APPENDIX C

Specification of Carbon-based Odour Abatement System (Simdean)

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simdean
GROUP LIMITED

G41 The Innovation Centre
Keckwick Lane
Daresbury
Cheshire WA4 4

Proposal for Design, Supply, Design, Installation and Commissioning of Simdean Odour Control System for Coes Road Facility Waste Transfer Station, Dundalk, Co.Louth (Half site extraction)

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Quotation Ref Q1512-16

Date 22nd December 2016

Prepared by Nick Carter
Technical Director
Simdean Envirotec Ltd

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We have pleasure in quoting for the above work as follows: -

To provide an odour control system for the proposed waste transfer facility at Coes Road, Dundalk. Odour control system to provide a total of 4 Ac/h for the building based on the following building volume

Assumed Building volume (50% of building)	6,500 m3
Required air change rate for building	4 ac/h
Extract volume required	26,000 m3/h

1. Contract Value

Item #	Description	Price €
1	Supply, delivery, installation and commissioning of 1-off Simdean odour control system as described in the accompanying details	369,600.00
2	Operation and Maintenance contract to maintain above equipment for a five year period as described in Schedule 4.9 below	82,000.00

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2. Terms of Contract

2.1 **Terms of Payment**

The terms of payment attaching to this quotation are as follows: -

25% with order
25% upon approval of drawings
30% upon availability of equipment for dispatch.
10% upon installation of equipment.
10% upon commissioning.

All payments will be on point of time basis.

2.3 Valuation of Variation and Claims

All changes to the contract including the price for the changes are to be agreed in writing by Oxigen prior to Simdean Envirotec Ltd carrying out any additional work which is not included in this scope of works.

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2.4 Warranty Period

The warranty period for all equipment supplied by Simdean Envirotec Ltd under this contract is 12 months from delivery to site.

2.5 Taxes and Duties

The prices listed in this quotation are subject to VAT at the appropriate rate ruling at the time of dispatch only if purchased by a UK VAT registered company.

2.6 Delivery

We estimate a delivery period for the equipment of approximately 22 – 24 weeks from our official acceptance of your order. Installation and commissioning is expected to require a further 6 – 8 weeks from delivery.

3.0 Process Description

The proposed system is generally as per described below:-

Odour Control for the plant will be achieved in 4 stages

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3.1 Extraction

The inlet ductwork to be located and installed within the waste transfer station will be added to enable a total of 26,000 m3/h to be extracted from the building

3.2 Removal of Particulates within the exhaust airstream

A reverse jet cartridge filter will be installed to ensure that the particulates are removed from the exhaust air stream. Providing the pulse jet filter is operated in accordance with the operating and maintenance instructions the unit will remove at least 99% of the dust burden below 1 micron and less and 99.9% of the dust burden when the average size of the particles is 10 microns or above entering the unit.

3.3 Removal of Odour with Carbon Adsorbers

The crux of the system in terms of odour control will be the carbon adsorber. We have included for installing a single unit which will each be capable of treating up to 26,000 m^3/h of air from the building.

No figures in terms of the contaminants present in the gas stream have been provided for the inlet gas stream to the odour reduction system, however we have assumed an average inlet odour concentration of 3000 Ou_E m^{-3} We have assumed that the odour will be made up of both basic components i.e. Ammonia and amines etc and acidic components i.e. H_2S, mercaptans, sulphides and disulphides and have designed our odour control system accordingly

We have designed the system to provide an overall efficiency of removal of acidic and basic components of better than 90%.

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3.4 Dispersion of exhaust Air

The adsorber will be provided with an exhaust stack which will discharge at a height of 10 metres above FFL. We have designed the overall adsorber system to produce outlet limit of less than 300 OuE/m^3 at the exit to the proposed stacks. We cannot guarantee an odour level at the nearest receptor as we have no control over the impact of odours from elsewhere on the waste handling site.

4.0 Design Specification

4.1 Extract Volumes

We have designed the system to extract a total of 26,000 m^3/h of air from the waste transfer buildings.

4.2 Carbon Adsorber

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The Carbon Adsorber will be housed in a GRP clad Polypropylene constructed housing. The Adsorber will be fitted with an internal cage which will house the general purpose activated carbon which will be used to remove the odourous components and act as a polishing bed. The total flowrate through the Adsorber will be 26,000 m^3/h. We have designed the Adsorber such that the total retention time within the Adsorber is approximately 2 secs.

Details of the type of activated carbon to be used within the Adsorber is given below:-

General Purpose Carbon

Base Carbon type	Coal
CTC (CCl_4 Activity)	60 % w/w min
Pellet diameter	4 mm $^{+}/_{-}$ 20%
Bulk Density	0.47 kg/l
Ignition Temp	400 degC
Ash	8 %
Surface Area	950 m^2/g

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In terms of the life of the adsorber beds whilst it is not possible to provide a guarantee a life for the carbon (this will be dependant on the constituents of the gas stream entering the Adsorber). We estimate that the Carbon is capable of adsorbing approximately 20% of its own weight. The total weight of carbon within the Adsorber is approximately 7.3 tonnes which means that a total of 1.4 tonnes of "contaminants" could be adsorbed within the Carbon.

If we assume that the average extract flowrate to the Adsorber is approximately 18,000 m^3/h then the Adsorber could operate for approximately one year (8000 h) continuously with an average loading of approximately 9.7 mg/m^3

In the annular section of the Adsorber a temperature transmitter will be fitted to monitor the temperature of the air exiting the Adsorber. A max temp would be set, above which the Fan would be stopped and an alarm would sound to prevent fire within the Adsorber.

The adsorber will be provided with a steelwork structure below the adsorber housing, this will allow ease of maintenance and or replacement of the carbon within the adsorber

The inlet and outlet ductwork connecting the Adsorber will be provided with sample ports to allow for measurement of odour concentrations.

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The adsorber housing will be designed and manufactured in accordance with BS4994. The basket for the retention of the annular carbon bed will be constructed from type 304 stainless steel and will be of fully welded construction with access panels for ease of removal of the carbon during changeout procedures. Mechanically the basket will be designed to contain the weight of carbon as a self –supporting unit.

A schematic layout of the adsorber is shown below:-

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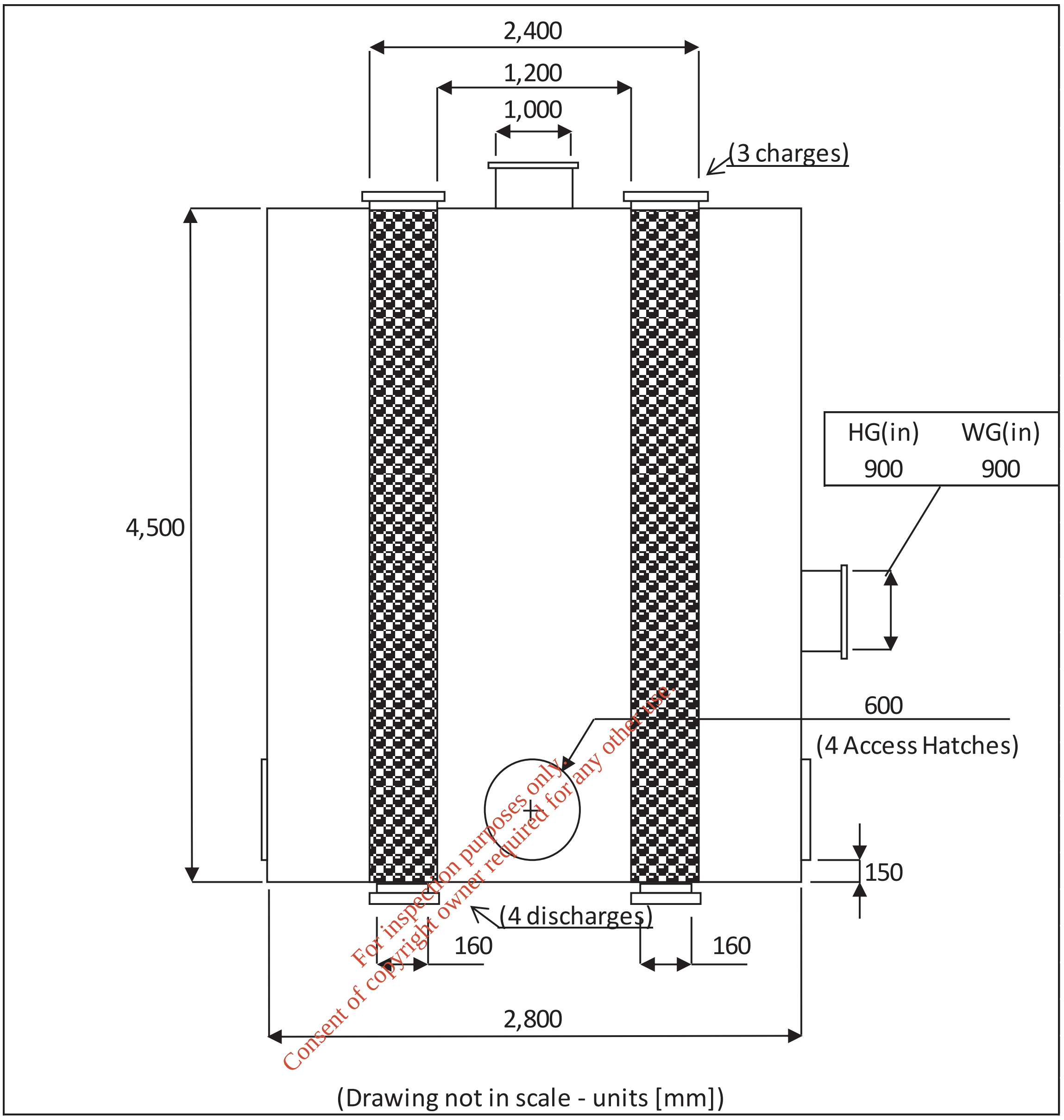

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4.3 Inlet filter

The inlet filter will comprise a pulse jet filter unit employing cartridges of pleated material of mixture of cellulose and polyester (80/20 mix) capable of treating 26,000 m^3/h, complete with pulse jet controller with digital pressure drop indication, eight hoppers with waste collection bins, support structure caged access ladder and handrails for ease of removal of cartridges.

The pulse jet filter will require a compressed air supply at a flowrate of 40 m^3/h at 6.0 bar.

The filter which will be constructed from 5 mm thick mild steel plates will be of fully welded unitary construction and will be built up in a modular assembly. Internally the unit will be finished with a coat of primer, externally the unit will shot blast to SA2.5, primed and three coats of paint applied.

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The normal working differential pressure across the reverse jet filters is 1000 Pa and our estimate of the cartridge life for the filters is approximately two years provided the unit is operated in accordance with our operating and maintenance instructions.

We have assumed at this stage that compressed air will be available for cleaning of the reverse jet filter . The conditions of air required are given below :

Volume	-	40 m3/h at 7.5 bar
Receiver capacity	-	1000 litr
Dew Point	-	-20 deg centigrade

Emission guarantee

We guarantee that providing the pulse jet filter is operated in accordance with the operating and maintenance instructions the unit will remove at least 99% of the dust burden below 1 micron and less and 99.9% of the dust burden when the average size of the particles is 10 microns or above entering the unit.

4.4 Control Panel

Within our quotation we have only included for the supply and installation of 1 – off control panel together with the field wiring of the equipment controlled by the panel

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We recommend that the panel comprises the following: -

1 - off sheet steel, wall mounted enclosure protected to IP55;

The enclosure to house the following controls:

Door interlocked mains isolator for the incoming electrical supply.

System start and stop push buttons.

Starter complete with suitable o/loads, inverter, circuit breakers and run/trip lights for system fans

Pressure drop monitors for the carbon Adsorber and inlet filters with alarm facility both audible and visual

High temperature indication for the extract air with alarm facility both audible and visual.

Indicators for power on, system running,

Allen Bradley programmable controller for possible incorporation into a SCADA system for overall control of the system. SCADA system to be located within the office complex on the facility site

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HMI touch screen for local operation of system

4.5 Exhaust Fan

We have included within our quotation for the supply of a single exhaust Fan set. The fans will be mounted between the reverse jet filter and the Carbon Adsorbers, and will comprise a centrifugal unit constructed from mild steel, with all housing parts in contact with airstream to be twin pack epoxy coated. The fan impellers will be constructed from type 4003 stainless steel, and the units will be rated at 26,000 m^3/hr against 3600 Pa at 20 degC. The fan set will be complete with a single motor rated at 75 kW protected to IP55 standard.

Details of the fan are as follows: -

Flow Rate	26,000 m^3/hr
Static Pressure	3600 Pa
Operating Temperature	20 degC
Fan Type	Centrifugal Backward Laminar
Material of construction	Mild Steel
Fan arrangement	Direct drive
Motor Power	37 kW
Electrical Supply	415V 3ph 50Hz
Enclosure	IP55
Insulation Class	F

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The fan will be supplied complete with access door, drain plug, acoustic scroll, galvanized base frame and anti vibration mounts.
We have included within our price for inverter control of the fan motor to allow for turndown of the system for periods of low activity within the waste handling facility.

4.6 Exhaust Stack

The exhaust stacks will be designed to accommodate the exhaust flow from the extraction system and will be constructed from GRP clad Celmar sheet. The stacks will be designed and manufactured in accordance with BS4994. The diameter of the stack will be such that the average velocity within the stack is less than 12 m/s and the

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efflux velocity will be greater than 15 m/s in accordance with process guidance notes included within the UK EPA 1990.

4.7 Exhaust Ductwork

Within our quotation we included the costing for the supply and installation of the extract ductwork from the waste transfer building. All of the internal building extract ducting will be constructed from low flammability PPs polypropylene. All external extract ductwork will be constructed from GRP clad Celmar. All ductwork will be constructed from suitably corrosion resistant materials and will be fitted with all necessary support structures and bracketing. The extract ductwork will be designed such that the average velocity within the ductwork will be approximately 12 m/s to prevent dust deposition within the ducting. In addition, the ductwork and supports where required will be designed and installed in accordance with HVCA DW151.

4.8 Extraction Grilles & Dampers

We have included within our costing for the supply and installation of extract grilles complete with balancing volume control dampers to be installed within the internal building ducting. The extract grilles will be supplied with GRP clad PP line plenum boxes for attachment to the existing ducting. Each of the dampers will be suitable for manual control and will be constructed from aluminium. The grilles themselves will be polyester powder coated. Each of the dampers will be of multileaf design to provide progressive reduction in exhaust flow upon closure.

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4.9 Service and Maintenance Contract

We have included under separate price within this quotation for a service and maintenance contract for five years. The work covered under this contract would include the following:-

4 – off visits /annum to check on correct operation of system. Servicing of equipment and minor works if necessary to be performed during visit.

1 – off of above visits to include for labour for replacement of both filter cartridges in the reverse jet filter and carbon in the Adsorber

Normal 12 month guarantee period to be unaffected.

All callouts after 12 month guarantee period is terminated to be charged at €55 .00/ man hour plus expenses.

All replacement equipment i.e. filter bags and carbon required to be charged at cost price plus 15%

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5. System Description

The equipment offered and priced in our Section 1 Price Schedule Item1 will comprise the following:-

- 1– off Carbon Adsorbers capable of handling 26,000 m^3/h of exhaust air and designed for the removal of VOC and acidic e.g. H_2S odours from the building exhausts
- 1 – off Pulse Jet Filter capable of handling 26,000 m^3/h of exhaust air and designed for the removal of dust and particulate matter.
- 1 - off Exhaust Fan complete with motors and inverters. Fan to be capable of handling 26,000 m3/h
- 1 – off Exhaust Stacks located on the carbon adsorber outlet. Stack capable of handling a flowrate of 26,000 m^3/h and to be constructed from GRP clad Celmar
- 1 – off range of extract ductwork installed within the waste handling facility.
- 1 – off range of extract ductwork between the waste handling facility existing extract ductwork, adsorber inlet and exhaust outlet
- 1 - off Control Panel and field wiring of above equipment
- 1 – off Range of Engineering services including, design ,supply, delivery, installation and commissioning of the above items

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6. Scope of Work

This is for the design, manufacture, delivery, mechanical and electrical installation and commissioning of the equipment detailed in paragraph 7 below.

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6.1 Design

- Design basis, Preliminary GA and P&ID Drawings
- P & ID and General Arrangements Drawing of the system
- Foundation loading drawing
- Process flow document
- Process control Philosophy
- Draft Operating and Maintenance Manual
- Construction Phase Health & Safety File
- Commissioning Procedures

6.2 Manufacture and Procurement

All manufacture and procurement will be carried out is strict accordance with Simdean Envirotec quality procedures and the project quality plan.

6.3 Installation

Simdean Envirotec wishes to discuss the scheduling of this work in greater detail with regard to the installation of the ductwork located inside the building.

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6.4 Safety

Simdean Envirotec will ensure that all aspects of the design, installation and operation of the system comply with current health and safety legislation, including carrying out:

- Design risk assessment
- Operability risk assessment
- Generic and project specific safety method statements and task risk assessments for the construction and installation phase
-

6.5 Training

Simdean Envirotec during commissioning will provide one session of training to nominated Oxigen staff.

6.6 Parts with Limited working life

Simdean Envirotec will provide details of recommended spares during the Contract.

6.7 Pre-Installation tests and procedures

Simdean Envirotec will ensure that all necessary pre-installation tests and procedures are carried out as follows:

- Visual inspection
- Sign off to QA plan

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6.8 Criteria for the completion of contract

Simdean Envirotec will ensure that all necessary documentation is signed by Oxigen prior to take over. This documentation is as follows:

- Completion certificate
- Performance test certificate

6.9 Takeover Procedure

Simdean Envirotec will ensure that all necessary activities have been completed before Oxigen takeover of the system. These activities are as follows:

- Commissioning
- Client training
- Issuance of takeover certificate

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6.10 Subcontracting

Simdean Envirotec will do the design, project management, supervision of installation and commission of the equipment and services. Simdean Envirotec will sub contract electrical panel manufacture and installation.

7 Equipment Supply

The equipment offered and priced in our Schedule Item1 will comprise the following:-

- 1– off Carbon Adsorbers capable of handling 26,000 m^3/h of exhaust air and designed for the removal of VOC and acidic e.g. H_2S odours from the building exhausts
- 1 – off Pulse Jet Filter capable of handling 26,000 m^3/h of exhaust air and designed for the removal of dust and particulate matter.
- 1 - off Exhaust Fan complete with motors and inverters. Fan to be capable of handling 26,000 m3/h
- 1 – off Exhaust Stacks located on the carbon adsorber outlet. Stack capable of handling a flowrate of 26,000 m^3/h and to be constructed from GRP clad Celmar
- 1 – off range of extract ductwork installed within the waste handling facility.
- 1 – off range of extract ductwork between the waste handling facility existing extract ductwork, adsorber inlet and exhaust outlet
- 1 - off Control Panel and field wiring of above equipment
- 1 – off Range of Engineering services including, design ,supply, delivery, installation and commissioning of the above items

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8 Materials of construction

The equipment detailed above will be constructed from the following materials of construction

Equipment	Parts in contact with exhaust Gas Stream	Parts not in contact with exhaust Gas stream
Activated Carbon Housing	Polypropylene Type 304 Stainless Steel	Fibreglass
Exhaust fan Impellors	Type 304 Stainless Steel	
Exhaust Fans	Epoxy coated Mild Steel	Mild Steel (Painted)
Reverse Jet Filter	Mild steel (Painted)	Mild steel (Painted)
Exhaust ductwork and Exhaust Stack	Polypropylene	Fibreglass
Fastenings	Type 304 stainless	Type 304 stainless

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	steel	steel Sheradized Mild Steel Galvanised Mild Steel
Control Panel		Mild steel (coated)
Compressor		Mild steel (coated)
Brackets And Supports		Galvanised Mild Steel, Sheradized Mild Steel
Extract Grilles	Powder Coated Aluminium	
Extract Dampers	Aluminium	

9. Exclusions

9.1 Main Exclusions

The following is excluded

- Performance testing (optional)
- All civil works
- Building skin sealing
- Provision of power to the Control Panel (power to be within 1 meter of proposed location of the connection points required). Services required are 415V 3 ph 50 Hz electrical supply with approximately 150 A capacity.
- All penetrations through the building and sealing of these openings
- Any additional sealing of the building

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9.2 Responsibilities of Oxigen Ltd

Simdean Envirotec have assumed that Oxigen will agree to perform the following:

- Provide detailed steel work drawings of the building to allow Simdean Envirotec to design ductwork supports.
- Any modification to the building to accommodate the protrusion of the ductwork through the side of the building
- Any work involved in re-routing pipe-work or cable trays in order to allow the ductwork system to be installed.
- Physical protection barriers for the equipment
- Role of Principal Contractor and Planning Supervisor
- Fire/smoke detectors should these be required
- Drainage
- Any detailed noise calculation which may require the services of a noise consultant.
- All civil works and foundations

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- That installation and commissioning work will be undertaken during normal working periods i.e. Monday to Friday 8 a.m. to 5 p.m.
- Craneage of the equipment into position
- That offloading facilities for the equipment will be provided.

Yours sincerely
For Simdean Envirotec Ltd

Nick Carter C. Eng
Technical Director
e-mail nick@simdean.co.uk
Mobile 07831 807238

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APPENDIX D

Specifications, Proposal and Design Report for Bio-scrubber Odour Abatement System (MEHS)

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BIO-SCRUBBER ODOUR CONTROL UNIT

STANDARD SPECIFICATION

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1 GENERAL

1.1 Scope

This document specifies the design and installation requirements for a Biological scrubber at Oxigen Environmental.

1.2 Objective

The objective of this Standard Specification is to provide designers, manufacturers, and installers of a Bio Scrubber requirements for its design, construction, installation and performance testing.

This document is written in the directive style. Where an obligation is given, and it is not stated who is to undertake these obligations, they are to be undertaken by the Contractor.

Where a submission, request, or proposal is required, and it is not stated who the recipient shall be, it is to be provided to Oxigen Environmental representative for written approval.

1.3 Purpose

In the procurement of a Scrubber, it is intended that this document would be appended to a procurement Contract document for a specific site where it would provide the general requirements for a Scrubber. Any additions, variations, or one off requirements for that specific site would be included in the Contract document itself. Unless specifically required otherwise in the Contract document, this Standard Specification shall be complied with.

The contract document shall provide for three hold points in the procurement process as follows:

Oxigen Environmental shall be provided with design criteria and concept design. The Contractor shall resolve with Oxigen Environmental any issues of concern that Oxigen Environmental may have as a result of its review of this information prior to proceeding with detailed design work.

- Oxigen Environmental shall be provided with the detailed design including details of any deviations from this Standard Specification. The Contractor shall resolve with Oxigen Environmental any issues of concern Oxigen Environmental may have as a result of its review of the detailed design prior to proceeding with ordering and manufacturing of the unit.
- All Work as Constructed documents, such as detailed drawings, troubleshooting guidelines and Operation and Maintenance (O&M) Manuals.

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1.4 New Designs and Innovations

This document specifies the minimum requirements for the Works. The Contractor may wish to produce their own alternative design that will comply with these minimum requirements.

Any alternative materials, designs, methods of assembly, and processes that do not comply with specific requirements of this Specification, or are not mentioned in it, but give equivalent or improved performance outcomes to those specified, are not necessarily prohibited.

Written approval from Oxigen Environmental must be obtained for any deviation from this Specification prior to ordering and manufacture of equipment affected by such deviation.

1.5 Style of this Specification

This document is written in the directive style. Where an obligation is given and it is not stated who is to undertake these obligations, they are to be undertaken by the Contractor.

Where a submission, request, proposal is required and it is not stated who the recipient shall be, it is to be provided to Oxigen Environmental representative for approval.

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1.6 Responsibilities

Responsibilities relating to the contractual terms and conditions, including financial matters, and site issues are covered in the Head Contract documents. Specific responsibilities are noted in this document, but they do not necessarily describe all the activities required for the Works.

For the purpose of developer funded works, the words “Principal” and “Contractor” in this document shall be replaced with the words “Oxigen Environmental” and “Developer” respectively.

1.6.1 Contractor

The Contractor shall be fully responsible for the detailed design, and construction to fully comply with the requirements in this document and provide a complete functional Scrubber, which meets all the necessary Standards, Codes of Practice, Industry Standards, and all statutory requirements. The complete systems shall include all pipework, fittings, fans, filters, instruments, and controls, from the point of foul air extraction to the point of treated air exhaust.

In addition, the Contractor shall provide the following, but not limited to:

- Additional equipment as may be necessary for the operation and maintenance of the particular odour treatment system being provided, or as recommended by Oxigen Environmental, the supplier and regulatory bodies.
- Stairs, ladders and walkways, where appropriate, to allow ease of access for changing of media, access sampling points and monitoring equipment, and all storage tanks and equipment. All such stairs, ladders and walkways shall be constructed of appropriate corrosion resistant materials.
- Safety facilities such as safety shower, eyewash station, fire extinguishers, and so on.
- Tags, labels, signs, and other markings, for all these systems which clearly indicate the individual system, chemical contents, hazards, warnings, asset numbers and any other pertinent information in accordance with the requirements of the relevant Standards, Codes of Practice and statutory authorities, and Oxigen Environmental Maintenance Management System.
- O&M Manuals, Unit Process Guidelines, WAC drawings, copies of Programmable Logic Controller (PLC) software programs and any other documents necessary for the optimal operation and maintenance of the Scrubber.
- Any additional items/equipment requested by Oxigen Environmental.

