for more details. • Rainwater collecting in tank bund areas will be collected and processed alongside waste inputs; spillages of aqueous reagents will be dealt with as appropriate to the reagent concerned which may include off-site transfer. <u>Adequate drainage infrastructure</u> • Adequate drainage infrastructure is in place on site for the collection of rainwater and surface waters in existing storage tanks for reuse or discharge to surface water via an interceptor or sewer as appropriate and to comply with the associated regulatory requirements. See **Appendix 5** of this report for the site's Drainage Plan. • Interceptors will be available at various locations on site to capture suspended solids, fuel or engine oils (from vehicle leaks); it will also be capable of being utilised for the capture of contaminated water in the event of a spill or fire (i.e., firewater). This collected water may be reused within the site activities subject to appropriate composition and need, and if the water is unsuitable or not required, this will be stored and if appropriate, discharged to sewer following the existing discharge consent in place at the site. • Collected oils/fuels will be removed from site to an appropriate treatment facility. <u>Design and maintenance provisions to allow detection and repair of leaks</u> • A Planned Preventative Maintenance programme will be put in place for all critical equipment and infrastructure. Regular inspection of surface integrity, container and bunding integrity. All tanks and pipework will be above ground and will

			undergo routine visual inspections to identify any leaks. This is addressed in the document ref. **IMS-4-04-01-02-KETP procedure specifying waste storage tank and pipework inspection regime.** • See **Appendix 7** of this report for details on leak detection and repair protocol. <u>Appropriate buffer storage capacity</u> • As mentioned in BAT 4 response above, the total storage in this area will be up to 4100m^3 within 13 tanks, with additional ~75m^3 storage for packaged reagents and biomass residues skips.
20	In order to reduce emissions to water, BAT is to treat waste water using an appropriate combination of techniques. The techniques relevant for the proposed Leachate and Aqueous Wastes Treatment in response to BAT 20 are: 1. Physico-chemical treatment (h) Stripping 2. Biological treatment (m) Membrane bioreactor 3. Nitrogen removal (n) Nitrification/denitrification when the treatment includes a biological treatment	Yes	The combination of these techniques, including reverse osmosis provides the following advantages: • The reverse osmosis delivers excellent effluent quality and is robust to changing feed quality; • The use of an MBR results in a good quality effluent which if required, can be further polished by nanofiltration or activated carbon; • The ammonia recovery stage creates a useful resource and reduces the complexity and reagent use for the final stage of biological treatment. • Suitable effluents may be discharged to the river or sewer or, with other residues, removed from site for further treatment at a suitable facility elsewhere.
	Emissions from accidents and incidents		
21	In order to prevent or limit the environmental consequences of accidents and incidents, BAT is to use all for the techniques given below, as part of the accident management plan (See BAT 1)	Yes	• An 'Environmental Risk Assessment' is provided as report ref. 5827-CAU-XX-XX-RP-V-0302. Risks from dust, odour, noise,

	a) Protection measures b) Management of incidental/accidental emissions c) Incident/accident registration and assessment system		other fugitive emissions, accidents and fire are considered to be 'low' from the proposed site activities. • The company's Integrated Management System will include an 'Accident Management Plan' for the proposed activities, with written procedures for handling, investigating, communicating and reporting environmental complaints and implementation of appropriate actions. • See **Appendix 4** of the report ref. 5827-CAU-XX-XX-RP-V-0305 for details on accident management procedures.
	Material Efficiency		
22	In order to use materials efficiently, BAT is to substitute materials with waste	Yes	Under the biological treatment phase, the substitution of the main chemical reagents by suitable wastes may be possible as and when they are available. This is the only instance where material efficiency can be applied. Since leachate usually do not contain sufficient easily biodegradable organics, a carbon source (e.g., acetic acid) can be dosed to the system. This reagent may be replaced by suitable wastes containing easily biodegradable organics and no other significant contaminants.
	Energy Efficiency		
23	In order to use energy efficiently, BAT is to use both of the techniques given below: a) Energy Efficiency plan b) Energy balance record	Yes	Energy Efficiency Plan • It is proposed that electrical equipment to be used for the proposed activities will be of the highest electrical efficiency appropriate for the operation. The design stage of the plants will prioritise energy minimisation whilst incorporating energy efficiency. • Housekeeping measures, including maintenance and operational procedures, will be in place for all areas to cushion machinery breakdown that can impact the environment or compromise the operator's ability to undertake operations/ activities. A planned preventive maintenance (PPM)

			programme will cover all equipment significantly impacting the plant's energy consumption or energy conservation. Where applicable, automated equipment monitoring, including auto shut-off, will be used to minimise unnecessary run time. • Appropriate training of staff and monitoring will be undertaken to ensure the obligations under ISO 50001 are met. Energy balance record Energy consumption information will be collated and reported in accordance with the permit as well as the requirement of the ISO 50001 standard in place at the site.
	Reuse of packaging		
24	In order to reduce the quantity of waste sent for disposal, BAT is to maximise the reuse of packaging, as part of the residues management plan (see BAT 1).	Yes	• It may be necessary for some residues to be taken off-site for further recovery or disposal, due consideration will be given to the Waste Hierarchy. • Any packaging e.g. pallets etc. will be returned to the supplier for efficient recycling and re-use where appropriate. The Operator will (where applicable) re-use clean packaging and/or recycle at a suitable facility to reduce the quantity of waste sent for disposal. • Containers and drums will be sent to the appropriate recycling or disposal facility.
	General BAT conclusions for the mechanical treatment of waste		
25	In order to reduce emissions to air of dust, and of particulate-bound metals, PCDD/F and dioxin-like PCBs, BAT is to apply BAT 14d and to use one or a combination of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the mechanical treatment in shredders of metal waste		
26	In order to improve the overall environmental performance, and to prevent emissions due to accidents and incidents, BAT is to use BAT 14g and all of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.

27	In order to prevent deflagrations and to reduce emissions when deflagrations occur, BAT is to use technique a. and one or both of the techniques b. and c. given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
28	In order to use energy efficiently, BAT is to keep the shredder feed stable.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the treatment of WEEE containing VFCs and/or VHCs		
29	In order to prevent or, where that is not practicable, to reduce emissions of organic compounds to air, BAT is to apply BAT 14d, BAT 14h and to use technique a. and one or both of the techniques b. and c. given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
30	In order to prevent emissions due to explosions when treating WEEE containing VFCs and/or VHCs, BAT is to use either of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the mechanical treatment of waste with calorific value		
31	In order to reduce emissions to air of organic compounds, BAT is to apply BAT 14d and to use one or a combination of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the mechanical treatment of WEEE containing mercury		
32	In order to reduce mercury emissions to air, BAT is to collect mercury emissions at source, to send them to abatement and to carry out adequate monitoring.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	General BAT conclusions for the biological treatment of waste		
33	In order to reduce odour emissions and to improve the overall environmental performance, BAT is to select the waste input.	Yes	See **Section 2.0** of report ref. 5827-CAU-XX-XX-RP-V-0308 for more details on pre-acceptance and waste acceptance procedures and waste compatibility in place at the site.
34	In order to reduce channelled emissions to air of dust, organic compounds and odorous compounds, including H2S and NH3, BAT is to use one or a combination of the techniques given.	Yes	As mentioned in BAT 8 above, appropriate air management system such as wet scrubber (acid or alkaline or a combination), will be in place to clean exhausted air before it is released to atmosphere.

35	In order to reduce the generation of waste water and to reduce water usage, BAT is to use all of the techniques given.	Yes	See response to BAT 19 above.
	BAT conclusions for the aerobic treatment of waste		
36	In order to reduce emissions to air and to improve the overall environmental performance, BAT is to monitor and/or control the key waste and process parameters.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
37	In order to reduce diffuse emissions to air of dust, odour and bioaerosols from open-air treatment steps, BAT is to use one or both of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the anaerobic treatment of waste		
38	In order to reduce emissions to air and to improve the overall environmental performance, BAT is to monitor and/or control the key waste and process parameters.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the mechanical biological treatment (MBT) of waste		
39	In order to reduce emissions to air, BAT is to use both of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the physico-chemical treatment of solid and/or pasty waste		
40	In order to improve the overall environmental performance, BAT is to monitor the waste input as part of the waste pre-acceptance and acceptance procedures.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
41	In order to reduce emissions of dust, organic compounds and NH3 to air, BAT is to apply BAT 14d and to use one or a combination of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the re-refining of waste oil		
42	In order to improve the overall environmental performance, BAT is to monitor the waste input as part of the waste pre-acceptance and acceptance procedures (see BAT 2).	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.

43	In order to reduce the quantity of waste sent for disposal, BAT is to use one or both of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
44	In order to reduce emissions of organic compounds to air, BAT is to apply BAT 14d and to use one or a combination of the techniques given. below.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the physico-chemical treatment of waste with calorific value		
45	In order to reduce emissions of organic compounds to air, BAT is to apply BAT 14d and to use one or a combination of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the regeneration of spent solvents		
46	In order to improve the overall environmental performance of the regeneration of spent solvents, BAT is to use one or both of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
47	In order to reduce emissions of organic compounds to air, BAT is to apply BAT 14d and to use a combination of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the thermal treatment of spent activated carbon, waste catalysts and excavated contaminated soil		
48	In order to improve the overall environmental performance of the thermal treatment of spent activated carbon, waste catalysts and excavated contaminated soil, BAT is to use all of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
49	In order to reduce emissions of HCl, HF, dust and organic compounds to air, BAT is to apply BAT 14d and to use one or a combination of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the water washing of excavated contaminated soil		
50	In order to reduce emissions of dust and organic compounds to air from the storage, handling, and washing steps, BAT is to apply BAT 14d and to use one or a combination of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.

	BAT conclusions for the decontamination of equipment containing PCBs		
51	In order to improve the overall environmental performance and to reduce channelled emissions of PCBs and organic compounds to air, BAT is to use all of the techniques given.	No	Not applicable to the Leachate and Aqueous Wastes Treatment process.
	BAT conclusions for the treatment of water-based liquid waste		
52	In order to improve the overall environmental performance, BAT is to monitor the waste input as part of the waste pre-acceptance and acceptance procedures (see BAT 2).	Yes	• As mentioned in BAT 2 above, part of the waste pre-acceptance and acceptance procedure will involve sampling and testing, among others, of the waste types to ensure they fall within the permitted wastes accepted onto the site and are suitable for processing. • Pre-acceptance samples will undergo suitable analysis by the site or laboratory chemist and may also be analysed at a third party laboratory.
53	In order to reduce emissions of HCl, NH_3 and organic compounds to air, BAT is to apply BAT 14d and to use one or a combination of the techniques given.	Yes	See response to BAT 14 above.

4.0 REFERENCES

1. Best Available Techniques (BAT) Conclusions for Waste 'Establishing best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament of the Council. (Updated 10th August 2018).

2. The Environment Agency's Sector Guidance Note (SGN IPPC 5.06) 'Guidance for the Recovery and Disposal of Hazardous and Non-Hazardous Waste' (Updated 10th October 2018).

3. Chemical waste: Appropriate measures for permitted facilities (Updated 18th November 2020) GOV.UK. Available at: https://www.gov.uk/guidance/chemical-waste-appropriate-measures-for-permitted-facilities (Accessed: 03 April 2025).

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DRAWINGS

5827-CAU-XX-XX-DR-V-1804 Permit Boundary Plan

5827-CAU-XX-XX-DR-V-1809 Sampling and Emission Point Plan - Waste Processing 07

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PROJECT: KNOTTINGLEY WASTE TO RESOURCE FACILITY

TITLE: PERMIT BOUNDARY PLAN

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APPENDIX 1

Indicative Technical Proposal - Reverse Osmosis Plant

Client:
FCC Environment

Date:
26/09/2022

A/C:
Ian Martin

No of pages:
29

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TECHNICAL PROPOSAL

LEACHATE TREATMENT PLANT
MOBILE REVERSE OSMOSIS SYSTEM (200 m^3/day)

Ref. PROJ202209_072SL_a_UK_FCC_Calvert_OI200

Figure 1: Reference AST - Landfill site in Tondela (Portugal) 2x200m3/day and 1x120 m3/day.

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1 Introduction

The present technical proposal specifies the scope of supply of a **Reverse Osmosis Leachate Treatment Plant** for the waste landfill site Calvert, owned and operated by FCC Environment.

