Attachment 4.8.1 Operational Report

1.0 SITE OVERVIEW

The following report relates to LEO Pharma Cork's pharmaceutical manufacturing installation at Little Island, County Cork. The installation is operated under the name of Wexport Limited and is a wholly owned subsidiary of LEO Pharmaceutical Products Limited (LEO) who have other facilities in Denmark, Ireland, Italy and France.

The Cork facility is the only LEO facility for active pharmaceutical intermediate (API) manufacturing of heparin products (heparin sodium and tinzaparin sodium). Heparin is a naturally occurring anticoagulant, isolated from pig mucosa (lining of the intestine), which interferes with the body's natural blood clotting mechanism. Tinzaparin is a low molecular weight heparin. While purification and API manufacture of these products is conducted at the Cork facility, formulation and filling of the finished product is conducted at LEO facility in Denmark.

The Little Island plant was constructed in 1985 with Heparin sodium production beginning in 1986, followed by production of tinzaparin sodium in 1987. The production processes have not altered significantly over the past 30 years.

The installation received its first IE licence (P0091-01) in 1996. The Licence was subsequently reviewed and approved in 2005 (P0091-02) to facilitate new treatment arrangements for the effluent discharge to sewer, to accommodate the discharge of filter unit permeate directly to the Lough Mahon estuary, and to bring the licence in line with the current legislation.

The facility is licenced under Class 5.16 of the First Schedule of the Environmental Protection Agency Act 1992, as amended, for '*the production of pharmaceutical products including intermediates'*, and Class 11.1 for '*The recovery or disposal of waste in a facility, within the meaning of the Act of 1996, which facility is connected or associated with another activity specified in this Schedule in respect of which a licence or revised licence under Part IV is in force or in respect of which a licence under the said Part is or will be required'.*

LEO Pharma Cork are now planning to construct a new production building for the wet Heparin Sodium and Tinzaparin processes. This new development will enclose the process vessels containing ethanol allowing fugitive emissions to be captured in a vent header for treatment. The proposal therefore also includes a new carbon air abatement system. Other changes include the addition of the Tinzaparin spray dryer into the IE Licence (major air emission) and a minor increase in the volume of wastewater discharged to the foul sewer.

In 2018 LEO Pharma Cork was granted planning permission by Cork County Council (CCC) for the new production building and ancillary facilities (planning ref. 18/04614). This application was accompanied with an Environmental Impact Assessment (EIA) screening and an Appropriate Assessment Screening (AAS) which have been supplied in Section 6 of this application.

The purpose of this licence review is therefore to incorporate the proposed additional production building and ancillary changes into the existing IE licence and to include the new carbon abatement system as a major air emission point. There are also small changes proposed to the existing licence to make it make it more workable in practice.

The installation currently operates 24 hours per day, 5 days per week. This may be increasing to 24 hours per day, 7 days per week and the impact assessments have accounted for this.

The plant will undergo a scheduled phased slowdown each year for required maintenance. Due to the design of the installation there will be minimal need for shut down due to isolated maintenance of equipment as redundancy is built in. All boilers, wastewater systems, and process controls will remain online over the course of the year.

2.0 PLANT DESCRIPTION

The Leo Pharma Cork installation is an API processing facility and includes a pilot plant, quality control laboratory and business support functions. The site layout is shown in Drawing no. 002 and includes the following areas:

- Existing Production Building
- Eluation Building
- Raw Production Storage
- Laboratories
- Pilot Plant
- Administration Building
- Utilities Building
- Final Packaging Area
- Maintenance Workshop
- Ethanol Tank Farm
- Utilities Yards and External Stores
- Wastewater system
- Existing Air-Cooled Chiller
- Cooling towers
- ESB Switch Room
- Gas AGI

The proposed development will consist of the following key site changes:

- New Production Building for Heparin and Tinzaparin production
- Carbon air abatement system
- Nitrogen Skid
- New Process Chiller
- Contractors compound and car park

There are 67 personnel currently employed at the LEO Pharma Cork site. In addition to this, there is ongoing supporting personnel such as temporary agency workers, contractors, external service providers, apprenticeships and interns and

additional personnel including those visiting from other offices from the wider LEO company. It is anticipated that following the development of the new building there will be only a very minor increase to the number of personnel employed at the facility (up to 72).

2.1 Existing Site Features

Existing Production Building

Heparin sodium and tinzaparin sodium are currently manufactured in the existing production building using traditional pharma methods. Following development of the new production building, these processes will be moved out of the existing production building.

The 2 no. heparin sodium spray dryers (Emission points A2-1 and A2-2) and the 1 no. tinzaparin sodium spray dryer will remain within the existing production building.

The existing practice for tinzaparin sodium drying will be altered – currently the tinzaparin is delivered to the dryer in single use disposable bags; this will be changing to fixed stainless steel vessels. There will be 2 no. new tinzaparin spray dryer feed vessels and associated Water for Injection (WFI) vessel installed in an existing room adjoining the Tinzaparin spray dryer room.

The filling stage is co-located with the spray dryers for both heparin sodium and tinzaparin sodium. Finished product is stored in the designated area within the existing production building as shown on Drawing no. 002.

The existing building will continue to be used for parts washing (filters, tubing, etc). There is also an autoclave for sterilisation of equipment prior to re-use, and a dry heat sterilisation 'oven' for sanitisation of the receptacles for the finished product.

Eluation Building

The Eluation building will continue to operate as existing following the development of the new production building. The eluation tanks are on the ground floor and contain aqueous heparin solutions in 8,000 – 15,000L vessels.

Storage of the raw materials to be used in the eluation process are stored on the first floor of this building.

As part of the new development a new heparin bleaching suite will be installed in a fallow space in the eluation building.

There is 1 no. natural gas fired domestic boiler in the Eluation building as shown on Drawing no. 004.

Raw Production Storage/Warehouse

The warehouse is located adjacent to the eluation building and is used for the storage of most raw materials for production (excluding the Heparin Sodium and Tinzaparin Sodium powders) as well as empty receptacles for the finished product.

Raw materials will be transferred from the warehouse to the production suites following the spine link corridor following designated routes.

Laboratories and Pilot Plant

The laboratories are located adjacent to the existing production building and will be unchanged as part of the new development. The laboratories are used for quality control testing of the finished product before is it sent offsite.

The pilot plant will be used to test the new processes involved in the development of the new production building. The new production building will use glass vessels rather than plastic and will alter significantly from the existing production. As such, new vessels are being installed at the pilot plant at present to research the new processes and ensure the product can still be produced to standard (i.e. pilot batches). These pilot batches will not be for human use.

Administration Building

The existing administration building will be unchanged by the development. The administration building contains offices, staff facilities, a medical room, and a server room.

There are 2 no. natural gas fired domestic boilers in the Administration building as shown on Drawing no. 004.

Utilities Building

The utilities building contains the 2 no. existing steam boilers and the 4 no. Reverse Osmosis units (for generating reverse osmosis water and purified water for production).

The Utilities Building will be extended slightly as part of the proposed development. This will include a Purified Water (PW) storage vessel and distribution loop to support the new production building and operations.

Maintenance Workshop

There is an existing engineering store and workshop located to the west of the facility. This is for general maintenance activities and contains storage for paints, oils, cleaning agents and other materials as required for maintenance of the facility. This area will not be changing as part of the proposed development.

Ethanol Tank Farm

Bulk Ethanol storage is contained within the designated concrete tank farm to the west of the existing production building. In the tank farm there are 2 no. 99% Pure Ethanol Tanks (25m^3 and 35 m^3), 2 no. Mother Liquor tanks (25m^3 and 35 m^3), and 2 no. 93% regenerated ethanol tanks (25m^3 each). There are also 2 no. bottoms waste tanks (13.6m^3 each).

External Stores and Bunded Areas

There are a number of metal prefabricated chemstores, plastic chemstores, concrete bunded areas as highlighted on Drawing no. 009.

Wastewater System

The Wastewater System comprises a 25m^3 Effluent Tank and a dosing system. It is located in the south east corner of the site and compromises flow balancing, temperature control and pH correction for all process wastewater and utilities wastewater from the site.

A 1,500L Acid (hydrochloric acid) tank and 3,000L caustic (sodium hydroxide) tank are provided for pH adjustment of the industrial wastewaters in the Effluent Tank.

Existing Air-Cooled Chillers and Cooling towers

There are 2 no. existing chillers which provide chilled water for process cooling and HVAC cooling in the existing buildings (these will be retained for cooling of office spaces and the existing dryer suite as well as some process cooling). There are also 2 no. small cooling towers that are used to cool the return (hot) side of the chilled water loop returning from the plant to chiller 1.

ESB Switch Room

The ESB switch room controls electricity across the site. This will remain physically unchanged following the new development; new supplies will be run from the switch room to the new production building.

Gas AGI

There is an existing Gas AGI in the north west corner of the site for supply of natural gas to the facility, in particular the natural gas fired steam and domestic boilers.

2.2 New Site Features

New Production Building

The new production building will house Heparin and Tinzaparin wet process operations. Whilst the Heparin and Tinzaparin processing will be in separate suites these will be joined by a shared lobby to facility operator movement.

There will be a shared materials preparation room serving both suites. In this room the raw materials will be staged, weighed and prepared for use. The room with be equipped with a fume cupboard and services utility station.

The new Heparin processing suite will contain a new precipitation vessel with ancillary equipment / services as well as the relocated Ultra-Filtration (UF) skid. Space has been allowed for a second precipitation vessel should LEO wish to expand their operations. The UF skid has a pump to transfer the batch to the spray dryer feed vessels in the existing production building. The permeate from the UF skid will be collected in an IBC and will be pumped to the permeate collection vessel in the UF room (adjacent to the new bleaching room).