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1.6.2 Principal

The Principal (Oxigen Environmental), through its appointed representative/consultant, shall be responsible to provide input from the various internal stakeholders for the development of both the concept and detailed design required by this Specification. They shall include, but not be limited to:

- This document;
- The concept purpose of the Scrubber (for example, Black Bin Storage Building);
- Location of the Scrubber;
- Scrubber expected equipment life term at the location (fixed or temporary);

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1.7 Acronyms, Abbreviations and Definitions

ASTM	American Society for Testing and Materials
CASANZ	Clean Air Society of Australia & New Zealand
H_2S	Hydrogen Sulphide
OCU	Odour Control Unit
OU	Odour Units (measurement)
P&ID	Process and Instrumentation Diagrams
PLC	Programmable Logic Controller
VSD	Variable Speed Drive, a device for
WAC	Work As Constructed

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2 DESIGN

2.1 Performance Requirements

The OCU shall be designed to:

- Provide reliable and effective odour removal to a level specified in the minimum requirements outlined in Section 2.2.3 of this Specification;
- Have a minimum of 20 years' service life. This does not apply to consumable components such as filter media;
- Comply with all relevant regulatory requirements, Standards and Codes of Practice including noise;
- Not cause interruption to the normal operation of the Oxigen Environmental.
- Be safe to construct, operate, maintain and decommission.

2.2 Design Criteria and Concept Design

2.2.1 General

The designer shall undertake investigations, which may include desktop study, field testing and modelling to determine the specific requirements for the Scrubber.

Layout details of the Oxigen Environmental Site, where the Scrubber is to be provided, and its surrounds shall be collected and documented. They shall be used for the selection of the optimal locations of extraction and discharge points. All features that may affect the operation and maintenance of the Scrubber shall be documented and considered in the design.

Data for the design of a Scrubber shall be collected and clearly documented including all calculations and assumptions. It shall be submitted to the Principal's representative for written approval prior to commencement of detail design work.

No Scrubber shall be placed in a "confined space" such as a below ground pit without written approval from the Principal.

The submitted information shall include, but not be limited to:

- Concept design showing the management of air inflows and extraction point to maximise removal of foul air and minimise the potential of gas escape leading to odour and/or corrosion problems;
- Current, peak and future quantity of odorous gas required to be treated;
- Physical properties of gas such as pressure, temperature, and humidity;
- Current and future level of odorous gas component(s) and fluctuation during different time/season;
- Location of treated gas discharge;
- Assessment of corrosive substances in the gas and surrounding, which may affect the unit;
- Proposed type of Scrubber;
- General site layout concept to allow adequate space around the Scrubber for its operation and maintenance, such as the changing of media, and removal of equipment.

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2.2.2 Minimum Requirements

Unless otherwise specified, the minimum requirements of the Bio Scrubber are specified below.

Minimum Requirements

ITEM	REQUIREMENTS
Outlet concentration as measured at the exit of the vent stack	Ammonia (NH_3) ≤ 5.0 ppm Amines ≤ 5.0 ppm Hydrogen Sulphide (H_2S) ≤ 1.0 ppm Mercaptans (Thiols) ≤ 1.0 ppm Odour concentration ≤ 1000 Odour Units (OU) Or otherwise, at a level that is demonstrated to achieve no odour nuisance at the nearest residence or public space.
Pressure Drop Across the Media	600 to 1200 Pa
Liquid to Gas Ration	2.0 to 6.0 Litres of Water/m^3 of Air to be treated
Empty Bed Gas Retention Time, Seconds	4 to 10 seconds
Packaging Void	95 to 98%
Flow rate	Minimum of 3 x airspace/headspace volume per hour. Refer to notes below for examples.
Fan(s)	Centrifugal type with forward or backward curved impellers fitted with a flameproof motor Class 1 Division 2.
Noise level	Not exceeding 85 dBA measured at the Scrubber, or 5dBA above the surrounding environment noise level whichever is the lower
Discharge vent stack	The discharge vent stack height shall (20m above ground level) unless otherwise agreed by the Principal. Typically, the vent stack shall be designed to maximise the air velocity out of the top of the stack to obtain maximum dilution with the surrounding air.
Removal Efficiency, Odour (OU/m3)	70 to 90%

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2.2.3 Selection of Odour Control Unit Type

Different types of OCU have different performance characteristics. These shall be considered thoroughly when selecting the type of OCU that will perform best given the type, volume, concentration and variability of the foul air odorous components. Attention shall also be given to operability, installation and maintenance requirements of the unit, particularly in terms of cost, availability of electricity, availability of critical spare parts, media or chemical replacements, requirements for any confined spaces entry, and ease of access.

For activated carbon and Scrubber systems, it is required that the fans be installed after the treatment component and draw air through the unit under vacuum, in order to remove the risk of gas leaks under pressure. Operation under vacuum will have implications on the structural design of the various elements and on the operation of the various monitors, and these shall be considered in the concept design.

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2.3 General Detailed Design Requirements

2.3.1 General

All materials specified in the design shall be suitable for installation in the proposed environment and be corrosion resistant for at least 20 years' service life.

Typically, an OCU consists of:

- Control panel, including telemetry system
- Extraction conduit
- Monitors, for example pressure, temperature, humidity, and Ammonia, Amines, Mercaptans and H_2S gas concentration. This is generally provided in a standalone panel.
- Scrubber heater (where required)
- Fan(s)
- Exhaust stack
- Gas sample off take points for inlet and outlet gases, and minimum of three points through the media/process.
- Auxiliary access platforms, ladders, water and electricity supply, and safety equipment

To allow easy installation and removal of equipment by lifting devices, suitably designed lifting lugs shall be fitted where necessary. Where the OCU is specified as temporary or moveable, lifting lugs shall be provided on the Unit.

2.3.2 Casing

The odour unit casing material and finish shall be of the following:

1. Glass-reinforced plastic (fibreglass); or
2. Stainless steel grade 316; or
3. Any other material, being equivalent to item 1 or 2 in strength, rigidity, and fire performance.

The OCU structure shall be suitably reinforced and supported to withstand all forces including wind loads, operating pressures (positive or negative), loading and unloading of media, and any other anticipated forces.

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2.3.3 Parts

All internal parts that may be in contact with the odorous gas shall be acid resistant, particularly sulphuric acid, and any other chemical used by the OCU.

All bolts, nuts, and washers shall be made from stainless steel grade 316. Potential for galvanic corrosion shall be minimised.

2.3.4 Adhesive, Sealants, and Gaskets

All adhesive, sealants and gaskets shall be resistant to oil, water, and acid (mainly sulphuric acid). They shall be non-supportive of microbial growth and dimensionally stable.

Where applicable, they shall also be resistant to any chemicals used by the OCU.

2.3.5 Inlet Isolation valve

An easily operated positive shut off isolation valve shall be provided on the extraction ductwork to the OCU. This valve is to provide a gas tight isolation of the OCU from the waste buildings gases for the purpose of carrying out maintenance activities. Lightweight dampers are not acceptable for this duty.

All valve spindles, bearings and ancillary components shall be stainless steel grade 316, and suitable for operation in an atmosphere where saturated air and H_2S gases are present. Any components where galvanizing is used or where copper or brass components are used will not be accepted.

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2.3.6 Ductwork

All ductwork shall be fabricated in galvanized steel or stainless steel grade 316 to the relevant Standards, unless otherwise specified in relevant sections of this Specification.

The design of the ductwork shall prevent the pooling of any liquid that cannot be easily drained.

Where necessary the ductwork shall be lagged to ensure sound pressure level at the boundary of the site does not exceed 45 dBA under free field conditions or 5dBA above ambient levels whichever is less.

2.3.7 Discharge stack

A discharge stack shall be provided to exhaust the treated air vertically from the odour treatment processes. The vent stack shall have a minimum exhaust velocity of 15 m/sec.

It shall be formed from welded stainless steel, and shall be self-supporting (including stainless steel guy wires where necessary).

Detailed design for the vent stack shall be provided to the Principal for written approval, along with calculations, prior to the fabrication of the stack.

2.3.8 Fans

The fan(s) shall provide exhaust ventilation of the waste buildings at the chosen location. For the OCU it is preferred that the fans be installed after the contactor and draw air through the contactor under vacuum in order to remove the risk of gas leaks under pressure.

The fans shall be selected to provide the designated airflow under the system head pressure. The fan shall be centrifugal with forward or backward curved impellers, and shall be suitable for the required design. Fan performance curves shall be provided with the design documents.

The fan shall be constructed from materials suitable for the environment in which it will operate. Materials of construction and clearances between impeller and fan scroll shall be provided to ensure that at all times, no spark potential is possible within the fan.

Airflow monitors (one per fan outlet) shall be provided to indicate whether a fan is running when called to operate. Failure of air flow shall be used to lock out operation of any duct heater/demister (and any other equipment of concern) and to raise a failure alarm.

The control panel shall provide for the installation of a Variable Speed Drive (VSD), should it be required for minor adjustment of fan speed.

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2.3.9 Integrity of System

The complete ductwork system, through the main duct, adsorber inlet and outlet ducts, any bypass duct and stacks, shall be completely gas tight and smoke tested at the operating pressure of the OCU. All ductwork and associated ventilation equipment shall be fabricated and installed to the Standards specified in this document.

Any joints, ducts, bends and so on, that do not meet this requirement shall be remade or replaced at no cost to the Principal.

2.3.10 Valves & Dampers

Dampers shall be provided to perform the functions of diverting or modulating the airstream to the OCU as required and as directed by the monitoring and control system. Dampers that are intended for air diversion only shall operate either in the fully open or fully closed position. Dampers used to modulate airflow and for balancing purposes shall be fabricated and installed in accordance with the specified Standards in this document, and to materials standards as specified in these Clauses.

The dampers shall be stainless steel or aluminium multiple curved blade gang operated, single thickness, factory assembled units. Each unit shall be supplied for heavy-duty operation for field assembly and shall operate through 90 degrees of operation, from fully open to fully closed.

All damper spindles, bearings and ancillary components shall be stainless steel, and suitable for operation in an atmosphere where saturated air and H_2S gases are present. Any components where galvanizing is used or where copper or brass components are used shall not be accepted.

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2.4 Mechanical Works

The design and construction of the mechanical works shall be in accordance with the requirements of Oxigen Environmental.

2.5 Electrical

The design and construction of the electrical works shall be in accordance with the requirements of Oxigen Environmental

All equipment shall be new and suitable for its purpose. They shall comply with the Irish Standards and shall be rated for continuous in service condition within a switchboard. All electrical equipment supplied shall be available off the shelf within Ireland.

All items of equipment shall be designed, manufactured and installed to perform their required functions reliably and efficiently. Considerations shall be made to ensure the designed system and selected equipment could be operated and maintained safely and efficiently. Particular attention shall be given to equipment installed in an adverse environment and/or exposed to weather.

Live equipment and terminals shall be located behind removable covers or doors, and shrouded, to prevent accidental contact when the control panels front doors are open, including equipment mounted on doors.

Where more than one item of equipment is supplied, and installed to perform a particular function, all such items of equipment shall be identical and completely interchangeable.

The site is subject to power failure. The equipment shall be designed for automatic restart when the power returns.

The Contractor shall develop electrical circuits and control panel layout and submit these drawings to the Principal's representative for review prior to manufacture. The Contractor shall resolve with Oxigen Environmental any issues of concern Oxigen Environmental may have as a result of its review of these drawings prior to proceeding with ordering and manufacture.

2.6 Instrumentation & Control

The Contractor shall resolve any issues of concern with the Principal and obtain written approval from the Principal prior to proceeding with ordering and manufacture.

If local PLC control is required, then the Contractor shall get agreement on the manufacture of PLC or other PLC by the Principal.

Where a Human Machine Interface (HMI) is to be provided then a 10-inch colour screen shall be provided with trending capability that will last a minimum of 30 days.

If Oxigen Environmental does not have current versions of the programming software for the PLC and HMI available, then these shall be provided by the Contractor.

Differential pressure transmitters shall be provided to measure the head loss across both the OCU. These transmitters shall be calibrated in Pascals and shall have a local display.

Instrumentation shall not be left exposed to sunlight, the elements, magnetic fields, vibration, or where local indicators are difficult to read, unless written approval is first obtained from the Principal's representative.

2.7 Access and Auxiliary Services

Adequate access shall be provided to allow all expected operational and maintenance activities to be carried out in a safe and efficient manner.

Suitable road access shall be provided for large vehicles required for media and equipment removal and installation (such as vacuum tankers, HIAB trucks or cranes).

Platform access shall be provided for media removal and replacement. It shall be large enough to hold two people and a pallet of media unless otherwise agreed by the Principal's representative.

Platforms where required shall be supported from the ground rather than from the adsorber and ductwork.

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A water supply with backflow prevention shall be provided in close proximity to the OCU for process use. The Reduced Pressure Zone (RPZ) shall be installed in a standard lockable cage.

A suitable lockable location shall be provided beside the OCU to provide storage of plant documentation (such as O&M manuals, Hazard ID list, plant diary, calibration records, and so on)

2.8 Civil Related

The design and construction of the civil works shall be in accordance with the Irish requirements.

2.8.1 Foundation

The OCU shall be located on a concrete slab. The slab shall be constructed on a suitably prepared ground. Its thickness and compressive strength shall be adequate to bear the load of the unit. Rubber mats shall be used for fibreglass tanks.

2.8.2 Drainage

The OCU shall have gravity drainage facilities to remove condensate. The material of construction shall be sulphuric acid resistant. Drains from the waste buildings. The drainage shall be directed to a permissible disposable location, such as a sewer.

Each drainage point must be from the lowest point in the item being drained and must have its own isolation valve. Sufficient drainage points must be supplied to prevent any condensate from collecting in the OCU.

Drains may only be combined for gases of like quality. In particular, no drain from downstream of the media bed is to be connected to any drain from upstream of the bed.

All drain discharge points must have a water seal, which can be easily checked/refilled by the plant operator.

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2.10 Facility and Equipment Identification and Labelling

All equipment shall have a unique identification number beginning with OE. Oxigen Environmental designates unique identification number for all its asset and associated equipment, and Oxigen Environmental will assign these.

A standard Oxigen Environmental Facility Asset sign shall be mounted on the OCU structure.

2.11 Critical Spares

The Contractor shall provide a list of any critical spares they consider necessary, including the cost of provision, with their detailed design submission. The Principal will review the list and advise those items that the Contractor shall provide under the contract.

2.12 Operating and Maintenance Manual

An Operating and Maintenance (O&M) manual shall be provided for the OCU. An acceptable O&M manual is considered a key requirement for successful contractual handover. It shall be provided in both paper form (2 copies) and electronic form (PDF format for every component). In addition, editable file copies shall also be provided where created by the Contractor in a format suitable for Oxigen Environmental (for example, Microsoft Word and Excel documents, AutoCAD for drawings and so on).

The manual shall be in accordance with Oxigen Environmental requirements.

The manual shall include, but not limited to:

- Overview of the OCU conceptual design and how it fits into the local management of odour and corrosion control, with reference to general location drawing.
- Detailed description of the unit and its components, process, and performance criteria.
- Detailed P&IDs, complete list of all equipment items (including electrical items) and a cross reference to Oxigen Environmental asset numbers where relevant.
- Detailed information for each supplied piece of equipment (Manufacturer, supplier, model number and so on).

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- A list of suppliers and their current contact details.
- Pump and fan curves where relevant (including any test data).
- Standard operating instructions covering all routine work requirements (for example, system start up, shut down, routine monitoring, changing of media and so on).
- Process optimisation and troubleshooting guide.
- Where relevant, a copy of the PLC functional description, Input / Output listings, HMI screen details, electronic copies of PLC and HMI programs, details of the programming software used (including version details) and where it can be obtained.
- Reference listing of all monitoring and alarm signals both locally and transmitted to PLC. For each alarm this shall include detail of how the alarm generates (primary device, condition, relevant relays and so on).
- Reference listing of all interlocks and system timers (their values and where these are set).
- Recommended routine inspection and maintenance schedule including replacement schedule of treatment media.
- List of any recommended spares to be held.
- Instructions on storage, loading/unloading, and Material Safety Data Sheet (MSDS) of treatment media.
- A drawing register of all drawings supplied (such as drawing number, title, revision number and so on, grouped by type)
- WAC drawings covering all aspects of the OCU installation
- Complete program settings for all programmable equipment (for example, Differential Pressure Transmitters).
- Supplier equipment manuals for all items provided (including electrical equipment)

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3 TECHNICAL SPECIFICATIONS – BIOSCRUBBER TYPE OCU

Multi stage designs and units with optional activated carbon polishing shall meet the minimums stated here, or better.

3.1 Bio-Scrubber Unit

The bio-scrubber units shall be capable of continuously treating odorous air at the specified flow rates and be designed to meet the required efficiency. Outlet conditions for the clean air discharge shall meet discharge odorous gas limit concentration.

The bio-scrubber shall be supplied complete with all auxiliary equipment required for system operation.

The bio-scrubber unit shall generally consist of an inlet isolation valve, one or more contactors containing a suitable bio growth media and support frame, a liquor recirculation system, if part of the supplier's design, to maintain the media in a moist state, a liquor decant and makeup (water and nutrients) system, extraction fan(s), discharge stack, control equipment panel, and monitoring equipment.

Support media will be of a design such that it provides sufficient surface and contact time to treat agreed contaminant loads to the agreed discharge quality whilst being open enough to not suffer from blockage or short circuiting. The Contractor shall submit calculations to the Principal, substantiating the choice of media to meet the required performance and life span.

The diameter and height of the bio-scrubber shall be properly sized to meet the specified performance requirements. The bio-scrubber must have a minimum contact time sufficient to provide 90% removal efficiency during normal operation.

The bio-scrubber shall be designed structurally to withstand both the operating gas pressures (whether operating under a vacuum as preferred or under positive pressure) as well as any other stresses that might be expected during loading and unloading of the media (for example, people standing on top).

The bio-scrubber shell, internal components, and structural components shall be made of either stainless steel grade 316 or fibreglass. Where fibreglass is used, the suitability of this material with resins selected for resistance to biological attack, the products of reaction and the general waste odour environment shall be demonstrated.

Where the design of the bio-scrubber includes an activated carbon polishing unit, the unit shall be adequately protected from aerosols and humidity. Monitoring of gas levels prior and after the activated carbon unit shall be provided. It shall be designed to provide sufficient contact time and installed in such a manner as to provide simple, safe and effective replacement of the unit.

The design shall include access hatches for loading and removal of support media, and for inspection of any other ancillary equipment. The hatches shall be of sufficient size to allow both removal of bio growth media through the side, and inspection and maintenance of the distribution sprays at the top. The hatches shall allow the easy removal of any internal components such as screens for maintenance purposes.

The bio contactor and associated ductwork shall be designed to minimise pressure drop, prevent any short circuiting of gas flow, and provide easy access for maintenance.

3.2 Monitoring

Monitoring systems shall be provided, as detailed in Section 7 of this Specification.

The Contractor shall provide any additional sampling points necessary to adequately monitor the performance of the OCU or its key components.

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3.3 Control system

The bio-scrubber liquor recirculation and decant/makeup systems shall be fully automated with allowance for manual operation. The Contractor shall provide a copy of the controller logic to the Principals representative for written approval.

The bio-scrubber unit shall be installed with the following additional sensors and monitors:

- pH level for the sump liquor – connected to PLC
- Level of liquor in contactor sump – connected to PLC. In addition, a manual sight glass shall be provided to allow visual checking.
- Level of nutrient in the nutrient storage tank – connected to PLC
- Air flow rate – connected to PLC

3.4 Liquor Recirculation System

A minimum of two pumps shall be provided to recirculate the sump liquor. They shall be in duty/standby arrangement. The pumps shall be centrifugal pumps and mechanically sealed. The pump head and seals shall be suitable for the corrosive nature of the sump liquor.

A sump purge valve shall be provided to flush out contaminants build up within the reticulation system.

Flow indication shall be provided for each component flow on the recirculation system including flows to the humidifier, to the spray in each contactor, to monitoring instruments.

A no flow alarm shall be provided should the recirculation of sump liquor fail. Similarly, a low liquor sump level alarm should stop the recirculation pumps. Failure of the reticulation system shall be connected to PLC.

Any automated valves shall be provided with a manual by-pass.

3.5 Nutrient Dosing System (if required)

A nutrient dosing system shall be provided to dose the sump liquor during purge makeup sequence. The dosing system shall consist of storage tank, duty dosing pump, calibration tube, backpressure valve, pressure gauge and dosing lines.

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4 INSTALLATION

4.1 Approval

Prior to installation, statutory approval from the local authorities shall be obtained.

4.2 Installation Practice

The installer shall be familiar with specification for the works and shall ensure that works are completed in accordance with good industrial practice. Written approval from the Principal and the designer shall be obtained for any deviations from the accepted design.

4.3 Materials and Equipment Inspection

Prior to transportation to site, materials and equipment shall be checked for compliance with the appropriate Specification or Standard by conducting a Factory Acceptance Test (See Section 5.1 of this Specification). The Contractor with the participation of the Principal's representative shall conduct these tests. On site, prior to installation, materials and equipment shall be checked to ensure that they are free from damage caused during transportation and are fit and suitable for use.

5 COMMISIONING

Following installation, the OCU shall be tested and commissioned in accordance with Oxigen Environmental requirement.

The Contractor shall develop a commissioning plan, which shall be submitted to the Principal's representative for review. Written approval from the Principal's representative shall be sought prior to commissioning.

The Contractor shall provide the necessary expertise and resources for successful commissioning of the unit.

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5.1 Pre-Commissioning (Factory Acceptance Test)

Pre-Commissioning of the OCU shall be carried out at the factory in the presence of relevant personnel from the Principal, prior to transportation to the relevant sites. The pre-commissioning work shall include the following:

- Running of the OCU and the testing of each fan's operation against its performance curve and design operating point.
- Testing of the control logic, sensors and programming.
- Testing of fail-safes and PLC alarms.
- Testing of dosing units, including pipe work, if pre-constructed.
- The whole structure of each OCU shall be examined for any fugitive emissions that may be the result of leaks.
- Air flow rates and designed retention times are to be confirmed.

The OCU shall not be transported to site until the Principal's representative has accepted the tests.

5.2 Site Commissioning

Following installation, the OCU shall be test run for a minimum period of one (1) week. The Contractor is responsible for conducting on site performance tests to the Principals satisfaction, to prove compliance with the guarantees. At a minimum, the following shall be checked or carried out:

- Odorous gas component(s) removal rate
- Pressure, relative humidity, and flow rate of inlet and outlet gases

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- Equipment operation and adjustment checks.
- Casing and insulation joint testing, for example, using Smoke test at operating pressure.
- Noise testing using certified testing equipment.
- Structural inspection by a certified Structural Engineer.

During the test run period, the Contractor shall maintain the OCU in a proper working manner. The unit shall be used to demonstrate system performance to the Principal's satisfaction. The Contractor shall carry out any work necessary to ensure the OCU is working correctly. At the end of this period, the Contractor shall issue a certificate to verify that the unit is working properly.

The Contractor shall supply all WAC Drawings, O&M Manuals along with trouble shooting guidelines and these shall be verified during the commissioning period.

5.3 Records

All tests and inspections shall be documented identifying the date of the test, inspectors name, equipment used, results, and any adjustment action taken.

Fully detailed written reports shall be provided to the Principal's representative following a successful commissioning.

5.4 Handover

The Commissioning plan shall be followed to ensure all issues are finalised before handover of the OCU to Oxigen Environmental Operations Division.

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OXIGEN ENVIRONMENTAL LTD COES ROAD ODOUR ABATEMENT PLANT

Bio-Scrubber Design Report

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January 2017

Montgomery EHS
Kantoher Business Park
Killeedy
Ballagh
Co. Limerick
Mobile (087) 239 0421
Email: trevor@mehs.ie

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OXIGEN ENVIRONMENTAL
BIO-SCRUBBER DESIGN REPORT

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Document No. …………. ES_P017_05-01

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1.0 Introduction

How do scrubbers work? To answer this question, we need only look to a critical part of Earth's natural pollution control system: how rain cleans the lower atmosphere. Obviously, this is most evidenced by the freshness of the air following a rainstorm. The simplicity of spraying water into a gas stream to remove a relatively high percentage of contaminants has contributed to scrubbers' extensive use within industry since the early 1900s. Heumann and Subramania (1997) point out that "most pollution control problems are solved by the selection of equipment based upon two simple questions …

(1) Will the equipment meet the pollution control requirements? and
(2) Which selection will cost the least?"

How are scrubbing systems capabilities evaluated? They are evaluated based on empirical relationships, theoretical models, and pilot scale test data. Two important parameters in the design and operation of wet scrubbing systems as a function of the process being controlled are dust properties and exhaust gas characteristics. Particle size distribution is the most critical parameter in choosing the most effective scrubber design and determining the overall collection efficiency.

In operation, scrubbers are considered universal control devices because they can control particulate and/or gaseous contaminants. Numerous types of scrubbers are available, including wet scrubbers, wet–dry scrubbers, and dry–dry scrubbers. Scrubbers use chemicals to accomplish contaminant removal, whereby the gaseous contaminants are absorbed or converted to particles, then wasted or removed from the stream.

Wet scrubbers (or collectors) have found widespread use in cleaning contaminated gas streams (acid mists, foundry dust emissions, and furnace fumes, for example) because of their ability to remove particulate and gaseous contaminants effectively. These types of scrubbers vary in complexity from simple spray chambers used to remove coarse particles to high-efficiency systems (Venturi types) that remove fine particles.

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Although wet scrubbers require relatively small space for installation, have low capital costs, and can handle high-temperature, high-humidity gas streams, their power and maintenance costs are relatively high. They may also create water disposal problems, their corrosion problems are more severe than dry systems, and their final product is collected wet (Spellman, 1999).

1.1 Wet Scrubber Collection Mechanisms & Efficiency

Although scrubbers are used predominantly for control of particulate air pollutants, these devices can simultaneously function as absorbers. Consequently, absorption devices used to remove gaseous contaminants are referred to as *absorbers* or *wet scrubbers*. To remove a gaseous pollutant by absorption, the exhaust stream must be passed through (brought into contact with) a liquid. The process involves three steps:

1. The gaseous pollutant diffuses from the bulk area of the gas phase to the gas–liquid interface.
2. The gas moves (transfers) across the interface to the liquid phase. This step occurs extremely rapidly once the gas molecules (pollutants) arrive at the interface area.
3. The gas diffuses into the bulk area of the liquid, thus making room for additional gas molecules to be absorbed. The rate of absorption (mass transfer of the pollutant from the gas phase to the liquid phase) depends on the diffusion rates of the pollutant in the gas phase (first step) and in the liquid phase (third step).