This Reverse Osmosis (RO) plant has a three purification stages to **guarantee a high discharge quality** and give the client the possibility of reusing the purified water and reduce the hydric footprint of his business.

The RO module has a treatment capacity of 200 m^3/day of raw leachate. The maximum operating pressure is 80 bar, to minimize the concentrate production. The present solution considers a 3-stage treatment because, due to variations of leachate quality and temperatures, solutions with two stages have revealed to be insufficient in terms of the quality compliance of the treated leachate.

The suggested technological solution will be completely installed inside one 40ft marine-type container, ready to use (turnkey solution), and its construction allows the direct feed with leachate from the usually used storage lagoons or tanks. On the other hand, it is a high-mobility solution, as the containers can rapidly be removed and set into operation in other landfill sites for the leachate treatment of those facilities.

The technology on which this solution is based on enables a **fast and easy adjustment to the naturally occurring variations of the leachate composition.**

The implementation of AST's new proprietary **Turboclean®** technology in leachate treatment systems enhances system availability, extends the membranes lifetime, and reduces the operational costs.

There are more than 100 similar units of this type in the market.

The design of these units was developed to **minimize the operational costs, maximize service life, and enable a safe and easy operation**. The following issues are crucial:

- Production of high-quality purified water.
- Minimization of concentrate production.
- Low membrane replacement costs.
- Protection of the system against corrosion/degradation: Container is divided, having a machine compartment and a monitoring and control compartment.
- Additional protection of the monitoring and control system by means of an air conditioning system *(to be provided locally by the client and not included in this offer price)* and forced air ventilation with activated carbon filtration to increase the service life of the electrical installation and control system.
- High level of automation for a comfortable and safe operation.
- Electromagnetic flow measuring devices with a higher reliability, which are installed in all important measuring points.

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- Visualization on a 19” monitor, color, for the easy and rapid perception of the process and the operation parameters.
- Up-to-date and robust industrial computers by Siemens.
- Easy change of operation parameters to enable a better and a more rapid adjustment regarding the change of the leachate.
- Remote control via Internet.
- Value and event recording system, with a report and graphic output.
- Container insulation (acoustical and thermal improvements)
- The container is constructed to serve as a retention basin, including a pump station and a level sensor, to avoid a possible leachate spillage into the environment.
- Cleaning tank with the possibility to use liquid or powdery products (reduction of operation costs).
- Acid injection system, completely closed in an acid-resistant housing and equipped with a sensor that shuts down the system when there is a spillage.

1.1 Optional Extras

1.1.1 Automatic cleaning program

Is a cleaning necessary, chemical pumps feed the selected liquid cleaner medium into the CIP tank until the desired amount is reached. The washing program starts automatically for the pre-settled time or until the maximum allowed temperature is reached.
The pH of the cleaning solution is constantly measured during the cleaning and corrected if necessary.
This method ensures that the optimum amount of chemicals is used during the cleaning. Advantages of this cleaning program and the use of automatically dosing are safety, the saving of chemicals, workforce, and downtime.

1.1.2 Operation in “Concentrate Mode”

The plant allows processing the already produced concentrate with a proprietary and automatized mode. The first concentrate will be sent to an intermediate storage lagoon (by the client). When the tank is full, the plant will be changed through local operator by selecting concentrate mode. This solution will be implemented on the software and hardware side and includes a daily acid cleaning and soaking cycle. In this case, the second and third purifications stage will be deactivated and therefore permeate of the plant usually do not comply with direct discharge parameters and must be sent to the leachate lagoon with the positive side effect of diluting. By experience, it is possible to reduce concentrate at around 30%. Naturally, the wear of the membrane increases by factor 4-6.

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1.1.3 Video Surveillance

Video Surveillance will be implemented in the interior of the container and can be accessed by remote control. Two cameras (one in the machine room and one in the control room) are allowing the video on-line supervision to see liquid spills and permitting operator online support and control.

1.1.4 Stripping tower

We would like to offer you the option to install a stripping tower for the treatment of the permeate. The advantage of the stripping tower is that it increases the ph-value of the permeate, and as a result, no caustic soda is needed. It is possible to recover the investment of the stripping tower within two years (return of investment).

1.1.5 Online measurement of ammonium

Optionally we propose you a multi-parameter probe for the online measurement of ammonium connected to the plc. It is a reliable device outclassing conventional analyzers in terms of measurement stability and lifetime. Precision is guaranteed by real-time compensation of the ammonium value with temperature, pH and potassium and a high-performance reference electrode.

Figure 1 – Three stage RO System, 200 m3/d, Brazil, Maceio.

2 Technical Description of the Reverse Osmosis System

2.1 Technological principles of the Reverse Osmosis

2.1.1 Cross-flow filtration

Modern membrane processes are based on the "cross flow" dynamic filtration, instead of the ordinary "dead-end" statistic filtration.

During the "cross flow" filtration, there is a high flow (volume) of the liquid that passes through the filtering membrane, to avoid the accumulation of particles on the membrane surface.

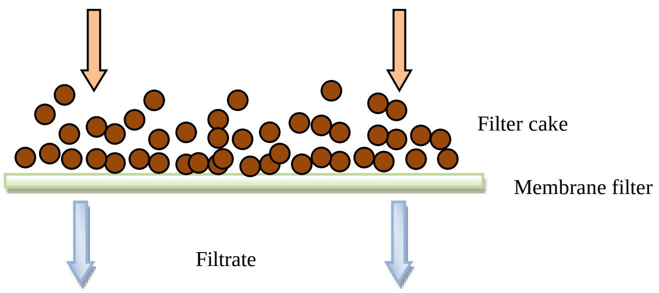

Figure 2: "Classical" filtration.

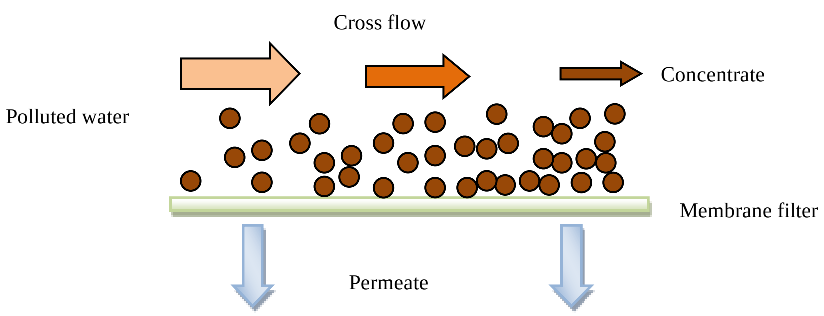

Figure 3: Cross flow – filtration.

The cross flow - filtration is a process that separates the liquid flow at the entrance into two types of effluent: permeate[1] and concentrate[2]. The relation between the two flows is the result of the concentration factor one of the indicators of the separation efficiency.

[1] The permeate is the clean effluent that passed through a membrane.

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2.1.2 Diffusion and osmosis

The phenomenon of diffusion is defined as being a process in which different concentrations has the tendency to equilibrate and homogenize/mix together, because of the random movement of its components: atoms, molecules, or ions.

If there is a separation of two liquids through one semipermeable membrane with the selection only for the molecules of the solvent, the result is a unidirectional diffusion of the solvent through this semi-permeable membrane. The movement of the solvent molecules takes place through the membrane, in the direction of the more concentrated solution. The resulting pressure on the membrane is called osmotic pressure.

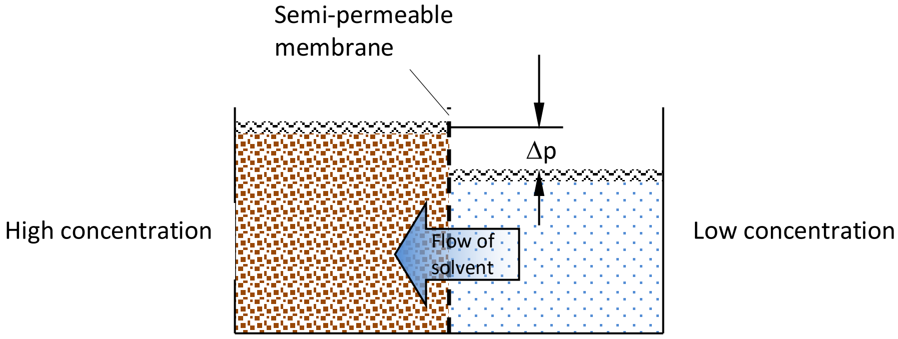

Figure 4: Osmosis.

When a high pressure is applied on the solution, with high concentration, the solvent diffuses through the membrane, starting from the more concentrated solution to the more diluted. This process is called REVERSE OSMOSIS.

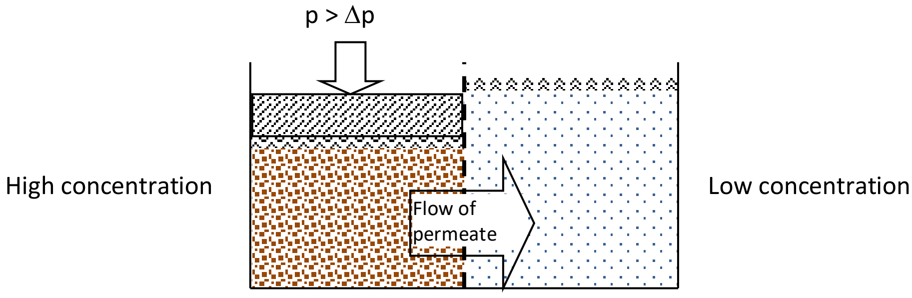

Figure 5: Reverse Osmosis.

The membrane process by cross-flow filtration, based on this effect of the Reverse Osmosis, allows the separation of nearly 100% of molecules with a molecular weight higher than 100g/mol and around 95-99% of salt retention. Individual effects are depending on the form and charge of the molecules.

[2] The concentrate is the liquid effluent ("filter cake") that did not pass through a membrane.

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2.2 Types of membranes

Membranes used in the Reverse Osmosis systems have a high selectivity, as they should retain nearly all dissolved substances, allowing only the diffusion of water molecules and a very small fraction of these substances. The retention amount depends on the type of substance, varying between 85-100%.

The form of utilization of the membranes normally used in the leachate treatment are tubular, disk or spiral-type membranes.

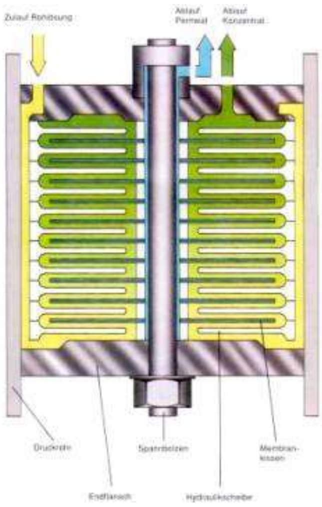

Figure 6: Disk module

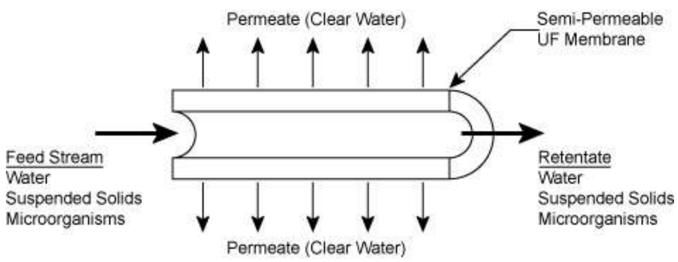

Figure 7: Tubular module.

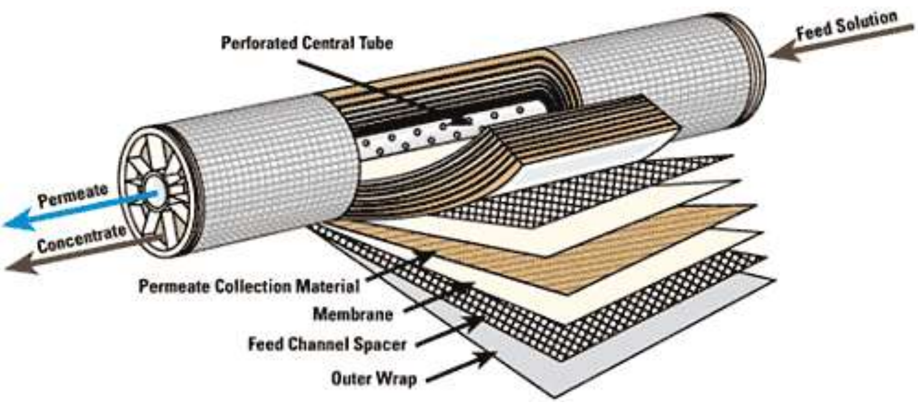

Figure 8: Spiral module.