The new Tinzaparin processing suite will contain two banks of vessels on either side of the room for the production of Tinzaparin Sodium. There will be a separate filter room in the Tinzaparin processing suite which will contain all open processing activities related to the process (including Celkate make up).

Between the Tinzaparin processing suite and the Heparin processing suite will be a shared process utilities space. This will contain supporting utilities, piping headers, a CIP skid, and temperature control units for both processing suites.

All new process vessels containing ethanol will have process vents that connect to a new vent header. The vent header will be connected to the new carbon air abatement system.

Carbon Air Abatement System

A new carbon air abatement system is required to treat waste gases collected in the new vent header. All vessels containing ethanol will vent to a common vent header that will be directed to a new end of line treatment system. This treatment system will bring the concentration of ethanol in the vent stream down to below the EPA emission limit value, before it is emitted to atmosphere through a stack of 10m in height.

The new unit will be located adjacent to the Utilities Building and waste gases will be supplied via the new overground pipe rack.

Nitrogen Skid (New)

As part of the design of the new enclosed ethanol vessels and vent header, a nitrogen skid is required for the supply of inert gas. This will be located adjacent to the site utility building. Nitrogen will be supplied to the new production building via the new overground pipe rack.

New Process Chiller

A new process chiller will be installed for the new production building. This will be located adjacent to the utility building and the new nitrogen skid.

Contractor Compound and Car Park

There is a new contractors car park and compound to the west of the facility. This is not a sealed area (gravel only) and will be disestablished following the completion of the new production building.

3.0 UNIT OPERATIONS

The LEO Pharma Cork facility is designed to complete steps 2 to 4 of the pharmaceutical production process for LEO's final products. The four steps are as follows.

- **Step 1:** Production of Heparin intermediate product
- **Step 2:** Eluation of Heparin intermediate
- **Step 3:** Production of Heparin Sodium final product
- **Step 4:** Production of Tinzaparin final product

These processes occur within different areas of the plant that are designated 'grey zones' and 'white zones' where grey zones are pre-viral inactivation and the white zones are post-viral inactivation. The grey zones include the Eluation Area, Heparin bleaching process, Warehouse and external process operations. The white zones include the Heparin Precipitation Area, Tinzaparin Processing Room, Spray Dryer Processing Rooms.

The new production building is designated as a 'white' zone, or post-viral zone, as viral inactivation will occur in the new bleaching suite in the fallow space of the eluation building.

A process flow diagram (PFD) outlining the existing and proposed production processes has been included as Drawing no. 014.

3.1 Step 1: Production of Heparin Intermediate Product

Step 1 is completed at the LEO facility in Denmark. This facility produces IBCs of Heparin within resin for use the LEO Pharma Cork facility.

The product is devised from pig mucosa (lining of the intestine) and is considered a biological material; however, the Heparin product received at the LEO Pharma Cork facility is no longer a live GMO.

3.2 Step 2: Eluation

The first step is to remove (elute) the Heparin from the resin. This is done within the 8,000 – 15,000L mix vessels on the ground floor of the Eluation Building.

The eluation step takes approximately 30 days per batch. Multiple batches can run simultaneously, and a new batch is started approximately every 10 days.

Each batch uses 10 IBCs of Heparin within resin to create 1 IBC of Heparin concentrate for use in step 3 of the production process. The resin is recovered for re-use as outlines below.

Inputs for the process include Heparin within resin, salt solution, Celkate.

Outputs from the process include concentrated Heparin eluate, recovered resin, oils/fats/greases wash water (waste), Celkate (waste), permeate of permeate wastewater (waste).

3.2.1 Removing Fats, Oils and Greases

The Heparin/Resin mix is washed to remove oils, fats and greases (OFG), and these are pumped to the 2. No OFG tanks external to the Eluation Building for discharge into the onsite sewer drainage network.

3.2.2 Salt Solution Addition

Salt from the 5M salt tank is added to the mixture to separate Heparin from the resin. This is first Eluation phase. Liquid salty solution from the 3M tank is then added for the end eluation phase.

The addition of the salty solutions causes the resin to sink to the bottom of the vessels. A valve on the bottom of the tanks is used to empty the resin back into the IBCs. Metabisulphite added to the recovered resin to preserve it, and the IBCs are returned to the LEO facility in Denmark for re-use.

3.2.3 Celkate Addition

Celkate solution is added to Heparin solution to remove impurities. A centrifuge or filter press (either / or) is then used to filter the Heparin and remove the Celkate which is collected as a solid waste. The Celkate solid material is non-hazardous and is disposed of as a municipal waste.

3.2.4 Ultra-Filtration

An Ultra Filtration (UF) skid is used to further filter the Heparin solution. Minor pH adjustments are made. The purpose of the UF is to separate the Heparin from the salty solution, or permeate, and create a concentrated Heparin product.

The permeate is filtered further and is pumped back to the Eluation vessels for re-use in another batch. The rejected product from this filtering process, the permeate of the permeate, is sent to the 20,000L Permeate Tank external to the Eluation Building. This permeate is then pumped via the permeate skid, located adjacent to the permeate tank in a plastic bund, into the onsite sewer drainage network.

3.3 Step 3: Heparin Sodium Production

Step 3 operations start with the Heparin eluate produced during Step 2.

The production of one batch of Heparin Sodium takes between 24 to 50 days. Multiple batches can run simultaneously, and a new batch is started approximately every week (although this could be increased to 2 batches started per week). Approximately 60 batches are currently made per year.

Each batch uses 1 IBC of concentrated Heparin eluate to make 120kg of final product.

Inputs for the process include concentrated Heparin eluate, Purified Water (PW), recycled PW washes from equipment, sodium chloride, acid and caustic (for pH adjustment), hydrogen peroxide (for bleaching), pure ethanol (for precipitation), other smaller quantities of raw material additions (confidential).

Outputs from the process include Heparin Sodium (product), mother liquor (sent for recovery), permeate (collected for re-use).

3.3.1 Heparin Sodium Bleach Process

Concentrated Heparin eluate preserved with sodium metabisulphite and stored in plastic IBCs is released tested for use in Heparin Sodium process. These IBCs will be staged in the staging room close to Eluation UF room or the materials warehouse and are brought to the grey side charging area in the heparin bleaching room.

The contents of each IBC will be mixed by recirculation before being transferring to the bleaching vessel. Purified Water (PW) is added to the vessel to bring the solution to the required volume. The quantity of PW to be added is determined from the initial sodium chloride concentration of the input eluate material. Empty IBCs and IBC charge lines will also be flushed using PW which is added to the vessel. Spray dryer and UF flushes (which also use PW) if available are also added to the vessel. These flush volumes are taken into account when bringing the batch to the required volume.

The salt concentration is adjusted using an addition of sodium chloride. The pH is adjusted using caustic prior to adding the hydrogen peroxide. The hydrogen peroxide is charged from a 200L drum using an automatic dosing system to the bleach vessel via a designated dip pipe. The automated valve on this line will open and the flowmeter on this line will be used to quantify the amount of hydrogen peroxide which has been added to the vessel.

Bleaching occurs in the agitated vessel over a 12 to 24-hour period. An acid is used to reduce pH to stop the bleaching process.

The batch is pumped through a filter in filter housings into the Heparin precipitation vessel.

3.3.2 Heparin Sodium Precipitation Process

After a batch volume adjustment, a calculated quantity pure or regenerated ethanol is added via a flow meter into the vessel. Ethanol is supplied from two separate tie in connection points at the tank farm. One is from the pure ethanol distribution header and the other is regenerated ethanol, from the ethanol recovery process. The two lines tie into each other just before they tie into the main process inlet line to the vessel with an actuated valve to provide double isolation between the ethanol streams and process line.

The batch is held under temperature and agitation control to allow the solid product to precipitate out. After a defined time, the upper liquid ethanol layer is decanted to a mother liquor tank using a filter valve before it is sent to solvent recovery for regeneration.

3.3.3 Ultra-filtration

When the ethanol decant is completed the Heparin precipitate is dissolved in PW.

The Heparin solution in the precipitation vessel is checked for residual peroxide and the pH is adjusted using sodium hydroxide. A small, calculated quantity of an additional (confidential) raw material is added. After 1 hour the Heparin solution is neutralized using an acid. This solution is passed through a series of filters into the Ultra Filtration skid for removal of salts.

When complete the Heparin solution in the ultra-filtration retentate is transferred to an available spray dryer feed tank. The ultra-filter permeate is collected in a collection IBC and subsequently pumped to a permeate collection vessel in the Heparin bleaching room for reuse in the elution process.

3.3.4 Drying the Final Product

The Heparin solution in the feed tank is filtered through a filter on the feed line to the spray dryer.

The Heparin Sodium solution is dried using one of the two existing spray dryers (used simultaneous with split feed). Heparin Sodium powder is filled into sterilized Aluminium containers directly from the dryer outfall. The containers are filled manually by personnel. The containers are then capped in a controlled environment.

The spray dryer is flushed with PW which is collected in an IBC and recycled back to the Heparin bleaching vessel.

3.4 Step 4: Tinzaparin Production

Step 4 operation start using the Heparin Sodium final product produced in Step 3. Whilst the Heparin product is considered a final product for human use it can be further developed to produce Tinzaparin Sodium.

The production of one batch of Tinzaparin Sodium takes between 27 to 50 days. Multiple batches can run simultaneously, and a new batch is started approximately every week. Approximately 55 batches are currently made each year.

Once batch of Heparin Sodium is used to make one batch of Tinzaparin Sodium (relatively similar volume).

Inputs for the process include Heparin Sodium, PW, Water for Injection (WFI), enzyme, acid and caustic (for pH adjustment), washed Celkate, sodium chloride, hydrogen peroxide (for bleaching), pure ethanol (for precipitation), and other smaller quantities of raw material additions (confidential).