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To enhance gas diffusion, and therefore absorption, steps include:

- Providing a large interfacial contact area between the gas and liquid phases
- Providing good mixing of the gas and liquid phases (turbulence)
- Allowing sufficient "residence" or "contact" time between the phases for adsorption to occur

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2.0 Odour Assessment Methodology & Reporting

2.1 Odour assessment

The goal of the Odour assessment is to ensure that the environmental impact is minimised, according to the principles of BAT.

Within the same industrial sector there may be different levels of odour control, and the type of assessment necessary for a hitherto uncontrolled process (i.e. a plant with no odour control) is likely to be different from that required for a partially or fully controlled process.

2.1.1 Collection of Odour from Waste Buildings

Many environmental and practical benefits result from the use of extraction and the control of Odours. Odour's from the waste buildings are significantly reduced and waste buildings losses will also be reduced by 60% to 90%.

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2.2 Installation of a Bio-Scrubber

2.2.1 Design Criteria

Traditionally, odour control has been achieved by oxidation using chemical scrubbers and conventional bio-filtration methods using compost media. The chemical scrubbing methods to treat (oxidize) the odorous organic compounds generated during the processes commonly use oxidizing agents such as chlorinated water, sodium hypochlorite, hydrogen peroxide, and potassium permanganate solutions.

Bio-scrubber using synthetic pelletized and structured media is gaining recognition, as an excellent alternative for treatment of air streams with higher organic loadings. Synthetic media bio-scrubber, as compared to natural media bio-filters, also allows effective control of biomass build-up. Extensive research has been conducted on the development of synthetic media bio-scrubbers for odour control applications. These bio-filters can handle higher concentrations of Odours without the eventual build-up of biomass. Montgomery EHS is small business company established in Limerick is involved in marketing bio-scrubber for commercial applications.

The contaminated gas is diffused in the bio-scrubber with the recirculation water and the bacterial mass and adsorbed onto the biofilm within the packing. This gives microorganisms the opportunity to degrade the pollutants and to produce energy and metabolic by-products in the form of CO_2 and H_2O.

This biological degradation process occurs by oxidation, and can be written as follows:

$$\text{Organic Pollutant} + O_2 \rightarrow CO_2 + H_2O + \text{Heat} + \text{Biomass}$$

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2.2.2 Process Description

A bio-scrubber consists of two reactors: a scrubber, a bioreactor, and a settling chamber (Figure 2). In the scrubber, contaminated inlet gas flows through a fine spray of water or water plus dispersed microbes (activated sludge). The water-soluble contaminants are absorbed out of the gas into the water or activated-sludge mixture. This contaminant laden water is pumped into the bioreactor. The cleaned gas is exhausted from the scrubber. In the bioreactor or activated sludge aeration tank the pollutants are degraded and the water is regenerated. Some of the bioreactor liquid is recycled back into the sprayer (Kirchner et al. 1985; Ottengraf 1987). Some is sent to a settling chamber where biomass is settled out. The biomass is returned to the bioreactor and excess water is sent to a drain.

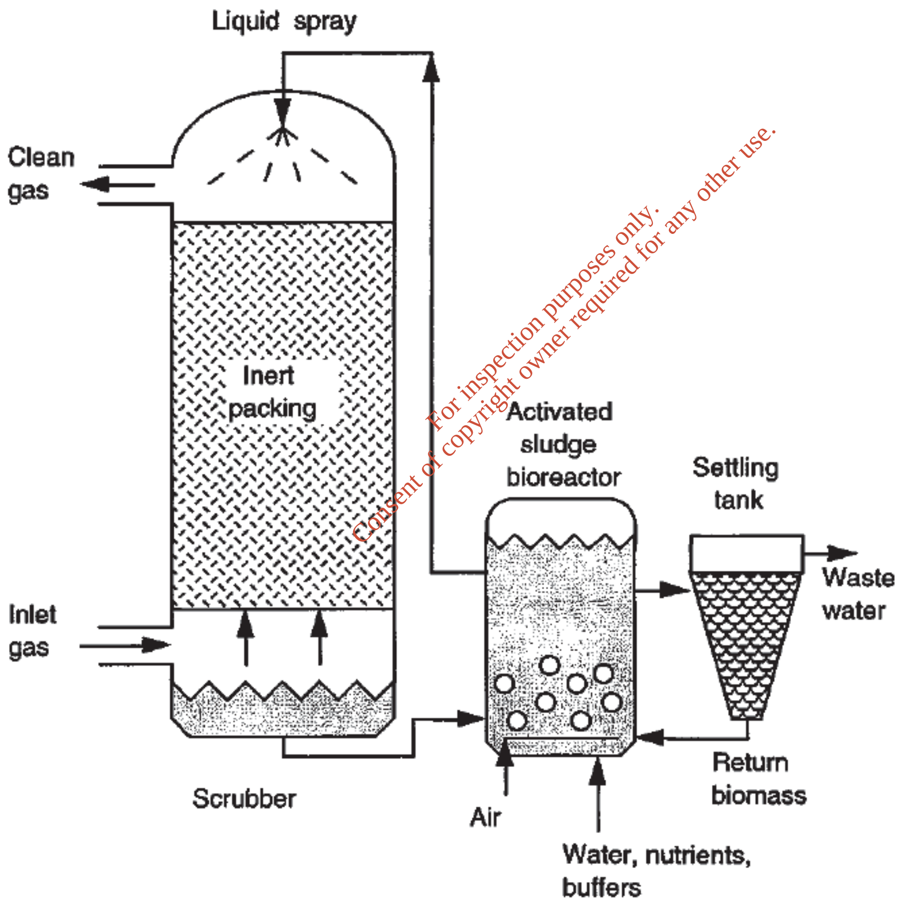

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Figure 2: A Bio-Scrubber

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Of the various bio-filtration systems, bio-scrubbers have the least space requirements, the highest operational stability and process-control, and greatest permeability to gas flow. But they also have the lowest scrubbing efficiency due to the reduced specific gas/liquid surface area for mass transfer (Van Groenestijn and Hesselink 1993).

Bio-scrubbers do well removing water soluble contaminants. To enhance capture of slightly soluble compounds, organic solvents that are immiscible in water, such as Ammonia, Amines, Hydrogen Sulphide, chlorides, etc.

The site has two buildings which require odour abatement systems namely:

- Black Bin Waste Storage area
- Storage Area for Dry Recyclable

In order to meet the waste license requirements

CONDITION 7 NUISANCE CONTROL

7.1 The licensee shall ensure that vermin, birds, flies, mud, dust, litter and odours do not give rise to nuisance at the facility or in the immediate area of the facility. Any method used by the licensee to control any such nuisance shall not cause environmental pollution.

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As a result of the above we have included 2 options for your consideration:

Requirement 1	Existing Wet Waste Area requires a MEHS MK1 running at 20,000 m3/hr (includes 20% additional capacity)
Requirement 2	Existing Wet Waste Area & Dry Recyclables area requires a MEHS MK 2 running at an air flow of 35,000 m3/hr (includes 20% additional capacity).

Option 1 Existing Wet Waste Area requires a treatment system of the rate of 20,000 m3/hr (includes 20% additional capacity).

MEHS MK1 (1 off) at air flow rates of 20,000 m3/hr (via 1 fan)

Option 2 Existing Wet Waste Area and Dry Recyclables Area requires a treatment system of the rate of 35,000 m3/hr (includes 20% additional capacity).

MEHS MK2 (1 off) at air flow rates of 35,000 m3/hr (via 1 fan)

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Typical Design Criteria:

Air flow rate dependent on loading rate:

- Flow rate, 5,000 to 35,000 m3/hr
- Loadings 40 – 120 m3/m2 (dependent on contaminant concentrations)
- Residence or Contact time 4 - 10 seconds
- Amines removal efficiency 85 – 90%
- Ammonia removal efficiency 85 – 90%
- H2S removal efficiency 85 – 90%
- VOC removal efficiency 60 – 80%
- Liquid to Gas ration design 6 litres/m3

2.2.3 Major Design Considerations:

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A. Irrigation

The media must be kept moist, but if irrigation is too frequent, the biomass may be deprived of oxygen. If irrigation is too infrequent, the media can dry out and reduce effectiveness. A programmable timer may be used to properly time irrigation cycles. The temperature of the process air will be measures during commissioning in order to establish cycle.

B. Media

Media should possess high surface area to volume ratios, good adsorption characteristics, low pressure drop, and good sloughing characteristics. For nitrogen and organic compounds treatment, media impregnated will be seeded with bacteria prior to commissioning.

C. Nutrients

Nutrients must be kept fresh to maintain healthy biomass. Appropriate nutrients essential to the various bacteria in the bio-scrubber will be identified. This will be determined prior to commissioning by sampling and running lab scale tests on samples of the leachate. Montgomery EHS will design a solution to provide exact nutrient requirements. A dosing pump will be installed to allow dosing of nutrients and Bacterial supply solution

D. Construction materials

Corrosion-resistant materials such as HDPE will be used

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E. Air distribution

Uniform air distribution through the media bed is important to efficient operation. Perforated FRP distribution plates have been used effectively to support the media bed and distribute the air flow uniformly.

2.3.1 Proposed Bio-Scrubber Design

The proposal as received requests that a bio-scrubber capable of treating air from the Wet Waste Processing area and the Dry Recyclables material the odorous air arising from the air discharge from buildings. If the normally parameter of 40 to 120 m^3/m^2/hour is applied the bio-scrubber are capable of treating.

We propose that an extraction system required for the Black Bin Waste Storage requires the removal of 20,000 m3/hr. We will install a Variable Speed Drive (VSD) on the fan motor to facilitate bio-scrubber airflow to be reduced to 5,000 m3/hr when no movement i.e. night time.

We propose that an extraction system required for the Black Bin Waste Storage and Dry Recyclables Storage requires the removal of 35,000 m3/hr. We will install a Variable Speed Drive (VSD) on the fan motor to facilitate bio-scrubber airflow to be reduced to 7,000 m3/hr when no movement i.e. night time.

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Price includes for:

- Ductwork and supports
- Formwork
- Supply of Bio-scrubber
- Fan & VSD
- Nutrient and Bacterial dosing pumps
- Differential pressure gauge

Measure and Monitoring conducted

Montgomery EHS and Oxigen Environmental will take a pro-activate approach to Odour control and will invest significant resources into controlling the Odour from the operation.

A large number of modifications to the bio-scrubber will take place for example:

- Ducting Odorous sources to the Bio-scrubber
- Sealing of the buildings
- Sealing joints, spray foam corners, etc.
- Installation of the Bio-Scrubber

The project will be independently sampled by Exova Catalyst Ireland to conduct monitoring at the facility for chemical analysis.

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The monitoring will include the

- VOC
- Ammonia
- Amines
- Hydrogen Sulphide
- Mercaptans

2.3 Predicting the environmental impact of Odour emissions

The normal operations at Oxigen Environmental Ltd facility has the potential to produce some intermittent odorous materials discharged through open tanks or as fugitive materials through doors or windows, into the atmosphere are diluted and dispersed by the wind and atmospheric turbulence. The process of atmospheric dispersion has an important role in the reduction of Odour impacts. Odours from Oxigen Environmental Ltd can be detected over the period of seconds and minutes. The levels of odour emissions emanating from Oxigen Environmental Ltd may be detected during the intermittent operation at the facility but in general will be below the Waste License Limits.

The concentrations of organics and nutrients varies with the process and upsets which occur.

2.4. Identification of abatement options

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Montgomery EHS examined all available control requirements have been established, it is possible to consider options for Odour minimisation and abatement. Bearing in mind the key considerations for VOC control (prevention, minimisation and rendering harmless), the following questions need to be addressed:

- Can the process be modified to reduce the Odour emissions?
- Can the Odour emissions be minimised by better site management?
- How effective and appropriate is any abatement equipment already in place?
- Are all emissions contained for abatement?
- Are there any secondary or fugitive sources that contribute to the emission?
- What level of Odour control is required?
- What are the specific characteristics of the gas streams (e.g. gas flow rate, temperature, moisture, pH, composition, calorific value etc.)?

2.4.1 Criteria affecting the choice of Odour's abatement

Montgomery EHS examined more than one method of abating a particular Odour nuisance. To assist in the choice there are several rules of thumb that can be used for guidance:

Odour source

The choice of abatement equipment is dependent on the type of Odour stream to be treated. There are two generic types of Odour gas streams; they are:

a) Process gas stream (typically high Odours concentration, low flow).

b) Ventilation air (typically low odour concentration, high flow).

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In many cases, it is more cost effective to treat the process and ventilation streams separately.

Containment

A first consideration should be whether the Odour nuisance can be avoided by better containment. Some processes are easily contained, e.g. paint spray booths, whilst others are not, e.g. batch rendering, landfill sites, effluent treatment etc. The first step in Odour abatement is to examine the process and to maximise the containment of total Odour within the building(s). The next step is to localise process Odour to reduce the volume of highly odorous gas.

Containment can be achieved by eliminating holes in buildings, avoiding storage of odorous materials outside the building and the transport of materials between buildings in open containers etc. Containment of highly odorous process gases may reduce the capital and operating (energy costs etc.) of the required abatement system(s).

NB. All control systems should exert a negative pressure within buildings to prevent odorous air leaking out.

Concentration and volume flow rates of Pollutants

As mentioned elsewhere in this report, Odours can be odorous and the odour strength is not necessarily associated with high chemical concentrations. However, generally:

- High odour concentration is associated with small air volumes. · Multi-stage scrubbing is often more cost effective for higher volumes of highly polluted air.
- Medium and low odour concentrations are liable to be associated with larger air flows, e.g. building ventilation systems. They are likely to require abatement by techniques with lower operating costs such as bio filtration or scrubbing.

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Temperature

The temperature of the gases to be treated will affect abatement options or may require the fitting of additional units, e.g. a gas cooler or condenser. For example, bio filters and carbon absorbers are unlikely to be effective if the gas temperature is in excess of 35°C and 40°C respectively. Conversely, high exhaust temperatures may reduce running costs if incineration was an option.

An additional factor affecting Odour abatement is the effect of the temperature on the material of construction. Plastic is frequently used because of its corrosion-resistant properties and lower cost; however, it may be susceptible to thermal damage.

Moisture content

The moisture content of the exhaust gas will often affect the suitability of an abatement technique. High moisture content is likely to reduce the cost effectiveness of absorbers due to the preferential take up of water vapour. High moisture content is slightly beneficial for bio filters because it reduces the amount of irrigation the bed requires and it has no detrimental effect on scrubber performance.

Chemical composition

The chemical composition of VOC gases can affect the suitability of abatement options in several ways. For example: organic compounds may not be suitable for abatement by a water based scrubber but may provide a significant fuel fraction for an incinerator.

If the odorous gas has high sulphur content then it may be unwise to use incineration as acidic oxides

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would be released and could cause damage, unless the incinerator had been designed to withstand the effects of these chemicals.

Acidic and basic gases are readily removed by chemical scrubbing with a neutralising chemical, e.g. to treat an acid gas you would use an alkali.

Conversely, easily soluble organic compounds are most suited to bio scrubbing or bio filtration, whereas aromatic compounds and those aromatic halogens are more difficult to oxidise by this method.

Disposal of waste produces

When deciding upon the choice of Odour abatement equipment, safe disposal routes for secondary wastes need to be considered. Bio-scrubber has the advantages in that the effluent can be added to the process.

2.5 Abatement techniques

The objective of the abatement techniques described is to reduce the Odour emission to such an extent that, when used in conjunction with an adequately sized stack, the residual odour complies with the IPPC License conditions. We have tried to illustrate the performance of the different techniques in terms of abatement efficiency, when sized, maintained and operated effectively.

Factors which will affect the choice of processes include:

- The maximum allowable odour intensity at the boundary of the site
- The flow-rate of air to be treated
- The type and concentration of odour compounds including variability (infrequent emissions of high odour strength potentially could exceed the capacity of a biological scrubber or the control system of a chemical scrubber), and
- The space availability and zoning requirements of the proposed location.

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Odour from buildings will include: Ammonia, Amines, Hydrogen Sulphide, Mercaptans and lower concentrations of other VOC compounds (typically less than 1 ppm).

Centralised odour treatment may have advantages in reduction of cost of treatment and simplicity in operation. However, it may not be appropriate in all cases, because the cost of ductwork may offset savings in unit costs. In addition, if the system does not meet the standard consistently, the combination of odour air into a single point discharge, rather than a number of diffuse sources, may exacerbate an odour problem. Designs should be based on site trials or data obtained from existing installations performing a similar duty. Specific performance guarantees should be sought from the supplier of odour treatment equipment, with performance testing of agreed parameters carried out during commissioning. Clear operating and maintenance procedures, and regular monitoring, are also required to ensure that performance is maintained.

The main types of odour treatment in use in industry are:

- Bio filters and bio scrubbers
- Wet chemical scrubbing
- Catalytic oxidation
- Dry scrubbing and adsorption, and
- Thermal Oxidisers

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2.5.1 Bio-filters and Bio-scrubbers.

Bio-filters and bio-scrubbers utilise the ability of microorganisms developing on a support medium to oxidise odour compounds to less bacterial mass, CO_2 and water. odour compounds, such as Isopropyl Chloride, first dissolve in the moisture or liquor around the media and are then oxidised biochemically. The medium must be wetted, in the case of bio-scrubbers with liquor re-circulated over the bed. In the case of bio-filters, some adsorption of insoluble compounds also occurs.

In bio-filters, the media which are most commonly used are moist peat, peat/heather mix, coir or similar fibre. In bio-scrubbers, which treat higher loading rates than the bio-filter, micro-organisms develop on plastic or other media such as mussel shells or calcified seaweed. In bio-filters and bio-scrubbers, although seeding may be employed, the unit will take several weeks to achieve optimum performance. Both are unsuitable for intermittent or very variable odour loads.

The bio-filter has proved to be popular and effective in treating relatively low and constant concentrations of ammonia (less than 100 ppm).

Higher concentrations of odour can lead to problems of acidity in the bio-filter as it is biochemically oxidised to acid compounds. This may be overcome by irrigation but if irrigation is excessive the overall removal of odour will be limited. The natural media used in bio filters have an associated odour (biological odour), which limits their performance in terms of percentage removal when treating lightly odorous air.

Operational problems with bio-filters have been associated with acidity in the bed, weed growth, drying out of the media, poor air distribution at the base of the bio-filter and short-circuiting of odorous air, sometimes through overflow pipes. The media will require occasional replacing (two to five years).

The bio-scrubber is generally used to treat higher concentrations of odour's (up to 500 ppm). The mussel shell and calcified seaweed versions of the process have the advantage that any acidity formed by the biochemical oxidation of odour's and any acidic compounds are neutralised by the carbonate content of the shells or seaweed. Over a period of time, this sacrificial use of the media to buffer the system leads to loss of the media, which will then require replacement.

Mussel shell and seaweed filters have been found very effective in treating high-strength Odours to a high standard (with the provisos about lifetime given above); in some cases, a second polishing stage is also required. Plastic media filters may be more durable, although the performance has been found to be more variable, and a second stage of treatment is usually required prior to discharge. Highly odorous air, e.g. from sludge tanks, can impose a considerable oxygen demand on a bio scrubber and can become oxygen limited. Most bio scrubbers employ final effluent as the re-circulating liquor, and better performance seems to have been associated with nitrified final effluents which can satisfy additional oxygen demand.

However, as complete removal of Odours is unlikely, there may be a risk of odour nuisance if the inlet air contains a high concentration of odours. Conventional biological filters have also been used to treat odorous air, with lightly odorous air vented to the base of the filter to be drawn up through the filter bed. It may be possible to use a covered surface-aeration plant in a similar way, by ducting air into the headspace. (The sparging of odour air through a significant depth of liquid in the plant is economically unattractive.)

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2.5.2 Wet chemical scrubbing.

In wet chemical scrubbing, the flow of odour air passes through a bed of medium over which chemicals dissolved in water are re-circulated. Several stages of scrubbing can be used, with different chemical additives in each. In three-stage scrubbers, it is common to use an acidic stage (to remove alkaline odours such as amines and ammonia), an alkaline and oxidising second stage (to remove and oxidise acidic odours such as H_2S) and an alkaline third stage (to remove residual oxidant and odours.

In single-stage scrubbing, alkali and oxidant (such as peroxide, ozone, chlorine dioxide or hypochlorite) would generally be used to remove the main contaminant such as Ammonia. In some proprietary versions, a catalyst (such as iron or nickel) is used to accelerate the oxidation.

Chemical scrubbing can achieve a high degree of treatment, typically 99.9% removal of Ammonia and around 98% of overall odour; it requires No start-up time before it is filly effective. Care will be needed to ensure that the oxidant (such as hypochlorite or ozone) does not itself contaminate the air stream and cause a nuisance, particularly at times when the Odour load is low.

A final stage of scrubbing with sulphite has been used to eliminate carry-over of hypochlorite. Because of the need to handle and store hazardous chemicals and the associated operational requirements, wet scrubbing is generally used at larger sites, including the treatment of ventilation air from totally enclosed processes.

The treated air from wet chemical scrubbing will be fully saturated with water and, even with mist elimination, may be visible due to condensation in the plume when the external temperature is cooler than that of the ventilation air. This can be avoided by dilution of the emitted air with ambient air.

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2.5.3 Dry scrubbing and adsorption.

Dry scrubbing uses an adsorptive medium (such as activated carbon) or media impregnated with an oxidising agent (such as potassium permanganate or stabilised chlorine dioxide), so that oxidation of adsorbed compounds will take place.

Dry scrubbing is widely used in passive filters (typically on storage-tank vents) and in building ventilation systems. The effectiveness of passive filters is dependent on the regular replacement of the media, which may become rapidly exhausted with strong Odours, and on ensuring that there is no other easier route for odorous air to follow (such as open hatches or overflow pipes).

Dry scrubbing in ventilated systems, if operated correctly, can achieve a very high standard of odour treatment, with the removal of both water soluble and non-soluble components in the odorous air to negligible concentrations. Moisture in the air will also be adsorbed so that there will be no condensation after discharge to make the vent plume visible. However, contamination with condensed water vapour is a prime cause of failure or short effective medium life for dry scrubbers.

'Breakthrough' of odours, or stripping of odours, occurs when the medium is exhausted. Some media can be tested by the supplier to determine their residual capacity. However, results need to be treated with caution as this calculation assumes a constant odour load which may not be the case (e.g. odour loads may increase significantly during the summer).

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The selection, and the rate of use of media, will depend on the type of compounds in the air, which should be specified. The expected rate (and cost) of replacement of media should be confirmed before installation. Due to the cost of media replacement, dry scrubbing is sometimes used to polish the air from a first stage of odour treatment.

The critical features for successful operation are:

- Relative humidity of the odorous air should be below 85% to avoid condensation on the media, which may reduce the adsorptive capacity and leach oxidant from the media. Warming the inlet air by around 5°C is generally sufficient to control humidity
- A regular procedure for replacement of media should be employed, to ensure that fresh media is in place at critical times (such as the start of summer)
- Empty bed retention periods of as low as 0.5 seconds may be sufficient for treatment but, generally, retention periods of several seconds are necessary to provide a reasonable bed life and performance.

2.5.4 Odour masking and counteractants

Sprays have been widely used throughout the Ireland at a number of facilities such as waste facilities to mask or counteract unpleasant odours, with variable success.

Sprays have been found to be successful in reducing the numbers of complaints when the concentration of odour is relatively low, and for short-term use while more permanent remedial measures are being installed. In the long term, the smell of the agent can become as unacceptable to the complainant as the original malodour. The cost of the chemicals can be significant.

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Measurements employing olfactometry have shown that some counteractants have little effect on the odour strength of air. Reasonably high doses of counteractant may modify a strong odour, but when the latter is extensively diluted to the limit of detection the counteractant is similarly diluted and no effect is observed.

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2.6 Selected Treatment System - Bio scrubbers

In a bio scrubber, odorous gases are oxidised by microbe enzymatic activity to produce by-products. The contaminated gas is passed up a tower against a flow of water (counter current flow) containing a population of microbes suitable for oxidising the components of the gas. The tower is designed to contain packing material on which the microbes adhere to form a biological "mat".

The proposed Bio-Scrubber is what is sometimes called a Bio-packed column are used for the continuous contact between liquid and gas. The counter current packed column (see Figure 2.1) is the most common type of unit encountered in gaseous pollutant control for the removal of the undesirable gas, vapour, or odour. This type of column has found widespread application in both the chemical and pollution control industries. The gas stream containing the pollutant moves upward through the bio scrubber against an absorbing or reacting liquid that is injected at the top of the packing. In addition, the bacterial mat will result in the highest possible transfer/control efficiency as the bacteria breakdown the odorous compounds.

Since the pollutant concentration in the gas stream decreases as it rises through the column, there is constantly fresher liquid available for contact. This provides a maximum average driving force for the transfer process throughout the bio scrubber. Liquid distribution plays an important role in the efficient operation of a packed column.

A good packing from a process viewpoint can be reduced in effectiveness by poor liquid distribution across the top of its upper surface. Poor distribution reduces the effective wetted packing area and promotes liquid channelling. The final selection of the mechanism of distributing the liquid across the packing depends on the size of the column, type of packing, tendency of packing to divert liquid to column walls, and materials of construction for distribution. For stacked packing, the liquid usually has little tendency to cross distribute and thus moves down the column uniformly in the cross-sectional area that it enters. In the dumped condition, most flow profiles follow a conical distribution down the column, with the apex of the cone at the liquid impingement point. For well-distributed liquid flow and reduced channelling of gas and liquid to produce efficient use of the bio scrubber, the impingement of the liquid onto the bed must be as uniform as possible. The liquid coming down through the packing and on the inside wall of the column should be redistributed after a bed depth of approximately 3 column diameters for Raschig rings and 5–10 column diameters for other packing (check literature for details of packing). As a guide, Raschig rings usually have a maximum of 3 to 6 meters of packing per section, while other packing can use a maximum of 4 to 6 meters. Generally, of thumb, however, the liquid should be redistributed every 3 meters of packed height. The redistribution brings the liquid off the wall and outer portions of the column and directs it toward the centre area of the column. As noted earlier, redistribution is seldom necessary for stacked bed packings, as the liquid flows essentially in vertical streams.