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The technological progresses of membranes have been considerable, especially in the conception of new structural forms. Spiral membranes are the result of this development and allow a best relation of membrane surface/space, this permitted the development of a dimensional "standard".

Structurally, the spiral of the membrane is constructed by "gluing" the membrane sheets in the form of an envelope inserting the open side into a central tube. The permeate enters the space in the envelope-like form where it is conducted until the central tube. The channels in between the membrane sheets are created by the utilization of "spacers". The spiral membranes of "wide-spacer" type which are used in the proposed system show the best relation of price/handling/space/performance in the leachate treatment and are, for these reasons, our choice for the Reverse Osmose system. The active material in the membrane surface is polyamide with a high mechanical and chemical resistance. There are several types of membrane surfaces which influence, specially, the higher or lower salt passage. The used membranes are of the "high rejection" type (of salts) to improve permeate.

Main characteristics and advantages of applied "wide-spacer" spiral membranes, compared to other current types:

- Considerably lower replacement costs.
- Lower maintenance costs, due to the easy accessibility - fast control and change.
- Optimization of space, due to the good relation of membrane area/volume.
- Optimized hydraulic characteristics with a tangential flow at high velocity on the membrane surface, resulting in a turbulent flow.
- Reduction of the blocking risk (phenomena of "Fouling and Scaling"[3]), resulting in a lower washing frequency and the increase of lifetime.
- The membrane type is a high rejection membrane to allow a better quality of the permeate.
- TFC (Thin film composite) - type with an active surface of polyamide, resistant to a wide temperature and pH range.

[3] Precipitation due to biological and chemical reasons.

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3 AST Technology for Leachate Treatment by Reverse Osmosis

The proposed system of Reverse Osmosis is executed according to the current standard in this type of equipment and integrates a three-stage treatment to ensure a high quality of the treated effluent and with a higher operating pressure, up to 80 bar, to optimize the permeate flow. The system is equipped with “wide spacer” spiral membranes and with the properties mentioned in the previous chapter.

It was found in many cases, that the treatment of leachate by Reverse Osmosis with a two-stage treatment is insufficient to reach permeate discharge quality. The proposed system has three purification stages, with the advantage of being able to treat heavy loads of leachate and being more adaptable to future situations in terms of variations of flow and quality of the affluent.

The operation is completely automatized including various security systems switching off the system in case of problems increasing the unit’s level of protection. Each detail of the process is visualized and monitored, and all data are registered by *software* enabling the assessment of the operation and process parameters. Automation, of a modern industrial standard, embodies the highest level of comfort and safety for the operator, who can follow the process, on every step of the treatment and intervene with a “Mouse click”. The proposed system is developed and assembled in Portugal according to the highest quality standard levels, and the applied construction standards is ISO.

3.1 Local integration of the Reverse Osmosis system

The feeding of the system consists of an external pump, placed inside the leachate lagoon or tank, and controlled by the Reverse Osmosis module. As the topography varies from place to place, this pump must be made available locally *(to be provided locally by the client and not included in this offer price).*

Figure 9: Reference: Landfill site in São Gonçalo – Rio de Janeiro (Brazil) 120 m^3/day (31 700 gpd).

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3.2 Flow

In this proposal the plant ensures an adequate treatment with a constant entry flow at the plant of 200 m^3/day (constant 24h) of leachate with or without pre-treatment.

For the balance of the masses in this proposal we considered an affluence of leachate with 21 500 µS/cm conductivity. The annual capacity of the system must be calculated by the availability which is typically 90%.

The complete system is assembled in a 40" container. The plant can also accept leachate with different conductivity values, with adapted operating parameters.

3.3 Description of the process

3.3.1 Feeding of the process

The leachate is pumped to the container by the mentioned external supply pump. The pump is controlled by the level signal of the leachate reception tank in the Osmosis. The leachate enters the container, passes a sieve, and flows into the leachate reception tank which is equipped with two level sensors, one sensor for controlling the feed pump and the other sensor to avoid spillages.

3.3.2 Treatment stages in the Reverse Osmosis container

The main treatment stages which are integrated in the container are the following:

- Sieve with a 1,5 mm - mesh
- Pre-filtration by a pressurized sand filter
- Control of pH by dosing of sulphuric acid
- Addition of antiscalant
- Pre-filtration by microfiltration 10µm (1-10 µm)
- 1st stage of Reverse Osmosis
- 2nd stage of Reverse Osmosis
- 3rd stage of Reverse Osmosis

After the RO process it is necessary to remove the dissolved gases from the permeate. The degasifier is installed outside the container due to the corrosion of the emitted gases. It serves for the removal ("stripping") of the dissolved gases in the permeate principally CO_2. To control quality of permeate at the outlet conductivity value is measured inline. The permeate can be discharged to the environment or, alternatively, be used for irrigation or as process water, etc…

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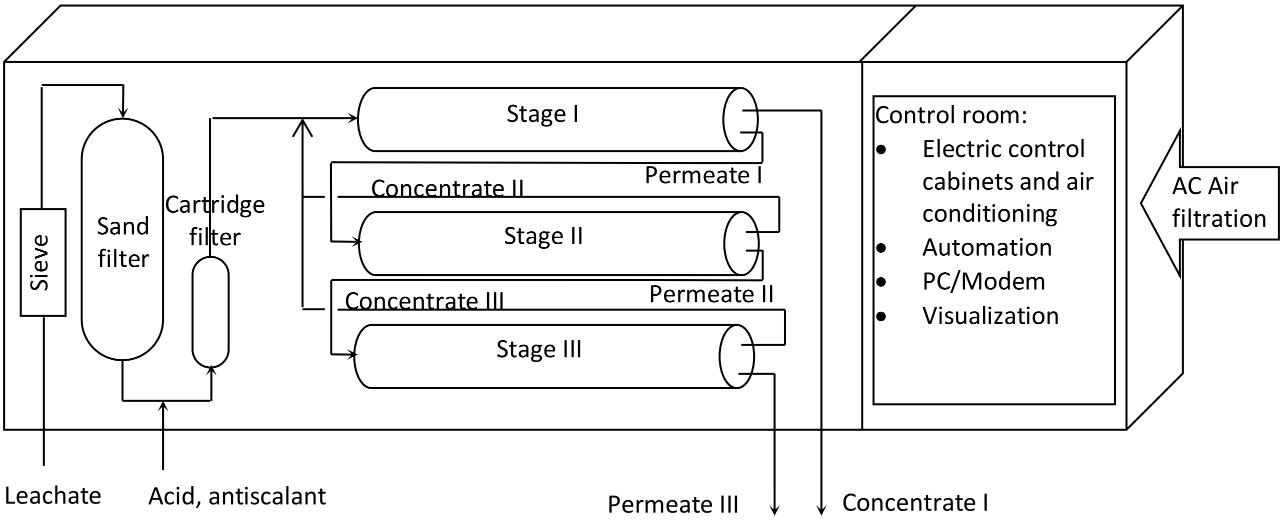

Figure 10: Scheme of a 3 stage containerized system.

3.3.3 Pre-filtration

As a pre-treatment and for the pumps and membranes protection there is a sieve with a 1,5mm mesh, a sand filtration and two microfiltration stations.

Sand filtration is carried out in pressurized filters. The sand filters are cleaned by applying an elevated (automatism included), the cleaning liquid is leachate. The periodicity depends on the content of suspended solids in the leachate and is usually weekly.

Figure 11: Cartridge filter.

After the sand filtration, there are two filtration stations with 10µm cartridge (microfiltration, porosity adjustable to the sort of leachate between 20 to 1µm) to avoid the entry of small particles which may damage the membranes. Each station takes various filtrating cartridges adapted on the size of the plant. In the case of blockage, a message appears on the system's screen. Replacement of cartridges is fast, simple, and economical and due to the parallel system, it can be executed during operation.

3.3.4 Chemical dosing system

The chemicals used in the process are used to increase the solubility of the salts and to reduce the precipitation of less volatile salts.

- pH adjustment with acid.
- Antiscalant.

Acidification is done with 96-98% concentrated sulfuric acid, which is usually the cheapest commercialized acid. The transportation and dosage pump are integrated in the container. For safety reasons, the acid injecting system is completely sealed in a chemically resistant box and equipped with a overfill sensor that switches the system off, in case of a spillage.

The pH of the leachate is controlled by the sulfuric acid dosage system, before passing through the membranes. The acid is injected directly into the piping with a dosing valve. Advantage of this solution – injection in a closed and pressurized system allows avoidance of production of foaming and strong odors.

Also, antiscalant and dispersant is added inline at a proper dosing station. Depending on the leachate composition, there are suitable products which are added to the process, to improve the performance of the plant in terms of treatment, washing cycles and lifetime of the membranes.

The pre-treatment system is equipped with pressure, flow, conductivity, temperature, and pH sensors used for the control and monitoring of the process.

3.3.5 Membrane system

The three stages of the Reverse Osmosis system are equipped with pressure sensors for process control. In case of a malfunction (under- or overpressure), the process shut down automatically. In addition, there is an overpressure safety valve in the first stage to avoid damage to the system.

3.3.5.1 1st Stage

Downstream the filtration stage, a piston pump increases the pressure according to the operating parameters (which depend on the characteristics of the leachate).

Several membrane modules are installed in a high-pressure tube, forming a block. In addition, each block is equipped with a recirculation pump which maintains the velocity at a high level, and thus, a

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turbulent flow over the membrane surface, to reduce the effects of "scaling and fouling." The high-pressure pump and a pneumatic pressure control valve create and control the pressure inside the blocks. The flow of the final concentrate is measured by an electromagnetic flow meter and controlled according to the adjusted efficiency by a special anti-cavitation pneumatic control valve with highly resistant stellite components. Depending on the type of operation, the plant can be controlled also by the pressure. Each block can be switched off separately (by-passed), to adapt the plant to different operating conditions.

The concentrates that result from the first stage can be sent to a specific area *(to be defined)*, at the remaining pressure of the modules (max. 5bar).

3.3.5.1 2nd and 3rd Stage

To ensure a proper treatment of the leachate and to guarantee the compliance of the limit values of discharge, the Osmosis system is equipped with a second and a third treatment stage. Permeate of the 1st stage follows directly to this 2nd stage without buffer tank. The operation of the process of the 2nd stage is identical to the 1st stage, only the pressure is naturally reduced due to the lower osmotic pressure (max. 35bar) in this 2nd stage. This allows a simplification of the membrane system and equipment which is executed in only one block. The concentrate of the 2nd stage is recirculated and sent to the inlet tank of the leachate in the inside of the container. This concentrate is treated together with the leachate.
The 2nd and 3rd stages can be switched off and permeate of the first stage can pass through the by-pass, directly to the receiving environment.

To ensure that there is no problem with the membrane system the permeate is monitored at the outlet by the conductivity value.

Cleaned leachate (permeate) can be discharged directly to the environment or reused for irrigation, washing of equipment, as process water or in another way by the client.

3.4 Concentrate

The proposed Reverse Osmosis system can operate up to a pressure of 80bar, diminishing significantly the volume of concentrate. There are various final solutions for the concentrate. In most cases in Europe, the concentrate is infiltrated again into the mass of waste, in a controlled manner. We can propose an additional system for the reduction of the concentrate called "Stage of concentrate". These systems have higher operational costs and, in many cases, do not compensate the level of reduction of the concentrate.

The proposed Reverse Osmosis system can pump the concentrate to a significant distance and height, without any additional energetic costs and using solely the residual pressure after the regulation valve.

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3.5 Expected lifetime of membranes

The lifetime of the 1st phase membranes depends on the composition of the leachate and of the operating and the performed maintenance. In our experience, the modules from the 1st phase have to be replaced, on average, every 2 to 3 years, and the 2nd and 3rd phase membranes every 5 to 10 years. AST has worked with the proposed membrane solution for more than 15 years; the accumulated experience allows to maximize the expected lifetime of the membranes by optimization of the operational parameters. For the operational cost's calculations, we assume a change every two years. This also allows a higher system efficiency and saves cleaning times and costs.