Outputs from the process include Heparin Sodium (product), mother liquor (sent for recovery), used Celkate (waste).

3.4.1 De-polymerisation reaction

Heparin Sodium powder is transferred into the Tinzaparin Reactor vessel where it is dissolved in PW. The reactor is to be controlled by a Temperature control Unit (TCU) to maintain the reactor temperature during the reactions. The pH is adjusted using acid and or caustic as necessary. Residual peroxide is neutralised.

Additional raw materials as requited for the reaction as set out by the confidential reaction calculations are added. The temperature and pH are adjusted before adding the enzyme as a liquid through a charge canister and agitating the solution.

When the reaction is complete, washed Celkate and additional raw materials (ingredients confidential) are added, and the solution is stirred to stop enzyme activity. An offline UV probe will be used to determine the end point of the reaction and when to add the Celkate / additional ingredients.

3.4.2 Fractioning

The resultant Tinzaparin solution with Celkate is passed through a lenticular filter to remove the Celkate and the filtered solution is transferred to one of the fractionation vessels. A PW flush from the reactor is transferred to the Fractioning Vessel. Sodium chloride is charged to the fractioning vessel via charge canister to adjust the salt level prior to fractionation.

A calculated quantity of pure ethanol is added via a flow meter into the vessel. The batch is held under temperature and agitation control to allow the solid product to precipitate out. After a defined time when the Tinzaparin has precipitated the supernatant liquid layer is decanted using a filter valve or to the mother liquor hold tank. The remaining Tinzaparin is dissolved in PW to a target volume using temperature and agitation control. A fixed quantity of sodium chloride is added prior to transfer to bleach vessel.

3.4.3 Bleaching

The Tinzaparin solution is then transferred to a bleaching vessel where washed Celkate slurry is added to scavenge remaining impurities. The Celkate slurry is hard piped from the Celkate make up vessel to the bleaching vessel. PW is added if required to bring batch to within acceptable volume limits. The pH is adjusted using doses of caustic and acid to a predefined setpoint.

Hydrogen peroxide is charged from a 200L drum using an automatic dosing system to the bleach vessel via a designated dip pipe. The automated valve on this line will open and the flowmeter on this line will be used to quantify the amount of hydrogen peroxide which has been added to the vessel. The pH is adjusted and bleach time started. Regular samples are taken to determine bleach end (max 4 hours) and the pH is readjusted to end bleaching when appropriate to do so.

When bleaching is complete the bleached solution is transferred to the Bleach Precipitation vessel though a filter press to remove the Celkate. The filter press is located in the filter room. A PW flush is then transferred to the Bleach Precipitation vessel and the filter press is blown through with clean air to maximise yield. The Celkate is removed manually for disposal as a municipal waste.

3.4.4 Precipitation

The bleached solution then goes to the bleach precipitation vessel. Sodium chloride is charged via a charge canister to the fractioning vessel to adjust the salt level if required prior to precipitation / decant.

Pure ethanol is added via a flow meter into the vessel. The batch is held under temperature and agitation control to allow the solid product to precipitate out. When the Tinzaparin has precipitated this second supernatant liquid layer is decanted using a filter valve to the mother liquor tank and onwards towards solvent recovery.

The remaining Tinzaparin is dissolved in PW to a target volume and pH adjusted using caustic or acid as appropriate. Then sodium chloride is added to achieve a Tinzaparin salt solution. This Tinzaparin solution is transferred into the final precipitation tank. If necessary, the salt content is adjusted, and the pH is adjusted using caustic or acid.

Pure ethanol is added again, and the batch is held under temperature and agitation control to allow the solid product to precipitate out. When the Tinzaparin has precipitated the supernatant liquid layer is decanted again to the mother liquor tank.

The remaining Tinzaparin is dissolved in WFI then agitated to give a Tinzaparin solution and pH adjusted using caustic or acid as necessary. The Tinzaparin solution is filtered through a filter as it is transferred to a spray dryer feed vessel (1 of 2) in the existing production building.

3.4.5 Drying the Final Product

The Tinzaparin solution is then transferred to the spray dryer and is dried. Tinzaparin Sodium powder is filled into sterilized Aluminium containers and capped in a controlled environment. The spray dryer fines are collected from the spray dryer cyclone and are charged back to the tinzaparin fractionation vessel using a charging canister.

4.0 KEY SUPPORT OPERATIONS

The following operations occur as part of the main production processes.

4.1 Materials Sampling

All raw materials are sampled within the materials sampling booth in the warehouse prior to being used in the process. This is enclosed to prevent contamination of the raw material during sampling (no fume hood).

4.2 Salty Solution Make Up

The 3M salty solution used in the second eluation phase is prepared within the 3M tank using salt from the 5M salt saturation and RO water from the utilities building. From here it is pumped to the eluation mix vessel where it is used during the eluation cycle.

4.3 Celkate Make Up

A dedicated Celkate wash vessel is used to prepare Celkate powder for use in the Tinzaparin process. Celkate powders are vacuum transferred into the vessel beneath the water surface to minimise dust generation. The mixture is agitated to wash the Celkate and remove calcium. The pH is adjusted using acid as necessary. The washed Celkate is charged to the Tinzaparin Reaction Vessel when required in the process.

4.4 Caustic Make Up

pH adjustments during Step 3 and Step 4 are done using a caustic solution which is prepared using Sodium Hydroxide. These are added to PW in a designated vessel within the new production building.

4.5 Solids / Powder Charging System

A new solids / powder charging system will be installed for the addition of Heparin powder to the Tinzaparin reactor. This will be employed to reduce dust generation.

The charging system will use a laminar air flow hood. A collar connection will be in place between the aluminium can (into which the product is stored) and the vessel port.

4.6 Ethanol Recovery

The facility stores bulk ethanol for use in the precipitation phase of the production process. 99% Pure Ethanol is delivered to the site and stored in bulk tanks in the tank farm. This is then piped from the Pure Ethanol tanks to the Heparin Sodium Precipitation vessel and the Tinzaparin Sodium Fractioning & Precipitation Vessels where it is charged into the vessels on an angle to prevent splash back and the generation of ethanol vapours.

The ethanol is not used in up in the precipitation process. A small amount of the ethanol is inevitably lost as vapour; and as part of the new production suite, this vapour will be collected in the new vent header for treatment in the carbon abatement system.

Decanting systems will be installed for the removal of mother liquor from the Heparin precipitation vessel, Tinzaparin fractioning vessels, and the Tinzaparin final precipitation vessel.

The used ethanol is transferred back to the mother liquor tank in the tank farm in welded pipelines to minimise the flange connections on the line. It is then sent to

the distillation columns for regeneration to 93% Ethanol. Some recovered ethanol may be re-used onsite; however, the majority is sent offsite for recovery and / or re-use (secondary use).

Two new Ethanol and Regenerated Ethanol lines will be run from the existing solvent tanks in the bulk tank farm to the new Production Building. Stainless Steel tubing will be used for these pipelines with the lines welded to minimize flanges.

Further detail on this is set out in Section 4.3 of the licence review application.

5.0 PROCESS UTILITIES

Process utilities will be tied into the existing site utility systems for services such as clean steam, plant steam, plant air, purified water (PW), water for injection (WFI) and process drains. In has been deemed that the existing generation of these services is sufficient for the new production building.

Additional utilities such as nitrogen for inerting of the ethanol process vessels will also be required.

5.1 Plant Steam and Clean Steam

Plant steam is supplied from the 2 no. natural gas boilers in the existing utilities building and is used for plant steam, clean steam, WFI generation (from clean steam). The new building will tie into this system. Plant steam condensate is collected and returned to the boilers for re-use. It is also used to pre-heat the feed water into the boiler.

Plant steam will be used sanitisation of the Tinzaparin reactor, Tinzaparin fractioning vessels, PW storage vessel, and the CIP skid.

The existing Clean Steam distribution header will be extended to supply the new Production facility. The existing clean steam generation capacity is 480Kg/hr @ 5.5 Bar and is deemed to be sufficient to support new user requirements. Clean steam condensate will be piped to the process drains as per the existing practice.

Clean steam is used in the autoclaves as well as for sanitisation of the Tinzaparin feed vessel, Tinzaparin WFI break tank, and Tinzaparin Reactor.

5.2 RO Water and Purified Water

Reverse Osmosis (RO) water is used during the eluation step (step 2) to make up the salty solution in 3M tank. It is also used for other eluation stage water additions (e.g. Celkate solution).

Purified Water (PW) is used in Heparin and Tinzaparin production (steps 3 and 4) for dissolution of precipitates and any other water additions, although WFI used in the later process steps. PW is also used for the parts washer. The PW is generated from the RO units.

Water waste from the RO units discharges into the site's stormwater network at 2 locations at the rear of the utilities building. This discharge was approved as part of the 2004 licence review application.

A new PW Storage Vessel, distribution pump and user loop are to be installed to service the new production facility. The existing PW storage tank and distribution loop will remain dedicated to the current process operations and will not be tie-into for the new production requirements. The new PW vessel will be supplied by the two existing RO generation skids.

5.3 Water for Injection (WFI)

WFI is generated using PW. The WFI stills are located in the existing production building and will remain as such following the completion of the new development. The WFI loop has a distribution pump and a heating heat exchanger for maintaining the temperature of the WFI in the distribution loop. The WFI loop is continuously run at 85C and is therefore self-sanitizing.