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2.6.1 Selection and Design Considerations

Bio scrubbers are more energy intensive than bio filters since both water and air are being re-circulated. However, their footprint is much smaller. The scrubbing tower should be designed to provide a contact time of about 1 second, but this will depend upon the composition of the inlet gas.

2.6.1.1 Typical applications

A bio scrubber can be used whenever bio-oxidation is an appropriate solution to the problem and the solubility of the target compounds is high. When compared to bio filters a bio scrubber has the

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advantage of requiring less land area and of discharging gas at height rather than at ground level. However, the technique is widely used in continental Europe for agricultural and chemical applications. Consequently, the plants failed and had to be replaced.

2.6.1.2 Performance Monitoring and Maintenance

This is typically undertaken by chemical analysis or odour assessment of the inlet and outlet gases, e.g. VOC species, Ammonia, Amines and Hydrogen Sulphide, etc.

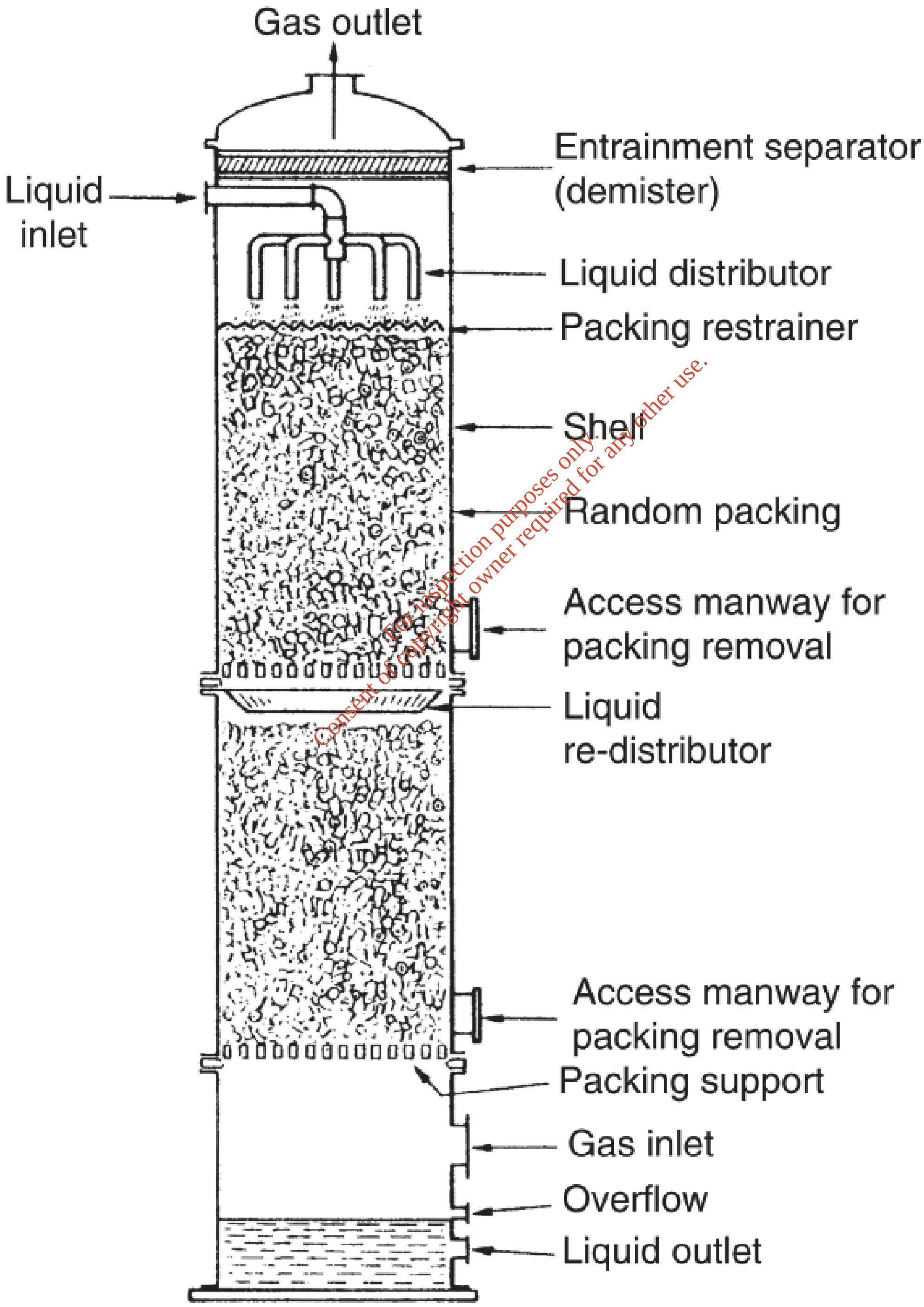

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Figure 2.1 Proposed Bio-Scrubbers at Oxigen Environmental Ltd

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Operational Issues Encountered with Bio scrubbers

Biomass may build up within the tower blocking the circulating water. Easy access to remove biomass is required. · Sometimes there can be an odour emitted from the liquid circulation hold-up tanks. If chemicals are used to remove the odour care must be taken to ensure that they do not poison the microbes within the tower. · Microbes can be 'carried over'. The air stream can carry the microbes to the exhaust. Therefore, microbial activity needs to be continuously measured and occasionally additional microbes will need to be added to the tower. The Installation of a mist eliminator will significantly reduce microbes present in the emissions

Absorption for odour removal

Gas absorbers (or scrubbers as they are often, though incorrectly, called) are widely used for removing odour from industrial processes.

Absorption is defined as a process which involves mass transfer between a soluble gas and a liquid solvent in a gas-liquid contacting device. Vapours and gases are absorbed from a contaminated exhaust stream into a chemical solution. The liquid phase is generally re-circulated with a small amount being continually being bled off and the same amount of fresh reagent being introduced. The main requirement is that the contaminated air should be brought into contact with the liquid. Special packing materials may be used to increase the gas-liquid contacting area. Gas absorbers which use water as the scrubbing liquor commonly have odour removal efficiencies of 90%. To increase absorber efficiency, chemicals are added to the scrubbing water to remove specific odorous compounds.

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The odorous components of a gas stream are transferred to the liquid phase where a chemical reaction takes place. Typically, acidic or alkaline gases are absorbed into pH controlled solutions, whilst other Odours are absorbed into appropriate chemical solutions according to composition. Oxidants (often chlorine based) are frequently used for aldehyde and ketone control. The efficiency of mass transfer depends on several factors:

- Solubility of the odorous component in the liquid phase.
- Gas - liquid contact time the area available for contact. The use of various forms of packing or other types of gas-liquid contactors will improve odour removal efficiency but at the expense of increasing pressure drop.
- The use of chemical reagents carries its own problems. If process conditions vary outside of control limits, droplet carry-over can occur. The use of oxidants can sometimes lead to the formation of other odorous compounds within the tower and poor effluent management can create odour sources. Therefore, the absorber, if poorly designed and controlled, can become a secondary source of odour. It should be possible to design a system to maintain a residual post-treatment odour emission of below 10 mg/m^3.
- Absorption is good for removing odour compounds of known composition and may also be used as an after treatment to incineration, if acid gases are produced. Gas temperatures of up to 40°C can be tolerated, but at more elevated temperatures, product solubility may change, particulate production may occur and downstream condensation may become a problem.

Typical Application of Bio-Scrubber.

The technique has been used with varying degrees of success for several different types of Odour emission. These include the emissions from waste site, chemical sites, plastic manufacturers, rendering plants, maggot farms, tanning, vegetable hydrolysis, tobacco processing, pharmaceutical production, fatty acids, waste water works, dye-stuffs, amines, phenolic resins and methyl methacrylate.

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Performance Monitoring and Maintenance
Abatement efficiency can be determined by monitoring the composition of the gaseous effluent, or an operational parameter of the system which correlates performance, e.g. pH. COD, Chloride, dissolved material concentration of outline, etc.

Gas concentrations at the inlet and outlet of the scrubber are preferably measured continuously, although periodic measurement may be satisfactory depending on the degree of variability of emissions. Semi-quantitative analysis and Odour tests can be performed on grab samples of gas taken at selected sampling points.

System monitoring can take the form of checking for large scale blockage of jets and packing by recording water supply pressure and air pressure either side of the absorber. Alternatively, liquid/reagent flow rates and reagent utilisation may be sufficient. System monitoring will not detect partial blockage and internal deterioration, so equipment will be visually inspected on a regular basis.

2.7 How to select the appropriate gas absorber?

There are four factors which determine the most appropriate type of absorber to be used:

- Required abatement efficiency;
- Energy efficiency;
- Reagent requirements;
- Properties of the incoming gas stream.

2.7.1 Chemistry

Absorption systems can have either aqueous or non-aqueous liquid phases. The selection of the relevant absorbing media will depend upon the properties of the odorous compounds.

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2.7.1.1 Solubility characteristics of common odorant species

Water is suitable for absorbing soluble acidic gases such as:

- Hydrogen chloride
- Hydrogen fluoride
- Silicon hexafluoride
- Ammonia

Alkaline solutions are suitable of absorbing less soluble acidic gases such as:

- Sulphur dioxide
- Hydrogen sulphide
- Chlorine
- Very soluble acidic gases to very low levels

Acid solutions may be needed for the absorption of:

- Very soluble basic gases to very low levels

Oxidising solutions can be used for:

- Oxidation of by-products of the above reactions
- Control of some soluble organic compounds

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Table 2.1 Summary of suitable absorption medium for different pollutants common odorant species

Pollutant	Suitable Absorption Medium
Acid gases HCl, HF and SO_2	Water, sodium sulphite solution, alkaline solutions/slurries.
Odorants Hydrogen sulphide	Absorbed at high pH. Oxidise particularly at high pH.
Mercaptans	Absorbed at high pH. Can be oxidised particularly at high pH. Weak oxidants may oxidise to odorous disulphide.
Sulphides	Can be oxidised. The use of a catalyst should be considered.
Disulphides	Can be oxidised; hypochlorous acid more effective than hypochlorite.
Aldehydes	React with bisulphite. Oxidise particularly at high pH.
Ketones	React with bisulphite (but less well than aldehydes) Oxidise particularly at high pH.
Fatty acids	Soluble in water or slightly alkaline solution.
Amines	Soluble in slightly acid solution. May be chlorinated to form strongly odorous reaction products. Can be oxidised. The use of a catalyst should be considered.
Unsaturated compounds	Can be oxidised.
Phenols	Absorbed at high pH. May be chlorinated.

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Organic solvents can be used to absorb organic species but this can lead to the generation of sludge or separation of the solute from the solvent. In almost all cases organic solvents as absorbing media are not used to remove odorous components - different abatement techniques are usually chosen, e.g. adsorption or incineration.

The driving force for odour removal by absorption is the difference between the partial pressure of the soluble gas in the gas mixture and the vapour pressure of the solute gas in the liquid film in contact with the gas. Mass transfer occurs by molecular diffusion across the gas/liquid interface.

Gas absorption is a rate process and consequently the concentration gradient (reaction driving force) and the surface area of contact between the liquid and gaseous phases are crucial design parameters.

2.8 Selected Equipment – Bio-Scrubber

Bio-Scrubbers or Packed bed absorbers are the mostly commonly used in the treatment of odour's. They consist of an outer shell containing a bed of packing material on support grids, liquid distributors, gas and liquid inlets and outlets and a mist eliminator. The absorbers are designed so that liquid is distributed continuously over the packing material forming a film which provides a large surface area for gas/liquid contact. The contaminated gas flow through the packed bed can be either counter current (gas flows in opposite direction to liquid flow), con-current (gas and liquid flow in the same direction) or cross current (gas and liquid flows are perpendicular).

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There are various types of packing material which can be packed in random or in a regular arrangement; the most common types are:

- Raschig rings;
- Lessing rings;
- Pall rings and modified pall rings - most commonly used in industry;
- Berl saddles;
- Interlox saddles;
- Tellerettes

2.8.1 Selection and Design Considerations

Packed towers give excellent gas-liquid contact and efficient mass transfer, and are almost always the preferred type of gas absorber.

Advantages of the packed column over other absorbers are high efficiency, low maintenance and relatively low pressure drop (typically about 50-75mm water).

Disadvantages are their relatively large size; typically, a diameter of 3 m and a height of 7m is required to accommodate a flow of $1m^3/s$. This type of scrubber is likely to be more than twice as expensive as a spray absorber but more tolerant of nozzle blocking because even if some nozzles block, gas-liquid contact will remain relatively large.

Counter current packed bed absorbers maximise the driving force for absorption because gas leaving the packed bed encounters fresh absorbing liquid. The liquid flow rate in counter current packed bed absorbers is limited by the possibility of flooding. Concurrent and cross current designs are mainly used in systems where the absorption reactions are rapid. These absorbers have the advantage that they are less susceptible to plugging by particles and operate at lower pressure drops. Cross current gas absorbers operate at low liquid: gas ratios.

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The choice of cross flow scrubber is usually made when the height of the unit is of greater concern than the pilot area.

2.8.2 Typical Applications

Packed bed absorbers, with the appropriate reagents, have been successfully used for absorbing acid gases and odours from boiler flue gases, chemical, food, metallurgical and petroleum processes.

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3.0 Oxigen Environmental Ltd - Bio-Scrubber Design Criteria

A bio scrubber consists of two reactors. The first part is an absorption tower, where pollutants are absorbed in a liquid phase. This liquid phase goes to a second reactor, which is a kind of activated sludge unit. In the latter, microorganisms growing in suspended floc's in the water, degrade the pollutants. The effluent of this unit is recirculated over the absorption tower in a co- or counter current way to the flow of the waste gas.

Performance Parameters

Different biological waste gas purification technologies can be compared based on the performance using a set of parameters. These parameters include

- Empty bed contact time [s],
- Surface loading rate [$m^3\ m^{-2}\ h^{-1}$],
- Mass loading rate [$g\ m^{-3}\ h^{-1}$],
- Volumetric loading rate [$m^3\ m^{-3}\ h^{-1}$],
- Elimination capacity [$g\ m^{-3}\ h^{-1}$],
- Removal efficiency [%].

Empty Bed Contact Time or True Contact Time
The residence time of the gas in a bioreactor can be calculated in two different ways;

(1) Superficial residence time or empty bed residence time based on the total volume of the reactor and referred to as empty bed contact time (EBCT)

$$EBCT = \frac{V \cdot 3{,}600}{Q} \quad [s]$$

(1)

where V pvolume of the filter material in the reactor [m3] and Q pwaste gas flow rate [$m^3\ h^{-1}$].

(2) True residence time t, which is based on the free space in the reactor and defined as

$$\tau = \frac{\varepsilon \cdot V \cdot 3{,}600}{} \quad [s]$$

(2)

where ε porosity of the packing materials (without dimension).

In many cases the exact porosity needed to calculate the true residence time, is not known. Hence, most often the empty bed contact time is used. The EBCT is typically used for comparison of gas residence times in different reactor technologies or under different loading conditions. However, one must keep in mind that this gives an overestimation of the true residence time. Due to preferential currents through the larger voids in the packing, there can be a considerable deviation of the actual residence time from the calculated residence time.

The residence time in the reactor is useful as an indicator of the time available for mass transfer of the pollutant from the gas phase to the liquid phase through the biofilm. The latter is often the factor limiting the microbial degradation.

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Surface Loading Rate (B_A)
The surface loading rate indicates the amount of air that is passed through the bioreactor per unit surface area per unit time.

$$B_A = \frac{Q}{A} \quad [\mathrm{m^3\,m^{-2}\,h^{-1}}] \tag{3}$$

Where A p total surface of the packing or filter material in the bioreactor [m^2]. One can also express the velocity of the gas [$m\ h^{-1}$] through the empty reactor. However, the reactor is normally filled with packing materials, which results in a higher velocity gas compared to the surface loading rate.

Mass Loading Rate (BV)
The mass loading rate gives the amount of pollutant which is introduced into the bioreactor per unit volume and per unit time.

$$B_V = \frac{Q \cdot C_{g\text{–}in}}{V} \quad [\mathrm{g\,m^{-3}\,h^{-1}}] \tag{4}$$

where Cg–in p concentration of the pollutant in the inlet waste gas stream [$g\ m^{-3}$].

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Volumetric Loading Rate (vS)
The volumetric loading rate is the amount of waste gas passed through the reactor per unit reactor volume.

$$v_S = \frac{Q}{V} \quad [\mathrm{m^3\,m^{-3}\,h^{-1}}] \tag{5}$$

Elimination Capacity (EC)
The elimination capacity EC gives the amount of pollutant removed per volume bioreactor per unit time. An overall elimination capacity is defined by Eq. (6).

$$EC = \frac{Q \cdot (C_{g\text{–}in} - C_{g\text{–}out})}{V} \quad [\mathrm{g\,m^{-3}\,h^{-1}}] \tag{6}$$

where Cg–out p concentration of the pollutant in effluent waste gas [$g\ m^{-3}$].

Removal Efficiency (RE)
Removal efficiency is the fraction of the pollutant removed in the bioreactor expressed as a percentage. It is defined as

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$$RE = \frac{(C_{g-in} - C_{g-out})}{C_{g-in}} \cdot 100\ [\%] \tag{7}$$

It should be noted that the different parameters are interdependent. There are only 4 independent design parameters: reactor height, volumetric loading rate, gas phase concentration at inlet (Cg–in) and outlet (Cg–out).

Summary of Key Points

Montgomery EHS employs the following approaches to evaluate the capabilities of scrubbing systems: empirical relationships, theoretical models, and pilot scale tests.

- Important parameters in the design and operation of wet scrubbing systems that are a function of the process being controlled are exhaust gas characteristics.
- Particle size distribution is the most critical parameter in choosing the most effective scrubber design and determining the overall collection efficiency.
- Static pressure drop of a system is dependent on the mechanical design of the system and collection efficiency required.
- The scrubber used most often to remove particulate matter from exhaust systems is a Venturi scrubber.
- The term *penetration* is defined as the fraction of particles that passes through a scrubber uncollected.
- No one simple equation can be used to estimate scrubber collection efficiency for all scrubber types.
- Efficient particle removal requires high gas-to-liquid (relative) velocities.
- The infinite throat model is used to estimate particle collection in Venturi scrubbers.
- The contact power theory is dependent on pilot test data to determine required collection efficiency.
- The total pressure loss, or contacting power, of the scrubbing system is represented by $P_T = P_G + P_L$, the symbol P_T.
- Efficient particle removal requires high gas-to-liquid (relative) velocities.
- According to the contact power theory, the higher the pressure drop is across the scrubbing system, the higher the collection efficiency will be.
- The following factors affect the pressure drop of a scrubbing system: scrubber design, gas velocity, and liquid-to-gas ratio.

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4.0 Basis for Selection of Bio scrubber

Routine evaluation of wet scrubbers depends on the assessment of scrubber operating variables that are both meaningful and measurable. Description of such a performance evaluation approach must start with the identification and understanding of the functions of the scrubber system. ·

4.1 Wet Scrubber System Components

Because operating problems affecting performance of wet scrubbers originate not only in the scrubber vessel, but al so in the process equipment and in the independent components of the scrubber system, the scrubber vessel must be evaluated as part of the larger system into which it is integrated, and not as an isolated piece of equipment. A wet scrubber system is composed of a large number of individual components all of which must work properly even when process conditions vary. Individual components which make up this particular system are listed below:

1. Scrubber vessel
2. Demister
3. Fan
4. Recirculation tank
5. Recirculation pumps
6. Bypass duct and dampers
7. Alkaline additive system
8. Clarifier
9. Vacuum filter
10. Purge and make-up systems
11. Stack
12. Flow monitors
13. pH monitors
14. Static pressure monitors

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There is considerable diversity in the design of wet scrubber systems due to the different control requirements, different water availabilities and qualities, and process related factors.

Gas movement through the wet scrubber system is maintained by the use of a fan. If the process equipment and the scrubber vessel are located before the fan, then the entire system operates at pressures lower than ambient. This is termed negative static pressure (static pressure is simply the pressure exerted by a gas in all directions, measured normal to the direction of flow, if any). With the fan in this position, ambient air will leak into the ductwork and scrubber if there are any holes, open access hatches, or weld gaps.

The pressure drop across the scrubber vessel is an important operating variable since it is often related to the effectiveness of particulate capture. The pressure drop is simply the mathematical difference between the static pressures before and after the scrubber.

The liquor flow through the scrubber can either be “once through “or recirculated. Most wet scrubber systems have a recirculating liquor system to reduce the volume of water needed, and to reduce the cost of treating the scrubber effluent liquor.

The recirculating liquor circuit is more complicated than the once-through system. The additional components required include the recirculation tank, the purge stream control s, and the makeup stream controls. The recirculating system is prone to build-up of bacterial solids and corrosive agents, while

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the once-through system is free of these potential problems as long as there is a sufficient supply of high quality water.
The advantages of the recirculating liquor system include lower operating cost and the opportunity to neutralize and treat the liquor prior to entry to the scrubber vessel.

An important parameter in wet scrubbing systems is the rate of liquid flow. It is common in wet scrubber terminology to express the liquid flow as a function of the gas flow rate that is being treated. This is commonly called the liquid-to-gas ratio (L/G ratio) and uses the units of litres/cubic meter (l/m^3).

Expressing the amount of liquid used as a ratio enables systems of different sizes to be readily compared. For particulate removal, the liquid-to-gas ratio is a function of the mechanical design of the system; while for gas absorption this ratio gives an indication of the difficulty of removing a pollutant. Most wet scrubbers used for particulate control operate with liquid-to-gas ratios in the range of 0.5 to 6 litres per actual m^3.

L/G ratio illustrates a number of points about the choice of wet scrubbers used for gas absorption. For example, because flue-gas desulfurization systems must deal with heavy particulate loadings, open, simple designs (such as venturi, spray chamber and moving bed) are used. Also, the liquid-to-gas ratio for the absorption process is higher than for particle removal and gas velocities are kept low to enhance the absorption process.

Solubility is a very important factor affecting the amount of a pollutant that can be absorbed. Solubility governs the amount of liquid required (liquid-to-gas ratio) and the necessary contact time. More soluble gases require less liquid. Also, more soluble gases will be absorbed faster.
A useful measure of the quantity of liquor being used by the scrubber system is the liquid-to-gas ratio which is normally abbreviated as l/m^3.

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This ratio is usually (but not always) defined as the total volume (in m3) of liquor entering the scrubber divided by the outlet gas flow rate (in m3/hr). The outlet gas flow rate is used as the basis of the parameter since this easier to measure than the inlet gas flow rate. The typical design of a MEHS scrubber is for example for Oxigen Environmental, we have a design of 20,000 m3/hr with a recirculating water flow of 120,000 l/hr. This would give a liquid to gas flow rate of 6.
As shown in the drawing, a recirculating liquor system must have some form of temporary liquor storage. The recirculation tank provides a good location for the addition of neutralising agents, bacteria, nutrients, etc. The monitoring of pH, Conductivity and other parameters can be achieved in recirculation liquor. The tank is also the site of the makeup water addition and purge from the system.

Because of the build-up of bacterial solids in the scrubbing liquor and the need to minimize the concentration of Nitrate from the bacterial action on Amines or Ammonia and Sulphates from the bacterial action on Hydrogen sulphide and Mercaptans, a portion of the recirculation liquor is often drawn off for disposal or further treatment. This purge stream usually consists of 2% to 5% of the total recirculation stream rate. In scrubber systems without a purge stream, all the liquor within the system is replaced on a regular basis. Depending on the frequency of replacement, the liquor quality varies considerably.

To maintain the desired recirculation flow rate, sufficient liquor is added to account for that removed in the purge stream and make up the liquor lost to evaporation and that lost with the wet sludge (if any).

This makeup stream is usually fresh process water, well water, or municipal water. The makeup stream can be added at a number of points in the scrubber system with the most common point of addition being the recirculation tank or pond.

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Alkaline material (Sodium hydroxide or sodium bicarbonate) is often added to the scrubber liquor circuit in order to maintain the pH in a range in which corrosion is not a problem. The process of oxidising nitrogen compounds removed from the air stream requires 4 mg of alkalinity for every 1 mg of Nitrogen oxidised to Nitrate. The rate of feed of the alkaline material is controlled by a pH meter within the scrubber system.

4.2 Pressure Drop as a performance Parameter

The static pressure drop of the gas stream passing through a biological wet scrubber is used extensively by both operators and inspectors to evaluate scrubber performance. In some cases, conclusions regarding adequacy of performance have been based solely on these data.

4.2.1 Definition of Pressure Drop

Pressure drop is the reduction in potential energy (through conversion to kinetic energy) of the gas stream as it passes from one point to another. It results from frictional losses on the ductwork and scrubber internal components, from acceleration of the gas and liquid streams, from the atomization of the liquor, and from any changes in elevation of the gas and liquid streams.

The scrubber pressure drop is simply the arithmetic difference between the static pressures of the gas stream at ·the inlet and at the outlet of the collector.

In order to properly define the pressure, drop, it is very important to specify the locations where the inlet and outlet measurements are made. A sketch of the system showing the scrubber, all major internal parts, and flow restrictions of the inlet and outlet ductwork is helpful in avoiding misinterpretation of the pressure drop value.

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4.2.2 Relationship Between Penetration and Pressure Drop

There is a useful relationship between the collection efficiency of a wet scrubber and the pressure drop of the gas stream passing through it. For this rea. son, operators have been using pressure drop as an indicator of scrubber performance for a long time.

In 1956, Kemack and Lapple proposed that penetration is a function of the total energy consumption within the scrubber, not just the energy loss represented by the gas phase pressure drop. This theory was expanded and stated in its present form by Semrau in 1960. Referred to as the Contact Power Theory, it has enjoyed broad acceptance by both operators and regulatory agencies.