3.5.1 Change of membranes

The modules of the membranes are exchanged on site, this work can also be performed by the client after training. The duration of the membrane exchange operation takes approximately 4 hours.

3.6 Membrane cleaning

There is an internal buffer tank receiving the first produced permeate, which is used for the washing and cleaning of the system (CIP Tank – Cleaning in Place Tank). The level of this tank is controlled and supervised by the system and can be altered by the operator.

Throughout the system's operating the phenomena of *scaling* and *fouling* are occurring naturally. The time until these effects are taking place depends on the composition of the leachate. Taking into consideration that the system controls the flows, an increase of pressure in the system indicates the need to wash the membranes. In case of a significant increase of pressure, the integrated safety system automatically initiates an operating system with pressure control, and in case of excessive pressure it switches off.

The cleaning frequency depends on the type and specific composition of the leachate and of the operation and it is usually weekly. Cleaning is made with the permeate originating from the internal tank with adequate products.

The cleaning process can be done by remote control, or by the operator by adding the cleaning product and starting the automatic cleaning cycle.

We foresee a cleaning cycle with weekly intervals ("typical" leachate) using for that effect a specific solution, which is pumped at high velocity and low pressure through the system.

The use of individual or combined cleaning depends on the consistency of the leachate. To increase the efficiency of the cleanings, these can be done with high temperatures, these cleanings must be made with accompaniment of AST.

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The cleaning products are regularly available in the international and national markets. Based on its practical experience of over 15 years with these plants AST uses a cleaning system which makes it possible to utilize of powdery or liquid cleaners.

Figure 12. RO Leachate System treatment in three stages, flow rate of 250 m3/d, and OR System for concentrate reduction followed by evaporation, Ibiza, Spain.

3.7 Command and control system

The functioning of the process is continuous and automatic, through a programmable automaton (PLC), in case of malfunctions, the plant automatically stops. Flow control is done by electro-pneumatic automatic valves, which are controlled by PLC. The transmission of signals to the valves is done with a Profi/Asi-Bus system.

In addition, the system is equipped with a remote-control system which allows remote visualization of all the control and supervision of the process on an external PC, including access permission and modem connection. The system enables a more comfortable control, simplifies the detection of malfunctions, and increases the speed of technical assistance (direct connection to AST). Remote alterations of the monitoring and control system can be done by the PLC programmers. It is also possible to connect other automation systems if they are compatible with the Profibus protocol. This interconnection is not covered in this proposal.

The control of the plant is done through a programmable automaton, PLC. An industrial PC, by SIEMENS serves as a parameter control unit. The visualization and control of the process, such as the acquisition, evaluation and data visualization are made through the PC screen and the visualization Software (SCADA). The control surface and the control system of Reverse Osmosis of the plant will be in English language, with aid of the client we can translate additionally to local languages. The operative system will be Windows 7 or a more recent version. Additionally, a program on electric

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tension supervision will be furnished, with a protection for the control system by UPS. For additional protection of the electronic system, tension stabilizers are installed.

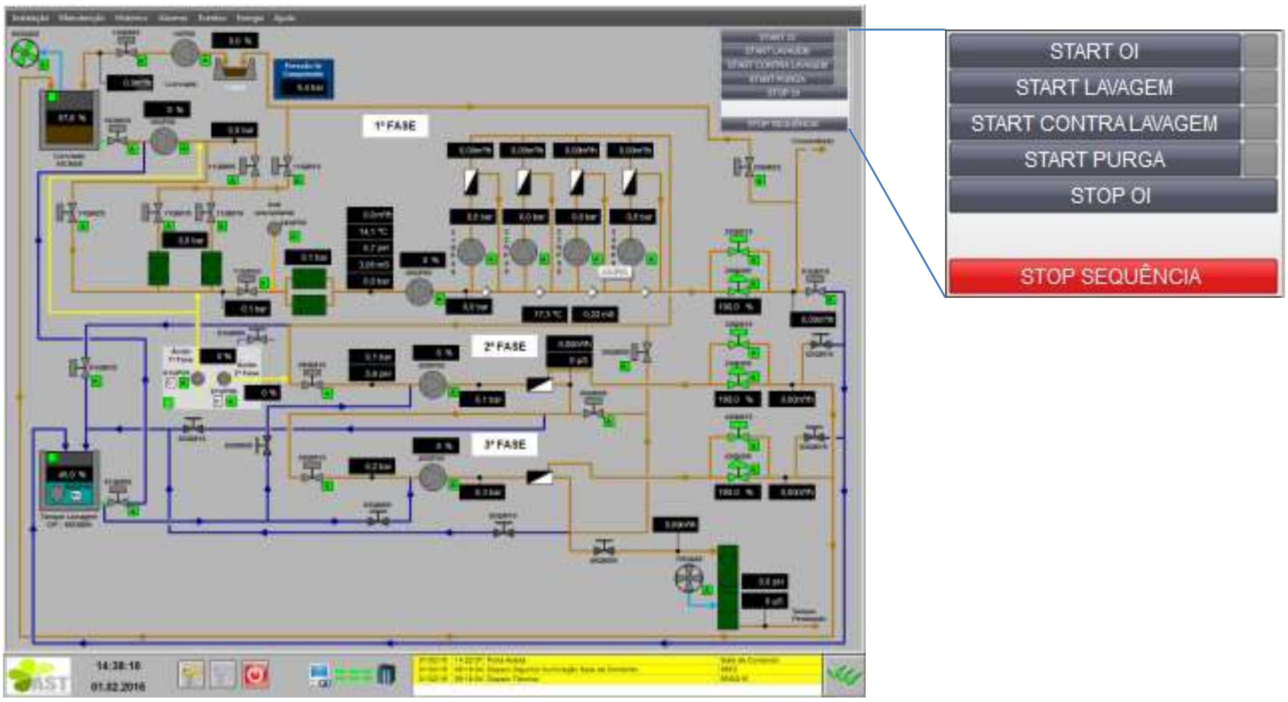

Figure 13. SCADA - Main screen from an AST RO unit.

3.8 Turboclean Technology

In the forefront of leachate treatment by Reverse Osmosis membrane systems and the more than 20 years of experience of AST's collaborators, allowed AST to acquire the sensitivity and knowledge necessary to develop/design and implement solutions to optimize the conventional process of Reverse Osmosis.

Reverse Osmosis membrane treatment systems are one of the standard solutions for landfill leachate treatment. Due to various chemical components and colloidal solids typically contained in leachate and other industrial wastewater, membrane purification systems can experience fouling resulting from the deposition of particles on their surface and in the channels of the membrane spacers, which we call particular fouling.

The removal of this fouling is extremely difficult and requires aggressive and prolonged chemical cleaning, in some cases cleaning is impossible and membrane replacement is inevitable.
AST is strongly committed to develop and improve its membrane systems not only to increase availability and robustness, but also to reduce operating costs. In this context. Therefor AST's engineering and design team have developed a proprietary technology that allows the flow direction over the membranes to be reversed during operation, "Turboclean®".

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This flow direction change system is fully automated and, although it can be activated manually, it has been designed to operate automatically.

For extreme applications, the mode of operation in directional flow change allows the clearing of membranes exposed to strong particular fouling effects. In this way, the AST solution reduces the frequency of flushing and increases the availability of the systems. In turn, a lower number of washes is not only reflected in a reduction in the consumption of cleaning chemicals, but also in the wear and tear on the membranes caused by cleaning, thus increasing their useful life.

3.9 Operation of the system

The mass balance - flow diagram with the results of the estimated flow calculations of the system operation is shown in another chapter. The calculations for the balance are based on the flow and the typical leachate composition, as shown in table 1. It is possible to operate the plant with higher concentration factors or conductivity, but the balance varies, of course, for each situation.

The proposed system is extremely flexible and allows the adaptation to different flow situations and effluent qualities.

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4 Technical Data of the Reverse Osmosis System

4.1 Leachate flowrate

The base data which have been considered for the plant design and calculations are the following:

Table 1: Leachate flowrate considered in plant design.

Parameter	Value / Unit
Plant Influent Flowrate	200 m^3/day
	8,33 m^3/h
	6.083 m^3/month
	73.000 m^3/year
Plant Design Availability	90%
Plant Effective Influent Flowrate	180 m^3/day
	7,50 m^3/h
	5.475 m^3/month
	65.700 m^3/year
Operating time	7.884 h/year

For the estimated balance of the leachate – permeate/concentrate, with calculated flows, see flow diagram in chapter 5.

4.2 Parameters for process calculation

As the base of process calculation, we considered the reference values for leachate which we received from the client. The following table shows these values, as well as complementary values to have been considered, necessary for the design of the system and to the guarantees related.

The calculations for the balance which is presented in this proposal are based on the shown values. If the leachate parameters remain within the limits of the following table, the system operation will achieve the predicted balance defined in this proposal; the operation costs will be according to the presented estimation, and the values of the discharge will attend the values which are shown in the table.

Regarding the operation guarantees and the costs for the normal operation of the RO unit, we also presumed that there are no substances in the leachate that damage or clog the membranes.

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Table 2: Leachate composition considered for the plant's design and quality and efficiency performance.

Parameter	Value / Unit
Conductivity	21500 µS/cm
pH	8
BOD	723.8 mg/L
COD	4710 mg/L
Chloride as Cl	21500 mg/L
Ammoniacal Nitrogen as N	1370 mg/L
Total Sulphur as SO4 (Dissolved)	280 mg/L
Zinc as Zn (Dissolved)	0.244 mg/L
Nickel as Ni (Dissolved)	0.202 mg/L
Lead as Pb (Dissolved)	< 0.01 mg/L
Copper as Cu (Dissolved)	< 0.01 mg/L
Chromium as Cr (Dissolved)	0.253 mg/L
Cadmium as Cd (Dissolved)	< 0.002 mg/L
Parameter maximum concentrations for design criteria:	
Total suspended solids	< 200 mg/L
Iron	< 10 mg/L
Fluoride	< 1 mg/L
Manganese	< 3 mg/L
Oils and greases	< 1 mg/L
Calcium	< 100 mg/L
Magnesium	< 40 mg/L
Silica	< 10 mg/L
addition and grouping of heavy metals (Zn+Pb+Cd+Cr+Cu+Hg+Ni) (in solution)	< 10 mg/L
each heavy metals (Zn+Pb+Cd+Cr+Cu+Hg+Ni) (in solution)	< 0,3 mg/L

Table 3: Guaranteed reduction rates.

Parameter	Reduction rate $(C_{in}-C_{out})/C_{in}$
BOD	98-99%
COD	98-99%
Total Nitrogen Kjeldahl	96-98%

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4.3 Operation data

Table 4: Technical data of the RO plant.

Parameter	Unit	Value
Leachate		
Transport capacity ("Feed")	m^3/h	7,50
Temperature (calculation base)	°C	20
Concentration factor		2 – 5
Min-max. efficiency	%	50– 80
pH after acid dosage		6 – 7
Pressures (20 °C)		
Pressure, outlet concentrate	bar	ca. 5
Pressure, outlet permeate (max.)	bar	0,5
Normal operation pressure	bar	Controlled by concentrate flow
Leachate pressure at inlet	bar	0,5 – 2 (1)
Max. pressure 1st stage	bar	80
Max. pressure 2nd stage	bar	35
Max. pressure 3rd stage	bar	35
Electric components (supply according to European Standards)		
System – three phase supply	V	400
Control voltage 1 (internal)	V	230
Frequency	Hz	50
Control voltage 2 (internal)	V	24 DC (stabilized)
Installed electrical power	kW	70
Specific electric energy consumption	kWh/m^3	8

4.4 Dimensioning of organs and equipment

All pumps, pipes, connections, filters, and other equipment are designed in order to resist to pressures that are higher than the expected maximum pressure in the respective organ. The piping and the transport capacity of the pumps were designed to allow the movement of the expected maximum leachate flow which has the composition as shown in Table 2. The geometric dimensions of the main components of the plant are shown in the drawing of the container presented in chapter 7.

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4.5 Chemical reagents

a) Sulfuric acid 96-98%;

b) Antiprecipitant – Antiscalant;

c) Powdery or liquid acid cleaning agent for membranes;

d) Powdery or liquid alkaline cleaning agent;

e) Buffer solutions for pH sensor;

f) Cleaning agents for the container: Washing-up liquid, etc.