WFI is used for any water additions to the process post-viral inactivation including Tinzaparin Sodium precipitation, and the Tinzaparin utility station and for the parts washer. WFI is used for flushing of the spray dryers as well. The existing WFI distribution loop will be extended to supply WFI to the Tinzaparin final precipitation vessel, Tinzaparin utility station and the Tinzaparin Spray Dryer WFU Break Tank. A new WFI Break Tank shall be added in order to supply WFI to the Tinzaparin Spray Dryer.

5.4 Compressed Air

Oil-free compressed air is generated on site for use as instrument air and process (clean) air.

Instrument air is routed from the receiver to the utility panels in the production areas at fixed pressure and distributed where required, typically for valve actuation and activities such as air driven pumps.

Process air is generated by filtering the compressed air through a filter to remove submicron particles. Process air is typically used for operations (e.g., reactor and vent header air supply) and process component blowdown/testing (e.g. filter blowdown and testing).

5.5 Nitrogen Inerting

The new process vessels containing ethanol will be nitrogen inerted prior to use. The inerting is done by firstly pressurising the vessel up to 1 barg and then depressurising it through a restriction orifice and out the process vent. This is repeated 3 times in order to bring the oxygen levels in the vessel to below the flammability concentration of 5%.

The nitrogen supply will be a separate, dedicated supply / storage system to support production. A nitrogen storage vessel will be leased from a vendor who

will monitor and maintain the storage skid through online telemetry to determine when it requires filling.

5.6 Cleaning in Place Systems

All major processing equipment is cleaned using an automated clean in place (CIP) system. This involves rinsing with PW only. There are no detergents used.

The new production building will be equipped with a new CIP skid with automated cleaning cycles to optimise efficiency.

There shall be no recirculation of CIP fluid. The resulting wash water from the CIP rinse is diverted to the Effluent Tank for discharge to the foul sewer.

5.7 Clean Out of Place System

A Clean-Out-of-Place (COP) area will be provided in the existing production building to clean mobile equipment such as filters, tubing, etc. For the cleaning of smaller items, particularly those that are used in the handling of solids and filter housing, the existing process washroom will be used.

Manual washing of parts is done using WFI or PW depending on what is being cleaned. There is also a steam autoclave for sterilising equipment.

A (dry heat) oven is in place in the existing production building for sanitisation of the aluminium cans prior to being filled with final product.

5.8 Process Control Systems

All process parameters will be controlled by a Process Control Systems (PCS) which allows for fine tuning of the process and the monitoring of all process parameters in order to optimise efficiency. The control systems turn on equipment only as needed to optimise energy use.

Individual PCSs will be in place for the process areas an vessels, WFI system, PW system, CIP system, ethanol supply and decanting systems, clean steam system, nitrogen inerting system, ultrafiltration skid transfer lines, temperature control skids, vacuum skid, and spray dryers. Uninterruptible power system (UPS) power will be provided for all manufacturing control system controllers and network electronics.

In the event of a malfunction, the PCS will cause the specific process to stop. For the spray driers, this will result in an automatic change over to water, rather than product, drying. In the event of a failure of the new vent header, the wet processes will halt to prevent any further waste gases entering the vent header. In the event of a power cut, all production processes will halt, and the vessels will contain the materials within until production re-starts.

Each PCS will alarm to the local control panel to alert the operator; this will provide details of the location and nature of the malfunction. The PCS will also alarm to the BMS which will display simplified details on the security control panel. The security

personnel will contact the relevant operations personnel in the event of an after-hours malfunction.

6.0 ANCILLARY SERVICES AND UTILITIES

The following operations and services apply the site as a whole. A site services plan is provided as Drawing no. 012.

6.1 Effluent / Wastewater

Wastewater is generated onsite from the following sources:

- Distillation Column Bottoms Waste;
- Contaminated stormwater from the tank farm bund and waste storage bund;
- Resin wash wastewater in the Eluation Mix Tank (oils/fats/greases);
- Process waste generated as permeate from the Ultrafiltration process in the Eluation area;
- Rejected water generated from either the Reverse Osmosis (RO) System or the Purified Water System (non-work days only);
- Laboratory wastewater;
- Domestic effluents;
- Production Wastewater;
- Contaminated stormwater due to spill or leak (irregular); and,
- Boiler blowdown (irregular).

Drain valves on vessel platforms will drain into tundishes and be piped down to appropriate floor drains. There will be no open drains within production areas.

All effluent streams are directed to the Effluent Tank, with a capacity of 25m^3. It is a semi-sunken concrete structure with a polypropylene lining. The effluent tank has a high level alarm, totaliser, pH meter, temperature probe, and agitator. Details of the instrumentation associated with the Effluent Tank are as follows:

- Totaliser - measures the volume of effluent discharged.
- pH Meter – located within the Effluent Tank. Measures the pH of the effluent on a continual basis.
- Temp. Probe– located within the Effluent Tank. Measures the temperature of the effluent on a continual basis.
- Agitator - located within the Effluent Tank. Mixes the effluent continually.

The pH is adjusted within the Effluent Tank using Hydrochloric Acid or Sodium Hydroxide which are dosed automatically from the bunded storage tanks adjacent to the Effluent Tank.

Effluent is pumped from the tank into the Irish Water sewer provided the pH is between 6.5 and 8.5 and the temp is below 30 degrees C. If these parameters are not met the discharge pumps stops automatically and will not restart until the emission limit values are met.

The autosampler is located at monitoring point SE-1a. This automatically collects samples of the effluent at pre-set intervals. These are then analysed for compliance with the IE Licenced Emission Limit Values (ELVs).

The wastewater drainage layout is provided in Drawing no. 007.

The existing process waste and sanitary waste underground drains are constructed of Polypropylene or PVC and vary in diameter from 100-150mm (with the line from the OFG tanks to the Effluent Tank having a 50mm diameter).

The new pressurised process drains associated with the new build will be double walled stainless steel. The non-pressurised drains will be normal stainless-steel lines.

6.2 Stormwater Drainage

Stormwater is collected from across the site and is gravity fed to the south east corner of the site where is it inspected and sampled, at a manhole labelled SW-1, before discharging into the Lough Mahon Estuary.

Water waste from the Reverse Osmosis system and / or the purified water system in the Utility Building is also discharged into the onsite stormwater network following monitoring of the water quality in accordance with the existing IE Licence. Further detail on this is covered in the Emissions section below.

There is not attenuation in place for the stormwater drainage. The hard paved area of the facility is small and the site does not receive stormwater from offsite sources.

SUDS are used to reduce the volume of stormwater generated and allow natural soak away of rainwater at the site.

As there is no storage of diesel onsite, and minimal car parking areas, hydrocarbon interceptors are not currently employed.

There is a penstock in place for spillages of other chemicals onsite during storage and / or transfer.In the case of an accidental spillage or leakage on site the penstock valve is closed to divert the surface water to the Effluent Tank and the Effluent Discharge Pump is turned off in accordance with SOP_002857. This is to contain any potential contaminants. No effluent is discharged until the effluent is sampled, analysed and results are within specification as alternative arrangements may need to be made to treat the effluent or remove it offsite for treatment (SOP_002857).
The stormwater drainage layout is provided in Drawing no. 007.

6.3 Process Cooling Systems

The process cooling requirements for the new building will be provided by a variable flow 400 kW chiller located outdoor at ground level in a chiller compound. The new chiller will be dedicated to the new building and will be separate to the existing process operations. The chiller will be complete with a unit mounted variable speed drive (VSD). Duty/standby cooling water pumps mounted beside

the chiller will provide the flow rate to the various process users. The Process Chiller is equipped with its own controller to control the pumps and shall be monitored by the BMS. The chilled water pipework shall be carbon steel, insulated throughout and clad in aluminium externally.

The 2 no. existing chillers provide chilled water for process cooling and HVAC cooling in the existing buildings and these will be retained for cooling of office spaces and the existing dryer suite as well as some process cooling. There are 2 no. small cooling towers that are used to cool the return (hot) side of the chilled water loop returning from the plant to chiller 1. The cooling tower pond is monitored and treated for legionella.

6.4 HVAC Heating and Cooling Systems

There is a new heat pump that will be installed at the new building (for generation of chilled water and LPHW). The unit shall be 4-pipe systems for the simultaneous production of chilled water (CHW) and low-pressure hot water (LPHW) means of two independent hydronic circuits. The new heat pump will efficiently generate hot and cold water simultaneously with efficiencies between the hot and cold water system (auxiliary heat exchangers incorporated to recover heat from the chiller water generation for reuse by the heat pump in hot water generation). The duty circulation pump operates with a variable volume flowrate to satisfy the heating loads on the system. The 2 no. circulation pumps are configured to operate as duty and standby.

The BMS will monitor the efficiency of the new heat pump and will control the heat pump by automatically adjust the setting of HVAC plant to ensure it works optimally.

At the existing facility, HVAC heating is done using heated hot water (HHW) / LPHW which has been heated by the steam from the steam boilers using heat exchanges. HVAC cooling is done using chilled water from the existing chillers.

6.5 Air Handling Units

The new Air Handling Units will all be once through units with heat recovery. This will allow the system to take maximum advantage of free-cooling when outside conditions are suitable without affecting the room pressure profiles or requiring complicated room pressure controls. Where possible, heat recovery will be by high efficiency thermal wheels. The AHU serving ATEX areas will use a run-around coil arrangement.

6.6 Building Management System (BMS)

The installation operates a BMS automation system for control, monitoring, data collection and alarm/reporting of the HVAC air handling systems and mechanical utility systems site wide. Specifically, this includes the Process Chilled Water, HVAC Chilled Water, Cooling Tower System.

The BMS is configured to alarm in the event of a system malfunction. Alarms are differentiated between alert alarms and action alarms. The BMS alarms are displayed at each BMS workstation.

6.7 Electrical Supply and Distribution

Electrical energy will be used to power the installation and will be supplied from the mains supply to the industrial estate. There are no proposed changes to the existing connection.