Since much of the available data are presented in the Contact Power format, the basis of this theory is briefly examined.

According to the Contact Power Theory, scrubber efficiency is directly related to the total energy consumption of the system. The power can be expended by the gas stream, the liquid stream, by a mechanical rotor, or by a combination of all three. Other variables such as collector size, scrubber design characteristics, liquid-to-gas ratio liquor surface tension, and gas velocity are assumed to have no independent effect on the scrubber performance. Accordingly, it we can quantify the emissions from a specific wet scrubber system using only those parameters with an effect on the power input.

The Contact Power Theory has al so been used to compile industry-by- industry mass emission-contact power curves. In this section, the adequacy of these unit specific and the industry wide applications of the theory are evaluated.

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4.3 Factors Affecting Scrubber System Reliability

The performance of a scrubber system is dependent on the operating characteristics discussed above and on the integrity of the scrubber internals. Failure of these components can lead to extended downtime of the system or operation in temporary non-compliance. ·Both the operator and the regulatory agency inspector have an interest in minimizing these problems by identifying the emergence of factors which threaten scrubber components and ultimately degrade scrubber performance.

4.3.1 Corrosion and Erosion of Scrubber Shell

The susceptibility of a scrubber to erosion is a direct function of the gas velocities within the entry ductwork and the scrubber shell.

A regular purge will prevent high solids and checking the solids levels on a weekly basis will ensure that this does not happen. A rough check on the quantity and character of the suspended solids can be made by obtaining a sample of the liquor leaving the scrubber sump and observing the initial turbidity and the rate of settling.

Due to the absorption of corrosive material s such as ammonia, hydrogen sulphide, mercaptans, etc., corrosion of the scrubber shell and ancillary equipment is a common problem.

It is important to maintain the pH of the liquor well above the levels at which steel is attacked. A pH of 6 or greater is usually satisfactory. An appropriate pH is maintained using alkaline additives such as sodium limestone, sodium hydroxide or lime. The performance of the alkaline additive delivery system and the process control instrumentation are very important in minimizing short term low pH excursions. The operation of the pH monitor used to control the rate of additive injection will be checked on at least a daily basis unless long term operating experience justifies less frequent inspection. A portable pH meter or pH paper can be used for this check. The sample will be collected at the sump of the scrubber since this is often the point of minimum pH.
The recirculation rate is an important factor in determining the extent to which halogenated compounds are building up in the scrubbing liquor.

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One convenient means we use to monitor potential corrosion problems is to prepare small coupons (small circular samples) of the various materials used throughout the scrubber system. These are placed in racks which can be mounted at various locations in the scrubber. During every outage, these are visually inspected for pitting and cracking and are weighed for material loss. This information provides an early indication of developing corrosion problems.

4.3.2 Erosion and Pluggage of Spray Nozzles

Spray nozzles are extremely susceptible to erosion and pluggage problems due to the high velocities of the liquid stream and due to the suspended solids within the stream. The most common types of nozzles in use include the hollow cone and the full 'cone. The latter is particularly prone to pluggage due to the presence of an internal spinner vane. The vane is installed to achieve the full cone spray pattern which is necessary for distribution of liquor on a bio scrubber.

Damage to the nozzles can sometimes be determined by observing the spray angle while the nozzles are operating at normal line pressures.

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4.3.3 Fans

Fans can either be installed before or after the scrubber.
The principal, problems of fans on wet scrubber systems include fan erosion, fan wheel build-up, and bearing failure. Corrosion is al so a common problem. Both fan wheel erosion and fan wheel build-up will eventually result in increased vibration which is usually audibly and visually detectable. For systems, prone to this problem, vibration sensors are advisable, enabling a source to have the fan automatically tripped if the vibration reaches undesirable levels. If during a routine inspection of a scrubber system, excessive fan vibration is noticed, extreme caution and immediate action is necessary. Disintegrating fans can fling metal parts over a wide area.

Fan bearings will be inspected on a frequent basis for oil level, oil colour, oil temperature, and vibration. Bearings found to be inadequately lubricated may require a greater frequency of lubrication or the installation of a forced lubrication system. Excessive bearing wear may be caused by a higher than originally specified fan operating temperature or by misalignment of the bearing mountings.
Fan belts will be checked periodically for wear. At the time of installation, belts will be checked for proper tension. Loose belts can cause the entire scrubber collector system to malfunction. Out-of-line sheaves will destroy belts; uneven wear on grooves of sheaves and the surfaces of the belts indicates misalignment.

Fan vibration can sometimes be caused by air flow factors and, in these cases, can be eliminated by adjusting the inlet or outlet dampers, modifying the inlet or outlet dampers, modifying the inlet and/or outlet ductwork, or changing the sheaves. The latter will have a direct effect on the gas flow rate and will result in a change in the tip speed (which should never exceed the manufacturer's recommended rate).

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4.3.4 Pumps

The two types of pumps in service on wet scrubber systems are the centrifugal and positive displacement pumps. The centrifugal pump is the most common.
Accelerated wear of the pump impeller occurs at high suspended solids levels. As is the case with spray nozzles, the best way to minimize scrubber downtime due to pump mal functions, is to minimize the total quantity of suspended solids and especially the larger suspended particles (greater than 25 micrometres). A strainer ahead of the pump will improve the quality of liquor passing through and thereby minimize wear.

Another common problem with pumps is leakage through the packing glands; pumps must be repacked whenever necessary. This can be minimized through the use of double seals with a clean water, pressurizing line. All bearings on the pumps and the pump couplings will be lubricated periodically in accordance with the manufacturer's instructions.

4.3.5 Piping and Valves

All piping is subject to erosion, especially at elbows. The rate of erosion is a function of the flow velocity, the quantity of suspended solids, the particle size distribution of the suspended solids, and the presence of corrosive agents. The proper materials of construction must be selected in order to minimize this problem.

Valves are al so subject to erosion. Those which are operated in either a fully open or closed position are affected much less than those used in a partially open mode for flow throttling purposes.
In order to reduce pluggage of lines during outages, the piping will be completely drained. This requires that each line have a modest slope so that a pocket of liquid cannot remain after draining. The drain will be at the lowest point of each piping system. Draining is al so necessary to prevent the freezing of lines during outages.

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During routine inspections, one should be aware of the piping design with regard to drainage capability. If it appears inadequate, and the systems runs in a cyclic nature, occasional pluggage and/or freezing problems should not be anticipated as the temperature of the scrubber will not be reduced below 14°C. Periods of noncompliance can occur initially after start-up of the system and prior to the rectification of a piping freezing / pluggage problem. In such cases, the pump discharge pressure will be high, the nozzle pressure will below, and the gas exit temperature from the scrubber will be high. The gas phase pressure drop across the scrubber will below due to the lack of typical liquor flow rates.

4.3.6 Ducts

The most common problems with the ducts leading to a scrubber include dust build-up, erosion/abrasion, flex failure, and failure of expansion joints. The last three of these conditions result in air infiltration and consequently, a reduction in the quantity of gas pulled from the process equipment. The extent of air infiltration can be quantified by preparing an oxygen profile at various points along the duct from the source to the scrubber.
Dust build-up occurs in low gas velocity zones of the duct work. This an occur wherever the duct work is oversize for the effluent gas flow rate and during periods of operation at reduced process rates.

4.4 Operation and Maintenance Procedures

The basic operation and maintenance procedures for wet scrubber systems. Since there is considerable diversity in the design of Scrubber systems and in applications, there is no one set of operation and maintenance procedures which is adequate in every case. Instead, it is necessary to tailor the procedures to the specific site involved; this is an evolutionary process in which the initial procedures are modified in response to the specific operating problems experienced at the site.

The procedures presented in this section represent the initial operation and maintenance requirements for a wet scrubber system. For some systems, these procedures include steps which are unnecessary and for some systems, important maintenance items may not be included.

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4.4.1 Start-up and Shutdown Procedures

Proper start-up and shutdown procedures are important in preventing

(1) damage to the corrosion and abrasion resistant lining in the scrubber (if used),
(2) overheating of the fan motor, and
(3) damage to the pump impeller and motor.

Routine Start-up

Inspect piping and valves and open or close valves to permit proper flow of fluid, from the system to recycle tank, pumps, and return lines.
Inspect ductwork system to assure that all ductwork leading to the scrubber is intact and that damper blades move with damper control activation. Flow of exhaust gas to scrubber will not be initialled until liquid circuit has been fully started. Inspect and test instruments to be sure they are operating properly.

- Make sure that the unit is level.
- Turn on all electrical switches for control s and instruments.
- Fill system with scrubbing liquid by opening plant water lines to scrubber or aeration tank, al low it to fill to proper level, and then start recycle pump.
- add required bacteria and nutrient
- Open liquid line to top of the scrubber and adjust to proper flow.
- Open damper to direct exhaust gas flow to scrubber and start the fan.

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Prior to the start-up of a scrubber, a complete internal inspection will be conducted. A partial list of the items to inspect include: the condition of the spray nozzles; the condition of the supply lines to the scrubber; presence of internal deposits; presence of worn or eroded linings; presence of partially plugged or warped demisters; and presence of corrosion on any components. A check is made to visually confirm that the inlet liquor flow is sufficient to completely wet the scrubber to avoid any wet-dry interface problems.

During start-up, fan is started slowly to ensure protection of the fan and prevention of over pressurisation of the scrubber

After operating conditions have stabilized, a complete set of readings will be taken and compared against the baseline operating levels. It is advisable to conduct a routine evaluation, as discussed earlier, to confirm that the system is operating properly.

It may become necessary to adjust the liquid flow rates to maintain the recycle tank level. This requires balancing the water make-up rate, the purge rate, the sludge removal rate, and the recycle rate.
Routine shutdown
Turn off the fan using the VSD to turn the fan off
Continue pump operation and the pumps are switched to low flow all internal water sprays until the scrubber system has cool ed.
If the system will be exposed to cold weather conditions, the water heater will be checked and the temperature will be maintained at a minimum of 14oC.

The system will be purged depending on bacteria levels and the concentration of

- Ammonia
- pH
- Conductivity
- Sulphate
- Dissolved Oxygen
- COD of filtered sample

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An internal inspection will be conducted to determine if there are eroded or plugged nozzles, damaged demisters, or other problems which warrant maintenance attention prior to start-up.
All deposits which could accelerate corrosion of the scrubber will be washed out.
During shutdown, it is particularly important not to expose the scrubber system to any high temperature excursions. For this reason, the pumps and internal sprays will be operated until well after the scrubber has been isolated from the process. It is al so important to continue the bicarbonate or alkali additions to the system long enough to prevent low pH excursions after shutdown.

4.5 Routine Maintenance

This section presents general information concerning the operation and maintenance of the scrubber components.

4.5.1 Fans

The types of operating problems experienced with fans depend on whether the fan unit is before or after the scrubber. In this case the fan is upstream of the scrubber, it is vulnerable to the build-up of solids and corrosion.

The fan will be visually inspected on a regular basis. A typical frequency is monthly, although in some applications weekly inspection is warranted. If the fan vibration increases noticeably, the fan wheel will be inspected as soon as possible.

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Fan bearings require frequent inspection; they will be checked for oil level, oil colour, and operating temperature. Bearing wear can cause vibration problems. The bearing housing and mountings will be checked on a weekly basis.

On belt-driven fans, the belt tension will be checked on a weekly basis. Loose belts are prone to a distinctive squealing which suggests an unintentional reduction of several hundred R.P.M. and a decrease in the gas flow delivered by the fan. The rotational speed of the fan can be checked using a manual tachometer or a strobotachometer.

4.5.2 Pumps

The most common pump related problems include erosion of the impellers, erosion and chipping of the liner, and leakage of the pump glands. All pump bearings will be lubricated regularly and inspected on a frequent basis. The actual schedule depends somewhat on the severity of the application, with more frequent attention required if the total solids content of the liquor is high and/or the pH is low. High wear pump parts will be kept on hand since delivery times are sometimes long. The proposed scrubber has a duty/standby pump arrangement

4.5.3 Valves

The operational status of all valves will be checked on at least a weekly basis. They are vulnerable to sticking, pluggage, and erosion.

4.5.4 Nozzles

The frequency of nozzle inspection varies with the type of scrubber and the quantity of suspended solids in the recirculation liquor. If the suspended solids level is greater than several percent, erosion and/or pluggage are probable. As an initial check, the nozzle operating pressures will be recorded daily. An increase or decrease in the operating pressure without a corresponding change in the liquor flow rate strongly suggests that the nozzle condition has deteriorated.

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If pluggage is suspected due to an increase in the nozzle pressure, the nozzles, will be cleaned and then the pressure rechecked.

When the scrubber is down, nozzle conditions can be evaluated by an internal inspection or by observing the spray angle while the liquor recirculation system is operating. We will supply a set of replacement nozzles when they are used in severe applications.

4.5.5 Aeration or Recirculation Tank

The gradual accumulation of sludge at the bottom of the recirculation tank is undesirable. Whenever the system is down for maintenance, the quantity of the deposits will be checked either by draining the system. The system has an aeration system installed to prevent any accumulation of solids in the scrubber.

The large scrubber has a recirculation pump to transfer scrubbing liquid to the aeration tank. The aeration tank and the scrubber will have aeration units installed. The aeration system will be checked on at least a monthly basis.

4.5.6 Dampers

It is advisable to exercise all, dampers at least once a month to confirm that they have not "frozen" in the open position. The damper drive mechanism and bearings will be lubricated in accordance with the manufacturers specifications.

If a purge air blower is necessary to keep the damper seating surfaces clean, this will be checked daily to ensure that the blower is operating.

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4.5.7 Instruments

Instrumentation systems are particularly prone to operating problems and therefore will be checked daily. The status of a pH control system will be checked using either a portable pH meter. It is important to take these measurements at approximately the same location as the pH probe of the instrumentation system, since pH can vary substantially throughout a biological scrubber system. Deviations from the baseline level and/or difference in the two readings suggest either a problem with the installed pH meter or failure of the alkaline additive delivery system. The most common pH meter problems are scaling. If the probe and breakage of the probe.

4.5.8 Motors

The motor bearings and the motor starting switches will be lubricated on a routine basis. The manufacturers ' guidelines will be followed. All contacts and other components will be inspected at least once per year.

4.5.9 Demisters

All chevron and mesh 'pad type demisters will be inspected on at least a weekly basis to prevent excessive solids build-up. Gradual scaling of the demister will lead to an increase in local gas velocities through, the open areas and this in turn will result in entrainment. Presence of solids on the demister can be determined by using a high intensity flashlight. The condition of the demister flush nozzles will be evaluated at the same time. Any deposits will be removed as soon as possible using either the existing spray system or an external hose.

4.6 Record and Report System

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A comprehensive record keeping system addressing the operation, maintenance, and performance of the biological scrubbers at a particular source can be of valuable assistance to both the control agency inspector and the plant manager. The information contained in such a system can provide the inspector with a preliminary indication of the overall condition and performance of the control equipment. It can also direct the inspector's attention to specific problem areas that may require special attention during the inspection.

The records will allow the operator to ascertain the effectiveness of his operation and maintenance program, as well as determine the extent of deterioration of control system components. The latter benefit can, in a well-maintained recordkeeping system, minimize the time that the process and control equipment is out of service due to repairs. In addition, significant cost savings can be realized by diagnosing and repairing major equipment failures before they occur.

For either the inspector or the plant manager to benefit from a recordkeeping and report program, there are several important aspects of the use of the program that will be realized. For the program to be effective, recordkeeping will be recorded daily. Some advance warning is usually given prior to equipment failure; however, the time between the initial indication of a problem and the resultant failure can be very short. The earlier a problem is discovered and rectified, the greater the reduction in repair time and cost.

A recordkeeping program will never have considered an entirely independent system on which decisions are based. The data contained in the records can, for many reasons, be inaccurate or misleading. The major cause of such problems is that the data are obtained from faulty instruments.

4.6.1 Scrubber Operation Record Elements

There are certain data common to all scrubber, which will be included in any scrubber recordkeeping system. These data elements are listed in Table 4-1. These routinely measured parameter values, compared to the baseline values obtained during a compliance test (or the initial performance evaluation test), can provide a very good indication of the performance of a scrubber. In addition,

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examination of these parameters over time can aid in the detection of component deterioration in the scrubber system.

It is recommended that whenever possible, th scrubber operation data be obtained using portable instruments. Each sample point through which a measurement is made will be cleaned prior to every measurement. Because the plugging of sample points occurs so frequently, cleaning of the sample points is important to ensure that a partially or completely plugged hole does not result in an erroneous measurement. This, in fact, is one of the reasons that portable instruments will be used rather than fixed gauges. Too often a reading from a fixed gauge will be recorded without checks to see that the gauge's tap hole is not plugged. Regardless of whether the instruments are fixed or portable each must be calibrated at intervals which are at least as frequent as the manufacturers' specifications.

TABLE 4-1. Scrubber Operational Data

Inlet Gas Temperature
Outlet Gas Temperature
Total Static Pressure Drop
Static Pressure Drop at the Mist Eliminator
Water Makeup Rate
Fan Current
Fan RPM
Pump Discharge Pressure
Liquor Solids Concentration
Recycle Bleed Rate
Chemical Addition Rate
Liquor pH
Liquor Ammonia Conc
Liquor Alkalinity Conc
Liquor Sulphate Conc
Liquor Total Bacterial Count
Liquor Dissolved Oxygen Conc
Inlet Ammonia, Amines, H2S & Mercaptans
Outlet Ammonia, Amines, H2S & Mercaptans

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The measurement of the inlet and outlet gas temperatures can provide an indication of problems in the heat exchange mechanics of the scrubber. For instance, abnormally high outlet gas temperatures suggest that the scrubber liquor flow is below normal or the gas flow rate is well above design value. In either case, the liquor-gas contact within the scrubber is less than optimum, which results in a lower particulate removal efficiency. A low outlet gas temperature can indicate allow gas flow rate through the scrubber or an in leakage of ambient air.

Pressure drop measurements can confirm problem areas identified by the temperature measurements. They can also indicate other potential problems. Low pressure drops across the scrubber are indicative of little or no liquor flow to the scrubber and low gas flow rates through the scrubber.

A high pressure drop on a scrubber is usually the result of the bed becoming plugged. Pressure drop increases are associated with unexpected increases in gas or liquor flow rate.

A determination of the gas flow rate through the scrubber can be made using information collected from fan measurements. It is very important to know if the scrubber is operating in the flow rate range for which it was designed. If the necessary baseline data were collected during a previous performance test, the fan current can be used to estimate the present flow rate.

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The measurement of the scrubbing liquor pH can provide insight into operational problems, as well as indicate potential damage to the scrubber structure. A low pH reading usually indicates loss of additive feed or low liquor flow rates. Since these rate measurements are included in the routinely collected scrubber data, the cause of the problem can be easily determined. Low pH measurements will serve as a warning that, corrosion damage to the scrubber shell may have occurred, and thus, a visual, internal inspection of the scrubber will be conducted.

Low nozzle operating pressure is usually a result of low liquor flow rate or erosion of the nozzles. If nozzle erosion has occurred, the droplet size emitted by the nozzles will be larger than the design size. Also, low liquor flow will produce altered droplet size distributions. Either situation will result in decreased collection efficiency. Since the liquor flow rate is a routinely measured parameter, an increase in the flow reading will prompt a visual inspection of the nozzles for erosion; at this time, the valves will also be examined for erosion.

A decrease in the flow can indicate pump impeller wear or liquor line pluggage. The recycle bleed rate measurements can show bleed line pluggage when the flow is reduced and valve wear when the flow increases.

The various combinations of pump motor current and discharge pressure can be used to identify several probable problems. For instance, a decrease in both water pressure and amperage draw can mean that there are nozzles missing, significant pump wear, or suction line plugging. Other combinations suggest nozzle or spray bar plugging and manifold or spray bar leakage due to holes. The pump motor current can also be used to determine if a decrease in scrubber liquid flow is caused by an equipment maintenance problem such as a plugged line, by a worn pump impeller, or in fact, may only be a result of an improperly calibrated flow meter.

The remaining scrubber operation data which will be monitored are liquor solids concentration and chemical addition rates. Monitoring the solids concentration can ensure that the desired collection efficiency is maintained and scaling is minimized. It also helps reduce abrasion in the liquor contact pints throughout the piping and scrubber system. In scrubbers, which use chemical additives to control the liquor pH or the concentration of dissolved solids, measurement of the rate of addition is important in reducing the problems created by corrosion and scaling.

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4.6.2 Process Record Elements

In addition to the scrubber data, there are certain process data that will be routinely recorded. These data are shown in Table 4-2.
Since baseline scrubber data are used as standards on which to judge subsequently measured scrubber parameters, it is equally important to know how the daily process data compare to the baseline values. Process variations in feed types and rates can affect the collection efficiency of scrubbers by altering the character of the inlet particulate gas stream. Of particular importance in this regard is the particle size distribution at the inlet, a parameter on which greatly affects scrubber performance.

The ancillary equipment in a scrubber system is also often responsible for many of the operational problems. This equipment includes the fans, pumps, motors, ductwork, piping, valves, clarifiers, and instrumentation. Failure of any of these components can be disastrous not only to the performance, but also to the longevity of the entire scrubber system.

In order to facilitate the recording of the scrubber parameters previously discussed, a suggested record format is presented in Table 4-2. The daily, monthly, and semi -annual performance logs for the scrubber's ancillary equipment are provided in Tables 4.3 and 4.4 respectively. The operation and maintenance record system, space is provided to explain any corrective actions which were initiated to resolve any abnormal observed values. It is highly recommended that all data be collected on a routine basis and compiled in a notebook used only for recordkeeping purposes.

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TABLE 4-2. Daily Scrubber Operational Data Log

Parameter			Monday		Tuesday		Wednesday		Thursday		Friday		Comment
		Limit	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	
Inlet Gas Temperature	°C	<60											
Outlet Gas Temperature	°C	<35											
Total Static Pressure Drop	Pa	<2000											
Scrubber Pressure Drop	Pa	<1300											
Static Pressure at Mist Eliminator	Pa	<400											
Liquor Recirculation Rate	M3/hr	Varies											
Liquor pH	pH Units	8.0 – 9.0											
Makeup Rate	litres/hr	Varies											
Nozzle Pressure Purge Rate	Pa	Varies											
Liquor Alkalinity	mg/l $CaCO_3$	>900											
Nutrient Addition	mls/day	N/A											
MEHS NR Addition Rate	mls/day	N/A											
MEHS AB Addition Rate	mls/day	N/A											
Bicarbonate Addition Rate	mls/day	N/A											
Liquor Temperature	°C	>14											
Scrubbing Solution Total Bacterial Count	TBC/ml	< 10_5											
Liquor Dissolved Oxygen	mg/l – O_2	>4											
Liquor Ammonia	mg/l - N	< 20											
Inlet Amines & Ammonia	ppm	< 100											
Inlet Mercaptans & H_2S	ppm	< 50											
Outlet Amines & Ammonia	ppm	< 5											
Outlet Mercaptans & H_2S	ppm	< 2											

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TABLE 4.3. Weekly Scrubber Ancillary Equipment Performance Log

Equipment	Status	Comment
FAN		
Vibration on Fan		
Fan Motor Bearings Lubrication		
Fan Pump bearing		
VSD check		
PUMP		
Pump motor bearing		
Lubrication of pump		
VSD check		
Liquor heater check		
Aeration system Check		
Blower check		
Dosing Pumps Check		
pH Probe Check		

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TABLE 4.4. Annual Scrubber Ancillary Equipment Performance Log

Equipment	Status	Comment
DUCT WORK		
Leakage·		
Excessive Flexing		
DAMPERS		
Operation		
Alignment		
NOZZLES		
Nozzle Plugging		
Nozzle Wear		
PIPES		
Plugging		
Leaking		
PRESSURE GAUGES		
Check operation		
MAIN BODY OF SCRUBBER		
Material Feed Build-up		
Abrasion / Corrosion		
FLOW METERS		
Accuracy		

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5.0 Operations – Standard Operating Procedures

Standard operating procedures are established to ensure that the Odour control system continues to operate effectively during the service life of the system, under all normal and abnormal operating conditions.
Standard operating procedures set out the steps to be followed in operating and maintaining the plant, including the following aspects:

- Daily check (week days) of Odour treatment unit conditions including manual test of discharge odour concentration at entry to and exit from treatment units;
- Daily check (week days) of negative pressures under covers;
- Procedures for responding to treatment unit alarms;
- Procedures for maintaining treatment units;
- Procedures for maintaining and removing mechanical equipment with minimal release of odour;
- Monthly reporting on performance of odour control system.
- Plan maintenance to avoid long shut-downs of equipment. Advise regulatory authority and residents of major maintenance on the plant when the plant will be out of operation.

5.1 Operations – Replacement of Scrubber Media

Bio-scrubber media is considered to have a service life of 30 years or more. Thus, when media needs to be replaced, it will be done one vessel at a time. During such periods, there will be no standby unit, so media replacement should be programmed where feasible for winter when odour inputs to the plant are lower.

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5.2 Monitoring – Regular odour Monitoring

The following odour monitoring will be carried out:
Manual verification of VOC;'s, analysis of VOC species, Ammonia, Amines, Hydrogen Sulphide and Mercaptans each fortnight at the entry to the treatment units and the entry to the stack.

5.3 Contingency Plans for Upsets or Maintenance

The target will be to keep the odour treatment systems operating effectively for >95 % of the year (excluding external events such as power failures). This should be seen as a goal and not as a mandatory target.

As noted above, replacement of media is a relatively infrequent event. From experience with odour control systems at other plants, the major types of upsets are:

- Power failures;
- Failures of mechanical equipment, such as dosing pumps; Failures of the computer control system.

The most common types of remedial actions are:

- Re-start following power or equipment failure; Replace equipment with standby equipment;
- Bypass some unit and operate remaining odour treatment units at a slightly lower rate with remaining odour treatment units.

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A period with high odour levels is taken to occur if there are 1 or more exceedances the unit. The protocol to follow in the contingency plan is set out below.