The products can be purchased freely in the market!

4.6 Applied materials

Materials in contact with leachate: steel 1.4401, 1.4539, 1.4571; PVC, PVC-C, PEAD, PP, PVDF, PTFE, NBR and glass fiber reinforced polyester.

4.7 Unit structure

The system is installed in a 40-foot container with standard dimensions:

L x W x H: 12,192 x 2,438 x 2,55 m

The container is thermally and acoustically isolated and includes the RO unit with all electromechanical equipment, tanks, electrical cabinets and a monitoring and control system. The monitoring and control system is installed in an independent compartment and equipped with a pressurizing system and air filtration by activated carbon filter. Air conditioning system for the control cabinet must be installed locally, physical space and electrical connections are included.

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5 Calculated Mass Balance

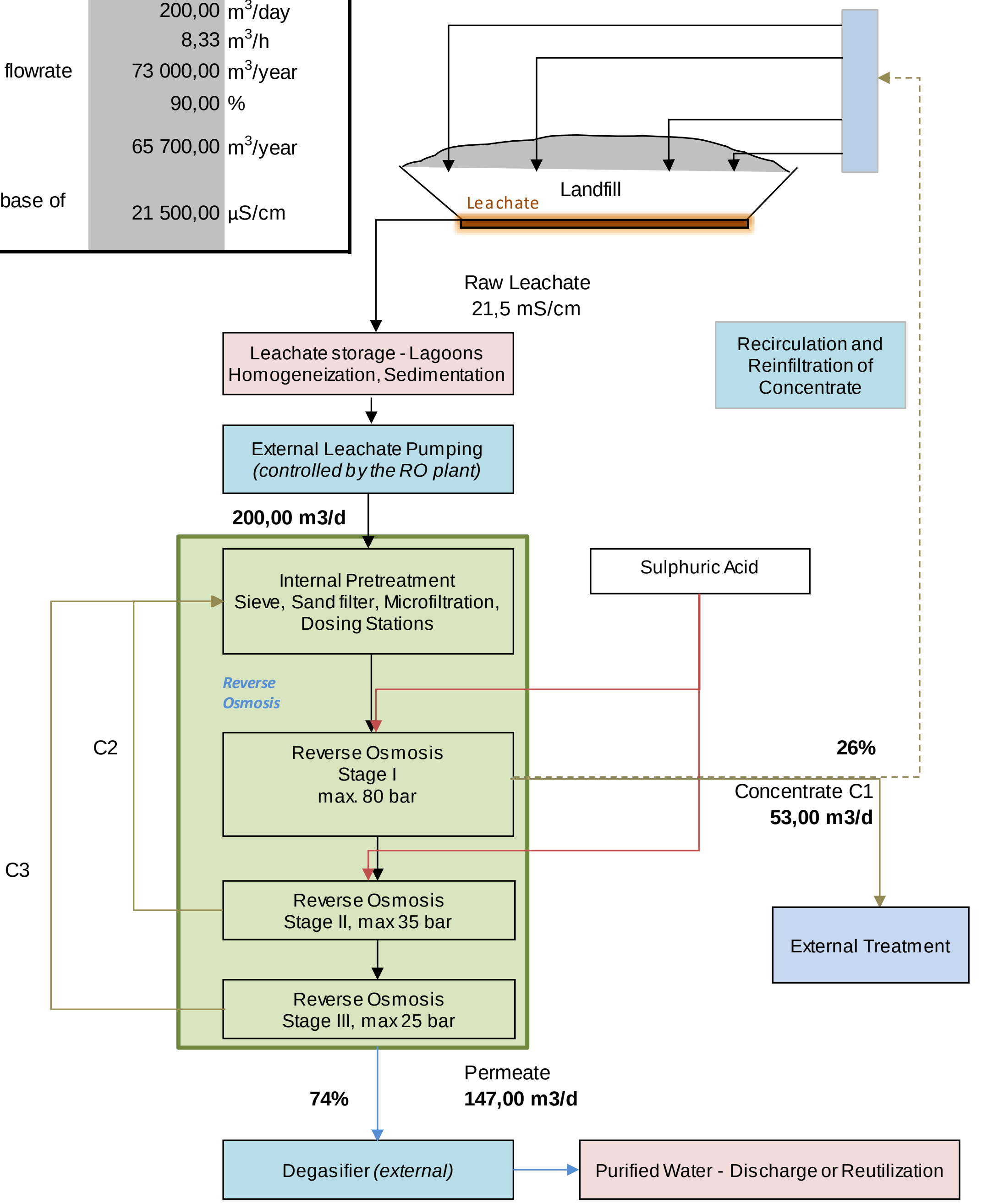
Preliminary Balance

Three Stage Reverse Osmosis Treatment of Landfill Leachate

FCC UK - Calvert Landfill

RO 1 x 200 m3/day; 3 stages

Calculation parameters:		
Normal flowrate	200,00	m^3/day
	8,33	m^3/h
Maximum theoretical flowrate	73 000,00	m^3/year
Availability rate	90,00	%
Effective flowrate	65 700,00	m^3/year
Conductivity (25 ºC), base of calculation	21 500,00	µS/cm



6 Operational Costs

Estimation of Operational Costs *(based on actual EU Costs)*			
FCC UK - Calvert Landfill			
Three Stage Reverse Osmosis Treatment of Landfill Leachate			
Bases for Calculation			
Leachate Conductivity	21 500 µS/cm		
Estimated Efficiency	73,50%		
Concentration Factor	3,77		
Maximum Input Flowrate	73 000 m3/year		
Availability	90%		
Operation Hours	7 884 h/year		
Average Input Flowrate	65 700 m3/year		
Permeate Generation	48 290 m3/year		

Operational Costs	**Estimated Cost**	**Consumption**	**Annual Cost**
Energy:			
Electrical consumption	0	525 600 kWh/year	€
Consumables:			
Sulfuric acid 96% -98%		229 950 kg/year	€
Acid cleaner		986 kg/year	€
Alkaline cleaner	/kg	2 628 kg/year	€
Inhibitor/Antiscalent	€/kg	657 kg/year	€
Cartridge filters	€/un	920 un/year	
Bag Filters	€/un	104 un/year	€
Wear and spare parts			
Annual average	€/year	1 un/year	€
Membranes:			
Membranes 1st Stage	€/un	15 un/year	€
Membranes 2nd and 3rd Stage	€/un	3 un/year	€
Labour			
Technician	€/month	12 /year	€
Total anual operation costs			**€**
Specific cost per volume of raw leachate fed to the RO plant			**€/m3**
Specific cost per volume of RO permeate			**€/m3**

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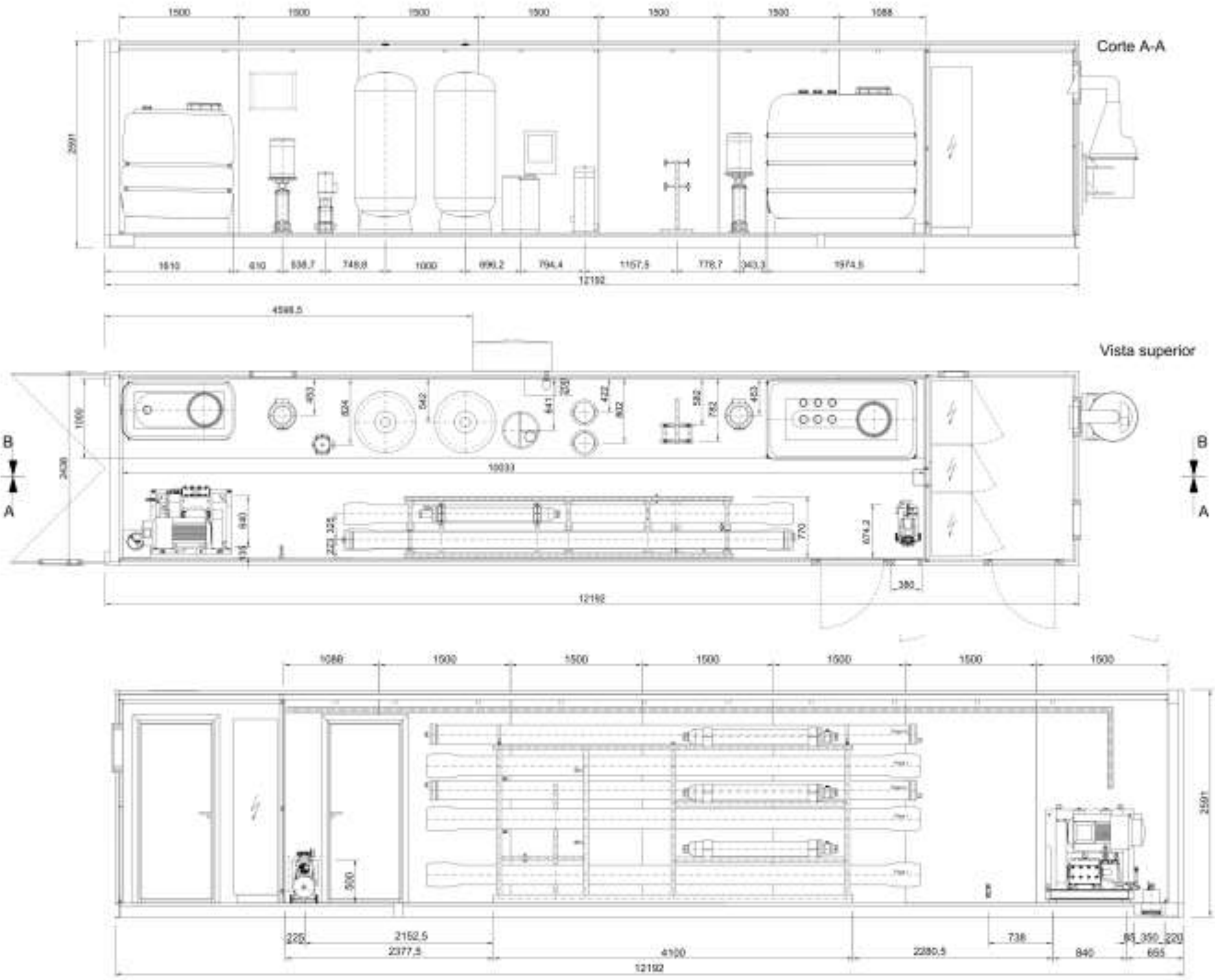
7 Similar System's Scheme



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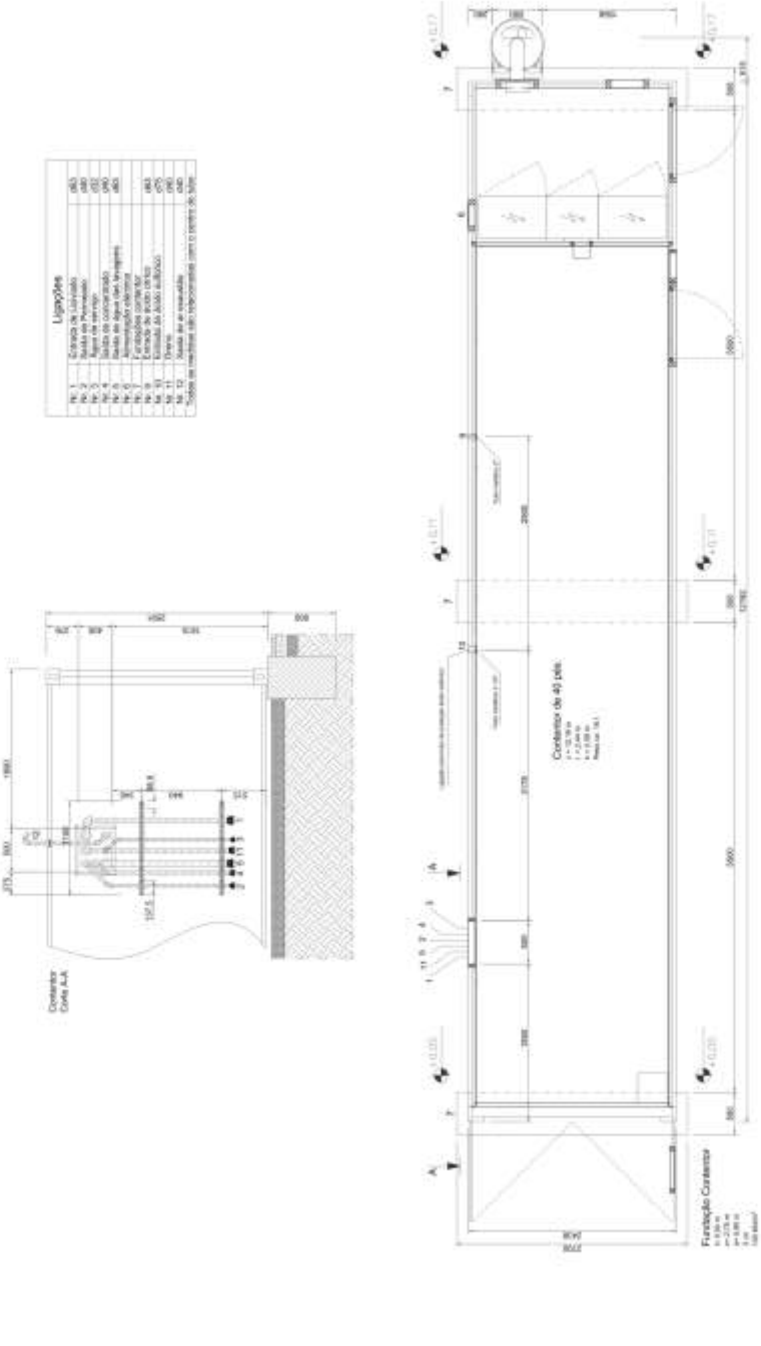
8 Basement Diagram and Connections of the System