6.8 Natural Gas Supply

Natural gas enters the site via an AGI skid in the north-west corner of the site from where low-pressure gas is distributed across the facility. This pre-existing supply is provided by Bord Gais.

6.9 Potable Water Supply

The water supply for the site comes from the public water supply. There are no proposed changes to the existing connection.

6.10 Firefighting Materials

There is an existing firewater ring main supplied from the water mains.

Firefighting water can be supplied across the site from 8 no. hydrants with approx. 4 Bar pressure, 900-1000L/min flowrate.

There are automatic sprinklers in the production areas (excluding the Warehouse and the laboratories) which are supplied from the mains. The new production building will also be equipped with sprinklers which will be connected to the existing system.

The server room and main electrical room have non-water based automatic suppression systems. Explosion suppression is available for the spray dryers. There are also 4 no. hose reels in the Eluation Building.

Fire foam is stored in a bunded IBC located near ethanol tanks and is accompanied with a supply cannon that applies at a rate of 1000L/min. The Foam IBC provides approx. 30 minutes of foam supply.

Local Fire extinguishers are located in all areas (CO_2, Foam, Powder as appropriate).

7.0 MANAGEMENT OF RAW MATERIALS, INTERMEDIARIES AND WASTES

A list of all raw materials in use on the site is provided in Attachment 4.6.2. This list also includes chemicals which will employed at the site once the new production building is operational. Drawing no. 009 provides a site plan showing the location of the raw materials product, and waste storage.

7.1 Raw Materials Management

Staff are fully trained in site procedures, including all Standard Operating Procedures (SOPs) and emergency response and safety procedures in relation to the storage and handling of all substances being used at the installation.

Raw materials and supplies are delivered to site by contractors/vendors. Shipments are delivered to the warehouse or to the bulk tanks directly. Raw materials are brought from the warehouse into the production areas following designated routes. Materials Air Locks (MAL) are used to control the movement of materials between differently classified zones, i.e. pre-viral inactivation or 'grey' zones, and post-viral inactivation or 'white' zones. Similarly, process waste from the production areas will be transferred to the waste areas using designated routes.

Trolleys and carts will be used for all material movements within the installation. Separate trolleys/ carts will be used for the differently classified zones (i.e. grey zones and white zones) as opposed to the individual processing rooms. Each individual processing room will have dedicated trolleys/ carts which will stay within the relevant rooms and will only travel to the individual room Materials Air Lock (MAL) to receive materials. Trolleys used to transport hazardous chemicals are bunded.

The delivery of hazardous materials to the site covered in the ADR Hazardous Goods SOP (WI_006127) which is accompanied by the ADR Hazardous Goods Deliveries Checklist (ENC_014201).

Storage of hazardous materials on site will be in bunded containers or compartments. All tanks are constructed of suitable materials for the chemicals stored within.

Bulk storage chemical tanks containing hazardous chemicals will be bunded and / or self-bunded and will be located on concrete hard stand. All bunds are capable of containing 110% of the volume of the largest drum/tank within the bund or 25 % of the total volume of the substance stored and will designed in accordance with the Environmental Protection Agency's guidelines for the storage and transfer of materials for scheduled activities (EPA, 2004).

LEO Pharma Cork have a Materials Segregation Policy (SOP_006217) which outlines which materials must be stored separately in accordance with the CLP Regulations. Acids and bases are kept in separate stores. There is no potential for mixing of these chemicals and no risk of uncontrolled reactions.

Spill kits are located across the site in highly visible and mobile units. These include absorbent socks, mats, pads, disposable bags, and PPE. Spill kits will be utilised in the event of a spill outside the designated bunds and staff are trained in the use of spill management materials. A Spill Control SOP (SOP_007750) is in place which includes the policy for spill kit monitoring.

A programme of preventative maintenance procedures in combination with regular visual inspections of non-moving parts (e.g. tanks, bunds, pipelines, valves, flanges) will identify potential issues and ensure they are remedied as required.

7.1.1 Ethanol Storage

The purchase, delivery, control and collection of Ethanol onsite is outlined in a SOP (SOP_002734). Ethanol tanks have high and low level alarms. Level alarms are connected to the Building Management System (BMS).

Stainless steel tubing will be used for the new ethanol transfer pipelines with the lines welded to minimize flanges. Supply valves on tanks are locked until use. SOP_002734 covers the control the transfer of ethanol from one tank to another or from the tanks to the production areas.

Loading/unloading from the ethanol tanks is carried out at the designated tanker loading bay. The loading bay is sloped towards a low point, and any spillage or leakage in this area would drain to the Effluent Tank.

7.1.2 Bulk Salt Tanks

There is a 12,000L 3M salt tank and a 50 tonne 5M salt tank (saturator) located adjacent to the Eluation Building. The 5M tank contains a semi-solid salt; this is used for the first eluation phase and is also used to make up the 3M salty solution.

Surface water drainage from around these tanks drains to the Effluent Tank, not to the stormwater network.

The stormwater drainage network also has an online conductivity probe at SW-1 and if salt is detected in the stormwater, a penstock is in place to switch the drainage over the Effluent Tank.

Salt volumes in the tanks vary daily. Volumes stated in Attachment 4-6-2 were based on recorded levels at the time of writing.

7.1.3 Production Chemicals

The majority of the raw materials to be used in production are stored in the Warehouse including ion recharge resin (bags), pH buffers, bagged salt, etc. Resin with Heparin, Concentrated Eluate, and Metabisulphite are stored in IBCs.

Hydrogen peroxide stored in bottles in a designated store within the main production building.

Acetic acid, hydrochloric acid, sodium hydroxide, caustic soda, and sodium hypochlorite are stored in the Eluation building on plastic spill pallets. Celkate and harbourlite (powder) are stored in sealed bags on pallets in the Eluation building. Metabisulphite is also stored in IBCs on the first floor of the Eluation Building.

7.1.4 Flammable and Hazardous Production Materials

There are a number of raw materials that by virtue of the flammable or hazardous properties are stored in portable self-bunded chemical stores external to the buildings. These include:

- Bund 3: metal chemstore for Sodium Hypochlorite
- Bund 4: metal chemstore for caustic soda liquor
- Bund 5: metal chemstore for hydrogen peroxide
- Bund 6: metal chemstore for hydrogen peroxide
- Bund 15: plastic chemstore for IPA
- Bund 20: metal chemstore for hydrogen peroxide drums – now relocated to a concrete bunded area (bund 24).
- Bund 22: metal chemstore for acetic acid
- Bund 23: metal chemstore for hydrochloric acid

The chemical stores are designed to provide sufficient bunding for the chemicals held within.

The new Bund 24 is a concrete partial bund (loading bay type) with a collection sump. Spilt materials and rainwater run-off collected in this sump will be tested and, if appropriate, will be pumped to the Effluent Tank.

7.1.5 Cleaning Chemicals

Environ Vesphene, Klericide, and Sporklenz are stored in designated areas within the Warehouse and within the production areas in small volumes. These are within plastic bottles of assorted sizes including spray bottles of Klericide.

7.1.6 Lab Chemicals

These are within the designated lab chemical storage areas. Volumes are small with a majority of the lab chemicals stored at less than 2L per chemical. Materials stored at less than 2L have been excluded from the chemical list (Attachment 4.6.2) and have been grouped at the end of the list for completeness.

Whilst some of these materials may be particularly hazardous, they are stored in small volumes only. The lab chemicals are segregated into different groups in dedicated storage cabinets within the lab areas.

7.1.7 Boiler Treatment Chemicals

These are stored internally within the utilities building. Other utilities chemicals are stored in a prefabricated metal chemstore (Bund 10).

7.1.8 Maintenance Chemicals

Assorted utilities and maintenance chemicals including pains, cleaning agents, and argon gas (for welding) are stored in the Engineering Stores and Workshop.

Utilities oils are stored within the designated plastic self-bunded store (Bund 9).

7.1.9 Wastewater Management System Chemicals

1,500L Acid (hydrochloric acid) tank and 3,000L caustic (sodium hydroxide) tank for pH adjustment of the industrial wastewaters. These are plastic self-bunded tanks with 'skirt' type bunds.

These are charged directly into the Effluent Tank within a contained area. Flange guards, which are inspected weekly, are in place on the pipelines.

Drainage from the area around the acid and caustic tanks goes to the Effluent Tank rather than to stormwater.

7.1.10 Bulk Gas Storage

Acetylene gas is stored in cylinders external to the laboratory in a designated cage. This is for use in the labs for atomic absorption. As this gas is highly flammable the gas cage is located sufficient distance from the building and the cage includes a wall on the building side for increased segregation. The laboratory also has a hydrogen generator.

The future build will include a new nitrogen storage tank. This will be supplied by the vendor (size to be confirmed during procurement). Nitrogen cylinders are currently being used for inerting some of the new process vessels as part of the trials as bulk Nitrogen is not yet onsite.

7.2 Process Intermediates

There is a bulk API store in the old production building for storage of the final product, stored within sealed cans for shipment offsite. This area will continue to be used during future operations.

7.3 Waste Management

Waste management is covered under Section 8 of this application. The process in the pharmaceutical manufacturing operation generate two categories of waste – solid and liquid wastes.

7.3.1 Solid Wastes

Hazardous solid wastes generated at the facility include the following:

- Packaging containing residues of or contaminated by hazardous substances;
- Solid waste containing dangerous substances;
- Contaminated solid waste e.g. absorbents, cloths, PPE etc;
- Fluorescent tubes;
- Inorganic hazardous waste; and
- Organic solid hazardous waste.

All solid wastes are shipped off-site for disposal/recovery as per Standard Operating Procedure (SOP) 002858 or else transported offsite for treatment in Ireland.