5.4 Reporting and Re-design as Required

An annual report will be prepared on the performance of the Bio-Scrubber, including the odour control system.

There will be an Odour audit every two years to establish the effectiveness of the Odour control system, the performance of the treatment units, the level of Odour coming from the process, response of the public (as reported by odour complaints or community surveys) and any remedial actions required.

The annual report and Odour audits will provide the information needed to select and optimise the design of future Odour control technologies in later stages of the Oxigen Environmental.

Bio-scrubber Aspect	Requirement
Design	
A Ducting	
A1	All selected buildings to be fully sealed with ducts to remove foul air
A2	Air extraction rates for building to meet best practice guidelines (3 air changes/hour)
A3	Design negative pressure of – 15 Pa.
A4	Sufficient suction on building to avoid dead zones.
A5	Measurement and monitoring points and equipment to be provided on ducts and before and after Odour treatment unit. Standard measurement station just before stack.

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B Bio-Scrubber	
B 1	All air extracted to be treated, with no bypassing
B 2	Redundancy to be provided, with a target availability for the Odour treatment unit system of >95% of the year
B 3	Major maintenance to be carried out during the winter
B 4	Measurement of Odour before and after Odour treatment units
B 5	Measurement and monitoring points installed on ducts for manual sampling, and flow measurement and balancing
B 6	Allow two weeks acclimatisation period for any bio-scrubbers with supply of water and nutrients
Commissioning	
C Checking performance	
C1	Smoke tests under covers to confirm satisfactory degree of sealing
C2	Measurement of negative pressure and velocity at air intakes to confirm they meet design limits
C3	Measurement of duct velocities to check satisfactory flow balance and capture of air from covered tanks
C4	Validation of all measurement equipment
C5	Odour sampling with tests will be undertaken.
C6	Measurement of Odour levels in ducts

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Bio-scrubber Aspect	Requirement
D Verification of performance	
D1	Verification of Odour capture
D2	Verification of Odour treatment unit performance with regular sampling thereafter
D3	Reports from Odour monitors on the boundary of the buffer zone during the commissioning stage, to confirm that Odour is not detectible
D4	Optional – Odour modelling using the actual Odour levels measured during the commissioning stage
Operations	
E Operations and maintenance	
E1	For operation and maintenance of covered tanks, duct and fan systems and Odour treatment unit systems, include: • Weekly checks of negative pressure; • Check for bacterial levels on the Bio-Scrubber; • maintaining and removing mechanical equipment with minimal release of Odours; • Monthly reporting on performance of Odours control system. • Plan maintenance to avoid long shut-downs of equipment. • Advise regulatory authority and local residents of major maintenance on the plant when the plant will be out of operation.
E2	Replace bio-scrubber media when needed > 20 years. Media replacement should be programmed where feasible for winter when odour inputs to the plant are lower

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Aspect to be addressed	Required Procedure
F Monitoring	
F1	Regular monitoring at the entry to all bio-scrubbers
F2	Regular monitoring at the discharge from the bio-scrubber
F3	Collect Odour samples at five nominated sampling points monthly for six months of operation after commissioning and regularly thereafter.
Contingency Plan	
H Contingency plan	
H1	In the event of upsets or major maintenance. The target will be to keep the Odour treatment systems operating effectively for >95% of the year
H2	MEHS will provide contingency cover to investigate and resolve events and periods with high Odour levels.
H3	MEHS will prepare an annual report on the performance of the plant, including the Odour control system
H4	MEHS will conduct an Odour audit every year to establish the effectiveness of the Odour control system, the performance of Odour treatment units, the level of Odour coming from the bio-scrubber, and any remedial actions required

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Appendix 1 Design Calculations for Oxigen Environmental

Option 1 20,000 m³/hr Bio-Scrubber

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SCRUBBER DESIGN (PACKED COLUMN)

Prepared by :	Trevor Montgomery	**Column Tag No.**	:	MK001
Checked by :	Trevor Montgomery	**Job No.**	:	17~5
Date :	Jan-17	**Client**	:	Oxigen Envn
		Project	:	Dundalk

Input Data

Stream : Waste Facility Odours

Packing type	=	Intallox Saddles			
Packing size	=	53	mm		
Packing MOC	=	PP			
Gas pr. Drop / m bed	=	15	mmWC / m packing height	=	147.09975 $(N/m^2)/m$
Total packing height	=	5	m (including all packed beds)		

Gas / Vapour Properties

Gas / Air flow rate	=	15,504	kg/h	OR		20,000 m^3/h
	=	4.3066	kg/s		=	5.555556 m^3/s
Gas pressure at entry	=	1.0000	atm			
Gas temperature at entry	=	25.00	^oC		=	298.00 ^oK
Gas / Air mol weight	=	29				

Component to be scrubbed

Component Name	=	Ammonia		
Component flow rate	=	70	Kg/h	
% comp. in air/gas	=	6	% (v/v)	(presumed) / ~~(given by client) / (by process cal.)~~
Molecular weight of comp.	=	36.5		

Liquid / Scrubbing media Properties

Scrubbing media	=	Water					
Liquid flow rate, L	=	120,000	kg/h				
	=	33.3333	kg/s				
Liquid Density, ρ_L	=	1100	kg/m^3	Conversion :			
Liquid Viscosity, μ_L	=	0.0035000	Ns/m^2	3.5	C_p	=	0.00350000 Ns/m^2

Packing factor, F_p	=	21	m^{-1}
Charac. Packing Factor, C_f	=	33	**Ref. Table 6.3, Characterstics of Random packings**
Conversion factor, J	=	1.0	factor for adequate liquid distribution & irrigation across the bed

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Calculations

TO CALCULATE COLUMN DIAMETER

Since larger flow quantities are at the bottom for an absorber, the diameter will be chosen to accommodate the bottom conditions.

To calculate Gas density

Avg. molecular weight = 29.45 Kg / Kmol

If gas flow rate is given in kg/h	If gas flow rate is given in m3/h
Gas in = 0.14623539 Kmol/s (kmol = mass / mol wt)	Gas in = $(m^3/s) \times \left(\frac{273}{T \text{ in kelvin}}\right) \times \left(\frac{\text{pr. in atm}}{1.0 \text{ atm}}\right) \times \left(\frac{1}{22.4}\right)$
= $(kmol/s) \times \left(\frac{T \text{ in kelvin}}{273}\right) \times \left(\frac{1.0 \text{ atm}}{\text{pr. In atm}}\right) \times \left(\frac{22.4}{1}\right)$	= 0.227209 Kmol/s
= 3.575643 m^3/s	= 6.69131 Kg/s (mass = mol wt x kmol)

Select vol. flow rate and mass flow rate from above,

Selected mass flow rate = 0.277778 Kg/s

Selected vol. Flow rate = 0.234499 m^3/s

Selected molar flow rate = 0.009432 Kmol/s

Therefore, gas density = 1.1846 Kg/m^3 (mass flow rate / vol. Flow rate)

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To find L', G' and Tower c/s area

Assuming essentially complete absorbtion,

Component removed = 0.0207 Kg/s (molar flow rate x % comp. x mol. Wt.)

Liquid leaving = 33.3540 Kg/s (Inlet liquid flow rate + comp. Removed)

$\left(\frac{\rho_G}{\rho_L}\right)^{0.5}$ = 3.94033

Using **3.94033** as ordinate, **Refer fig.6.34** using a gas pressure drop **147.09975** $(N/m^2)/m$

$\frac{G'^2 C_f \mu_L^{0.1} J}{\rho_G(\rho_L - \rho_G) g_c}$ = 0.04 (from graph)

Therefore, G' = $\left(\frac{0.04\ \rho_G(\rho_L - \rho_G) g_c}{C_f\ \mu_L^{0.1} J}\right)^{0.5}$

= 1.6665 $Kg / m^2.s$

Tower c/s area = 0.1667 m^2 (c/s area = mass flow rate / G')

Tower diameter = 0.4607 m = 460.7 mm

= 3000 mm

Corresponding c/s area = 7.0686 m^2

TO ESTIMATE POWER REQUIREMENT

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Efficiency of fan / blower = 60 % assumed / ~~given~~

To calculate pressure drop

Pressure drop for irrigated packing = 735.50 N/m^2 (pressure drop per m packing x total ht. of packing)

For dry packing,

O/L Gas flow rate, G' = 0.0364 $Kg / m^2.s$ (Gas inlet flow rate - Component removed) / c/s area

O/L Gas pressure = 100589.5 N/m^2 (subtracting pressure drop across packing)

Gas density, σ_G = $\left(\frac{\text{gas mol wt.}}{22.41 m3/Kmol}\right) \times \left(\frac{273}{\text{T in kelvin}}\right) \times \left(\frac{\text{gas o/l pr.}}{101330}\right)$

= 1.1768 Kg/m^3

C_D = 96.7 **Ref. Table 6.3, Characterstics of Random packings**

$$\frac{\text{Delta P}}{Z} = C_D \left(\frac{G'^2}{\sigma_G}\right)$$

= 0.11 N/m^2

Pressure drop for packing = 735.61 N/m^2 (irrigated packing + dry packing)

Pressure drop for internals = 200 mmWC (packing supports and liquid distributors)

= 1961.33 N/m^2

Gas velocity = 7.5 m/s

Inlet expansion & outlet contraction losses = 1.5 x Velocity heads = 1.5 x (V^2 / 2g)

= 42.19 N m / Kg

= 49.97 N/m^2 (divide by density)

Total pressure drop = 2746.91 N/m^2 (packing + internals + losses)

Fan power output = $\frac{\text{pressure drop}, N/m^2 \times \text{(gas in - component removed) Kg/s}}{\text{O/L gas density}, Kg/m^3}$

= 600.16 N .m / s

= 0.60 kW

Power for fan motor = 1.00 kW (fan power output / motor efficiency)

= 1.34 hp

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COLUMN DIAMETER / HYDRAULIC CHECK

Liq.-Vap. Flow factor, F_{LV} = $(L / V) \times \sqrt{(\rho_V / \rho_L)}$

= **3.9379**

Design for an initial pressure drop of **15** mm H2O /m packing

From K_4 v/s F_{LV},

K_4 = 0.85

K_4 at flooding = 6.50

Trial % flooding = $\left(\sqrt{(K_4 / K_4 \text{ at flooding})}\right) \times 100$

= **36.1620**

Gas mass flow rate, V_m = $\left[\frac{K_4 \cdot \rho_V (\rho_L - \rho_V)}{13.1\, F_p (\mu_L / \rho_L)^{0.1}}\right]^{(1/2)}$

= **3.7763** $kg/m^2.s$

Trial column c/s area (Trial A_s) = V / V_m

= **0.0736** m^2

Trial column dia., D = **0.3060** m $D = \sqrt{(4/pi) \times \text{Trial } A_s}$

Round off 'D' to nearest standard size

Therefore, D = 3.000 m

Column C/S area, A_s = **7.0686** m^2 $A_s = (pi/4) \times D^2$

% flooding = **0.3763**   % flooding = Trial % flooding x (Trial A_s / A_s)

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Conclusion

Generally packed towers are designed for 50% -- 85% flooding.

If flooding is to be reduced,

(i) Select larger packing size and repeat the above steps.

OR

(ii) Increase the column diameter and repeat the above steps.

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HETP PREDICTION

Norton's Correlation : **ln HETP = n - 0.187 ln σ + 0.213 ln μ**

Applicable when,
liquid phase surface tension > 4 dyne/cm & < 36 dyne/cm
liquid viscosity > 0.08 cP & < 0.83 cP

Conversion :
0.018 N/m = 18 dyne/cm

Input Data

Liquid-phase
Surface Tension, σ = 20 dyne/cm

Norton's Correlation Applicable

Liquid Viscosity = 3.5 cP

Norton's Correlation NOT applicable

n = 1.13080

Calculation

ln HETP = 0.837437

HETP = 2.310437 ft
= 0.704221 m

For separations, less than 15 theoritical stages, a 20% design safety factor can be applied.

Considering 20% safety factor,
HETP = 0.845065 m

For separations, requiring 15 to 25 theoritical stages, a 15% design safety factor can be applied.

Considering 15% safety factor,
HETP = 0.809854 m

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COLUMN MEDIA VOLUME

Loading Rate	120.0	m3/m2/hr
Require Retention Time	6.0	Seconds
Volume of Media	33.333	volume of media

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Appendix 2 Design Calculations for Oxigen Environmental

Option 2 35,000 m^3/hr Bio-Scrubber

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SCRUBBER DESIGN (PACKED COLUMN)

Prepared by :	Trevor Montgomery
Checked by :	Trevor Montgomery
Date :	Jan-17

Column Tag No.	:	MK002
Job No.	:	17~5
Client	:	Oxigen Envn
Project	:	Dundalk

Input Data

Stream : Waste Facility Odours

Packing type	=	Intallox Saddles				
Packing size	=	53	mm			
Packing MOC	=	PP				
Gas pr. Drop / m bed	=	75	mmWC / m packing height	=	735.49875	$(N/m^2)/m$
Total packing height	=	7	m (including all packed beds)			

Gas / Vapour Properties

Gas / Air flow rate	=	27,132	kg/h	OR		35,000	m^3/h
	=	7.5366	kg/s		=	9.722222	m^3/s
Gas pressure at entry	=	1.0000	atm				
Gas temperature at entry	=	25.00	^oC		=	298.00	^oK
Gas / Air mol weight	=	29					

Component to be scrubbed

Component Name	=	Ammonia		
Component flow rate	=	70	Kg/h	
% comp. in air/gas	=	6	% (v/v)	(presumed) / ~~(given by client) / (by process cal.)~~
Molecular weight of comp.	=	36.5		

Liquid / Scrubbing media Properties

Scrubbing media	=	Water					
Liquid flow rate, L	=	200,000	kg/h				
	=	55.5556	kg/s				
Liquid Density, σ_L	=	1100	kg/m^3	Conversion :			
Liquid Viscosity, μ_L	=	0.0035000	Ns/m^2	3.5 C_p	=	0.00350000	Ns/m^2

Packing factor, F_p	=	21	m^{-1}
Charac. Packing Factor, C_f	=	33	**Ref. Table 6.3, Characterstics of Random packings**
Conversion factor, J	=	1.0	factor for adequate liquid distribution & irrigation across the bed

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Calculations

TO CALCULATE COLUMN DIAMETER

Since larger flow quantities are at the bottom for an absorber, the diameter will be chosen to accommodate the bottom conditions.

To calculate Gas density

Avg. molecular weight = 29.45 Kg / Kmol

If gas flow rate is given in kg/h	If gas flow rate is given in m3/h
Gas in = 0.25591193 Kmol/s (kmol = mass / mol wt) = (kmol/s) x (T in kelvin / 273) x (1.0 atm / pr. In atm) x (22.4 / 1) = 6.257375 m^3/s	Gas in = (m^3/s) x (273 / T in kelvin) x (pr. in atm / 1.0 atm) x (1 / 22.4) = 0.397616 Kmol/s = 11.70979 Kg/s (mass = mol wt x kmol)

Select vol. flow rate and mass flow rate from above,

Selected mass flow rate = 0.277778 Kg/s

Selected vol. Flow rate = 0.234499 m^3/s

Selected molar flow rate = 0.009432 Kmol/s

Therefore, gas density = 1.1846 Kg/m^3 (mass flow rate / vol. Flow rate)

To find L', G' and Tower c/s area

Assuming essentially complete absorbtion,

Component removed = 0.0207 Kg/s (molar flow rate x % comp. x mol. Wt.)

Liquid leaving = 55.5762 Kg/s (Inlet liquid flow rate + comp. Removed)

$$\frac{L'}{G'}\left(\frac{\rho_G}{\rho_L}\right)^{0.5} = 6.56558$$

Using **6.56558** as ordinate, **Refer fig.6.34** using a gas pressure drop **735.49875** $(N/m^2)/m$

$$\frac{G'^2 C_f \mu_L^{0.1} J}{\rho_G(\rho_L - \rho_G) g_c} = 0.04 \text{ (from graph)}$$

$$\text{Therefore, } G' = \left(\frac{0.04\, \rho_G(\rho_L - \rho_G) g_c}{C_f \mu_L^{0.1} J}\right)^{0.5}$$

= 1.6665 $Kg / m^2.s$

Tower c/s area = 0.1667 m^2 (c/s area = mass flow rate / G')

Tower diameter = 0.4607 m = 460.7 mm

= 3000 mm

Corresponding c/s area = 7.0686 m^2

TO ESTIMATE POWER REQUIREMENT

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Efficiency of fan / blower = 60 % assumed / ~~given~~

To calculate pressure drop

Pressure drop for irrigated packing = 5148.49 N/m^2 (pressure drop per m packing x total ht. of packing)

For dry packing,

O/L Gas flow rate, G' = 0.0364 $Kg / m^2.s$ (Gas inlet flow rate - Component removed) / c/s area

O/L Gas pressure = 96176.51 N/m^2 (subtracting pressure drop across packing)

Gas density, σ_G $= \left(\frac{\text{gas mol wt.}}{22.41\text{m3/Kmol}}\right) x \left(\frac{273}{\text{T in kelvin}}\right) x \left(\frac{\text{gas o/l pr.}}{101330}\right)$

= 1.1252 Kg/m^3

C_D = 96.7 **Ref. Table 6.3, Characterstics of Random packings**

$$\frac{\text{Delta P}}{Z} = C_D \left(\frac{G'^2}{\sigma_G}\right)$$

= 0.11 N/m^2

Pressure drop for packing = 5148.60 N/m^2 (irrigated packing + dry packing)

Pressure drop for internals = 200 mmWC (packing supports and liquid distributors)

= 1961.33 N/m^2

Gas velocity = 7.5 m/s

Inlet expansion & outlet contraction losses = 1.5 x Velocity heads = 1.5 x (V^2 / 2g)

= 42.19 N m / Kg

= 49.97 N/m^2 (divide by density)

Total pressure drop = 7159.91 N/m^2 (packing + internals + losses)

Fan power output $= \frac{\text{pressure drop},N/m^2 \text{ x (gas in - component removed) Kg/s}}{\text{O/L gas density, } Kg/m^3}$

= 1636.11 N .m / s

= 1.64 kW

Power for fan motor = 2.73 kW (fan power output / motor efficiency)

= 3.66 hp

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COLUMN DIAMETER / HYDRAULIC CHECK

Liq.-Vap. Flow factor, F_{LV} = $(L / V) \times \sqrt{(\rho_V / \rho_L)}$

= 6.5631

Design for an initial pressure drop of **75** mm H2O /m packing

From K_4 v/s F_{LV},

K_4 = 0.85

K_4 at flooding = 6.50

Trial % flooding = $\left(\sqrt{(K_4 / K_4 \text{ at flooding})}\right) \times 100$

= 36.1620

Gas mass flow rate, V_m = $\left[\dfrac{K_4 \cdot \rho_V (\rho_L - \rho_V)}{13.1\, F_p (\mu_L / \rho_L)^{0.1}}\right]^{(1/2)}$

= 3.7763 $kg/m^2.s$

Trial column c/s area (Trial A_s) = V / V_m

= 0.0736 m^2

Trial column dia., D = 0.3060 m $D = \sqrt{(4/pi) \times \text{Trial } A_s}$

Round off 'D' to nearest standard size

Therefore, D = 3.000 m

Column C/S area, A_s = 7.0686 m^2 $A_s = (pi/4) \times D^2$

% flooding = 0.3763 % flooding = Trial % flooding x (Trial A_s / A_s)

Conclusion

Generally packed towers are designed for 50% -- 85% flooding.

If flooding is to be reduced,

(i) Select larger packing size and repeat the above steps.

OR

(ii) Increase the column diameter and repeat the above steps.

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HETP PREDICTION

Norton's Correlation : **ln HETP = n - 0.187 ln σ + 0.213 ln μ**

Applicable when,
liquid phase surface tension > 4 dyne/cm & < 36 dyne/cm
liquid viscosity > 0.08 cP & < 0.83 cP

Conversion :
0.018 N/m = 18 dyne/cm

Input Data

Liquid-phase
Surface Tension, σ = 20 dyne/cm

Liquid Viscosity = 3.5 cP

n = 1.13080

Norton's Correlation Applicable

Norton's Correlation NOT applicable

Calculation

ln HETP = 0.837437

HETP = 2.310437 ft
= 0.704221 m

For separations, less than 15 theoritical stages, a 20% design safety factor can be applied.

Considering 20% safety factor,
HETP = 0.845065 m

For separations, requiring 15 to 25 theoritical stages, a 15% design safety factor can be applied.

Considering 15% safety factor,
HETP = 0.809854 m

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COLUMN MEDIA VOLUME

Loading Rate	120.0	m3/m2/hr
Require Retention Time	6.0	Seconds
Volume of Media	58.333	volume of media

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PROPOSAL

Proposal to install a 20,000 or 35,000 m3/hr Bio-Scrubber at the Oxigen Environmental Coes Road, Dundalk, Co. Louth

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19th January 2017

Ref. MEHS_2017_P005_01 R1

Prepared by	Client
Trevor Montgomery Kantoher Business Park, Killeedy, Ballagh Co. Louth	Brian Moylan Oxigen Environmental Coe Road, Dundalk Co. Louth
Tel: 00353 69 85896	Tel: 01 426 3125
Mob: 087 2390421	Mob: 086 0246075
Email: trevor@mehs.ie	Email: bmoylan@oxigen.ie

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Table of Contents

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1.0 Introduction

Montgomery EHS in response to a request from Brian Moylan of Oxigen Environmental are please to submit a quotation for the control and treatment of odours arising from the waste operation at the Dundalk facility.

There are two options within the proposals based on the request for submission of a tendered price:

Option 1 20,000 m^3/hr for the extraction of odorous air from the black bin shed

Option 2 35,000 m^3/hr for the extraction of odorous air from the black bin shed and the dry recyclables shed

This document outlines the services that we propose to provide. We have included information on the following:

- The Scope of Work;
- The proposed Tender Price.

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The scope of the work involved 4 components

- Ducting to the Bio-scrubber
  - Option 1 Ducting from the black bin shed
  - Option 2 Ducting for the black bin shed and dry recyclables shed
- Installation of bio-scrubber
  - Option 1 Bioscrubber containing the aeration tank
  - Option 2 Bioscrubber and separate aeration tank.
- Installation of the 20 m Stack as a stand only structure connected to the bio-scrubber
- Commissioning, validation and long term management

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2.0 Proposal Details

2.1 Installation of a Bio-Scrubber

2.1.1 Design Criteria

Traditionally, odour control has been achieved by oxidation using chemical scrubbers and conventional bio-filtration methods using compost media. The chemical scrubbing methods to treat (oxidize) the odorous organic compounds generated during the processes commonly use oxidizing agents such as chlorinated water, sodium hypochlorite, hydrogen peroxide, and potassium permanganate solutions.

Bio-scrubber using synthetic pelletized and structured media is gaining recognition, as an excellent alternative for treatment of air streams with higher organic loadings. Synthetic media bio-scrubber, as compared to natural media bio-filters, also allows effective control of biomass build-up. Extensive research has been conducted on the development of synthetic media bio-scrubbers for odour / VOC control applications. These bio-filters are able to handle higher concentrations of VOCs without the eventual build-up of biomass. Montgomery EHS is small business company established in Limerick is involved in marketing bio-scrubber for commercial applications.

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Bio filtration is a relatively new pollution control technology. It is an attractive technique for the elimination of malodorous gas emissions and of low concentrations of volatile organic compounds (VOCs).

The contaminated gas is diffused in the bio-scrubber with the recirculation water and the bacterial mass and adsorbed onto the biofilm within the packing. This gives microorganisms the opportunity to degrade the pollutants and to produce energy and metabolic by-products in the form of CO_2 and H_2O.

This biological degradation process occurs by oxidation, and can be written as follows:

$$\text{Organic Pollutant} + O_2 \rightarrow CO_2 + H_2O + \text{Heat} + \text{Biomass}$$

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2.1.2 Process Description

The larger bio-scrubber consists of two reactors: a scrubber and bioreactor (Figure 2). In the scrubber contaminated inlet gas flows through a fine spray of water or water plus dispersed microbes (activated sludge). Smaller scrubbers the bioreactor is contained with the scrubber. The water-soluble contaminants are absorbed out of the gas into the water or activated-sludge mixture. This contaminant laden water is pumped into the bioreactor. The cleaned gas is exhausted from the scrubber. In the bioreactor or activated sludge aeration tank the pollutants are degraded and the water is regenerated. Some of the bioreactor liquid is recycled back into the scrubber (Kirchner et al. 1985; Ottengraf 1987). The excess bacteria is drained out of the system on a daily basis, the volume is based on the daily analysis.