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9 Pictures of a Similar System

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(2) Crime of disclosure of secret;
(3) Crime of violation of professional secrecy;

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APPENDIX 2

Knottingley Waste to Resource Equipment Tag Spreadsheet

Caulmert
engineering environmental planning

Registered Office: InTec, Parc Menai, Bangor, Gwynedd, LL57 4FG
Tel: 01248 672666
Email: contact@caulmert.com
Web: www.caulmert.com

Process Identifier	Item Type/description	Tag Number	Capacity
Waste Processing 01	Extraction Hood (EP01)	P01-AP-1 1	15800m³/hr
Waste Processing 01	Extraction Hood (EP09)	P01-AP-2 1	15800m³/hr
Waste Processing 01	Storage Bay	P01-BS-0 1	n/a
Waste Processing 01	Storage Bay	P01-BS-0 2	n/a
Waste Processing 01	Storage Bay	P01-BS-0 3	n/a
Waste Processing 01	Storage Bay	P01-BS-0 4	n/a
Waste Processing 01	Crusher	P01-CP-0 1	n/a
Waste Processing 01	Shredder	P01-SP-0 1	n/a
Waste Processing 01	Process Building	P01-ZP-0 1	n/a
Waste processing 02	Carbon filter (EP02)	P02-AP-0 1	3510m³/hr
Waste processing 02	Storage Bay	P02-BS-0 1	n/a
Waste processing 02	Storage Bay	P02-BS-0 2	n/a
Waste processing 02	Storage Bay	P02-BS-0 3	n/a
Waste processing 02	Storage Bay	P02-BS-0 4	n/a
Waste processing 02	Crusher	P02-CP-1 1	n/a
Waste processing 02	Shredder	P02-SP-1 1	n/a
Waste processing 02	Process Building	P02-ZP-0 1	n/a
Waste Processing 03	Carbon filter (EP03)	P03-AP-0 1	24600m³/hr
Waste Processing 03	Storage Bay	P03-BS-0 1	n/a
Waste Processing 03	Storage Bay	P03-BS-0 2	n/a
Waste Processing 03	Storage Bay	P03-BS-0 3	n/a
Waste Processing 03	Quarantine Area	P03-BS-0 4	n/a
Waste Processing 03	Shredder	P03-SP-1 1	n/a
Waste Processing 03	Shredder	P03-SP-2 x	n/a
Waste Processing 03	Process Building	P03-ZP-0 1	n/a
Waste Processing 03	Water Tank	WS1-TP-1 1	n/a
Waste Processing 04	Carbon filter (EP04)	P04-AP-0 1	4570m³/hr
Waste Processing 04	Scrubber (EP14)	P04-AP-0 2	3510m³/hr
Waste Processing 04	Scrubber (EP13)	P04-AP-0 3	3510m³/hr
Waste Processing 04	Filter Press	P04-FP-1 1	n/a
Waste Processing 04	Filter Press	P04-FP-2 1	n/a
Waste Processing 04	Filter Press	P04-FP-3 1	n/a
Waste Processing 04	Precipitation Vessel Tank	P04-TP-1 1	30m³
Waste Processing 04	Precipitation Vessel Tank	P04-TP-1 2	30m³
Waste Processing 04	Precipitation Vessel Tank	P04-TP-1 3	30m³
Waste Processing 04	Precipitation Vessel Tank	P04-TP-2 1	30m³
Waste Processing 04	Precipitation Vessel Tank	P04-TP-2 2	30m³
Waste Processing 04	Precipitation Vessel Tank	P04-TP-2 3	30m³
Waste Processing 04	Precipitation Vessel Tank	P04-TP-3 1	30m³
Waste Processing 04	Precipitation Vessel Tank	P04-TP-3 2	30m³
Waste Processing 04	Precipitation Vessel Tank	P04-TP-3 3	30m³
Waste Processing 04	Tank	P04-TP-x x	30m³
Waste Processing 04	Tank	P04-TP-x x	30m³

Waste Processing 04	Tank	P04-TP-x x	$30m^3$
Waste Processing 04	Offload	P04-TS-0 1	$100m^3$
Waste Processing 04	Offload	P04-TS-0 2	$100m^3$
Waste Processing 04	Sodium Hydroxide	P04-TS-0 3	$30m^3$
Waste Processing 04	Filtrate	P04-TS-0 4	$100m^3$
Waste Processing 04	Sulphuric Acid	P04-TS-0 5	$50m^3$
Waste Processing 04	Sulphuric Acid	P04-TS-0 6	$50m^3$
Waste Processing 04	Sodium Sulphate	P04-TS-0 7	$30m^3$
Waste Processing 04	Metal Recovery Building	P04-ZP-0 1	n/a
Waste Processing 05	Dust/Carbon filter (EP05)	P05-AP-0 1	$19500m^3/hr$
Waste Processing 05	Dryer	P05-YP-1 1	n/a
Waste Processing 05	Process Building	P05-ZP-0 1	n/a
Waste Processing 06	Carbon filter (EP06)	P06-AP-0 1	$3510m^3/hr$
Waste Processing 06	Carbon filter (EP11)	P06-AP-0 2	$3510m^3/hr$
Waste Processing 06	Scrubber (EP10)	P06-AP-0 3	$3510m^3/hr$
Waste Processing 06	Filter Press	P06-FP-1 1	n/a
Waste Processing 06	Filter Press	P06-FP-1 2	n/a
Waste Processing 06	Filter Press	P06-FP-2 1	n/a
Waste Processing 06	Filter Press	P06-FP-2 2	n/a
Waste Processing 06	APCr Silo	P06-LS-3 6	$100m^3$
Waste Processing 06	APCr Silo	P06-LS-3 7	$100m^3$
Waste Processing 06	APCr Silo	P06-LS-3 8	$100m^3$
Waste Processing 06	Conditioner	P06-RP-3 1	n/a
Waste Processing 06	Reaction Vessel	P06-TP-1 1	$50m^3$
Waste Processing 06	Reaction Vessel	P06-TP-1 2	$50m^3$
Waste Processing 06	Reaction Vessel	P06-TP-1 3	$50m^3$
Waste Processing 06	Reaction Vessel	P06-TP-2 1	$50m^3$
Waste Processing 06	Reaction Vessel	P06-TP-2 2	$50m^3$
Waste Processing 06	Reaction Vessel	P06-TP-2 3	$50m^3$
Waste Processing 06	Acid Tank	P06-TP-3 1	$50m^3$
Waste Processing 06	Effluent Tank	P06-TS-1 1	$100m^3$
Waste Processing 06	Product Tank	P06-TS-1 2	$100m^3$
Waste Processing 06	Product Tank	P06-TS-1 3	$100m^3$
Waste Processing 06	Reagent Tank	P06-TS-1 4	$50m^3$
Waste Processing 06	Bulk Tank	P06-TS-1 5	$100m^3$
Waste Processing 06	Bulk Tank	P06-TS-1 6	$100m^3$
Waste Processing 06	Treated Residue Tank	P06-TS-1 7	$100m^3$
Waste Processing 06	Effluent Tank	P06-TS-2 1	$100m^3$
Waste Processing 06	Product Tank	P06-TS-2 2	$100m^3$
Waste Processing 06	Product Tank	P06-TS-2 3	$100m^3$
Waste Processing 06	Reagent Tank	P06-TS-2 4	$50m^3$
Waste Processing 06	Bulk Tank	P06-TS-2 5	$100m^3$
Waste Processing 06	Bulk Tank	P06-TS-2 6	$100m^3$
Waste Processing 06	Treated Residue Tank	P06-TS-2 7	$100m^3$

Waste Processing 06	Treated Residue Tank	P06-TS-3 1	100m³
Waste Processing 06	Effluent Tank	P06-TS-3 2	100m³
Waste Processing 06	Slurry Tank	P06-TS-3 3	100m³
Waste Processing 06	Slurry Tank	P06-TS-3 4	100m³
Waste Processing 06	Slurry Tank	P06-TS-3 5	100m³
Waste Processing 06	Process Building	P06-ZP-1 1	n/a
Waste Processing 06	Process Building	P06-ZP-2 1	n/a
Waste Processing 06	Process Building	P06-ZP-3 1	n/a
Waste Processing 07	Carbon filter (EP07)	P07-AP-0 1	4570m³/hr
Waste Processing 07	Balance Tank	P07-TP-0 1	250m³
Waste Processing 07	Denitrification Tank	P07-TP-1 1	180m³
Waste Processing 07	Nitrification Tank	P07-TP-1 2	500m³
Waste Processing 07	Nitrification Tank	P07-TP-1 3	500m³
Waste Processing 07	Post Aeration Tank	P07-TP-1 4	180m³
Waste Processing 07	Post Denitrification Tank	P07-TP-1 5	50m³
Waste Processing 07	Denitrification Tank	P07-TP-2 1	180m³
Waste Processing 07	Nitrification Tank	P07-TP-2 2	500m³
Waste Processing 07	Nitrification Tank	P07-TP-2 3	500m³
Waste Processing 07	Post Aeration Tank	P07-TP-2 4	180m³
Waste Processing 07	Post Denitrification Tank	P07-TP-2 5	50m³
Waste Processing 07	Stripping Column	P07-TP-3 1	n/a
Waste Processing 07	Scrubbing Column	P07-TP-3 2	n/a
Waste Processing 07	Concentrating Column	P07-TP-3 3	n/a
Waste Processing 07	Humidification Vessel	P07-TP-3 4	n/a
Waste Processing 07	Offload Tank	P07-TS-0 1	600m³
Waste Processing 07	Offload Tank	P07-TS-0 2	600m³
Waste Processing 07	Discharge Tank	P07-TS-0 3	200m³
Waste Processing 07	Acetic Acid Tank	P07-TS-0 4	20m³
Waste Processing 07	Sulphuric Acid Tank	P07-TS-0 5	20m³
Waste Processing 07	Ammonia Solution Tank	P07-TS-0 6	50m³
Waste Processing 07	Leachate Treatment Building	P07-ZP-1 1	n/a
Waste Storage 01	Drum Storage Bay	S01-OS-0 1	n/a
Waste Storage 02	Acids Storage Bay	S02-BS-0 1	n/a
Waste Storage 02	Environmental Hazard Storage Bay	S02-BS-0 2	n/a
Waste Storage 02	Alkalis Storage Bay	S02-BS-0 3	n/a
Waste Storage 02	Oily Rags Storage Bay	S02-BS-0 4	n/a
Waste Storage 02	Non Hazardous Storage Bay	S02-BS-0 5	n/a
Waste Storage 02	Non Hazardous Storage Bay	S02-BS-0 6	n/a
Waste Storage 02	Non Hazardous Storage Bay	S02-BS-0 7	n/a
Waste Storage 02	Quarantine Storage Bay	S02-BS-0 8	n/a
Waste Storage 02	Packaged Waste Storage Building	S02-ZS-0 1	n/a

APPENDIX 3

Summary of Emission points with their corresponding Grid references.