Non-hazardous solid wastes including paper/cardboard, plastic packaging, commercial and industrial bulky waste, domestic type wastes, and WEEE. These will be segregated and stored within the designated waste storage area prior to being removed offsite for recycling where possible, or disposal at waste to energy facility.

Transport of all waste leaving the site is by appropriately permitted hauliers only, and all waste is taken to suitably registered, permitted or licensed facilities; and records and copies of relevant documentation of all waste leaving the site is maintained on file.

7.3.2 Liquid Wastes

Process wastewater is discharged to sewer as outlined above. The internal process drainage system is capable of safely retaining any spill or leakage within the production areas. This is connected to the wastewater system.

The OFG wash water and the Permeate of Permeate wastewater from the Eluation process are stored external to the Eluation building in self-bunded tanks with 'skirt' type bunds. Surface water drainage from around these tanks drains to the Effluent Tank, not to the stormwater network.

Liquid waste streams containing ethanol will be separated and either directed to the existing ethanol recovery system or will be collected in drums for appropriate disposal.

Certain lab chemicals and liquid wastes not suitable for discharge to the sewer will be collected, labelled as hazardous waste, and transferred to the lab smalls chemstore (Bund 8).

Waste oils are stored in the designated double skinned plastic bund (Bunds 14a&b) adjacent to the utilities building. This contains assorted utilities oils. The store has been relocated and is now within a concrete bay (Bund 25) equipped with a collection sump. Spilt materials and rainwater run-off collected in this sump will be tested and, if appropriate, will be pumped to the Effluent Tank.

Other production liquid wastes are stored in a concrete loading area (Bund 2) located adjacent to the ethanol tank farm. This area also has a collection sump which can be pumped out as appropriate to the Effluent Tank.

Empty (clean) drums are stored in Bunds 11 & 12 (metal chemstores) for use for production wastes.

7.4 Bunds and Pipelines

Regular inspections of all tanks and bunds are carried out by LEO personnel. Integrity testing of the bunds is carried out every 3 years as per the IE licence. Tanks are scanned every 3 years for integrity.

The concrete bunds have local sumps which will be used to pump out uncontaminated rainwater to the Effluent Tank. Collected rainfall is tested by site maintenance staff and, if clean and free from contaminants, it will be pumped out using a via a mobile pump. The Effluent Discharge and Monitoring SOP outlines the policy on this (SOP_002859).

Above ground pipelines include extensive process pipelines, refrigerant pipelines for the refrigerant circuits in the new and existing HVAC systems, LPHW pipelines, 5M salt and 3M salt supply lines, mains water, natural gas, and glycol water in the new and existing chilled water loops. These will be constructed of appropriate materials. Above ground process drains will be constructed of stainless steel. New and existing pipes are subject to necessary preventative maintenance.

Ethanol distribution lines are constructed of stainless steel and are fully welded as far as possible to prevent leaks. These pipelines are above ground (with a small approx. 3m section underground that is routinely inspected by maintenance).

The only underground pipelines are for wastewater and surface water lines. The wastewater and stormwater characteristics are as such that double containment is not necessary as per the EPA 2004 guidance on the storage and transfer of materials. Integrity tested of underground pipelines is undertaken every 3 years as per IE licence requirement.

8.0 EMISSIONS

8.1 Air Emissions

8.1.1 Main Air Emissions

Drawing no. 005 provides a site layout with the location of the main air emission points. The details of the emissions are included in Attachment 7-4-1.

Existing Main Emissions

There are 3 no. existing main air emission points that relate to the two existing spray dryers and the existing production area (spray dryer area) extract. These will be re-labelled from A1/A2/A3 to A2-1/A2-2/A2-3. The emission from these units is Pharmaceutical Dust measured as Particulate Matter (PM).

The stack heights on A2-2 and have been increased by 600mm each to ensure the length of the stack from the sampling port to the exit is in accordance with the EPA's Air Monitoring Guidance Note (AG2) (i.e. greater than 5 diameters of the pipe from the monitoring point to the top of the stack). The production area emission (A2-1) has a stack height of 8 meters above ground level. The existing

spray dryers (A2-2, A2-3) have stacks with a height of 7.6 meters above ground level each.

Monitoring requirements for these emission points are set out in the existing IE Licence and there are no proposed changes to these.

New Carbon Abatement Unit

One of the key design features of the new production building is the enclosing of production vessels containing ethanol.

As outlined above, all new process vessels in both the Tinzaparin processing suite and the Heparin processing suite will be designed with both a relief vent and a process vent. Relief vents will be fitted with rupture discs and will vent to roof atmosphere (potential air emissions), process vents will vent to either roof atmosphere (minor air emissions) or, in the case of vessels containing ethanol, to the new vent header.

The new vent header will collect the waste gases from the process vents on the new process vessels containing ethanol and divert them to a new carbon abatement system (major air emission).

The wate gas will consist predominantly of ethanol vapours saturated in nitrogen and waste nitrogen gas vented from the vessels during inerting, purging and blanketing. Other substances present in the vessels may only be present in very small concentrations within the vent header including:

- Water;
- Sodium chloride;
- Celkate;
- Acid and caustic;
- Hydrogen peroxide; and,
- Small amounts of other (confidential) raw materials added to the production vessels.

The new carbon abatement system will have a stack height of 10 meter above ground level. Emissions will consist of predominantly ethanol expressed as total carbon.

Monitoring of the ethanol concentrations in the final emission will be continuous and will be monitored as TOC.

Monitoring of the carbon abatement system performance will also be undertaken as part of the IE licence compliance once installed. Continuous monitoring of the fan status and inflow of waste gases into the carbon unit will be controlled by the PCS which will detect any issues / malfunctions of the unit.

Tinzaparin Spray Dryer

There is an additional spray dryer in place for Tinzaparin Sodium drying that is not listed on the IE Licence. The emission from this unit will be Pharmaceutical Dust measured as PM as per the existing dryers.

The Tinzaparin spray dryer consists of the following components:

- Duty/standby fan – for drawing air into the unit;
- Electric heater – to heat the incoming air to the specified temperature;
- Incoming air HEPA filter – prior to the drying chamber;
- Main drying chamber for drying of the product;
- Feed pump – for supply of product to the drying chamber;
- Cyclone chamber – following the drying chamber; causes the product to settle out so that is can be collected in the aluminium cans;
- Bag filter for removal of product fines that have by-passed the cyclone chamber;
- HEPA filter for removal or any additional powders in the exhaust air;
- Exhaust stack with a height of 10.65 meters above ground level.

Monitoring of the emissions from the exhaust stack will be in accordance with the current practice for the existing dryers.

Existing Steam Boilers

There are 2 no. existing natural gas fired steam boilers (Boiler 1 is 1.5 MW; Boiler 2 is 1.2MW). These were previously classified as minor air emission points; however, following the Medium Combustion Plant (MCP) regulations, these will be re-designated as major air emissions.

The boilers are in operation 24/7 on a typical duty/standby arrangement with Boilers 1 operating as the lead boilers and Boiler 2 operating as hot standby or if extra steam is required. The main emissions include combustion products from the ignition of natural gas. The air dispersion model has assumed that both boilers operate at the same time for completeness.

Boiler 1 (Emission Point A1-1) has a stack hight of 8.15 meters above ground level and Boiler 2 has (Emission Point A1-2) has a stack height of 8.65 meters above ground level. These are sufficient to ensure minimal impact on the ambient air quality in the vicinity of the site (see Attachment 7-1-3-2).

Monitoring proposed is in accordance with the MCP regulations and will include NOx and CO every 3 years.

8.1.2 Minor emissions

Minor emissions consist of predominantly process ventilation emissions containing trace levels of contaminants. These include:

- production chemical vapours from production area AHUs and HVAC exhausts;
- production chemical vapours/powders from lab fume hoods and extraction arm vents;

- water vapour from the process waste drain vents and cooling tower dosing vent;
- steam from the utilities building extracts, autoclave vent, boiler blowdown vents and WFI stills;
- pharmaceutical dust from Tinzaparin spray dryer feed vessel process vent;
- natural gas from boiler regulator vents;
- refrigerants from the chiller vents;
- water vapour from the cooling towers; and,
- assorted trace levels of chemicals from the conservation vents on external tanks.

AHU units in non-process areas (e.g. canteen, non- airlock corridors, office spaces, warehouse, etc) have not been included as minor emission points in the licence.

There are also 3 no. small (<1MW thermal capacity) domestic boilers which are included in the minor air emissions list.

Drawing no. 004 is a site plan with the location of the minor and potential emissions. Further details are also supplied in Attachment 7-4-2.

8.1.3 Potential Emissions

Potential emissions include relief valves on the steam boilers and autoclave (steam emissions), chiller relief vents (trace refrigerant emissions), spray dryer relief vents for the Tinzaparin spray dryer and the Tinzaparin spray dryer feed vessel relief vent (pharmaceutical dust), and nitrogen generation skid pressure relief valves (Nitrogen emissions). These emissions only occur during abnormal events, for example over-pressurisation.

The new Bleaching Vessel relief vent (Sodium Heparin, Hydrogen Peroxide) and the new Tinzaparin Reactor Vessel relief vent (Sodium Heparin) will vent directly to atmosphere and have therefore been included as potential air emissions as well.

Drawing no. 004 is a site plan with the location of the minor and potential emissions. Further details are also supplied in Attachment 7-4-2.

8.1.4 Fugitive Emissions

Fugitive emissions are defined as low level diffuse emissions, mainly of volatile organic compounds, that occur when either gaseous or liquid process fluids escape from plant equipment.