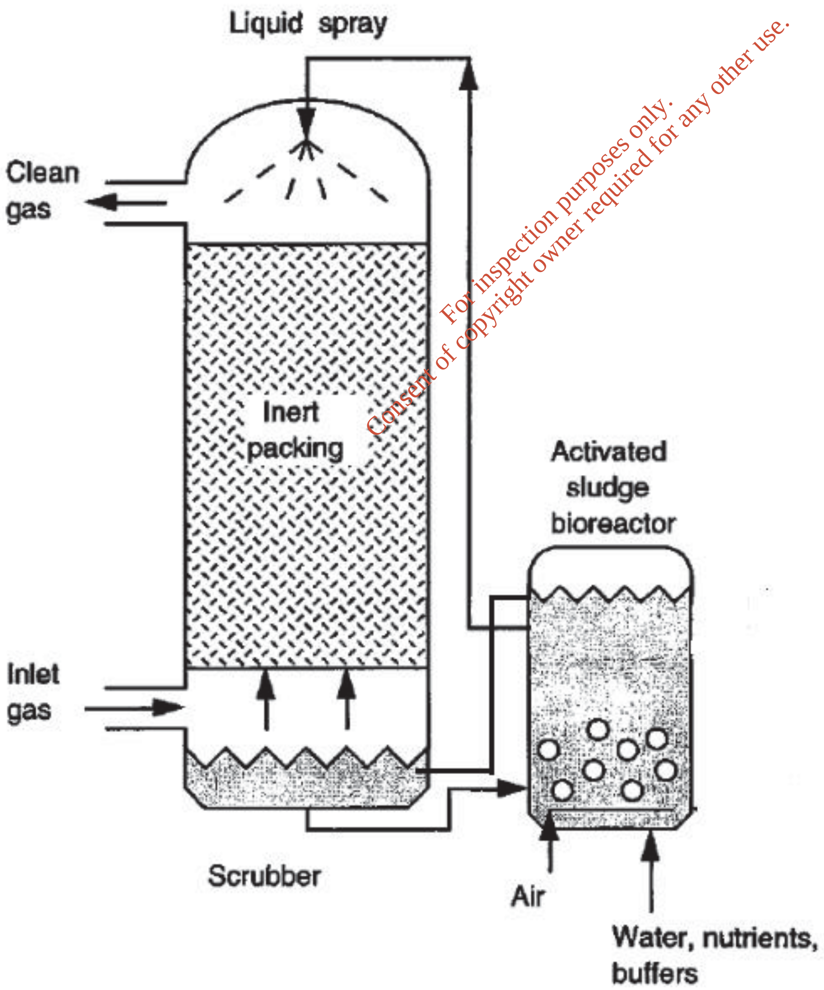

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Figure 2: A Bio-Scrubber

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Of the various bio-filtration systems, bio-scrubbers have the least space requirements, the highest operational stability and process-control, and greatest permeability to gas flow. But they also have the lowest scrubbing efficiency due to the reduced specific gas/liquid surface area for mass transfer (Van Groenestijn and Hesselink 1993).

Bio-scrubbers do well removing water soluble contaminants. To enhance capture of slightly soluble compounds, organic solvents that are immiscible in water, such as Ammonia, Amines, Hydrogen Sulphide, chlorides, etc.

Typical Design Criteria:
Air flow rate dependent on loading rate:

- Flow rate, 6000 to 35,000 m^3/hr
- Loadings 40 – 140 m^3/m^2 (dependent on contaminant concentrations)
- Contact time 4 - 10 seconds
- Amines removal efficiency 85 – 90%
- Ammonia removal efficiency 85 – 90%
- H_2S removal efficiency 85 – 90%
- VOC removal efficiency 60 – 80%

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2.1.3 Major Design Considerations:

A. Irrigation

The media must be kept moist, but if irrigation is too frequent, the biomass may be deprived of oxygen. If irrigation is too infrequent, the media can dry out and reduce effectiveness. A programmable timer may be used to properly time irrigation cycles. The temperature of the process air will be measures during commissioning in order to establish cycle.

B. Media

Media should possess high surface area to volume ratios, good adsorption characteristics, low pressure drop, and good sloughing characteristics. For nitrogen and organic compounds treatment, media impregnated will be seeded with bacteria prior to commissioning.

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C. Nutrients

Nutrients must be kept fresh to maintain healthy biomass. Appropriate nutrients essential to the various bacteria in the bio-scrubber will be identified. This will be determined prior to commissioning by sampling and running lab scale tests on samples of the leachate. Montgomery EHS will design a solution to provide exact nutrient requirements. A dosing pump will be installed to allow dosing of nutrients and bacteria selected for particulate odorous compounds.

D. Construction materials

Corrosion-resistant materials such as Stainless steel and HDPE will be used

E. Air distribution

Uniform air distribution through the media bed is important to efficient operation. Perforated FRP distribution plates have been used effectively to support the media bed and distribute the air flow uniformly.

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2.1.4 Similar Location

Similar bio-scrubbers are located in

- Brandon Products, Asdee, Co. Kerry – seaweed high pressure extraction
- Alert Packaging Ltd, Bray, Wicklow – printing

2.2 Installation of fans and ducting

Montgomery EHS will used galvanise steel ducting which will be used to duct odour source to the bio-scrubber.

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2.3 Commissioning, validation and long term management

As part of the Commissioning, validation and long term management we will include 2-months back-up and monitoring servicing, this will cover:

- Air Monitoring (Gastec tubes)
- Scrubber water sampling and analysis
- Differential Pressure checks
- Air flow monitoring
- pH monitoring
- Alkalinity testing

The proposed bacterial mix is part of a product called MEHS-Treat OC, MEHS-Treat AB and MEHS-Treat NR. The Bio-scrubber maintenance from a chemical and bacteriological view point has developed to the point that we manage the composition by adding various bacterial, feed and nutrient products to the scrubber on a weekly and as required basis. The addition of the products is based on chemical and bacterial results and observations from routine checks.

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The chemical and micro-biological parameters of the recirculation water in the bio-scrubber is monitored on a regular basis for the following parameters

- Total Bacterial Count
- Total Nitrogen
- Ammonia
- BOD / COD
- Suspended Solids
- Volatile Organic Matter (measure of bacterial mass)
- Alkalinity

The bio-scrubber will be part of the on-going improvement programme work on the scrubber had external contractors to determine the efficiency.

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We proposed to use Exova Catalyst Ireland to conduct chemical analysis on the inlet and outlet of the bio-scrubber and the results will demonstrate compliance with EPA air Emission Limits for Bio-Scrubber.

The Bio-scrubber systems are a stable and effective odour abatement system and as part of on-going monitoring continue to examine opportunities to improve the treatment efficiency. The bio-scrubber meets all the EPA limits for comparable treatment systems and the external monitoring conducted by approved EPA contractors.

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3.0 Tender Price

The Price for the Scope of Work in the Proposal

Option 1 20,000 m3/hr

Description	Euro
Installation of Test Bio-Scrubber Unit	
1. Installation of Ducting to the Bio-Scrubber	**€25,000**
2. Installation of bio-scrubber (Sub-Total)	**€274,230**
A. Scrubber	€124,730
B. Fan	€18,000
C. Pumps	€11,200
D. Media	€32,000
E. Pipework	€4,800
F. Bacterial & Nutrient Dosing	€2,000
G. Aeration system	€2,500
H. Transport	€5,000
I. Mist eliminator	€8,000
J. Installation civils	€6,000
K. Electrical (including VSD's) Option HMI control with remote access via phone or Ipad	€34,000 €12,000
L. Commissioning (bacteria, nutrient, sterilisation, etc.) two months	€14,000
3. 20 m Stack	**€88,000**
4. External Air Sampling	€7,200
TOTAL	**€394,430**

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Any additional work not covered in the Scope of Work would be charged at our standard rates as follows, no additional fees will be charged without the prior agreement of the Client:

- €75 per hour for a Consultant;
- €35 per hour for an Operator
- €50 per hour for an electrician

The electrical price is subject to site visit and includes 50 meters of supply cable to electrical panel
The ducting price is subject to site visit and roof having carrying capacity of the installed duct.

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The Price for the Scope of Work in the Proposal

Option 2   35,000 m3/hr

Description	Euro
Installation of Test Bio-Scrubber Unit	
5. Installation of Ducting to the Bio-Scrubber	**€38,000**
6. Installation of bio-scrubber (Sub-Total)	**€401,900**
A. Scrubber	€154,100
B. Aeration Tank (30 m3)	€49,000
C. Fan	€27,000
D. Pumps	€19,200
E. Media	€45,000
F. Pipework	€6,100
G. Bacterial & Nutrient Dosing	€2,000
H. Aeration system	€2,500
I. Transport	€6,500
J. Mist eliminator	€12,000
K. Installation civils	€7,500
L. Electrical (including VSD's) Option HMI control with remote access via phone or Ipad	€45,000 €12,000
M. Commissioning (bacteria, nutrient, sterilisation, etc.) two months	€14,000
7. 20 m Stack	**€88,000**
8. External Air Sampling	€7,200
TOTAL	**€535,100**

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Any additional work not covered in the Scope of Work would be charged at our standard rates as follows, no additional fees will be charged without the prior agreement of the Client:

- €75 per hour for a Consultant;
- €35 per hour for an Operator
- €50 per hour for an electrician

The electrical price is subject to site visit and includes 50 meters of supply cable to electrical panel
The ducting price is subject to site visit and roof having carrying capacity of the installed duct.

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4.0 Terms and Conditions

This proposal is issued subject to the following terms and conditions.

- All prices are exclusive of VAT
- The proposal is valid for a total of 60 days from the date of issue.
- Payment terms as follows
  70% of contract value payable on placement of order
  20% payable 30 Days from completion
  10% payable on retention 6 months after completion of Commissioning and Installation (Payable immediately on anniversary date).
- Should you wish us to proceed with the work outlined above; we will require a Purchase Order number or written instruction to proceed along with confirmation of the invoicing address.
- An invoice will be issued at the end of each month during which work has been undertaken for the Client. Each invoice will be for all work carried out during the month of issue.
- Payment terms are strictly 30 days from the date of issue of invoice.
- All information will be treated as confidential.

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5.0 Instruction to Proceed

Oxigen Environmental, Coes Rd, Dundalk, Co. Louth

PROPOSAL TO INSTALL ODOUR CONTROL AT COES ROAD DUNDALK.

OPTION	SELECTED OPTION
Option 1 – 20,000 m^3/hr	
Option 2 – 35,000 m^3/hr	

In order for Montgomery EHS to commence work on this project the Client must complete and return this form to: Montgomery EHS, Trevor Montgomery EHS Consultant, Montgomery EHS, Kantoher Business Park, Killeedy, Ballagh, Co. Limerick, Ph: (087) 2390421, e-mail: trevor@mehs.ie

I/we confirm acceptance of the fee proposal as submitted by Montgomery EHS Ref. MEHS/017/05/01 R1 and hereby issue instruction to proceed with the works outlined therein.

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Signed: ______________________________

Company: ______________________________

Date: ______________________________

INVOICING DETAILS

Please provide contact details for invoicing purposes.

Company Name	
Address	
Contact Name	
Phone	
MEHS Contact	Trevor Montgomery

This Section is reserved for MEHS Office Use

Accounts	*Project Reference*

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APPENDIX E

Maintenance Procedures for Carbon-based Odour Abatement System (Simdean)

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simdean
GROUP LIMITED

G41 The Innovation Centre
Keckwick Lane
Daresbury
Cheshire WA4 4

Typical Maintenance & Training Procedures for Simdean Odour Control System

In terms of the daily operating schedule for the odour control system we would recommend the following :-

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1 Perform a daily “sniff check” of the odour present at the exhaust stack of the unit. This can be achieved using the “sniff tubes” fitted to both the carbon adsorber unit and the exhaust stack

2 Perform a minimum of a daily check of the SCADA screens to ensure that the system is operating correctly . Any alarms or failures on the system can be provided as email alerts to the relevant factory personnel. This feature is normally set up during the commissioning phase of the project

3 Set up an odour log and on a daily basis check for the presence of any odours at the facility perimeters

4 Set up a weather station to log wind speed and direction at the facility

The following has been extracted from one of our operating and maintenance manuals and describes the typical maintenance requirements for the odour control system.

Maintenance

The odour control system is virtually maintenance free. To keep it running efficiently it is vital that the other proprietary items of equipment are regularly inspected and serviced. Where appropriate we include the operating and maintenance manuals for the particular proprietary equipment. These are included in Section 8 of this manual.

In general terms we would make the following observations

Ducting

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Should be inspected regularly for damage and leakage with particular attention being to damage of the ductwork at high level within the section of the waste transfer area not being extracted from. If damage occurs in this area it will allow that extraction from the “odourous area” to be reduced thus allowing the possibility of fugitive emissions leaving the building.

Damper settings within the extract grilles are not easily identifiable. In general the dampers are either fully open or approximately 70 % closed.

System Exhaust fans

The extract fans are central to the operation of the odour control plant and should be regularly inspected and serviced. Please refer to the Operating and Maintenance manual supplied within Section 9 of the operating manual.

Dust Collector

The reverse jet cartridge filter is also of paramount importance to the optimal performance of the odour control plant and should be regularly inspected and serviced.

The dust collector is fitted with a pressure sensor which initiates cleaning of the unit. Please refer to the Operating and Maintenance manual supplied with the Reverse Jet Filter .

The Reverse jet filter requires a compressed air feed of approximately 60 m^3/h FA at 6 Barg. This is provided by a dedicated air compressor fitted to the reverse jet filter and located within the control panel room area.

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For details of how to replace the dust cartridge within the dust collector please refer to the maintenance procedure detailed in the Operating and Maintenance manual for the Optiflo unit supplied with the unit

Compressor

The air compressor is intimately connected to the optimal performance of the reverse jet filter and should be regularly inspected and serviced.

The compressor is fitted with a pressure sensor which initiates operation of the unit. Please note that whilst in operation the compressor may start up without any notice. All maintenance on this compressor should be performed with this proviso in mind. For details of the maintenance procedures please refer to the Operating and Maintenance manual supplied with the unit.

Adsorbers

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In essence each of the adsorbers are maintenance free; the unit is fitted with a temperature sensor, a resistance thermometer, pressure monitoring equipment and odour sensing pipe work. Maintenance of the units is limited to ensuring that the temperature sensor is operational and that the odour sensing pipe work is kept clean and open to atmosphere.

Changeout of carbon

The procedures involved in changing out the Carbon from the adsorber as follows:-

Equipment needed on site:

Crane for lifting bags of carbon to refill adsorber.

Big Bags (1m^3 Capacity) or Skip(s) for disposal of spent carbon

Long handled brush (handle length approx. 6000 mm)

Rake

Flexible ducting for draining of carbon from adsorber 160Ø

The amount of carbon present in the adsorber is roughly equivalent to 17.5 tonnes which will occupy a volume of approx 35 m^3. The skip(s) for disposal will need to be large enough to handle this volume.

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During the unloading and especially the reloading period of the carbon changeout a degree of dust will be generated. Personnel performing this work should wear masks to avoid inhalation of the carbon dust. Carbon dust does not appear to cause significant harmful effects after a single short-term exposure, except general effects that would be expected with any fine dust (high concentrations can cause coughing and mild, temporary irritation).

The steps involved in changing out are as follows:-

1. Using either access ladder or cherry picker lift personnel to the top of the adsorber and remove access panels
2. Locate big bags or skip(s) for collection of carbon below the adsorber platform
3. Fit flexible ducting to the outlet pipes below the adsorber. Ensure end of flexible is located in big bag / skips
4. Remove access panel at low level on adsorber so that adsorber carbon holding cage can be viewed

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5. Open spade damper on one of the outlet pipes and allow carbon to drain out of adsorber
6. Repeat with all outlet pipes
7. Using long handled brush from top access panels ensure all carbon is removed from the holding cage
8. If adsorber is wet through then ensure that exhaust fan is run to allow the unit to dry out prior to refilling with carbon.
9. Replace lower access panels
10. With crane lift bags of carbon above adsorber, break bag and fill unit with carbon.
11. As units become filled ensure that carbon is evenly distributed around the adsorber using rake.
12. The final few inches of filling for the adsorber may need to done using buckets of carbon taken from the big bags to prevent over filling. With rake ensure even filling and attempt to compact carbon as much as possible.
13. Replace access panels on top of unit

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The personnel who do the work will inevitably be covered in dust and should wear disposable overall and protective breathing masks and be able to access showering facilities after refilling of the adsorber.

We would recommend that at least 3 people are dedicated to the work

The carbon to be used for replacement should be a virgin activated carbon with a granulated finish with a pellet size of 4 mm minimum. The Carbon to have a CTC Value of 60 minimum

For full details of the type of carbon to be used for replacement within the Carbon adsorbers please contact Simdean Envirotec Ltd

General Maintenance Schedules

The table shown below details the preventative maintenance schedules for the overall plant. For detailed maintenance instructions consult the appropriate proprietary equipment maintenance manuals

Equipment	Daily	Monthly	3 Monthly	Annually
Exhaust Fans & Ducting				

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Verify Speed and ampage of fan on control panel

Inspect impellor for signs of excessive vibration, corrosion or solids build up

Inspect external housing for signs of corrosion or wear

Duct Volume Control Dampers , blow down face of damper to remove dust build up

Reverse Jet Filter

Compare pressure drops across filter shown on digital (Delta Pulse) and analogue (CMR Sensors) to check for continuity

Empty dust bins below hoppers

Open Access Doors and check for any damage to cartridges

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Carbon Adsorber

Check pressure drop across adsorber and compare with output on SCADA system
Perform olfactory test on outlet gas (Check sniff tubes)

Check for settling of Carbon within the adsorber.
Remove top access panels and top up when necessary

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APPENDIX F

Maintenance Procedures for Bio-scrubber Odour Abatement System (MEHS)

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INSTALLATION, OPERATION AND MAINTENANCE MANUAL

MEHS BIO_SCRUBBER SCRUBBER

Serial Number:______________________________________

Date Manufactured:___________________________________

Drawing Number:____________________________________

Tag____

Reference____

Project____

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MEHS
ENVIRONMENT, HEALTH & SAFETY

Office: Kantoher Business Park, Killeedy, Ballagh, Co. Limerick
Phone 00 353 87 239 0421
VISIT US AT: www.MEHS.ie

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PACKING MAINTENANCE

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INTRODUCTION

This Scrubber Installation, Operation and Maintenance manual has been written for you, the Installer, Operation and Maintenance Personnel. Although we have attempted to include each component on your scrubber, each scrubber system is unique and built on a custom basis. Furthermore, there are hundreds of different chemicals that can be scrubbed and your chemical scrubbing process is unique. Therefore, it is impossible to cover all components, operating conditions and chemical processes. In addition to this manual, separate manuals are available for accessory item such as pH controllers, flowmeters, heater controllers, etc. Do not hesitate to connect MEHS or your Sales Representative for additional manuals or for any further assistance.

1.1 General Information

1. All parts of the scrubber equipment have been thoroughly inspected and pre-tested at the factory. Upon receipt of shipment, a complete inspection of the equipment is recommended to determine if any damage was sustained during shipment or parts have vibrated loose. If any damage is found, a claim should be immediately filed against the freight carrier.

2. It is advised to have equipment installed by personnel familiar with the installation of air handling equipment. In most cases, your sales person can recommend a qualified contractor.

3. Check the nameplates and tags on equipment for special instructions.

4. The scrubber should be mounted on a solid surface which completely supports the bottom of the scrubber. When the scrubber is to be mounted on a problem, the platform should be thoroughly braced. If the scrubber is roof mounted, consult a structural engineer to prevent overloading the roof structure. Refer to the scrubber drawing for the operating weight. Finally, we recommend the scrubber be mounted on a six (6) inch housekeeping pad. This will simplify the drain connection and assist in drainage.

5. Air temperatures at the inlet to the scrubber should never exceed 55 °C unless the material of construction has been designed at a higher temperature. The water temperature of the recalculating liquid should not exceed 40 °C for schedule 80 PVC construction (180 F for CPVC and 200deg F for Polypropylene).

6. Equipment is constructed of Stainless Steel and thermoplastic materials. Care must be taken during handling and installation to prevent damage which may be caused by external stress or shock.

7. Certain accessory items such as pressure gauges, solenoid valves, controls and instrumentation may have been shipped loose to prevent damage in transit. Install these items to the scrubber system as required.

8. Refer to Appendix B for a check list for start-up procedure. Refer to Appendix C for an exploded view of a horizontal scrubber.

INSTALLATION

2.1 Unloading and Rigging

Utilize nylon straps when lifting the scrubber from the truck bed to the final position. If lifting lugs are incorporated, use them. If there are no lifting lugs, place nylon straps around the scrubber flanges for lifting. These flanges are strong and will support the dry weight of the scrubber.

2.2 Packing Installation Procedure (when shipped loose)

There are many ways to install plastic random fill packing. Installation procedures very depending on the column size, size of packing, packed bed height, and position of other internals. Generally, if common sense is used, problems can be avoided. The installation procedure is as follows:

1. Distribute packing pieces in a random manner and never let them free fall more than fifteen 5 meters. In cold water weather (below 14°C) particular care must be taken in handling and installing plastic packing since the brittleness of the plastic resin will be greatly increased.

2. Make sure the packing fills all the space in the packed bed section. Pay particular attention to the access doors and irregular spaces.

3. If workmen are in the scrubber, use plywood to distribute load over as large an area as possible. Never exert a concentrated load onto a few of the individual packing pieces. Check the structural integrity of the packing supports before placing men inside the tower.

4. Be careful not to leave any foreign materials in the packed bed section. Make sure all plywood, boxes and bags are removed.

2.3 Packing Inspection

Inspect the packing material to determine if damage, shifting or settling has occurred during shipment. Inspection can be made by looking in the access door or through the polypropylene access ports. The packing should be even across the top surface to prevent dry spots in the packing and prevent any air from passing over the top of the packing. Adjust as required. Should you require additional packing due to excessive setting, please contact MEHS.

2.4 Mist Eliminator Section

Horizontal scrubbers usually have the mist eliminator contained in the outlet transition. The mist eliminator is place in the outlet ducting. Verify the mist eliminator sections have not moved during transit or installation by viewing their position from the top access door.

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2.5 Bolted Transitions and Flanges

Larger scrubbers require the installation of the inlet and outlet transitions. The outlet transition usually contains the mist eliminator and must be located on the down stream side of the scrubber.

Tubes of butyl caulking compound and stainless hardware are provided by MEHS. A single ribbon of caulking material should be applied on the inlet and outlet flanges and the scrubber main body. For best results, apply the caulking on the inboard side of the flange holes. The transitions are then installed to the scrubber body with the mounting hardware supplied. Tighten the hardware evenly around the perimeter of the flanges to ensure gradual and even flange compression. Repeat the same procedure for all scrubber flanges. The above procedure is not required for the smaller one piece horizontal scrubbers.

2.6 Inlet Connection

To aid in the proper air flow into the scrubber, allow at least two (2) equivalent duct diameters or straight duct leading into the scrubber inlet.

Contact incoming duct to the inlet transition using a flexible connector.

Hint: Be sure to slope the incoming duct into scrubber to allow proper drainage of any liquid from the inlet duct into the scrubber.

2.7 Outlet Connection

Connect the scrubber outlet to the exhaust fan or discharge dust as required.

NOTE: using a flexible connection on the outlet duct connections will simplify equipment alignment, isolate fan vibration from the scrubber and allow equipment access for maintenance

2.8 Hold Down Lugs

Seismic hold down lugs is provided on the scrubber bottom. Use suitable hardware to secure these lugs.

CAUTION: MEHS does not recommend cast-in-place concrete anchors. Set the scrubber in place, mark the location of each hole, and either core drill the cement or use expansion hardware.

2.9 Water Supply Connections

Install a one (1) inch water supply pipe per figure:

1 A gate valve, solenoid and flowmeter should be utilized as shown for the water make-up control. Install the piping as shown for the float valve located in the pump in the pump box still well per figure

2. Check with the city codes concerning installation or back-flow preventer. If these parts are not included, MEHS can provide these parts for your scrubber system.

2.10 Water Make-up Piping System

The electric solenoid can be connected to the pump starter auxiliary contact. This will shut off the water make-up system when the pumps are not operating. The gate valve is used to regulate the amount of flow and the inline flowmeter provides a visible means of adjusting the flow to the desired amount.

2.11 Chemical Feeds System

A chemical feed system can be utilized to maintain a predetermined pH value in the scrubber sump liquid by adding a chemical agent. The following list includes all the parts required for a standard chemical feed system:

100 liters Chemical Tank

Chemical Feed Pump
pH Controlling System

If a chemical feed system has been included by MEHS, refer to the drawing provided by MEHS for further details.

The chemical tank should be located as close as practical to the scrubber. The chemical feed pump is mounted to the chemical feed tank. The inlet plumbing from the tank to the pump and outlet plumbing from the pump to the scrubber must be supplied and installed by the customer.

The mixer is mounted to the top of the chemical feed tank using a PVC flange fitting.

The pH controller is mounted in a convenient location and a submersible pH probe is located in the pump box cover. Refer to the manuals provided with the pH controller system for installation and wiring instructions. When wired properly, the pH controller signals the chemical feed pump when to pump chemical from the tank into the scrubber.

WARNING: MEHS does not recommend an in-line installation for a pH sensor system. For proper operation, the flow rate must be at 4 FPS or less, and the sensor must be installed with the electrode pointing downward to ensure adequate electrolyte flow (in the vertical position).

HINT: When connecting a pH probe to a controller, use flexible conduit and allow enough extra conduct to remove the probe for routine calibration.

2.12 Overflow and Drain Fitting

Install drainage piping to the overflow and drain fitting as shown per figure 2.

IMPORTANT: Since the scrubber pump box is operating under a vacuum be sure to include a vent on the drain line as shown.

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2.13 Valve Position

Check all valves to ensure proper position. All spray header valves should be in the open position with the handles in line with the flow. The drain valve should be closed with the handle in a line across the fluid flow.

2.14 Heater System

If a heater system has been included, it will consist of a heater controller, RTD temperature sensor mounted in the pump box, a screw plug heating element located in the sump, a heat sensitivities fuse link located in the heating element and a low sump level switch mounted on the pump box exterior. The low sump level switch and heat sensitive fuse link Must be properly wired to the heater controller to prevent heater burnout in the event of a low sump level condition or detection of an excessive temperature in the heating elements.

2.15 Electrical Connection

Make the necessary electrical connection as required using qualified personnel. All electrical work should be done according to the National Electrical Code. Also, check with the city for the proper codes.

2.16 Pressure Gauge Assembly

If an optional pressure gauge assembly has been included in the scrubber system, it will consist of an isolation valve, gauge guard filled with glycerin and a liquid filled pressure gauge. The assembly has been shipped loose for field installation. Prior to installation, check the level of glycerin in the gauge guard. Remove the pressure gauge and bleed screw and fill with glycerin to remove all air. This can be achieved by pouring the oil into the upper gauge cavity and tilting the gauge guard in several positions to be sure that no air is trapped within. After filling completely, turn the gauge guard over quickly and screw in the pressure gauge. Any excess oil will come out of the bleed screw. Install the bleed screw and assemble the pressure gauge assembly to the recalculating line. If a pressure gauge was not included in your system. MEHS can offer one to suit your needs.

2.17 Removal of Debris

The scrubber should be thoroughly cleaned after installation is complete to remove any construction debris foreign object. Spray water on the packed bed, mist eliminator section, scrubber body, and transition with a hose spray nozzle and wash the material out of the scrubber.