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ID NEW	ID OLD	TANK ID	Grid References
SW1			SE 51236 23988
S1			SE 50944 23920
SP1			SE 51349 23903
SP2			SE 51345 23903
SITE WIDE			
EP01	EP01	GS1-TS-01	SE 51202 23827
EP02	EP02		SE 51155 23906
EP03	EP03		SE 51074 23822
EP04	EP04		SE 51301 23757
EP05	EP05		SE 51234 23838
EP06	EP06		SE 51292 23832
EP07		P07-AP-0 1	SE 51326 23924
EP08	EP08		SE 51324 23809
EP09	EP11		SE 51193 23826
EP10	EP26		SE 51292 23853
EP11	EP16		SE 51314 23832
EP12	EP18		SE 51333 23792
EP13	EP24	P04-AP-0 3	SE 51355 23764
EP14	EP14	P04-AP-0 2	SE 51349 23764
WASTE PROCESSING 04			
EP15		P04-TS-0 3	SE 51346 23761
EP16		P04-TS-0 1	SE 51339 23758
EP17		P04-TS-0 2	SE 51339 23749
EP18		P04-TS-0 4	SE 51352 23758
EP19		P04-TS-0 5	SE 51350 23751
EP20		P04-TS-0 6	SE 51349 23745
EP21		P04-TS-0 7	SE 51354 23752
EP22		P04-TS-1 1	SE 51360 23761
EP23		P04-TS-1 2	SE 51360 23758
EP24		P04-TS-1 3	SE 51360 23755
EP25		P04-TS-2 1	SE 51359 23752
EP26		P04-TS-2 2	SE 51359 23749
EP27		P04-TS-2 3	SE 51359 23746
EP28		P04-TS-3 1	SE 51366 23760
EP29		P04-TS-3 2	SE 51366 23757
EP30		P04-TS-3 3	SE 51366 23754
EP31		P04-TS-3 4	SE 51365 23751
EP32		P04-TS-3 5	SE 51365 23748
EP33		P04-TS-3 6	SE 51365 23745
WASTE PROCESSING 06			

EP34	P06-TS-1 1	SE 51276 23867
EP35	P06-TS-1 2	SE 51280 23867
EP36	P06-TS-1 3	SE 51285 23867
EP37	P06-TS-1 4	SE 51276 23862
EP38	P06-TS-1 5	SE 51276 23857
EP39	P06-TS-1 6	SE 51280 23857
EP40	P06-TS-1 7	SE 51285 23857
EP41	P06-TS-2 1	SE 51298 23867
EP42	P06-TS-2 1	SE 51303 23867
EP43	P06-TS-2 3	SE 51307 23867
EP44	P06-TS-2 4	SE 51298 23862
EP45	P06-TS-2 5	SE 51298 23857
EP46	P06-TS-2 6	SE 51303 23857
EP47	P06-TS-2 7	SE 51307 23857
EP48	P06-TS-3 1	SE 51320 23867
EP49	P06-TS-3 2	SE 51324 23867
EP50	P06-TS-3 3	SE 51320 23862
EP51	P06-TS-3 4	SE 51324 23862
EP52	P06-TS-3 5	SE 51329 23862
EP53	P06-LS-3 6	SE 51320 23857
EP54	P06-LS-3 7	SE 51324 23857
EP55	P06-LS-3 8	SE 51329 23857
WASTE PROCESSING 07		
EP56	P07-TS-0 3	SE 51279 23922
EP57	P07-TS-0 2	SE 51286 23928
EP58	P07-TS-0 1	SE 51286 23915
EP59	P07-TP-1 1	SE 51295 23929
EP60	P07-TP-0 1	SE 51295 23921
EP61	P07-TP-2 1	SE 51295 23914
EP62	P07-TP-1 2	SE 51303 23928
EP63	P07-TP-2 2	SE 51303 23915
EP64	P07-TP-1 3	SE 51314 23928
EP65	P07-TP-2 3	SE 51314 23915
EP66	P07-TP-1 5	SE 51322 23930
EP67	P07-TP-1 4	SE 51322 23926
EP68	P07-TP-2 4	SE 51322 23918
EP69	P07-TP-2 5	SE 51322 23913
EP70	P07-TS-0 6	SE 51322 23913
EP71	P07-TP-3 2	SE 51314 23902

APPENDIX 4

Secondary Containment

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Containment

The Knottingley Waste to Resource Facility is designed to provide secondary containment for all tank storage and allows for tertiary containment due to the presence of a drainage system which collects runoff waters from the site and holds them prior to release from the facility.

Tank storage areas are associated with:

Waste Processing 4 – Metals and inorganic salts recovery;

Waste Processing 6 – Physical and Physico-chemical treatment of acids and alkalis;

Waste Processing 7 – Physico-chemical and Biological treatment of landfill leachate and aqueous wastes.

Where tanks are within buildings, these are self-bunded, to provide protection to staff working in the building, and the building itself is bunded to allow spill containment.

Bunded storage areas

Waste Processing 4 bund associated with building (P04-ZP-01)

- Total tank capacity within bund: 820 m^3
- Largest tank in the bund: 100 m^3
- Basal area occupied by tanks: 239 m^2 (19 tanks maximum 4 m diameter bases)
- Bund area total: 782 m^2
- Bund height: 1m
- Total capacity: 782 m^3
- Total available capacity: 581 m^3
- **% largest tank: 581 %**

Waste Processing 6 bund associated with building (P06-ZP-11)

- Total tank capacity within bund: 650 m^3
- Largest tank in the bund: 100 m^3
- Basal area occupied by tanks: 88 m^2 (7 tanks maximum 4 m diameter bases)
- Bund area total: 374 m^2
- Bund height: 1m
- Total capacity: 374 m^3
- Total available capacity: 286 m^3
- **% largest tank: 286 %**

Waste Processing 6 bund associated with building (P06-ZP-21)

- Total tank capacity within bund: 500 m^3
- Largest tank in the bund: 100 m^3
- Basal area occupied by tanks: 88 m^2 (7 tanks maximum 4 m diameter bases)
- Bund area total: 374 m^2
- Bund height: 1m
- Total capacity: 374 m^3
- Total available capacity: 286 m^3
- **% largest tank: 286 %**

Waste Processing 6 bund associated with building (P06-ZP-31)

- Total tank capacity within bund: 800 m^3
- Largest tank in the bund: 100 m^3
- Basal area occupied by tanks: 101 m^2 (8 tanks maximum 4 m diameter bases)
- Bund area total: 389 m^2
- Bund height: 1m
- Total capacity: 389 m^3
- Total available capacity: 288 m^3
- **% largest tank 288 %**

Waste Processing 7 bund associated with building (P07-ZP-01)

- Total tank capacity within bund: 4755 m^3
- Largest tank in the bund: 600 m^3
- Basal area occupied by tanks: 517 m^2 (15 tanks, multiple base sizes area occupied)
- Bund area total: 1336 m^2
- Bund height: 1.1 m
- Total capacity: 1469 m^3
- Total available capacity: 952 m^3
- **% largest tank: 159 %**

APPENDIX 5

Site Drainage Plan

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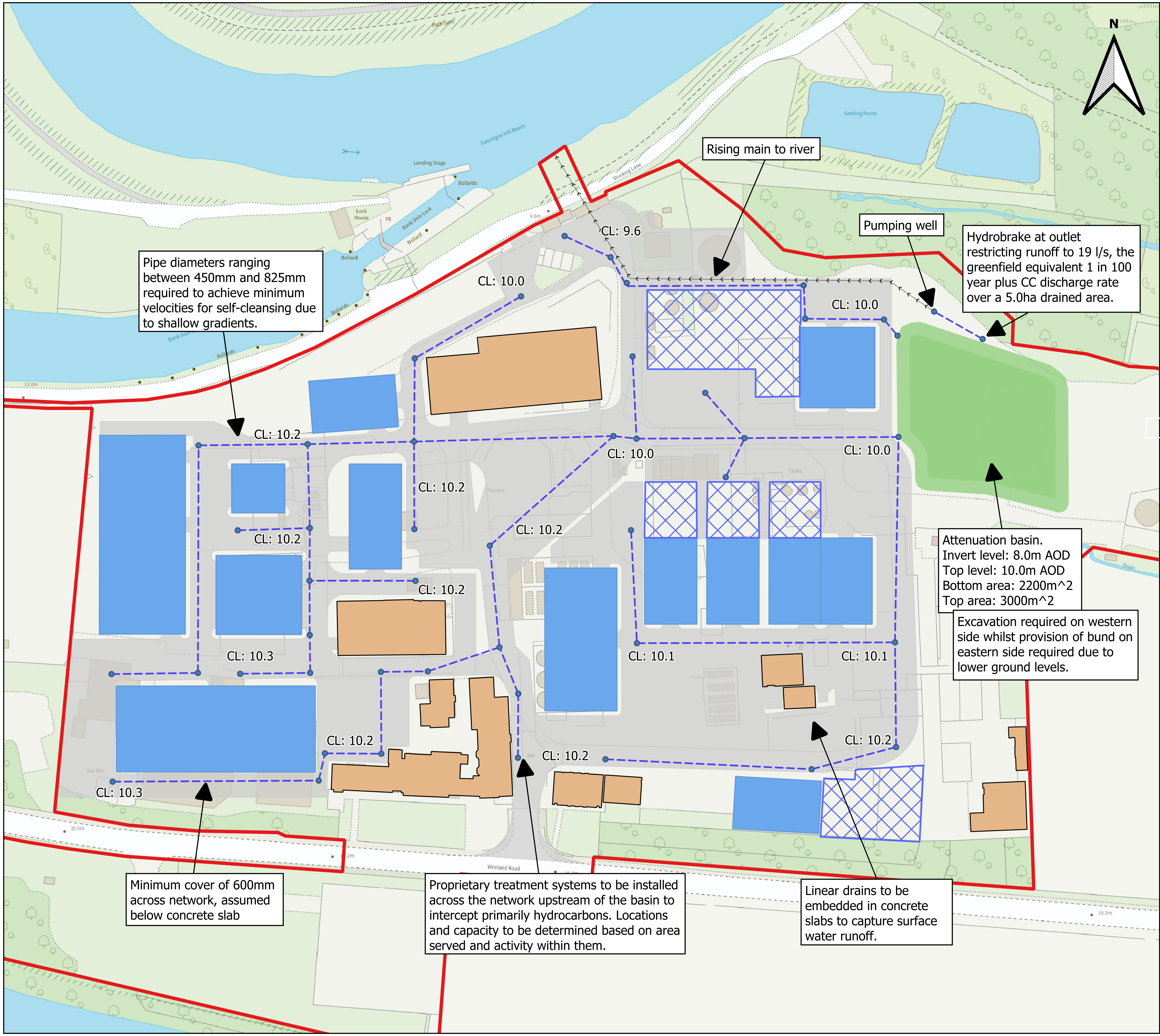

Project :

Waste to Resource Park

Client :

Axis

Legend :

- Proposed Manholes
- Rising Main
- Gravity Sewer
- Attenuation Basin
- Site Boundary
- Existing Building
- Proposed Building
- Bunded Tank Area
- Proposed Roads
- CL Cover Level

Scale :

0 20 40 60 80 m

Title :

Waste to Resource Park 33 Outline Surface Water Drainage Strategy

Drawing :	Rev :
WHS10192-T01-0001	1

WHS

APPENDIX 6

Identification and selection of emission control equipment and how it meets BAT.

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Identification and selection of Emission Control equipment: FCCE Knottingley Waste to Resource Facility

The use of the Best Available Techniques approach requires the identification of potential emissions to air and, where appropriate and practicable their control. The Best Available Techniques (BAT) Reference Document for Waste Treatment (2018) highlights the best available techniques for such control based upon the activities undertaken. This information, together with equipment selection and performance information from suppliers, knowledge of the waste treatment processes to be employed at the site and of existing experience has informed the selection of appropriate emissions control techniques to be employed at the facility.

All buildings where waste processing occurs are designed to operate as far as practicable as enclosed, with air being extracted through an appropriate or precautionary emission control system. The operation of the building, extraction and emission control system will be such as to maximise their ability to control emissions and complement waste pre-acceptance, acceptance and operational measures to minimise emissions to air.