As part of the design of the facility the project engineers have identified a number of measures designed to limit emission sources, improve integrity of process equipment and connections etc. The production processes will be enclosed and the waste gases from the process vents on vessels containing ethanol will be collected in a vent header for treatment in the new carbon abatement unit. The Tinzaparin bleaching vessel will also vent to the end of line abatement unit.

New pipelines for the transfer of Pure Ethanol from the existing solvent tanks in the bulk tank farm to the new Production Building, for the transfer of Mother Liquor from the production vessels to the bulk tank farm, will be stainless Steel tubing with the lines welded to minimize flanges.

Ethanol tanks are closed tanks with breathing vents. Fugitive emissions from the ethanol tank vents are monitored every 3 years with the most recent monitoring done in September 2018. Ethanol samples are extracted using pre-calibrated sampling pumps onto charcoal tubes. These are analysed in accordance with GC-FID. The concentrations are calculated from the laboratory results divided by air volume sampled and are converted to mg/m^3. Results in kg/h are calculated from concentration of pollutant and stack flow rate. All results are corrected to Standard Temperature and Pressure and if required to Reference Oxygen and Dry conditions.

Other solvents are used in small volumes for production (acetic acid) and cleaning of workspaces (IPA). Acetic acid is used up in the process and there are minimal fugitive emissions. IPA is sprayed onto the surfaces and wiped away with a sterile cloth; the IPA will evaporate into room air however it is also not feasible to treat by abatement as it would be present in Parts Per Billion (ppb) concentrations.

8.2 Emissions to Sewer (Wastewater Emissions)

The installation is currently licensed to dispose of up to 200m^3 of wastewater per day. The proposed changes to wastewater under this licence review include an increased wastewater discharge into the municipal network up to 250m^3 and a resulting increase in the total emissions.

There are no proposed changes to the Emission Limit Values (ELVs) other than a minor change to the pH range to match similar IE Licences as well as the acceptable pH range for the receiving Wastewater Treatment Plant (WWTP). LEO currently only emit wastewater from the site between 6.5-8.5pH and will continue to do so as best practice.

LEO Pharma Cork currently monitors the quality of wastewater discharged to sewer via SE-1 in line with its IE Licence requirements, monitoring the performance of its effluent for pH and flow with a continuous monitoring system. BOD, COD, suspended solids, Total Nitrogen, Total Phosphorus, Oils/Fats/Greases, and Heavy Metals are monitored by composite sampler and reported monthly for daily, weekly, monthly or annual averages in accordance with the existing licence. A similar monitoring programme will continue once the new development is operational subject to agreement with the Environmental Protection Agency.

Drawing no. 008 is a site plan with the location of the wastewater and stormwater monitoring locations. Further details are also supplied in Attachment 7-3-1.

8.3 Emissions to Surface Water

Water systems waste from the RO units in the utility building discharge into the onsite surface water drainage network at Emission Points SW-1A and SW-1B. This water waste is only discharged to surface water during working days; during weekends or shut down the water is discharged to the Effluent Tank. This is done by manual change over. The total contribution from SW-1A and SW-1B combined is c. 30m^3/day.

Both emission points are monitored weekly for conductivity, TOC and pH by grab sample. Note: the current licence states that the surface water be sampled using grab samples, however it also mentions a TOC analyser and pH probe. This appears to be an error; the monitoring is by grab sample only

Drawing no. 008 is a site plan with the location of the wastewater and stormwater monitoring locations. Further details are also supplied in Attachment 7-2.

8.4 Stormwater Emissions

The storm water discharge from the site at SW-1 in the south-east corner of the site and enters the Lough Mahon estuary. There is no existing attenuation required.
Conductivity and pH monitoring are currently monitored daily by grab sample, and temperature is monitored weekly using a thermometer (usually at the same time as the visual inspection). LEO also take a grab sample once per week to be analysed for COD. Conductivity and pH monitoring are proposed to be changed to weekly as sufficient data has been collected to date on the nature of the stormwater run-off.

Weekly visual inspections will be undertaken at SW-1 in accordance with the installation's existing IE Licence.

Drawing no. 008 is a site plan with the location of the wastewater and stormwater monitoring locations. Further details are also supplied in Attachment 7-7.

8.5 Emissions to Ground

There are no existing emissions points to ground from the installation.

There are 2 no. new groundwater monitoring wells (GW-1 and GW-2) which will be monitored annually and assessed against the EPA's Interim Groundwater Values 2003 and the Groundwater Regulations SI No. 9 of 2010. The locations of the groundwater monitoring wells are shown on Drawing no. 010.

8.6 Noise Emissions

There will be several new items of noise generating equipment operating on the site. These include the heat pump, the nitrogen skids, the carbon abatement system, the process chiller, and the new building AHUs.

The existing facility also contains noise generating plant. Emissions from the site's dominant noise sources (i.e. compressor louver, roof top extract, cooling town) are monitored annually as part of the compliance monitoring and reporting.

Drawing no. 013 is a site plan with the location of the noise sources. Further details are also supplied in Attachment 7-5.

The noise report included with Attachment 7.1.3.2 provides a list of the existing and proposed noise sources.

Annual day time and night-time monitoring is undertaken at the installation from designated boundary locations. Data recorded from these locations is used to estimate off site noise levels.

9.0 TREATMENT AND ABATEMENT SYSTEMS

9.1 Air Emissions

9.1.1 Major Air Emissions

New VOC Abatement system

As outlined above, all new process vessels in both the Tinzaparin processing suite and the Heparin processing suite will be designed with both a relief vent and a process vent. Process vents will vent to either roof atmosphere or, in the case of vessels containing volatile organic compounds (VOCs), to the new vent header.

The only VOC used in the manufacture of Heparin or Tinzaparin Sodium is ethanol. Ethanol is used as a solvent during the precipitation steps for both the Heparin and Tinzaparin manufacturing processes. Therefore, all vessels containing ethanol will vent to a common vent header that will be directed to a new end of line treatment system. This will remove 99% of the ethanol from the waste gas stream.

In the current process on site, it has been found that residual ethanol is left behind following the decant step and is being passed onto the next step in the process. In the Heparin process, the step following the precipitation step is Ultrafiltration. In the Tinzaparin process, the steps following precipitation are bleaching and spray drying. In the future process it is possible that the volume of residual ethanol left behind may increase as the method used for decanting is changing from manual to automated. For this reason, the Heparin Ultrafiltration skid and the Permeate collection vessel will vent to the end of line abatement unit. The Tinzaparin bleaching vessel will also vent to the end of line abatement unit.

The vent header going to the abatement unit will be designed as a lean header in order to avoid the formation of flammable mixtures in the line. Fresh air will constantly flow through the header at a rate that ensures the concentration of ethanol will be kept below 25% of the Lower Explosion Limit (LEL). An LEL analyser will be installed at the end of the header with an air supply to dilute the solvent vapours to the required set point.

The new system will consist of the following key items:

- Flame Arrestor
- Duct Header
- Lead Mobile Carbon Vessel
- Lag Mobile Carbon Vessel
- Duty / Standby fan
- Emission Stack

A PDF outlining the process is provided as Drawing no. 015.

The Flame Arrestor will be located at the end of the vent header, immediately upstream of the carbon abatement system. The purpose of this unit is to mitigate against flash back from the abatement unit (which may act as an ignition source).

The Duct Header or a demister will be incorporated into the design of the vent system. As water will compete with ethanol for the carbon in the abatement units, a pre-conditioning step is required to reduce the humidity in the vent header.

The 2 no. single use carbon beds will operate in series in a lead-lag configuration. The leading bed will be used as a "buffer" to shave the peaks, and the lagging unit will have a rather stable inlet concentration. Once the leading bed becomes saturated, it is changed out and the current lagging bed becomes the new leading bed.

A centrifugal fan will be required to draw fresh air into the vent header the keep the vent stream diluted below 25% of the LEL. The fans can be set up in a duty standby arrangement so that in the case where one fan fails, the other immediately starts up.

The final emission to atmosphere will be via the 10m stack which will be equipped with a monitoring platform for emissions monitoring.

Control monitoring of in inflow rate of the waste gas and the fan status will be undertaken and controlled by the PCS.

In the event of a failure of the new vent header or the carbon abatement system the PCS will cause the production processes will shut down to prevent any further waste gases entering the vent header. Any by-passes will be short in nature and will be reported to the Environmental Protection Agency in accordance with the IE Licence.

Existing Dust Abatement

The existing spray drier area extract (A2-1) has a course filter (85% efficiency) and the existing spray dryers (A2-2, A2-3) have cartridge filters. These are designed to remove pharmaceutical dust to below the licenced emission levels.

Monitoring of the filter on the A2-1 emission point is completed in accordance with the existing IE Licence requirements. This includes continuous monitoring of the pressure in the unit by BMS. Annual visual inspections are undertaken during filter change out; the filters are changes out twice per year or as required. LEO Pharma

Cork request to remove the requirement for quarterly pressure testing as this is superfluous.

Monitoring of the cartridge filters on A2-2 and A2-3 includes continuous monitoring of the pressure in the unit by the PCS and annual visual inspections as per the existing IE Licence requirement. Filters are changed out approximately every 3 years or as required.

Tinzaparin Spray Dryer Abatement

The Tinzaparin spray dryer has both a bag filter and a HEPA filter. These are designed to remove pharmaceutical dust from the exhaust air. The filters are 99.95% efficient at 0.3-0.5micron particule size and 100% efficient c.1.0 micron particule size.

The bag filter consists of a cylindrical filter chamber which removes particulates that have by-passed the cyclone chamber. Particulates collect on the walls of the bag and an opening at the bottom of the bag is used to remove the product.

The HEPA filter follows the bag filter and is in place to capture any of the remaining particulates in the exhaust air stream. This also acts as a backup in the event of a failure of the bag filter.