2.18 Pump Rotation

In most applications vertical sump pumps are used for the recirculating system. Prior to adding water to the scrubber sump, check the pump rotation. The motor should operate in a clockwise direction when viewed from the top. The label on the motor also indicates the proper rotation.

HINT: For FPI penguin pumps, remove the fan cover using the three screws located on the side of the motor. Bump start the motor.

2.19 Pump Motor Rotation – Three Phase

If the pump motor is rotating in a clockwise rotation when looking at motor fan, rotation is correct. If rotation is not correct, interchange any two main power leads to obtain the correct rotation.

WARNING: Reverse rotation will damage thermoplastic vertical sump pumps such as FPI Penguin pumps. Check pumps rotation before filling the scrubber sump!

2.20 Water addition to the Scrubber Sump

After the above has been completed, water can be added to the scrubber sump using the float valve.

2.21 Check for leaks and Loose Fittings

Start the scrubber pump (s) and check for loose ball valves, check valves and union. Use a strap wrench to tighten any fittings that may have vibrated loose during shipment. Also check all piping, flange connections and access doors for leaks.

HINTS: Before locating a fan on the positive side (inlet) of a scrubber, consider the following. A negative pressure scrubbing system is always preferred for several reasons: The fan is located on the clean side; a small leak in the exhaust system will not allow fumes to escape; access doors can be opened without allowing fumes to escape; pressure differential gauges will not be damaged by corrosive fumes.

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OPERATION

3.1 Principles of Operation

A biological scrubber is designed to promote the contact of a gas and a liquid stream. Air contaminants are removed from a gas stream by dissolving or absorbing them in a liquid in which they can be more concentrated.

The process of absorption depends on intimate contact of gas and liquid under conditions which maximize the exposure of surface of gas and/or liquid to each other. This requires breaking up the liquid into many tiny slow-flowing films which form and re-form through a volume of gas.

A biological scrubber is capable of removing many air containments through one of three methods. The simplest method of removing some contaminants is by the process of mist elimination. The MEHS biological scrubbers are rated to remove all mist and fume particles at 99 percent down to 5 microns. Mist elimination is accomplished by impinging the particle onto the packing and by physical capture. The recirculating scrubber liquid (usually water), continuously washes the particles off the packed and the particle is dissolved in the scrubbing liquid.

The second method is called mass transfer and is the process of transferring a gas or vapor from the gas phase to the liquid phase using a recirculating liquid such as water. The rate of this transfer is affected by four factors….. the packing depth, water recirculation rate, air velocity and type of packing. For biological

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Selected bacterial blends are added to the scrubber and the bacteria breakdown the chemicals absorbed will improve the rate of transfer.

The third method requires the addition of a chemical additive such as an acid, caustic or oxidizing agent and changes the air contaminant into a new species through a chemical reaction. The absorption of ammonia is pH dependent.

EXAMPLE: The chemical reaction of hydrochloric acid and sodium hydroxide results in sodium chloride and water (HCl+NaOH =NaCi+H20)

There are several hundred different types of air contaminants that can be removed using a MEHS biological scrubber using one of the three above methods. MEHS can assist you in determining the suitability of scrubbing various air contaminants using computer programs and a large chemical data base.

3.2 Mist Eliminator

The most common type of horizontal mist eliminator utilized is a PVC mesh type mist eliminator in the shape of a sine wave mounted on one inch centers. The mist eliminator is capable of removing droplets down to 15 microns at a velocity of 5 m/s.

3.3 Water Make up

Fresh water must be continuously added to the scrubber recirculation system to 1.) Maintain the quality of the recirculating liquid 2.) Provide a source of water for humidifying the incoming air, and 3.) Minimize buildup of minerals inside the scrubber.

Normally the addition of fresh water is controlled by using a solenoid valve, gate valve and an inline flow meter. The solenoid can be connected to the pump starter auxiliary contact. The gate valve is used to regulate the amount of flow and the inline flow meter provides a visible means of adjusting the flow to the desired amount.

As fresh water is added to the scrubber recirculation system, excess contaminated water will flow through the overflow fitting located on the pump box. The rate at which this water flows out is commonly called the blow down rate.

3.4 Make up Water Rate

The amount of make up water required will depend upon 1.) The amount of air contaminant being processed through the scrubber, 2.) The humidity of the incoming air and, 3.) The hardness of the water.

If the inlet loading of the air contaminant is known, the make-up water rate can be calculated using the solubility of the chemical in water, usually enough fresh water should be added to the scrubber sump to maintain the solubility of the contaminant within approximately twenty (20) to thirty (30) percent of the solubility limit of the contaminant or end product in water.

EXAMPLE: If the solubility of the contaminant is 10 per cent by weight in water, enough fresh water should be added to maintain the solubility at 2-3 per cent by weight.

A small amount of the water make up is also used to fully humidify the incoming air. Since the air is being washed by water, the relative humidity of the air will increase to about 100 per cent (about 2 per cent by weight). The amount of water used will depend upon the relative humidity of the incoming air.

Since most water supplies contain various minerals, and only pure water will evaporate from the scrubber recirculating liquid, the concentration of these minerals in the scrubber recirculating system will increase over time. To avoid this gradual buildup, the scrubber system is completely shutdown, thoroughly cleaned and fresh water is added. This procedure should be performed at least twice per year.

For most applications, the above water make up rates are not calculated. As a general rule, use a water make up rate of 1 – 5% of the recirculating liquid rate.

EXAMPLE: If the scrubber recirculation rate is 100 m^3/hr, the water make up rate is 1 to 5 m^3/hr.

3.5 Pumps

In most applications, horizontal sump pumps are used for recirculating scrubbing liquid. These horizontal pumps are stainless steel. Since they have no seals, they can operate dry without harm. As a result, they are virtually maintenance free.

For a CPVC vertical sump pump, a restricted suction will cause damage to the impeller and the shaft. Also do not run the pump against a closed discharge valve for more than five (5) minutes. This will cause overheating of the fluid in the pump and will damage all CPVC parts.

Always make sure there is enough liquid in the reservoir and the level is high enough considering the capacity of the pump unit. Inadequate liquid will cause a vortex in the pump box. A vortex occurs when air mixes from the surface into the fluid, which can disturb the flow and also prevent the pump from priming.

After operating the pumps, check the running amps versus the full load amps. If they exceed the full load amps, gradually close the spray line valves until the running amps are within the full load amps.

3.6 Liquid Level

For horizontal sump pumps, the correct pump box liquid level is very important. A liquid level which is too high could cause motor damage since liquid could enter the weep hole in the pump housing and cause the lower motor bearing to fail. During start up or priming of the pump, the pump impeller housing must be covered with water. Once the pump is primed, the sump level will drop since the water is being pumped into the plumbing line and packing area. The float valve will make up for the drop in water level. Each time the pump is turned off, the extra water added will flow out of the overflow fitting.

If the exhaust fan is located on the discharge side of the scrubber (negative system), you will notice the water level in the pump box will drop. Therefore, It is a

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good idea to start the pump first, and then the exhaust fan. Under a positive pressure system (fan located on the inlet of the scrubber), the water level in the pump box will be raised slightly.

3.7 Float Valve

The float valve acts as a control for a low water level condition. The float valve is used only to fill the scrubber sump initially, add water for evaporation control and act as a back-up in case the make up water supply has been turned off. It should not be used in place of make-up control.

3.8 pH Control

If your scrubber includes a pH system, it will monitor the pH of the recirculation liquid. A pH system can also be used to control the addition of a chemical additive. The addition of caustic such as sodium hydroxide will improve the scrubber of many acid contaminants, and the pH can be maintained as 8.0 to 9.0.

MEHS can recommend whether a chemical additive is required for your application and provide a complete chemical feed system. For additional information on the pH system, refer to the operation manuals provided for your system.

3.9 Chemical Feed System

The pH controller system will monitor and control the solution pH in the scrubber sump. For scrubbing many acids, the ideal pH in the sump is 8.0 to 9.0. When the recalculating sump pH reaches the control set point, the pH controller signals the chemical feed pump to pump a chemical additive from the chemical feed tank to the scrubber sump. The metering pump will continue to pump until the pH controller signals it to stop.

The aerator is to agitate the biological solution in the scrubber or aeration tank. The aerator will be linked to a GSM alarm system to ensure continuous operation.

3.10 Flow Meter

If an optional flow meter has been included in the scrubber system, they are either a horizontal inline flow meter with a float, or a paddle wheel design with an analog or digital display. The flow meter will include the total water recirculation rate. If a flow meter was not included in your system, MEHS can offer one to suit your needs.

3.11 Pressure Gauge

If a pressure gauge has been included in the scrubber system, it will consist of an isolation valve, gauge guard filled with glycerin and a liquid filled pressure gauge. The pressure reading is unique for each system and will measure the hydraulic pressure at the installation point, not the pump discharge pressure. If a pressure gauge was not included in your system, MEHS can offer one to suit your needs.

3.12 Pressure Differential Gauge

If an optional scrubber pressure drop gauge has been included in your scrubber system, it will provide a reading of the total scrubber pressure drop in inches of water column. If a pressure drop indicator was not included in your system, MEHS can offer one to suit your needs.

3.13 Scrubber Heater

A heater system is designed to prevent the sump liquid from going below 14°C. It will consist of a heater controller, RTD temperature sensor located in the scrubber, a screw plug heating element, a heat sensitive fuse link and a low sump level switch. The low sump level switch and heat sensitive fuse, when properly wired to the heater controller, will prevent heater burnout in the event of a low sump level condition or detection of an excessive temperature in the heating element.

The heater controller will indicate the sum liquid temperature, and a temperature control point can be entered in the heater controller. Our initial suggested setting is 14 °C, and can be adjusted to suit your requirements.

CAUTION: The level of solution must be kept above the hot zone at all times. Allowing solution to fall below this level will cause excessive temperature which will pose a significant fire hazard.

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MAINTENANCE

4.1 General Maintenance Instructions

Adequate access has been engineered into the unit to create a minimum of work when cleaning or servicing is required. Reference to the exploded view drawing (Appendix C) will help to identify the scrubber components.

Appendix A contains the recommended maintenance frequency for the various scrubber components and devices.

4.2 Mist Eliminator Access

The smaller top bolted cover allows access to the mist eliminator section. The mist eliminator profiles can be removed individually by sliding them out the top of the unit. Removal may be difficult since blade replacement can be difficult. Therefore, we recommend periodic inspections during shut down periods. The maintenance should include:

1. Visual check out of internal blade elements for solids build-up

2. Clean all areas with high pressure hoses as required, being careful not to damage the blades

When re-installing the transition, use butyl caulking on the flanges for proper sealing.

4.3 Pumps-Removal and replacement

The pump (s) should rarely require maintenance because they have no seals or bearings in the fluid to wear out, and can be run dry indefinitely without harm.

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There are times when, due to inadvertent installation or maintenance miscalculations, removal and replacement may be required.
The pump (s) is mounted on a polypropylene plate which is bolted to the sump box. The pump (s) is plumbed to the spray piping with unions. To remove the pump:

1. Turn off electrical power to the pump at the main disconnect switch.

2. Disconnect electrical wiring from pump motor.

3. Turn off ball valve, unscrew union nut on ball valve connecting pump outlet pipe to spray header piping.

4. Remove bolts that attach pump plate to sump box.

5. Remove pump and return to factory for repair or replacement.

6. Reverse above steps to re-install pump (s).

7. Be sure to reconnect wiring for proper pump rotation. Turn the ball valve back on.

CAUTION: All electrical power to the motor should be disconnected prior to pump removal.

For additional information on pump maintenance, request the installation, operation and maintenance manual for the specific pump.

HINT: If change in flow reading is observed, it probably indicates the pressure of debris or foreign material in the pump inlet housing. This condition can also cause pump cavitations as indicated by excessive pump noise. This condition must be corrected to prevent pump impeller damage. Finally, the debris may also have lodged in another part of the recirculating system.

4.4 Pump Motor Maintenance

Cleaning and Inspection: A clean motor runs cooler. The motor should be cleaned and inspected at regular intervals. Operating conditions involving continuous running, hot, dirty or dusty surroundings, etc., require frequent attention. Always check motor shaft bearings when any unusual noise or vibration develops in the motor.

Inspect bearings for roughness by removing the pump from the sump box and turning the pump impeller by hand, if the bearings feel "rough" or stick in spots, replace them.

4.5 Float Valve

The operation of the float valve should be checked weekly. A scale deposit could develop allowing the float valve to stick. Open up the access door to the float valve located in the still well, and push down on it to verify operation.

4.6 pH System

A pH system will require regular maintenance. A pH probe will need to be calibrated once per month. Also check for buildup on the pH glass membrane. Finally, a pH electrode degrades with time and usage. The first indication of a depleted electrode is a reading that constantly drifts or takes a long time to stabilize (>10 seconds) while in the pH solution. The same symptoms can indicate a problem in the meter. Refer to the pH manuals provided with your pH system for additional information.

HINT: If the pH of the scrubber liquid needs to be maintained below a pH of 7, use buffer solutions of 7.0 and 4.0 to calibrate the pH probe. If on the other hand, the scrubber liquid needs to be maintained above a pH of 7.0, use a pH buffer solution of 7 and 10.

4.7 Flowmeter

Check the operation of the flow meter and clean as required. If the flow meter is a paddle wheel sensor with an analog or digital display, remove the flow sensor from the recirculating line and check the o-rings and replace them when necessary. The paddle wheel must always turn freely. Be sure the connections to the indicator and additional cable are still intact. Lubricate the barrel and o-rings with G.E. silicone compound #G660 every three months. Keep the paddlewheel and pin free of any lubricant. A spare rotor kit consisting of a paddlewheel. O-rings and a pin is available. It is suggested that you check your flowsensor periodically until some history of your specific application can be created.

The paddlewheel is designed to rotate on the shaft; the shaft should not rotate with respect to the housing. The paddlewheel must turn freely. If it does not, clean the paddlewheel assembly as follows:

1. Remove the flowsensor from the pipe and insert a plug into the pipe fitting. Clean any external debris from the paddlewheel.

2. For the MK 515, using a small flat-bladed screwdriver, gently pry one of the paddlewheel mounting ears away from the pin.

3. When one end of the pin is free, gently work the paddlewheel and pin out of the remaining mounting ear.

4. Thoroughly clean the pin, paddle, and pin holes with a wire brush and/or toothpick along with alcohol and/or soap and water.

5. To reinstall the paddlewheel and pin, reverse steps 1, 2, and 3.

6. After cleaning, the paddlewheel should spin freely without binding sticking.

4.8 Pressure Gauge

The pressure reading should be checked weekly and recorded. An increase in pressure indicates a gradual plugging of the recirculating system. Usually, the spray nozzles should be inspected for debris and possible scale buildup.

4.9 Pressure Differential Gauge

Check the scrubber pressure drop on a monthly basis, and record the reading. An increase in pressure drop indicates a gradual fouling of the packing media and scrubber interior. When the pressure drop increases by 50%, it is time to perform maintenance. Refer to the packing maintenance section.

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The differential gauge required no lubrication or periodic servicing. The interior should be protected from duct, dirt, corrosive gases and fluids. Zero adjustments should be checked and reset occasionally to maintain accuracy. Use the zero adjusting screw located at the bottom of the front cover, while the high and low pressure taps are both open to atmosphere.

4.10 Heater System

Once a month, verify the proper operation of the low sump level by pressing down on it and simulating a low sump level condition. The heater should not energize in the event of a low sump condition.

Tank sludge, if allowed to build up around the heaters, will reduce heater life substantially. Inspected for and remove all sediment and sludge BEFORE they contact the heater surfaces.

Inspect heater surface regularly and chemically remove any material that build up on the surface. Scraping heater surface can shorten the life of the material heaters.

4.11 Draining the Recirculating Lines

MEHS scrubbers have a check valve with a manual valve. If present, this will allow liquid to drain from the plumbing lines into the sump prior to maintenance on the recirculating system. All scrubbers are now equipped with a small drain lines and valve. This valve should remain closed during normal operation. Prior to performing maintenance on the recirculation system, open this valve and allow liquid to drain into the sump.

4.12 Pump Filter

The pump filters are located between the pumps and the main unit body. They are white perforated polypropylene, with handles at the top, which slide in a track. Removal of the filter (s) from the unit will allow cleaning. The filters should be checked and cleaned once a week.

4.13 Sump Access

On larger scrubber, an optional access door is provided into the scrubber base. This access is also used when replacing packing materials. The sump access is located in the inlet transition, and is a sliding panel for scrubbers operating under negative pressure. Positive pressure systems will have a bolted door.

The sliding door must not be opened during operation or the door may not re-seal.

4.14 Packing Access

The top of the unit has cover which id bolted to the main body. Removal of the cover will allow complete access to the packed section. The system must not be in operation while this cover is being removed.

4.15 View Ports

Round polypropylene viewing ports are located in area to allow observance of the spray nozzles. Inspect the nozzle once a month for proper spray patterns.

4.16 Spray Nozzle Access

The spray headers are individually removable for a scrubber operating under negative system to aid in the servicing of the spray nozzles. The unit does not have to be shut down to service the spray headers or nozzles. To remove the spray headers:

1. Turn off the ball valve supplying the spray harness.
2. Unscrew the union nut on the outlet side of the valve to free the harness.
3. Remove the hardware holding the round flange to the scrubber body.
4. Rotate the spray header 90 degrees and pull the remove.
5. Unscrew the nozzles for maintenance.
6. Reverse the above steps to re-install the spray headers.
7. Remember to turn ball valve back on

Do not over tighten bolts or screws, or union nuts on the ball valves.

4.17 Spray Nozzles

If required, the spray nozzles can be removed for cleaning. A scale buildup can usually be removed by soaking the spray nozzles in a dilute solution of muriatic acid. A small steel wire brush can also be used.

HINT: It is always a good idea to keep some spare spray nozzles in stock. This will allow you to thoroughly soak and clean the plugged up spray nozzles, and continue normal scrubber operation.

4.18 Ball Valve

To prevent the buildup of scale and maintain free operation of the valve, operate them at least once per week.

4.19 System Cleaning

The entire scrubber system should be completely cleaned when required. During this process, the liquid should be drained and the entire scrubber interior be cleaned. It may be necessary to store the scrubber liquid which contains valuable bacterial mass

PACKING MAINTENANCE

5.1 Inspection and Cleaning of Packing Face Area

Inspection of the packing face area should be performed on a semi annual basis. Observe for a build up of scale and excess biological deposit. Often the bacteria being scrubbed will build up on the packing face area.

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In the air stream, the concentration of the containment being scrubbed will be very dilute, but will be highly concentrated after a deposit has built up on the packing face area. Under these conditions, many chemicals can attack the packing material and will require packing replacements. To avoid this, cleaning can be done with chemical acid baths, high pressure hosing, or a combination of both. Check the chemical resistance of the packing material before using any chemicals to clean the packing.

5.2 Maintenance and Cleaning

Inspection of the packing should be done on a regularly scheduled basis. Maintenance of the packing is determined by the amount of fouling (collection of deposit such as iron, carbonate, and bacteria) which has accumulated on the packing. Past experience indicate a minimum inspection period of six (6) months to check for excess fouling. The optimum inspection time will vary from area to area depending on the rate of concentration of deposits from your water source. The packing can be removed and cleaned if fouling is not permitted to get excessive. The packing should always be kept wet until cleaning can be done to prevent the deposits from solidifying and becoming much more different to remove. Cleaning can be done with chemical acid baths, high pressure hosing, or a combination of both. Check the chemical resistance of the packing material before using any chemical to clean the packing.

5.3 Packing Material Cleaning Procedure

Under some circumstances the packing media may foul with iron oxide, manganese oxide, calcium carbonate and/or algae. If the proper steps are taken in a timely fashion, the fouling can be reversed. If these procedures are too time consuming or the manpower is not available to perform theses duties, contact MEHS. There are services companies throughout the Ireland and MEHS can provide recommendations.

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5.4 Cleaning Procedure for Iron Oxide, Manganese Oxide and Calcium Carbonate.

The pressure drop through the packed bed should be monitored on a weekly basis. Once the pressure drop has increased by fifty percent (50%) of the original reading, it is time to clean the system.

Shut down the scrubber and drain it. Inspect the sump for salt formation, remove the salt and flush the sump with water. Close the drain and fill the sump with a water solution of three percent (3%) Hydrochloric acid (HCl). This solution should be recirculated over the packing using the existing recirculation pump until the packing is clean approximately two to three (2-3) hours WITHOUT running the fan. Again, drain the column after the packing is cleaned and thoroughly flush the system with water. The scrubber can now be placed back in operation.

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Appendix A

MIANTENANCE FREQUENCY

	Weekly	Monthly	Semi Annual	Annual
Record Flowmeter Reading				
Inspect and Clean Sump Filter				
Verify Operation of Float Valve				
Operate Ball Valves				
Calibrate pH Probe				
Inspect Spray Nozzle Pattern				
Record Pressure Drop Reading				
Inspect Sump Heater Operation				
Verify low Sump Level Switch Operation				
Check Water Make-Up Rate				
System Cleaning				
Inspect Flowmeter Paddlewheel Assembly				
Check Pump Motor Amps				
Clean and Inspect Pump Motor				
Inspect Packing Face for Build up				
Inspect Packing for Build up				
Inspect Mist Eliminator for Build up				

*Suggested frequency until some history of your specific application can be created

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APPENDIX B

Check List for Start - Up Procedures

- ☐ Check for packing settling or shifting
- ☐ Missing Items
- ☐ Piping cracks/breakage or leaking
- ☐ Caulking on Flanges
- ☐ Clean scrubber sump and pump box
- ☐ Water supply to flow valve
- ☐ Water supply to water make-up
- ☐ Drain and overflow connection
- ☐ Drain Installed with a vent
- ☐ Check pump motor rotation
- ☐ Electrical connection
- ☐ Check spray nozzle pattern
- ☐ Adjust Water Make-up Rate
- ☐ Check Pump Motor Rotation

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pH System

- ☐ Calibrate at pH 7 and 10
- ☐ Enter Alarm and operating point

Sump Heater System

- ☐ Test low sump level switch
- ☐ Enter temperature operating point

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APPENDIX C

MEHS Biological Scrubber

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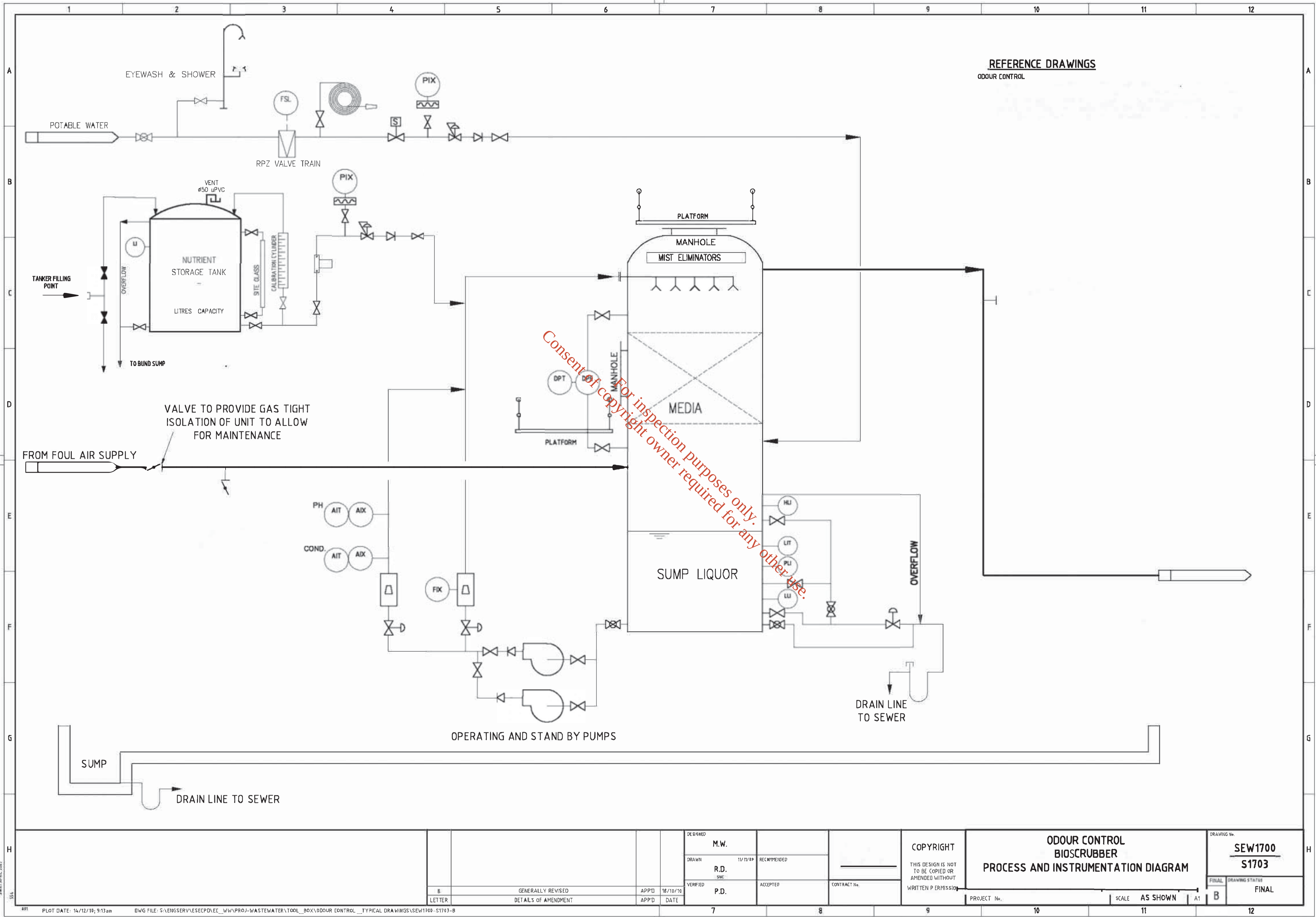

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