Where activated carbon is chosen as the primary emission control technique, the carbon grade for each individual application will be selected, with advice from the supplier, to be the most suited for the range of substances required to be removed. Where practicable, carbon will be removed for regeneration once spent, as opposed to appropriate disposal.

The choice of wet scrubber configuration and associated operating conditions for each individual application will be selected, with advice from the supplier, to be the most suited for the range of substances required to be removed.

The choice of fabric filtration unit, filter media and its operating conditions for each individual application will be selected, with advice from the supplier, to be that most suited.

Where wastes are stored in buildings in an unpackaged form, emission control equipment will be operated continuously and during times of maintenance or equipment failure stocks minimised.

Where emission control is required for process tanks or vessels or waste treatment activities are being undertaken within a building, the emission control system will be in operation. During time of maintenance or equipment failure waste processing operations will cease.

Equipment will be maintained and operated in line of good practice with appropriate monitoring and routine maintenance undertaken as applicable.

Compliance with the BAT Reference Document and the Appropriate measures document has been highlighted in the appropriate documents of this permit variation application.

Control of organic emissions

Waste Processing 1

Air emissions from this building (P01-ZP-01) will contain organic substances at low concentration from bulking operations from small containers to larger containers involving organic solvents such as methanol and the shredding of retail containers and contaminated packaging. These activities are undertaken within hooded areas where air is extracted to minimise the occupational health risk to employees and visitors. The extracted air is cleaned within an activated carbon filter which is highlighted within the BAT Reference Document and known in practice to be the best technique for such emission control. Efficiency of removal exceeds 90 %.

The building is fitted with doors, and the extraction of air maintains the building under negative pressure when in use.

No processing vessels or storage tanks area associated with this activity.

Waste Processing 2

Air emissions from this building (P02-ZP-01) may contain organic vapours at very low concentration from bulking operations from small containers to larger containers involving non-volatile organic or organic substances containing wastes e.g., water-based paints and detergents and the shredding of retail containers and contaminated packaging. Inorganic wastes with very low risk of emissions are also processed in this area and exclude those that may generate gaseous emissions e.g., strong acids for which an alternative process area is provided. Wastes maybe processed anywhere, this coupled with the low risk of emissions of organic substances has resulted in the selection of activated carbon filtration as the means of emission control as highlighted in the BAT Reference Document as the most practicable technique. Efficiency of removal is expected to exceed 90 % and is the most efficient technique available for this duty.

No processing vessels or storage tanks are associated with this activity.

Waste Processing 3

Air emissions from this building (P03-ZP-01) may contain dusts and organic vapours at very low concentration from shredding and storage operations associated with non-hazardous wastes such as contaminated water-based paint containers. Waste processed are not putrescible and residence time within the building is limited to a maximum of 7 days.

Two complementary emission control systems are used. A recirculation system employing fabric dust filtration and carbon filtration, which acts to clean air and return it to the building and an air extraction system to remove potential nuisance odours or organic substances prior to emission to air via the emission point. The latter ensures negative pressure within the building as a whole, the former allows extraction of air from specific process areas and allows air to be recirculated and therefore minimising the need for space heating.

Fabric filtration for dusts is identified as a best practicable technique within the BAT Reference Document and is expected to achieve > 95 % removal of particulates. The use of activated carbon to control the emission of organic substances at low levels is highlighted in the BAT Reference Document as the best practicable technique. Efficiency of removal is expected to exceed 90 %. Both fabric filtration and activated carbon adsorption are the most efficient techniques available for their identified duties.

The building is fitted with doors, and the extraction of air maintains the building under negative pressure, this is maintained 24/7 due to the presence of unpackaged wastes.

No processing vessels or storage tanks are associated with this activity.

Control of inorganic emissions

Waste Processing 4

These activities include a building (P04-ZP-01) and an associated tank farm with mixing vessels with wastes being processed limited to inorganic solutions or solids with negligible volatile organic composition. Emission control is therefore to manage the potential presence of acid or alkaline inorganic gases specifically hydrogen chloride, sulfur dioxide and ammonia which may result from storage or processing activities of wastes or reagents containing these dissolved gases.

The use of appropriate wet scrubbing techniques is highlighted in the BAT reference document as the best practicable and most efficient means of dealing with air emissions of inorganic acid or alkaline gases. Two such scrubbing systems are to be provided, one suited for acid and one suited for alkaline gases for the tank farm and mixing vessels. Scrubbing for acid gases will be by use of a sodium hydroxide solution and of alkaline gases by a sulfuric acid solution with monitoring of these reagents being undertaken to ensure neutralising capacity is available.

All storage tanks and mixing vessels will be connected to an appropriate scrubber based upon their contents and negative pressure will be maintained 24/7 while material is present in the associated tank or vessel.

A building is used for the final filtration and processing and storage of recovered products. There is negligible risk of emissions from these activities, but the building will be maintained under negative pressure and activated carbon filtration used to clean the removed air as a precautionary measure.

Waste Processing 5

These activities are undertaken in a building (P05-ZP-01) which houses a drying unit for inorganic solid wastes. The unit is enclosed, and the presence of volatile organic materials will be negligible, however the warming of wastes may result in some odours. The building will therefore be maintained under negative pressure with activated carbon being used to clean the air removed as a precautionary measure.

Waste Processing 6

These activities are spread across three buildings each with an associated tank farm with mixing vessels present within the buildings and within the tank bunds. Tank storage is provided for liquid and solid (powder) wastes and reagents. Waste processing is limited to solid and liquids with limited inorganic solutions or solids with negligible volatile organic composition. Emission control is therefore to manage the potential presence of acidic inorganic gases, specifically hydrogen chloride and sulfur dioxides from vessels containing liquids and dusts from vessels holding powder wastes or reagents

Buildings P06-ZP-11 and ZP-21 are concerned with dealing with aqueous and solid inorganic wastes which may be acidic or alkaline and require reagents such as calcium hydroxide or sulfuric acid. Wastes and reagents may be bulk powders or liquids or packaged solids and liquids. Wet scrubbing utilising sodium hydroxide as a reagent is provided for storage vessels, reaction and mixing vessels.

The buildings are provided with an activated carbon filter to deal with what will be negligible emissions from the processing and storage activities in these buildings, but will allow the buildings to be kept under negative pressure.

Building P06-ZP-31 is concerned with the processing of Air Pollution Control (APCr) derived wastes from Energy from Waste facilities, cement kilns and similar, by washing and filtering or conditioning. The potential for emissions to atmosphere is considered negligible as the mixing of APCrs with reagents is undertaken within enclosed equipment within a building. The building is provided with an activated carbon filter to deal with what will be negligible emissions from the processing and storage activities in the building but will allow the buildings to be kept under negative pressure.

Within the associated tank farm, storage vessels or mixing vessels holding liquids, except for reagent inorganic acids, are not extracted as the potential for emissions to atmosphere are negligible – the wastes concerned being aqueous solutions of calcium hydroxide or sodium carbonate-based powders with negligible organic or other volatile components. Reagent acid storage tanks are extracted and scrubbed by a sodium hydroxide scrubber shared with the adjacent building (P06-ZP-21).

Tank storage for powders is equipped with self-cleaning fabric filters with captured dusts returned to the storage tank or removed. Fabric filters are identified within the BAT Reference Document as the best practicable technique for this application.

The use of wet scrubbing techniques with appropriate reagents is highlighted in the BAT Reference Document as the best practicable and most efficient means of dealing with air emissions of inorganic acid gases.

Control of inorganic and organic emissions

<u>Waste Processing 7</u>

Waste processing activity 7 is associated primarily with the treatment of landfill leachates to recover ammonia and return clean water to productive use in the environment. There are three distinct processing activities:

- Membrane filtration, reverse osmosis and ultrafiltration with the potential for nanofiltration, all of which are undertaken in a building (PO7-ZP-01), the equipment is sealed with no open vessels;
- Ammonia stripping and scrubbing and associated storage of the recovered aqueous ammonia solution;
- Biological treatment of landfill leachate and similar biodegradable wastes with where practical, waste substituting for reagents.

Leachate received at the facility will be from predominately closed landfills where stabilisation of the organic content has occurred. Leachate from open landfills may be received and will be partially or fully stabilised from closed cells and not operational areas. Stabilised leachate has a very low presence of volatile organic substances but does contain dissolved ammonia. The emission control rationale is therefore as follows:

- Membrane filtration units are housed within a building kept under negative pressure using an activated carbon filtration system to deal with fugitive odours should they occur. The selection of activated carbon filtration as the means of emission control is highlighted in the BAT Reference Document as the most practicable technique for such emissions. Efficiency of removal is expected to exceed 90 % and is the most efficient technique available for this duty.
- The ammonia stripping and scrubbing unit is sealed process except for a minimal air bleed and the storage tank for the recovered product. The air bleed may be a source of odour from the concentrate leachate being processed so is equipped with an activated carbon filter, the ammonia storage tank is equipped with a wet scrubber unit utilising a sulfuric acid solution to deal with displaced air.
- The biological treatment activity consists of a number of tanks where aerobic and anoxic conditions are maintained to sustain a microorganism population by

aeration or not, as appropriate, and the provision of appropriate nutrients – principally within the waste being treated. All tanks are enclosed with venting to remove displaced air (from aerated tanks) or as overfill protection. Operation of similar plants, including BAT compliant facilities, indicates no further emission controls are required.

APPENDIX 7

Leak detection and Repair protocol

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Leak Detection and Repair Plan

Provisions to prevent accident releases of pollutants to the Environment are described in the BAT document. This document summarises those activities.

Ensuring adequate monitoring and maintenance of equipment forms part of the Integrated Management System and associated procedures to be employed on the site. The application and suitability of these systems are audited both internal and by external auditors to maintain the British Standard certifications issued to the facility.

To mitigate against the risks of leakage of reagents and wastes the Knottingley Waste to Recovery facility provides:

- That operational areas are on impermeable surfaces with kerbing or bunding as appropriate to protect non operational areas. Daily site walkovers will take place to monitor the condition of the impermeable floors, kerbing and bunding to visually identify any wear or damage that may lead to loss of containment and identify any need for remedial action. The need for such action is logged, appropriate immediate action undertaken (e.g. additional temporary containment measures or cessation of activities in an area) and a defect report raised to instigate a suitable repair or modification to ensure the area concerned remains fit for purpose.
- That tanks, process equipment and vessels, ducting and pipework, other than associated with site drainage system and spill collection sumps, are above ground and within the impermeable area. Additional containment is provided within the main process areas with internal bunding of the buildings, including those storing reagents or wastes, tanks either individually bunded or grouped within a specific bunded area. Daily site walkovers will inspect tanks, process vessels, and pipework for signs of damage or leak, or unusual odours or other signs of leakage, and identify any need for remedial action. The need for such action is logged, appropriate immediate action undertaken (e.g. temporary repairs or cessation of use) and a defect report raised to instigate a suitable repair, modification, or replacement to ensure the equipment concerned remains fit for purpose. An Engineering Protocol will be developed and employed to ensure the routine maintenance inspection of tanks, process equipment and vessels and pipework in line with good practice. Engineering works identified, or undertaken as routine servicing and inspection, will be undertaken by suitably qualified staff or contractors.
- That the use of underground sumps will be avoided and limited to blind sumps for the collection of rainwater or spillages in impermeable areas or interceptors for the cleaning of (potentially) contaminated surface waters. Such sumps will be observed as fit for purpose and subject to an annual integrity test.

- That the site drainage system is such that all waters not within a tank or building bunds, are collected at a central point prior to being pumped to surface water or sewer as appropriate. Monitoring of this water provides an additional indication that a leak may have occurred and will prompt an investigation and appropriate action to remedy any relevant issue.
- That in addition to routine monitoring staff are trained in ‘near miss and incident reporting’ which allows for reporting of issues outside of formal daily or other routine inspections. An electronic incident management system is used to record these reports and instigate action by the relevant individuals– ‘see it, say it, sorted’ approach. Near miss and incident reports, with associated actions are collated and reviewed monthly to identify any negative trends or learning lessons.
- That the practices and procedures highlighted form part of the Integrated Management System which is subject to internal and external independent audit on an annual basis which may identify correct actions or opportunities for improvement.

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