Control monitoring of the abatement filters is similar to the existing dryers and includes monitoring of the differential pressure across the filter by the PCS as well as annual visual inspections. The bag filters are changed out after every batch; the HEPA filters are changed out only as required (however they are visually inspected twice yearly).

Boilers

No specific abatement is in place for the major (boiler) air emissions. NO_2 modelling results at the worst-case off-site receptor i.e., the highest NO_2 concentrations measured off-site (including the site boundary) showed no significant impact.

9.1.2 Minor Air Emissions

Minor emissions from production vessels, emissions from fume hoods, tank vents, and steam boilers are not considered to be significant and appropriate abatement (i.e. HEPA filters and course filters as appropriate) will be employed to remove trace contaminants.

9.2 Wastewater

Abatement measures and monitoring are in place only for the process wastewater, whilst domestic effluent flows straight to the sewer.

Process-integrated techniques and wastewater pre-treatment (pH and temperature adjustment) have been utilised. Final wastewater treatment is via the municipal Wastewater Treatment Plant (WWTP).

9.2.1 Wastewater Balancing

Process effluent is collected in the Effluent Tank (25m^3) to smooth out any variations in the flow and pollutant loads. This allows a more uniform wastewater stream to be sent to the Irish Water municipal sewer. There is no proposed change to this system.

9.2.2 Naturalisation

In addition to flow balancing the process wastewater will require pH correction prior to being sent to the municipal sewer. This occurs within the Effluent Tank which is equipped with a chemical dosing system (acid and caustic). There are 2 no. pH sensors at different locations to ensure effective pH treatment.

9.2.3 Other Control Methods

Other methods are employed to reduce the impact on the sewer including:

- The Distillation Column Bottoms Waste is monitored for COD and is only discharged to the Effluent Tank if the result is <33,000 mg/l. If the result is <33,000 mg/l the distillation column bottoms waste is discharged into the Effluent Tank at a rate of <3000Lts per day. If it exceeds, this will be investigated, and the waste may be removed by a waste contractor for offsite disposal.

- Before any waste from either bunded area is discharged to the Effluent Tank it is sampled for COD analysis and pH. The results must be <33,000 mg/l. If the COD result is less than the effluent specification, the bund can be discharged into the marked effluent drain but if the result exceeds the effluent specification, the source of the COD failure must be investigated.

- Permeate waste is slowly discharged from the Permeate Tank to the Effluent Tank via a dosing skid to prevent peaks in the salt concentration of the wastewater stream.

- OFGs from the eluation process are slowly discharged from the designated tank into the Effluent Tank as a set rate.

9.3 Emissions to Surface Water

This water waste is only discharged to surface water during working days; during weekends or shut down the water is discharged to the Effluent Tank.

Conductivity is monitored continuously at SW-1. This is not part of the licenced monitoring for Emission Point SW-1 but is part of the operational practices in place at LEO (control monitoring). If the conductivity approaches the ELV then the discharge is directed to the Effluent Tank rather than the surface water drainage system. See further detail below.

9.4 Stormwater Emissions

As there is no diesel stored onsite there is no requirement for hydrocarbon interceptors. The car park areas are small and there will be minimal hydrocarbon loses from vehicles.

In the case of accidental chemical spill or leak from the chemicals stored the surface water may be contaminated. Whilst not required under condition of the existing IE Licence, LEO Pharma Cork have installed a conductivity probe and penstock valve at SW-1 in order to detect possible contamination of the surface water before it enters the Lough Mahon Estuary. In the event that the conductivity exceeds 1700 micro Siemens, the surface water is diverted to the Effluent Tank in accordance with onsite Standard Operating Procedure (SOP) SOP_002857. The Effluent Tank sample results will dictate whether the effluent can be discharged in accordance with Section 8.0 on SOP_002859 or whether alternative arrangements need to be made to treat or remove the contaminated effluent offsite for treatment in accordance with SOP_002858. The penstock valve will not re-open until the conductivity goes below the set level. The penstock can also be manually changed over to discharge stormwater to the Effluent Tank when ethanol tankers are on the site.

9.5 Noise Emissions

Where possible, external plant layout has utilised barrier screening of on-site buildings, low noise generating plant items have been selected, and noisy plant items have been located within buildings. Rooftop AHU's are likely to have acoustic attenuators fitted as standard. A noise management plan including noise monitoring will be outlined in the installation's EMS as required.

9.6 Waste

Measures to address waste and minimize waste production are addressed in Section 8 of this IE Licence review application.

10.0 MANAGEMENT SYSTEMS

LEO Pharma Cork have an established Environmental Management System (EMS) which is accredited to ISO14001.The EMS outlines the management of the sites environmental program in a comprehensive, systematic, planned and documented manner.

10.1 Emergency Response Plan

An on-site Emergency Response Plan (ERP), Procedure ref. SOP_002861, is in place at the installation and will be updated to include the new production building. The ERP details the required response of the emergency response team (ERT) in the event of an incident on site and covers out of hours response. The ERP is reviewed regularly by the EHS manager and is updated as required.

10.2 Standard Operating Procedures

LEO Pharma Cork are an established pharmaceutical installation with a number of SOPs in place for the prevention and management environmentally hazardous events. These include:

- SOP_002857 Procedure to deal with an environmental emergency;
- SOP_002858 Collection, storage, disposal and monitoring of waste;
- SOP_002734 Purchases, delivery, control and collection of ethanol;
- SOP_006217 Materials segregation policy;
- SOP_007750 Spill control;
- WI_006127 ADR hazardous goods
- WI_006344 Control of F-gases
- SOP_21490 Traffic Management
- WI_007376 Natural Gas Distribution and Isolation
- WI_004539 Competence, training and awareness

The installation's SOPs will be updated to accommodate the changes to the installation including the new production building.

11.0 ALTERNATIVES

11.1 Process alternatives

The proposed development will upgrade the existing production processes at the facility and will enclose the vessels containing ethanol so that waste gases can be collected in a vent header rather than venting to room space (current process).

The production process itself has not changed significantly over the past 30 years. The reaction calculations are set and there is little movement for altering the process.

As such, there were three alternatives available,

- ❖ Keep the existing production process as existing;
- ❖ Enclose the existing vessels;
- ❖ Relocate the production process to a new production building with enclosed vessels.

It was not considered viable to keep the facility as is, as the production processes no longer meet BAT and GMP requirements. It was also not viable to enclose the existing vessels as the existing production building is not designed to accommodate such a change. As such, it was determined that a new production building should be designed to incorporate the existing production processes whilst also minimising fugitive emissions.

11.2 Abatement Alternatives

A VOC abatement unit will be used to treat the process vent that contains ethanol from the process. A variety of VOC abatement technologies were considered for

the process. These technologies include those listed in the relevant BREF and BAT Guidance Notes:

- Carbon Single Use
- Carbon Bed Regeneration
- Water Scrubbing
- Vent Condenser
- Cryogenic Condensation
- Thermal Oxidation

In order to choose the one most suitable for the application, the technologies were compared based on their complexity, size, cost and public perception. It is also essential that the technology selected ensures compliance with the relevant emissions regulations and is capable of dealing with the flowrates and composition of the inlet air.

As the VOCs emitting from the manufacturing process consist only of ethanol in low concentrations, a number of the technologies listed above were immediately deemed unsuitable due to over-complexity and high cost.

Cryogenic condensation involves passing the vent stream through several condensing heat exchangers in which the cooling medium is liquid nitrogen. This method has a high capital cost and requires a high nitrogen demand. Therefore, the technology was ruled out on the basis of cost.

Thermal oxidation involves the complete thermal combustion/oxidation of the VOC's in the vent stream. The air stream is sent to a combustion chamber where an exothermic reaction takes place, converting the VOCs to carbon dioxide and water vapour. Thermal oxidation has major public relation impacts, a gas supply is required and there are issues around stack height location and high temperature flue gas. Overall, the technology is not considered due to cost and public relations issues.

Utilisation of Vent Condensers involves passing the vent stream through a cooling heat exchanger which condenses the VOCs. The liquid waste is collected for recovery or disposal. This technology is not considered as it is not possible to attain outlet concentrations below the ELVs given the solvents used and the inlet air concentration.

After rejecting these technologies, the suitable technologies were narrowed down to the following three: water scrubbing, single use carbon beds and regenerative carbon beds.

Water Scrubbing involves passing the air stream through a tower containing an open packing through which water is cascading. The water absorbs the solvent vapour as it is recirculated. Water is dumped and replenished either batch-wise or continuously to maintain the required solvent concentration and to maintain water and salt levels due to evaporative losses of water to the air flow. This method generates a low grade aqueous solvent waste. Equipment will be tall and water consumption will be high. Preliminary calculations carried out by vendors suggested that the scrubber system will have to be designed as a single pass

system. It will require a constant feed of water at a flowrate of approximately 1.15 m^3/h. The tower diameter will be approximately 0.325 m and the total height will be approximately 5.6 m.

Single Use-Carbon beds operate by passing the vent stream through a bed of activated carbon. Carbon is removed for disposal and replaced once depleted. This system has a relatively low capital cost and operating cost. It is less complex than other methods and it deals well with relatively lean VOC streams as well as intermittent venting.

Regenerated Carbon Beds work in the same way as single use beds except that the bed is regenerated using steam. The steam and VOC are condensed to form a water-solvent mixed liquid waste stream. This method is more complex and will have a higher capital cost than single use units.

Single use carbon adsorption was therefore selected as the most suitable end of line abatement unit as it was deemed most appropriate to the scale, utilisation, operability and safety requirements of the current and foreseen unit operations at the facility. Moreover, its capital and operating cost is low relative to the other technologies discussed above.